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1 Algorithms (334)

Searching, Sorting, Hashing, Asymptotic worst case time and Space complexity, Algorithm design techniques: Greedy, Dynamic programming, and Divide-and-conquer, Graph search, Minimum spanning trees, Shortest paths.

Mark Distribution in Previous GATE

Year	2025 - 1	2025 - 2	2024 - 1	2024 - 2	2023	2022	2021 - 1	2021 - 2	Minimum	Average	Maximu
1 Mark Count	2	2	1	2	2	2	3	2	1	2	3
2 Marks Count	3	3	4	2	2	2	3	4	2	2.88	4
Total Marks	8	8	9	6	6	6	9	10	**6**	**7.75**	**10**

1.0.1 GATE CSE 2025 | Set 2 | Question: 49

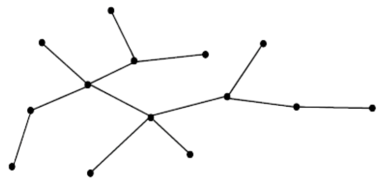
Consider the following algorithm **someAlgo** that takes an undirected graph G as input.

someAlgo (G)

1. Let v be any vertex in G. Run BFS on G starting at v. Let u be a vertex in G at maximum distance from v as given by the BFS.
2. Run BFS on G again with u as the starting vertex. Let z be the vertex at maximum distance from u as given by the BFS.
3. Output the distance between u and z in G.

6

The output of **someAlgo** (T) for the tree shown in the given figure is ____________. (Answer in integer)



gatecse2025-set2 algorithms breadth-first-search numerical-answers two-marks

Answer key

1.1 Algorithm Design (8)

1.1.1 Algorithm Design: GATE CSE 1992 | Question: 8

Let T be a Depth First Tree of a undirected graph G. An array P indexed by the vertices of G is given. $P[V]$ is the parent of vertex V, in T. Parent of the root is the root itself.

Give a method for finding and printing the cycle formed if the edge (u, v) of G not in T (i.e., $e \in G - T$) is now added to T.

Time taken by your method must be proportional to the length of the cycle.

Describe the algorithm in a PASCAL (C) – like language. Assume that the variables have been suitably declared.

gate1992 algorithms descriptive algorithm-design

Answer key

1.1.2 Algorithm Design: GATE CSE 1994 | Question: 7

An array A contains n integers in locations $A[0], A[1], \ldots A[n-1]$. It is required to shift the elements of the array cyclically to the left by K places, where $1 \leq K \leq n-1$. An incomplete algorithm for doing this in linear time, without using another array is given below. Complete the algorithm by filling in the blanks. Assume all variables are suitably declared.

```
min:=n;
i=0;
while _____ do
begin
   temp:=A[i];
```

```
    j:=i;
    while ____ do
    begin
      A[j]:=____;
      j:=(j+K) mod n;
     if j<min then
      min:=j;
    end;
    A[(n+i-K)mod n]:=____;
    i:=______;
end;
```

gatecse1994 algorithms normal algorithm-design fill-in-the-blanks

Answer key

1.1.3 Algorithm Design: GATE CSE 2006 | Question: 17

An element in an array X is called a leader if it is greater than all elements to the right of it in X. The best algorithm to find all leaders in an array

A. solves it in linear time using a left to right pass of the array
B. solves it in linear time using a right to left pass of the array
C. solves it using divide and conquer in time $\Theta(n \log n)$
D. solves it in time $\Theta(n^2)$

gatecse-2006 algorithms normal algorithm-design

Answer key

1.1.4 Algorithm Design: GATE CSE 2006 | Question: 54

Given two arrays of numbers $a_1, \dots, a_n$ and $b_1, \dots, b_n$ where each number is 0 or 1, the fastest algorithm to find the largest span (i, j) such that $a_i + a_{i+1} + \dots + a_j = b_i + b_{i+1} + \dots + b_j$ or report that there is not such span,

A. Takes $O(3^n)$ and $\Omega(2^n)$ time if hashing is permitted
B. Takes $O(n^3)$ and $\Omega(n^{2.5})$ time in the key comparison mode
C. Takes $\Theta(n)$ time and space
D. Takes $O(\sqrt{n})$ time only if the sum of the $2n$ elements is an even number

gatecse-2006 algorithms normal algorithm-design time-complexity

Answer key

1.1.5 Algorithm Design: GATE CSE 2014 Set 1 | Question: 37

There are 5 bags labeled 1 to 5. All the coins in a given bag have the same weight. Some bags have coins of weight 10 gm, others have coins of weight 11 gm. I pick $1, 2, 4, 8, 16$ coins respectively from bags 1 to 5 Their total weight comes out to 323 gm. Then the product of the labels of the bags having 11 gm coins is ___.

12

gatecse-2014-set1 algorithms numerical-answers normal algorithm-design

Answer key

1.1.6 Algorithm Design: GATE CSE 2019 | Question: 25

Consider a sequence of 14 elements: $A = [-5, -10, 6, 3, -1, -2, 13, 4, -9, -1, 4, 12, -3, 0]$. The sequence sum $S(i, j) = \Sigma_{k=i}^{j} A[k]$. Determine the maximum of $S(i, j)$, where $0 \leq i \leq j < 14$. (Divide and conquer approach may be used.)

Answer: 29

gatecse-2019 numerical-answers algorithms algorithm-design one-mark

Answer key

1.1.7 Algorithm Design: GATE CSE 2021 Set 1 | Question: 40

Define R_n to be the maximum amount earned by cutting a rod of length n meters into one or more pieces of integer length and selling them. For $i > 0$, let $p[i]$ denote the selling price of a rod whose length is i meters. Consider the array of prices:

$$\mathrm{p}[1]=1, \mathrm{p}[2]=5, \mathrm{p}[3]=8, \mathrm{p}[4]=9, \mathrm{p}[5]=10, \mathrm{p}[6]=17, \mathrm{p}[7]=18$$

Which of the following statements is/are correct about R_7?

A. $R_7 = 18$
B. $R_7 = 19$
C. R_7 is achieved by three different solutions
D. R_7 cannot be achieved by a solution consisting of three pieces

gatecse-2021-set1 multiple-selects algorithms algorithm-design two-marks

Answer key

1.1.8 Algorithm Design: GATE CSE 2024 | Set 2 | Question: 32

Consider an array X that contains n positive integers. A subarray of X is defined to be a sequence of array locations with consecutive indices.

The C code snippet given below has been written to compute the length of the longest subarray of X that contains at most two distinct integers. The code has two missing expressions labelled (P) and (Q).

```
int first=0, second=0, len1=0, len2=0, maxlen=0;
for (int i=0; i < n; i++) {
  if (X[i] == first) {
    len2++; len1++;
  } else if (X[i] == second) {
    len2++;
    len1 = ____(P)____;

    second = first;
  } else {
    len2 = ____(Q)____;

    len1 = 1; second = first;
  }
  if (len2 > maxlen) {
    maxlen = len2;
  }
  first = X[i];
}
```

Which one of the following options gives the CORRECT missing expressions?

(**Hint:** At the end of the i-th iteration, the value of $len1$ is the length of the longest subarray ending with $\mathrm{X}[i]$ that contains all equal values, and $len2$ is the length of the longest subarray ending with $\mathrm{X}[i]$ that contains at most two distinct values.)

A. $(\mathrm{P})\ \mathrm{len1}+1$ $(\mathrm{Q})\ \mathrm{len2}+1$
B. $(\mathrm{P})\ 1$ $(\mathrm{Q})\ \mathrm{len1}+1$
C. $(\mathrm{P})\ 1$ $(\mathrm{Q})\ \mathrm{len2}+1$
D. $(\mathrm{P})\ \mathrm{len2}+1$ $(\mathrm{Q})\ \mathrm{len1}+1$

gatecse2024-set2 algorithms algorithm-design two-marks

Answer key

1.2 Algorithm Design Technique (9)

1.2.1 Algorithm Design Technique: GATE CSE 1990 | Question: 12b

Consider the following problem. Given n positive integers $a_1, a_2 \ldots a_n$, it is required to partition them in to two parts A and B such that, $\left|\sum_{i \in A} a_i - \sum_{i \in B} a_i\right|$ is minimised

Consider a greedy algorithm for solving this problem. The numbers are ordered so that $a_1 \geq a_2 \geq \dots a_n$, and at i^{th} step, a_i is placed in that part whose sum in smaller at that step. Give an example with $n = 5$ for which the solution produced by the greedy algorithm is not optimal.

gate1990 descriptive algorithms algorithm-design-technique

Answer key

1.2.2 Algorithm Design Technique: GATE CSE 1990 | Question: 2-vii

Match the pairs in the following questions:

(a)	Strassen's matrix multiplication algorithm	(p)	Greedy method
(b)	Kruskal's minimum spanning tree algorithm	(q)	Dynamic programming
(c)	Biconnected components algorithm	(r)	Divide and Conquer
(d)	Floyd's shortest path algorithm	(s)	Depth-first search

gate1990 match-the-following algorithms algorithm-design-technique easy

Answer key

1.2.3 Algorithm Design Technique: GATE CSE 1994 | Question: 1.19, ISRO2016-31

Algorithm design technique used in quicksort algorithm is?

A. Dynamic programming
B. Backtracking
C. Divide and conquer
D. Greedy method

gate1994 algorithms algorithm-design-technique quick-sort easy isro2016

Answer key

1.2.4 Algorithm Design Technique: GATE CSE 1995 | Question: 1.5

Merge sort uses:

A. Divide and conquer strategy
B. Backtracking approach
C. Heuristic search
D. Greedy approach

gate1995 algorithms sorting easy algorithm-design-technique merge-sort

Answer key

1.2.5 Algorithm Design Technique: GATE CSE 1997 | Question: 1.5

The correct matching for the following pairs is

A.	All pairs shortest path	1.	Greedy
B.	Quick Sort	2.	Depth-First Search
C.	Minimum weight spanning tree	3.	Dynamic Programming
D.	Connected Components	4.	Divide and Conquer

A. A-2 B-4 C-1 D-3
B. A-3 B-4 C-1 D-2
C. A-3 B-4 C-2 D-1
D. A-4 B-1 C-2 D-3

gate1997 algorithms normal algorithm-design-technique easy match-the-following

Answer key

1.2.6 Algorithm Design Technique: GATE CSE 1998 | Question: 1.21, ISRO2008-16

Which one of the following algorithm design techniques is used in finding all pairs of shortest distances in a graph?

A. Dynamic programming
B. Backtracking
C. Greedy
D. Divide and Conquer

gate1998 algorithms algorithm-design-technique easy isro2008

Answer key

1.2.7 Algorithm Design Technique: GATE CSE 2015 Set 1 | Question: 6

Match the following:

P.	Prim's algorithm for minimum spanning tree	i.	Backtracking
Q.	Floyd-Warshall algorithm for all pairs shortest path	ii.	Greedy method
R.	Merge sort	iii.	Dynamic programming
S.	Hamiltonian circuit	iv.	Divide and conquer

A. P-iii, Q-ii, R-iv, S-i
B. P-i, Q-ii, R-iv, S-iii
C. P-ii, Q-iii, R-iv, S-i
D. P-ii, Q-i, R-iii, S-iv

gatecse-2015-set1 algorithms normal match-the-following algorithm-design-technique

Answer key

1.2.8 Algorithm Design Technique: GATE CSE 2015 Set 2 | Question: 36

Given below are some algorithms, and some algorithm design paradigms.

1.	Dijkstra's Shortest Path	i.	Divide and Conquer
2.	Floyd-Warshall algorithm to compute all pair shortest path	ii.	Dynamic Programming
3.	Binary search on a sorted array	iii.	Greedy design
4.	Backtracking search on a graph	iv.	Depth-first search
		v.	Breadth-first search

Match the above algorithms on the left to the corresponding design paradigm they follow.

A. 1-i, 2-iii, 3-i, 4-v
B. 1-iii, 2-iii, 3-i, 4-v
C. 1-iii, 2-ii, 3-i, 4-iv
D. 1-iii, 2-ii, 3-i, 4-v

gatecse-2015-set2 algorithms easy algorithm-design-technique match-the-following

Answer key

1.2.9 Algorithm Design Technique: GATE CSE 2017 Set 1 | Question: 05

Consider the following table:

	Algorithms		Design Paradigms
(P)	Kruskal	(i)	Divide and Conquer
(Q)	Quicksort	(ii)	Greedy
(R)	Floyd-Warshall	(iii)	Dynamic Programming

Match the algorithms to the design paradigms they are based on.

A. $(P) \leftrightarrow (ii), (Q) \leftrightarrow (iii), (R) \leftrightarrow (i)$
B. $(P) \leftrightarrow (iii), (Q) \leftrightarrow (i), (R) \leftrightarrow (ii)$
C. $(P) \leftrightarrow (ii), (Q) \leftrightarrow (i), (R) \leftrightarrow (iii)$
D. $(P) \leftrightarrow (i), (Q) \leftrightarrow (ii), (R) \leftrightarrow (iii)$

gatecse-2017-set1 algorithms algorithm-design-technique easy match-the-following

Answer key

1.3 Asymptotic Notation (7)

1.3.1 Asymptotic Notation: GATE CSE 1999 | Question: 2.21

If $T_1 = O(1)$, give the correct matching for the following pairs:

(M) $T_n = T_{n-1} + n$	(U) $T_n = O(n)$
(N) $T_n = T_{n/2} + n$	(V) $T_n = O(n \log n)$
(O) $T_n = T_{n/2} + n \log n$	(W) $T_n = O(n^2)$
(P) $T_n = T_{n-1} + \log n$	(X) $T_n = O(\log^2 n)$

A. M-W, N-V, O-U, P-X
B. M-W, N-U, O-X, P-V
C. M-V, N-W, O-X, P-U
D. M-W, N-U, O-V, P-X

gate1999 algorithms recurrence-relation asymptotic-notation normal match-the-following

Answer key☟

1.3.2 Asymptotic Notation: GATE CSE 2017 Set 1 | Question: 04

Consider the following functions from positive integers to real numbers:

$10, \sqrt{n}, n, \log_2 n, \frac{100}{n}$.
The CORRECT arrangement of the above functions in increasing order of asymptotic complexity is:

A. $\log_2 n, \frac{100}{n}, 10, \sqrt{n}, n$
B. $\frac{100}{n}, 10, \log_2 n, \sqrt{n}, n$
C. $10, \frac{100}{n}, \sqrt{n}, \log_2 n, n$
D. $\frac{100}{n}, \log_2 n, 10, \sqrt{n}, n$

gatecse-2017-set1 algorithms asymptotic-notation normal

Answer key☟

1.3.3 Asymptotic Notation: GATE CSE 2021 Set 1 | Question: 3

Consider the following three functions.

$$f_1 = 10^n \quad f_2 = n^{\log n} \quad f_3 = n^{\sqrt{n}}$$

Which one of the following options arranges the functions in the increasing order of asymptotic growth rate?

A. f_3, f_2, f_1
B. f_2, f_1, f_3
C. f_1, f_2, f_3
D. f_2, f_3, f_1

gatecse-2021-set1 algorithms asymptotic-notation one-mark

Answer key☟

1.3.4 Asymptotic Notation: GATE CSE 2022 | Question: 1

Which one of the following statements is TRUE for all positive functions $f(n)$?

A. $f(n^2) = \theta(f(n)^2)$, when $f(n)$ is a polynomial
B. $f(n^2) = o(f(n)^2)$
C. $f(n^2) = O(f(n)^2)$, when $f(n)$ is an exponential function
D. $f(n^2) = \Omega(f(n)^2)$

gatecse-2022 algorithms asymptotic-notation one-mark

Answer key☟

1.3.5 Asymptotic Notation: GATE CSE 2023 | Question: 19

Let f and g be functions of natural numbers given by $f(n) = n$ and $g(n) = n^2$. Which of the following statements is/are TRUE?

A. $f \in O(g)$
B. $f \in \Omega(g)$

C. $f \in o(g)$

D. $f \in \Theta(g)$

gatecse-2023 algorithms asymptotic-notation multiple-selects one-mark

Answer key

1.3.6 Asymptotic Notation: GATE CSE 2023 | Question: 44

Consider functions **Function_1** and **Function_2** expressed in pseudocode as follows:

```
Function_1
  while n>1 do
    for i=1 to n do
      x = x + 1;
    end for
    n = ⌊n/2⌋;
  end while
```

```
Function_2
  for i = 1 to 100 * n do
    x = x + 1;
  end for
```

Let $f_1(n)$ and $f_2(n)$ denote the number of times the statement "$\mathrm{x} = \mathrm{x} + 1$" is executed in **Function_1** and **Function_2**, respectively.

Which of the following statements is/are TRUE?

A. $f_1(n) \in \Theta(f_2(n))$

B. $f_1(n) \in o(f_2(n))$

C. $f_1(n) \in \omega(f_2(n))$

D. $f_1(n) \in O(n)$

gatecse-2023 algorithms asymptotic-notation multiple-selects two-marks

Answer key

1.3.7 Asymptotic Notation: GATE CSE 2024 | Set 2 | Question: 5

Let $\mathrm{T(n)}$ be the recurrence relation defined as follows:

$$\begin{aligned} &T(0) = 1, \\ &T(1) = 2, \text{ and} \\ &T(n) = 5T(n-1) - 6T(n-2) \text{ for } n \geq 2 \end{aligned}$$

Which one of the following statements is TRUE?

A. $T(n) = \Theta(2^n)$

B. $T(n) = \Theta(n2^n)$

C. $T(n) = \Theta(3^n)$

D. $T(n) = \Theta(n3^n)$

gatecse2024-set2 algorithms recurrence-relation asymptotic-notation one-mark

Answer key

1.4 Asymptotic Notations (14)

1.4.1 Asymptotic Notations: GATE CSE 1994 | Question: 1.23

Consider the following two functions:

$$g_1(n) = \begin{cases} n^3 \text{ for } 0 \leq n \leq 10,000 \\ n^2 \text{ for } n > 10,000 \end{cases}$$

$$g_2(n) = \begin{cases} n \text{ for } 0 \leq n \leq 100 \\ n^3 \text{ for } n > 100 \end{cases}$$

Which of the following is true?

A. $g_1(n)$ is $O(g_2(n))$

B. $g_1(n)$ is $O(n^3)$

C. $g_2(n)$ is $O(g_1(n))$

D. $g_2(n)$ is $O(n)$

gate1994 algorithms asymptotic-notations normal multiple-selects

Answer key

1.4.2 Asymptotic Notations: GATE CSE 1996 | Question: 1.11

Which of the following is false?

A. $100n \log n = O(\frac{n \log n}{100})$

B. $\sqrt{\log n} = O(\log \log n)$

C. If $0 < x < y \text{ then } n^x = O\left(n^y\right)$

D. $2^n \neq O\left(nk\right)$

gate1996 algorithms asymptotic-notations normal

Answer key

1.4.3 Asymptotic Notations: GATE CSE 2000 | Question: 2.17

Consider the following functions

- $f(n) = 3n^{\sqrt{n}}$
- $g(n) = 2^{\sqrt{n}\log_2 n}$
- $h(n) = n!$

Which of the following is true?

A. $h(n)$ is $O(f(n))$

B. $h(n)$ is $O(g(n))$

C. $g(n)$ is not $O(f(n))$

D. $f(n)$ is $O(g(n))$

gatecse-2000 algorithms asymptotic-notations normal

Answer key

1.4.4 Asymptotic Notations: GATE CSE 2001 | Question: 1.16

Let $f(n) = n^2 \log n$ and $g(n) = n(\log n)^{10}$ be two positive functions of n. Which of the following statements is correct?

A. $f(n) = O(g(n)) \text{ and } g(n) \neq O(f(n))$

B. $g(n) = O(f(n)) \text{ and } f(n) \neq O(g(n))$

C. $f(n) \neq O(g(n)) \text{ and } g(n) \neq O(f(n))$

D. $f(n) = O(g(n)) \text{ and } g(n) = O(f(n))$

gatecse-2001 algorithms asymptotic-notations time-complexity normal

Answer key

1.4.5 Asymptotic Notations: GATE CSE 2003 | Question: 20

Consider the following three claims:

I. $(n+k)^m = \Theta(n^m)$ where k and m are constants
II. $2^{n+1} = O(2^n)$
III. $2^{2n+1} = O(2^n)$

Which of the following claims are correct?

A. I and II

B. I and III

C. II and III

D. I, II, and III

gatecse-2003 algorithms asymptotic-notations normal

Answer key

1.4.6 Asymptotic Notations: GATE CSE 2004 | Question: 29

The tightest lower bound on the number of comparisons, in the worst case, for comparison-based sorting is of the order of

A. n

B. n^2

C. $n \log n$

D. $n \log^2 n$

gatecse-2004 algorithms sorting asymptotic-notations easy

Answer key

1.4.7 Asymptotic Notations: GATE CSE 2005 | Question: 37

Suppose $T(n) = 2T(\frac{n}{2}) + n, T(0) = T(1) = 1$

Which one of the following is FALSE?

A. $T(n) = O(n^2)$
B. $T(n) = \Theta(n \log n)$
C. $T(n) = \Omega(n^2)$
D. $T(n) = O(n \log n)$

gatecse-2005 algorithms asymptotic-notations recurrence-relation normal

Answer key☟

1.4.8 Asymptotic Notations: GATE CSE 2008 | Question: 39

Consider the following functions:

- $f(n) = 2^n$
- $g(n) = n!$
- $h(n) = n^{\log n}$

Which of the following statements about the asymptotic behavior of $f(n)$, $g(n)$ and $h(n)$ is true?

A. $f(n) = O(g(n)); g(n) = O(h(n))$
B. $f(n) = \Omega(g(n)); g(n) = O(h(n))$
C. $g(n) = O(f(n)); h(n) = O(f(n))$
D. $h(n) = O(f(n)); g(n) = \Omega(f(n))$

gatecse-2008 algorithms asymptotic-notations normal

Answer key☟

1.4.9 Asymptotic Notations: GATE CSE 2011 | Question: 37

Which of the given options provides the increasing order of asymptotic complexity of functions f_1, f_2, f_3 and f_4?

- $f_1(n) = 2^n$
- $f_2(n) = n^{3/2}$
- $f_3(n) = n \log_2 n$
- $f_4(n) = n^{\log_2 n}$

A. f_3, f_2, f_4, f_1
B. f_3, f_2, f_1, f_4
C. f_2, f_3, f_1, f_4
D. f_2, f_3, f_4, f_1

gatecse-2011 algorithms asymptotic-notations normal

Answer key☟

1.4.10 Asymptotic Notations: GATE CSE 2012 | Question: 18

Let $W(n)$ and $A(n)$ denote respectively, the worst case and average case running time of an algorithm executed on an input of size n. Which of the following is **ALWAYS TRUE**?

A. $A(n) = \Omega(W(n))$
B. $A(n) = \Theta(W(n))$
C. $A(n) = \mathrm{O}(W(n))$
D. $A(n) = \mathrm{o}(W(n))$

gatecse-2012 algorithms easy asymptotic-notations

Answer key☟

1.4.11 Asymptotic Notations: GATE CSE 2015 Set 3 | Question: 4

Consider the equality $\displaystyle\sum_{i=0}^{n} i^3 = X$ and the following choices for X:

I. $\Theta(n^4)$
II. $\Theta(n^5)$
III. $O(n^5)$
IV. $\Omega(n^3)$

The equality above remains correct if X is replaced by

A. Only I
B. Only II
C. I or III or IV but not II
D. II or III or IV but not I

gatecse-2015-set3 algorithms asymptotic-notations normal

Answer key☟

1.4.12 Asymptotic Notations: GATE CSE 2015 Set 3 | Question: 42

Let $f(n) = n$ and $g(n) = n^{(1+\sin\ n)}$, where n is a positive integer. Which of the following statements is/are correct?

I. $f(n) = O(g(n))$
II. $f(n) = \Omega(g(n))$

A. Only I
B. Only II
C. Both I and II
D. Neither I nor II

gatecse-2015-set3 algorithms asymptotic-notations normal

Answer key☟

1.4.13 Asymptotic Notations: GATE IT 2004 | Question: 55

Let $f(n)$, $g(n)$ and $h(n)$ be functions defined for positive integers such that $f(n) = O(g(n))$, $g(n) \neq O(f(n))$, $g(n) = O(h(n))$, and $h(n) = O(g(n))$.
Which one of the following statements is FALSE?

A. $f(n) + g(n) = O(h(n) + h(n))$
B. $f(n) = O(h(n))$
C. $h(n) \neq O(f(n))$
D. $f(n)h(n) \neq O(g(n)h(n))$

gateit-2004 algorithms asymptotic-notations normal

Answer key☟

1.4.14 Asymptotic Notations: GATE IT 2008 | Question: 10

Arrange the following functions in increasing asymptotic order:

a. $n^{1/3}$
b. e^n
c. $n^{7/4}$
d. $n \log^9 n$
e. 1.0000001^n

A. a, d, c, e, b
B. d, a, c, e, b
C. a, c, d, e, b
D. a, c, d, b, e

gateit-2008 algorithms asymptotic-notations normal

Answer key☟

1.5 Bellman Ford (2)

1.5.1 Bellman Ford: GATE CSE 2009 | Question: 13

Which of the following statement(s) is/are correct regarding Bellman-Ford shortest path algorithm?

P: Always finds a negative weighted cycle, if one exists.

Q: Finds whether any negative weighted cycle is reachable from the source.

A. P only
B. Q only
C. Both P and Q
D. Neither P nor Q

gatecse-2009 algorithms graph-algorithms normal bellman-ford

Answer key☟

1.5.2 Bellman Ford: GATE CSE 2013 | Question: 19

What is the time complexity of Bellman-Ford single-source shortest path algorithm on a complete graph of n vertices?

A. $\theta(n^2)$
B. $\theta(n^2 \log n)$
C. $\theta(n^3)$
D. $\theta(n^3 \log n)$

gatecse-2013 algorithms graph-algorithms normal bellman-ford

Answer key

1.6 Binary Search (3)

1.6.1 Binary Search: GATE CSE 2021 Set 2 | Question: 8

What is the worst-case number of arithmetic operations performed by recursive binary search on a sorted array of size n?

A. $\Theta(\sqrt{n})$
B. $\Theta(\log_2(n))$
C. $\Theta(n^2)$
D. $\Theta(n)$

gatecse-2021-set2 algorithms binary-search time-complexity one-mark

Answer key

1.6.2 Binary Search: GATE DA 2025 | Question: 17

For which of the following inputs does binary search take time $O(\log n)$ in the worst case?

A. An array of n integers in any order
B. A linked list of n integers in any order
C. An array of n integers in increasing order
D. A linked list of n integers in increasing order

gateda-2025 algorithms binary-search multiple-selects one-mark

Answer key

1.6.3 Binary Search: GATE DS&AI 2024 | Question: 30

Let $F(n)$ denote the maximum number of comparisons made while searching for an entry in a sorted array of size n using binary search.

Which ONE of the following options is TRUE?

A. $F(n) = F(\lfloor n/2 \rfloor) + 1$
B. $F(n) = F(\lfloor n/2 \rfloor) + F(\lceil n/2 \rceil)$
C. $F(n) = F(\lfloor n/2 \rfloor)$
D. $F(n) = F(n-1) + 1$

gate-ds-ai-2024 algorithms binary-search two-marks

Answer key

1.7 Bitonic Array (1)

1.7.1 Bitonic Array: GATE CSE 2025 | Set 2 | Question: 31

An array A of length n with distinct elements is said to be bitonic if there is an index $1 \leq i \leq n$ such that $A[1..i]$ is sorted in the non-decreasing order and $A[i+1...n]$ is sorted in the non-increasing order.

Which ONE of the following represents the best possible asymptotic bound for the worst-case number of comparisons by an algorithm that searches for an element in a bitonic array A ?

A. $\Theta(n)$
B. $\Theta(1)$
C. $\Theta\left(\log^2 n\right)$
D. $\Theta(\log n)$

gatecse2025-set2 algorithms searching bitonic-array time-complexity two-marks

Answer key

1.8 Depth First Search (1)

1.8.1 Depth First Search: GATE DS&AI 2024 | Question: 34

Consider a state space where the start state is number 1. The successor function for the state numbered n returns two states numbered $n+1$ and $n+2$. Assume that the states in the unexpanded state list are expanded in the ascending order of numbers and the previously expanded states are not added to the unexpanded state list.

Which ONE of the following statements about breadth-first search (BFS) and depth-first search (DFS) is true, when reaching the goal state number 6?

A. BFS expands more states than DFS.
B. DFS expands more states than BFS.
C. Both BFS and DFS expand equal number of states.
D. Both BFS and DFS do not reach the goal state number 6.

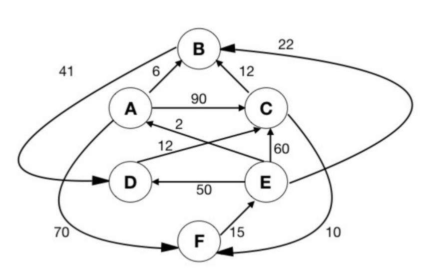
gate-ds-ai-2024 algorithms breadth-first-search depth-first-search two-marks

Answer key

1.9 Dijkstras Algorithm (6)

1.9.1 Dijkstras Algorithm: GATE CSE 1996 | Question: 17

Let G be the directed, weighted graph shown in below figure



We are interested in the shortest paths from A.

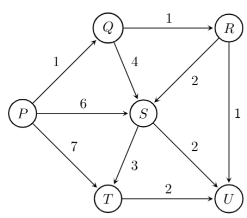
a. Output the sequence of vertices identified by the Dijkstra's algorithm for single source shortest path when the algorithm is started at node A
b. Write down sequence of vertices in the shortest path from A to E
c. What is the cost of the shortest path from A to E?

gate1996 algorithms graph-algorithms normal dijkstras-algorithm descriptive

Answer key

1.9.2 Dijkstras Algorithm: GATE CSE 2004 | Question: 44

Suppose we run Dijkstra's single source shortest path algorithm on the following edge-weighted directed graph with vertex P as the source.



In what order do the nodes get included into the set of vertices for which the shortest path distances are finalized?

A. P,Q,R,S,T,U B. P,Q,R,U,S,T C. P,Q,R,U,T,S D. P,Q,T,R,U,S

gatecse-2004 algorithms graph-algorithms normal dijkstras-algorithm

Answer key

1.9.3 Dijkstras Algorithm: GATE CSE 2005 | Question: 38

Let $G(V, E)$ be an undirected graph with positive edge weights. Dijkstra's single source shortest path algorithm can be implemented using the binary heap data structure with time complexity:

A. $O\left(|V|^2\right)$

B. $O\left(|E| + |V| \log |V|\right)$

C. $O\left(|V| \log |V|\right)$

D. $O\left(\left(|E| + |V|\right) \log |V|\right)$

gatecse-2005 algorithms graph-algorithms normal dijkstras-algorithm

Answer key

1.9.4 Dijkstras Algorithm: GATE CSE 2006 | Question: 12

To implement Dijkstra's shortest path algorithm on unweighted graphs so that it runs in linear time, the data structure to be used is:

A. Queue

B. Stack

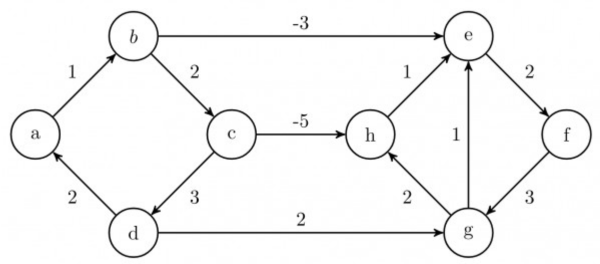
C. Heap

D. B-Tree

gatecse-2006 algorithms graph-algorithms easy dijkstras-algorithm

Answer key

1.9.5 Dijkstras Algorithm: GATE CSE 2008 | Question: 45



Dijkstra's single source shortest path algorithm when run from vertex a in the above graph, computes the correct shortest path distance to

A. only vertex a

B. only vertices a, e, f, g, h

C. only vertices a, b, c, d

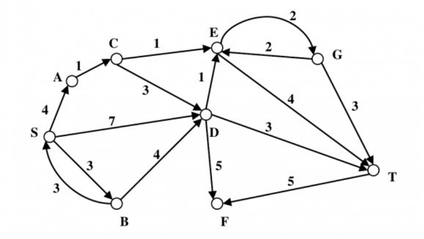
D. all the vertices

gatecse-2008 algorithms graph-algorithms normal dijkstras-algorithm

Answer key

1.9.6 Dijkstras Algorithm: GATE CSE 2012 | Question: 40

Consider the directed graph shown in the figure below. There are multiple shortest paths between vertices S and T. Which one will be reported by Dijkstra's shortest path algorithm? Assume that, in any iteration, the shortest path to a vertex v is updated only when a strictly shorter path to v is discovered.



A. SDT

B. SBDT

C. SACDT

D. SACET

gatecse-2012 algorithms graph-algorithms normal dijkstras-algorithm

Answer key

1.10 Directed Graph (1)

1.10.1 Directed Graph: GATE DA 2025 | Question: 55

Consider a directed graph $G=(V,E)$, where $V=\{0,1,2,\ldots,100\}$ and $E=\{(i,j):0<j-i\leq 2,$ for all $i,j\in V\}$. Suppose the adjacency list of each vertex is in decreasing order of vertex number, and depth-first search (DFS) is performed at vertex 0. The number of vertices that will be discovered after vertex 50 is ____________ (Answer in integer)

gateda-2025 algorithms depth-first-search directed-graph numerical-answers two-marks

1.11 Double Hashing (1)

1.11.1 Double Hashing: GATE CSE 2025 | Set 1 | Question: 55

In a double hashing scheme, $h_1(k)=k \bmod 11$ and $h_2(k)=1+(k \bmod 7)$ are the auxiliary hash functions. The size m of the hash table is 11. The hash function for the i-th probe in the open address table is $[h_1(k)+ih_2(k)] \bmod m$. The following keys are inserted in the given order: $63,50,25,79,67,24$.

The slot at which key 24 gets stored is ___________ . (Answer in integer)

gatecse2025-set1 algorithms hashing double-hashing numerical-answers easy two-marks

Answer key☟

1.12 Dynamic Programming (9)

1.12.1 Dynamic Programming: GATE CSE 2008 | Question: 80

The subset-sum problem is defined as follows. Given a set of n positive integers, $S=\{a_1,a_2,a_3,\ldots,a_n\}$, and positive integer W, is there a subset of S whose elements sum to W? A dynamic program for solving this problem uses a 2-dimensional Boolean array, X, with n rows and $W+1$ columns. $X[i,j],1\leq i\leq n,0\leq j\leq W$, is TRUE, if and only if there is a subset of $\{a_1,a_2,\ldots,a_i\}$ whose elements sum to j.

Which of the following is valid for $2\leq i\leq n$, and $a_i\leq j\leq W$?

A. $X[i,j]=X[i-1,j]\vee X[i,j-a_i]$
B. $X[i,j]=X[i-1,j]\vee X[i-1,j-a_i]$
C. $X[i,j]=X[i-1,j]\wedge X[i,j-a_i]$
D. $X[i,j]=X[i-1,j]\wedge X[i-1,j-a_i]$

gatecse-2008 algorithms normal dynamic-programming

Answer key☟

1.12.2 Dynamic Programming: GATE CSE 2008 | Question: 81

The subset-sum problem is defined as follows. Given a set of n positive integers, $S=\{a_1,a_2,a_3,\ldots,a_n\}$, and positive integer W, is there a subset of S whose elements sum to W? A dynamic program for solving this problem uses a 2-dimensional Boolean array, X, with n rows and $W+1$ columns. $X[i,j],1\leq i\leq n,0\leq j\leq W$, is TRUE, if and only if there is a subset of $\{a_1,a_2,\ldots,a_i\}$ whose elements sum to j.

Which entry of the array X, if TRUE, implies that there is a subset whose elements sum to W?

A. $X[1,W]$ B. $X[n,0]$ C. $X[n,W]$ D. $X[n-1,n]$

gatecse-2008 algorithms normal dynamic-programming

Answer key☟

1.12.3 Dynamic Programming: GATE CSE 2009 | Question: 53

A sub-sequence of a given sequence is just the given sequence with some elements (possibly none or all) left out. We are given two sequences $X[m]$ and $Y[n]$ of lengths m and n, respectively with indexes of X and Y starting from 0.

We wish to find the length of the longest common sub-sequence (LCS) of $X[m]$ and $Y[n]$ as $l(m,n)$, where an incomplete recursive definition for the function $I(i,j)$ to compute the length of the LCS of $X[m]$ and $Y[n]$ is given below:

I(i,j) = 0, if either i = 0 or j = 0
= expr1, if i,j > 0 and X[i-1] = Y[j-1]
= expr2, if i,j > 0 and X[i-1] ≠ Y[j-1]

Which one of the following options is correct?

A. $\text{expr1} = l(i-1,j)+1$
B. $\text{expr1} = l(i,j-1)$
C. $\text{expr2} = \max(l(i-1,j), l(i,j-1))$
D. $\text{expr2} = \max(l(i-1,j-1), l(i,j))$

gatecse-2009 algorithms normal dynamic-programming recursion

Answer key☟

1.12.4 Dynamic Programming: GATE CSE 2009 | Question: 54

A sub-sequence of a given sequence is just the given sequence with some elements (possibly none or all) left out. We are given two sequences $X[m]$ and $Y[n]$ of lengths m and n, respectively with indexes of X and Y starting from 0.

We wish to find the length of the longest common sub-sequence (LCS) of $X[m]$ and $Y[n]$ as $l(m,n)$, where an incomplete recursive definition for the function $I(i,j)$ to compute the length of the LCS of $X[m]$ and $Y[n]$ is given below:

I(i,j) = 0, if either i = 0 or j = 0
= expr1, if i,j > 0 and X[i-1] = Y[j-1]
= expr2, if i,j > 0 and X[i-1] ≠ Y[j-1]

The value of $l(i,j)$ could be obtained by dynamic programming based on the correct recursive definition of $l(i,j)$ of the form given above, using an array $L[M,N]$, where $M = m+1$ and $N = n+1$, such that $L[i,j] = l(i,j)$.

Which one of the following statements would be TRUE regarding the dynamic programming solution for the recursive definition of $l(i,j)$?

A. All elements of L should be initialized to 0 for the values of $l(i,j)$ to be properly computed.
B. The values of $l(i,j)$ may be computed in a row major order or column major order of $L[M,N]$.
C. The values of $l(i,j)$ cannot be computed in either row major order or column major order of $L[M,N]$.
D. $L[p,q]$ needs to be computed before $L[r,s]$ if either $p < r$ or $q < s$.

gatecse-2009 normal algorithms dynamic-programming recursion

Answer key☟

1.12.5 Dynamic Programming: GATE CSE 2010 | Question: 34

The weight of a sequence $a_0, a_1, \dots, a_{n-1}$ of real numbers is defined as $a_0 + a_1/2 + \dots + a_{n-1}/2^{n-1}$. A subsequence of a sequence is obtained by deleting some elements from the sequence, keeping the order of the remaining elements the same. Let X denote the maximum possible weight of a subsequence of $a_o, a_1, \dots, a_{n-1}$ and Y the maximum possible weight of a subsequence of $a_1, a_2, \dots, a_{n-1}$. Then X is equal to

A. $max(Y, a_0 + Y)$
B. $max(Y, a_0 + Y/2)$
C. $max(Y, a_0 + 2Y)$
D. $a_0 + Y/2$

gatecse-2010 algorithms dynamic-programming normal

Answer key☟

1.12.6 Dynamic Programming: GATE CSE 2011 | Question: 25

An algorithm to find the length of the longest monotonically increasing sequence of numbers in an array $A[0:n-1]$ is given below.

Let L_i, denote the length of the longest monotonically increasing sequence starting at index i in the array.

Initialize $L_{n-1} = 1$.

For all i such that $0 \leq i \leq n-2$

$$L_i = \begin{cases} 1 + L_{i+1} & \text{if A[i]} < \text{A[i+1]} \\ 1 & \text{Otherwise} \end{cases}$$

Finally, the length of the longest monotonically increasing sequence is $\max(L_0, L_1, \ldots, L_{n-1})$.

Which of the following statements is **TRUE**?

A. The algorithm uses dynamic programming paradigm
B. The algorithm has a linear complexity and uses branch and bound paradigm
C. The algorithm has a non-linear polynomial complexity and uses branch and bound paradigm
D. The algorithm uses divide and conquer paradigm

gatecse-2011 algorithms easy dynamic-programming

Answer key☟

1.12.7 Dynamic Programming: GATE CSE 2014 Set 2 | Question: 37

Consider two strings A = *"qpqrr"* and B = *"pqprqrp"*. Let x be the length of the longest common subsequence *(not necessarily contiguous)* between A and B and let y be the number of such longest common subsequences between A and B. Then $x + 10y =$ ___.

gatecse-2014-set2 algorithms normal numerical-answers dynamic-programming

Answer key☟

1.12.8 Dynamic Programming: GATE CSE 2014 Set 3 | Question: 37

Suppose you want to move from 0 to 100 on the number line. In each step, you either move right by a unit distance or you take a *shortcut*. A shortcut is simply a pre-specified pair of integers $i,\ j$ with $i < j$. Given a shortcut (i, j), if you are at position i on the number line, you may directly move to j. Suppose $T(k)$ denotes the smallest number of steps needed to move from k to 100. Suppose further that there is at most 1 shortcut involving any number, and in particular, from 9 there is a shortcut to 15. Let y and z be such that $T(9) = 1 + \min(T(y), T(z))$. Then the value of the product yz is _____.

gatecse-2014-set3 algorithms normal numerical-answers dynamic-programming

Answer key☟

1.12.9 Dynamic Programming: GATE CSE 2016 Set 2 | Question: 14

The Floyd-Warshall algorithm for all-pair shortest paths computation is based on

A. Greedy paradigm.
B. Divide-and-conquer paradigm.
C. Dynamic Programming paradigm.
D. Neither Greedy nor Divide-and-Conquer nor Dynamic Programming paradigm.

gatecse-2016-set2 algorithms dynamic-programming easy

Answer key☟

1.13 Graph Algorithms (11)

1.13.1 Graph Algorithms: GATE CSE 1994 | Question: 1.22

Which of the following statements is false?

A. Optimal binary search tree construction can be performed efficiently using dynamic programming
B. Breadth-first search cannot be used to find connected components of a graph
C. Given the prefix and postfix walks over a binary tree, the binary tree cannot be uniquely constructed.
D. Depth-first search can be used to find connected components of a graph

gate1994 algorithms normal graph-algorithms

Answer key

1.13.2 Graph Algorithms: GATE CSE 2003 | Question: 70

Let $G = (V, E)$ be a directed graph with n vertices. A path from v_i to v_j in G is a sequence of vertices ($v_i, v_{i+1}, \dots, v_j$) such that $(v_k, v_{k+1}) \in E$ for all k in i through $j - 1$. A simple path is a path in which no vertex appears more than once.

Let A be an $n \times n$ array initialized as follows:

$$A[j,k] = \begin{cases} 1, & \text{if } (j,k) \in E \\ 0, & \text{otherwise} \end{cases}$$

Consider the following algorithm:

```
for i=1 to n
   for j=1 to n
      for k=1 to n
         A[j,k] = max(A[j,k], A[j,i] + A[i,k]);
```

Which of the following statements is necessarily true for all j and k after termination of the above algorithm?

A. $A[j,k] \leq n$
B. If $A[j,j] \geq n - 1$ then G has a Hamiltonian cycle
C. If there exists a path from j to k, $A[j,k]$ contains the longest path length from j to k
D. If there exists a path from j to k, every simple path from j to k contains at most $A[j,k]$ edges

gatecse-2003 algorithms graph-algorithms normal

Answer key

1.13.3 Graph Algorithms: GATE CSE 2005 | Question: 82a

Let s and t be two vertices in a undirected graph $G = (V, E)$ having distinct positive edge weights. Let $[X, Y]$ be a partition of V such that $s \in X$ and $t \in Y$. Consider the edge e having the minimum weight amongst all those edges that have one vertex in X and one vertex in Y.

The edge e must definitely belong to:

A. the minimum weighted spanning tree of G
B. the weighted shortest path from s to t
C. each path from s to t
D. the weighted longest path from s to t

gatecse-2005 algorithms graph-algorithms normal

Answer key

1.13.4 Graph Algorithms: GATE CSE 2005 | Question: 82b

Let s and t be two vertices in a undirected graph $G = (V, E)$ having distinct positive edge weights. Let $[X, Y]$ be a partition of V such that $s \in X$ and $t \in Y$. Consider the edge e having the minimum weight amongst all those edges that have one vertex in X and one vertex in Y.

Let the weight of an edge e denote the congestion on that edge. The congestion on a path is defined to be the maximum of the congestions on the edges of the path. We wish to find the path from s to t having minimum congestion. Which of the following paths is always such a path of minimum congestion?

A. a path from s to t in the minimum weighted spanning tree
B. a weighted shortest path from s to t
C. an Euler walk from s to t
D. a Hamiltonian path from s to t

gatecse-2005 algorithms graph-algorithms normal

Answer key

1.13.5 Graph Algorithms: GATE CSE 2016 Set 2 | Question: 41

In an adjacency list representation of an undirected simple graph $G = (V, E)$, each edge (u, v) has two adjacency list entries: $[v]$ in the adjacency list of u, and $[u]$ in the adjacency list of v. These are called twins of each other. A twin pointer is a pointer from an adjacency list entry to its twin. If $|E| = m$ and $|V| = n$, and the memory size is not a constraint, what is the time complexity of the most efficient algorithm to set the twin pointer in each entry in each adjacency list?

A. $\Theta\left(n^2\right)$
B. $\Theta\left(n+m\right)$
C. $\Theta\left(m^2\right)$
D. $\Theta\left(n^4\right)$

gatecse-2016-set2 algorithms graph-algorithms normal

Answer key☟

1.13.6 Graph Algorithms: GATE CSE 2017 Set 1 | Question: 26

Let $G = (V, E)$ be *any* connected, undirected, edge-weighted graph. The weights of the edges in E are positive and distinct. Consider the following statements:

I. Minimum Spanning Tree of G is always unique.
II. Shortest path between any two vertices of G is always unique.

Which of the above statements is/are necessarily true?

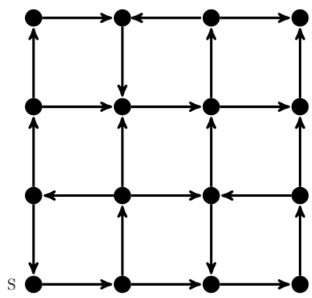
A. I only
B. II only
C. both I and II
D. neither I nor II

gatecse-2017-set1 algorithms graph-algorithms normal

Answer key☟

1.13.7 Graph Algorithms: GATE CSE 2021 Set 2 | Question: 46

Consider the following directed graph:



Which of the following is/are correct about the graph?

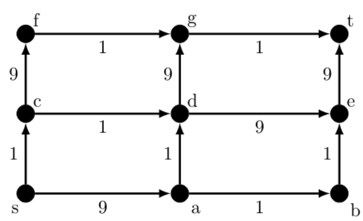
A. The graph does not have a topological order
B. A depth-first traversal starting at vertex S classifies three directed edges as back edges
C. The graph does not have a strongly connected component
D. For each pair of vertices u and v, there is a directed path from u to v

gatecse-2021-set2 multiple-selects algorithms graph-algorithms two-marks

Answer key☟

1.13.8 Graph Algorithms: GATE CSE 2021 Set 2 | Question: 55

In a directed acyclic graph with a source vertex **s**, the $quality\text{-}score$ of a directed path is defined to be the product of the weights of the edges on the path. Further, for a vertex v other than **s**, the quality-score of v is defined to be the maximum among the quality-scores of all the paths from **s** to v. The quality-score of **s** is assumed to be 1.



The sum of the quality-scores of all vertices on the graph shown above is _______ gatecse-2021-set2 algorithms graph-algorithms directed-acyclic-graph numerical-answers two-marks

Answer key

1.13.9 Graph Algorithms: GATE IT 2005 | Question: 15

In the following table, the left column contains the names of standard graph algorithms and the right column contains the time complexities of the algorithms. Match each algorithm with its time complexity.

1.	Bellman-Ford algorithm	A:	$O(m \log n)$
2.	Kruskal's algorithm	B:	$O(n^3)$
3.	Floyd-Warshall algorithm	C:	$O(nm)$
4.	Topological sorting	D:	$O(n+m)$

A. $1 \rightarrow$ C, $2 \rightarrow$ A, $3 \rightarrow$ B, $4 \rightarrow$ D

B. $1 \rightarrow$ B, $2 \rightarrow$ D, $3 \rightarrow$ C, $4 \rightarrow$ A

C. $1 \rightarrow$ C, $2 \rightarrow$ D, $3 \rightarrow$ A, $4 \rightarrow$ B

D. $1 \rightarrow$ B, $2 \rightarrow$ A, $3 \rightarrow$ C, $4 \rightarrow$ D

gateit-2005 algorithms graph-algorithms match-the-following easy

Answer key

1.13.10 Graph Algorithms: GATE IT 2005 | Question: 84a

A sink in a directed graph is a vertex i such that there is an edge from every vertex $j \neq i$ to i and there is no edge from i to any other vertex. A directed graph G with n vertices is represented by its adjacency matrix A, where $A[i][j] = 1$ if there is an edge directed from vertex i to j and 0 otherwise. The following algorithm determines whether there is a sink in the graph G.

```
i = 0;
do {
   j = i + 1;
   while ((j < n) && E1) j++;
   if (j < n) E2;
} while (j < n);
flag = 1;
for (j = 0; j < n; j++)
   if ((j! = i) && E3) flag = 0;
if (flag) printf("Sink exists");
else printf ("Sink does not exist");
```

Choose the correct expressions for E_1 and E_2

A. $E_1 : A[i][j]$ and $E_2 : i = j;$

B. $E_1 : \ !A[i][j]$ and $E_2 : i = j + 1;$

C. $E_1 : \ !A[i][j]$ and $E_2 : i = j;$

D. $E_1 : A[i][j]$ and $E_2 : i = j + 1;$

gateit-2005 algorithms graph-algorithms normal

Answer key

1.13.11 Graph Algorithms: GATE IT 2005 | Question: 84b

A sink in a directed graph is a vertex i such that there is an edge from every vertex $j \neq i$ to i and there is no edge from i to any other vertex. A directed graph G with n vertices is represented by its adjacency matrix A, where $A[i][j] = 1$ if there is an edge directed from vertex i to j and 0 otherwise. The following algorithm determines whether there is a sink in the graph G.

```
i = 0;
do {
   j = i + 1;
   while ((j < n) && E1) j++;
   if (j < n) E2;
} while (j < n);
flag = 1;
for (j = 0; j < n; j++)
   if ((j! = i) && E3) flag = 0;
if (flag) printf("Sink exists") ;
else printf ("Sink does not exist");
```

Choose the correct expression for E_3

A. $(A[i][j] \ \&\& \ !A[j][i])$

B. $(!A[i][j] \ \&\& \ A[j][i])$

C. $(!A[i][j] \ || \ A[j][i])$

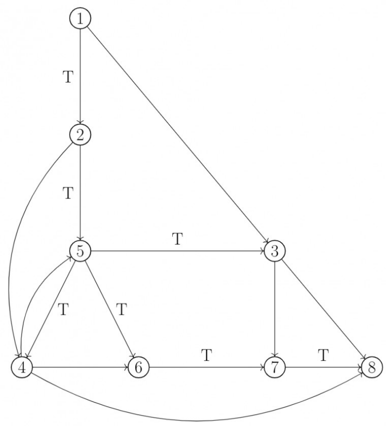
D. $(A[i][j] \ || \ !A[j][i])$

gateit-2005 algorithms graph-algorithms normal

Answer key☟

1.14 Graph Search (22)

1.14.1 Graph Search: GATE CSE 1989 | Question: 4-vii



In the graph shown above, the depth-first spanning tree edges are marked with a $'T'$. Identify the forward, backward, and cross edges.

gate1989 descriptive algorithms graph-algorithms depth-first-search graph-search

Answer key☟

1.14.2 Graph Search: GATE CSE 2000 | Question: 1.13

The most appropriate matching for the following pairs

X: depth first search	1: heap
Y: breadth first search	2: queue
Z: sorting	3: stack

is:

A. $\text{X - 1, Y - 2, Z - 3}$

B. $\text{X - 3, Y - 1, Z - 2}$

C. $\text{X - 3, Y - 2, Z - 1}$

D. $\text{X - 2, Y - 3, Z - 1}$

gatecse-2000 algorithms easy graph-algorithms graph-search match-the-following

Answer key☟

1.14.3 Graph Search: GATE CSE 2000 | Question: 2.19

Let G be an undirected graph. Consider a depth-first traversal of G, and let T be the resulting depth-first search tree. Let u be a vertex in G and let v be the first new (unvisited) vertex visited after visiting u in the traversal. Which of the following statement is always true?

A. $\{u, v\}$ must be an edge in G, and u is a descendant of v in T

B. $\{u, v\}$ must be an edge in G, and v is a descendant of u in T

C. If $\{u, v\}$ is not an edge in G then u is a leaf in T

D. If $\{u, v\}$ is not an edge in G then u and v must have the same parent in T

gatecse-2000 algorithms graph-algorithms normal graph-search

Answer key☟

1.14.4 Graph Search: GATE CSE 2001 | Question: 2.14

Consider an undirected, unweighted graph G. Let a breadth-first traversal of G be done starting from a node r. Let $d(r,u)$ and $d(r,v)$ be the lengths of the shortest paths from r to u and v respectively in G. If u is visited before v during the breadth-first traversal, which of the following statements is correct?

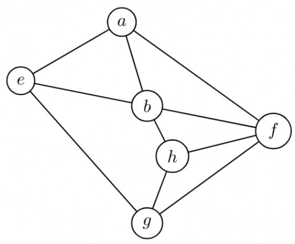
A. $d(r,u) < d(r,v)$
B. $d(r,u) > d(r,v)$
C. $d(r,u) \leq d(r,v)$
D. None of the above

gatecse-2001 algorithms graph-algorithms normal graph-search

Answer key

1.14.5 Graph Search: GATE CSE 2003 | Question: 21

Consider the following graph:



Among the following sequences:

I. abeghf
II. abfehg
III. abfhge
IV. afghbe

Which are the depth-first traversals of the above graph?

A. I, II and IV only
B. I and IV only
C. II, III and IV only
D. I, III and IV only

gatecse-2003 algorithms graph-algorithms normal graph-search

Answer key

1.14.6 Graph Search: GATE CSE 2006 | Question: 48

Let T be a depth first search tree in an undirected graph G. Vertices u and ν are leaves of this tree T. The degrees of both u and ν in G are at least 2. which one of the following statements is true?

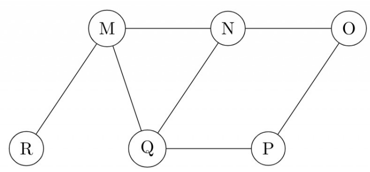
A. There must exist a vertex w adjacent to both u and ν in G
B. There must exist a vertex w whose removal disconnects u and ν in G
C. There must exist a cycle in G containing u and ν
D. There must exist a cycle in G containing u and all its neighbours in G

gatecse-2006 algorithms graph-algorithms normal graph-search

Answer key

1.14.7 Graph Search: GATE CSE 2008 | Question: 19

The Breadth First Search algorithm has been implemented using the queue data structure. One possible order of visiting the nodes of the following graph is:



A. MNOPQR
B. NQMPOR
C. QMNPRO
D. QMNPOR

gatecse-2008 normal algorithms graph-algorithms graph-search

Answer key

1.14.8 Graph Search: GATE CSE 2014 Set 1 | Question: 11

Let G be a graph with n vertices and m edges. What is the tightest upper bound on the running time of Depth First Search on G, when G is represented as an adjacency matrix?

A. $\Theta(n)$ B. $\Theta(n+m)$ C. $\Theta(n^2)$ D. $\Theta(m^2)$

gatecse-2014-set1 algorithms graph-algorithms normal graph-search

Answer key

1.14.9 Graph Search: GATE CSE 2014 Set 2 | Question: 14

Consider the tree arcs of a BFS traversal from a source node W in an unweighted, connected, undirected graph. The tree T formed by the tree arcs is a data structure for computing

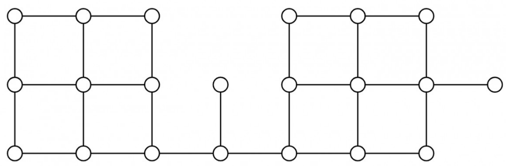
A. the shortest path between every pair of vertices.
B. the shortest path from W to every vertex in the graph.
C. the shortest paths from W to only those nodes that are leaves of T.
D. the longest path in the graph.

gatecse-2014-set2 algorithms graph-algorithms normal graph-search

Answer key

1.14.10 Graph Search: GATE CSE 2014 Set 3 | Question: 13

Suppose depth first search is executed on the graph below starting at some unknown vertex. Assume that a recursive call to visit a vertex is made only after first checking that the vertex has not been visited earlier. Then the maximum possible recursion depth (including the initial call) is _________.



gatecse-2014-set3 algorithms graph-algorithms numerical-answers normal graph-search

Answer key

1.14.11 Graph Search: GATE CSE 2015 Set 1 | Question: 45

Let $G=(V,E)$ be a simple undirected graph, and s be a particular vertex in it called the source. For $x \in V$, let $d(x)$ denote the shortest distance in G from s to x. A breadth first search (BFS) is performed starting at s. Let T be the resultant BFS tree. If (u,v) is an edge of G that is not in T, then which one of the following CANNOT be the value of $d(u)-d(v)$?

A. -1 B. 0 C. 1 D. 2

gatecse-2015-set1 algorithms graph-algorithms normal graph-search

Answer key

1.14.12 Graph Search: GATE CSE 2016 Set 2 | Question: 11

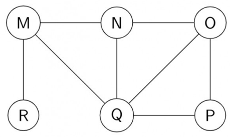
Breadth First Search (BFS) is started on a binary tree beginning from the root vertex. There is a vertex t at a distance four from the root. If t is the n^{th} vertex in this BFS traversal, then the maximum possible value of n is __________

gatecse-2016-set2 algorithms graph-algorithms normal numerical-answers graph-search

Answer key

1.14.13 Graph Search: GATE CSE 2017 Set 2 | Question: 15

The Breadth First Search (BFS) algorithm has been implemented using the queue data structure. Which one of the following is a possible order of visiting the nodes in the graph below?



A. MNOPQR B. NQMPOR C. QMNROP D. POQNMR

gatecse-2017-set2 algorithms graph-algorithms graph-search

Answer key☟

1.14.14 Graph Search: GATE CSE 2018 | Question: 30

Let G be a simple undirected graph. Let T_D be a depth first search tree of G. Let T_B be a breadth first search tree of G. Consider the following statements.

I. No edge of G is a cross edge with respect to T_D. (A cross edge in G is between two nodes neither of which is an ancestor of the other in T_D).
II. For every edge (u, v) of G, if u is at depth i and v is at depth j in T_B, then $|i - j| = 1$.

Which of the statements above must necessarily be true?

A. I only B. II only C. Both I and II D. Neither I nor II

gatecse-2018 algorithms graph-algorithms graph-search normal two-marks

Answer key☟

1.14.15 Graph Search: GATE CSE 2023 | Question: 46

Let $U = \{1, 2, 3\}$. Let 2^U denote the powerset of U. Consider an undirected graph G whose vertex set is 2^U. For any $A, B \in 2^U$, (A, B) is an edge in G if and only if (i) $A \neq B$, and (ii) either $A \subsetneq B$ or $B \subsetneq A$. For any vertex A in G, the set of all possible orderings in which the vertices of G can be visited in a Breadth First Search (BFS) starting from A is denoted by $\mathcal{B}(A)$.

If $\emptyset$ denotes the empty set, then the cardinality of $\mathcal{B}(\emptyset)$ is ______________.

gatecse-2023 algorithms breadth-first-search numerical-answers two-marks graph-search

Answer key☟

1.14.16 Graph Search: GATE CSE 2024 | Set 1 | Question: 35

Let G be a directed graph and T a depth first search (DFS) spanning tree in G that is rooted at a vertex v. Suppose T is also a breadth first search (BFS) tree in G, rooted at v. Which of the following statements is/are TRUE for *every* such graph G and tree T?

A. There are no back-edges in G with respect to the tree T
B. There are no cross-edges in G with respect to the tree T
C. There are no forward-edge in G with respect to the tree T
D. The only edges in G are the edges in T

gatecse2024-set1 algorithms multiple-selects graph-search two-marks

Answer key☟

1.14.17 Graph Search: GATE CSE 2024 | Set 1 | Question: 50

The number of edges present in the forest generated by the DFS traversal of an undirected graph G with 100 vertices is 40. The number of connected components in G is __________.

gatecse2024-set1 numerical-answers graph-search graph-algorithms two-marks

Answer key

1.14.18 Graph Search: GATE DS&AI 2024 | Question: 4

Consider performing depth-first search (DFS) on an undirected and unweighted graph G starting at vertex s. For any vertex u in $G, d[u]$ is the length of the shortest path from s to u. Let (u, v) be an edge in G such that $d[u] < d[v]$. If the edge (u, v) is explored first in the direction from u to v during the above DFS, then (u, v) becomes a ________ edge.

A. tree
B. cross
C. back
D. gray

gate-ds-ai-2024 graph-search depth-first-search algorithms one-mark

Answer key

1.14.19 Graph Search: GATE IT 2005 | Question: 14

In a depth-first traversal of a graph G with n vertices, k edges are marked as tree edges. The number of connected components in G is

A. k
B. $k+1$
C. $n-k-1$
D. $n-k$

gateit-2005 algorithms graph-algorithms normal graph-search

Answer key

1.14.20 Graph Search: GATE IT 2006 | Question: 47

Consider the depth-first-search of an undirected graph with 3 vertices P, Q, and R. Let discovery time $d(u)$ represent the time instant when the vertex u is first visited, and finish time $f(u)$ represent the time instant when the vertex u is last visited. Given that

$d(P) = 5$ units	$f(P) = 12$ units
$d(Q) = 6$ units	$f(Q) = 10$ units
$d(R) = 14$ unit	$f(R) = 18$ units

Which one of the following statements is TRUE about the graph?

A. There is only one connected component
B. There are two connected components, and P and R are connected
C. There are two connected components, and Q and R are connected
D. There are two connected components, and P and Q are connected

gateit-2006 algorithms graph-algorithms normal graph-search depth-first-search

Answer key

1.14.21 Graph Search: GATE IT 2007 | Question: 24

A depth-first search is performed on a directed acyclic graph. Let $d[u]$ denote the time at which vertex u is visited for the first time and $f[u]$ the time at which the DFS call to the vertex u terminates. Which of the following statements is always TRUE for all edges (u, v) in the graph ?

A. $d[u] < d[v]$
B. $d[u] < f[v]$
C. $f[u] < f[v]$
D. $f[u] > f[v]$

gateit-2007 algorithms graph-algorithms normal graph-search depth-first-search

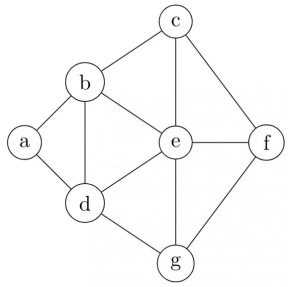
Answer key

1.14.22 Graph Search: GATE IT 2008 | Question: 47

Consider the following sequence of nodes for the undirected graph given below:

1. $a\,b\,e\,f\,d\,g\,c$
2. $a\,b\,e\,f\,c\,g\,d$
3. $a\,d\,g\,e\,b\,c\,f$
4. $a\,d\,b\,c\,g\,e\,f$

A Depth First Search (DFS) is started at node a. The nodes are listed in the order they are first visited. Which of the above is/are possible output(s)?



A. 1 and 3 only
B. 2 and 3 only
C. $2, 3$ and 4 only
D. $1, 2$ and 3 only

gateit-2008 algorithms graph-algorithms normal graph-search depth-first-search

Answer key

1.15 Greedy Algorithms (5)

1.15.1 Greedy Algorithms: GATE CSE 1999 | Question: 2.20

The minimum number of record movements required to merge five files A (with 10 records), B (with 20 records), C (with 15 records), D (with 5 records) and E (with 25 records) is:

A. 165
B. 90
C. 75
D. 65

gate1999 algorithms normal greedy-algorithms

Answer key

1.15.2 Greedy Algorithms: GATE CSE 2003 | Question: 69

The following are the starting and ending times of activities A, B, C, D, E, F, G and H respectively in chronological order: "$a_s\ b_s\ c_s\ a_e\ d_s\ c_e\ e_s\ f_s\ b_e\ d_e\ g_s\ e_e\ f_e\ h_s\ g_e\ h_e$". Here, x_s denotes the starting time and x_e denotes the ending time of activity X. We need to schedule the activities in a set of rooms available to us. An activity can be scheduled in a room only if the room is reserved for the activity for its entire duration. What is the minimum number of rooms required?

A. 3
B. 4
C. 5
D. 6

gatecse-2003 algorithms normal greedy-algorithms

Answer key

1.15.3 Greedy Algorithms: GATE CSE 2005 | Question: 84a

We are given 9 tasks $T_1, T_2, \ldots, T_9$. The execution of each task requires one unit of time. We can execute one task at a time. Each task T_i has a profit P_i and a deadline d_i. Profit P_i is earned if the task is completed before the end of the d_i^{th} unit of time.

Task	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9
Profit	15	20	30	18	18	10	23	16	25
Deadline	7	2	5	3	4	5	2	7	3

Are all tasks completed in the schedule that gives maximum profit?

A. All tasks are completed
B. T_1 and T_6 are left out
C. T_1 and T_8 are left out
D. T_4 and T_6 are left out

gatecse-2005 algorithms greedy-algorithms process-scheduling normal

Answer key

1.15.4 Greedy Algorithms: GATE CSE 2005 | Question: 84b

We are given 9 tasks $T_1, T_2, \dots, T_9$. The execution of each task requires one unit of time. We can execute one task at a time. Each task T_i has a profit P_i and a deadline d_i. Profit P_i is earned if the task is completed before the end of the d_i^{th} unit of time.

Task	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9
Profit	15	20	30	18	18	10	23	16	25
Deadline	7	2	5	3	4	5	2	7	3

What is the maximum profit earned?

A. 147 B. 165 C. 167 D. 175

gatecse-2005 algorithms greedy-algorithms process-scheduling normal

Answer key

1.15.5 Greedy Algorithms: GATE CSE 2018 | Question: 48

Consider the weights and values of items listed below. Note that there is only one unit of each item.

Item number	**Weight (in Kgs)**	**Value (in rupees)**
1	10	60
2	7	28
3	4	20
4	2	24

The task is to pick a subset of these items such that their total weight is no more than 11 Kgs and their total value is maximized. Moreover, no item may be split. The total value of items picked by an optimal algorithm is denoted by V_{opt}. A greedy algorithm sorts the items by their value-to-weight ratios in descending order and packs them greedily, starting from the first item in the ordered list. The total value of items picked by the greedy algorithm is denoted by V_{greedy}.

The value of $V_{opt} - V_{greedy}$ is _____

gatecse-2018 algorithms greedy-algorithms numerical-answers two-marks

Answer key

1.16 Hashing (7)

1.16.1 Hashing: GATE CSE 1989 | Question: 1-vii, ISRO2015-14

A hash table with ten buckets with one slot per bucket is shown in the following figure. The symbols $S1$ to $S7$ initially entered using a hashing function with linear probing. The maximum number of comparisons needed in searching an item that is not present is

0	S7
1	S1
2	
3	S4
4	S2
5	
6	S5
7	
8	S6
9	S3

A. 4 B. 5 C. 6 D. 3

hashing isro2015 gate1989 algorithms normal

Answer key

1.16.2 Hashing: GATE CSE 1990 | Question: 13b

Consider a hash table with chaining scheme for overflow handling:

i. What is the worst-case timing complexity of inserting n elements into such a table?
ii. For what type of instance does this hashing scheme take the worst-case time for insertion?

gate1990 hashing algorithms descriptive

Answer key

1.16.3 Hashing: GATE CSE 2020 | Question: 23

Consider a double hashing scheme in which the primary hash function is $h_1(k) = k \bmod 23$, and the secondary hash function is $h_2(k) = 1 + (k \bmod 19)$. Assume that the table size is 23. Then the address returned by probe 1 in the probe sequence (assume that the probe sequence begins at probe 0) for key value $k = 90$ is____________.

gatecse-2020 numerical-answers algorithms hashing one-mark

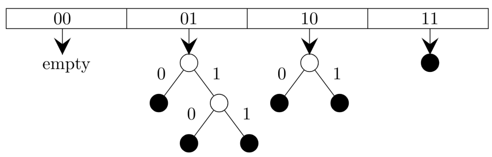
Answer key

1.16.4 Hashing: GATE CSE 2021 Set 1 | Question: 47

Consider a $dynamic$ hashing approach for 4-bit integer keys:

1. There is a main hash table of size 4.
2. The 2 least significant bits of a key is used to index into the main hash table.
3. Initially, the main hash table entries are empty.
4. Thereafter, when more keys are hashed into it, to resolve collisions, the set of all keys corresponding to a main hash table entry is organized as a binary tree that grows on demand.
5. First, the 3^{rd} least significant bit is used to divide the keys into left and right subtrees.
6. To resolve more collisions, each node of the binary tree is further sub-divided into left and right subtrees based on the 4^{th} least significant bit.
7. A split is done only if it is needed, i.e., only when there is a collision.

Consider the following state of the hash table.



Which of the following sequences of key insertions can cause the above state of the hash table (assume the keys are in decimal notation)?

A. $5, 9, 4, 13, 10, 7$
B. $9, 5, 10, 6, 7, 1$
C. $10, 9, 6, 7, 5, 13$
D. $9, 5, 13, 6, 10, 14$

gatecse-2021-set1 multiple-selects algorithms hashing two-marks

Answer key

1.16.5 Hashing: GATE CSE 2022 | Question: 6

Suppose we are given n keys, m hash table slots, and two simple uniform hash functions h_1 and h_2. Further suppose our hashing scheme uses h_1 for the odd keys and h_2 for the even keys. What is the expected number of keys in a slot?

A. $\frac{m}{n}$ B. $\frac{n}{m}$ C. $\frac{2n}{m}$ D. $\frac{n}{2m}$

gatecse-2022 algorithms hashing uniform-hashing one-mark

Answer key

1.16.6 Hashing: GATE CSE 2023 | Question: 10

An algorithm has to store several keys generated by an adversary in a hash table. The adversary is malicious who tries to maximize the number of collisions. Let k be the number of keys, m be the number of slots in the hash table, and $k > m$.

Which one of the following is the best hashing strategy to counteract the adversary?

A. Division method, i.e., use the hash function $h(k) = k \bmod m$.
B. Multiplication method, i.e., use the hash function $h(k) = \lfloor m(kA - \lfloor kA \rfloor) \rfloor$, where A is a carefully chosen constant.
C. Universal hashing method.
D. If k is a prime number, use Division method. Otherwise, use Multiplication method.

gatecse-2023 algorithms hashing one-mark

Answer key

1.16.7 Hashing: GATE IT 2005 | Question: 16

A hash table contains 10 buckets and uses linear probing to resolve collisions. The key values are integers and the hash function used is $\text{key}\%10$. If the values $43, 165, 62, 123, 142$ are inserted in the table, in what location would the key value 142 be inserted?

A. 2 B. 3 C. 4 D. 6

gateit-2005 algorithms hashing easy

Answer key

1.17 Huffman Code (6)

1.17.1 Huffman Code: GATE CSE 1989 | Question: 13a

A language uses an alphabet of six letters, $\{a, b, c, d, e, f\}$. The relative frequency of use of each letter of the alphabet in the language is as given below:

LETTER	RELATIVE FREQUENCY OF USE
a	0.19
b	0.05
c	0.17
d	0.08
e	0.40
f	0.11

Design a prefix binary code for the language which would minimize the average length of the encoded words of the language.

descriptive gate1989 algorithms huffman-code

Answer key

1.17.2 Huffman Code: GATE CSE 2007 | Question: 76

Suppose the letters $a,\ b,\ c,\ d,\ e,\ f$ have probabilities $\frac{1}{2}, \frac{1}{4}, \frac{1}{8}, \frac{1}{16}, \frac{1}{32}, \frac{1}{32}$, respectively.

Which of the following is the Huffman code for the letter $a,\ b,\ c,\ d,\ e,\ f$?

A. 0, 10, 110, 1110, 11110, 11111
B. 11, 10, 011, 010, 001, 000
C. 11, 10, 01, 001, 0001, 0000
D. 110, 100, 010, 000, 001, 111

gatecse-2007 algorithms greedy-algorithms normal huffman-code

Answer key

1.17.3 Huffman Code: GATE CSE 2007 | Question: 77

Suppose the letters $a,\ b,\ c,\ d,\ e,\ f$ have probabilities $\dfrac{1}{2}, \dfrac{1}{4}, \dfrac{1}{8}, \dfrac{1}{16}, \dfrac{1}{32}, \dfrac{1}{32}$, respectively.

What is the average length of the Huffman code for the letters $a,\ b,\ c,\ d,\ e,\ f$?

A. 3 B. 2.1875 C. 2.25 D. 1.9375

gatecse-2007 algorithms greedy-algorithms normal huffman-code

Answer key

1.17.4 Huffman Code: GATE CSE 2017 Set 2 | Question: 50

A message is made up entirely of characters from the set $X=\{P, Q, R, S, T\}$. The table of probabilities for each of the characters is shown below:

Character	Probability
P	0.22
Q	0.34
R	0.17
S	0.19
T	0.08
Total	1.00

If a message of 100 characters over X is encoded using Huffman coding, then the expected length of the encoded message in bits is ______.

gatecse-2017-set2 huffman-code numerical-answers algorithms

Answer key

1.17.5 Huffman Code: GATE CSE 2021 Set 2 | Question: 26

Consider the string abbccddeee. Each letter in the string must be assigned a binary code satisfying the following properties:

1. For any two letters, the code assigned to one letter must not be a prefix of the code assigned to the other letter.
2. For any two letters of the same frequency, the letter which occurs earlier in the dictionary order is assigned a code whose length is at most the length of the code assigned to the other letter.

Among the set of all binary code assignments which satisfy the above two properties, what is the minimum length of the encoded string?

A. 21 B. 23 C. 25 D. 30

gatecse-2021-set2 algorithms huffman-code two-marks

Answer key

1.17.6 Huffman Code: GATE IT 2006 | Question: 48

The characters a to h have the set of frequencies based on the first 8 Fibonacci numbers as follows

$a:1, b:1, c:2, d:3, e:5, f:8, g:13, h:21$

A Huffman code is used to represent the characters. What is the sequence of characters corresponding to the following code?

110111100111010

A. $fdheg$ B. $ecgdf$ C. $dchfg$ D. $fehdg$

gateit-2006 algorithms greedy-algorithms normal huffman-code

Answer key

1.18 Identify Function (38)

1.18.1 Identify Function: GATE CSE 1989 | Question: 8a

What is the output produced by the following program, when the input is "HTGATE"

```
Function what (s:string): string;
var n:integer;
begin
    n = s.length
    if n <= 1
    then what := s
    else what :=contact (what (substring (s, 2, n)), s.C [1])
end;
```

Note

i. type string=record
   length:integer;
   C:array[1..100] of char
   end
ii. Substring (s, i, j): this yields the string made up of the i^{th} through j^{th} characters in s; for appropriately defined in i and j.
iii. Contact (s_1, s_2): this function yields a string of length s_1 length + s_2 - length obtained by concatenating s_1 with s_2 such that s_1 precedes s_2.

gate1989 descriptive algorithms identify-function

Answer key

1.18.2 Identify Function: GATE CSE 1990 | Question: 11b

The following program computes values of a mathematical function $f(x)$. Determine the form of $f(x)$.

```
main ()
{
   int m, n; float x, y, t;
   scanf ("%f%d", &x, &n);
   t = 1; y = 0; m = 1;
   do
   {
      t *= (-x/m);
      y += t;
   } while (m++ < n);
   printf ("The value of y is %f", y);
}
```

gate1990 descriptive algorithms identify-function

Answer key

1.18.3 Identify Function: GATE CSE 1991 | Question: 03-viii

Consider the following Pascal function:

```
Function X(M:integer):integer;
Var i:integer;
Begin
   i := 0;
   while i*i < M
   do i:= i+1
   X := i
 end
```

The function call $X(N)$, if N is positive, will return

A. $\lfloor\sqrt{N}\rfloor$
B. $\lfloor\sqrt{N}\rfloor + 1$
C. $\lceil\sqrt{N}\rceil$
D. $\lceil\sqrt{N}\rceil + 1$
E. None of the above

gate1991 algorithms easy identify-function multiple-selects

Answer key

1.18.4 Identify Function: GATE CSE 1993 | Question: 7.4

What does the following code do?

```
var a, b: integer;
begin
   a:=a+b;
   b:=a-b;
   a:=a-b;
end;
```

A. exchanges a and b
B. doubles a and stores in b
C. doubles b and stores in a
D. leaves a and b unchanged
E. none of the above

gate1993 algorithms identify-function easy

Answer key

1.18.5 Identify Function: GATE CSE 1994 | Question: 6

What function of x, n is computed by this program?

```
Function what(x, n:integer): integer:
Var
   value : integer
begin
   value := 1
   if n > 0 then
   begin
      if n mod 2 =1 then
         value := value * x;
      value := value * what(x*x, n div 2);
   end;
   what := value;
end;
```

gate1994 algorithms identify-function normal descriptive

Answer key

1.18.6 Identify Function: GATE CSE 1995 | Question: 1.4

In the following Pascal program segment, what is the value of X after the execution of the program segment?

```
X := -10; Y := 20;
If X > Y then if X < 0 then X := abs(X) else X := 2*X;
```

A. 10
B. -20
C. -10
D. None

gate1995 algorithms identify-function easy

Answer key

1.18.7 Identify Function: GATE CSE 1995 | Question: 2.3

Assume that X and Y are non-zero positive integers. What does the following Pascal program segment do?

```
while X <> Y do
if  X > Y then
   X := X - Y
else
   Y := Y - X;
write(X);
```

A. Computes the LCM of two numbers
B. Divides the larger number by the smaller number
C. Computes the GCD of two numbers
D. None of the above

gate1995 algorithms identify-function normal

Answer key

1.18.8 Identify Function: GATE CSE 1995 | Question: 4

A. Consider the following Pascal function where A and B are non-zero positive integers. What is the value of $\text{GET}(3, 2)$?

```
function GET(A,B:integer): integer;
begin
   if B=0 then
      GET:= 1
   else if A < B then
      GET:= 0
   else
      GET:= GET(A-1, B) + GET(A-1, B-1)
end;
```

B. The Pascal procedure given for computing the transpose of an $N \times N, (N > 1)$ matrix A of integers has an error. Find the error and correct it. Assume that the following declaration are made in the main program

```
const
   MAXSIZE=20;
type
   INTARR=array [1..MAXSIZE,1..MAXSIZE] of integer;
Procedure TRANSPOSE (var A: INTARR; N : integer);
var
   I, J, TMP: integer;
begin
   for I:=1 to N – 1 do
   for J:=1 to N do
   begin
      TMP:= A[I, J];
      A[I, J]:= A[J, I];
      A[J, I]:= TMP
   end
end;
```

gate1995 algorithms identify-function normal descriptive

Answer key☟

1.18.9 Identify Function: GATE CSE 1998 | Question: 2.12

What value would the following function return for the input $x = 95$?

```
Function fun (x:integer):integer;
Begin
  If x > 100 then fun = x – 10
  Else fun = fun(fun (x+11))
End;
```

A. 89
B. 90
C. 91
D. 92

gate1998 algorithms recursion identify-function normal

Answer key☟

1.18.10 Identify Function: GATE CSE 1999 | Question: 2.24

Consider the following C function definition

```
int Trial (int a, int b, int c)
{
  if ((a>=b) && (c<b)) return b;
  else if (a>=b) return Trial(a, c, b);
  else return Trial(b, a, c);
}
```

The functional Trial:

A. Finds the maximum of a, b, and c
B. Finds the minimum of a, b, and c
C. Finds the middle number of a, b, c
D. None of the above

gate1999 algorithms identify-function normal

Answer key

1.18.11 Identify Function: GATE CSE 2000 | Question: 2.15

Suppose you are given an array $s[1 \ldots n]$ and a procedure reverse (s, i, j) which reverses the order of elements in s between positions i and j (both inclusive). What does the following sequence do, where $1 \leqslant k \leqslant n$:

```
reverse (s, 1, k);
reverse (s, k+1, n);
reverse (s, 1, n);
```

A. Rotates s left by k positions
B. Leaves s unchanged
C. Reverses all elements of s
D. None of the above

gatecse-2000 algorithms normal identify-function

Answer key

1.18.12 Identify Function: GATE CSE 2003 | Question: 1

Consider the following C function.

For large values of y, the return value of the function f best approximates

```
float f,(float x, int y) {
   float p, s; int i;
   for (s=1,p=1,i=1; i<y; i++) {
      p *= x/i;
      s += p;
   }
   return s;
}
```

A. x^y
B. e^x
C. $\ln(1+x)$
D. x^x

gatecse-2003 algorithms identify-function normal

Answer key

1.18.13 Identify Function: GATE CSE 2003 | Question: 88

In the following C program fragment, j, k, n and TwoLog_n are integer variables, and A is an array of integers. The variable n is initialized to an integer $\geqslant 3$, and TwoLog_n is initialized to the value of $2^* \lceil \log_2(n) \rceil$

```
for (k = 3;  k <= n; k++)
      A[k] = 0;
for (k = 2; k <= TwoLog_n; k++)
   for (j = k+1; j <= n; j++)
      A[j] = A[j] || (j%k);
for (j = 3; j <= n; j++)
   if (!A[j]) printf("%d", j);
```

The set of numbers printed by this program fragment is

A. $\{m \mid m \leq n, (\exists i) \, [m = i!]\}$
B. $\{m \mid m \leq n, (\exists i) \, [m = i^2]\}$
C. $\{m \mid m \leq n, \text{m is prime}\}$
D. { }

gatecse-2003 algorithms identify-function normal

Answer key

1.18.14 Identify Function: GATE CSE 2004 | Question: 41

Consider the following C program

```
main()
{
   int x, y, m, n;
   scanf("%d %d", &x, &y);
   /* Assume x>0 and y>0*/
   m = x; n = y;
   while(m != n)
      {
         if (m > n)
```

```
            m = m-n;
        else
            n = n-m;
    }
    printf("%d", n);
}
```

The program computes

A. $x + y$ using repeated subtraction
B. $x \mod y$ using repeated subtraction
C. the greatest common divisor of x and y
D. the least common multiple of x and y

gatecse-2004 algorithms normal identify-function

Answer key☟

1.18.15 Identify Function: GATE CSE 2004 | Question: 42

What does the following algorithm approximate? (Assume $m > 1, \epsilon > 0$).

```
x = m;
y = 1;
While (x-y > ϵ)
{
    x = (x+y)/2;
    y = m/x;
}
print(x);
```

A. $\log m$
B. m^2
C. $m^{\frac{1}{2}}$
D. $m^{\frac{1}{3}}$

gatecse-2004 algorithms identify-function normal

Answer key☟

1.18.16 Identify Function: GATE CSE 2005 | Question: 31

Consider the following C-program:

```
void foo (int n, int sum) {
    int k = 0, j = 0;
    if (n == 0) return;
    k = n % 10; j = n/10;
    sum = sum + k;
    foo (j, sum);
    printf ("%d,",k);
}

int main() {
    int a = 2048, sum = 0;
    foo(a, sum);
    printf("%d\n", sum);
}
```

What does the above program print?

A. $8, 4, 0, 2, 14$
B. $8, 4, 0, 2, 0$
C. $2, 0, 4, 8, 14$
D. $2, 0, 4, 8, 0$

gatecse-2005 algorithms identify-function recursion normal

Answer key☟

1.18.17 Identify Function: GATE CSE 2006 | Question: 50

A set X can be represented by an array $x[n]$ as follows:

$$x\left[i\right] = \begin{cases} 1 & \text{if } i \in X \\ 0 & \text{otherwise} \end{cases}$$

Consider the following algorithm in which x, y, and z are Boolean arrays of size n:

```
algorithm zzz(x[], y[], z[]) {
int i;

for(i=0; i<n; ++i)
z[i] = (x[i] ∧ ~y[i]) ∨ (~x[i] ∧ y[i]);
```

```
}
```

The set Z computed by the algorithm is:

A. $(X \cup Y)$
B. $(X \cap Y)$
C. $(X - Y) \cap (Y - X)$
D. $(X - Y) \cup (Y - X)$

gatecse-2006 algorithms identify-function normal

Answer key

1.18.18 Identify Function: GATE CSE 2006 | Question: 53

Consider the following C-function in which $a[n]$ and $b[m]$ are two sorted integer arrays and $c[n+m]$ be another integer array,

```
void xyz(int a[], int b [], int c []){
  int i,j,k;
  i=j=k=0;
  while ((i<n) && (j<m))
    if (a[i] < b[j]) c[k++] = a[i++];
    else c[k++] = b[j++];
}
```

Which of the following condition(s) hold(s) after the termination of the while loop?

i. $j < m, k = n + j - 1$ and $a[n-1] < b[j]$ if $i = n$
ii. $i < n, k = m + i - 1$ and $b[m-1] \leq a[i]$ if $j = m$

A. only (i)
B. only (ii)
C. either (i) or (ii) but not both
D. neither (i) nor (ii)

gatecse-2006 algorithms identify-function normal

Answer key

1.18.19 Identify Function: GATE CSE 2009 | Question: 18

Consider the program below:

```
#include <stdio.h>
int fun(int n, int *f_p) {
    int t, f;
    if (n <= 1) {
        *f_p = 1;
        return 1;
    }
    t = fun(n-1, f_p);
    f = t + *f_p;
    *f_p = t;
    return f;
}

int main() {
    int x = 15;
    printf("%d/n", fun(5, &x));
    return 0;
}
```

The value printed is:

A. 6
B. 8
C. 14
D. 15

gatecse-2009 algorithms recursion identify-function normal

Answer key

1.18.20 Identify Function: GATE CSE 2010 | Question: 35

What is the value printed by the following C program?

```
#include<stdio.h>

int f(int *a, int n)
{
  if (n <= 0) return 0;
  else if (*a % 2 == 0) return *a+f(a+1, n-1);
  else return *a - f(a+1, n-1);
```

```
}

int main()
{
    int a[] = {12, 7, 13, 4, 11, 6};
    printf("%d", f(a, 6));
    return 0;
}
```

A. -9 B. 5 C. 15 D. 19

gatecse-2010 algorithms recursion identify-function normal

Answer key

1.18.21 Identify Function: GATE CSE 2011 | Question: 48

Consider the following recursive C function that takes two arguments.

```
unsigned int foo(unsigned int n, unsigned int r) {
    if (n>0) return ((n%r) + foo(n/r, r));
    else return 0;
}
```

What is the return value of the function foo when it is called as $\text{foo}(345, 10)$?

A. 345 B. 12 C. 5 D. 3

gatecse-2011 algorithms recursion identify-function normal

Answer key

1.18.22 Identify Function: GATE CSE 2011 | Question: 49

Consider the following recursive C function that takes two arguments.

```
unsigned int foo(unsigned int n, unsigned int r) {
    if (n>0) return ((n%r) + foo(n/r, r));
    else return 0;
}
```

What is the return value of the function foo when it is called as $\text{foo}(513, 2)$?

A. 9 B. 8 C. 5 D. 2

gatecse-2011 algorithms recursion identify-function normal

Answer key

1.18.23 Identify Function: GATE CSE 2013 | Question: 31

Consider the following function:

```
int unknown(int n){

int i, j, k=0;
for (i=n/2; i<=n; i++)
    for (j=2; j<=n; j=j*2)
        k = k + n/2;
 return (k);

}
```

The return value of the function is

A. $\Theta(n^2)$ B. $\Theta(n^2 \log n)$
C. $\Theta(n^3)$ D. $\Theta(n^3 \log n)$

gatecse-2013 algorithms identify-function normal

Answer key

1.18.24 Identify Function: GATE CSE 2014 Set 1 | Question: 41

Consider the following C function in which **size** is the number of elements in the array **E**:

```
int MyX(int *E, unsigned int size)
```

```
{
   int Y = 0;
   int Z;
   int i, j, k;

   for(i = 0; i< size; i++)
         Y = Y + E[i];

    for(i=0; i < size; i++)
       for(j = i; j < size; j++)
       {
          Z = 0;
          for(k = i; k <= j; k++)
             Z = Z + E[k];
          if(Z > Y)
             Y = Z;
       }
   return Y;
}
```

The value returned by the function **MyX** is the

A. maximum possible sum of elements in any sub-array of array **E**.
B. maximum element in any sub-array of array **E.**
C. sum of the maximum elements in all possible sub-arrays of array **E**.
D. the sum of all the elements in the array **E.**

gatecse-2014-set1 algorithms identify-function normal

Answer key

1.18.25 Identify Function: GATE CSE 2014 Set 2 | Question: 10

Consider the function func shown below:

```
int func(int num) {
   int count = 0;
   while (num) {
     count++;
     num>>= 1;
   }
   return (count);
}
```

The value returned by func(435) is ________

gatecse-2014-set2 algorithms identify-function numerical-answers easy

Answer key

1.18.26 Identify Function: GATE CSE 2014 Set 3 | Question: 10

Let A be the square matrix of size $n \times n$. Consider the following pseudocode. What is the expected output?

```
C=100;
for i=1 to n do
   for j=1 to n do
   {
      Temp = A[i][j]+C;
      A[i][j] = A[j][i];
      A[j][i] = Temp -C;
   }
for i=1 to n do
   for j=1 to n do
      output (A[i][j]);
```

A. The matrix A itself
B. Transpose of the matrix A
C. Adding 100 to the upper diagonal elements and subtracting 100 from lower diagonal elements of A
D. None of the above

gatecse-2014-set3 algorithms identify-function easy

Answer key

1.18.27 Identify Function: GATE CSE 2015 Set 1 | Question: 31

Consider the following C function.

```
int fun1 (int n) {
    int i, j, k, p, q = 0;
    for (i = 1; i < n; ++i)
    {
      p = 0;
     for (j = n; j > 1; j = j/2)
        ++p;
     for (k = 1; k < p; k = k * 2)
        ++q;
    }
    return q;
}
```

Which one of the following most closely approximates the return value of the function fun1?

A. n^3 B. $n(\log n)^2$ C. $n \log n$ D. $n \log(\log n)$

gatecse-2015-set1 algorithms normal identify-function

Answer key

1.18.28 Identify Function: GATE CSE 2015 Set 2 | Question: 11

Consider the following C function.

```
int fun(int n) {
   int x=1, k;
   if (n==1) return x;
   for (k=1; k<n; ++k)
      x = x + fun(k) * fun (n-k);
   return x;
}
```

The return value of $fun(5)$ is ______.

gatecse-2015-set2 algorithms identify-function recurrence-relation normal numerical-answers

Answer key

1.18.29 Identify Function: GATE CSE 2015 Set 3 | Question: 49

Suppose $c = \langle c[0], \dots, c[k-1] \rangle$ is an array of length k, where all the entries are from the set $\{0, 1\}$. For any positive integers a and n, consider the following pseudocode.

```
DOSOMETHING (c, a, n)

z ← 1
for i ← 0 to k-1
    do z ← z² mod n
    if c[i]=1
        then z ← (z × a) mod n
return z
```

If $k = 4, c = \langle 1, 0, 1, 1 \rangle, a = 2,$ and $n = 8$, then the output of DOSOMETHING(*c, a, n)* is _______.

gatecse-2015-set3 algorithms identify-function normal numerical-answers

Answer key

1.18.30 Identify Function: GATE CSE 2019 | Question: 26

Consider the following C function.

```
void convert (int n ) {
      if (n<0)
          printf("%d", n);
      else {
          convert(n/2);
          printf("%d", n%2);
```

```
        }
    }
```

Which one of the following will happen when the function *convert* is called with any positive integer n as argument?

A. It will print the binary representation of n and terminate
B. It will print the binary representation of n in the reverse order and terminate
C. It will print the binary representation of n but will not terminate
D. It will not print anything and will not terminate

gatecse-2019 algorithms identify-function two-marks

Answer key☟

1.18.31 Identify Function: GATE CSE 2020 | Question: 48

Consider the following C functions.

```
int tob (int b, int* arr) {
    int i;
    for (i = 0; b>0; i++)  {
        if (b%2)  arr [i] = 1;
        else      arr[i] = 0;
        b = b/2;
    }
    return (i);
}
```

```
int pp(int a, int b)  {
    int  arr[20];
    int i, tot = 1, ex, len;
    ex = a;
    len = tob(b, arr);
    for (i=0; i<len ; i++) {
        if (arr[i] ==1)
            tot = tot * ex;
        ex= ex*ex;
    }
    return (tot) ;
}
```

The value returned by $pp(3,4)$ is _______.

gatecse-2020 numerical-answers identify-function two-marks

Answer key☟

1.18.32 Identify Function: GATE CSE 2021 Set 1 | Question: 48

Consider the following ANSI C function:

```
int SimpleFunction(int Y[], int n, int x)
{
    int total = Y[0], loopIndex;
    for (loopIndex=1; loopIndex<=n-1; loopIndex++)
        total=x*total +Y[loopIndex];
    return total;
}
```

Let Z be an array of 10 elements with $\mathsf{Z}[i]=1$, for all i such that $0 \leq i \leq 9$. The value returned by $\mathsf{SimpleFunction}(\mathsf{Z}, 10, 2)$ is __________

gatecse-2021-set1 algorithms numerical-answers identify-function two-marks

Answer key☟

1.18.33 Identify Function: GATE CSE 2021 Set 2 | Question: 23

Consider the following ANSI C function:

```
int SomeFunction (int x, int y)
{
    if ((x==1) || (y==1)) return 1;
    if (x==y) return x;
    if (x > y) return SomeFunction(x-y, y);
    if (y > x) return SomeFunction (x, y-x);

}
```

The value returned by $\text{SomeFunction}(15, 255)$ is __________ gatecse-2021-set2 numerical-answers algorithms identify-function output one-mark

Answer key

1.18.34 Identify Function: GATE IT 2005 | Question: 53

The following C function takes two ASCII strings and determines whether one is an anagram of the other. An anagram of a string s is a string obtained by permuting the letters in s.

```
int anagram (char *a, char *b) {
   int count [128], j;
   for (j = 0;  j < 128; j++) count[j] = 0;
   j = 0;
   while (a[j] && b[j]) {
      A;
      B;
   }
   for (j = 0; j < 128; j++) if (count [j]) return 0;
   return 1;
}
```

Choose the correct alternative for statements A and B.

A. A: count [a[j]]++ and B: count[b[j]]--
B. A: count [a[j]]++ and B: count[b[j]]++
C. A: count [a[j++]]++ and B: count[b[j]]--
D. A: count [a[j]]++ and B: count[b[j++]]--

gateit-2005 normal identify-function

Answer key

1.18.35 Identify Function: GATE IT 2005 | Question: 57

What is the output printed by the following program?

```
#include <stdio.h>

int f(int n, int k) {
   if (n == 0) return 0;
   else if (n % 2) return f(n/2, 2*k) + k;
   else return f(n/2, 2*k) - k;
}

int main () {
   printf("%d", f(20, 1));
   return 0;
}
```

A. 5 B. 8 C. 9 D. 20

gateit-2005 algorithms identify-function normal

Answer key

1.18.36 Identify Function: GATE IT 2006 | Question: 52

The following function computes the value of $\binom{m}{n}$ correctly for all legal values m and n ($m \geq 1, n \geq 0$ and $m > n$)

```
int func(int m, int n)
{
   if (E) return 1;
   else return(func(m -1, n) + func(m - 1, n - 1));
}
```

In the above function, which of the following is the correct expression for E?

A. $(n == 0) || (m == 1)$
B. $(n == 0)$ && $(m == 1)$
C. $(n == 0) || (m == n)$
D. $(n == 0)$ && $(m == n)$

gateit-2006 algorithms identify-function normal

Answer key

1.18.37 Identify Function: GATE IT 2008 | Question: 82

Consider the code fragment written in C below :

```
void f (int n)
{
 if (n <=1)  {
  printf ("%d", n);
 }
 else {
  f (n/2);
  printf ("%d", n%2);
 }
}
```

What does f(173) print?

A. 010110101 B. 010101101 C. 10110101 D. 10101101

gateit-2008 algorithms recursion identify-function normal

Answer key

1.18.38 Identify Function: GATE IT 2008 | Question: 83

Consider the code fragment written in C below :

```
void f (int n)
{
    if (n <= 1)  {
        printf ("%d", n);
    }
    else {
        f (n/2);
        printf ("%d", n%2);
    }
}
```

Which of the following implementations will produce the same output for $f(173)$ as the above code?

P1

```
void f (int n)
{
    if (n/2)  {
        f(n/2);
    }
    printf ("%d", n%2);
}
```

P2

```
void f (int n)
{
    if (n <=1)  {
        printf ("%d", n);
    }
    else {
        printf ("%d", n%2);
        f (n/2);
    }
}
```

A. Both $P1$ and $P2$ B. $P2$ only C. $P1$ only D. Neither $P1$ nor $P2$

gateit-2008 algorithms recursion identify-function normal

Answer key

1.19 Insertion Sort (3)

1.19.1 Insertion Sort: GATE CSE 2003 | Question: 22

The usual $\Theta(n^2)$ implementation of Insertion Sort to sort an array uses linear search to identify the position where an element is to be inserted into the already sorted part of the array. If, instead, we use binary search to identify the position, the worst case running time will

A. remain $\Theta(n^2)$
B. become $\Theta(n(\log n)^2)$
C. become $\Theta(n \log n)$
D. become $\Theta(n)$

gatecse-2003 algorithms sorting time-complexity normal insertion-sort

Answer key

1.19.2 Insertion Sort: GATE CSE 2003 | Question: 62

In a permutation $a_1 \dots a_n$, of n distinct integers, an inversion is a pair (a_i, a_j) such that $i < j$ and $a_i > a_j$. What would be the worst case time complexity of the Insertion Sort algorithm, if the inputs are restricted to permutations of $1 \dots n$ with at most n inversions?

A. $\Theta(n^2)$ B. $\Theta(n \log n)$ C. $\Theta(n^{1.5})$ D. $\Theta(n)$

gatecse-2003 algorithms sorting normal insertion-sort

Answer key

1.19.3 Insertion Sort: GATE DA 2025 | Question: 19

Suppose that insertion sort is applied to the array $[1, 3, 5, 7, 9, 11, x, 15, 13]$ and it takes exactly two swaps to sort the array. Select all possible values of x.

A. 10 B. 12 C. 14 D. 16

gateda-2025 algorithms insertion-sort sorting multiple-selects easy one-mark

Answer key

1.20 Linear Probing (1)

1.20.1 Linear Probing: GATE DA 2025 | Question: 8

Consider a hash table of size 10 with indices $\{0, 1, \dots, 9\}$, with the hash function

$$h(x) = 3x (\bmod 10)$$

where linear probing is used to handle collisions. The hash table is initially empty and then the following sequence of keys is inserted into the hash table: $1, 4, 5, 6, 14, 15$. The indices where the keys 14 and 15 are stored are, respectively

A. 2 and 5 B. 2 and 6 C. 4 and 5 D. 4 and 6

gateda-2025 algorithms hashing linear-probing easy one-mark

Answer key

1.21 Matrix Chain Ordering (3)

1.21.1 Matrix Chain Ordering: GATE CSE 2011 | Question: 38

Four Matrices M_1, M_2, M_3 and M_4 of dimensions $p \times q,\ q \times r,\ r \times s$ and $s \times t$ respectively can be multiplied in several ways with different number of total scalar multiplications. For example when multiplied as $((M_1 \times M_2) \times (M_3 \times M_4))$, the total number of scalar multiplications is $pqr + rst + prt$. When multiplied as $(((M_1 \times M_2) \times M_3) \times M_4)$, the total number of scalar multiplications is $pqr + prs + pst$.

If $p = 10, q = 100, r = 20, s = 5$ and $t = 80$, then the minimum number of scalar multiplications needed is

A. 248000 B. 44000 C. 19000 D. 25000

gatecse-2011 algorithms dynamic-programming normal matrix-chain-ordering

Answer key

1.21.2 Matrix Chain Ordering: GATE CSE 2016 Set 2 | Question: 38

Let A_1, A_2, A_3 and A_4 be four matrices of dimensions $10 \times 5, 5 \times 20, 20 \times 10$ and 10×5, respectively. The minimum number of scalar multiplications required to find the product $A_1 A_2 A_3 A_4$ using the basic matrix multiplication method is _________.

gatecse-2016-set2 dynamic-programming algorithms matrix-chain-ordering normal numerical-answers

Answer key

1.21.3 Matrix Chain Ordering: GATE CSE 2018 | Question: 31

Assume that multiplying a matrix G_1 of dimension $p \times q$ with another matrix G_2 of dimension $q \times r$ requires pqr scalar multiplications. Computing the product of n matrices $G_1 G_2 G_3 \dots G_n$ can be done by parenthesizing in different ways. Define $G_i G_{i+1}$ as an **explicitly computed pair** for a given paranthesization if they are directly multiplied. For example, in the matrix multiplication chain $G_1 G_2 G_3 G_4 G_5 G_6$ using parenthesization $(G_1(G_2G_3))(G_4(G_5G_6))$, G_2G_3 and G_5G_6 are only explicitly computed pairs.

Consider a matrix multiplication chain $F_1F_2F_3F_4F_5$, where matrices F_1, F_2, F_3, F_4 and F_5 are of dimensions $2 \times 25, 25 \times 3, 3 \times 16, 16 \times 1$ and 1×1000, respectively. In the parenthesization of $F_1F_2F_3F_4F_5$ that minimizes the total number of scalar multiplications, the explicitly computed pairs is/are

A. F_1F_2 and F_3F_4 only
B. F_2F_3 only
C. F_3F_4 only
D. F_1F_2 and F_4F_5 only

gatecse-2018 algorithms dynamic-programming two-marks matrix-chain-ordering

Answer key

1.22 Merge Sort (3)

1.22.1 Merge Sort: GATE CSE 1999 | Question: 1.14, ISRO2015-42

If one uses straight two-way merge sort algorithm to sort the following elements in ascending order:

$20, 47, 15, 8, 9, 4, 40, 30, 12, 17$

then the order of these elements after second pass of the algorithm is:

A. $8, 9, 15, 20, 47, 4, 12, 17, 30, 40$
B. $8, 15, 20, 47, 4, 9, 30, 40, 12, 17$
C. $15, 20, 47, 4, 8, 9, 12, 30, 40, 17$
D. $4, 8, 9, 15, 20, 47, 12, 17, 30, 40$

gate1999 algorithms merge-sort normal isro2015 sorting

Answer key

1.22.2 Merge Sort: GATE CSE 2012 | Question: 39

A list of n strings, each of length n, is sorted into lexicographic order using the merge-sort algorithm. The worst case running time of this computation is

A. $O(n \log n)$
B. $O(n^2 \log n)$
C. $O(n^2 + \log n)$
D. $O(n^2)$

gatecse-2012 algorithms sorting normal merge-sort

Answer key

1.22.3 Merge Sort: GATE CSE 2015 Set 3 | Question: 27

Assume that a mergesort algorithm in the worst case takes 30 seconds for an input of size 64. Which of the following most closely approximates the maximum input size of a problem that can be solved in 6 minutes?

A. 256
B. 512
C. 1024
D. 2018

gatecse-2015-set3 algorithms sorting merge-sort

Answer key

1.23 Merging (2)

1.23.1 Merging: GATE CSE 1995 | Question: 1.16

For merging two sorted lists of sizes m and n into a sorted list of size $m + n$, we require comparisons of

A. $O(m)$
B. $O(n)$
C. $O(m + n)$
D. $O(\log m + \log n)$

gate1995 algorithms sorting normal merging

Answer key

1.23.2 Merging: GATE CSE 2014 Set 2 | Question: 38

Suppose P, Q, R, S, T are sorted sequences having lengths $20, 24, 30, 35, 50$ respectively. They are to be merged into a single sequence by merging together two sequences at a time. The number of comparisons that will be needed in the worst case by the optimal algorithm for doing this is ____.

gatecse-2014-set2 algorithms sorting normal numerical-answers merging

Answer key

1.24 Minimum Spanning Tree (34)

1.24.1 Minimum Spanning Tree: GATE CSE 1991 | Question: 03,vi

Kruskal's algorithm for finding a minimum spanning tree of a weighted graph G with n vertices and m edges has the time complexity of:

A. $O(n^2)$
B. $O(mn)$
C. $O(m+n)$
D. $O(m \log n)$
E. $O(m^2)$

gate1991 algorithms graph-algorithms minimum-spanning-tree time-complexity multiple-selects

Answer key

1.24.2 Minimum Spanning Tree: GATE CSE 1992 | Question: 01,ix

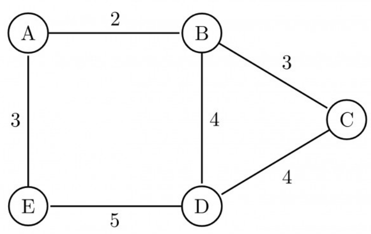
Complexity of Kruskal's algorithm for finding the minimum spanning tree of an undirected graph containing n vertices and m edges if the edges are sorted is _______

gate1992 minimum-spanning-tree algorithms time-complexity easy fill-in-the-blanks

Answer key

1.24.3 Minimum Spanning Tree: GATE CSE 1995 | Question: 22

How many minimum spanning trees does the following graph have? Draw them. (Weights are assigned to edges).



gate1995 algorithms graph-algorithms minimum-spanning-tree easy descriptive

Answer key

1.24.4 Minimum Spanning Tree: GATE CSE 1996 | Question: 16

A complete, undirected, weighted graph G is given on the vertex $\{0, 1, \dots, n-1\}$ for any fixed 'n'. Draw the minimum spanning tree of G if

A. the weight of the edge (u, v) is $|u-v|$
B. the weight of the edge (u, v) is $u+v$

gate1996 algorithms graph-algorithms minimum-spanning-tree normal descriptive

Answer key

1.24.5 Minimum Spanning Tree: GATE CSE 1997 | Question: 9

Consider a graph whose vertices are points in the plane with integer co-ordinates (x, y) such that $1 \leq x \leq n$ and $1 \leq y \leq n$, where $n \geq 2$ is an integer. Two vertices (x_1, y_1) and (x_2, y_2) are adjacent iff $|x_1 - x_2| \leq 1 \text{ and } |y_1 - y_2| \leq 1$. The weight of an edge $\{(x_1, y_1), (x_2, y_2)\}$ is $\sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$

A. What is the weight of a minimum weight-spanning tree in this graph? Write only the answer without any explanations.
B. What is the weight of a maximum weight-spanning tree in this graph? Write only the answer without any explanations.

gate1997 algorithms minimum-spanning-tree normal descriptive

Answer key

1.24.6 Minimum Spanning Tree: GATE CSE 2000 | Question: 2.18

Let G be an undirected connected graph with distinct edge weights. Let e_{max} be the edge with maximum weight and e_{min} the edge with minimum weight. Which of the following statements is false?

A. Every minimum spanning tree of G must contain e_{min}
B. If e_{max} is in a minimum spanning tree, then its removal must disconnect G
C. No minimum spanning tree contains e_{max}
D. G has a unique minimum spanning tree

gatecse-2000 algorithms minimum-spanning-tree normal

Answer key

1.24.7 Minimum Spanning Tree: GATE CSE 2001 | Question: 15

Consider a weighted undirected graph with vertex set $V = \{n1, n2, n3, n4, n5, n6\}$ and edge set $E = \{(n1, n2, 2), (n1, n3, 8), (n1, n6, 3), (n2, n4, 4), (n2, n5, 12), (n3, n4, 7), (n4, n5, 9), (n4, n6, 4)\}$.
The third value in each tuple represents the weight of the edge specified in the tuple.

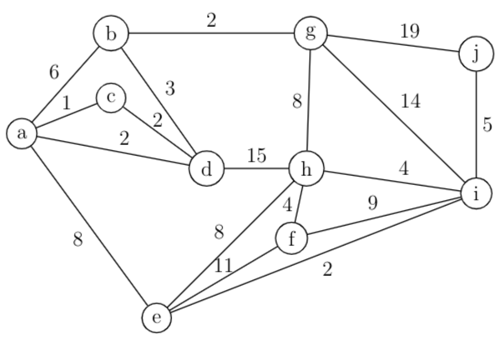
A. List the edges of a minimum spanning tree of the graph.
B. How many distinct minimum spanning trees does this graph have?
C. Is the minimum among the edge weights of a minimum spanning tree unique over all possible minimum spanning trees of a graph?
D. Is the maximum among the edge weights of a minimum spanning tree unique over all possible minimum spanning tree of a graph?

gatecse-2001 algorithms minimum-spanning-tree normal descriptive

Answer key

1.24.8 Minimum Spanning Tree: GATE CSE 2003 | Question: 68

What is the weight of a minimum spanning tree of the following graph?



A. 29 B. 31 C. 38 D. 41

gatecse-2003 algorithms minimum-spanning-tree normal

Answer key

1.24.9 Minimum Spanning Tree: GATE CSE 2005 | Question: 6

An undirected graph G has n nodes. its adjacency matrix is given by an $n \times n$ square matrix whose (i) diagonal elements are 0's and (ii) non-diagonal elements are 1's. Which one of the following is TRUE?

A. Graph G has no minimum spanning tree (MST)
B. Graph G has unique MST of cost $n-1$
C. Graph G has multiple distinct MSTs, each of cost $n-1$
D. Graph G has multiple spanning trees of different costs

gatecse-2005 algorithms minimum-spanning-tree normal

Answer key

1.24.10 Minimum Spanning Tree: GATE CSE 2006 | Question: 11

Consider a weighted complete graph G on the vertex set $\{v_1, v_2, \dots\dots v_n\}$ such that the weight of the edge (v_i, v_j) is $2|i-j|$. The weight of a minimum spanning tree of G is:

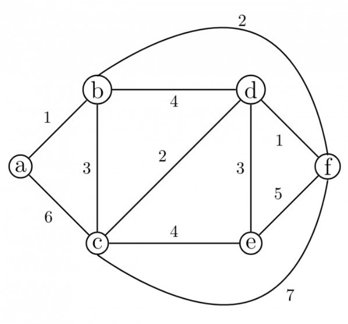
A. $n-1$
B. $2n-2$
C. $\binom{n}{2}$
D. n^2

gatecse-2006 algorithms minimum-spanning-tree normal

Answer key

1.24.11 Minimum Spanning Tree: GATE CSE 2006 | Question: 47

Consider the following graph:



Which one of the following cannot be the sequence of edges added, **in that order**, to a minimum spanning tree using Kruskal's algorithm?

A. $(a-b), (d-f), (b-f), (d-c), (d-e)$
B. $(a-b), (d-f), (d-c), (b-f), (d-e)$
C. $(d-f), (a-b), (d-c), (b-f), (d-e)$
D. $(d-f), (a-b), (b-f), (d-e), (d-c)$

gatecse-2006 algorithms graph-algorithms minimum-spanning-tree normal

Answer key

1.24.12 Minimum Spanning Tree: GATE CSE 2007 | Question: 49

Let w be the minimum weight among all edge weights in an undirected connected graph. Let e be a specific edge of weight w. Which of the following is FALSE?

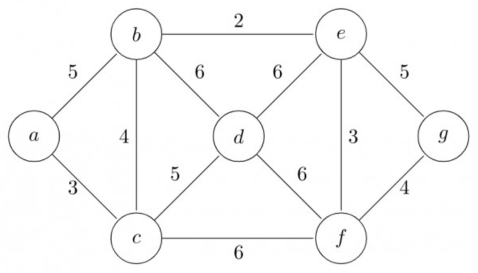
A. There is a minimum spanning tree containing e
B. If e is not in a minimum spanning tree T, then in the cycle formed by adding e to T, all edges have the same weight.
C. Every minimum spanning tree has an edge of weight w
D. e is present in every minimum spanning tree

gatecse-2007 algorithms minimum-spanning-tree normal

Answer key

1.24.13 Minimum Spanning Tree: GATE CSE 2009 | Question: 38

Consider the following graph:



Which one of the following is NOT the sequence of edges added to the minimum spanning tree using Kruskal's algorithm?

A. (b, e) (e, f) (a, c) (b, c) (f, g) (c, d)
B. (b, e) (e, f) (a, c) (f, g) (b, c) (c, d)
C. (b, e) (a, c) (e, f) (b, c) (f, g) (c, d)
D. (b, e) (e, f) (b, c) (a, c) (f, g) (c, d)

gatecse-2009 algorithms minimum-spanning-tree normal

Answer key

1.24.14 Minimum Spanning Tree: GATE CSE 2010 | Question: 50

Consider a complete undirected graph with vertex set $\{0, 1, 2, 3, 4\}$. Entry W_{ij} in the matrix W below is the weight of the edge $\{i, j\}$

$$W = \begin{pmatrix} 0 & 1 & 8 & 1 & 4 \\ 1 & 0 & 12 & 4 & 9 \\ 8 & 12 & 0 & 7 & 3 \\ 1 & 4 & 7 & 0 & 2 \\ 4 & 9 & 3 & 2 & 0 \end{pmatrix}$$

What is the minimum possible weight of a spanning tree T in this graph such that vertex 0 is a leaf node in the tree T?

A. 7 B. 8 C. 9 D. 10

gatecse-2010 algorithms minimum-spanning-tree normal

Answer key

1.24.15 Minimum Spanning Tree: GATE CSE 2010 | Question: 51

Consider a complete undirected graph with vertex set $\{0, 1, 2, 3, 4\}$. Entry W_{ij} in the matrix W below is the weight of the edge $\{i, j\}$

$$W = \begin{pmatrix} 0 & 1 & 8 & 1 & 4 \\ 1 & 0 & 12 & 4 & 9 \\ 8 & 12 & 0 & 7 & 3 \\ 1 & 4 & 7 & 0 & 2 \\ 4 & 9 & 3 & 2 & 0 \end{pmatrix}$$

What is the minimum possible weight of a path P from vertex 1 to vertex 2 in this graph such that P contains at most 3 edges?

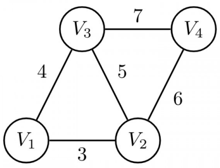
A. 7 B. 8 C. 9 D. 10

gatecse-2010 normal algorithms minimum-spanning-tree

Answer key

1.24.16 Minimum Spanning Tree: GATE CSE 2011 | Question: 54

An undirected graph $G(V, E)$ contains $n\ (n > 2)$ nodes named $v_1, v_2, \ldots, v_n$. Two nodes v_i, v_j are connected if and only if $0 <| i - j | \leq 2$. Each edge (v_i, v_j) is assigned a weight $i + j$. A sample graph with $n = 4$ is shown below.



What will be the cost of the minimum spanning tree (MST) of such a graph with n nodes?

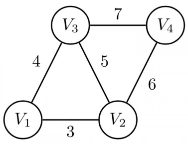
A. $\frac{1}{12}(11n^2 - 5n)$ B. $n^2 - n + 1$ C. $6n - 11$ D. $2n + 1$

gatecse-2011 algorithms graph-algorithms minimum-spanning-tree normal

Answer key

1.24.17 Minimum Spanning Tree: GATE CSE 2011 | Question: 55

An undirected graph $G(V, E)$ contains $n\ (n > 2)$ nodes named $v_1, v_2, \ldots, v_n$. Two nodes v_i, v_j are connected if and only if $0 <| i - j | \leq 2$. Each edge (v_i, v_j) is assigned a weight $i + j$. A sample graph with $n = 4$ is shown below.



The length of the path from v_5 to v_6 in the MST of previous question with $n = 10$ is

A. 11 B. 25 C. 31 D. 41

gatecse-2011 algorithms graph-algorithms minimum-spanning-tree normal

Answer key

1.24.18 Minimum Spanning Tree: GATE CSE 2012 | Question: 29

Let G be a weighted graph with edge weights greater than one and G' be the graph constructed by squaring the weights of edges in G. Let T and T' be the minimum spanning trees of G and G', respectively, with total weights t and t'. Which of the following statements is **TRUE**?

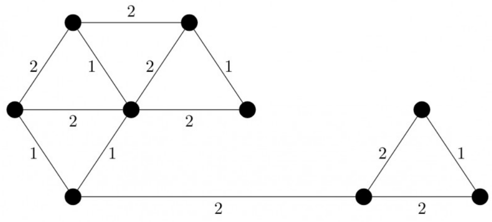
A. $T' = T$ with total weight $t' = t^2$
B. $T' = T$ with total weight $t' < t^2$
C. $T' \neq T$ but total weight $t' = t^2$
D. None of the above

gatecse-2012 algorithms minimum-spanning-tree normal marks-to-all

Answer key

1.24.19 Minimum Spanning Tree: GATE CSE 2014 Set 2 | Question: 52

The number of distinct minimum spanning trees for the weighted graph below is _____

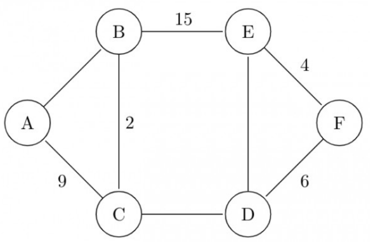


gatecse-2014-set2 algorithms minimum-spanning-tree numerical-answers normal

Answer key

1.24.20 Minimum Spanning Tree: GATE CSE 2015 Set 1 | Question: 43

The graph shown below has 8 edges with distinct integer edge weights. The minimum spanning tree (**MST**) is of weight 36 and contains the edges: $\{(A, C), (B, C), (B, E), (E, F), (D, F)\}$. The edge weights of only those edges which are in the **MST** are given in the figure shown below. The minimum possible sum of weights of all 8 edges of this graph is_______________.



gatecse-2015-set1 algorithms minimum-spanning-tree normal numerical-answers

Answer key

1.24.21 Minimum Spanning Tree: GATE CSE 2015 Set 3 | Question: 40

Let G be a connected undirected graph of 100 vertices and 300 edges. The weight of a minimum spanning tree of G is 500. When the weight of each edge of G is increased by five, the weight of a minimum spanning tree becomes ______.

gatecse-2015-set3 algorithms minimum-spanning-tree easy numerical-answers

Answer key

1.24.22 Minimum Spanning Tree: GATE CSE 2016 Set 1 | Question: 14

Let G be a weighted connected undirected graph with distinct positive edge weights. If every edge weight is increased by the same value, then which of the following statements is/are TRUE?

- P: Minimum spanning tree of G does not change.
- Q: Shortest path between any pair of vertices does not change.

A. P only B. Q only C. Neither P nor Q D. Both P and Q

gatecse-2016-set1 algorithms minimum-spanning-tree normal

Answer key

1.24.23 Minimum Spanning Tree: GATE CSE 2016 Set 1 | Question: 39

Let G be a complete undirected graph on 4 vertices, having 6 edges with weights being $1, 2, 3, 4, 5,$ and 6. The maximum possible weight that a minimum weight spanning tree of G can have is __________

gatecse-2016-set1 algorithms minimum-spanning-tree normal numerical-answers

Answer key

1.24.24 Minimum Spanning Tree: GATE CSE 2016 Set 1 | Question: 40

$G = (V, E)$ is an undirected simple graph in which each edge has a distinct weight, and e is a particular edge of G. Which of the following statements about the minimum spanning trees $(MSTs)$ of G is/are TRUE?

I. If e is the lightest edge of some cycle in G, then every MST of G includes e.
II. If e is the heaviest edge of some cycle in G, then every MST of G excludes e.

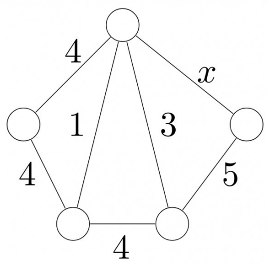
A. I only.
B. II only.
C. Both I and II.
D. Neither I nor II.

gatecse-2016-set1 algorithms minimum-spanning-tree normal

Answer key☟

1.24.25 Minimum Spanning Tree: GATE CSE 2018 | Question: 47

Consider the following undirected graph G:



Choose a value for x that will maximize the number of minimum weight spanning trees (MWSTs) of G. The number of MWSTs of G for this value of x is ____.

gatecse-2018 algorithms graph-algorithms minimum-spanning-tree numerical-answers two-marks

Answer key☟

1.24.26 Minimum Spanning Tree: GATE CSE 2020 | Question: 31

Let $G = (V, E)$ be a weighted undirected graph and let T be a Minimum Spanning Tree (MST) of G maintained using adjacency lists. Suppose a new weighed edge $(u, v) \in V \times V$ is added to G. The worst case time complexity of determining if T is still an MST of the resultant graph is

A. $\Theta(\mid E \mid + \mid V \mid)$

B. $\Theta(\mid E \mid\mid V \mid)$

C. $\Theta(E \mid \log \mid V \mid)$

D. $\Theta(\mid V \mid)$

gatecse-2020 algorithms minimum-spanning-tree graph-algorithms two-marks

Answer key☟

1.24.27 Minimum Spanning Tree: GATE CSE 2020 | Question: 49

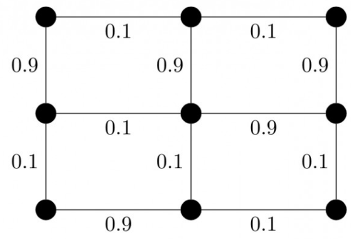
Consider a graph $G = (V, E)$, where $V = \{v_1, v_2, \ldots, v_{100}\}$, $E = \{(v_i, v_j) \mid 1 \leq i < j \leq 100\}$, and weight of the edge (v_i, v_j) is $|i - j|$. The weight of minimum spanning tree of G is _________

gatecse-2020 numerical-answers algorithms graph-algorithms two-marks minimum-spanning-tree

Answer key☟

1.24.28 Minimum Spanning Tree: GATE CSE 2021 Set 1 | Question: 17

Consider the following undirected graph with edge weights as shown:



The number of minimum-weight spanning trees of the graph is ___________.

gatecse-2021-set1 algorithms graph-algorithms minimum-spanning-tree numerical-answers one-mark

Answer key☟

1.24.29 Minimum Spanning Tree: GATE CSE 2021 Set 2 | Question: 1

Let G be a connected undirected weighted graph. Consider the following two statements.

- S_1: There exists a minimum weight edge in G which is present in every minimum spanning tree of G.
- S_2: If every edge in G has distinct weight, then G has a unique minimum spanning tree.

Which one of the following options is correct?

A. Both S_1 and S_2 are true
B. S_1 is true and S_2 is false
C. S_1 is false and S_2 is true
D. Both S_1 and S_2 are false

gatecse-2021-set2 algorithms graph-algorithms minimum-spanning-tree one-mark

Answer key☟

1.24.30 Minimum Spanning Tree: GATE CSE 2022 | Question: 39

Consider a simple undirected weighted graph G, all of whose edge weights are distinct. Which of the following statements about the minimum spanning trees of G is/are TRUE?

A. The edge with the second smallest weight is always part of any minimum spanning tree of G.
B. One or both of the edges with the third smallest and the fourth smallest weights are part of any minimum spanning tree of G.
C. Suppose $S \subseteq V$ be such that $S \neq \phi$ and $S \neq V$. Consider the edge with the minimum weight such that one of its vertices is in S and the other in $V \setminus S$. Such an edge will always be part of any minimum spanning tree of G.
D. G can have multiple minimum spanning trees.

gatecse-2022 algorithms minimum-spanning-tree multiple-selects two-marks

Answer key☟

1.24.31 Minimum Spanning Tree: GATE CSE 2022 | Question: 48

Let $G(V,E)$ be a directed graph, where $V = \{1,2,3,4,5\}$ is the set of vertices and E is the set of directed edges, as defined by the following adjacency matrix A.

$$A[i][j] = \begin{cases} 1, & 1 \leq j \leq i \leq 5 \\ 0, & \text{otherwise} \end{cases}$$

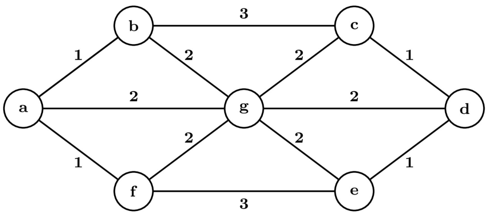
$A[i][j] = 1$ indicates a directed edge from node i to node j. A *directed spanning tree* of G, rooted at $r \in V$, is defined as a subgraph T of G such that the undirected version of T is a tree, and T contains a directed path from r to every other vertex in V. The number of such directed spanning trees rooted at vertex 5 is ___________________.

gatecse-2022 numerical-answers algorithms minimum-spanning-tree two-marks

Answer key☟

1.24.32 Minimum Spanning Tree: GATE CSE 2024 | Set 2 | Question: 49

The number of distinct minimum-weight spanning trees of the following graph is

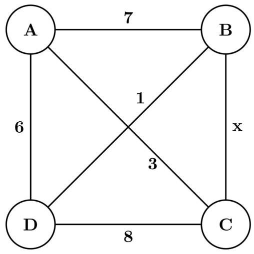


gatecse2024-set2 numerical-answers algorithms minimum-spanning-tree two-marks

Answer key

1.24.33 Minimum Spanning Tree: GATE CSE 2025 | Set 1 | Question: 54

The maximum value of x such that the edge between the nodes B and C is included in every minimum spanning tree of the given graph is _________. (answer in integer)



gatecse2025-set1 algorithms minimum-spanning-tree numerical-answers easy two-marks

Answer key

1.24.34 Minimum Spanning Tree: GATE IT 2005 | Question: 52

Let G be a weighted undirected graph and e be an edge with maximum weight in G. Suppose there is a minimum weight spanning tree in G containing the edge e. Which of the following statements is always TRUE?

A. There exists a cutset in G having all edges of maximum weight.
B. There exists a cycle in G having all edges of maximum weight.
C. Edge e cannot be contained in a cycle.
D. All edges in G have the same weight.

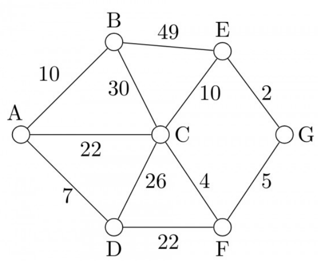
gateit-2005 algorithms minimum-spanning-tree normal

Answer key

1.25 Prims Algorithm (2)

1.25.1 Prims Algorithm: GATE IT 2004 | Question: 56

Consider the undirected graph below:



Using Prim's algorithm to construct a minimum spanning tree starting with node A, which one of the following sequences of edges represents a possible order in which the edges would be added to construct the minimum spanning tree?

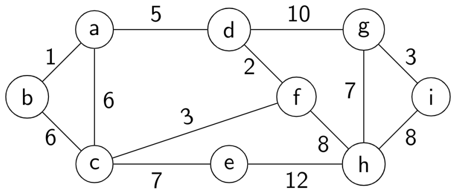
A. $(\text{E}, \text{G}), (\text{C}, \text{F}), (\text{F}, \text{G}), (\text{A}, \text{D}), (\text{A}, \text{B}), (\text{A}, \text{C})$
B. $(\text{A}, \text{D}), (\text{A}, \text{B}), (\text{A}, \text{C}), (\text{C}, \text{F}), (\text{G}, \text{E}), (\text{F}, \text{G})$
C. $(\text{A}, \text{B}), (\text{A}, \text{D}), (\text{D}, \text{F}), (\text{F}, \text{G}), (\text{G}, \text{E}), (\text{F}, \text{C})$
D. $(\text{A}, \text{D}), (\text{A}, \text{B}), (\text{D}, \text{F}), (\text{F}, \text{C}), (\text{F}, \text{G}), (\text{G}, \text{E})$

gateit-2004 algorithms graph-algorithms normal prims-algorithm

Answer key

1.25.2 Prims Algorithm: GATE IT 2008 | Question: 45

For the undirected, weighted graph given below, which of the following sequences of edges represents a correct execution of Prim's algorithm to construct a Minimum Spanning Tree?



A. $(\text{a}, \text{b}), (\text{d}, \text{f}), (\text{f}, \text{c}), (\text{g}, \text{i}), (\text{d}, \text{a}), (\text{g}, \text{h}), (\text{c}, \text{e}), (\text{f}, \text{h})$
B. $(\text{c}, \text{e}), (\text{c}, \text{f}), (\text{f}, \text{d}), (\text{d}, \text{a}), (\text{a}, \text{b}), (\text{g}, \text{h}), (\text{h}, \text{f}), (\text{g}, \text{i})$
C. $(\text{d}, \text{f}), (\text{f}, \text{c}), (\text{d}, \text{a}), (\text{a}, \text{b}), (\text{c}, \text{e}), (\text{f}, \text{h}), (\text{g}, \text{h}), (\text{g}, \text{i})$
D. $(\text{h}, \text{g}), (\text{g}, \text{i}), (\text{h}, \text{f}), (\text{f}, \text{c}), (\text{f}, \text{d}), (\text{d}, \text{a}), (\text{a}, \text{b}), (\text{c}, \text{e})$

gateit-2008 algorithms graph-algorithms minimum-spanning-tree normal prims-algorithm

Answer key

1.26 Quick Sort (14)

1.26.1 Quick Sort: GATE CSE 1987 | Question: 1-xviii

Let P be a quicksort program to sort numbers in ascending order. Let t_1 and t_2 be the time taken by the program for the inputs $[1\ 2\ 3\ 4]$ and $[5\ 4\ 3\ 2\ 1]$, respectively. Which of the following holds?

A. $t_1 = t_2$
B. $t_1 > t_2$
C. $t_1 < t_2$
D. $t_1 = t_2 + 5 \log 5$

gate1987 algorithms sorting quick-sort

Answer key

1.26.2 Quick Sort: GATE CSE 1989 | Question: 9

An input files has 10 records with keys as given below:

$25 \quad 7 \quad 34 \quad 2 \quad 70 \quad 9 \quad 61 \quad 16 \quad 49 \quad 19$

This is to be sorted in non-decreasing order.

i. Sort the input file using QUICKSORT by correctly positioning the first element of the file/subfile. Show the subfiles obtained at all intermediate steps. Use square brackets to demarcate subfiles.
ii. Sort the input file using 2-way- MERGESORT showing all major intermediate steps. Use square brackets to demarcate subfiles.

gate1989 descriptive algorithms sorting quick-sort

Answer key

1.26.3 Quick Sort: GATE CSE 1992 | Question: 03,iv

Assume that the last element of the set is used as partition element in Quicksort. If n distinct elements from the set $[1 \dots n]$ are to be sorted, give an input for which Quicksort takes maximum time.

gate1992 algorithms sorting easy quick-sort descriptive

Answer key

1.26.4 Quick Sort: GATE CSE 1996 | Question: 2.15

Quick-sort is run on two inputs shown below to sort in ascending order taking first element as pivot

i. $1, 2, 3, \dots n$
ii. $n, n-1, n-2, \dots, 2, 1$

Let C_1 and C_2 be the number of comparisons made for the inputs (i) and (ii) respectively. Then,

A. $C_1 < C_2$
B. $C_1 > C_2$
C. $C_1 = C_2$
D. we cannot say anything for arbitrary n

gate1996 algorithms sorting normal quick-sort

Answer key

1.26.5 Quick Sort: GATE CSE 2001 | Question: 1.14

Randomized quicksort is an extension of quicksort where the pivot is chosen randomly. What is the worst case complexity of sorting n numbers using Randomized quicksort?

A. $O(n)$
B. $O(n \log n)$
C. $O(n^2)$
D. $O(n!)$

gatecse-2001 algorithms sorting time-complexity easy quick-sort

Answer key

1.26.6 Quick Sort: GATE CSE 2006 | Question: 52

The median of n elements can be found in $O(n)$ time. Which one of the following is correct about the complexity of quick sort, in which median is selected as pivot?

A. $\Theta(n)$
B. $\Theta(n \log n)$
C. $\Theta(n^2)$
D. $\Theta(n^3)$

gatecse-2006 algorithms sorting easy quick-sort

Answer key

1.26.7 Quick Sort: GATE CSE 2008 | Question: 43

Consider the Quicksort algorithm. Suppose there is a procedure for finding a pivot element which splits the list into two sub-lists each of which contains at least one-fifth of the elements. Let $T(n)$ be the number of comparisons required to sort n elements. Then

A. $T(n) \leq 2T(n/5) + n$
B. $T(n) \leq T(n/5) + T(4n/5) + n$
C. $T(n) \leq 2T(4n/5) + n$
D. $T(n) \leq 2T(n/2) + n$

gatecse-2008 algorithms sorting easy quick-sort

Answer key

1.26.8 Quick Sort: GATE CSE 2009 | Question: 39

In quick-sort, for sorting n elements, the $(n/4)^{th}$ smallest element is selected as pivot using an $O(n)$ time algorithm. What is the worst case time complexity of the quick sort?

A. $\Theta(n)$
B. $\Theta(n \log n)$
C. $\Theta(n^2)$
D. $\Theta(n^2 \log n)$

gatecse-2009 algorithms sorting normal quick-sort

Answer key

1.26.9 Quick Sort: GATE CSE 2014 Set 1 | Question: 14

Let P be quicksort program to sort numbers in ascending order using the first element as the pivot. Let t_1 and t_2 be the number of comparisons made by P for the inputs $[1\ 2\ 3\ 4\ 5]$ and $[4\ 1\ 5\ 3\ 2]$ respectively. Which one of the following holds?

A. $t_1 = 5$
B. $t_1 < t_2$
C. $t_1 > t_2$
D. $t_1 = t_2$

gatecse-2014-set1 algorithms sorting easy quick-sort

Answer key

1.26.10 Quick Sort: GATE CSE 2014 Set 3 | Question: 14

You have an array of n elements. Suppose you implement quicksort by always choosing the central element of the array as the pivot. Then the tightest upper bound for the worst case performance is

A. $O(n^2)$
B. $O(n \log n)$
C. $\Theta(n \log n)$
D. $O(n^3)$

gatecse-2014-set3 algorithms sorting easy quick-sort

Answer key

1.26.11 Quick Sort: GATE CSE 2015 Set 1 | Question: 2

Which one of the following is the recurrence equation for the worst case time complexity of the quick sort algorithm for sorting $n\ (\geq 2)$ numbers? In the recurrence equations given in the options below, c is a constant.

A. $T(n) = 2T(n/2) + cn$
B. $T(n) = T(n-1) + T(1) + cn$
C. $T(n) = 2T(n-1) + cn$
D. $T(n) = T(n/2) + cn$

gatecse-2015-set1 algorithms recurrence-relation sorting easy quick-sort

Answer key

1.26.12 Quick Sort: GATE CSE 2015 Set 2 | Question: 45

Suppose you are provided with the following function declaration in the C programming language.

```
int partition(int a[], int n);
```

The function treats the first element of $a[\,]$ as a pivot and rearranges the array so that all elements less than or equal to the pivot is in the left part of the array, and all elements greater than the pivot is in the right part. In addition, it moves the pivot so that the pivot is the last element of the left part. The return value is the number of elements in the left part.

The following partially given function in the C programming language is used to find the k^{th} smallest element in an array $a[\,]$ of size n using the partition function. We assume $k \leq n$.

```
int kth_smallest (int a[], int n, int k)
{
   int left_end = partition (a, n);
   if (left_end+1==k) {
      return a[left_end];
   }
   if (left_end+1 > k) {
      return kth_smallest (___________);
   } else {
      return kth_smallest (___________);
   }
}
```

The missing arguments lists are respectively

A. $(a,$ left_end$, k)$ and $(a+$left_end$+1, n-$left_end$-1, k-$left_end$-1)$

B. $(a,$ left_end$, k)$ and $(a, n-$left_end$-1, k-$left_end$-1)$

C. $(a+$left_end$+1, n-$left_end$-1, k-$left_end$-1)$ and $(a,$

D. $(a, n-$left_end$-1, k-$left_end$-1)$ and $(a,$left_end$, k)$

left_end, k)

gatecse-2015-set2 algorithms normal sorting quick-sort

Answer key

1.26.13 Quick Sort: GATE CSE 2019 | Question: 20

An array of 25 distinct elements is to be sorted using quicksort. Assume that the pivot element is chosen uniformly at random. The probability that the pivot element gets placed in the worst possible location in the first round of partitioning (rounded off to 2 decimal places) is ________

gatecse-2019 numerical-answers algorithms quick-sort probability one-mark

Answer key

1.26.14 Quick Sort: GATE DS&AI 2024 | Question: 20

Consider sorting the following array of integers in ascending order using an inplace Quicksort algorithm that uses the last element as the pivot.

60	70	80	90	100

The minimum number of swaps performed during this Quicksort is ________.

gate-ds-ai-2024 numerical-answers algorithms quick-sort one-mark

Answer key

1.27 Recurrence Relation (35)

1.27.1 Recurrence Relation: GATE CSE 1987 | Question: 10a

Solve the recurrence equations:

- $T(n) = T(n-1) + n$
- $T(1) = 1$

gate1987 algorithms recurrence-relation descriptive

Answer key

1.27.2 Recurrence Relation: GATE CSE 1988 | Question: 13iv

Solve the recurrence equations:

- $T(n) = T(\frac{n}{2}) + 1$
- $T(1) = 1$

gate1988 descriptive algorithms recurrence-relation

Answer key

1.27.3 Recurrence Relation: GATE CSE 1989 | Question: 13b

Find a solution to the following recurrence equation:

- $T(n) = \sqrt{n} + T\left(\frac{n}{2}\right)$
- $T(1) = 1$

gate1989 descriptive algorithms recurrence-relation

Answer key

1.27.4 Recurrence Relation: GATE CSE 1990 | Question: 17a

Express $T(n)$ in terms of the harmonic number $H_n = \sum_{i=1}^{n} \frac{1}{i}, \quad n \geq 1,$ where $T(n)$ satisfies the recurrence relation,

$T(n) = \frac{n+1}{n} T(n-1) + 1$, for $n \geq \sum$ and $T(1) = 1$

What is the asymptotic behaviour of $T(n)$ as a function of n ?

gate1990 descriptive algorithms recurrence-relation

Answer key

1.27.5 Recurrence Relation: GATE CSE 1992 | Question: 07a

Consider the function $F(n)$ for which the pseudocode is given below :

```
Function F(n)
begin
F1 ← 1
if(n=1) then F ← 3
 else
   For i = 1 to n do
       begin
         C ← 0
        For j = 1 to n – 1 do
        begin C ← C + 1 end
        F1 = F1 * C
      end
 F = F1
end
```

[n is a positive integer greater than zero]

A. Derive a recurrence relation for $F(n)$.

gate1992 algorithms recurrence-relation descriptive

Answer key

1.27.6 Recurrence Relation: GATE CSE 1992 | Question: 07b

Consider the function $F(n)$ for which the pseudocode is given below :

```
Function F(n)
begin
F1 ← 1
if(n=1) then F ← 3
 else
   For i = 1 to n do
       begin
         C ← 0
        For j = 1 to n – 1 do
        begin C ← C + 1 end
        F1 = F1 * C
      end
 F = F1
end
```

[n is a positive integer greater than zero]

B. Solve the recurrence relation for a closed form solution of $F(n)$.

gate1992 algorithms recurrence-relation descriptive

Answer key

1.27.7 Recurrence Relation: GATE CSE 1993 | Question: 15

Consider the recursive algorithm given below:

```
procedure bubblesort (n);
var i,j: index; temp : item;
begin
   for i:=1 to n-1 do
      if A[i] > A[i+1] then
      begin
         temp := A[i];
         A[i] := A[i+1];
         A[i+1] := temp;
      end;
   bubblesort (n-1)
end
```

Let a_n be the number of times the 'if…then…' statement gets executed when the algorithm is run with value n. Set up the recurrence relation by defining a_n in terms of a_{n-1}. Solve for a_n.

gate1993 algorithms recurrence-relation normal descriptive

Answer key

1.27.8 Recurrence Relation: GATE CSE 1994 | Question: 1.7, ISRO2017-14

The recurrence relation that arises in relation with the complexity of binary search is:

A. $T(n) = 2T\left(\frac{n}{2}\right) + k, \text{ k is a constant}$

B. $T(n) = T\left(\frac{n}{2}\right) + k, \text{ k is a constant}$

C. $T(n) = T\left(\frac{n}{2}\right) + \log n$

D. $T(n) = T\left(\frac{n}{2}\right) + n$

gate1994 algorithms recurrence-relation easy isro2017

Answer key

1.27.9 Recurrence Relation: GATE CSE 1996 | Question: 2.12

The recurrence relation

- $T(1) = 2$
- $T(n) = 3T(\frac{n}{4}) + n$

has the solution $T(n)$ equal to

A. $O(n)$

B. $O(\log n)$

C. $O\left(n^{\frac{3}{4}}\right)$

D. None of the above

gate1996 algorithms recurrence-relation normal

Answer key

1.27.10 Recurrence Relation: GATE CSE 1997 | Question: 15

Consider the following function.

```
Function F(n, m:integer):integer;
begin
   if (n<=0) or (m<=0) then F:=1
   else
     F:F(n-1, m) + F(n-1, m-1);
end;
```

Use the recurrence relation $\begin{pmatrix} n \\ k \end{pmatrix} = \begin{pmatrix} n-1 \\ k \end{pmatrix} + \begin{pmatrix} n-1 \\ k-1 \end{pmatrix}$ to answer the following questions. Assume that n, m are positive integers. Write only the answers without any explanation.

a. What is the value of $F(n, 2)$?

b. What is the value of $F(n, m)$?

c. How many recursive calls are made to the function F, including the original call, when evaluating $F(n, m)$.

gate1997 algorithms recurrence-relation descriptive

Answer key☟

1.27.11 Recurrence Relation: GATE CSE 1997 | Question: 4.6

Let $T(n)$ be the function defined by $T(1) = 1,\ T(n) = 2T(\lfloor \frac{n}{2} \rfloor) + \sqrt{n}$ for $n \geq 2$.
Which of the following statements is true?

A. $T(n) = O\sqrt{n}$
B. $T(n) = O(n)$
C. $T(n) = O(\log n)$
D. None of the above

gate1997 algorithms recurrence-relation normal

Answer key☟

1.27.12 Recurrence Relation: GATE CSE 1998 | Question: 6a

Solve the following recurrence relation

$x_n = 2x_{n-1} - 1, n > 1$

$x_1 = 2$

gate1998 algorithms recurrence-relation descriptive

Answer key☟

1.27.13 Recurrence Relation: GATE CSE 2002 | Question: 1.3

The solution to the recurrence equation $T(2^k) = 3T(2^{k-1}) + 1, T(1) = 1$ is

A. 2^k
B. $\frac{(3^{k+1}-1)}{2}$
C. $3^{\log_2 k}$
D. $2^{\log_3 k}$

gatecse-2002 algorithms recurrence-relation normal

Answer key☟

1.27.14 Recurrence Relation: GATE CSE 2002 | Question: 2.11

The running time of the following algorithm

Procedure $A(n)$

If $n \leqslant 2$ return (1) else return $(A(\lceil \sqrt{n} \rceil))$;

is best described by

A. $O(n)$
B. $O(\log n)$
C. $O(\log \log n)$
D. $O(1)$

gatecse-2002 algorithms recurrence-relation normal

Answer key☟

1.27.15 Recurrence Relation: GATE CSE 2003 | Question: 35

Consider the following recurrence relation

$T(1) = 1$

$T(n+1) = T(n) + \lfloor \sqrt{n+1} \rfloor$ for all $n \geq 1$

The value of $T(m^2)$ for $m \geq 1$ is

A. $\frac{m}{6}(21m - 39) + 4$
B. $\frac{m}{6}(4m^2 - 3m + 5)$
C. $\frac{m}{2}(3m^{2.5} - 11m + 20) - 5$
D. $\frac{m}{6}(5m^3 - 34m^2 + 137m - 104) + \frac{5}{6}$

gatecse-2003 algorithms time-complexity recurrence-relation difficult

Answer key☟

1.27.16 Recurrence Relation: GATE CSE 2004 | Question: 83, ISRO2015-40

The time complexity of the following C function is (assume $n > 0$)

```
int recursive (int n) {
   if(n == 1)
      return (1);
   else
      return (recursive (n-1) + recursive (n-1));
}
```

A. $O(n)$ B. $O(n \log n)$ C. $O(n^2)$ D. $O(2^n)$

gatecse-2004 algorithms recurrence-relation time-complexity normal isro2015

Answer key☟

1.27.17 Recurrence Relation: GATE CSE 2004 | Question: 84

The recurrence equation
$T(1) = 1$
$T(n) = 2T(n-1) + n, n \geq 2$

evaluates to

A. $2^{n+1} - n - 2$ B. $2^n - n$ C. $2^{n+1} - 2n - 2$ D. $2^n + n$

gatecse-2004 algorithms recurrence-relation normal

Answer key☟

1.27.18 Recurrence Relation: GATE CSE 2006 | Question: 51, ISRO2016-34

Consider the following recurrence:

$$T(n) = 2T\left(\sqrt{n}\right) + 1, T(1) = 1$$

Which one of the following is true?

A. $T(n) = \Theta(\log \log n)$
B. $T(n) = \Theta(\log n)$
C. $T(n) = \Theta(\sqrt{n})$
D. $T(n) = \Theta(n)$

algorithms recurrence-relation isro2016 gatecse-2006

Answer key☟

1.27.19 Recurrence Relation: GATE CSE 2008 | Question: 78

Let x_n denote the number of binary strings of length n that contain no consecutive 0s.
Which of the following recurrences does x_n satisfy?

A. $x_n = 2x_{n-1}$
B. $x_n = x_{\lfloor n/2 \rfloor} + 1$
C. $x_n = x_{\lfloor n/2 \rfloor} + n$
D. $x_n = x_{n-1} + x_{n-2}$

gatecse-2008 algorithms recurrence-relation normal

Answer key☟

1.27.20 Recurrence Relation: GATE CSE 2008 | Question: 79

Let x_n denote the number of binary strings of length n that contain no consecutive 0s.
The value of x_5 is

A. 5 B. 7 C. 8 D. 16

gatecse-2008 algorithms recurrence-relation normal

Answer key☟

1.27.21 Recurrence Relation: GATE CSE 2009 | Question: 35

The running time of an algorithm is represented by the following recurrence relation:

$$T(n) = \begin{cases} n & n \leq 3 \\ T(\frac{n}{3}) + cn & \text{otherwise} \end{cases}$$

Which one of the following represents the time complexity of the algorithm?

A. $\Theta(n)$
B. $\Theta(n \log n)$
C. $\Theta(n^2)$
D. $\Theta(n^2 \log n)$

gatecse-2009 algorithms recurrence-relation time-complexity normal

Answer key

1.27.22 Recurrence Relation: GATE CSE 2012 | Question: 16

The recurrence relation capturing the optimal execution time of the $Towers\ of\ Hanoi$ problem with n discs is

A. $T(n) = 2T(n-2) + 2$
B. $T(n) = 2T(n-1) + n$
C. $T(n) = 2T(n/2) + 1$
D. $T(n) = 2T(n-1) + 1$

gatecse-2012 algorithms easy recurrence-relation

Answer key

1.27.23 Recurrence Relation: GATE CSE 2014 Set 2 | Question: 13

Which one of the following correctly determines the solution of the recurrence relation with $T(1) = 1$?

$$T(n) = 2T\left(\frac{n}{2}\right) + \log n$$

A. $\Theta(n)$
B. $\Theta(n \log n)$
C. $\Theta(n^2)$
D. $\Theta(\log n)$

gatecse-2014-set2 algorithms recurrence-relation normal

Answer key

1.27.24 Recurrence Relation: GATE CSE 2015 Set 1 | Question: 49

Let a_n represent the number of bit strings of length n containing two consecutive 1s. What is the recurrence relation for a_n?

A. $a_{n-2} + a_{n-1} + 2^{n-2}$
B. $a_{n-2} + 2a_{n-1} + 2^{n-2}$
C. $2a_{n-2} + a_{n-1} + 2^{n-2}$
D. $2a_{n-2} + 2a_{n-1} + 2^{n-2}$

gatecse-2015-set1 algorithms recurrence-relation normal

Answer key

1.27.25 Recurrence Relation: GATE CSE 2015 Set 3 | Question: 39

Consider the following recursive C function.

```
void get(int n)
{
   if (n<1) return;
   get (n-1);
   get (n-3);
   printf("%d", n);
}
```

If $get(6)$ function is being called in $main()$ then how many times will the $get()$ function be invoked before returning to the $main()$?

A. 15
B. 25
C. 35
D. 45

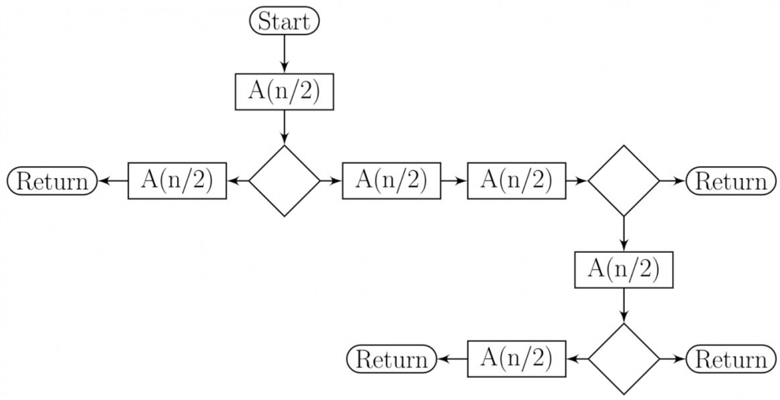
gatecse-2015-set3 algorithms recurrence-relation normal

Answer key

1.27.26 Recurrence Relation: GATE CSE 2016 Set 2 | Question: 39

The given diagram shows the flowchart for a recursive function $A(n)$. Assume that all statements, except for the recursive calls, have $O(1)$ time complexity. If the worst case time complexity of this function is $O(n^{\alpha})$, then the least possible value (accurate up to two decimal positions) of α is ________.

Flow chart for Recursive Function $A(n)$.



gatecse-2016-set2 algorithms time-complexity recurrence-relation normal numerical-answers

Answer key

1.27.27 Recurrence Relation: GATE CSE 2017 Set 2 | Question: 30

Consider the recurrence function

$$T(n) = \begin{cases} 2T(\sqrt{n}) + 1, & n > 2 \\ 2, & 0 < n \leq 2 \end{cases}$$

Then $T(n)$ in terms of Θ notation is

A. $\Theta(\log \log n)$
B. $\Theta(\log n)$
C. $\Theta(\sqrt{n})$
D. $\Theta(n)$

gatecse-2017-set2 algorithms recurrence-relation

Answer key

1.27.28 Recurrence Relation: GATE CSE 2020 | Question: 2

For parameters a and b, both of which are $\omega(1)$, $T(n) = T(n^{1/a}) + 1$, and $T(b) = 1$. Then $T(n)$ is

A. $\Theta(\log_a \log_b n)$
B. $\Theta(\log_{ab} n)$
C. $\Theta(\log_b \log_a \ n)$
D. $\Theta(\log_2 \log_2 n)$

gatecse-2020 algorithms recurrence-relation one-mark

Answer key

1.27.29 Recurrence Relation: GATE CSE 2021 Set 1 | Question: 30

Consider the following recurrence relation.

$$T\,(n) = \begin{cases} T(n\,/\,2) + T(2n\,/\,5) + 7n & \text{if } n > 0 \\ 1 & \text{if } n = 0 \end{cases}$$

Which one of the following options is correct?

A. $T(n) = \Theta(n^{5/2})$
B. $T(n) = \Theta(n \log n)$
C. $T(n) = \Theta(n)$
D. $T(n) = \Theta((\log n)^{5/2})$

gatecse-2021-set1 algorithms recurrence-relation time-complexity two-marks

Answer key

1.27.30 Recurrence Relation: GATE CSE 2021 Set 2 | Question: 39

For constants $a \geq 1$ and $b > 1$, consider the following recurrence defined on the non-negative integers:

$$T(n) = a \cdot T\left(\frac{n}{b}\right) + f(n)$$

Which one of the following options is correct about the recurrence $T(n)$?

A. If $f(n)$ is $n \log_2(n)$, then $T(n)$ is $\Theta(n \log_2(n))$
B. If $f(n)$ is $\dfrac{n}{\log_2(n)}$, then $T(n)$ is $\Theta(\log_2(n))$
C. If $f(n)$ is $O(n^{\log_b(a)-\epsilon})$ for some $\epsilon > 0$, then $T(n)$ is $\Theta(n^{\log_b(a)})$
D. If $f(n)$ is $\Theta(n^{\log_b(a)})$, then $T(n)$ is $\Theta(n^{\log_b(a)})$

gatecse-2021-set2 algorithms recurrence-relation two-marks

Answer key☟

1.27.31 Recurrence Relation: GATE CSE 2024 | Set 1 | Question: 32

Consider the following recurrence relation:

$$T(n) = \begin{cases} \sqrt{n}T(\sqrt{n}) + n \text{ for } n \geq 1, \\ 1 \quad \text{for } n = 1 \end{cases}$$

Which one of the following options is CORRECT?

A. $T(n) = \Theta(n \log \log n)$
B. $T(n) = \Theta(n \log n)$
C. $T(n) = \Theta\left(n^2 \log n\right)$
D. $T(n) = \Theta\left(n^2 \log \log n\right)$

gatecse2024-set1 algorithms recurrence-relation two-marks

Answer key☟

1.27.32 Recurrence Relation: GATE CSE 2025 | Set 1 | Question: 10

Consider the following recurrence relation:

$$T(n) = 2T(n-1) + n2^n \text{ for } n > 0, \quad T(0) = 1$$

Which ONE of the following options is CORRECT?

A. $T(n) = \Theta\left(n^2 2^n\right)$
B. $T(n) = \Theta\left(n2^n\right)$
C. $T(n) = \Theta\left((\log n)^2 2^n\right)$
D. $T(n) = \Theta\left(4^n\right)$

gatecse2025-set1 algorithms time-complexity recurrence-relation one-mark

Answer key☟

1.27.33 Recurrence Relation: GATE IT 2004 | Question: 57

Consider a list of recursive algorithms and a list of recurrence relations as shown below. Each recurrence relation corresponds to exactly one algorithm and is used to derive the time complexity of the algorithm.

	Recursive Algorithm		Recurrence Relation
P	Binary search	I.	$T(n) = T(n-k) + T(k) + cn$
Q.	Merge sort	II.	$T(n) = 2T(n-1) + 1$
R.	Quick sort	III.	$T(n) = 2T(n/2) + cn$
S.	Tower of Hanoi	IV.	$T(n) = T(n/2) + 1$

Which of the following is the correct match between the algorithms and their recurrence relations?

A. P-II, Q-III, R-IV, S-I
B. P-IV, Q-III, R-I, S-II
C. P-III, Q-II, R-IV, S-I
D. P-IV, Q-II, R-I, S-III

gateit-2004 algorithms recurrence-relation normal match-the-following

Answer key☟

1.27.34 Recurrence Relation: GATE IT 2005 | Question: 51

Let $T(n)$ be a function defined by the recurrence

$T(n) = 2T(n/2) + \sqrt{n}$ for $n \geq 2$ and
$T(1) = 1$

Which of the following statements is **TRUE**?

A. $T(n) = \Theta(\log n)$
B. $T(n) = \Theta(\sqrt{n})$
C. $T(n) = \Theta(n)$
D. $T(n) = \Theta(n \log n)$

gateit-2005 algorithms recurrence-relation easy

Answer key

1.27.35 Recurrence Relation: GATE IT 2008 | Question: 44

When $n = 2^{2k}$ for some $k \geqslant 0$, the recurrence relation

$T(n) = \surd(2)T(n/2) + \surd n, T(1) = 1$

evaluates to :

A. $\surd(n)(\log n + 1)$
B. $\surd(n) \log n$
C. $\surd(n) \log \surd(n)$
D. $n \log \surd n$

gateit-2008 algorithms recurrence-relation normal

Answer key

1.28 Recursion (4)

1.28.1 Recursion: GATE CSE 1995 | Question: 2.9

A language with string manipulation facilities uses the following operations

```
head(s): first character of a string
tail(s): all but exclude the first character of a string
```

```
concat(s1, s2): s1s2
```

For the string "$acbc$" what will be the output of

```
concat(head(s), head(tail(tail(s))))
```

A. ac
B. bc
C. ab
D. cc

gate1995 algorithms normal recursion

Answer key

1.28.2 Recursion: GATE CSE 2007 | Question: 44

In the following C function, let $n \geq m$.

```
int gcd(n,m)  {
    if (n%m == 0) return m;
    n = n%m;
    return gcd(m,n);
}
```

How many recursive calls are made by this function?

A. $\Theta(\log_2 n)$
B. $\Omega(n)$
C. $\Theta(\log_2 \log_2 n)$
D. $\Theta(\sqrt{n})$

gatecse-2007 algorithms recursion time-complexity normal

Answer key

1.28.3 Recursion: GATE CSE 2018 | Question: 45

Consider the following program written in pseudo-code. Assume that x and y are integers.

```
Count (x, y) {
```

```
    if (y !=1 ) {
        if (x !=1) {
            print("*");
            Count (x/2, y);
        }
        else {
            y=y-1;
            Count (1024, y);
        }
    }
}
```

The number of times that the $print$ statement is executed by the call $Count(1024, 1024)$ is _____

gatecse-2018 numerical-answers algorithms recursion two-marks

Answer key

1.28.4 Recursion: GATE CSE 2021 Set 2 | Question: 49

Consider the following ANSI C program

```
#include <stdio.h>
int foo(int x, int y, int q)
    {
        if ((x<=0) && (y<=0))
        return q;
        if (x<=0)
        return foo(x, y-q, q);
        if (y<=0)
        return foo(x-q, y, q);
        return foo(x, y-q, q) + foo(x-q, y, q);
    }
int main( )
{
    int r = foo(15, 15, 10);
    printf("%d", r);
    return 0;
}
```

The output of the program upon execution is _________

gatecse-2021-set2 algorithms recursion output numerical-answers two-marks

Answer key

1.29 Searching (7)

1.29.1 Searching: GATE CSE 1996 | Question: 18

Consider the following program that attempts to locate an element x in an array $a[]$ using binary search. Assume $N > 1$. The program is erroneous. Under what conditions does the program fail?

```
var i,j,k: integer; x: integer;
    a: array; [1..N] of integer;
begin i:= 1; j:= n;
repeat
    k:(i+j) div 2;
    if a[k] < x then i:= k
    else j:= k
until (a[k] = x) or (i >= j);

if (a[k] = x) then
    writeln ('x is in the array')
else
    writeln ('x is not in the array')
end;
```

gate1996 algorithms searching normal descriptive

Answer key

1.29.2 Searching: GATE CSE 1996 | Question: 2.13, ISRO2016-28

The average number of key comparisons required for a successful search for sequential search on n items is

A. $\frac{n}{2}$

B. $\frac{n-1}{2}$

C. $\frac{n+1}{2}$

D. None of the above

gate1996 algorithms easy isro2016 searching

Answer key

1.29.3 Searching: GATE CSE 2002 | Question: 2.10

Consider the following algorithm for searching for a given number x in an unsorted array $A[1..n]$ having n distinct values:

1. Choose an i at random from $1..n$
2. If $A[i] = x$, then Stop else Goto 1;

Assuming that x is present in A, what is the expected number of comparisons made by the algorithm before it terminates?

A. n

B. $n-1$

C. $2n$

D. $\frac{n}{2}$

gatecse-2002 searching normal

Answer key

1.29.4 Searching: GATE CSE 2008 | Question: 84

Consider the following C program that attempts to locate an element x in an array $Y[\,]$ using binary search. The program is erroneous.

```
f (int Y[10] , int x) {
  int i, j, k;
  i= 0; j = 9;
  do {
      k = (i+ j) / 2;
      if( Y[k] < x) i = k;else j = k;
      } while (Y[k] != x) && (i < j)) ;
  if(Y[k] == x) printf(" x is in the array ") ;
  else printf(" x is not in the array ") ;
}
```

On which of the following contents of Y and x does the program fail?

A. Y is $[1\ 2\ 3\ 4\ 5\ 6\ 7\ 8\ 9\ 10]$ and $x < 10$
B. Y is $[1\ 3\ 5\ 7\ 9\ 11\ 13\ 15\ 17\ 19]$ and $x < 1$
C. Y is $[2\ 2\ 2\ 2\ 2\ 2\ 2\ 2\ 2\ 2]$ and $x > 2$
D. Y is $[2\ 4\ 6\ 8\ 10\ 12\ 14\ 16\ 18\ 20]$ and $2 < x < 20$ and x is even

gatecse-2008 algorithms searching normal

Answer key

1.29.5 Searching: GATE CSE 2008 | Question: 85

Consider the following C program that attempts to locate an element x in an array $Y[\,]$ using binary search. The program is erroneous.

```
f (int Y[10] , int x) {
  int i, j, k;
  i= 0; j = 9;
  do {
      k = (i + j) / 2;
      if( Y[k] < x) i = k;else j = k;
      } while (Y[k] != x) && (i < j)) ;
  if(Y[k] == x) printf(" x is in the array ") ;
  else printf(" x is not in the array ") ;
}
```

The correction needed in the program to make it work properly is

A. Change line 6 to: if $(Y[k] < x) i = k + 1$; else $j = k - 1$;

B. Change line 6 to: if $(Y[k] < x) i = k - 1$; else $j = k + 1$;
C. Change line 6 to: if $(Y[k] < x) i = k$; else $j = k$;
D. Change line 7 to: } while $((Y[k] == x) \&\& (i < j))$;

gatecse-2008 algorithms searching normal

Answer key

1.29.6 Searching: GATE CSE 2017 Set 1 | Question: 48

Let A be an array of 31 numbers consisting of a sequence of 0's followed by a sequence of 1's. The problem is to find the smallest index i such that $A[i]$ is 1 by probing the minimum number of locations in A. The *worst case* number of probes performed by an *optimal* algorithm is ____________.

gatecse-2017-set1 algorithms normal numerical-answers searching

Answer key

1.29.7 Searching: GATE CSE 2025 | Set 2 | Question: 19

Which of the following statements regarding Breadth First Search (BFS) and Depth First Search (DFS) on an undirected simple graph G is/are TRUE?

A. A DFS tree of G is a Shortest Path tree of G.
B. Every non-tree edge of G with respect to a DFS tree is a forward/back edge.
C. If (u, v) is a non-tree edge of G with respect to a BFS tree, then the distances from the source vertex s to u and v in the BFS tree are within ± 1 of each other.
D. Both BFS and DFS can be used to find the connected components of G.

gatecse2025-set2 algorithms searching breadth-first-search depth-first-search multiple-selects one-mark

Answer key

1.30 Shortest Path (9)

1.30.1 Shortest Path: GATE CSE 2002 | Question: 12

Fill in the blanks in the following template of an algorithm to compute all pairs shortest path lengths in a directed graph G with $n * n$ adjacency matrix A. $A[i, j]$ equals 1 if there is an edge in G from i to j, and 0 otherwise. Your aim in filling in the blanks is to ensure that the algorithm is correct.

```
INITIALIZATION: For i = 1 ... n
   {For j = 1 ... n
      { if a[i,j] = 0 then P[i,j] =_______ else P[i,j] =_______;}
   }

ALGORITHM: For i = 1 ... n
   {For j = 1 ... n
      {For k = 1 ... n
         {P[__,__] = min{_______,_______}; }
      }
   }
```

a. Copy the complete line containing the blanks in the Initialization step and fill in the blanks.
b. Copy the complete line containing the blanks in the Algorithm step and fill in the blanks.
c. Fill in the blank: The running time of the Algorithm is O(___).

gatecse-2002 algorithms graph-algorithms time-complexity normal descriptive shortest-path

Answer key

1.30.2 Shortest Path: GATE CSE 2003 | Question: 67

Let $G = (V, E)$ be an undirected graph with a subgraph $G_1 = (V_1, E_1)$. Weights are assigned to edges of G as follows.

$$w(e) = \begin{cases} 0, & \text{if } e \in E_1 \\ 1, & \text{otherwise} \end{cases}$$

A single-source shortest path algorithm is executed on the weighted graph (V, E, w) with an arbitrary vertex v_1 of V_1 as the source. Which of the following can always be inferred from the path costs computed?

A. The number of edges in the shortest paths from v_1 to all vertices of G
B. G_1 is connected
C. V_1 forms a clique in G
D. G_1 is a tree

gatecse-2003 algorithms graph-algorithms normal shortest-path

Answer key

1.30.3 Shortest Path: GATE CSE 2007 | Question: 41

In an unweighted, undirected connected graph, the shortest path from a node S to every other node is computed most efficiently, in terms of *time complexity*, by

A. Dijkstra's algorithm starting from S.
B. Warshall's algorithm.
C. Performing a DFS starting from S.
D. Performing a BFS starting from S.

gatecse-2007 algorithms graph-algorithms easy shortest-path

Answer key

1.30.4 Shortest Path: GATE CSE 2020 | Question: 40

Let $G = (V, E)$ be a directed, weighted graph with weight function $w : E \to \mathbb{R}$. For some function $f : V \to \mathbb{R}$, for each edge $(u, v) \in E$, define $w'(u, v)$ as $w(u, v) + f(u) - f(v)$.

Which one of the options completes the following sentence so that it is TRUE?

"The shortest paths in G under w are shortest paths under w' too,_____________".

A. for every $f : V \to \mathbb{R}$
B. if and only if $\forall u \in V,\ f(u)$ is positive
C. if and only if $\forall u \in V,\ f(u)$ is negative
D. if and only if $f(u)$ is the distance from s to u in the graph obtained by adding a new vertex s to G and edges of zero weight from s to every vertex of G

gatecse-2020 algorithms graph-algorithms two-marks shortest-path

Answer key

1.30.5 Shortest Path: GATE CSE 2025 | Set 1 | Question: 33

Let $G(V, E)$ be an undirected and unweighted graph with 100 vertices. Let $d(u, v)$ denote the number of edges in a shortest path between vertices u and v in V. Let the maximum value of $d(u, v), u, v \in V$ such that $u \neq v$, be 30. Let T be any breadth-first-search tree of G. Which ONE of the given options is CORRECT for every such graph G ?

A. The height of T is exactly 15.
B. The height of T is exactly 30.
C. The height of T is at least 15.
D. The height of T is at least 30.

gatecse2025-set1 algorithms breadth-first-search shortest-path two-marks

Answer key

1.30.6 Shortest Path: GATE CSE 2025 | Set 1 | Question: 8

Let G be any undirected graph with positive edge weights, and T be a minimum spanning tree of G. For any two vertices, u and v, let $d_1(u, v)$ and $d_2(u, v)$ be the shortest distances between u and v in G and T, respectively. Which ONE of the options is CORRECT for all possible G, T, u and v ?

A. $d_1(u,v) = d_2(u,v)$
B. $d_1(u,v) \leq d_2(u,v)$

C. $d_1(u,v) \geq d_2(u,v)$

D. $d_1(u,v) \neq d_2(u,v)$

gatecse2025-set1 algorithms minimum-spanning-tree shortest-path one-mark

Answer key

1.30.7 Shortest Path: GATE CSE 2025 | Set 2 | Question: 27

Let G be an edge-weighted undirected graph with positive edge weights. Suppose a positive constant α is added to the weight of every edge.

Which ONE of the following statements is TRUE about the minimum spanning trees (MSTs) and shortest paths (SPs) in G before and after the edge weight update?

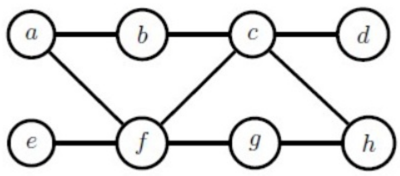
A. Every MST remains an MST, and every SP remains an SP.
B. MSTs need not remain MSTs, and every SP remains an SP.
C. Every MST remains an MST, and SPs need not remain SPs.
D. MSTs need not remain MSTs, and SPs need not remain SPs.

gatecse2025-set2 algorithms minimum-spanning-tree shortest-path two-marks

Answer key

1.30.8 Shortest Path: GATE DA 2025 | Question: 48

Let G be a simple, unweighted, and undirected graph. A subset of the vertices and edges of G are shown below.



It is given that $a-b-c-d$ is a shortest path between a and d; $e-f-g-h$ is a shortest path between e and h; $a-f-c-h$ is a shortest path between a and h. Which of the following is/are NOT the edges of G ?

A. (b,d)

B. (b,g)

C. (b,h)

D. (e,g)

gateda-2025 algorithms shortest-path multiple-selects two-marks

1.30.9 Shortest Path: GATE IT 2007 | Question: 3, UGCNET-June2012-III: 34

Consider a weighted, undirected graph with positive edge weights and let uv be an edge in the graph. It is known that the shortest path from the source vertex s to u has weight 53 and the shortest path from s to v has weight 65. Which one of the following statements is always TRUE?

A. Weight $(u,v) \leq 12$

B. Weight $(u,v) = 12$

C. Weight $(u,v) \geq 12$

D. Weight $(u,v) > 12$

gateit-2007 algorithms graph-algorithms normal ugcnetcse-june2012-paper3 shortest-path

Answer key

1.31 Sorting (28)

1.31.1 Sorting: GATE CSE 1988 | Question: 1iii

Quicksort is ________ efficient than heapsort in the worst case.

gate1988 algorithms sorting fill-in-the-blanks easy

Answer key

1.31.2 Sorting: GATE CSE 1990 | Question: 3-v

The complexity of comparison based sorting algorithms is:

A. $\Theta(n \log n)$
B. $\Theta(n)$
C. $\Theta(n^2)$
D. $\Theta(n\sqrt{n})$

gate1990 normal algorithms sorting easy time-complexity multiple-selects

Answer key

1.31.3 Sorting: GATE CSE 1991 | Question: 01,vii

The minimum number of comparisons required to sort 5 elements is ______

gate1991 normal algorithms sorting numerical-answers

Answer key

1.31.4 Sorting: GATE CSE 1991 | Question: 13

Give an optimal algorithm in pseudo-code for sorting a sequence of n numbers which has only k distinct numbers (k is not known a Priori). Give a brief analysis for the time-complexity of your algorithm.

gate1991 sorting time-complexity algorithms difficult descriptive

Answer key

1.31.5 Sorting: GATE CSE 1992 | Question: 02,ix

Following algorithm(s) can be used to sort n in the range $[1 \dots n^3]$ in $O(n)$ time

a. Heap sort
b. Quick sort
c. Merge sort
d. Radix sort

gate1992 easy algorithms sorting multiple-selects

Answer key

1.31.6 Sorting: GATE CSE 1995 | Question: 12

Consider the following sequence of numbers:

$$92, 37, 52, 12, 11, 25$$

Use Bubble sort to arrange the sequence in ascending order. Give the sequence at the end of each of the first five passes.

gate1995 algorithms sorting easy descriptive bubble-sort

Answer key

1.31.7 Sorting: GATE CSE 1996 | Question: 14

A two dimensional array $A[1..n][1..n]$ of integers is partially sorted if $\forall i, j \in [1..n-1], A[i][j] < A[i][j+1] \text{ and } A[i][j] < A[i+1][j]$

a. The smallest item in the array is at $A[i][j]$ where $i =$ __ and $j =$ __.
b. The smallest item is deleted. Complete the following $O(n)$ procedure to insert item x (which is guaranteed to be smaller than any item in the last row or column) still keeping A partially sorted.

```
procedure insert (x: integer);
var i,j: integer;
begin
  i:=1; j:=1, A[i][j]:=x;
  while (x > __ or x > __) do
    if A[i+1][j] < A[i][j] ___ then begin
      A[i][j]:=A[i+1][j]; i:=i+1;
    end
    else begin
      _____
    end
  A[i][j]:= ____
end
```

gate1996 algorithms sorting normal descriptive

Answer key

1.31.8 Sorting: GATE CSE 1998 | Question: 1.22

Give the correct matching for the following pairs:

(A)	$O(\log n)$	(P)	Selection
(B)	$O(n)$	(Q)	Insertion sort
(C)	$O(n \log n)$	(R)	Binary search
(D)	$O(n^2)$	(S)	Merge sort

A. A-R B-P C-Q D-S
B. A-R B-P C-S D-Q
C. A-P B-R C-S D-Q
D. A-P B-S C-R D-Q

gate1998 algorithms sorting easy match-the-following

Answer key

1.31.9 Sorting: GATE CSE 1999 | Question: 1.12

A sorting technique is called stable if

A. it takes $O(n \log n)$ time
B. it maintains the relative order of occurrence of non-distinct elements
C. it uses divide and conquer paradigm
D. it takes $O(n)$ space

gate1999 algorithms sorting easy

Answer key

1.31.10 Sorting: GATE CSE 1999 | Question: 8

Let A be an $n \times n$ matrix such that the elements in each row and each column are arranged in ascending order. Draw a decision tree, which finds 1^{st}, 2^{nd} and 3^{rd} smallest elements in minimum number of comparisons.

gate1999 algorithms sorting normal descriptive

Answer key

1.31.11 Sorting: GATE CSE 2000 | Question: 17

An array contains four occurrences of 0, five occurrences of 1, and three occurrences of 2 in any order. The array is to be sorted using swap operations (elements that are swapped need to be adjacent).

a. What is the minimum number of swaps needed to sort such an array in the worst case?
b. Give an ordering of elements in the above array so that the minimum number of swaps needed to sort the array is maximum.

gatecse-2000 algorithms sorting normal descriptive

Answer key

1.31.12 Sorting: GATE CSE 2003 | Question: 61

In a permutation $a_1 \ldots a_n$, of n distinct integers, an inversion is a pair (a_i, a_j) such that $i < j$ and $a_i > a_j$.

If all permutations are equally likely, what is the expected number of inversions in a randomly chosen permutation of $1 \ldots n$?

A. $\frac{n(n-1)}{2}$
B. $\frac{n(n-1)}{4}$
C. $\frac{n(n+1)}{4}$
D. $2n[\log_2 n]$

gatecse-2003 algorithms sorting inversion normal

Answer key

1.31.13 Sorting: GATE CSE 2005 | Question: 39

Suppose there are $\lceil \log n \rceil$ sorted lists of $\lfloor n/ \log n \rfloor$ elements each. The time complexity of producing a sorted list of all these elements is: (Hint:Use a heap data structure)

A. $O(n \log \log n)$
B. $\Theta(n \log n)$
C. $\Omega(n \log n)$
D. $\Omega\left(n^{3/2}\right)$

gatecse-2005 algorithms sorting normal

Answer key

1.31.14 Sorting: GATE CSE 2006 | Question: 14, ISRO2011-14

Which one of the following in place sorting algorithms needs the minimum number of swaps?

A. Quick sort
B. Insertion sort
C. Selection sort
D. Heap sort

gatecse-2006 algorithms sorting easy isro2011

Answer key

1.31.15 Sorting: GATE CSE 2007 | Question: 14

Which of the following sorting algorithms has the lowest worse-case complexity?

A. Merge sort
B. Bubble sort
C. Quick sort
D. Selection sort

gatecse-2007 algorithms sorting time-complexity easy

Answer key

1.31.16 Sorting: GATE CSE 2009 | Question: 11

What is the number of swaps required to sort n elements using selection sort, in the worst case?

A. $\Theta(n)$
B. $\Theta(n \log n)$
C. $\Theta(n^2)$
D. $\Theta(n^2 \log n)$

gatecse-2009 algorithms sorting easy selection-sort

Answer key

1.31.17 Sorting: GATE CSE 2013 | Question: 30

The number of elements that can be sorted in $\Theta(\log n)$ time using heap sort is

A. $\Theta(1)$
B. $\Theta(\sqrt{\log} n)$
C. $\Theta(\frac{\log n}{\log \log n})$
D. $\Theta(\log n)$

gatecse-2013 algorithms sorting normal heap-sort

Answer key

1.31.18 Sorting: GATE CSE 2013 | Question: 6

Which one of the following is the tightest upper bound that represents the number of swaps required to sort n numbers using selection sort?

A. $O(\log n)$
B. $O(n)$
C. $O(n \log n)$
D. $O(n^2)$

gatecse-2013 algorithms sorting easy selection-sort

Answer key

1.31.19 Sorting: GATE CSE 2014 Set 1 | Question: 39

The minimum number of comparisons required to find the minimum and the maximum of 100 numbers is ________ gatecse-2014-set1 algorithms numerical-answers normal maximum-minimum sorting

Answer key

1.31.20 Sorting: GATE CSE 2016 Set 1 | Question: 13

The worst case running times of *Insertion sort* , *Merge sort* and *Quick sort*, respectively are:

A. $\Theta(n \log n)$, $\Theta(n \log n)$ and $\Theta(n^2)$
B. $\Theta(n^2)$, $\Theta(n^2)$ and $\Theta(n \log n)$
C. $\Theta(n^2)$, $\Theta(n \log n)$ and $\Theta(n \log n)$
D. $\Theta(n^2)$, $\Theta(n \log n)$ and $\Theta(n^2)$

gatecse-2016-set1 algorithms sorting easy

Answer key

1.31.21 Sorting: GATE CSE 2016 Set 2 | Question: 13

Assume that the algorithms considered here sort the input sequences in ascending order. If the input is already in the ascending order, which of the following are **TRUE**?

I. Quicksort runs in $\Theta(n^2)$ time
II. Bubblesort runs in $\Theta(n^2)$ time
III. Mergesort runs in $\Theta(n)$ time
IV. Insertion sort runs in $\Theta(n)$ time

A. I and II only
B. I and III only
C. II and IV only
D. I and IV only

gatecse-2016-set2 algorithms sorting time-complexity normal ambiguous

Answer key

1.31.22 Sorting: GATE CSE 2021 Set 1 | Question: 9

Consider the following array.

23	32	45	69	72	73	89	97

Which algorithm out of the following options uses the least number of comparisons (among the array elements) to sort the above array in ascending order?

A. Selection sort
B. Mergesort
C. Insertion sort
D. Quicksort using the last element as pivot

gatecse-2021-set1 algorithms sorting one-mark

Answer key

1.31.23 Sorting: GATE CSE 2024 | Set 1 | Question: 31

An array $[82, 101, 90, 11, 111, 75, 33, 131, 44, 93]$ is heapified. Which one of the following options represents the first three elements in the heapified array?

A. $82, 90, 101$
B. $82, 11, 93$
C. $131, 11, 93$
D. $131, 111, 90$

gatecse2024-set1 algorithms heap-sort sorting two-marks

Answer key

1.31.24 Sorting: GATE CSE 2024 | Set 2 | Question: 25

Let A be an array containing integer values. The distance of A is defined as the minimum number of elements in A that must be replaced with another integer so that the resulting array is sorted in non-decreasing order. The distance of the array $[2, 5, 3, 1, 4, 2, 6]$ is __________.

gatecse2024-set2 numerical-answers algorithms sorting one-mark

Answer key

1.31.25 Sorting: GATE CSE 2025 | Set 2 | Question: 10

Consider an unorders list of N distinct integers.

What is the minimum number of element comaparisons required to find an integer in the list that is NOT the largest in the list?

A. 1 B. $N-1$ C. N D. $2N-1$

gatecse2025-set2 algorithms sorting one-mark

Answer key

1.31.26 Sorting: GATE DS&AI 2024 | Question: 35

Consider the following sorting algorithms:

i. Bubble sort
ii. Insertion sort
iii. Selection sort

Which ONE among the following choices of sorting algorithms sorts the numbers in the array $[4,3,2,1,5]$ in increasing order after exactly two passes over the array?

A. (i) only B. (iii) only C. (i) and (iii) only D. (ii) and (iii) only

gate-ds-ai-2024 algorithms sorting two-marks

Answer key

1.31.27 Sorting: GATE IT 2005 | Question: 59

Let a and b be two sorted arrays containing n integers each, in non-decreasing order. Let c be a sorted array containing $2n$ integers obtained by merging the two arrays a and b. Assuming the arrays are indexed starting from 0, consider the following four statements

I. $a[i] \geq b[i] \Rightarrow c[2i] \geq a[i]$
II. $a[i] \geq b[i] \Rightarrow c[2i] \geq b[i]$
III. $a[i] \geq b[i] \Rightarrow c[2i] \leq a[i]$
IV. $a[i] \geq b[i] \Rightarrow c[2i] \leq b[i]$

Which of the following is TRUE?

A. only I and II B. only I and IV C. only II and III D. only III and IV

gateit-2005 algorithms sorting normal

Answer key

1.31.28 Sorting: GATE IT 2008 | Question: 43

If we use Radix Sort to sort n integers in the range $\left(n^{k/2}, n^k\right]$, for some $k > 0$ which is independent of n, the time taken would be?

A. $\Theta(n)$ B. $\Theta(kn)$ C. $\Theta(n \log n)$ D. $\Theta(n^2)$

gateit-2008 algorithms sorting normal

Answer key

1.32 Space Complexity (1)

1.32.1 Space Complexity: GATE CSE 2005 | Question: 81a

```
double foo(int n)
```

```
{
    int i;
    double sum;
    if(n == 0)
    {
        return 1.0;
    }
    else
    {
        sum = 0.0;
        for(i = 0; i < n; i++)
        {
            sum += foo(i);
        }
        return sum;
    }
}
```

The space complexity of the above code is?

A. $O(1)$
B. $O(n)$
C. $O(n!)$
D. n^n

gatecse-2005 algorithms recursion normal space-complexity

Answer key

1.33 Strongly Connected Components (3)

1.33.1 Strongly Connected Components: GATE CSE 2008 | Question: 7

The most efficient algorithm for finding the number of connected components in an undirected graph on n vertices and m edges has time complexity

A. $\Theta(n)$
B. $\Theta(m)$
C. $\Theta(m+n)$
D. $\Theta(mn)$

gatecse-2008 algorithms graph-algorithms time-complexity normal strongly-connected-components

Answer key

1.33.2 Strongly Connected Components: GATE CSE 2018 | Question: 43

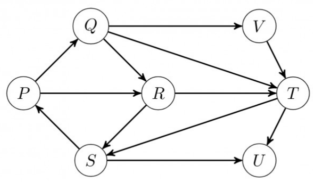
Let G be a graph with $100!$ vertices, with each vertex labelled by a distinct permutation of the numbers $1, 2, \ldots, 100$. There is an edge between vertices u and v if and only if the label of u can be obtained by swapping two adjacent numbers in the label of v. Let y denote the degree of a vertex in G, and z denote the number of connected components in G. Then, $y + 10z =$ ______.

gatecse-2018 algorithms graph-algorithms numerical-answers two-marks strongly-connected-components

Answer key

1.33.3 Strongly Connected Components: GATE IT 2006 | Question: 46

Which of the following is the correct decomposition of the directed graph given below into its strongly connected components?



A. $\{P, Q, R, S\}, \{T\}, \{U\}, \{V\}$
B. $\{P, Q, R, S, T, V\}, \{U\}$
C. $\{P, Q, S, T, V\}, \{R\}, \{U\}$
D. $\{P, Q, R, S, T, U, V\}$

gateit-2006 algorithms graph-algorithms normal strongly-connected-components

Answer key

1.34.1 Time Complexity: GATE CSE 1988 | Question: 6i

Given below is the sketch of a program that represents the path in a two-person game tree by the sequence of active procedure calls at any time. The program assumes that the payoffs are real number in a limited range; that the constant INF is larger than any positive payoff and its negation is smaller than any negative payoff and that there is a function "payoff" and that computes the payoff for any board that is a leaf. The type "boardtype" has been suitably declared to represent board positions. It is player-1's move if mode = MAX and player-2's move if mode=MIN. The type modetype = (MAX, MIN). The functions "min" and "max" find the minimum and maximum of two real numbers.

```
function search(B: boardtype; mode: modetype): real;
  var
    C:boardtype; {a child of board B}
    value:real;
  begin
    if B is a leaf then
      return (payoff(B))
    else
      begin
      if mode = MAX then value :=-INF
      else
        value:INF;
      for each child C of board B do
      if mode = MAX then
        value:=max (value, search (C, MIN))
      else
        value:=min(value, search(C, MAX))
      return(value)
      end
  end; (search)
```

Comment on the working principle of the above program. Suggest a possible mechanism for reducing the amount of search.

gate1988 normal descriptive algorithms time-complexity

Answer key

1.34.2 Time Complexity: GATE CSE 1989 | Question: 2-iii

Match the pairs in the following:

(A)	$O(\log n)$	(p)	Heapsort
(B)	$O(n)$	(q)	Depth-first search
(C)	$O(n \log n)$	(r)	Binary search
(D)	$O(n^2)$	(s)	Selection of the k^{th} smallest element in a set of n elements

gate1989 match-the-following algorithms time-complexity

Answer key

1.34.3 Time Complexity: GATE CSE 1993 | Question: 8.7

$\sum\limits_{1 \leq k \leq n} O(n)$, where $O(n)$ stands for order n is:

A. $O(n)$

B. $O(n^2)$

C. $O(n^3)$

D. $O(3n^2)$

E. $O(1.5n^2)$

gate1993 algorithms time-complexity easy

Answer key

1.34.4 Time Complexity: GATE CSE 1999 | Question: 1.13

Suppose we want to arrange the n numbers stored in any array such that all negative values occur before all positive ones. Minimum number of exchanges required in the worst case is

A. $n-1$ B. n C. $n+1$ D. None of the above

gate1999 algorithms time-complexity normal

Answer key

1.34.5 Time Complexity: GATE CSE 1999 | Question: 1.16

If n is a power of 2, then the minimum number of multiplications needed to compute a^n is

A. $\log_2 n$ B. $\sqrt{n}$ C. $n-1$ D. n

gate1999 algorithms time-complexity normal

Answer key

1.34.6 Time Complexity: GATE CSE 1999 | Question: 11a

Consider the following algorithms. Assume, procedure A and procedure B take $O(1)$ and $O(1/n)$ unit of time respectively. Derive the time complexity of the algorithm in O-notation.

```
algorithm what (n)
begin
    if n = 1 then call A
    else
        begin
            what (n-1);
            call B(n)
        end
end.
```

gate1999 algorithms time-complexity normal descriptive

Answer key

1.34.7 Time Complexity: GATE CSE 2000 | Question: 1.15

Let S be a sorted array of n integers. Let $T(n)$ denote the time taken for the most efficient algorithm to determined if there are two elements with sum less than 1000 in S. Which of the following statement is true?

A. $T(n)$ is $O(1)$
B. $n \leq T(n) \leq n \log_2 n$
C. $n \log_2 n \leq T(n) < \frac{n}{2}$
D. $T(n) = \binom{n}{2}$

gatecse-2000 easy algorithms time-complexity

Answer key

1.34.8 Time Complexity: GATE CSE 2003 | Question: 66

The cube root of a natural number n is defined as the largest natural number m such that $(m^3 \leq n)$. The complexity of computing the cube root of n (n is represented by binary notation) is

A. $O(n)$ but not $O(n^{0.5})$
B. $O(n^{0.5})$ but not $O((\log n)^k)$ for any constant $k > 0$
C. $O((\log n)^k)$ for some constant $k > 0$, but not $O((\log \log n)^m)$ for any constant $m > 0$
D. $O((\log \log n)^k)$ for some constant $k > 0.5$, but not $O((\log \log n)^{0.5})$

gatecse-2003 algorithms time-complexity normal

Answer key

1.34.9 Time Complexity: GATE CSE 2004 | Question: 39

Two matrices M_1 and M_2 are to be stored in arrays A and B respectively. Each array can be stored either in row-major or column-major order in contiguous memory locations. The time complexity of an algorithm to compute $M_1 \times M_2$ will be

A. best if A is in row-major, and B is in column-major order
B. best if both are in row-major order
C. best if both are in column-major order
D. independent of the storage scheme

gatecse-2004 algorithms time-complexity easy

Answer key☟

1.34.10 Time Complexity: GATE CSE 2004 | Question: 82

Let $A[1,\ldots,n]$ be an array storing a bit (1 or 0) at each location, and $f(m)$ is a function whose time complexity is $\Theta(m)$. Consider the following program fragment written in a C like language:

```
counter = 0;
for (i=1; i<=n; i++)
{
   if (a[i] == 1) counter++;
   else {f (counter); counter = 0;}
}
```

The complexity of this program fragment is

A. $\Omega(n^2)$
B. $\Omega(n \log n)$ and $O(n^2)$
C. $\Theta(n)$
D. $o(n)$

gatecse-2004 algorithms time-complexity normal

Answer key☟

1.34.11 Time Complexity: GATE CSE 2006 | Question: 15

Consider the following C-program fragment in which i, j and n are integer variables.

```
for( i = n, j = 0; i > 0; i /= 2, j +=i );
```

Let $val(j)$ denote the value stored in the variable j after termination of the for loop. Which one of the following is true?

A. $val(j) = \Theta(\log n)$
B. $val(j) = \Theta(\sqrt{n})$
C. $val(j) = \Theta(n)$
D. $val(j) = \Theta(n \log n)$

gatecse-2006 algorithms normal time-complexity

Answer key☟

1.34.12 Time Complexity: GATE CSE 2007 | Question: 15, ISRO2016-26

Consider the following segment of C-code:

```
int j, n;
j = 1;
while (j <= n)
   j = j * 2;
```

The number of comparisons made in the execution of the loop for any $n > 0$ is:

A. $\lceil \log_2 n \rceil + 1$
B. n
C. $\lceil \log_2 n \rceil$
D. $\lfloor \log_2 n \rfloor + 1$

gatecse-2007 algorithms time-complexity normal isro2016

Answer key☟

1.34.13 Time Complexity: GATE CSE 2007 | Question: 45

What is the time complexity of the following recursive function?

```
int  DoSomething (int n) {
   if (n <= 2)
      return 1;
   else
```

```
    return (DoSomething (floor (sqrt(n))) + n);
}
```

A. $\Theta(n^2)$
B. $\Theta(n \log_2 n)$
C. $\Theta(\log_2 n)$
D. $\Theta(\log_2 \log_2 n)$

gatecse-2007 algorithms time-complexity normal

Answer key

1.34.14 Time Complexity: GATE CSE 2007 | Question: 50

An array of n numbers is given, where n is an even number. The maximum as well as the minimum of these n numbers needs to be determined. Which of the following is **TRUE** about the number of comparisons needed?

A. At least $2n - c$ comparisons, for some constant c are needed.
B. At most $1.5n - 2$ comparisons are needed.
C. At least $n \log_2 n$ comparisons are needed
D. None of the above

gatecse-2007 algorithms time-complexity easy

Answer key

1.34.15 Time Complexity: GATE CSE 2007 | Question: 51

Consider the following C program segment:

```
int IsPrime (n)
  {
    int i, n;
    for (i=2; i<=sqrt(n);i++)
      if(n%i == 0)
        {printf("Not Prime \n"); return 0;}
    return 1;
  }
```

Let $T(n)$ denote number of times the for loop is executed by the program on input n. Which of the following is TRUE?

A. $T(n) = O(\sqrt{n})$ and $T(n) = \Omega(\sqrt{n})$
B. $T(n) = O(\sqrt{n})$ and $T(n) = \Omega(1)$
C. $T(n) = O(n)$ and $T(n) = \Omega(\sqrt{n})$
D. None of the above

gatecse-2007 algorithms time-complexity normal

Answer key

1.34.16 Time Complexity: GATE CSE 2008 | Question: 40

The minimum number of comparisons required to determine if an integer appears more than $\frac{n}{2}$ times in a sorted array of n integers is

A. $\Theta(n)$
B. $\Theta(\log n)$
C. $\Theta(\log^* n)$
D. $\Theta(1)$

gatecse-2008 normal algorithms time-complexity

Answer key

1.34.17 Time Complexity: GATE CSE 2008 | Question: 47

We have a binary heap on n elements and wish to insert n more elements (not necessarily one after another) into this heap. The total time required for this is

A. $\Theta(\log n)$
B. $\Theta(n)$
C. $\Theta(n \log n)$
D. $\Theta(n^2)$

gatecse-2008 algorithms time-complexity normal

Answer key

1.34.18 Time Complexity: GATE CSE 2008 | Question: 74

Consider the following C functions:

```
int f1 (int n)
{
    if(n == 0 || n == 1)
        return n;
    else
        return (2 * f1(n-1) + 3 * f1(n-2));
}
int f2(int n)
{
    int i;
    int X[N], Y[N], Z[N];
    X[0] = Y[0] = Z[0] = 0;
    X[1] = 1; Y[1] = 2; Z[1] = 3;
    for(i = 2; i <= n; i++){
        X[i] = Y[i-1] + Z[i-2];
        Y[i] = 2 * X[i];
        Z[i] = 3 * X[i];
    }
    return X[n];
}
```

The running time of $f1(n)$ and $f2(n)$ are

A. $\Theta(n)$ and $\Theta(n)$
B. $\Theta(2^n)$ and $\Theta(n)$
C. $\Theta(n)$ and $\Theta(2^n)$
D. $\Theta(2^n)$ and $\Theta(2^n)$

gatecse-2008 algorithms time-complexity normal

Answer key

1.34.19 Time Complexity: GATE CSE 2008 | Question: 75

Consider the following C functions:

```
int f1 (int n)
{
    if(n == 0 || n == 1)
        return n;
    else
        return (2 * f1(n-1) + 3 * f1(n-2));
}
int f2(int n)
{
    int i;
    int X[N], Y[N], Z[N];
    X[0] = Y[0] = Z[0] = 0;
    X[1] = 1; Y[1] = 2; Z[1] = 3;
    for(i = 2; i <= n; i++){
        X[i] = Y[i-1] + Z[i-2];
        Y[i] = 2 * X[i];
        Z[i] = 3 * X[i];
    }
    return X[n];
}
```

$f1(8)$ and $f2(8)$ return the values

A. 1661 and 1640
B. 59 and 59
C. 1640 and 1640
D. 1640 and 1661

gatecse-2008 normal algorithms time-complexity

Answer key

1.34.20 Time Complexity: GATE CSE 2010 | Question: 12

Two alternative packages A and B are available for processing a database having 10^k records. Package A requires $0.0001n^2$ time units and package B requires $10n\log_{10} n$ time units to process n records. What is the smallest value of k for which package B will be preferred over A?

A. 12
B. 10
C. 6
D. 5

gatecse-2010 algorithms time-complexity easy

Answer key

1.34.21 Time Complexity: GATE CSE 2014 Set 1 | Question: 42

Consider the following pseudo code. What is the total number of multiplications to be performed?

```
D = 2
for i = 1 to n do
   for j = i to n do
      for k = j + 1 to n do
         D = D * 3
```

A. Half of the product of the 3 consecutive integers.
B. One-third of the product of the 3 consecutive integers.
C. One-sixth of the product of the 3 consecutive integers.
D. None of the above.

gatecse-2014-set1 algorithms time-complexity normal

Answer key

1.34.22 Time Complexity: GATE CSE 2015 Set 1 | Question: 40

An algorithm performs $(\log N)^{\frac{1}{2}}$ find operations , N insert operations, $(\log N)^{\frac{1}{2}}$ delete operations, and $(\log N)^{\frac{1}{2}}$ decrease-key operations on a set of data items with keys drawn from a linearly ordered set . For a delete operation, a pointer is provided to the record that must be deleted . For the decrease-key operation, a pointer is provided to the record that has its key decreased. Which one of the following data structures is the most suited for the algorithm to use, if the goal is to achieve the best total asymptotic complexity considering all the operations?

A. Unsorted array
B. Min - heap
C. Sorted array
D. Sorted doubly linked list

gatecse-2015-set1 algorithms data-structures normal time-complexity

Answer key

1.34.23 Time Complexity: GATE CSE 2015 Set 2 | Question: 22

An unordered list contains n distinct elements. The number of comparisons to find an element in this list that is neither maximum nor minimum is

A. $\Theta(n \log n)$
B. $\Theta(n)$
C. $\Theta(\log n)$
D. $\Theta(1)$

gatecse-2015-set2 algorithms time-complexity easy

Answer key

1.34.24 Time Complexity: GATE CSE 2017 Set 2 | Question: 03

Match the algorithms with their time complexities:

Algorithms	**Time Complexity**
P. Tower of Hanoi with n disks	i. $\Theta(n^2)$
Q. Binary Search given n sorted numbers	ii. $\Theta(n \log n)$
R. Heap sort given n numbers at the worst case	iii. $\Theta(2^n)$
S. Addition of two $n \times n$ matrices	iv. $\Theta(\log n)$

A. $P \to (iii) \quad Q \to (iv) \quad r \to (i) \quad S \to (ii)$
B. $P \to (iv) \quad Q \to (iii) \quad r \to (i) \quad S \to (ii)$
C. $P \to (iii) \quad Q \to (iv) \quad r \to (ii) \quad S \to (i)$
D. $P \to (iv) \quad Q \to (iii) \quad r \to (ii) \quad S \to (i)$

gatecse-2017-set2 algorithms time-complexity match-the-following easy

Answer key

1.34.25 Time Complexity: GATE CSE 2017 Set 2 | Question: 38

Consider the following C function

```
int fun(int n) {
    int i, j;
    for(i=1; i<=n; i++) {
        for (j=1; j<n; j+=i) {
            printf("%d %d", i, j);
        }
    }
}
```

Time complexity of fun in terms of Θ notation is

A. $\Theta(n\sqrt{n})$
B. $\Theta(n^2)$
C. $\Theta(n \log n)$
D. $\Theta(n^2 \log n)$

gatecse-2017-set2 algorithms time-complexity

Answer key

1.34.26 Time Complexity: GATE CSE 2019 | Question: 37

There are n unsorted arrays: $A_1, A_2, \ldots, A_n$. Assume that n is odd.Each of $A_1, A_2, \ldots, A_n$ contains n distinct elements. There are no common elements between any two arrays. The worst-case time complexity of computing the median of the medians of $A_1, A_2, \ldots, A_n$ is

A. $O(n)$
B. $O(n \text{ log } n)$
C. $O(n^2)$
D. $\Omega(n^2 \log n)$

gatecse-2019 algorithms time-complexity two-marks

Answer key

1.34.27 Time Complexity: GATE CSE 2024 | Set 1 | Question: 7

Given an integer array of size N, we want to check if the array is sorted (in either ascending or descending order). An algorithm solves this problem by making a single pass through the array and comparing each element of the array only with its adjacent elements. The worst-case time complexity of this algorithm is

A. both $\mathrm{O}(N)$ and $\Omega(N)$
B. $\mathrm{O}(N)$ but $\text{not}\,\Omega(N)$
C. $\Omega(N)$ but not $\mathrm{O}(N)$
D. neither $\mathrm{O}(N)$ nor $\Omega(N)$

gatecse2024-set1 algorithms time-complexity one-mark

Answer key

1.34.28 Time Complexity: GATE IT 2007 | Question: 17

Exponentiation is a heavily used operation in public key cryptography. Which of the following options is the tightest upper bound on the number of multiplications required to compute $b^n \bmod m, 0 \leq b, n \leq m$?

A. $O(\log n)$
B. $O(\sqrt{n})$
C. $O\left(\frac{n}{\log n}\right)$
D. $O(n)$

gateit-2007 algorithms time-complexity normal

Answer key

1.34.29 Time Complexity: GATE IT 2007 | Question: 81

Let $P_1, P_2, \ldots, P_n$ be n points in the xy-plane such that no three of them are collinear. For every pair of points P_i and P_j, let L_{ij} be the line passing through them. Let L_{ab} be the line with the steepest gradient among all $n(n-1)/2$ lines.

The time complexity of the best algorithm for finding P_a and P_b is

A. $\Theta\left(n\right)$
B. $\Theta\left(n\log n\right)$
C. $\Theta\left(n\log^2 n\right)$
D. $\Theta\left(n^2\right)$

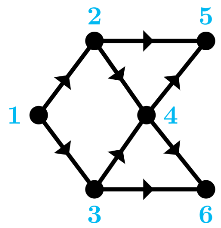
gateit-2007 algorithms time-complexity normal

Answer key

1.35 Topological Sort (4)

1.35.1 Topological Sort: GATE CSE 2007 | Question: 5

Consider the DAG with $V = \{1, 2, 3, 4, 5, 6\}$ shown below.



Which of the following is not a topological ordering?

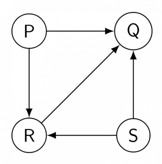
A. $1\ 2\ 3\ 4\ 5\ 6$ B. $1\ 3\ 2\ 4\ 5\ 6$ C. $1\ 3\ 2\ 4\ 6\ 5$ D. $3\ 2\ 4\ 1\ 6\ 5$

gatecse-2007 algorithms graph-algorithms topological-sort easy

Answer key

1.35.2 Topological Sort: GATE CSE 2014 Set 1 | Question: 13

Consider the directed graph below given.



Which one of the following is **TRUE**?

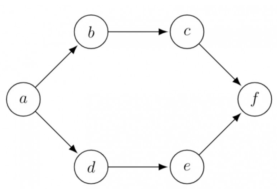
A. The graph does not have any topological ordering.
B. Both PQRS and SRQP are topological orderings.
C. Both PSRQ and SPRQ are topological orderings.
D. PSRQ is the only topological ordering.

gatecse-2014-set1 graph-algorithms easy topological-sort

Answer key

1.35.3 Topological Sort: GATE CSE 2016 Set 1 | Question: 11

Consider the following directed graph:



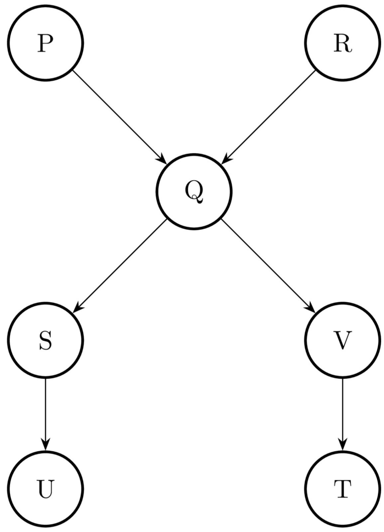
The number of different topological orderings of the vertices of the graph is ______________.

gatecse-2016-set1 algorithms graph-algorithms normal numerical-answers topological-sort

Answer key

1.35.4 Topological Sort: GATE DS&AI 2024 | Question: 41

Consider the directed acyclic graph (DAG) below:



Which of the following is/are valid vertex orderings that can be obtained from a topological sort of the DAG?

A. P Q R S T U V
B. P R Q V S U T
C. P Q R S V U T
D. P R Q S V T U

gate-ds-ai-2024 algorithms topological-sort directed-acyclic-graph multiple-selects two-marks

Answer key☟

Answer Keys

1.0.1	6:6	1.1.1	N/A	1.1.2	N/A	1.1.3	B	1.1.4	C
1.1.5	12	1.1.6	29	1.1.7	A;C	1.1.8	B	1.2.1	N/A
1.2.2	N/A	1.2.3	C	1.2.4	A	1.2.5	B	1.2.6	A
1.2.7	C	1.2.8	C	1.2.9	C	1.3.1	X	1.3.2	B
1.3.3	D	1.3.4	A	1.3.5	A;C	1.3.6	A;D	1.3.7	A
1.4.1	A;B	1.4.2	B	1.4.3	D	1.4.4	B	1.4.5	A
1.4.6	C	1.4.7	C	1.4.8	D	1.4.9	A	1.4.10	C
1.4.11	C	1.4.12	D	1.4.13	D	1.4.14	A	1.5.1	B
1.5.2	C	1.6.1	B	1.6.2	C	1.6.3	A	1.7.1	D
1.8.1	C	1.9.1	N/A	1.9.2	B	1.9.3	D	1.9.4	A
1.9.5	D	1.9.6	D	1.10.1	75:75	1.11.1	10:10	1.12.1	B
1.12.2	C	1.12.3	C	1.12.4	B	1.12.5	B	1.12.6	A
1.12.7	34	1.12.8	150	1.12.9	C	1.13.1	B	1.13.2	D
1.13.3	A	1.13.4	A	1.13.5	B	1.13.6	A	1.13.7	A;B
1.13.8	929 : 929	1.13.9	A	1.13.10	C	1.13.11	D	1.14.1	N/A
1.14.2	C	1.14.3	C	1.14.4	C	1.14.5	D	1.14.6	D
1.14.7	C	1.14.8	C	1.14.9	B	1.14.10	19	1.14.11	D
1.14.12	31	1.14.13	D	1.14.14	A	1.14.15	5040	1.14.16	C
1.14.17	60	1.14.18	A	1.14.19	D	1.14.20	D	1.14.21	D
1.14.22	B	1.15.1	A	1.15.2	B	1.15.3	D	1.15.4	A
1.15.5	16	1.16.1	B	1.16.2	N/A	1.16.3	13	1.16.4	C

1.16.5	B
1.17.3	D
1.18.2	N/A
1.18.7	C
1.18.12	B
1.18.17	D
1.18.22	D
1.18.27	D
1.18.32	1023 : 1023
1.18.37	D
1.20.1	D
1.22.2	B
1.24.2	N/A
1.24.7	N/A
1.24.12	D
1.24.17	C
1.24.22	A
1.24.27	99
1.24.32	9
1.26.1	C
1.26.6	B
1.26.11	B
1.27.2	N/A
1.27.7	N/A
1.27.12	N/A
1.27.17	A
1.27.22	D
1.27.27	B
1.27.32	A
1.28.2	A
1.29.3	A
1.30.1	N/A
1.30.6	B
1.31.2	A
1.31.7	N/A
1.31.12	B
1.31.17	C
1.31.22	C
1.31.27	C

1.16.6	C
1.17.4	225
1.18.3	C
1.18.8	N/A
1.18.13	D
1.18.18	D
1.18.23	B
1.18.28	51
1.18.33	15 : 15
1.18.38	C
1.21.1	C
1.22.3	B
1.24.3	2
1.24.8	B
1.24.13	D
1.24.18	X
1.24.23	7
1.24.28	3 : 3
1.24.33	5:5
1.26.2	N/A
1.26.7	B
1.26.12	A
1.27.3	N/A
1.27.8	B
1.27.13	B
1.27.18	B
1.27.23	A
1.27.28	A
1.27.33	B
1.28.3	10230
1.29.4	C
1.30.2	B
1.30.7	C
1.31.3	7
1.31.8	B
1.31.13	A
1.31.18	B
1.31.23	D
1.31.28	C

1.16.7	D
1.17.5	B
1.18.4	A
1.18.9	C
1.18.14	C
1.18.19	B
1.18.24	A
1.18.29	0
1.18.34	D
1.19.1	A
1.21.2	1500
1.23.1	C
1.24.4	N/A
1.24.9	C
1.24.14	D
1.24.19	6
1.24.24	B
1.24.29	C
1.24.34	A
1.26.3	N/A
1.26.8	B
1.26.13	0.08
1.27.4	N/A
1.27.9	A
1.27.14	C
1.27.19	D
1.27.24	A
1.27.29	C
1.27.34	C
1.28.4	60 : 60
1.29.5	A
1.30.3	D
1.30.8	A;C;D
1.31.4	N/A
1.31.9	B
1.31.14	C
1.31.19	147.1 : 148.1
1.31.24	3
1.32.1	B

1.17.1	2.33
1.17.6	A
1.18.5	N/A
1.18.10	D
1.18.15	C
1.18.20	C
1.18.25	9
1.18.30	D
1.18.35	C
1.19.2	D
1.21.3	C
1.23.2	358
1.24.5	N/A
1.24.10	B
1.24.15	B
1.24.20	69
1.24.25	4
1.24.30	A;B;C
1.25.1	D
1.26.4	C
1.26.9	C
1.26.14	0
1.27.5	N/A
1.27.10	N/A
1.27.15	B
1.27.20	X
1.27.25	B
1.27.30	C
1.27.35	A
1.29.1	N/A
1.29.6	5
1.30.4	A
1.30.9	C
1.31.5	D
1.31.10	N/A
1.31.15	A
1.31.20	D
1.31.25	A
1.33.1	C

1.17.2	A
1.18.1	N/A
1.18.6	C
1.18.11	A
1.18.16	D
1.18.21	B
1.18.26	A
1.18.31	81
1.18.36	C
1.19.3	A;C
1.22.1	B
1.24.1	B;D;E
1.24.6	C
1.24.11	D
1.24.16	B
1.24.21	995
1.24.26	D
1.24.31	24
1.25.2	C
1.26.5	C
1.26.10	A
1.27.1	N/A
1.27.6	N/A
1.27.11	B
1.27.16	D
1.27.21	A
1.27.26	2.32 : 2.33
1.27.31	A
1.28.1	C
1.29.2	C
1.29.7	B;C;D
1.30.5	C
1.31.1	N/A
1.31.6	N/A
1.31.11	N/A
1.31.16	A
1.31.21	D
1.31.26	B
1.33.2	109

1.33.3	B
1.34.5	A
1.34.10	C
1.34.15	B
1.34.20	C
1.34.25	C
1.35.1	D

1.34.1	N/A
1.34.6	N/A
1.34.11	C
1.34.16	B
1.34.21	C
1.34.26	C
1.35.2	C

1.34.2	N/A
1.34.7	A
1.34.12	D
1.34.17	B
1.34.22	A
1.34.27	A
1.35.3	6

1.34.3	B;C;D;E
1.34.8	C
1.34.13	D
1.34.18	B
1.34.23	D
1.34.28	A
1.35.4	B;D

1.34.4	D
1.34.9	D
1.34.14	B
1.34.19	C
1.34.24	C
1.34.29	B

CO & Architecture (238)

Machine instructions and Addressing modes. ALU, data-path and control unit. Instruction pipelining. **Pipeline hazards,** Memory hierarchy: cache, main memory and secondary storage; I/O interface (Interrupt and DMA mode)

Mark Distribution in Previous GATE

Year	2025 - 1	2025 - 2	2024 - 1	2024 - 2	2023	2022	2021 - 1	2021 - 2	Minimum	Average	Maximu
1 Mark Count	2	1	2	2	2	3	1	2	1	1.88	3
2 Marks Count	3	4	3	3	4	2	2	2	2	2.88	4
Total Marks	8	9	8	8	10	7	5	6	**5**	**7.63**	**10**

2.1 Addressing Modes (18)

2.1.1 Addressing Modes: GATE CSE 1987 | Question: 1-V

The most relevant addressing mode to write position-independent codes is:

A. Direct mode
B. Indirect mode
C. Relative mode
D. Indexed mode

gate1987 co-and-architecture addressing-modes easy

Answer key

2.1.2 Addressing Modes: GATE CSE 1988 | Question: 9iii

In the program scheme given below indicate the instructions containing any operand needing relocation for position independent behaviour. Justify your answer.

$$\begin{array}{rll} & Y = 10 & \\ & \text{MOV} & X(R_0), R_1 \\ & \text{MOV} & X, R_0 \\ & \text{MOV} & 2(R_0), R_1 \\ & \text{MOV} & Y(R_0), R_5 \\ & . & \\ & . & \\ & . & \\ X: & \text{WORD} & 0, 0, 0 \end{array}$$

gate1988 normal descriptive co-and-architecture addressing-modes

Answer key

2.1.3 Addressing Modes: GATE CSE 1989 | Question: 2-ii

Match the pairs in the following questions:

(A)	Base addressing	(p)	Reentrancey
(B)	Indexed addressing	(q)	Accumulator
(C)	Stack addressing	(r)	Array
(D)	Implied addressing	(s)	Position independent

gate1989 match-the-following co-and-architecture addressing-modes easy

Answer key

2.1.4 Addressing Modes: GATE CSE 1993 | Question: 10

The instruction format of a CPU is:

OP CODE	MODE	RegR

← One Memory word →

Mode and RegR together specify the operand. RegR specifies a CPU register and Mode specifies an addressing mode. In particular, $\text{Mode} = 2$ specifies that ‘the register RegR contains the address of the operand, after fetching the operand, the contents of RegR are incremented by 1'.

An instruction at memory location 2000 specifies $\text{Mode} = 2$ and the RegR refers to program counter (PC).

A. What is the address of the operand?
B. Assuming that is a non-jump instruction, what are the contents of PC after the execution of this instruction?

gate1993 co-and-architecture addressing-modes normal descriptive

Answer key

2.1.5 Addressing Modes: GATE CSE 1996 | Question: 1.16, ISRO2016-42

Relative mode of addressing is most relevant to writing:

A. Co – routines
B. Position – independent code
C. Shareable code
D. Interrupt Handlers

gate1996 co-and-architecture addressing-modes easy isro2016

Answer key

2.1.6 Addressing Modes: GATE CSE 1998 | Question: 1.19

Which of the following addressing modes permits relocation without any change whatsoever in the code?

A. Indirect addressing
B. Indexed addressing
C. Base register addressing
D. PC relative addressing

gate1998 co-and-architecture addressing-modes easy

Answer key

2.1.7 Addressing Modes: GATE CSE 1999 | Question: 2.23

A certain processor supports only the immediate and the direct addressing modes. Which of the following programming language features cannot be implemented on this processor?

A. Pointers
B. Arrays
C. Records
D. Recursive procedures with local variable

gate1999 co-and-architecture addressing-modes normal multiple-selects

Answer key

2.1.8 Addressing Modes: GATE CSE 2000 | Question: 1.10

The most appropriate matching for the following pairs

$$\begin{array}{ll} \text{X: Indirect addressing} & \text{1: Loops} \\ \text{Y: Immediate addressing} & \text{2: Pointers} \\ \text{Z: Auto decrement addressing} & \text{3: Constants} \end{array}$$

is

A. $X-3, Y-2, Z-1$
B. $X-1, Y-3, Z-2$
C. $X-2, Y-3, Z-1$
D. $X-3, Y-1, Z-2$

gatecse-2000 co-and-architecture easy addressing-modes match-the-following

Answer key

2.1.9 Addressing Modes: GATE CSE 2001 | Question: 2.9

Which is the most appropriate match for the items in the first column with the items in the second column:

X.	Indirect Addressing	I.	Array implementation
Y.	Indexed Addressing	II.	Writing relocatable code
Z.	Base Register Addressing	III.	Passing array as parameter

A. (X, III), (Y, I), (Z, II)
B. (X, II), (Y, III), (Z, I)
C. (X, III), (Y, II), (Z, I)
D. (X, I), (Y, III), (Z, II)

gatecse-2001 co-and-architecture addressing-modes easy match-the-following

Answer key☟

2.1.10 Addressing Modes: GATE CSE 2002 | Question: 1.24

In the absolute addressing mode:

A. the operand is inside the instruction
B. the address of the operand in inside the instruction
C. the register containing the address of the operand is specified inside the instruction
D. the location of the operand is implicit

gatecse-2002 co-and-architecture addressing-modes easy

Answer key☟

2.1.11 Addressing Modes: GATE CSE 2004 | Question: 20

Which of the following addressing modes are suitable for program relocation at run time?

I. Absolute addressing
II. Based addressing
III. Relative addressing
IV. Indirect addressing

A. I and IV
B. I and II
C. II and III
D. I, II and IV

gatecse-2004 co-and-architecture addressing-modes easy

Answer key☟

2.1.12 Addressing Modes: GATE CSE 2005 | Question: 65

Consider a three word machine instruction

$\text{ADD} A[R_0], @B$

The first operand (destination) "$A[R_0]$" uses indexed addressing mode with R_0 as the index register. The second operand (source) "$@B$" uses indirect addressing mode. A and B are memory addresses residing at the second and third words, respectively. The first word of the instruction specifies the opcode, the index register designation and the source and destination addressing modes. During execution of ADD instruction, the two operands are added and stored in the destination (first operand).

The number of memory cycles needed during the execution cycle of the instruction is:

A. 3
B. 4
C. 5
D. 6

gatecse-2005 co-and-architecture addressing-modes normal

Answer key☟

2.1.13 Addressing Modes: GATE CSE 2005 | Question: 66

Match each of the high level language statements given on the left hand side with the most natural addressing mode from those listed on the right hand side.

(1)	$A[I] = B[J]$	(a)	Indirect addressing
(2)	while $(^*A{+}{+});$	(b)	Indexed addressing
(3)	int temp $=^* x$	(c)	Auto increment

A. $(1, c), (2, b), (3, a)$
B. $(1, c), (2, c), (3, b)$
C. $(1, b), (2, c), (3, a)$
D. $(1, a), (2, b), (3, c)$

gatecse-2005 co-and-architecture addressing-modes match-the-following easy

Answer key

2.1.14 Addressing Modes: GATE CSE 2008 | Question: 33, ISRO2009-80

Which of the following is/are true of the auto-increment addressing mode?

I. It is useful in creating self-relocating code
II. If it is included in an Instruction Set Architecture, then an additional ALU is required for effective address calculation
III. The amount of increment depends on the size of the data item accessed

A. I only
B. II only
C. III only
D. II and III only

gatecse-2008 addressing-modes co-and-architecture normal isro2009

Answer key

2.1.15 Addressing Modes: GATE CSE 2011 | Question: 21

Consider a hypothetical processor with an instruction of type LW R1, 20(R2), which during execution reads a 32-bit word from memory and stores it in a 32-bit register R1. The effective address of the memory location is obtained by the addition of a constant 20 and the contents of register R2. Which of the following best reflects the addressing mode implemented by this instruction for the operand in memory?

A. Immediate addressing
B. Register addressing
C. Register Indirect Scaled Addressing
D. Base Indexed Addressing

gatecse-2011 co-and-architecture addressing-modes easy

Answer key

2.1.16 Addressing Modes: GATE CSE 2017 Set 1 | Question: 11

Consider the C struct defined below:

```
struct data {
   int marks [100];
   char grade;
   int cnumber;
};
struct data student;
```

The base address of student is available in register $R1$. The field student.grade can be accessed efficiently using:

A. Post-increment addressing mode, $(R1)+$
B. Pre-decrement addressing mode, $-(R1)$
C. Register direct addressing mode, $R1$
D. Index addressing mode, $X(R1)$, where X is an offset represented in $2's$ complement 16-bit representation

gatecse-2017-set1 co-and-architecture addressing-modes

Answer key

2.1.17 Addressing Modes: GATE IT 2006 | Question: 39, ISRO2009-42

Which of the following statements about relative addressing mode is FALSE?

A. It enables reduced instruction size
B. It allows indexing of array element with same instruction

C. It enables easy relocation of data
D. It enables faster address calculation than absolute addressing

gateit-2006 co-and-architecture addressing-modes normal isro2009

Answer key

2.1.18 Addressing Modes: GATE IT 2006 | Question: 40

The memory locations $1000, 1001$ and 1020 have data values $18, 1$ and 16 respectively before the following program is executed.

$$\begin{array}{lll} \text{MOVI} & R_s, 1 & ;\text{Move immediate} \\ \text{LOAD} & R_d, 1000(R_s) & ;\text{Load from memory} \\ \text{ADDI} & R_d, 1000 & ;\text{Add immediate} \\ \text{STOREI} & 0(R_d), 20 & ;\text{Store immediate} \end{array}$$

Which of the statements below is TRUE after the program is executed ?

A. Memory location 1000 has value 20
B. Memory location 1020 has value 20
C. Memory location 1021 has value 20
D. Memory location 1001 has value 20

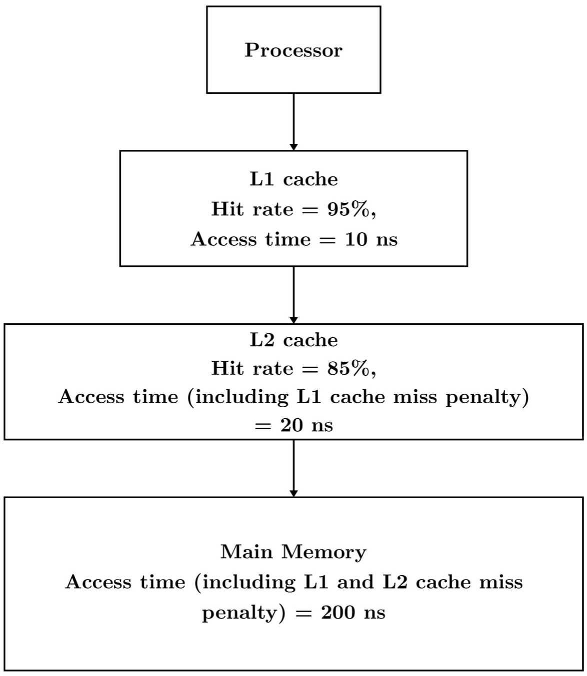
gateit-2006 co-and-architecture addressing-modes normal

Answer key

2.2 Average Memory Access Time (2)

2.2.1 Average Memory Access Time: GATE CSE 2025 | Set 1 | Question: 43

A computer has a memory hierarchy consisting of two-level cache $(\text{L1}$ and $\text{L2})$ and a main memory. If the processor needs to access data from memory, it first looks into L1 cache. If the data is not found in L1 cache, it goes to L2 cache. If it fails to get the data from L2 cache, it goes to main memory, where the data is definitely available. Hit rates and access times of various memory units are shown in the figure. The average memory access time in nanoseconds (ns) is ________. (rounded off to two decimal places)



gatecse2025-set1 co-and-architecture cache-memory multilevel-cache average-memory-access-time numerical-answers two-marks

Answer key

2.2.2 Average Memory Access Time: GATE CSE 2025 | Set 2 | Question: 45

Given a computing system with two levels of cache (L1 and L2) and a main memory. The first level (L1) cache access time is 1 nanosecond (ns) and the "hit rate" for L1 cache is 90% while the processor is accessing the data from L1 cache. Whereas, for the second level (L2) cache, the "hit rate" is 80% and the "miss penalty" for transferring data from L2 cache to L1 cache is 10 ns . The "miss penalty" for the data to be transferred from main memory to L2 cache is 100 ns .

Then the average memory access time in this system in nanoseconds is ___________ . (rounded off to one decimal place)

gatecse2025-set2 co-and-architecture cache-memory average-memory-access-time multilevel-cache numerical-answers two-marks

Answer key

2.3 CISC RISC Architecture (2)

2.3.1 CISC RISC Architecture: GATE CSE 1999 | Question: 2.22

The main difference(s) between a CISC and a RISC processor is/are that a RISC processor typically

A. has fewer instructions
B. has fewer addressing modes
C. has more registers
D. is easier to implement using hard-wired logic

gate1999 co-and-architecture normal cisc-risc-architecture multiple-selects

Answer key

2.3.2 CISC RISC Architecture: GATE CSE 2018 | Question: 5

Consider the following processor design characteristics:

I. Register-to-register arithmetic operations only
II. Fixed-length instruction format
III. Hardwired control unit

Which of the characteristics above are used in the design of a RISC processor?

A. I and II only
B. II and III only
C. I and III only
D. I, II and III

gatecse-2018 co-and-architecture cisc-risc-architecture easy one-mark

Answer key

2.4 Cache Memory (73)

2.4.1 Cache Memory: GATE CSE 1987 | Question: 4b

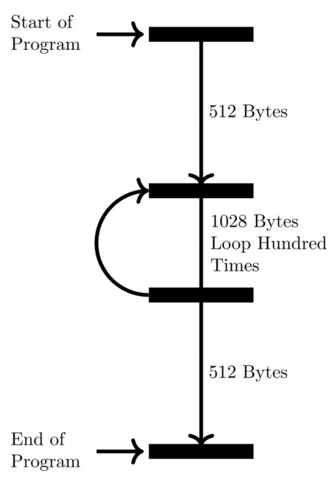
What is cache memory? What is rationale of using cache memory?

gate1987 co-and-architecture cache-memory descriptive

Answer key

2.4.2 Cache Memory: GATE CSE 1989 | Question: 6a

A certain computer system was designed with cache memory of size 1 Kbytes and main memory size of 256 Kbytes. The cache implementation was fully associative cache with 4 bytes per block. The CPU memory data path was 16 bits and the memory was $2-$way interleaved. Each memory read request presents two $16-$bit words. A program with the model shown below was run to evaluate the cache design.



Answer the following questions:

i. What is the hit ratio?
ii. Suggest a change in the program size of model to improve the hit ratio significantly.

gate1989 descriptive co-and-architecture cache-memory

Answer key☟

2.4.3 Cache Memory: GATE CSE 1990 | Question: 4-iv

Transferring data in blocks from the main memory to the cache memory enables an interleaved main memory unit to operate unit at its maximum speed.True/False. Explain.

gate-1990 true-false co-and-architecture cache-memory descriptive

Answer key☟

2.4.4 Cache Memory: GATE CSE 1990 | Question: 7a

A block-set associative cache memory consists of 128 blocks divided into four block sets. The main memory consists of $16,384$ blocks and each block contains 256 eight bit words.

1. How many bits are required for addressing the main memory?
2. How many bits are needed to represent the TAG, SET and WORD fields?

gate1990 descriptive co-and-architecture cache-memory

Answer key☟

2.4.5 Cache Memory: GATE CSE 1992 | Question: 5-a

The access times of the main memory and the Cache memory, in a computer system, are 500 n sec and 50 nsec, respectively. It is estimated that 80% of the main memory request are for read the rest for write. The hit ratio for the read access only is 0.9 and a write-through policy (where both main and cache memories are updated simultaneously) is used. Determine the average time of the main memory (in ns).

gate1992 co-and-architecture cache-memory normal numerical-answers

Answer key☟

2.4.6 Cache Memory: GATE CSE 1993 | Question: 11

In the three-level memory hierarchy shown in the following table, p_i denotes the probability that an access request will refer to M_i.

Hierarchy Level (M_i)	Access Time (t_i)	Probability of Access (p_i)	Page Transfer Time (T_i)
M_1	10^{-6}	0.99000	0.001 sec
M_2	10^{-5}	0.00998	0.1 sec
M_3	10^{-4}	0.00002	---

If a miss occurs at level M_i, a page transfer occurs from M_{i+1} to M_i and the average time required for such a page swap is T_i. Calculate the average time t_A required for a processor to read one word from this memory system.

gate1993 co-and-architecture cache-memory normal descriptive

Answer key ☟

2.4.7 Cache Memory: GATE CSE 1995 | Question: 1.6

The principle of locality justifies the use of:

A. Interrupts
B. DMA
C. Polling
D. Cache Memory

gate1995 co-and-architecture cache-memory easy

Answer key ☟

2.4.8 Cache Memory: GATE CSE 1995 | Question: 2.25

A computer system has a $4\ K$ word cache organized in block-set-associative manner with 4 blocks per set, 64 words per block. The number of bits in the SET and WORD fields of the main memory address format is:

A. $15, 40$
B. $6, 4$
C. $7, 2$
D. $4, 6$

gate1995 co-and-architecture cache-memory normal

Answer key ☟

2.4.9 Cache Memory: GATE CSE 1996 | Question: 26

A computer system has a three-level memory hierarchy, with access time and hit ratios as shown below:

Level 1 (Cache memory)
Access time $= 50 nsec/byte$

Size	Hit ratio
$8M$ bytes	0.80
$16M$ bytes	0.90
$64M$ bytes	0.95

Level 2 (Main memory)
Access time $= 200 nsec/byte$

Size	Hit ratio
$4M$ bytes	0.98
$16M$ bytes	0.99
$64M$ bytes	0.995

Level 3
Access time $= 5\mu$sec/byte

Size	Hit ratio
$260M$ bytes	1.0

A. What should be the minimum sizes of level 1 and 2 memories to achieve an average access time of less than $100 nsec$?
B. What is the average access time achieved using the chosen sizes of level 1 and level 2 memories?

gate1996 co-and-architecture cache-memory normal

Answer key ☟

2.4.10 Cache Memory: GATE CSE 1998 | Question: 18

For a set-associative Cache organization, the parameters are as follows:

t_c	Cache Access Time
t_m	Main memory access time
l	Number of sets
b	Block size
$k \times b$	Set size

Calculate the hit ratio for a loop executed 100 times where the size of the loop is $n \times b$, and $n = k \times m$ is a non-zero integer and $1 \leq m \leq l$.

Give the value of the hit ratio for $l = 1$.

gate1998 co-and-architecture cache-memory descriptive

Answer key

2.4.11 Cache Memory: GATE CSE 1999 | Question: 1.22

The main memory of a computer has 2 cm blocks while the cache has 2 c blocks. If the cache uses the set associative mapping scheme with 2 blocks per set, then block k of the main memory maps to the set:

A. $(k \mod m)$ of the cache
B. $(k \mod c)$ of the cache
C. $(k \mod 2c)$ of the cache
D. $(k \mod 2\ cm)$ of the cache

gate1999 co-and-architecture cache-memory normal

Answer key

2.4.12 Cache Memory: GATE CSE 2001 | Question: 1.7, ISRO2008-18

More than one word are put in one cache block to:

A. exploit the temporal locality of reference in a program
B. exploit the spatial locality of reference in a program
C. reduce the miss penalty
D. none of the above

gatecse-2001 co-and-architecture easy cache-memory isro2008

Answer key

2.4.13 Cache Memory: GATE CSE 2001 | Question: 9

A CPU has $32-bit$ memory address and a $256\ KB$ cache memory. The cache is organized as a $4-way$ set associative cache with cache block size of 16 bytes.

A. What is the number of sets in the cache?
B. What is the size (in bits) of the tag field per cache block?
C. What is the number and size of comparators required for tag matching?
D. How many address bits are required to find the byte offset within a cache block?
E. What is the total amount of extra memory (in bytes) required for the tag bits?

gatecse-2001 co-and-architecture cache-memory normal descriptive

Answer key

2.4.14 Cache Memory: GATE CSE 2002 | Question: 10

In a C program, an array is declared as $\text{float } A[2048]$. Each array element is 4 Bytes in size, and the starting address of the array is $0x00000000$. This program is run on a computer that has a direct mapped data cache of size 8 Kbytes, with block (line) size of 16 Bytes.

A. Which elements of the array conflict with element $A[0]$ in the data cache? Justify your answer briefly.
B. If the program accesses the elements of this array one by one in reverse order i.e., starting with the last element and ending with the first element, how many data cache misses would occur? Justify your answer briefly. Assume that the data cache is initially empty and that no other data or instruction accesses are to be considered.

gatecse-2002 co-and-architecture cache-memory normal descriptive

Answer key

2.4.15 Cache Memory: GATE CSE 2004 | Question: 65

Consider a small two-way set-associative cache memory, consisting of four blocks. For choosing the block to be replaced, use the least recently used (LRU) scheme. The number of cache misses for the following sequence of block addresses is:

$8, 12, 0, 12, 8.$

A. 2
B. 3
C. 4
D. 5

gatecse-2004 co-and-architecture cache-memory normal

Answer key

2.4.16 Cache Memory: GATE CSE 2005 | Question: 67

Consider a direct mapped cache of size $32\ KB$ with block size $32\ bytes$. The CPU generates $32\ bit$ addresses. The number of bits needed for cache indexing and the number of tag bits are respectively,

A. $10, 17$
B. $10, 22$
C. $15, 17$
D. $5, 17$

gatecse-2005 co-and-architecture cache-memory easy

Answer key

2.4.17 Cache Memory: GATE CSE 2006 | Question: 74

Consider two cache organizations. First one is 32 KB 2-way set associative with 32 byte block size, the second is of same size but direct mapped. The size of an address is 32 bits in both cases . A 2-to-1 multiplexer has latency of 0.6 ns while a k-bit comparator has latency of $\frac{k}{10}$ns. The hit latency of the set associative organization is h_1 while that of direct mapped is h_2.

The value of h_1 is:

A. 2.4 ns
B. 2.3 ns
C. 1.8 ns
D. 1.7 ns

gatecse-2006 co-and-architecture cache-memory normal

Answer key

2.4.18 Cache Memory: GATE CSE 2006 | Question: 75

Consider two cache organizations. First one is $32\ kB$ 2-way set associative with $32\ byte$ block size, the second is of same size but direct mapped. The size of an address is $32\ bits$ in both cases . A 2-to-1 multiplexer has latency of $0.6 ns$ while a $k-$bit comparator has latency of $\frac{k}{10} ns$. The hit latency of the set associative organization is h_1 while that of direct mapped is h_2.
The value of h_2 is:

A. $2.4\ ns$
B. $2.3\ ns$
C. $1.8\ ns$
D. $1.7\ ns$

gatecse-2006 co-and-architecture cache-memory normal

Answer key

2.4.19 Cache Memory: GATE CSE 2006 | Question: 80

A CPU has a $32 KB$ direct mapped cache with 128 byte-block size. Suppose A is two dimensional array of size 512×512 with elements that occupy 8-bytes each. Consider the following two C code segments, $P1$ and $P2$.

P1:

```
for (i=0; i<512; i++)
{
   for (j=0; j<512; j++)
   {
      x +=A[i] [j];
   }
```

```
}
```

P2:

```
for (i=0; i<512; i++)
{
   for (j=0; j<512; j++)
   {
      x +=A[j] [i];
   }
}
```

$P1$ and $P2$ are executed independently with the same initial state, namely, the array A is not in the cache and i, j, x are in registers. Let the number of cache misses experienced by $P1$ be M_1 and that for $P2$ be M_2.

The value of M_1 is:

A. 0 B. 2048 C. 16384 D. 262144

gatecse-2006 co-and-architecture cache-memory normal

Answer key

2.4.20 Cache Memory: GATE CSE 2006 | Question: 81

A **CPU** has a $32\ KB$ direct mapped cache with 128 byte-block size. Suppose A is two dimensional array of size 512×512 with elements that occupy $8-bytes$ each. Consider the following two C code segments, $P1$ and $P2$.

$P1$:

```
for (i=0; i<512; i++)
{
   for (j=0; j<512; j++)
   {
      x +=A[i] [j];
   }
}
```

P2:

```
for (i=0; i<512; i++)
{
   for (j=0; j<512; j++)
   {
      x +=A[j] [i];
   }
}
```

$P1$ and $P2$ are executed independently with the same initial state, namely, the array A is not in the cache and i, j, x are in registers. Let the number of cache misses experienced by $P1$ be $M1$ and that for $P2$ be $M2$.

The value of the ratio $\frac{M_1}{M_2}$:

A. 0 B. $\frac{1}{16}$ C. $\frac{1}{8}$ D. 16

co-and-architecture cache-memory normal gatecse-2006

Answer key

2.4.21 Cache Memory: GATE CSE 2007 | Question: 10

Consider a 4-way set associative cache consisting of 128 lines with a line size of 64 words. The **CPU** generates a $20-bit$ address of a word in main memory. The number of bits in the TAG, LINE and WORD fields are respectively:

A. $9,6,5$ B. $7,7,6$ C. $7,5,8$ D. $9,5,6$

gatecse-2007 co-and-architecture cache-memory normal

Answer key

2.4.22 Cache Memory: GATE CSE 2007 | Question: 80

Consider a machine with a byte addressable main memory of 2^{16} bytes. Assume that a direct mapped data cache consisting of 32 lines of 64 bytes each is used in the system. A 50×50 two-dimensional array of bytes is stored in the main memory starting from memory location $1100H$. Assume that the data cache is initially empty. The complete array is accessed twice. Assume that the contents of the data cache do not change in between the two accesses.

How many data misses will occur in total?

A. 48 B. 50 C. 56 D. 59

gatecse-2007 co-and-architecture cache-memory normal

Answer key

2.4.23 Cache Memory: GATE CSE 2007 | Question: 81

Consider a machine with a byte addressable main memory of 2^{16} bytes. Assume that a direct mapped data cache consisting of 32 lines of 64 bytes each is used in the system. A 50 x 50 two-dimensional array of bytes is stored in the main memory starting from memory location $1100H$. Assume that the data cache is initially empty. The complete array is accessed twice. Assume that the contents of the data cache do not change in between the two accesses.

Which of the following lines of the data cache will be replaced by new blocks in accessing the array for the second time?

A. line 4 to line 11
B. line 4 to line 12
C. line 0 to line 7
D. line 0 to line 8

gatecse-2007 co-and-architecture cache-memory normal

Answer key

2.4.24 Cache Memory: GATE CSE 2008 | Question: 35

For inclusion to hold between two cache levels L_1 and L_2 in a multi-level cache hierarchy, which of the following are necessary?

I. L_1 must be write-through cache
II. L_2 must be a write-through cache
III. The associativity of L_2 must be greater than that of L_1
IV. The L_2 cache must be at least as large as the L_1 cache

A. IV only B. I and IV only C. I, II and IV only D. I, II, III and IV

gatecse-2008 co-and-architecture cache-memory normal

Answer key

2.4.25 Cache Memory: GATE CSE 2008 | Question: 71

Consider a machine with a 2-way set associative data cache of size 64Kbytes and block size 16bytes. The cache is managed using 32 bit virtual addresses and the page size is 4Kbytes. A program to be run on this machine begins as follows:

```
double ARR[1024][1024];
int i, j;
/*Initialize array ARR to 0.0 */
for(i = 0; i < 1024; i++)
   for(j = 0; j < 1024; j++)
      ARR[i][j] = 0.0;
```

The size of double is 8Bytes. Array ARR is located in memory starting at the beginning of virtual page 0xFF000 and stored in row major order. The cache is initially empty and no pre-fetching is done. The only data memory references made by the program are those to array ARR.

The total size of the tags in the cache directory is:

A. 32Kbits B. 34Kbits C. 64Kbits D. 68Kbits

gatecse-2008 co-and-architecture cache-memory normal

Answer key

2.4.26 Cache Memory: GATE CSE 2008 | Question: 72

Consider a machine with a 2-way set associative data cache of size 64 Kbytes and block size 16 bytes. The cache is managed using 32 bit virtual addresses and the page size is 4 Kbytes. A program to be run on this machine begins as follows:

```
double ARR[1024][1024];
int i, j;
/*Initialize array ARR to 0.0 */
for(i = 0; i < 1024; i++)
   for(j = 0; j < 1024; j++)
      ARR[i][j] = 0.0;
```

The size of double is 8 bytes. Array ARR is located in memory starting at the beginning of virtual page 0xFF000 and stored in row major order. The cache is initially empty and no pre-fetching is done. The only data memory references made by the program are those to array ARR.

Which of the following array elements have the same cache index as $\text{ARR}[0][0]$?

A. $\text{ARR}[0][4]$ B. $\text{ARR}[4][0]$ C. $\text{ARR}[0][5]$ D. $\text{ARR}[5][0]$

gatecse-2008 co-and-architecture cache-memory normal

Answer key

2.4.27 Cache Memory: GATE CSE 2008 | Question: 73

Consider a machine with a 2-way set associative data cache of size 64 Kbytes and block size 16 bytes. The cache is managed using 32 bit virtual addresses and the page size is 4 Kbytes. A program to be run on this machine begins as follows:

```
double ARR[1024][1024];
int i, j;
/*Initialize array ARR to 0.0 */
for(i = 0; i < 1024; i++)
   for(j = 0; j < 1024; j++)
      ARR[i][j] = 0.0;
```

The size of double is 8 bytes. Array ARR is located in memory starting at the beginning of virtual page 0xFF000 and stored in row major order. The cache is initially empty and no pre-fetching is done. The only data memory references made by the program are those to array ARR.

The cache hit ratio for this initialization loop is:

A. 0% B. 25% C. 50% D. 75%

gatecse-2008 co-and-architecture cache-memory normal

Answer key

2.4.28 Cache Memory: GATE CSE 2009 | Question: 29

Consider a 4-way set associative cache (initially empty) with total 16 cache blocks. The main memory consists of 256 blocks and the request for memory blocks are in the following order:

$0, 255, 1, 4, 3, 8, 133, 159, 216, 129, 63, 8, 48, 32, 73, 92, 155.$

Which one of the following memory block will NOT be in cache if LRU replacement policy is used?

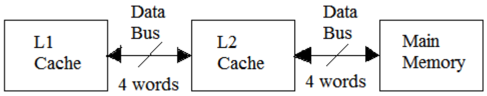
A. 3 B. 8 C. 129 D. 216

gatecse-2009 co-and-architecture cache-memory normal

Answer key

2.4.29 Cache Memory: GATE CSE 2010 | Question: 48

A computer system has an $L1$ cache, an $L2$ cache, and a main memory unit connected as shown below. The block size in $L1$ cache is 4 words. The block size in $L2$ cache is 16 words. The memory access times are 2 nanoseconds, 20 nanoseconds and 200 nanoseconds for $L1$ cache, $L2$ cache and the main memory unit respectively.



When there is a miss in $L1$ cache and a hit in $L2$ cache, a block is transferred from $L2$ cache to $L1$ cache. What is the time taken for this transfer?

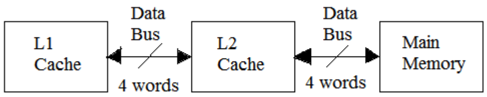
A. 2 nanoseconds
B. 20 nanoseconds
C. 22 nanoseconds
D. 88 nanoseconds

gatecse-2010 co-and-architecture cache-memory normal barc2017

Answer key

2.4.30 Cache Memory: GATE CSE 2010 | Question: 49

A computer system has an $L1$ cache, an $L2$ cache, and a main memory unit connected as shown below. The block size in $L1$ cache is 4 words. The block size in $L2$ cache is 16 words. The memory access times are 2 nanoseconds, 20 nanoseconds and 200 nanoseconds for $L1$ cache, $L2$ cache and the main memory unit respectively.



When there is a miss in both $L1$ cache and $L2$ cache, first a block is transferred from main memory to $L2$ cache, and then a block is transferred from $L2$ cache to $L1$ cache. What is the total time taken for these transfers?

A. 222 nanoseconds
B. 888 nanoseconds
C. 902 nanoseconds
D. 968 nanoseconds

gatecse-2010 co-and-architecture cache-memory normal

Answer key

2.4.31 Cache Memory: GATE CSE 2011 | Question: 43

A n 8KB direct-mapped write-back cache is organized as multiple blocks, each size of 32-bytes. The processor generates 32-bit addresses. The cache controller contains the tag information for each cache block comprising of the following.

- 1 valid bit
- 1 modified bit
- As many bits as the minimum needed to identify the memory block mapped in the cache.

What is the total size of memory needed at the cache controller to store meta-data (tags) for the cache?

A. 4864 bits
B. 6144 bits
C. 6656 bits
D. 5376 bits

gatecse-2011 co-and-architecture cache-memory normal

Answer key

2.4.32 Cache Memory: GATE CSE 2012 | Question: 54

A computer has a 256-KByte, 4-way set associative, write back data cache with block size of 32-Bytes. The processor sends 32-bit addresses to the cache controller. Each cache tag directory entry contains, in addition to address tag, 2 valid bits, 1 modified bit and 1 replacement bit.

The number of bits in the tag field of an address is

A. 11 B. 14 C. 16 D. 27

gatecse-2012 co-and-architecture cache-memory normal

Answer key

2.4.33 Cache Memory: GATE CSE 2012 | Question: 55

A computer has a 256-KByte, 4-way set associative, write back data cache with block size of 32 Bytes. The processor sends 32 bit addresses to the cache controller. Each cache tag directory entry contains, in addition to address tag, 2 valid bits, 1 modified bit and 1 replacement bit.

The size of the cache tag directory is:

A. 160 Kbits B. 136 Kbits C. 40 Kbits D. 32 Kbits

normal gatecse-2012 co-and-architecture cache-memory

Answer key

2.4.34 Cache Memory: GATE CSE 2013 | Question: 20

In a k-way set associative cache, the cache is divided into v sets, each of which consists of k lines. The lines of a set are placed in sequence one after another. The lines in set s are sequenced before the lines in set $(s+1)$. The main memory blocks are numbered 0 onwards. The main memory block numbered j must be mapped to any one of the cache lines from

A. $(j \bmod v) * k \text{ to } (j \bmod v) * k + (k-1)$
B. $(j \bmod v) \text{ to } (j \bmod v) + (k-1)$
C. $(j \bmod k) \text{ to } (j \bmod k) + (v-1)$
D. $(j \bmod k) * v \text{ to } (j \bmod k) * v + (v-1)$

gatecse-2013 co-and-architecture cache-memory normal

Answer key

2.4.35 Cache Memory: GATE CSE 2014 Set 1 | Question: 44

An access sequence of cache block addresses is of length N and contains n unique block addresses. The number of unique block addresses between two consecutive accesses to the same block address is bounded above by k. What is the miss ratio if the access sequence is passed through a cache of associativity $A \geq k$ exercising least-recently-used replacement policy?

A. $\left(\frac{n}{N}\right)$ B. $\left(\frac{1}{N}\right)$ C. $\left(\frac{1}{A}\right)$ D. $\left(\frac{k}{n}\right)$

gatecse-2014-set1 co-and-architecture cache-memory normal

Answer key

2.4.36 Cache Memory: GATE CSE 2014 Set 2 | Question: 43

In designing a computer's cache system, the cache block (or cache line) size is an important parameter. Which one of the following statements is correct in this context?

A. A smaller block size implies better spatial locality
B. A smaller block size implies a smaller cache tag and hence lower cache tag overhead
C. A smaller block size implies a larger cache tag and hence lower cache hit time
D. A smaller block size incurs a lower cache miss penalty

gatecse-2014-set2 co-and-architecture cache-memory normal

Answer key

2.4.37 Cache Memory: GATE CSE 2014 Set 2 | Question: 44

If the associativity of a processor cache is doubled while keeping the capacity and block size unchanged, which one of the following is guaranteed to be NOT affected?

A. Width of tag comparator
B. Width of set index decoder
C. Width of way selection multiplexer
D. Width of processor to main memory data bus

gatecse-2014-set2 co-and-architecture cache-memory normal

Answer key

2.4.38 Cache Memory: GATE CSE 2014 Set 2 | Question: 9

A 4-way set-associative cache memory unit with a capacity of 16 KB is built using a block size of 8 words. The word length is 32 bits. The size of the physical address space is 4 GB. The number of bits for the TAG field is ____

gatecse-2014-set2 co-and-architecture cache-memory numerical-answers normal

Answer key

2.4.39 Cache Memory: GATE CSE 2014 Set 3 | Question: 44

The memory access time is 1 nanosecond for a read operation with a hit in cache, 5 nanoseconds for a read operation with a miss in cache, 2 nanoseconds for a write operation with a hit in cache and 10 nanoseconds for a write operation with a miss in cache. Execution of a sequence of instructions involves 100 instruction fetch operations, 60 memory operand read operations and 40 memory operand write operations. The cache hit-ratio is 0.9. The average memory access time (in nanoseconds) in executing the sequence of instructions is ______.

gatecse-2014-set3 co-and-architecture cache-memory numerical-answers normal

Answer key

2.4.40 Cache Memory: GATE CSE 2015 Set 2 | Question: 24

Assume that for a certain processor, a read request takes 50 nanoseconds on a cache miss and 5 nanoseconds on a cache hit. Suppose while running a program, it was observed that 80% of the processor's read requests result in a cache hit. The average read access time in nanoseconds is ______.

gatecse-2015-set2 co-and-architecture cache-memory easy numerical-answers

Answer key

2.4.41 Cache Memory: GATE CSE 2015 Set 3 | Question: 14

Consider a machine with a byte addressable main memory of 2^{20} bytes, block size of 16 bytes and a direct mapped cache having 2^{12} cache lines. Let the addresses of two consecutive bytes in main memory be $(\text{E201F})_{16}$ and $(\text{E2020})_{16}$. What are the tag and cache line addresses (in hex) for main memory address $(\text{E201F})_{16}$?

A. E, 201
B. F, 201
C. E, E20
D. 2, 01F

gatecse-2015-set3 co-and-architecture cache-memory normal

Answer key

2.4.42 Cache Memory: GATE CSE 2016 Set 2 | Question: 32

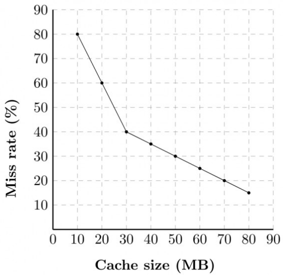
The width of the physical address on a machine is 40 bits. The width of the tag field in a 512 KB 8-way set associative cache is ________ bits.

gatecse-2016-set2 co-and-architecture cache-memory normal numerical-answers

Answer key

2.4.43 Cache Memory: GATE CSE 2016 Set 2 | Question: 50

A file system uses an in-memory cache to cache disk blocks. The miss rate of the cache is shown in the figure. The latency to read a block from the cache is 1 ms and to read a block from the disk is 10 ms. Assume that the cost of checking whether a block exists in the cache is negligible. Available cache sizes are in multiples of 10 MB.



The smallest cache size required to ensure an average read latency of less than 6 ms is _________ MB.

gatecse-2016-set2 co-and-architecture cache-memory normal numerical-answers

Answer key

2.4.44 Cache Memory: GATE CSE 2017 Set 1 | Question: 25

Consider a two-level cache hierarchy with $L1$ and $L2$ caches. An application incurs 1.4 memory accesses per instruction on average. For this application, the miss rate of $L1$ cache is 0.1; the $L2$ cache experiences, on average, 7 misses per 1000 instructions. The miss rate of $L2$ expressed correct to two decimal places is ________.

gatecse-2017-set1 co-and-architecture cache-memory numerical-answers

Answer key

2.4.45 Cache Memory: GATE CSE 2017 Set 1 | Question: 51

Consider a 2-way set associative cache with 256 blocks and uses LRU replacement. Initially the cache is empty. Conflict misses are those misses which occur due to the contention of multiple blocks for the same cache set. Compulsory misses occur due to first time access to the block. The following sequence of access to memory blocks :

$$\{0, 128, 256, 128, 0, 128, 256, 128, 1, 129, 257, 129, 1, 129, 257, 129\}$$

is repeated 10 times. The number of *conflict misses* experienced by the cache is _________ .

gatecse-2017-set1 co-and-architecture cache-memory conflict-misses normal numerical-answers

Answer key

2.4.46 Cache Memory: GATE CSE 2017 Set 1 | Question: 54

A cache memory unit with capacity of N words and block size of B words is to be designed. If it is designed as a direct mapped cache, the length of the TAG field is 10 bits. If the cache unit is now designed as a 16-way set-associative cache, the length of the TAG field is ____________ bits.

gatecse-2017-set1 co-and-architecture cache-memory normal numerical-answers

Answer key

2.4.47 Cache Memory: GATE CSE 2017 Set 2 | Question: 29

In a two-level cache system, the access times of L_1 and L_2 caches are 1 and 8 clock cycles, respectively. The miss penalty from the L_2 cache to main memory is 18 clock cycles. The miss rate of L_1 cache is twice that of L_2. The average memory access time (AMAT) of this cache system is 2 cycles. The miss rates of L_1 and L_2 respectively are

A. 0.111 and 0.056
B. 0.056 and 0.111
C. 0.0892 and 0.1784
D. 0.1784 and 0.0892

gatecse-2017-set2 cache-memory co-and-architecture normal

Answer key

2.4.48 Cache Memory: GATE CSE 2017 Set 2 | Question: 45

The read access times and the hit ratios for different caches in a memory hierarchy are as given below:

Cache	Read access time (in nanoseconds)	Hit ratio
I-cache	2	0.8
D-cache	2	0.9
L2-cache	8	0.9

The read access time of main memory in 90 nanoseconds. Assume that the caches use the referred-word-first read policy and the write-back policy. Assume that all the caches are direct mapped caches. Assume that the dirty bit is always 0 for all the blocks in the caches. In execution of a program, 60% of memory reads are for instruction fetch and 40% are for memory operand fetch. The average read access time in nanoseconds (up to 2 decimal places) is _________

gatecse-2017-set2 co-and-architecture cache-memory numerical-answers

Answer key☟

2.4.49 Cache Memory: GATE CSE 2017 Set 2 | Question: 53

Consider a machine with a byte addressable main memory of 2^{32} bytes divided into blocks of size 32 bytes. Assume that a direct mapped cache having 512 cache lines is used with this machine. The size of the tag field in bits is _______

gatecse-2017-set2 co-and-architecture cache-memory numerical-answers

Answer key☟

2.4.50 Cache Memory: GATE CSE 2018 | Question: 34

The size of the physical address space of a processor is 2^P bytes. The word length is 2^W bytes. The capacity of cache memory is 2^N bytes. The size of each cache block is 2^M words. For a K-way set-associative cache memory, the length (in number of bits) of the tag field is

A. $P - N - \log_2 K$
B. $P - N + \log_2 K$
C. $P - N - M - W - \log_2 K$
D. $P - N - M - W + \log_2 K$

gatecse-2018 co-and-architecture cache-memory normal two-marks

Answer key☟

2.4.51 Cache Memory: GATE CSE 2019 | Question: 1

A certain processor uses a fully associative cache of size 16 kB, The cache block size is 16 bytes. Assume that the main memory is byte addressable and uses a 32-bit address. How many bits are required for the *Tag* and the *Index* fields respectively in the addresses generated by the processor?

A. 24 bits and 0 bits
B. 28 bits and 4 bits
C. 24 bits and 4 bits
D. 28 bits and 0 bits

gatecse-2019 co-and-architecture cache-memory normal one-mark

Answer key☟

2.4.52 Cache Memory: GATE CSE 2019 | Question: 45

A certain processor deploys a single-level cache. The cache block size is 8 words and the word size is 4 bytes. The memory system uses a 60-MHz clock. To service a cache miss, the memory controller first takes 1 cycle to accept the starting address of the block, it then takes 3 cycles to fetch all the eight words of the block, and finally transmits the words of the requested block at the rate of 1 word per cycle. The maximum bandwidth for the memory system when the program running on the processor issues a series of read operations is _______ $\times 10^6$ bytes/sec.

gatecse-2019 numerical-answers co-and-architecture cache-memory two-marks

Answer key☟

2.4.53 Cache Memory: GATE CSE 2020 | Question: 21

A direct mapped cache memory of 1 MB has a block size of 256 bytes. The cache has an access time of 3 ns and a hit rate of 94%. During a cache miss, it takes 20 ns to bring the first word of a block from the main memory, while each subsequent word takes 5 ns. The word size is 64 bits. The average memory access time in ns (round off to 1 decimal place) is______.

gatecse-2020 numerical-answers co-and-architecture cache-memory one-mark

Answer key

2.4.54 Cache Memory: GATE CSE 2020 | Question: 30

A computer system with a word length of 32 bits has a 16 MB byte- addressable main memory and a 64 KB, 4-way set associative cache memory with a block size of 256 bytes. Consider the following four physical addresses represented in hexadecimal notation.

- $A1 =$ 0x42C8A4,
- $A2 =$ 0x546888,
- $A3 =$ 0x6A289C,
- $A4 =$ 0x5E4880

Which one of the following is TRUE?

A. $A1$ and $A4$ are mapped to different cache sets.
B. $A2$ and $A3$ are mapped to the same cache set.
C. $A3$ and $A4$ are mapped to the same cache set.
D. $A1$ and $A3$ are mapped to the same cache set.

gatecse-2020 co-and-architecture cache-memory two-marks

Answer key

2.4.55 Cache Memory: GATE CSE 2021 Set 1 | Question: 22

Consider a computer system with a byte-addressable primary memory of size 2^{32} bytes. Assume the computer system has a direct-mapped cache of size 32 KB (1 KB = 2^{10} bytes), and each cache block is of size 64 bytes.

The size of the tag field is __________ bits.

gatecse-2021-set1 co-and-architecture cache-memory numerical-answers one-mark

Answer key

2.4.56 Cache Memory: GATE CSE 2021 Set 2 | Question: 19

Consider a set-associative cache of size 2KB $(1\text{KB} = 2^{10}$ bytes$)$ with cache block size of 64 bytes. Assume that the cache is byte-addressable and a 32 -bit address is used for accessing the cache. If the width of the tag field is 22 bits, the associativity of the cache is _________

gatecse-2021-set2 numerical-answers co-and-architecture cache-memory one-mark

Answer key

2.4.57 Cache Memory: GATE CSE 2021 Set 2 | Question: 27

Assume a two-level inclusive cache hierarchy, $L1$ and $L2$, where $L2$ is the larger of the two. Consider the following statements.

- S_1: Read misses in a write through $L1$ cache do not result in writebacks of dirty lines to the $L2$
- S_2: Write allocate policy *must* be used in conjunction with write through caches and no-write allocate policy is used with writeback caches.

Which of the following statements is correct?

A. S_1 is true and S_2 is false
B. S_1 is false and S_2 is true
C. S_1 is true and S_2 is true
D. S_1 is false and S_2 is false

gatecse-2021-set2 co-and-architecture cache-memory two-marks

Answer key

2.4.58 Cache Memory: GATE CSE 2022 | Question: 14

Let WB and WT be two set associative cache organizations that use LRU algorithm for cache block replacement. WB is a write back cache and WT is a write through cache. Which of the following statements is/are FALSE?

A. Each cache block in WB and WT has a dirty bit.
B. Every write hit in WB leads to a data transfer from cache to main memory.
C. Eviction of a block from WT will not lead to data transfer from cache to main memory.
D. A read miss in WB will never lead to eviction of a dirty block from WB.

gatecse-2022 co-and-architecture cache-memory multiple-selects one-mark

Answer key

2.4.59 Cache Memory: GATE CSE 2022 | Question: 23

A cache memory that has a hit rate of 0.8 has an access latency $10\ \mathrm{ns}$ and miss penalty $100\ \mathrm{ns}.$ An optimization is done on the cache to reduce the miss rate. However, the optimization results in an increase of cache access latency to $15\ \mathrm{ns},$ whereas the miss penalty is not affected. The minimum hit rate *(rounded off to two decimal places)* needed after the optimization such that it should not increase the average memory access time is _______________.

gatecse-2022 numerical-answers co-and-architecture cache-memory one-mark

Answer key

2.4.60 Cache Memory: GATE CSE 2022 | Question: 44

Consider a system with $2\ \mathrm{KB}$ direct mapped data cache with a block size of $64\ \mathrm{bytes}.$ The system has a physical address space of $64\ \mathrm{KB}$ and a word length of $16\ \mathrm{bits}.$ During the execution of a program, four data words $\mathrm{P, Q, R,}$ and S are accessed in that order 10 times $(\mathrm{i.e., PQRSPQRS}\ldots).$ Hence, there are 40 accesses to data cache altogether. Assume that the data cache is initially empty and no other data words are accessed by the program. The addresses of the first bytes of $\mathrm{P, Q, R,}$ and S are $0\mathrm{xA}248, 0\mathrm{xC}28\mathrm{A}, 0\mathrm{xCA}8\mathrm{A},$ and $0\mathrm{xA}262,$ respectively. For the execution of the above program, which of the following statements is/are TRUE with respect to the data cache?

A. Every access to S is a hit.
B. Once P is brought to the cache it is never evicted.
C. At the end of the execution only R and S reside in the cache.
D. Every access to R evicts Q from the cache.

gatecse-2022 co-and-architecture direct-mapping multiple-selects two-marks cache-memory

Answer key

2.4.61 Cache Memory: GATE CSE 2023 | Question: 54

An 8-way set associative cache of size $64\ \mathrm{KB}\ (1\ \mathrm{KB} = 1024\ \mathrm{bytes})$ is used in a system with 32-bit address. The address is sub-divided into $\mathrm{TAG, INDEX,}$ and $\mathrm{BLOCK\ OFFSET}.$

The number of bits in the TAG is ___________.

gatecse-2023 co-and-architecture cache-memory numerical-answers two-marks

Answer key

2.4.62 Cache Memory: GATE CSE 2024 | Set 1 | Question: 43

Consider two set-associative cache memory architectures: WBC, which uses the write back policy, and WTC, which uses the write through policy. Both of them use the LRU *(Least Recently Used)* block replacement policy. The cache memory is connected to the main memory. Which of the following statements is/are TRUE?

A. A read miss in WBC never evicts a dirty block
B. A read miss in WTC never triggers a write back operation of a cache block to main memory
C. A write hit in WBC can modify the value of the dirty bit of a cache block
D. A write miss in WTC always writes the victim cache block to main memory before loading the missed block to the cache

gatecse2024-set1 co-and-architecture cache-memory multiple-selects two-marks

Answer key

2.4.63 Cache Memory: GATE CSE 2024 | Set 1 | Question: 46

A given program has 25% load/store instructions. Suppose the ideal CPI (cycles per instruction) without any memory stalls is 2. The program exhibits 2% miss rate on instruction cache and 8% miss rate on data cache. The miss penalty is 100 cycles. The speedup *(rounded off to two decimal places)* achieved with a perfect cache (i.e., with NO data or instruction cache misses) is __________.

gatecse2024-set1 numerical-answers co-and-architecture cache-memory two-marks

Answer key

2.4.64 Cache Memory: GATE CSE 2025 | Set 1 | Question: 26

Consider a memory system with $1\mathrm{M}$ bytes of main memory and $16\ \mathrm{K}$ bytes of cache memory. Assume that the processor generates 20-bit memory address, and the cache block size is 16 bytes. If the cache uses direct mapping, how many bits will be required to store all the tag values? [Assume memory is byte addressable, $1\ \mathrm{K} = 2^{10}$, $1\mathrm{M} = 2^{20}$.]

A. 6×2^{10}
B. 8×2^{10}
C. 2^{12}
D. 2^{14}

gatecse2025-set1 co-and-architecture cache-memory direct-mapping easy two-marks

Answer key

2.4.65 Cache Memory: GATE CSE 2025 | Set 2 | Question: 29

For a direct-mapped cache, 4 bits are used for the tag field and 12 bits are used to index into a cache block. The size of each cache block is one byte. Assume that there is no other information stored for each cache block.

Which ONE of the following is the CORRECT option for the sizes of the main memory and the cache memory in this system (byte addressable), respectively?

A. 64 KB and 4 KB
B. 128 KB and 16 KB
C. 64 KB and 8 KB
D. 128 KB and 6 KB

gatecse2025-set2 co-and-architecture direct-mapping cache-memory two-marks

Answer key

2.4.66 Cache Memory: GATE IT 2004 | Question: 12, ISRO2016-77

Consider a system with 2 level cache. Access times of Level 1 cache, Level 2 cache and main memory are $1\ ns$, $10\ ns$, and $500\ ns$ respectively. The hit rates of Level 1 and Level 2 caches are 0.8 and 0.9, respectively. What is the average access time of the system ignoring the search time within the cache?

A. 13.0
B. 12.8
C. 12.6
D. 12.4

gateit-2004 co-and-architecture cache-memory normal isro2016

Answer key

2.4.67 Cache Memory: GATE IT 2004 | Question: 48

Consider a fully associative cache with 8 cache blocks (numbered $0-7$) and the following sequence of memory block requests:

$4, 3, 25, 8, 19, 6, 25, 8, 16, 35, 45, 22, 8, 3, 16, 25, 7$

If LRU replacement policy is used, which cache block will have memory block 7?

A. 4 B. 5 C. 6 D. 7

gateit-2004 co-and-architecture cache-memory normal

Answer key

2.4.68 Cache Memory: GATE IT 2005 | Question: 61

Consider a 2-way set associative cache memory with 4 sets and total 8 cache blocks $(0-7)$ and a main memory with 128 blocks $(0-127)$. What memory blocks will be present in the cache after the following sequence of memory block references if **LRU** policy is used for cache block replacement. Assuming that initially the cache did not have any memory block from the current job?

$0\ 5\ 3\ 9\ 7\ 0\ 16\ 55$

A. $0\ 3\ 5\ 7\ 16\ 55$
B. $0\ 3\ 5\ 7\ 9\ 16\ 55$
C. $0\ 5\ 7\ 9\ 16\ 55$
D. $3\ 5\ 7\ 9\ 16\ 55$

gateit-2005 co-and-architecture cache-memory normal

Answer key

2.4.69 Cache Memory: GATE IT 2006 | Question: 42

A cache line is 64 bytes. The main memory has latency $32\ ns$ and bandwidth $1\ GBytes/s$. The time required to fetch the entire cache line from the main memory is:

A. $32\,ns$ B. $64\,ns$ C. $96\ ns$ D. $128\,ns$

gateit-2006 co-and-architecture cache-memory normal

Answer key

2.4.70 Cache Memory: GATE IT 2006 | Question: 43

A computer system has a level-1 instruction cache (1-cache), a level-1 data cache (D-cache) and a level-2 cache ($L2$-cache) with the following specifications:

	Capacity	**Mapping Method**	**Block Size**
I-Cache	$4K$ words	Direct mapping	4 words
D-Cache	$4K$ words	2 -way set associative mapping	4 words
$L2$-Cache	$64K$ words	4-way set associative mapping	16 words

The length of the physical address of a word in the main memory is 30 bits. The capacity of the tag memory in the I-cache, D-cache and $L2$-cache is, respectively,

A. 1 K x 18-bit, 1 K x 19-bit, 4 K x 16-bit
B. 1 K x 16-bit, 1 K x 19-bit, 4 K x 18-bit
C. 1 K x 16-bit, 512 x 18-bit, 1 K x 16-bit
D. 1 K x 18-bit, 512 x 18-bit, 1 K x 18-bit

gateit-2006 co-and-architecture cache-memory normal

Answer key

2.4.71 Cache Memory: GATE IT 2007 | Question: 37

Consider a Direct Mapped Cache with 8 cache blocks (numbered $0-7$). If the memory block requests are in the following order

$3, 5, 2, 8, 0, 63, 9, 16, 20, 17, 25, 18, 30, 24, 2, 63, 5, 82, 17, 24.$

Which of the following memory blocks will not be in the cache at the end of the sequence ?

A. 3　　B. 18　　C. 20　　D. 30

gateit-2007　co-and-architecture　cache-memory　normal

Answer key

2.4.72 Cache Memory: GATE IT 2008 | Question: 80

Consider a computer with a 4-ways set-associative mapped cache of the following characteristics: a total of $1\ MB$ of main memory, a word size of 1 byte, a block size of 128 words and a cache size of $8\ KB$.

The number of bits in the TAG, SET and WORD fields, respectively are:

A. $7, 6, 7$　　B. $8, 5, 7$　　C. $8, 6, 6$　　D. $9, 4, 7$

gateit-2008　co-and-architecture　cache-memory　normal

Answer key

2.4.73 Cache Memory: GATE IT 2008 | Question: 81

Consider a computer with a 4-ways set-associative mapped cache of the following characteristics: a total of $1\ \text{MB}$ of main memory, a word size of $1\ \text{byte}$, a block size of 128 words and a cache size of $8\ \text{KB}$.

While accessing the memory location $0\text{C}795\text{H}$ by the **CPU**, the contents of the TAG field of the corresponding cache line is:

A. 000011000　　B. 110001111　　C. 00011000　　D. 110010101

gateit-2008　co-and-architecture　cache-memory　normal

Answer key

2.5 Clock Cycles (1)

2.5.1 Clock Cycles: GATE CSE 2025 | Set 2 | Question: 51

An application executes 6.4×10^8 number of instructions in 6.3 seconds. There are four types of instructions, the details of which are given in the table. The duration of a clock cycle in nanoseconds is __________. (rounded off to one decimal place)

Instruction type	Clock cycles required per instruction (CPI)	Number of instructions executed
Branch	2	2.25×10^8
Load	5	1.20×10^8
Store	4	1.65×10^8
Arithmetic	3	1.30×10^8

gatecse2025-set2　co-and-architecture　instruction-execution　clock-cycles　numerical-answers　two-marks

Answer key

2.6 DMA (9)

2.6.1 DMA: GATE CSE 2004 | Question: 68

A hard disk with a transfer rate of 10 Mbytes/second is constantly transferring data to memory using DMA. The processor runs at 600 MHz, and takes 300 and 900 clock cycles to initiate and complete DMA transfer respectively. If the size of the transfer is 20 Kbytes, what is the percentage of processor time consumed for the transfer operation?

A. 5.0%　　B. 1.0%　　C. 0.5%　　D. 0.1%

gatecse-2004 dma normal co-and-architecture

Answer key

2.6.2 DMA: GATE CSE 2005 | Question: 70

Consider a disk drive with the following specifications:

16 surfaces, 512 tracks/surface, 512 sectors/track, 1 KB/sector, rotation speed 3000 rpm. The disk is operated in cycle stealing mode whereby whenever one 4 byte word is ready it is sent to memory; similarly, for writing, the disk interface reads a 4 byte word from the memory in each DMA cycle. Memory cycle time is 40 nsec. The maximum percentage of time that the CPU gets blocked during DMA operation is:

A. 10
B. 25
C. 40
D. 50

gatecse-2005 co-and-architecture disk normal dma

Answer key

2.6.3 DMA: GATE CSE 2011 | Question: 28

On a non-pipelined sequential processor, a program segment, which is the part of the interrupt service routine, is given to transfer 500 bytes from an I/O device to memory.

```
      Initialize the address register
      Initialize the count to 500
LOOP:   Load a byte from device
      Store in memory at address given by address register
      Increment the address register
      Decrement the count
      If count !=0 go to LOOP
```

Assume that each statement in this program is equivalent to a machine instruction which takes one clock cycle to execute if it is a non-load/store instruction. The load-store instructions take two clock cycles to execute.

The designer of the system also has an alternate approach of using the DMA controller to implement the same transfer. The DMA controller requires 20 clock cycles for initialization and other overheads. Each DMA transfer cycle takes two clock cycles to transfer one byte of data from the device to the memory.

What is the approximate speed up when the DMA controller based design is used in a place of the interrupt driven program based input-output?

A. 3.4
B. 4.4
C. 5.1
D. 6.7

gatecse-2011 co-and-architecture dma normal

Answer key

2.6.4 DMA: GATE CSE 2016 Set 1 | Question: 31

The size of the data count register of a DMA controller is 16 bits. The processor needs to transfer a file of $29,154$ kilobytes from disk to main memory. The memory is byte addressable. The minimum number of times the DMA controller needs to get the control of the system bus from the processor to transfer the file from the disk to main memory is _________.

gatecse-2016-set1 co-and-architecture dma normal numerical-answers

Answer key

2.6.5 DMA: GATE CSE 2021 Set 2 | Question: 20

Consider a computer system with DMA support. The DMA module is transferring one 8-bit character in one CPU cycle from a device to memory through *cycle stealing* at regular intervals. Consider a 2 MHz processor. If 0.5% processor cycles are used for DMA, the data transfer rate of the device is ___________ bits per second.

gatecse-2021-set2 numerical-answers co-and-architecture dma one-mark

Answer key

2.6.6 DMA: GATE CSE 2022 | Question: 7

Which one of the following facilitates transfer of bulk data from hard disk to main memory with the highest throughput?

A. DMA based I/O transfer
B. Interrupt driven I/O transfer
C. Polling based I/O transfer
D. Programmed I/O transfer

gatecse-2022 co-and-architecture dma one-mark

Answer key

2.6.7 DMA: GATE CSE 2024 | Set 1 | Question: 5

Which one of the following statements is FALSE?

A. In the cycle stealing mode of DMA, one word of data is transferred between an I/O device and main memory in a stolen cycle
B. For bulk data transfer, the burst mode of DMA has a higher throughput than the cycle stealing mode
C. Programmed I/O mechanism has a better CPU utilization than the interrupt driven I/O mechanism
D. The CPU can start executing an interrupt service routine faster with vectored interrupts than with non-vectored interrupts

gatecse2024-set1 co-and-architecture dma one-mark

Answer key

2.6.8 DMA: GATE CSE 2024 | Set 2 | Question: 1

Consider a computer with a 4MHz processor. Its DMA controller can transfer 8 bytes in 1 cycle from a device to main memory through cycle stealing at regular intervals. Which one of the following is the data transfer rate *(in bits per second)* of the DMA controller if 1% of the processor cycles are used for DMA?

A. $2,56,000$
B. $3,200$
C. $25,60,000$
D. $32,000$

gatecse2024-set2 co-and-architecture dma one-mark

Answer key

2.6.9 DMA: GATE IT 2004 | Question: 51

The storage area of a disk has the innermost diameter of 10 cm and outermost diameter of 20 cm. The maximum storage density of the disk is 1400 bits/cm. The disk rotates at a speed of 4200 RPM. The main memory of a computer has 64-bit word length and 1μs cycle time. If cycle stealing is used for data transfer from the disk, the percentage of memory cycles stolen for transferring one word is

A. 0.5%
B. 1%
C. 5%
D. 10%

gateit-2004 co-and-architecture dma normal

Answer key

2.7 Data Dependency (2)

2.7.1 Data Dependency: GATE CSE 2015 Set 3 | Question: 47

Consider the following code sequence having five instructions from I_1 to I_5. Each of these instructions has the following format.

OP Ri, Rj, Rk

Where operation OP is performed on contents of registers Rj and Rk and the result is stored in register Ri.

I_1: ADD R1, R2, R3

I_2: MUL R7, R1, R3

I_3: SUB R4, R1, R5

I_4: ADD R3, R2, R4

I_5: MUL R7, R8, R9

Consider the following three statements.

S1: There is an anti-dependence between instructions I_2 and I_5

S2: There is an anti-dependence between instructions I_2 and I_4

S3: Within an instruction pipeline an anti-dependence always creates one or more stalls

Which one of the above statements is/are correct?

A. Only S1 is true
B. Only S2 is true
C. Only S1 and S3 are true
D. Only S2 and S3 are true

gatecse-2015-set3 co-and-architecture pipelining data-dependency normal

Answer key

2.7.2 Data Dependency: GATE IT 2007 | Question: 39

Data forwarding techniques can be used to speed up the operation in presence of data dependencies. Consider the following replacements of LHS with RHS.

i. $R1 \to Loc, Loc \to R2 \quad \equiv R1 \to R2, R1 \to Loc$
ii. $R1 \to Loc, Loc \to R2 \quad \equiv R1 \to R2$
iii. $R1 \to Loc, R2 \to Loc \quad \equiv R1 \to Loc$
iv. $R1 \to Loc, R2 \to Loc \quad \equiv R2 \to Loc$

In which of the following options, will the result of executing the RHS be the same as executing the LHS irrespective of the instructions that follow ?

A. i and iii
B. i and iv
C. ii and iii
D. ii and iv

gateit-2007 data-dependency co-and-architecture

Answer key

2.8 Data Path (7)

2.8.1 Data Path: GATE CSE 1990 | Question: 8a

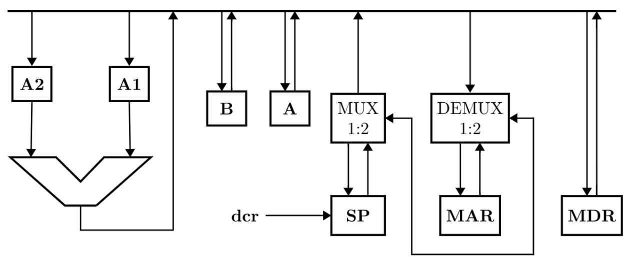
A single bus CPU consists of four general purpose register, namely, $R0, \dots, R3, \text{ALU}, \text{MAR}, \text{MDR}, \text{PC}, \text{SP}$ and IR (Instruction Register). Assuming suitable microinstructions, write a microroutine for the instruction, $\text{ADD } R0, R1$.

gate1990 descriptive co-and-architecture data-path

Answer key

2.8.2 Data Path: GATE CSE 2001 | Question: 2.13

Consider the following data path of a simple non-pipelined CPU. The registers A, B, A_1, A_2, MDR, the **bus** and the ALU are 8-bit wide. SP and MAR are 16-bit registers. The MUX is of size $8 \times (2:1)$ and the DEMUX is of size $8 \times (1:2)$. Each memory operation takes 2 CPU clock cycles and uses MAR (Memory Address Register) and MDR (Memory Date Register). SP can be decremented locally.



The CPU instruction "push r" where, $r = A$ or B has the specification

- $M[SP] \leftarrow r$
- $SP \leftarrow SP - 1$

How many CPU clock cycles are required to execute the "push r" instruction?

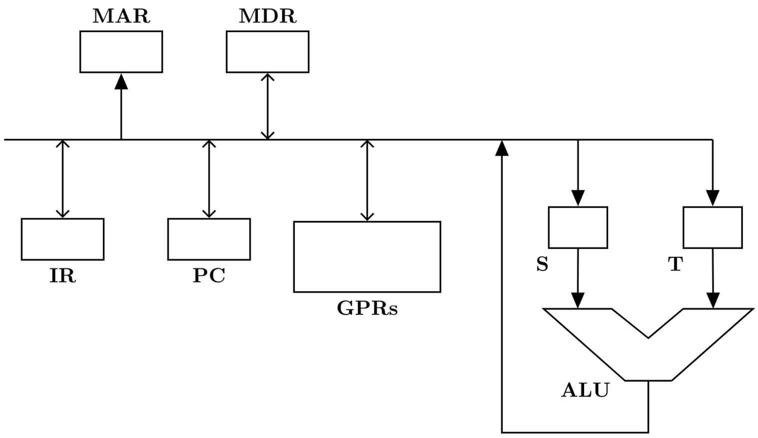
A. 2 B. 3 C. 4 D. 5

gatecse-2001 co-and-architecture data-path machine-instruction normal

Answer key

2.8.3 Data Path: GATE CSE 2005 | Question: 79

Consider the following data path of a CPU.



The ALU, the bus and all the registers in the data path are of identical size. All operations including incrementation of the PC and the GPRs are to be carried out in the ALU. Two clock cycles are needed for memory read operation – the first one for loading address in the MAR and the next one for loading data from the memory bus into the MDR.

The instruction "add R0, R1" has the register transfer interpretation $R0 \Leftarrow R0 + R1$. The minimum number of clock cycles needed for execution cycle of this instruction is:

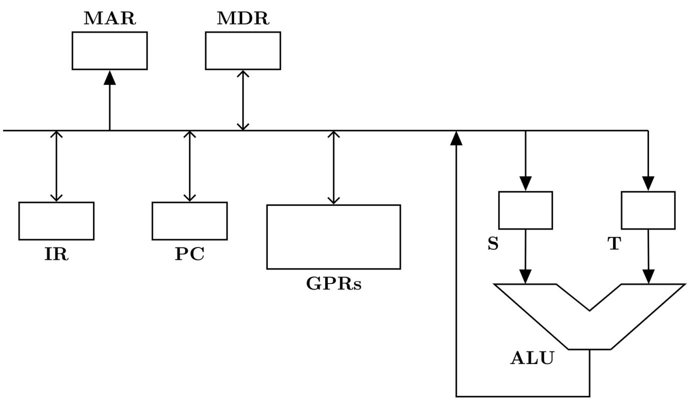
A. 2 B. 3 C. 4 D. 5

gatecse-2005 co-and-architecture machine-instruction data-path normal

Answer key

2.8.4 Data Path: GATE CSE 2005 | Question: 80

Consider the following data path of a CPU.



The ALU, the bus and all the registers in the data path are of identical size. All operations including incrementation of the PC and the GPRs are to be carried out in the ALU. Two clock cycles are needed for memory read operation – the first one for loading address in the MAR and the next one for loading data from the memory bus into the MDR.

The instruction "call Rn, sub" is a two word instruction. Assuming that PC is incremented during the fetch cycle of the first word of the instruction, its register transfer interpretation is

$Rn \leftarrow PC + 1;$

$PC \leftarrow M[PC];$

The minimum number of **CPU** clock cycles needed during the execution cycle of this instruction is:

A. 2 B. 3 C. 4 D. 5

co-and-architecture normal gatecse-2005 data-path machine-instruction

Answer key

2.8.5 Data Path: GATE CSE 2016 Set 2 | Question: 30

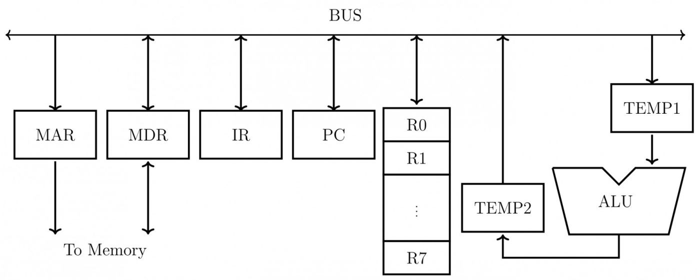
Suppose the functions F and G can be computed in 5 and 3 nanoseconds by functional units U_F and U_G, respectively. Given two instances of U_F and two instances of U_G, it is required to implement the computation $F(G(X_i))$ for $1 \leq i \leq 10$. Ignoring all other delays, the minimum time required to complete this computation is ____________ nanoseconds.

gatecse-2016-set2 co-and-architecture data-path normal numerical-answers

Answer key

2.8.6 Data Path: GATE CSE 2020 | Question: 4

Consider the following data path diagram.



Consider an instruction: $R0 \leftarrow R1 + R2$. The following steps are used to execute it over the given data path. Assume that PC is incremented appropriately. The subscripts r and w indicate read and write operations, respectively.

1. $R2_r$, TEMP1_r, ALU_{add}, TEMP2_w
2. $R1_r$, TEMP1_w
3. PC_r, MAR_w, MEM_r
4. TEMP2_r, R0_w
5. MDR_r, IR_w

Which one of the following is the correct order of execution of the above steps?

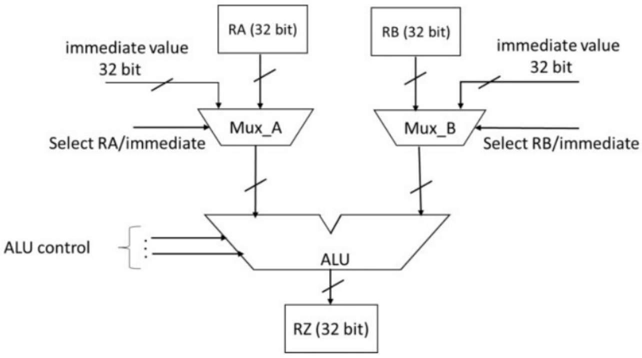
A. $2,1,4,5,3$ B. $1,2,4,3,5$ C. $3,5,2,1,4$ D. $3,5,1,2,4$

gatecse-2020 co-and-architecture data-path one-mark

Answer key

2.8.7 Data Path: GATE CSE 2025 | Set 1 | Question: 17

A partial data path of a processor is given in the figure, where RA, RB, and RZ are 32-bit registers. Which option(s) is/are CORRECT related to arithmetic operations using the data path as shown?



A. The data path can implement arithmetic operations involving two registers.
B. The data path can implement arithmetic operations involving one register and one immediate value.
C. The data path can implement arithmetic operations involving two immediate values.
D. The data path can only implement arithmetic operations involving one register and one immediate value.

gatecse2025-set1 co-and-architecture data-path multiple-selects one-mark

Answer key☟

2.9 IO Handling (7)

2.9.1 IO Handling: GATE CSE 1987 | Question: 2a

State whether the following statements are TRUE or FALSE

In a microprocessor-based system, if a bus (DMA) request and an interrupt request arrive sumultaneously, the microprocessor attends first to the bus request.

gate1987 co-and-architecture interrupts io-handling true-false

Answer key☟

2.9.2 IO Handling: GATE CSE 1987 | Question: 2b

State whether the following statements are TRUE or FALSE:

Data transfer between a microprocessor and an I/O device is usually faster in memory-mapped-I/O scheme than in I/O-mapped -I/O scheme.

gate1987 co-and-architecture io-handling true-false

Answer key☟

2.9.3 IO Handling: GATE CSE 1990 | Question: 4-ii

State whether the following statements are TRUE or FALSE with reason:

The data transfer between memory and I/O devices using programmed I/O is faster than interrupt-driven I/O.

gate1990 true-false co-and-architecture io-handling interrupts

Answer key☟

2.9.4 IO Handling: GATE CSE 1996 | Question: 1.24

For the daisy chain scheme of connecting I/O devices, which of the following statements is true?

A. It gives non-uniform priority to various devices
B. It gives uniform priority to all devices
C. It is only useful for connecting slow devices to a processor device
D. It requires a separate interrupt pin on the processor for each device

gate1996 co-and-architecture io-handling normal

Answer key

2.9.5 IO Handling: GATE CSE 1996 | Question: 25

A hard disk is connected to a 50 MHz processor through a DMA controller. Assume that the initial set-up of a DMA transfer takes 1000 clock cycles for the processor, and assume that the handling of the interrupt at DMA completion requires 500 clock cycles for the processor. The hard disk has a transfer rate of 2000 Kbytes/sec and average block transferred is 4 K bytes. What fraction of the processor time is consumed by the disk, if the disk is actively transferring 100% of the time?

gate1996 co-and-architecture io-handling dma numerical-answers normal

Answer key

2.9.6 IO Handling: GATE CSE 1997 | Question: 2.4

The correct matching for the following pairs is:

$$\begin{array}{ll} \text{(A) DMA I/O} & \text{(1) High speed RAM} \\ \text{(B) Cache} & \text{(2) Disk} \\ \text{(C) Interrupt I/O} & \text{(3) Printer} \\ \text{(D) Condition Code Register} & \text{(4) ALU} \end{array}$$

A. $A-4 \quad B-3 \quad C-1 \quad D-2$

B. $A-2 \quad B-1 \quad C-3 \quad D-4$

C. $A-4 \quad B-3 \quad C-2 \quad D-1$

D. $A-2 \quad B-3 \quad C-4 \quad D-1$

gate1997 co-and-architecture normal io-handling match-the-following

Answer key

2.9.7 IO Handling: GATE CSE 2008 | Question: 64, ISRO2009-13

Which of the following statements about synchronous and asynchronous I/O is NOT true?

A. An ISR is invoked on completion of I/O in synchronous I/O but not in asynchronous I/O
B. In both synchronous and asynchronous I/O, an ISR (Interrupt Service Routine) is invoked after completion of the I/O
C. A process making a synchronous I/O call waits until I/O is complete, but a process making an asynchronous I/O call does not wait for completion of the I/O
D. In the case of synchronous I/O, the process waiting for the completion of I/O is woken up by the ISR that is invoked after the completion of I/O

gatecse-2008 operating-system io-handling normal isro2009

Answer key

2.10 Instruction Execution (6)

2.10.1 Instruction Execution: GATE CSE 1990 | Question: 4-iii

State whether the following statements are TRUE or FALSE with reason:

The flags are affected when conditional CALL or JUMP instructions are executed.

gate1990 true-false co-and-architecture instruction-execution

Answer key

2.10.2 Instruction Execution: GATE CSE 1992 | Question: 01-iv

Many of the advanced microprocessors prefetch instructions and store it in an instruction buffer to speed up processing. This speed up is achieved because ________

gate1992 co-and-architecture easy instruction-execution fill-in-the-blanks

Answer key

2.10.3 Instruction Execution: GATE CSE 1995 | Question: 1.2

Which of the following statements is true?

A. ROM is a Read/Write memory
B. PC points to the last instruction that was executed
C. Stack works on the principle of LIFO
D. All instructions affect the flags

gate1995 co-and-architecture normal instruction-execution

Answer key

2.10.4 Instruction Execution: GATE CSE 2002 | Question: 1.13

Which of the following is not a form of memory

A. instruction cache
B. instruction register
C. instruction opcode
D. translation look-a-side buffer

gatecse-2002 co-and-architecture easy instruction-execution

Answer key

2.10.5 Instruction Execution: GATE CSE 2006 | Question: 43

Consider a new instruction named branch-on-bit-set (mnemonic bbs). The instruction “bbs reg, pos, label” jumps to label if bit in position pos of register operand reg is one. A register is 32 -bits wide and the bits are numbered 0 to $31,$ bit in position 0 being the least significant. Consider the following emulation of this instruction on a processor that does not have bbs implemented.

$$temp \leftarrow reg\&mask$$

Branch to label if temp is non-zero. The variable temp is a temporary register. For correct emulation, the variable mask must be generated by

A. $mask \leftarrow 0\text{x}1 << pos$
B. $mask \leftarrow 0\text{xffffffff} << pos$
C. $mask \leftarrow pos$
D. $mask \leftarrow 0\text{xf}$

gatecse-2006 co-and-architecture normal instruction-execution

Answer key

2.10.6 Instruction Execution: GATE CSE 2017 Set 1 | Question: 49

Consider a RISC machine where each instruction is exactly 4 bytes long. Conditional and unconditional branch instructions use PC-relative addressing mode with Offset specified in bytes to the target location of the branch instruction. Further the Offset is always with respect to the address of the next instruction in the program sequence. Consider the following instruction sequence

Instr. No.	Instruction
i:	add R2, R3, R4
i+1:	sub R5, R6, R7
i+2:	cmp R1, R9, R10
i+3:	beq R1, Offset

If the target of the branch instruction is $i,$ then the decimal value of the Offset is ____________ .

gatecse-2017-set1 co-and-architecture normal numerical-answers instruction-execution

Answer key

2.11 Instruction Format (9)

2.11.1 Instruction Format: GATE CSE 1988 | Question: 2-ii

Using an expanding opcode encoding for instructions, is it possible to encode all of the following in an instruction format shown in the below figure. Justify your answer.

14	double address instructions
127	single address instructions
60	no address (zero address) instructions

$\leftarrow$ 4 bits $\rightarrow$	$\leftarrow$ 6 bits $\rightarrow$	$\leftarrow$ 6 bits $\rightarrow$
Opcode	Operand 1 Address	Operand 2 Address

gate1988 normal co-and-architecture instruction-format descriptive

Answer key

2.11.2 Instruction Format: GATE CSE 1992 | Question: 01-vi

In an 11-bit computer instruction format, the size of address field is 4-bits. The computer uses expanding OP code technique and has 5 two-address instructions and 32 one-address instructions. The number of zero-address instructions it can support is ________

gate1992 co-and-architecture machine-instruction instruction-format normal numerical-answers

Answer key

2.11.3 Instruction Format: GATE CSE 1994 | Question: 3.2

State True or False with one line explanation

Expanding opcode instruction formats are commonly employed in RISC. (Reduced Instruction Set Computers) machines.

gate1994 co-and-architecture machine-instruction instruction-format normal true-false

Answer key

2.11.4 Instruction Format: GATE CSE 2014 Set 1 | Question: 9

A machine has a 32-bit architecture, with 1-word long instructions. It has 64 registers, each of which is 32 bits long. It needs to support 45 instructions, which have an immediate operand in addition to two register operands. Assuming that the immediate operand is an unsigned integer, the maximum value of the immediate operand is ____________

gatecse-2014-set1 co-and-architecture machine-instruction instruction-format numerical-answers normal

Answer key

2.11.5 Instruction Format: GATE CSE 2016 Set 2 | Question: 31

Consider a processor with 64 registers and an instruction set of size twelve. Each instruction has five distinct fields, namely, opcode, two source register identifiers, one destination register identifier, and twelve-bit immediate value. Each instruction must be stored in memory in a byte-aligned fashion. If a program has 100 instructions, the amount of memory (in bytes) consumed by the program text is _________.

gatecse-2016-set2 instruction-format machine-instruction co-and-architecture normal numerical-answers

Answer key

2.11.6 Instruction Format: GATE CSE 2018 | Question: 51

A processor has 16 integer registers $(\text{R0}, \text{R1}, \ldots, \text{R15})$ and 64 floating point registers $(\text{F0}, \text{F1}, \ldots, \text{F63})$. It uses a 2- byte instruction format. There are four categories of instructions: $\text{Type-1}, \text{Type-2}, \text{Type-3},$ and Type-4. Type-1 category consists of four instructions, each with 3 integer register operands (3Rs). Type-2 category consists of eight instructions, each with 2 floating point register operands (2Fs). Type-3 category consists of fourteen instructions, each with one integer register operand and one floating point register operand $(1\text{R}+1\text{F})$. Type-4 category consists of N instructions, each with a floating point register operand (1F).

The maximum value of N is _________.

gatecse-2018 co-and-architecture machine-instruction instruction-format numerical-answers two-marks

Answer key

2.11.7 Instruction Format: GATE CSE 2020 | Question: 44

A processor has 64 registers and uses 16-bit instruction format. It has two types of instructions: I-type and R-type. Each I-type instruction contains an opcode, a register name, and a 4-bit immediate value. Each R-type instruction contains an opcode and two register names. If there are 8 distinct I-type opcodes, then the maximum number of distinct R-type opcodes is _______.

gatecse-2020 co-and-architecture numerical-answers instruction-format machine-instruction two-marks

Answer key

2.11.8 Instruction Format: GATE CSE 2024 | Set 2 | Question: 47

A processor with 16 general purpose registers uses a 32-bit instruction format. The instruction format consists of an opcode field, an addressing mode field, two register operand fields, and a 16-bit scalar field. If 8 addressing modes are to be supported, the maximum number of unique opcodes possible for every addressing mode is ___________.

gatecse2024-set2 numerical-answers co-and-architecture instruction-format two-marks

Answer key

2.11.9 Instruction Format: GATE CSE 2024 | Set 2 | Question: 51

A processor uses a 32-bit instruction format and supports byte-addressable memory access. The ISA of the processor has 150 distinct instructions. The instructions are equally divided into two types, namely R-type and I-type, whose formats are shown below.

R - type Instruction Format:

$OPCODE$	$UNUSED$	$DSTRegister$	$SRCRegister1$	$SRCRegister2$

I - type Instruction Format:

$OPCODE$	$DSTRegister$	$SRCRegister$	$\#Immediatevalue/address$

In the OPCODE, 1 bit is used to distinguish between I-type and R-type instructions and the remaining bits indicate the operation. The processor has 50 architectural registers, and all register fields in the instructions are of equal size.

Let X be the number of bits used to encode the UNUSED field, Y be the number of bits used to encode the OPCODE field, and Z be the number of bits used to encode the immediate value/address field. The value of $\text{X}+2\text{Y}+\text{Z}$ is __________.

gatecse2024-set2 numerical-answers co-and-architecture instruction-format two-marks

Answer key

2.12 Instruction Set Architecture (1)

2.12.1 Instruction Set Architecture: GATE CSE 2025 | Set 2 | Question: 18

Which of the following is/are part of an Instruction Set Architecture of a processor?

A. The size of the cache memory

B. The clock frequency of the processor

C. The number of cache memory

D. The total number of registers

levels

gatecse2025-set2 co-and-architecture instruction-set-architecture multiple-selects easy one-mark

Answer key

2.13 Interrupts (9)

2.13.1 Interrupts: GATE CSE 1987 | Question: 1-viii

On receiving an interrupt from a I/O device the CPU:

A. Halts for a predetermined time.
B. Hands over control of address bus and data bus to the interrupting device.
C. Branches off to the interrupt service routine immediately.
D. Branches off to the interrupt service routine after completion of the current instruction.

gate1987 co-and-architecture interrupts

Answer key

2.13.2 Interrupts: GATE CSE 1995 | Question: 1.3

In a vectored interrupt:

A. The branch address is assigned to a fixed location in memory
B. The interrupting source supplies the branch information to the processor through an interrupt vector
C. The branch address is obtained from a register in the processor
D. None of the above

gate1995 co-and-architecture interrupts normal

Answer key

2.13.3 Interrupts: GATE CSE 1998 | Question: 1.20

Which of the following is true?

A. Unless enabled, a CPU will not be able to process interrupts.
B. Loop instructions cannot be interrupted till they complete.
C. A processor checks for interrupts before executing a new instruction.
D. Only level triggered interrupts are possible on microprocessors.

gate1998 co-and-architecture interrupts normal

Answer key

2.13.4 Interrupts: GATE CSE 2002 | Question: 1.9

A device employing INTR line for device interrupt puts the CALL instruction on the data bus while:

A. $\overline{\text{INTA}}$ is active
B. HOLD is active
C. READY is inactive
D. None of the above

gatecse-2002 co-and-architecture interrupts normal

Answer key

2.13.5 Interrupts: GATE CSE 2005 | Question: 69

A device with data transfer rate 10 KB/sec is connected to a CPU. Data is transferred byte-wise. Let the interrupt overhead be 4μsec. The byte transfer time between the device interface register and CPU or memory is negligible. What is the minimum performance gain of operating the device under interrupt mode over operating it under program-controlled mode?

A. 15
B. 25
C. 35
D. 45

gatecse-2005 co-and-architecture interrupts

Answer key☟

2.13.6 Interrupts: GATE CSE 2009 | Question: 8, UGCNET-June2012-III: 58

A CPU generally handles an interrupt by executing an interrupt service routine:

A. As soon as an interrupt is raised.
B. By checking the interrupt register at the end of fetch cycle.
C. By checking the interrupt register after finishing the execution of the current instruction.
D. By checking the interrupt register at fixed time intervals.

gatecse-2009 co-and-architecture interrupts normal ugcnetcse-june2012-paper3

Answer key☟

2.13.7 Interrupts: GATE CSE 2020 | Question: 3

Consider the following statements.

I. Daisy chaining is used to assign priorities in attending interrupts.
II. When a device raises a vectored interrupt, the CPU does polling to identify the source of interrupt.
III. In polling, the CPU periodically checks the status bits to know if any device needs its attention.
IV. During DMA, both the CPU and DMA controller can be bus masters at the same time.

Which of the above statements is/are TRUE?

A. I and II only
B. I and IV only
C. I and III only
D. III only

gatecse-2020 co-and-architecture interrupts one-mark

Answer key☟

2.13.8 Interrupts: GATE CSE 2023 | Question: 24

A keyboard connected to a computer is used at a rate of 1 keystroke per second. The computer system polls the keyboard every 10 ms (milli seconds) to check for a keystroke and consumes $100 \ \mu s$ (micro seconds) for each poll. If it is determined after polling that a key has been pressed, the system consumes an additional $200 \ \mu s$ to process the keystroke. Let T_1 denote the fraction of a second spent in polling and processing a keystroke.

In an alternative implementation, the system uses interrupts instead of polling. An interrupt is raised for every keystroke. It takes a total of 1 ms for servicing an interrupt and processing a keystroke. Let T_2 denote the fraction of a second spent in servicing the interrupt and processing a keystroke.

The ratio $\dfrac{T_1}{T_2}$ is _____________. (Rounded off to one decimal place)

gatecse-2023 co-and-architecture interrupts numerical-answers one-mark

Answer key☟

2.13.9 Interrupts: GATE CSE 2025 | Set 1 | Question: 1

Suppose a program is running on a non-pipelined single processor computer system. The computer is connected to an external device that can interrupt the processor asynchronously. The processor needs to execute the interrupt service routine (ISR) to serve this interrupt. The following steps (not necessarily in order) are taken by the processor when the interrupt arrives:

i. The processor saves the content of the program counter.
ii. The program counter is loaded with the start address of the ISR.
iii. The processor finishes the present instruction.

Which ONE of the following is the CORRECT sequence of steps?

A. (iii), (i), (ii)
B. (i), (iii), (ii)
C. (i), (ii), (iii)
D. (iii), (ii), (i)

gatecse2025-set1 co-and-architecture interrupts easy one-mark

Answer key

2.14 Machine Instruction (21)

2.14.1 Machine Instruction: GATE CSE 1988 | Question: 9i

The following program fragment was written in an assembly language for a single address computer with one accumulator register:

```
LOAD B
MULT C
STORE T1
ADD A
STORE T2
MULT T2
ADD T1
STORE Z
```

Give the arithmetic expression implemented by the fragment.

gate1988 normal descriptive co-and-architecture machine-instruction

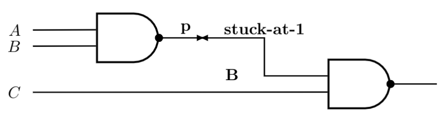
Answer key

2.14.2 Machine Instruction: GATE CSE 1994 | Question: 12

A. Assume that a CPU has only two registers R_1 and R_2 and that only the following instruction is available $XOR\, R_i, R_j; \{R_j \leftarrow R_i \oplus R_j, \text{ for } i, j = 1, 2\}$

   Using this XOR instruction, find an instruction sequence in order to exchange the contents of the registers R_1 and R_2

B. The line p of the circuit shown in figure has stuck at 1 fault. Determine an input test to detect the fault.



gate1994 co-and-architecture machine-instruction normal descriptive

Answer key

2.14.3 Machine Instruction: GATE CSE 1999 | Question: 17

Consider the following program fragment in the assembly language of a certain hypothetical processor. The processor has three general purpose registers $R1, R2$ and $R3$. The meanings of the instructions are shown by comments (starting with ;) after the instructions.

```
X:  CMP R1, 0;  Compare R1 and 0, set flags appropriately in status register
    JZ  Z;   Jump if zero to target Z
    MOV R2, R1; Copy contents of R1 to R2
    SHR R1; Shift right R1 by 1 bit
    SHL R1; Shift left R1 by 1 bit
    CMP R2, R1; Compare R2 and R1 and set flag in status register
    JZ  Y;    Jump if zero to target Y
    INC R3; Increment R3 by 1;
Y:  SHR R1; Shift right R1 by 1 bit
    JMP X;  Jump to target X
Z:...
```

A. Initially $R1, R2$ and $R3$ contain the values 5,0 and 0 respectively, what are the final values of $R1$ and $R3$ when control reaches Z?
B. In general, if $R1, R2$ and $R3$ initially contain the values n, 0, and 0 respectively. What is the final value of $R3$ when control reaches Z?

gate1999 co-and-architecture machine-instruction normal descriptive

Answer key

2.14.4 Machine Instruction: GATE CSE 2003 | Question: 48

Consider the following assembly language program for a hypothetical processor $A, B,$ and C are $8-$bit registers. The meanings of various instructions are shown as comments.

	MOV B, #0	;	$B \leftarrow 0$
	MOV C, #8	;	$C \leftarrow 8$
Z:	CMP C, #0	;	compare C with 0
	JZ X	;	jump to X if zero flag is set
	SUB C, #1	;	$C \leftarrow C - 1$
	RRC A, #1	;	right rotate A through carry by one bit. Thus:
		;	If the initial values of A and the carry flag are $a_7 \dots a_0$ and
		;	c_0 respectively, their values after the execution of this
		;	instruction will be $c_0 a_7 \dots a_1$ and a_0 respectively.
	JC Y	;	jump to Y if carry flag is set
	JMP Z	;	jump to Z
Y:	ADD B, #1	;	$B \leftarrow B + 1$
	JMP Z	;	jump to Z
X:		;	

If the initial value of register A is A0 the value of register B after the program execution will be

A. the number of 0 bits in A_0
B. the number of 1 bits in A_0
C. A_0
D. 8

gatecse-2003 co-and-architecture machine-instruction normal

Answer key

2.14.5 Machine Instruction: GATE CSE 2003 | Question: 49

Consider the following assembly language program for a hypothetical processor $A, B,$ and C are 8 bit registers. The meanings of various instructions are shown as comments.

	MOV B, #0	; $B \leftarrow 0$
	MOV C, #8	; $C \leftarrow 8$
Z:	CMP C, #0	; compare C with 0
	JZ X	; jump to X if zero flag is set
	SUB C, #1	; $C \leftarrow C - 1$
	RRC A, #1	; right rotate A through carry by one bit. Thus:
		; If the initial values of A and the carry flag are $a_7 .. a_0$ and
		; c_0 respectively, their values after the execution of this
		; instruction will be $c_0 a_7 .. a_1$ and a_0 respectively.
	JC Y	; jump to Y if carry flag is set
	JMP Z	; jump to Z
Y:	ADD B, #1	; $B \leftarrow B + 1$
	JMP Z	; jump to Z
X:		

Which of the following instructions when inserted at location X will ensure that the value of the register A after program execution is as same as its initial value?

A. $\text{RRC A}, \#1$
B. NOP; no operation
C. $\text{LRC A},\#1$; left rotate A through carry flag by one bit
D. $\text{ADD A},\#1$

gatecse-2003 co-and-architecture machine-instruction normal

Answer key

2.14.6 Machine Instruction: GATE CSE 2004 | Question: 63

Consider the following program segment for a hypothetical CPU having three user registers R_1, R_2 and R_3.

Instruction	Operation	Instruction size (in words)
MOV $R_1, 5000$	$R_1 \leftarrow$ Memory[5000]	2
MOV $R2, (R1)$	$R2 \leftarrow$ Memory[(R_1)]	1
ADD R_2, R_3	$R2 \leftarrow R_2 + R_3$	1
MOV $6000, R_2$	Memory[6000] $\leftarrow R_2$	2
HALT	Machine Halts	1

Consider that the memory is byte addressable with size 32 bits, and the program has been loaded starting from memory location 1000 (decimal). If an interrupt occurs while the CPU has been halted after executing the HALT instruction, the return address (in decimal) saved in the stack will be

A. 1007
B. 1020
C. 1024
D. 1028

gatecse-2004 co-and-architecture machine-instruction normal

Answer key

2.14.7 Machine Instruction: GATE CSE 2004 | Question: 64

Consider the following program segment for a hypothetical CPU having three user registers R_1, R_2 and R_3.

Instruction	Operation	Instruction size (in Words)
MOV $R_1, 5000$	$R1 \leftarrow$ Memory[5000]	2
MOV $R_2(R_1)$	$R2 \leftarrow$ Memory[(R_1)]	1
ADD R_2, R_3	$R_2 \leftarrow R_2 + R_3$	1
MOV $6000, R_2$	Memory[6000] $\leftarrow R_2$	2
Halt	Machine Halts	1

Let the clock cycles required for various operations be as follows:

Register to/from memory transfer	3 clock cycles
ADD with both operands in register	1 clock cycles
Instruction fetch and decode	2 clock cycles

The total number of clock cycles required to execute the program is

A. 29
B. 24
C. 23
D. 20

gatecse-2004 co-and-architecture machine-instruction normal

Answer key

2.14.8 Machine Instruction: GATE CSE 2006 | Question: 09, ISRO2009-35

A CPU has 24-bit instructions. A program starts at address 300 (in decimal). Which one of the following is a legal program counter (all values in decimal)?

A. 400 B. 500 C. 600 D. 700

gatecse-2006 co-and-architecture machine-instruction easy isro2009

Answer key

2.14.9 Machine Instruction: GATE CSE 2007 | Question: 54

In a simplified computer the instructions are:

OP R_j, R_i	Perform R_j OP R_i and store the result in register R_j
OP m, R_i	Perform val OP R_i and store the result in register R_i val denotes the content of the memory location m
MOV m, R_i	Moves the content of memory location m to register R_i
MOV R_i, m	Moves the content of register R_i to memory location m

The computer has only two registers, and OP is either ADD or SUB. Consider the following basic block:

- $t_1 = a+b$
- $t_2 = c+d$
- $t_3 = e-t_2$
- $t_4 = t_1-t_3$

Assume that all operands are initially in memory. The final value of the computation should be in memory. What is the minimum number of MOV instructions in the code generated for this basic block?

A. 2 B. 3 C. 5 D. 6

gatecse-2007 co-and-architecture machine-instruction normal

Answer key

2.14.10 Machine Instruction: GATE CSE 2007 | Question: 71

Consider the following program segment. Here $\mathrm{R1}$, $\mathrm{R2}$ and $\mathrm{R3}$ are the general purpose registers.

	Instruction	Operation	Instruction Size (no. of words)
	MOV R1,(3000)	R1← M[3000]	2
LOOP:	MOV R2,(R3)	R2← M[R3]	1
	ADD R2,R1	R2← R1 + R2	1
	MOV (R3),R2	M[R3]← R2	1
	INC R3	R3← R3 + 1	1
	DEC R1	R1← R1 − 1	1
	BNZ LOOP	Branch on not zero	2
	HALT	Stop	1

Assume that the content of memory location 3000 is 10 and the content of the register $\mathrm{R3}$ is 2000. The content of each of the memory locations from 2000 to 2010 is 100. The program is loaded from the memory location 1000. All the numbers are in decimal.

Assume that the memory is word addressable. The number of memory references for accessing the data in executing the program completely is

A. 10 B. 11 C. 20 D. 21

gatecse-2007 co-and-architecture machine-instruction interrupts normal

Answer key

2.14.11 Machine Instruction: GATE CSE 2007 | Question: 72

Consider the following program segment. Here $R1$, $R2$ and $R3$ are the general purpose registers.

	Instruction	Operation	Instruction Size (no. of words)
	MOV R1,(3000)	R1← M[3000]	2
LOOP:	MOV R2,(R3)	R2← M[R3]	1
	ADD R2,R1	R2← R1 + R2	1
	MOV (R3),R2	M[R3]← R2	1
	INC R3	R3← R3 + 1	1
	DEC R1	R1← R1 − 1	1
	BNZ LOOP	Branch on not zero	2
	HALT	Stop	1

Assume that the content of memory location 3000 is 10 and the content of the register $R3$ is 2000. The content of each of the memory locations from 2000 to 2010 is 100. The program is loaded from the memory location 1000. All the numbers are in decimal.

Assume that the memory is word addressable. After the execution of this program, the content of memory location 2010 is:

A. 100 B. 101 C. 102 D. 110

gatecse-2007 co-and-architecture machine-instruction interrupts normal

Answer key☟

2.14.12 Machine Instruction: GATE CSE 2007 | Question: 73

Consider the following program segment. Here $R1$, $R2$ and $R3$ are the general purpose registers.

	Instruction	Operation	Instruction Size (no. of words)
	MOV R1,(3000)	R1← M[3000]	2
LOOP:	MOV R2,(R3)	R2← M[R3]	1
	ADD R2,R1	R2← R1 + R2	1
	MOV (R3),R2	M[R3]← R2	1
	INC R3	R3← R3 + 1	1
	DEC R1	R1← R1 − 1	1
	BNZ LOOP	Branch on not zero	2
	HALT	Stop	1

Assume that the content of memory location 3000 is 10 and the content of the register $R3$ is 2000. The content of each of the memory locations from 2000 to 2010 is 100. The program is loaded from the memory location 1000. All the numbers are in decimal.

Assume that the memory is byte addressable and the word size is 32 bits. If an interrupt occurs during the execution of the instruction "INC R3", what return address will be pushed on to the stack?

A. 1005 B. 1020 C. 1024 D. 1040

gatecse-2007 co-and-architecture machine-instruction interrupts normal

Answer key☟

2.14.13 Machine Instruction: GATE CSE 2008 | Question: 34

Which of the following must be true for the RFE (Return From Exception) instruction on a general purpose processor?

I. It must be a trap instruction
II. It must be a privileged instruction
III. An exception cannot be allowed to occur during execution of an RFE instruction

A. I only B. II only C. I and II only D. I, II and III only

gatecse-2008 co-and-architecture machine-instruction normal

Answer key

2.14.14 Machine Instruction: GATE CSE 2015 Set 2 | Question: 42

Consider a processor with byte-addressable memory. Assume that all registers, including program counter (PC) and Program Status Word (PSW), are size of two bytes. A stack in the main memory is implemented from memory location $(0100)_{16}$ and it grows upward. The stack pointer (SP) points to the top element of the stack. The current value of SP is $(016E)_{16}$. The CALL instruction is of two words, the first word is the op-code and the second word is the starting address of the subroutine (one word = 2 bytes). The CALL instruction is implemented as follows:

- Store the current value of PC in the stack
- Store the value of PSW register in the stack
- Load the statring address of the subroutine in PC

The content of PC just before the fetch of a CALL instruction is $(5FA0)_{16}$. After execution of the CALL instruction, the value of the stack pointer is:

A. $(016A)_{16}$ B. $(016C)_{16}$ C. $(0170)_{16}$ D. $(0172)_{16}$

gatecse-2015-set2 co-and-architecture machine-instruction easy

Answer key

2.14.15 Machine Instruction: GATE CSE 2016 Set 2 | Question: 10

A processor has 40 distinct instruction and 24 general purpose registers. A 32-bit instruction word has an opcode, two registers operands and an immediate operand. The number of bits available for the immediate operand field is_______.

gatecse-2016-set2 machine-instruction co-and-architecture easy numerical-answers

Answer key

2.14.16 Machine Instruction: GATE CSE 2021 Set 1 | Question: 55

Consider the following instruction sequence where registers $\text{R1}, \text{R2}$ and R3 are general purpose and MEMORY[X] denotes the content at the memory location X.

Instruction	**Semantics**	**Instruction Size** (bytes)
MOV R1, (5000)	R1 ← MEMORY[5000]	4
MOV R2, (R3)	R2← MEMORY[R3]	4
ADDR2, R1	R2 ← R1 + R2	2
MOV (R3), R2	MEMORY[R3]← R2	4
INC R3	R3 ← R3 + 1	2
DEC R1	R1 ← R1 − 1	2
BNZ 1004	Branch if not zero to the given absolute address	2
HALT	Stop	1

Assume that the content of the memory location 5000 is 10, and the content of the register R3 is 3000. The content of each of the memory locations from 3000 to 3020 is 50. The instruction sequence starts from the memory location 1000. All the numbers are in decimal format. Assume that the memory is byte addressable.

After the execution of the program, the content of memory location 3010 is ____________

gatecse-2021-set1 co-and-architecture machine-instruction numerical-answers two-marks

Answer key

2.14.17 Machine Instruction: GATE CSE 2023 | Question: 31

Consider the given C-code and its corresponding assembly code, with a few operands $\mathrm{U1}$-$\mathrm{U4}$ being unknown. Some useful information as well as the semantics of each unique assembly instruction is annotated as inline comments in the code. The memory is byte-addressable.

```
//C-code

int a[10], b[10], i;
 // int is 32 bit
 for(i=0; i<10; i++)
   a[i] = b[i] * 8;
```

```
;assembly code (; indicates comments)
;r1-r5 are 32-bit integer registers
;initialize r1=0, r2=10
;initialize r3, r4 with base address of a, b

 L01: jeq r1, r2, end  ;if(r1==r2) goto end
 L02: lw, r5, 0(r4)    ;r5 <- Memory[r4+0]
 L03: shl, r5, r5, U1  ;r5 <- r5 << U1
 L04: sw, r5, 0(r3)    ;Memory[r3+0] <- r5
 L05: add, r3, r3, U2  ;r3 <- r3+U2
 L06: add, r4, r4, U3
 L07: add, r1, r1, 1
 L08: jmp U4           ;goto U4
 L09: end
```

Which one of the following options is a $\mathrm{CORRECT}$ replacement for operands in the position $(\mathrm{U1}, \mathrm{U2}, \mathrm{U3}, \mathrm{U4})$ in the above assembly code?

A. $(8,4,1,\mathrm{L02})$
B. $(3,4,4,\mathrm{L01})$
C. $(8,1,1,\mathrm{L02})$
D. $(3,1,1,\mathrm{L01})$

gatecse-2023 co-and-architecture machine-instruction two-marks

Answer key

2.14.18 Machine Instruction: GATE CSE 2025 | Set 1 | Question: 27

A processor has 64 general-purpose registers and 50 distinct instruction types. An instruction is encoded in 32-bits. What is the maximum number of bits that can be used to store the immediate operand for the given instruction?

$$\mathrm{ADD\ R1, \#25} \ // \ \mathrm{R\ 1{=}R\ 1{+}25}$$

A. 16
B. 20
C. 22
D. 24

gatecse2025-set1 co-and-architecture machine-instruction easy two-marks

Answer key

2.14.19 Machine Instruction: GATE IT 2004 | Question: 46

If we use internal data forwarding to speed up the performance of a CPU (R1, R2 and R3 are registers and M[100] is a memory reference), then the sequence of operations

R1 → M[100]
M[100] → R2
M[100] → R3

can be replaced by

A. R1 → R3
R2 → M[100]

B. M[100] → R2
R1 → R2
R1 → R3

C. R1 → M[100]
R2 → R3

D. R1 → R2
R1 → R3
R1 → M[100]

gateit-2004 co-and-architecture machine-instruction easy

Answer key

2.14.20 Machine Instruction: GATE IT 2007 | Question: 41

Following table indicates the latencies of operations between the instruction producing the result and instruction using the result.

Instruction producing the result	Instruction using the result	Latency
ALU Operation	ALU Operation	2
ALU Operation	Store	2
Load	ALU Operation	1
Load	Store	0

Consider the following code segment:

```
Load R1, Loc 1; Load R1 from memory location Loc1
Load R2, Loc 2; Load R2 from memory location Loc 2
Add R1, R2, R1; Add R1 and R2 and save result in R1
Dec R2;        Decrement R2
Dec R1;        Decrement R1
Mpy R1, R2, R3; Multiply R1 and R2 and save result in R3
Store R3, Loc 3; Store R3 in memory location Loc 3
```

What is the number of cycles needed to execute the above code segment assuming each instruction takes one cycle to execute?

A. 7 B. 10 C. 13 D. 14

gateit-2007 co-and-architecture machine-instruction normal

Answer key

2.14.21 Machine Instruction: GATE IT 2008 | Question: 38

Assume that EA = (X)+ is the effective address equal to the contents of location X, with X incremented by one word length after the effective address is calculated; EA = −(X) is the effective address equal to the contents of location X, with X decremented by one word length before the effective address is calculated; EA = (X)− is the effective address equal to the contents of location X, with X decremented by one word length after the effective address is calculated. The format of the instruction is (opcode, source, destination), which means (destination ← source op destination). Using X as a stack pointer, which of the following instructions can pop the top two elements from the stack, perform the addition operation and push the result back to the stack.

A. ADD (X)−, (X)
B. ADD (X), (X)−
C. ADD −(X), (X)+
D. ADD −(X), (X)

gateit-2008 co-and-architecture machine-instruction normal

Answer key

2.15 Memory Interfacing (6)

2.15.1 Memory Interfacing: GATE CSE 1991 | Question: 01,ii

In interleaved memory organization, consecutive words are stored in consecutive memory modules in ________ interleaving, whereas consecutive words are stored within the module in ________ interleaving.

gate1991 co-and-architecture normal memory-interfacing descriptive

Answer key

2.15.2 Memory Interfacing: GATE CSE 2006 | Question: 41

A CPU has a cache with block size 64 bytes. The main memory has k banks, each bank being c bytes wide. Consecutive c − byte chunks are mapped on consecutive banks with wrap-around. All the k banks can be accessed in parallel, but two accesses to the same bank must be serialized. A cache block access may involve multiple iterations of parallel bank accesses depending on the amount of data obtained by accessing all the k banks in parallel. Each iteration requires decoding the bank numbers to be accessed in parallel and this takes

$\frac{k}{2}ns$.The latency of one bank access is 80 ns. If $c = 2$ and $k = 24$, the latency of retrieving a cache block starting at address zero from main memory is:

A. 92 ns
B. 104 ns
C. 172 ns
D. 184 ns

gatecse-2006 co-and-architecture cache-memory memory-interfacing normal

Answer key

2.15.3 Memory Interfacing: GATE CSE 2016 Set 1 | Question: 09

A processor can support a maximum memory of 4 GB, where the memory is word-addressable (a word consists of two bytes). The size of address bus of the processor is at least _________bits.

gatecse-2016-set1 co-and-architecture easy numerical-answers memory-interfacing

Answer key

2.15.4 Memory Interfacing: GATE CSE 2018 | Question: 23

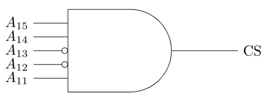
A 32-bit wide main memory unit with a capacity of 1 GB is built using 256M $\times$ 4-bit DRAM chips. The number of rows of memory cells in the DRAM chip is 2^{14}. The time taken to perform one refresh operation is 50 nanoseconds. The refresh period is 2 milliseconds. The percentage (rounded to the closest integer) of the time available for performing the memory read/write operations in the main memory unit is _________.

gatecse-2018 co-and-architecture memory-interfacing normal numerical-answers one-mark

Answer key

2.15.5 Memory Interfacing: GATE CSE 2019 | Question: 2

The chip select logic for a certain DRAM chip in a memory system design is shown below. Assume that the memory system has 16 address lines denoted by A_{15} to A_0. What is the range of address (in hexadecimal) of the memory system that can get enabled by the chip select (CS) signal?



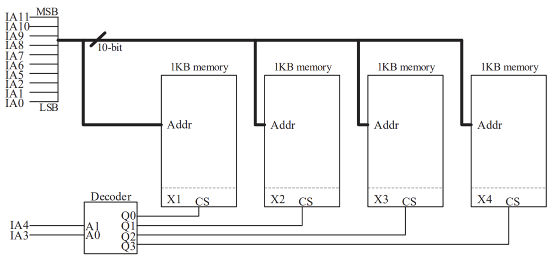
A. C800 to CFFF
B. CA00 to CAFF
C. C800 to C8FF
D. DA00 to DFFF

gatecse-2019 co-and-architecture dram memory-interfacing one-mark

Answer key

2.15.6 Memory Interfacing: GATE CSE 2023 | Question: 32

A 4 kilobyte (KB) byte-addressable memory is realized using four 1 KB memory blocks. Two input address lines $(\mathrm{IA4}$ and $\mathrm{IA3})$ are connected to the chip select (CS) port of these memory blocks through a decoder as shown in the figure. The remaining ten input address lines from $\mathrm{IA11}$-$\mathrm{IA0}$ are connected to the address port of these blocks. The chip select (CS) is active high.



The input memory addresses $(\mathrm{IA11}$-$\mathrm{IA0})$, in decimal, for the starting locations $(\mathrm{Addr} = 0)$ of each block (indicated as $\mathrm{X1}$, $\mathrm{X2}$, $\mathrm{X3}$, $\mathrm{X4}$ in the figure) are among the options given below. Which one of the following options is $\mathrm{CORRECT}$?

A. $(0,1,2,3)$ B. $(0,1024,2048,3072)$ C. $(0,8,16,24)$ D. $(0,0,0,0)$

gatecse-2023 co-and-architecture memory-interfacing two-marks

Answer key

2.16 Microprogramming (13)

2.16.1 Microprogramming: GATE CSE 1987 | Question: 1-vi

A microprogrammed control unit

A. Is faster than a hard-wired control unit.
B. Facilitates easy implementation of new instruction.
C. Is useful when very small programs are to be run.
D. Usually refers to the control unit of a microprocessor.

gate1987 co-and-architecture control-unit microprogramming

Answer key

2.16.2 Microprogramming: GATE CSE 1987 | Question: 4a

Find out the width of the control memory of a horizontal microprogrammed control unit, given the following specifications:

- 16 control lines for the processor consisting of ALU and 7 registers.
- Conditional branching facility by checking 4 status bits.
- Provision to hold 128 words in the control memory.

gate1987 co-and-architecture microprogramming descriptive

Answer key

2.16.3 Microprogramming: GATE CSE 1996 | Question: 2.25

A micro program control unit is required to generate a total of 25 control signals. Assume that during any micro instruction, at most two control signals are active. Minimum number of bits required in the control word to generate the required control signals will be:

A. 2 B. 2.5 C. 10 D. 12

gate1996 co-and-architecture microprogramming normal

Answer key

2.16.4 Microprogramming: GATE CSE 1997 | Question: 5.3

A micro instruction is to be designed to specify:

a. none or one of the three micro operations of one kind and
b. none or upto six micro operations of another kind

The minimum number of bits in the micro-instruction is:

A. 9 B. 5 C. 8 D. None of the above

gate1997 co-and-architecture microprogramming normal

Answer key

2.16.5 Microprogramming: GATE CSE 1999 | Question: 2.19

Arrange the following configuration for CPU in decreasing order of operating speeds:
Hard wired control, Vertical microprogramming, Horizontal microprogramming.

A. Hard wired control, Vertical microprogramming, Horizontal microprogramming.
B. Hard wired control, Horizontal microprogramming, Vertical microprogramming.

C. Horizontal microprogramming, Vertical microprogramming, Hard wired control.

D. Vertical microprogramming, Horizontal microprogramming, Hard wired control.

gate1999 co-and-architecture microprogramming normal

Answer key

2.16.6 Microprogramming: GATE CSE 2002 | Question: 2.7

Horizontal microprogramming:

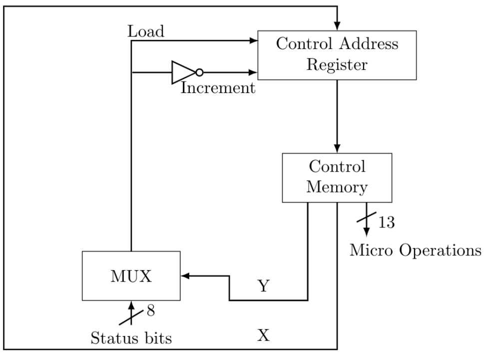
A. does not require use of signal decoders
B. results in larger sized microinstructions than vertical microprogramming
C. uses one bit for each control signal
D. all of the above

gatecse-2002 co-and-architecture microprogramming

Answer key

2.16.7 Microprogramming: GATE CSE 2004 | Question: 67

The microinstructions stored in the control memory of a processor have a width of 26 bits. Each microinstruction is divided into three fields: a micro-operation field of 13 bits, a next address field (X), and a MUX select field (Y). There are 8 status bits in the input of the MUX.



How many bits are there in the X and Y fields, and what is the size of the control memory in number of words?

A. $10, 3, 1024$ B. $8, 5, 256$ C. $5, 8, 2048$ D. $10, 3, 512$

gatecse-2004 co-and-architecture microprogramming normal

Answer key

2.16.8 Microprogramming: GATE CSE 2013 | Question: 28

Consider the following sequence of micro-operations.

```
MBR ← PC
MAR ← X  PC ← Y
Memory ← MBR
```

Which one of the following is a possible operation performed by this sequence?

A. Instruction fetch
B. Operand fetch
C. Conditional branch
D. Initiation of interrupt service

gatecse-2013 co-and-architecture microprogramming normal

Answer key

2.16.9 Microprogramming: GATE IT 2004 | Question: 49

A CPU has only three instructions $I1, I2$ and $I3$, which use the following signals in time steps $T1-T5$:

$I1 : T1$: Ain, Bout, Cin

$T2$: PCout, Bin

$T3$: Zout, Ain
$T4$: Bin, Cout
$T5$: End

$I2 : T1$: Cin, Bout, Din
$T2$: Aout, Bin
$T3$: Zout, Ain
$T4$: Bin, Cout
$T5$: End

$I3 : T1$: Din, Aout
$T2$: Ain, Bout
$T3$: Zout, Ain
$T4$: Dout, Ain
$T5$: End

Which of the following logic functions will generate the hardwired control for the signal Ain ?

A. $T1.I1 + T2.I3 + T4.I3 + T3$
B. $(T1 + T2 + T3).I3 + T1.I1$
C. $(T1 + T2).I1 + (T2 + T4).I3 + T3$
D. $(T1 + T2).I2 + (T1 + T3).I1 + T3$

gateit-2004 co-and-architecture microprogramming normal

Answer key

2.16.10 Microprogramming: GATE IT 2005 | Question: 45

A hardwired CPU uses 10 control signals S_1 to S_{10}, in various time steps T_1 to T_5, to implement 4 instructions I_1 to I_4 as shown below:

	$\mathbf{T_1}$	$\mathbf{T_2}$	$\mathbf{T_3}$	$\mathbf{T_4}$	$\mathbf{T_5}$
$\mathbf{I_1}$	S_1, S_3, S_5	S_2, S_4, S_6	S_1, S_7	S_{10}	S_3, S_8
$\mathbf{I_2}$	S_1, S_3, S_5	S_8, S_9, S_{10}	$S_5, S_6 S_7$	S_6	S_{10}
$\mathbf{I_3}$	S_1, S_3, S_5	S_7, S_8, S_{10}	S_2, S_6, S_9	S_{10}	S_1, S_3
$\mathbf{I_4}$	S_1, S_3, S_5	S_2, S_6, S_7	S_5, S_{10}	S_6, S_9	S_{10}

Which of the following pairs of expressions represent the circuit for generating control signals S_5 and S_{10} respectively?

($(I_j + I_k)T_n$ indicates that the control signal should be generated in time step T_n if the instruction being executed is I_j or l_k)

A. $S_5 = T_1 + I_2 \cdot T_3$ and
$S_{10} = (I_1 + I_3) \cdot T_4 + (I_2 + I_4) \cdot T_5$
B. $S_5 = T_1 + (I_2 + I_4) \cdot T_3$ and
$S_{10} = (I_1 + I_3) \cdot T_4 + (I_2 + I_4) \cdot T_5$
C. $S_5 = T_1 + (I_2 + I_4) \cdot T_3$ and
$S_{10} = (I_2 + I_3 + I_4) \cdot T_2 + (I_1 + I_3) \cdot T_4 + (I_2 + I_4) \cdot T_5$
D. $S_5 = T_1 + (I_2 + I_4) \cdot T_3$ and
$S_{10} = (I_2 + I_3) \cdot T_2 + I_4 \cdot T_3 + (I_1 + I_3) \cdot T_4 + (I_2 + I_4) \cdot T_5$

gateit-2005 co-and-architecture microprogramming normal

Answer key

2.16.11 Microprogramming: GATE IT 2005 | Question: 49

An instruction set of a processor has 125 signals which can be divided into 5 groups of mutually exclusive signals as follows:

Group $1 : 20$ signals, Group $2 : 70$ signals, Group $3 : 2$ signals, Group $4 : 10$ signals, Group $5 : 23$ signals.

How many bits of the control words can be saved by using vertical microprogramming over horizontal microprogramming?

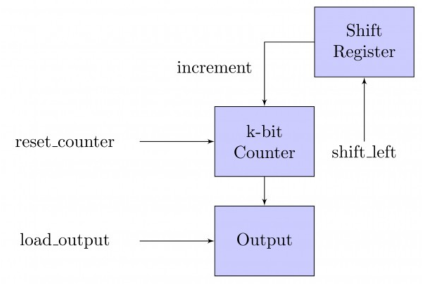
A. 0 B. 103 C. 22 D. 55

gateit-2005 co-and-architecture microprogramming normal

Answer key

2.16.12 Microprogramming: GATE IT 2006 | Question: 41

The data path shown in the figure computes the number of $1s$ in the $32-bit$ input word corresponding to an unsigned even integer stored in the shift register.
The unsigned counter, initially zero, is incremented if the most significant bit of the shift register is $1.$



The microprogram for the control is shown in the table below with missing control words for microinstructions $I_1, I_2, \ldots I_n$.

Microinstruction	Reset_Counter	Shift_left	Load_output
BEGIN	1	0	0
I1	?	?	?
:	:	:	:
In	?	?	?
END	0	0	1

The counter width (k), the number of missing microinstructions (n), and the control word for microinstructions $I_1, I_2, \ldots I_n$ are, respectively,

A. $32,5,010$ B. $5,32,010$ C. $5,31,011$ D. $5,31,010$

gateit-2006 co-and-architecture microprogramming normal

Answer key

2.16.13 Microprogramming: GATE IT 2008 | Question: 39

Consider a CPU where all the instructions require 7 clock cycles to complete execution. There are 140 instructions in the instruction set. It is found that 125 control signals are needed to be generated by the control unit. While designing the horizontal microprogrammed control unit, single address field format is used for branch control logic. What is the minimum size of the control word and control address register?

A. $125,7$ B. $125,10$ C. $135,9$ D. $135,10$

gateit-2008 co-and-architecture microprogramming normal

Answer key

2.17 Pipelining (43)

2.17.1 Pipelining: GATE CSE 1999 | Question: 13

An instruction pipeline consists of 4 stages – Fetch (F), Decode field (D), Execute (E) and Result Write (W). The 5 instructions in a certain instruction sequence need these stages for the different number of clock cycles as shown by the table below

Instruction	F	D	E	W
1	1	2	1	1
2	1	2	2	1
3	2	1	3	2
4	1	3	2	1
5	1	2	1	2

Find the number of clock cycles needed to perform the 5 instructions.

gate1999 co-and-architecture pipelining normal numerical-answers

Answer key☟

2.17.2 Pipelining: GATE CSE 2000 | Question: 1.8

Comparing the time T1 taken for a single instruction on a pipelined CPU with time T2 taken on a non-pipelined but identical CPU, we can say that

A. T1 ≤ T2
B. T1 ≥ T2
C. T1 < T2
D. T1 and T2 plus the time taken for one instruction fetch cycle

gatecse-2000 pipelining co-and-architecture easy

Answer key☟

2.17.3 Pipelining: GATE CSE 2000 | Question: 12

An instruction pipeline has five stages where each stage take 2 nanoseconds and all instruction use all five stages. Branch instructions are not overlapped. i.e., the instruction after the branch is not fetched till the branch instruction is completed. Under ideal conditions,

A. Calculate the average instruction execution time assuming that 20% of all instructions executed are branch instruction. Ignore the fact that some branch instructions may be conditional.
B. If a branch instruction is a conditional branch instruction, the branch need not be taken. If the branch is not taken, the following instructions can be overlapped. When 80% of all branch instructions are conditional branch instructions, and 50% of the conditional branch instructions are such that the branch is taken, calculate the average instruction execution time.

gatecse-2000 co-and-architecture pipelining normal descriptive

Answer key☟

2.17.4 Pipelining: GATE CSE 2001 | Question: 12

Consider a $5-$stage pipeline - IF (Instruction Fetch), ID (Instruction Decode and register read), EX (Execute), MEM (memory), and WB (Write Back). All (memory or register) reads take place in the second phase of a clock cycle and all writes occur in the first phase. Consider the execution of the following instruction sequence:

I1:	sub $r2, r3, r4$	/* $r2 \leftarrow r3 - r4$ */
I2:	sub $r4, r2, r3$	/* $r4 \leftarrow r2 - r3$ */
I3:	sw $r2, 100(r1)$	/* $M[r1 + 100] \leftarrow \text{r2}$ */
I4:	sub $r3, r4, r2$	/* $r3 \leftarrow r4 - r2$ */

A. Show all data dependencies between the four instructions.
B. Identify the data hazards.
C. Can all hazards be avoided by forwarding in this case.

gatecse-2001 co-and-architecture pipelining normal descriptive

Answer key☟

2.17.5 Pipelining: GATE CSE 2002 | Question: 2.6, ISRO2008-19

The performance of a pipelined processor suffers if:

A. the pipeline stages have different delays
B. consecutive instructions are dependent on each other
C. the pipeline stages share hardware resources
D. All of the above

gatecse-2002 co-and-architecture pipelining easy isro2008

Answer key

2.17.6 Pipelining: GATE CSE 2003 | Question: 10, ISRO-DEC2017-41

For a pipelined CPU with a single ALU, consider the following situations

I. The $j+1^{st}$ instruction uses the result of the j^{th} instruction as an operand
II. The execution of a conditional jump instruction
III. The j^{th} and $j+1^{st}$ instructions require the ALU at the same time.

Which of the above can cause a hazard

A. I and II only B. II and III only C. III only D. All the three

gatecse-2003 co-and-architecture pipelining normal isrodec2017

Answer key

2.17.7 Pipelining: GATE CSE 2004 | Question: 69

A 4-stage pipeline has the stage delays as 150, 120, 160 and 140 $nanoseconds$, respectively. Registers that are used between the stages have a delay of 5 $nanoseconds$ each. Assuming constant clocking rate, the total time taken to process 1000 data items on this pipeline will be:

A. 120.4 microseconds
B. 160.5 microseconds
C. 165.5 microseconds
D. 590.0 microseconds

gatecse-2004 co-and-architecture pipelining normal

Answer key

2.17.8 Pipelining: GATE CSE 2005 | Question: 68

A 5 stage pipelined CPU has the following sequence of stages:

- IF – instruction fetch from instruction memory
- RD – Instruction decode and register read
- EX – Execute: ALU operation for data and address computation
- MA – Data memory access – for write access, the register read at RD state is used.
- WB – Register write back

Consider the following sequence of instructions:

- I_1: $L\ R0, loc\ 1; R0 \Leftarrow M[loc1]$
- I_2: $A\ R0, R0; R0 \Leftarrow R0 + R0$
- I_3: $S\ R2, R0; R2 \Leftarrow R2 - R0$

Let each stage take one clock cycle.

What is the number of clock cycles taken to complete the above sequence of instructions starting from the fetch of I_1?

A. 8 B. 10 C. 12 D. 15

gatecse-2005 co-and-architecture pipelining normal

Answer key

2.17.9 Pipelining: GATE CSE 2006 | Question: 42

A CPU has a five-stage pipeline and runs at 1 GHz frequency. Instruction fetch happens in the first stage of the pipeline. A conditional branch instruction computes the target address and evaluates the condition in the third stage of the pipeline. The processor stops fetching new instructions following a conditional branch until the branch outcome is known. A program executes 10^9 instructions out of which 20% are conditional branches. If each instruction takes one cycle to complete on average, the total execution time of the program is:

A. 1.0 second
B. 1.2 seconds
C. 1.4 seconds
D. 1.6 seconds

gatecse-2006 co-and-architecture pipelining normal

Answer key

2.17.10 Pipelining: GATE CSE 2007 | Question: 37, ISRO2009-37

Consider a pipelined processor with the following four stages:

- IF: Instruction Fetch
- ID: Instruction Decode and Operand Fetch
- EX: Execute
- WB: Write Back

The IF, ID and WB stages take one clock cycle each to complete the operation. The number of clock cycles for the EX stage depends on the instruction. The ADD and SUB instructions need 1 clock cycle and the MUL instruction needs 3 clock cycles in the EX stage. Operand forwarding is used in the pipelined processor. What is the number of clock cycles taken to complete the following sequence of instructions?

$$\begin{array}{lll} \textbf{ADD} & \text{R2, R1, R0} & \text{R2} \leftarrow \text{R1+R0} \\ \textbf{MUL} & \text{R4, R3, R2} & \text{R4} \leftarrow \text{R3*R2} \\ \textbf{SUB} & \text{R6, R5, R4} & \text{R6} \leftarrow \text{R5−R4} \end{array}$$

A. 7
B. 8
C. 10
D. 14

gatecse-2007 co-and-architecture pipelining normal isro2009

Answer key

2.17.11 Pipelining: GATE CSE 2008 | Question: 36

Which of the following are NOT true in a pipelined processor?

I. Bypassing can handle all RAW hazards
II. Register renaming can eliminate all register carried WAR hazards
III. Control hazard penalties can be eliminated by dynamic branch prediction

A. I and II only
B. I and III only
C. II and III only
D. I, II and III

gatecse-2008 pipelining co-and-architecture normal

Answer key

2.17.12 Pipelining: GATE CSE 2008 | Question: 76

Delayed branching can help in the handling of control hazards

For all delayed conditional branch instructions, irrespective of whether the condition evaluates to true or false,

A. The instruction following the conditional branch instruction in memory is executed
B. The first instruction in the fall through path is executed
C. The first instruction in the taken path is executed
D. The branch takes longer to execute than any other instruction

gatecse-2008 co-and-architecture pipelining normal

Answer key

2.17.13 Pipelining: GATE CSE 2008 | Question: 77

Delayed branching can help in the handling of control hazards

The following code is to run on a pipelined processor with one branch delay slot:

I1: ADD $R2 \leftarrow R7 + R8$

I2: Sub $R4 \leftarrow R5 – R6$

I3: ADD $R1 \leftarrow R2 + R3$

I4: STORE Memory $[R4] \leftarrow R1$

BRANCH to Label if $R1 == 0$

Which of the instructions I1, I2, I3 or I4 can legitimately occupy the delay slot without any program modification?

A. I1
B. I2
C. I3
D. I4

gatecse-2008 co-and-architecture pipelining normal

Answer key

2.17.14 Pipelining: GATE CSE 2009 | Question: 28

Consider a 4 stage pipeline processor. The number of cycles needed by the four instructions $I1, I2, I3, I4$ in stages $S1, S2, S3, S4$ is shown below:

	S1	S2	S3	S4
I1	2	1	1	1
I2	1	3	2	2
I3	2	1	1	3
I4	1	2	2	2

What is the number of cycles needed to execute the following loop?

For (i=1 to 2) {I1; I2; I3; I4;}

A. 16
B. 23
C. 28
D. 30

gatecse-2009 co-and-architecture pipelining normal

Answer key

2.17.15 Pipelining: GATE CSE 2010 | Question: 33

A $5-$stage pipelined processor has Instruction Fetch (IF), Instruction Decode (ID), Operand Fetch (OF), Perform Operation (PO) and Write Operand (WO) stages. The IF, ID, OF and WO stages take 1 clock cycle each for any instruction. The PO stage takes 1 clock cycle for ADD and SUB instructions, 3 clock cycles for MUL instruction and 6 clock cycles for DIV instruction respectively. Operand forwarding is used in the pipeline. What is the number of clock cycles needed to execute the following sequence of instructions?

Instruction	Meaning of instruction
t_0: MUL R_2, R_0, R_1	$R_2 \leftarrow R_0 * R_1$
t_1: DIV R_5, R_3, R_4	$R_5 \leftarrow R_3 / R_4$
t_2: ADD R_2, R_5, R_2	$R_2 \leftarrow R_5 + R_2$
t_3 : SUB R_5, R_2, R_6	$R_5 \leftarrow R_2 - R_6$

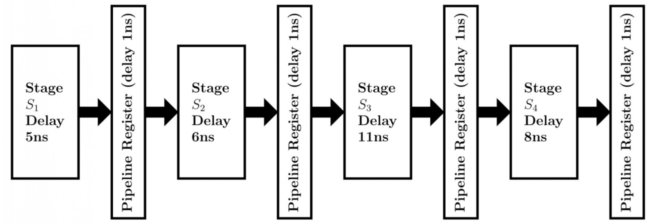
A. 13
B. 15
C. 17
D. 19

gatecse-2010 co-and-architecture pipelining normal

Answer key

2.17.16 Pipelining: GATE CSE 2011 | Question: 41

Consider an instruction pipeline with four stages $(\text{S1}, \text{S2}, \text{S3 and S4})$ each with combinational circuit only. The pipeline registers are required between each stage and at the end of the last stage. Delays for the stages and for the pipeline registers are as given in the figure.



What is the approximate speed up of the pipeline in steady state under ideal conditions when compared to the corresponding non-pipeline implementation?

A. 4.0 B. 2.5 C. 1.1 D. 3.0

gatecse-2011 co-and-architecture pipelining normal

Answer key

2.17.17 Pipelining: GATE CSE 2012 | Question: 20, ISRO2016-23

Register renaming is done in pipelined processors:

A. as an alternative to register allocation at compile time
B. for efficient access to function parameters and local variables
C. to handle certain kinds of hazards
D. as part of address translation

gatecse-2012 co-and-architecture pipelining easy isro2016

Answer key

2.17.18 Pipelining: GATE CSE 2013 | Question: 45

Consider an instruction pipeline with five stages without any branch prediction:

Fetch Instruction (FI), Decode Instruction (DI), Fetch Operand (FO), Execute Instruction (EI) and Write Operand (WO). The stage delays for FI, DI, FO, EI and WO are $5\text{ ns}, 7\text{ ns}, 10\text{ ns}, 8\text{ ns}$ and $6\text{ ns},$ respectively. There are intermediate storage buffers after each stage and the delay of each buffer is $1\text{ ns}.$ A program consisting of 12 instructions $\text{I1}, \text{I2}, \text{I3}, \dots, \text{I12}$ is executed in this pipelined processor. Instruction I4 is the only branch instruction and its branch target is $\text{I9}.$ If the branch is taken during the execution of this program, the time (in ns) needed to complete the program is

A. 132 B. 165
C. 176 D. 328

gatecse-2013 normal co-and-architecture pipelining

Answer key

2.17.19 Pipelining: GATE CSE 2014 Set 1 | Question: 43

Consider a 6-stage instruction pipeline, where all stages are perfectly balanced. Assume that there is no cycle-time overhead of pipelining. When an application is executing on this 6-stage pipeline, the speedup achieved with respect to non-pipelined execution if 25% of the instructions incur 2 pipeline stall cycles is ______

gatecse-2014-set1 co-and-architecture pipelining numerical-answers normal

Answer key

2.17.20 Pipelining: GATE CSE 2014 Set 3 | Question: 43

An instruction pipeline has five stages, namely, instruction fetch (IF), instruction decode and register fetch (ID/RF), instruction execution (EX), memory access (MEM), and register writeback (WB) with stage latencies 1 ns, 2.2 ns, 2 ns, 1 ns, and 0.75 ns, respectively (ns stands for nanoseconds). To gain in terms of frequency, the designers have decided to split the ID/RF stage into three stages (ID, RF1, RF2) each of latency $2.2/3$ ns. Also, the EX stage is split into two stages (EX1, EX2) each of latency 1 ns. The new design has a total of eight pipeline stages. A program has 20% branch instructions which execute in the EX stage and produce the next instruction pointer at the end of the EX stage in the old design and at the end of the EX2 stage in the new design. The IF stage stalls after fetching a branch instruction until the next instruction pointer is computed. All instructions other than the branch instruction have an average CPI of one in both the designs. The execution times of this program on the old and the new design are P and Q nanoseconds, respectively. The value of P/Q is __________.

gatecse-2014-set3 co-and-architecture pipelining numerical-answers normal

Answer key

2.17.21 Pipelining: GATE CSE 2014 Set 3 | Question: 9

Consider the following processors (ns stands for nanoseconds). Assume that the pipeline registers have zero latency.

- P1: Four-stage pipeline with stage latencies $1 \text{ ns}, 2 \text{ ns}, 2 \text{ ns}, 1 \text{ ns}$.
- P2: Four-stage pipeline with stage latencies $1 \text{ ns}, 1.5 \text{ ns}, 1.5 \text{ ns}, 1.5 \text{ ns}$.
- P3: Five-stage pipeline with stage latencies $0.5 \text{ ns}, 1 \text{ ns}, 1 \text{ ns}, 0.6 \text{ ns}, 1 \text{ ns}$.
- P4: Five-stage pipeline with stage latencies $0.5 \text{ ns}, 0.5 \text{ ns}, 1 \text{ ns}, 1 \text{ ns}, 1.1 \text{ ns}$.

Which processor has the highest peak clock frequency?

A. P1 B. P2 C. P3 D. P4

gatecse-2014-set3 co-and-architecture pipelining normal

Answer key

2.17.22 Pipelining: GATE CSE 2015 Set 1 | Question: 38

Consider a non-pipelined processor with a clock rate of 2.5 gigahertz and average cycles per instruction of four. The same processor is upgraded to a pipelined processor with five stages; but due to the internal pipeline delay, the clock speed is reduced to 2 gigahertz. Assume that there are no stalls in the pipeline. The speedup achieved in this pipelined processor is_______________.

gatecse-2015-set1 co-and-architecture pipelining normal numerical-answers

Answer key

2.17.23 Pipelining: GATE CSE 2015 Set 2 | Question: 44

Consider the sequence of machine instruction given below:

$$\begin{array}{ll} \text{MUL} & \text{R5, R0, R1} \\ \text{DIV} & \text{R6, R2, R3} \\ \text{ADD} & \text{R7, R5, R6} \\ \text{SUB} & \text{R8, R7, R4} \end{array}$$

In the above sequence, $R0$ to $R8$ are general purpose registers. In the instructions shown, the first register shows the result of the operation performed on the second and the third registers. This sequence of instructions is to be executed in a pipelined instruction processor with the following 4 stages: (1) Instruction Fetch and Decode (IF), (2) Operand Fetch (OF), (3) Perform Operation (PO) and (4) Write back the result (WB). The IF, OF and WB stages take 1 clock cycle each for any instruction. The PO stage takes 1 clock cycle for ADD and SUB instruction, 3 clock cycles for MUL instruction and 5 clock cycles for DIV instruction. The pipelined processor uses operand forwarding from the PO stage to the OF stage. The number of clock cycles taken for the execution of the above sequence of instruction is _________.

gatecse-2015-set2 co-and-architecture pipelining normal numerical-answers

Answer key

2.17.24 Pipelining: GATE CSE 2015 Set 3 | Question: 51

Consider the following reservation table for a pipeline having three stages S_1, S_2 and S_3.

Time →					
	1	2	3	4	5
S_1	X				X
S_2		X		X	
S_3			X		

The minimum average latency (MAL) is ______

gatecse-2015-set3 co-and-architecture pipelining difficult numerical-answers

Answer key

2.17.25 Pipelining: GATE CSE 2016 Set 1 | Question: 32

The stage delays in a 4-stage pipeline are $800, 500, 400$ and 300 picoseconds. The first stage (with delay 800 picoseconds) is replaced with a functionality equivalent design involving two stages with respective delays 600 and 350 picoseconds. The throughput increase of the pipeline is ___________ percent.

gatecse-2016-set1 co-and-architecture pipelining normal numerical-answers

Answer key

2.17.26 Pipelining: GATE CSE 2016 Set 2 | Question: 33

Consider a 3 GHz (gigahertz) processor with a three stage pipeline and stage latencies τ_1, τ_2 and τ_3 such that $\tau_1 = \dfrac{3\tau_2}{4} = 2\tau_3$. If the longest pipeline stage is split into two pipeline stages of equal latency , the new frequency is __________ GHz, ignoring delays in the pipeline registers.

gatecse-2016-set2 co-and-architecture pipelining normal numerical-answers

Answer key

2.17.27 Pipelining: GATE CSE 2017 Set 1 | Question: 50

Instruction execution in a processor is divided into 5 stages, *Instruction Fetch* (IF), *Instruction Decode* (ID), *Operand fetch* (OF), *Execute* (EX), and *Write Back* (WB). These stages take **5, 4, 20, 10** and **3 nanoseconds (ns)** respectively. A pipelined implementation of the processor requires buffering between each pair of consecutive stages with a delay of **2 ns**. Two pipelined implementation of the processor are contemplated:

i. a naive pipeline implementation (NP) with 5 stages and
ii. an efficient pipeline (EP) where the OF stage is divided into stages OF1 and OF2 with execution times of **12 ns** and **8 ns** respectively.

The speedup (correct to two decimal places) achieved by EP over NP in executing 20 independent instructions with no hazards is _________ .

gatecse-2017-set1 co-and-architecture pipelining normal numerical-answers

Answer key

2.17.28 Pipelining: GATE CSE 2018 | Question: 50

The instruction pipeline of a RISC processor has the following stages: Instruction Fetch (IF), Instruction Decode (ID), Operand Fetch (OF), Perform Operation (PO) and Writeback (WB), The IF, ID, OF and WB stages take 1 clock cycle each for every instruction. Consider a sequence of 100 instructions. In the PO

stage, 40 instructions take 3 clock cycles each, 35 instructions take 2 clock cycles each, and the remaining 25 instructions take 1 clock cycle each. Assume that there are no data hazards and no control hazards.

The number of clock cycles required for completion of execution of the sequence of instruction is _____.

gatecse-2018 co-and-architecture pipelining numerical-answers two-marks

Answer key☟

2.17.29 Pipelining: GATE CSE 2020 | Question: 43

Consider a non-pipelined processor operating at 2.5 GHz. It takes 5 clock cycles to complete an instruction. You are going to make a 5- stage pipeline out of this processor. Overheads associated with pipelining force you to operate the pipelined processor at 2 GHz. In a given program, assume that 30% are memory instructions, 60% are ALU instructions and the rest are branch instructions. 5% of the memory instructions cause stalls of 50 clock cycles each due to cache misses and 50% of the branch instructions cause stalls of 2 cycles each. Assume that there are no stalls associated with the execution of ALU instructions. For this program, the speedup achieved by the pipelined processor over the non-pipelined processor (round off to 2 decimal places) is____________.

gatecse-2020 numerical-answers co-and-architecture pipelining two-marks

Answer key☟

2.17.30 Pipelining: GATE CSE 2021 Set 1 | Question: 53

A five-stage pipeline has stage delays of $150, 120, 150, 160$ and 140 nanoseconds. The registers that are used between the pipeline stages have a delay of 5 nanoseconds each.
The total time to execute 100 independent instructions on this pipeline, assuming there are no pipeline stalls, is _______ nanoseconds.

gatecse-2021-set1 co-and-architecture pipelining numerical-answers two-marks

Answer key☟

2.17.31 Pipelining: GATE CSE 2021 Set 2 | Question: 53

Consider a pipelined processor with 5 stages, $\text{Instruction Fetch}(\text{IF})$, $\text{Instruction Decode}(\text{ID})$, Execute (EX), $\text{Memory Access (MEM)}$, and Write Back (WB). Each stage of the pipeline, except the EX stage, takes one cycle. Assume that the ID stage merely decodes the instruction and the register read is performed in the EX stage. The EX stage takes one cycle for ADD instruction and two cycles for MUL instruction. Ignore pipeline register latencies.

Consider the following sequence of 8 instructions:

$$\text{ADD, MUL, ADD, MUL, ADD, MUL, ADD, MUL}$$

Assume that every MUL instruction is data-dependent on the ADD instruction just before it and every ADD instruction (except the first ADD) is data-dependent on the MUL instruction just before it. The $speedup$ defined as follows.

$$Speedup = \frac{\text{Execution time without operand forwarding}}{\text{Execution time with operand forearding}}$$

The $Speedup$ achieved in executing the given instruction sequence on the pipelined processor (rounded to 2 decimal places) is _____________

gatecse-2021-set2 co-and-architecture pipelining numerical-answers two-marks

Answer key☟

2.17.32 Pipelining: GATE CSE 2022 | Question: 51

A processor X_1 operating at 2 GHz has a standard $5-$stage RISC instruction pipeline having a base $\text{CPI (cycles per instruction)}$ of one without any pipeline hazards. For a given program P that has 30% branch instructions, control hazards incur 2 cycles stall for every branch. A new version of the processor X_2 operating at same clock frequency has an additional branch predictor unit (BPU) that completely eliminates stalls for correctly predicted branches. There is neither any savings nor any additional stalls for wrong predictions. There are no structural hazards and data hazards for X_1 and X_2. If the BPU has a prediction accuracy of 80%, the speed up *(rounded off to two decimal places)* obtained by X_2 over X_1 in executing P is ________.

gatecse-2022 numerical-answers co-and-architecture pipelining stall two-marks

Answer key

2.17.33 Pipelining: GATE CSE 2023 | Question: 23

Consider a 3-stage pipelined processor having a delay of 10 ns (nanoseconds), 20 ns, and 14 ns, for the first, second, and the third stages, respectively. Assume that there is no other delay and the processor does not suffer from any pipeline hazards. Also assume that one instruction is fetched every cycle.

The total execution time for executing 100 instructions on this processor is ________ ns.

gatecse-2023 co-and-architecture pipelining numerical-answers one-mark

Answer key

2.17.34 Pipelining: GATE CSE 2024 | Set 1 | Question: 20

Consider a 5-stage pipelined processor with Instruction Fetch (IF), Instruction Decode (ID), Execute (EX), Memory Access (MEM), and Register Writeback (WB) stages. Which of the following statements about *forwarding* is/are CORRECT?

A. In a pipelined execution, forwarding means the result from a source stage of an earlier instruction is passed on to the destination stage of a later instruction
B. In forwarding, data from the output of the MEM stage can be passed on to the input of the EX stage of the next instruction
C. Forwarding cannot prevent all pipeline stalls
D. Forwarding does not require any extra hardware to retrieve the data from the pipeline stages

gatecse2024-set1 multiple-selects co-and-architecture pipelining one-mark

Answer key

2.17.35 Pipelining: GATE CSE 2024 | Set 2 | Question: 21

An instruction format has the following structure:

Instruction Number: *Opcode destination reg, source reg-*1*, source reg-*2

Consider the following sequence of instructions to be executed in a pipelined processor:

$I\,1$: DIV $R3, R1, R2$

$I\,2$: SUB $R5, R3, R4$

$I\,3$: ADD $R3, R5, R6$

$I\,4$: MUL $R7, R3, R8$

Which of the following statements is/are TRUE?

1. There is a RAW dependency on $R\,3$ between $I\,1$ and $I\,2$
2. There is a WAR dependency on $R\,3$ between $I\,1$ and $I\,3$
3. There is a RAW dependency on $R\,3$ between $I\,2$ and $I\,3$
4. There is a WAW dependency on $R\,3$ between $I\,3$ and $I\,4$

gatecse2024-set2 co-and-architecture multiple-selects pipelining one-mark

Answer key

2.17.36 Pipelining: GATE CSE 2024 | Set 2 | Question: 48

A non-pipelined instruction execution unit operating at 2GHz takes an average of 6 cycles to execute an instruction of a program P. The unit is then redesigned to operate on a 5 -stage pipeline at 2GHz. Assume that the ideal throughput of the pipelined unit is 1 instruction per cycle. In the execution of program P, 20% instructions incur an average of 2 cycles stall due to data hazards and 20% instructions incur an average of 3 cycles stall due to control hazards. The speedup (rounded off to one decimal place) obtained by the pipelined design over the non-pipelined design is ____________.

gatecse2024-set2 numerical-answers co-and-architecture pipelining two-marks

Answer key

2.17.37 Pipelining: GATE CSE 2025 | Set 2 | Question: 46

A 5-stage instruction pipeline has stage delays of $180, 250, 150, 170,$ and 250, respectively, in nanoseconds. The delay of an inter-stage latch is 10 nanoseconds. Assume that there are no pipeline stalls due to branches and other hazards. The time taken to process 1000 instructions in microseconds is __________. (rounded off to two decimal places)

gatecse2025-set2 co-and-architecture pipelining numerical-answers easy two-marks

Answer key

2.17.38 Pipelining: GATE IT 2004 | Question: 47

Consider a pipeline processor with 4 stages $S1$ to $S4$. We want to execute the following loop:

```
for (i = 1; i < = 1000; i++)
   {I1, I2, I3, I4}
```

where the time taken (in ns) by instructions $I1$ to $I4$ for stages $S1$ to $S4$ are given below:

	S_1	S_2	S_3	S_4
I1	1	2	1	2
I2	2	1	2	1
I3	1	1	2	1
I4	2	1	2	1

The output of $I1$ for $i = 2$ will be available after

A. 11 ns
B. 12 ns
C. 13 ns
D. 28 ns

gateit-2004 co-and-architecture pipelining normal

Answer key

2.17.39 Pipelining: GATE IT 2005 | Question: 44

We have two designs $D1$ and $D2$ for a synchronous pipeline processor. $D1$ has 5 pipeline stages with execution times of 3 nsec, 2 nsec, 4 nsec, 2 nsec and 3 nsec while the design $D2$ has 8 pipeline stages each with 2 nsec execution time How much time can be saved using design $D2$ over design $D1$ for executing 100 instructions?

A. 214 nsec
B. 202 nsec
C. 86 nsec
D. -200 nsec

gateit-2005 co-and-architecture pipelining normal

Answer key

2.17.40 Pipelining: GATE IT 2006 | Question: 78

A pipelined processor uses a $4-$stage instruction pipeline with the following stages: Instruction fetch (IF), Instruction decode (ID), Execute (EX) and Writeback (WB). The arithmetic operations as well as the load and store operations are carried out in the EX stage. The sequence of instructions corresponding to the statement $X = (S - R * (P + Q))/T$ is given below. The values of variables P, Q, R, S and T are available in the registers $R0, R1, R2, R3$ and $R4$ respectively, before the execution of the instruction sequence.

$$\begin{array}{lll}
\text{ADD} & \text{R5, R0, R1} & ; \text{R5} \leftarrow \text{R0} + \text{R1} \\
\text{MUL} & \text{R6, R2, R5} & ; \text{R6} \leftarrow \text{R2 * R5} \\
\text{SUB} & \text{R5, R3, R6} & ; \text{R5} \leftarrow \text{R3 - R6} \\
\text{DIV} & \text{R6, R5, R4} & ; \text{R6} \leftarrow \text{R5/R4} \\
\text{STORE} & \text{R6, X} & ; \text{X} \leftarrow \text{R6}
\end{array}$$

The number of Read-After-Write (RAW) dependencies, Write-After-Read(WAR) dependencies, and Write-After-Write (WAW) dependencies in the sequence of instructions are, respectively,

A. $2,2,4$ B. $3,2,3$ C. $4,2,2$ D. $3,3,2$

gateit-2006 co-and-architecture pipelining normal

Answer key☟

2.17.41 Pipelining: GATE IT 2006 | Question: 79

A pipelined processor uses a 4-stage instruction pipeline with the following stages: Instruction fetch (IF), Instruction decode (ID), Execute (EX) and Writeback (WB). The arithmetic operations as well as the load and store operations are carried out in the EX stage. The sequence of instructions corresponding to the statement $X = (S - R * (P + Q))/T$ is given below. The values of variables P, Q, R, S and T are available in the registers $R0, R1, R2, R3$ and $R4$ respectively, before the execution of the instruction sequence.

$$\begin{array}{lll}
\text{ADD} & R5, R0, R1 & ; R5 \leftarrow \text{R0} + \text{R1} \\
\text{MUL} & R6, R2, R5 & ; R6 \leftarrow \text{R2 * R5} \\
\text{SUB} & R5, R3, R6 & ; R5 \leftarrow \text{R3 -R6} \\
\text{DIV} & R6, R5, R4 & ; R6 \leftarrow \text{R5/R4} \\
\text{STORE} & R6, X & ; X \leftarrow \text{R6}
\end{array}$$

The IF, ID and WB stages take 1 clock cycle each. The EX stage takes 1 clock cycle each for the ADD, SUB and STORE operations, and 3 clock cycles each for MUL and DIV operations. Operand forwarding from the EX stage to the ID stage is used. The number of clock cycles required to complete the sequence of instructions is

A. 10 B. 12 C. 14 D. 16

gateit-2006 co-and-architecture pipelining normal

Answer key☟

2.17.42 Pipelining: GATE IT 2007 | Question: 6, ISRO2011-25

A processor takes 12 cycles to complete an instruction I. The corresponding pipelined processor uses 6 stages with the execution times of $3, 2, 5, 4, 6$ and 2 cycles respectively. What is the asymptotic speedup assuming that a very large number of instructions are to be executed?

A. 1.83 B. 2 C. 3 D. 6

gateit-2007 co-and-architecture pipelining normal isro2011

Answer key☟

2.17.43 Pipelining: GATE IT 2008 | Question: 40

A non pipelined single cycle processor operating at 100 MHz is converted into a synchronous pipelined processor with five stages requiring 2.5 nsec, 1.5 nsec, 2 nsec, 1.5 nsec and 2.5 nsec, respectively. The delay of the latches is 0.5 nsec. The speedup of the pipeline processor for a large number of instructions is:

A. 4.5 B. 4.0 C. 3.33 D. 3.0

gateit-2008 co-and-architecture pipelining normal

Answer key☟

2.18 Runtime Environment (2)

2.18.1 Runtime Environment: GATE CSE 2001 | Question: 1.10, UGCNET-Dec2012-III: 36

Suppose a processor does not have any stack pointer registers, which of the following statements is true?

A. It cannot have subroutine call instruction
B. It cannot have nested subroutines call
C. Interrupts are not possible
D. All subroutine calls and interrupts are possible

gatecse-2001 co-and-architecture normal ugcnetcse-dec2012-paper3 runtime-environment

Answer key☟

2.18.2 Runtime Environment: GATE CSE 2008 | Question: 37, ISRO2009-38

The use of multiple register windows with overlap causes a reduction in the number of memory accesses for:

I. Function locals and parameters
II. Register saves and restores
III. Instruction fetches

A. I only
B. II only
C. III only
D. I, II and III

gatecse-2008 co-and-architecture normal isro2009 runtime-environment

Answer key☟

2.19 Speedup (4)

2.19.1 Speedup: GATE CSE 2014 Set 1 | Question: 55

Consider two processors P_1 and P_2 executing the same instruction set. Assume that under identical conditions, for the same input, a program running on P_2 takes 25% less time but incurs 20% more CPI (clock cycles per instruction) as compared to the program running on P_1. If the clock frequency of P_1 is $1 \mathrm{GHZ}$, then the clock frequency of P_2 (in GHz) is ______.

gatecse-2014-set1 co-and-architecture numerical-answers normal speedup

Answer key☟

2.19.2 Speedup: GATE CSE 2024 | Set 1 | Question: 45

The baseline execution time of a program on a $2 \mathrm{GHz}$ single core machine is 100 nanoseconds (ns). The code corresponding to 90% of the execution time can be fully parallelized. The overhead for using an additional core is $10\ ns$ when running on a multicore system. Assume that all cores in the multicore system run their share of the parallelized code for an equal amount of time.

The number of cores that minimize the execution time of the program is __________.

gatecse2024-set1 numerical-answers co-and-architecture speedup two-marks

Answer key☟

2.19.3 Speedup: GATE IT 2004 | Question: 50

In an enhancement of a design of a CPU, the speed of a floating point unit has been increased by 20% and the speed of a fixed point unit has been increased by 10%. What is the overall speedup achieved if the ratio of the number of floating point operations to the number of fixed point operations is $2:3$ and the floating point operation used to take twice the time taken by the fixed point operation in the original design?

A. 1.155
B. 1.185
C. 1.255
D. 1.285

gateit-2004 normal co-and-architecture speedup

Answer key☟

2.19.4 Speedup: GATE IT 2007 | Question: 36

The floating point unit of a processor using a design D takes $2t$ cycles compared to t cycles taken by the fixed point unit. There are two more design suggestions D_1 and D_2. D_1 uses 30% more cycles for fixed point unit but 30% less cycles for floating point unit as compared to design D. D_2 uses 40% less cycles for fixed point unit but 10% more cycles for floating point unit as compared to design D. For a given program which has 80% fixed point operations and 20% floating point operations, which of the following ordering reflects the relative performances of three designs?
($D_i > D_j$ denotes that D_i is faster than D_j)

A. $D_1 > D > D_2$
B. $D_2 > D > D_1$
C. $D > D_2 > D_1$
D. $D > D_1 > D_2$

gateit-2007 co-and-architecture normal speedup

Answer key

2.20 Virtual Memory (3)

2.20.1 Virtual Memory: GATE CSE 1991 | Question: 03,iii

The total size of address space in a virtual memory system is limited by:

A. the length of MAR
B. the available secondary storage
C. the available main memory
D. all of the above
E. none of the above

gate1991 co-and-architecture virtual-memory normal multiple-selects

Answer key

2.20.2 Virtual Memory: GATE CSE 2004 | Question: 47

Consider a system with a two-level paging scheme in which a regular memory access takes 150 $nanoseconds$, and servicing a page fault takes 8 $milliseconds$. An average instruction takes 100 nanoseconds of CPU time, and two memory accesses. The TLB hit ratio is 90%, and the page fault rate is one in every $10,000$ instructions. What is the effective average instruction execution time?

A. 645 nanoseconds
B. 1050 nanoseconds
C. 1215 nanoseconds
D. 1230 nanoseconds

gatecse-2004 co-and-architecture virtual-memory normal

Answer key

2.20.3 Virtual Memory: GATE CSE 2008 | Question: 38

In an instruction execution pipeline, the earliest that the data TLB (Translation Lookaside Buffer) can be accessed is:

A. before effective address calculation has started
B. during effective address calculation
C. after effective address calculation has completed
D. after data cache lookup has completed

gatecse-2008 co-and-architecture virtual-memory normal

Answer key

Answer Keys

2.1.1	C	2.1.2	N/A	2.1.3	N/A	2.1.4	N/A	2.1.5	B
2.1.6	D	2.1.7	A;B;C;D	2.1.8	C	2.1.9	A	2.1.10	B
2.1.11	C	2.1.12	B	2.1.13	C	2.1.14	C	2.1.15	D
2.1.16	D	2.1.17	D	2.1.18	D	2.2.1	11.83:11.87	2.2.2	4:4

2.3.1	A;B;C;D	2.3.2	D	2.4.1	N/A	2.4.2	N/A	2.4.3	True
2.4.4	22	2.4.5	180	2.4.6	N/A	2.4.7	D	2.4.8	D
2.4.9	61.25	2.4.10	N/A	2.4.11	B	2.4.12	B	2.4.13	N/A
2.4.14	N/A	2.4.15	C	2.4.16	A	2.4.17	A	2.4.18	D
2.4.19	C	2.4.20	B	2.4.21	D	2.4.22	C	2.4.23	A
2.4.24	A	2.4.25	D	2.4.26	B	2.4.27	C	2.4.28	D
2.4.29	C	2.4.30	C	2.4.31	D	2.4.32	C	2.4.33	A
2.4.34	A	2.4.35	A	2.4.36	D	2.4.37	D	2.4.38	20
2.4.39	1.68	2.4.40	14	2.4.41	A	2.4.42	24	2.4.43	30
2.4.44	0.05	2.4.45	76	2.4.46	14	2.4.47	A	2.4.48	4.7 : 4.8
2.4.49	18	2.4.50	B	2.4.51	D	2.4.52	160	2.4.53	13.3:13.3;13.5:13.5
2.4.54	B	2.4.55	17 : 17	2.4.56	2 : 2	2.4.57	A	2.4.58	A;B;D
2.4.59	0.85	2.4.60	A;B;D	2.4.61	19	2.4.62	B;C	2.4.63	3
2.4.64	A	2.4.65	A	2.4.66	C	2.4.67	B	2.4.68	C
2.4.69	C	2.4.70	A	2.4.71	B	2.4.72	D	2.4.73	A
2.5.1	3.0:3.0	2.6.1	D	2.6.2	B	2.6.3	A	2.6.4	456
2.6.5	80000 : 80000	2.6.6	A	2.6.7	C	2.6.8	C	2.6.9	C
2.7.1	B	2.7.2	B	2.8.1	N/A	2.8.2	D	2.8.3	B
2.8.4	B	2.8.5	28	2.8.6	C	2.8.7	A;B;C	2.9.1	True
2.9.2	True	2.9.3	False	2.9.4	A	2.9.5	1.4 : 1.5	2.9.6	B
2.9.7	B	2.10.1	False	2.10.2	N/A	2.10.3	C	2.10.4	C
2.10.5	A	2.10.6	-16.0	2.11.1	N/A	2.11.2	256	2.11.3	True
2.11.4	16383	2.11.5	500	2.11.6	32	2.11.7	14	2.11.8	32
2.11.9	34	2.12.1	D	2.13.1	D	2.13.2	B	2.13.3	A
2.13.4	A	2.13.5	B	2.13.6	C	2.13.7	C	2.13.8	10.2
2.13.9	A	2.14.1	N/A	2.14.2	N/A	2.14.3	N/A	2.14.4	B
2.14.5	A	2.14.6	D	2.14.7	B	2.14.8	C	2.14.9	B
2.14.10	D	2.14.11	A	2.14.12	C	2.14.13	D	2.14.14	D
2.14.15	16	2.14.16	50 : 50	2.14.17	B	2.14.18	B	2.14.19	D
2.14.20	C	2.14.21	A	2.15.1	N/A	2.15.2	D	2.15.3	31
2.15.4	59 : 60	2.15.5	A	2.15.6	C	2.16.1	B	2.16.2	N/A
2.16.3	C	2.16.4	C	2.16.5	B	2.16.6	D	2.16.7	A
2.16.8	D	2.16.9	A	2.16.10	D	2.16.11	B	2.16.12	D
2.16.13	D	2.17.1	15	2.17.2	B	2.17.3	N/A	2.17.4	N/A
2.17.5	D	2.17.6	D	2.17.7	C	2.17.8	A	2.17.9	C
2.17.10	B	2.17.11	B	2.17.12	A	2.17.13	D	2.17.14	B
2.17.15	B	2.17.16	B	2.17.17	C	2.17.18	B	2.17.19	4
2.17.20	1.50 : 1.60	2.17.21	C	2.17.22	3.2	2.17.23	13	2.17.24	3

2.17.25	33.0 : 34.0
2.17.30	17160 : 17160
2.17.35	A
2.17.40	C
2.18.2	A
2.20.1	A;B

2.17.26	4
2.17.31	1.87 : 1.88
2.17.36	3
2.17.41	B
2.19.1	1.6
2.20.2	D

2.17.27	1.50 : 1.51
2.17.32	1.42:1.45
2.17.37	260.20:261.20
2.17.42	B
2.19.2	3
2.20.3	C

2.17.28	219
2.17.33	2040
2.17.38	C
2.17.43	C
2.19.3	A

2.17.29	2.15:2.18
2.17.34	A;B;C
2.17.39	B
2.18.1	X
2.19.4	B

3 Compiler Design (234)

Lexical analysis, Parsing, Syntax-directed translation, Runtime environments, Intermediate code generation.

Mark Distribution in Previous GATE

Year	2025 - 1	2025 - 2	2024 - 1	2024 - 2	2023	2022	2021 - 1	2021 - 2	Minimum	Average	Maximu
1 Mark Count	2	2	2	2	1	2	1	2	1	1.75	2
2 Marks Count	2	2	4	3	3	1	3	2	1	2.5	4
Total Marks	6	6	10	8	7	4	7	6	**4**	**6.75**	**10**

3.1 Assembler (9)

3.1.1 Assembler: GATE CSE 1992 | Question: 01,viii

The purpose of instruction location counter in an assembler is _______

gate1992 compiler-design assembler normal fill-in-the-blanks

Answer key

3.1.2 Assembler: GATE CSE 1992 | Question: 03,ii

Mention the pass number for each of the following activities that occur in a two pass assembler:

A. object code generation
B. literals added to literal table
C. listing printed
D. address resolution of local symbols

gate1992 compiler-design assembler easy

Answer key

3.1.3 Assembler: GATE CSE 1992 | Question: 3,i

Write short answers to the following:

i. Which of the following macros can put a macro assembler into an infinite loop?

.MACRO M1,X .IF EQ,X M1 X+1 .ENDC .IF NE,X .WORD X .ENDC .ENDM	.MACRO M2,X .IF EQ,X M2 X .ENDC .IF NE,X .WORD X+1 .ENDC .ENDM

Give an example call that does so.

gate1992 compiler-design assembler normal descriptive

Answer key

3.1.4 Assembler: GATE CSE 1993 | Question: 7.6

A simple two-pass assembler does the following in the first pass:

A. It allocates space for the literals.
B. It computes the total length of the program.
C. It builds the symbol table for the symbols and their values.
D. It generates code for all the load and store register instructions.
E. None of the above.

gate1993 compiler-design assembler easy multiple-selects

Answer key

3.1.5 Assembler: GATE CSE 1994 | Question: 17a

State whether the following statements are True or False with reasons for your answer:

Coroutine is just another name for a subroutine.

gate1994 compiler-design normal assembler true-false descriptive

Answer key☟

3.1.6 Assembler: GATE CSE 1994 | Question: 17b

State whether the following statements are True or False with reasons for your answer:

A two pass assembler uses its machine opcode table in the first pass of assembly.

gate1994 compiler-design normal assembler true-false descriptive

Answer key☟

3.1.7 Assembler: GATE CSE 1994 | Question: 18a

State whether the following statements are True or False with reasons for your answer

A subroutine cannot always be used to replace a macro in an assembly language program.

gate1994 compiler-design normal assembler true-false descriptive

Answer key☟

3.1.8 Assembler: GATE CSE 1994 | Question: 18b

State whether the following statements are True or False with reasons for your answer

A symbol declared as ‘external’ in an assembly language program is assigned an address outside the program by the assembler itself.

gate1994 compiler-design normal assembler true-false descriptive

Answer key☟

3.1.9 Assembler: GATE CSE 1996 | Question: 1.17

The pass numbers for each of the following activities

i. object code generation
ii. literals added to literal table
iii. listing printed
iv. address resolution of local symbols that occur in a two pass assembler

respectively are

A. $1,2,1,2$ B. $2,1,2,1$ C. $2,1,1,2$ D. $1,2,2,2$

gate1996 compiler-design normal assembler

Answer key☟

3.2 Backpatching (1)

3.2.1 Backpatching: GATE CSE 2025 | Set 2 | Question: 11

Consider the following statements about the use of backpatching in a compiler for intermediate code generation:

I. Backpatching can be used to generate code for Boolean expression in one pass.
II. Back[atching can be used to generate code for flow-of-control statements in one pass.

Which ONE of the folloeing options is CORRECT?

A. Only I is correct
B. Only II is correct
C. Both I and II are correct
D. Neither I nor II is correct

gatecse2025-set2 compiler-design backpatching intermediate-code one-mark

Answer key

3.3 Basic Blocks (1)

3.3.1 Basic Blocks: GATE CSE 2025 | Set 1 | Question: 42

Refer to the given 3-address code sequence. This code sequence is split into basic blocks. The number of basic blocks is ________. (Answer in integer)

```
1001: i = 1
1002: j = 1
1003: t1 = 10*i
1004: t2 = t1+j
1005: t3 = 8*t2
1006: t4 = t3-88
1007: a[t4] = 0.0
1008: j = j+1
1009: if j <= 10 goto 1003
1010: i = i+1
1011: if i <= 10 goto 1002
1012: i = 1
1013: t5 = i-1
1014: t6 = 88*t5
1015: a[t6] = 1.0
1016: i = i+1
1017: if i <= 10 goto 1013
```

gatecse2025-set1 compiler-design three-address-code basic-blocks numerical-answers easy two-marks

Answer key

3.4 Code Optimization (10)

3.4.1 Code Optimization: GATE CSE 2006 | Question: 55

Consider these two functions and two statements S1 and S2 about them.

<table><tr><td>

```
int work1(int *a, int i, int j)
{
   int x = a[i+2];
   a[j] = x+1;
   return a[i+2] - 3;
}
```

</td><td>

```
int work2(int *a, int i, int j)
{
   int t1 = i+2;
   int t2 = a[t1];
   a[j] = t2+1;
   return t2 - 3;
}
```

</td></tr></table>

S1: The transformation form *work1* to *work2* is valid, i.e., for any program state and input arguments, *work2* will compute the same output and have the same effect on program state as *work1*

S2: All the transformations applied to *work1* to get *work2* will always improve the performance (i.e reduce CPU time) of *work2* compared to *work1*

A. S1 is false and S2 is false
B. S1 is false and S2 is true
C. S1 is true and S2 is false
D. S1 is true and S2 is true

gatecse-2006 compiler-design normal code-optimization

Answer key

3.4.2 Code Optimization: GATE CSE 2006 | Question: 60

Consider the following C code segment.

```
for (i = 0, i < n; i++)
{
   for (j = 0; j < n; j++)
   {
      if (i%2)
      {
```

```
        x += (4*j + 5*i);
        y += (7 + 4*j);
      }
    }
}
```

Which one of the following is false?

A. The code contains loop invariant computation
B. There is scope of common sub-expression elimination in this code
C. There is scope of strength reduction in this code
D. There is scope of dead code elimination in this code

gatecse-2006 compiler-design code-optimization

Answer key

3.4.3 Code Optimization: GATE CSE 2008 | Question: 12

Some code optimizations are carried out on the intermediate code because

A. They enhance the portability of the compiler to the target processor
B. Program analysis is more accurate on intermediate code than on machine code
C. The information from dataflow analysis cannot otherwise be used for optimization
D. The information from the front end cannot otherwise be used for optimization

gatecse-2008 normal code-optimization compiler-design

Answer key

3.4.4 Code Optimization: GATE CSE 2014 Set 1 | Question: 17

Which one of the following is **FALSE**?

A. A basic block is a sequence of instructions where control enters the sequence at the beginning and exits at the end.
B. Available expression analysis can be used for common subexpression elimination.
C. Live variable analysis can be used for dead code elimination.
D. $x = 4 * 5 \Rightarrow x = 20$ is an example of common subexpression elimination.

gatecse-2014-set1 compiler-design code-optimization normal

Answer key

3.4.5 Code Optimization: GATE CSE 2014 Set 3 | Question: 11

The minimum number of arithmetic operations required to evaluate the polynomial $P(X) = X^5 + 4X^3 + 6X + 5$ for a given value of X, using only one temporary variable is ______.

gatecse-2014-set3 compiler-design numerical-answers normal code-optimization

Answer key

3.4.6 Code Optimization: GATE CSE 2014 Set 3 | Question: 34

Consider the basic block given below.

```
a = b + c
c = a + d
d = b + c
e = d - b
a = e + b
```

The minimum number of nodes and edges present in the DAG representation of the above basic block respectively are

A. 6 and 6 B. 8 and 10 C. 9 and 12 D. 4 and 4

gatecse-2014-set3 compiler-design code-optimization directed-acyclic-graph normal

Answer key

3.4.7 Code Optimization: GATE CSE 2015 Set 2 | Question: 14

In the context of abstract-syntax-tree (AST) and control-flow-graph (CFG), which one of the following is TRUE?

A. In both AST and CFG, let node N_2 be the successor of node N_1. In the input program, the code corresponding to N_2 is present after the code corresponding to N_1
B. For any input program, neither AST nor CFG will contain a cycle
C. The maximum number of successors of a node in an AST and a CFG depends on the input program
D. Each node in AST and CFG corresponds to at most one statement in the input program

gatecse-2015-set2 compiler-design easy abstract-syntax-tree code-optimization

Answer key

3.4.8 Code Optimization: GATE CSE 2021 Set 1 | Question: 50

Consider the following C code segment:

```
a = b + c;
e = a + 1;
d = b + c;
f = d + 1;
g = e + f;
```

In a compiler, this code segment is represented internally as a directed acyclic graph (DAG). The number of nodes in the DAG is _____________

gatecse-2021-set1 compiler-design code-optimization directed-acyclic-graph numerical-answers two-marks

Answer key

3.4.9 Code Optimization: GATE CSE 2021 Set 2 | Question: 30

Consider the following ANSI C code segment:

```
z=x + 3 + y->f1 + y->f2;
for (i = 0; i < 200; i = i + 2)
{
  if (z > i)
  {
    p = p + x + 3;
    q = q + y->f1;
  } else
  {
    p = p + y->f2;
    q = q + x + 3;
  }
}
```

Assume that the variable y points to a **struct** (allocated on the heap) containing two fields **f1** and **f2**, and the local variables **x, y, z, p, q,** and **i** are allotted registers. Common sub-expression elimination (CSE) optimization is applied on the code. The number of addition and the dereference operations (of the form **y** $->$**f1** or **y** $->$**f2**) in the optimized code, respectively, are:

A. 403 and 102
B. 203 and 2
C. 303 and 102
D. 303 and 2

gatecse-2021-set2 code-optimization compiler-design two-marks

Answer key

3.4.10 Code Optimization: GATE CSE 2025 | Set 1 | Question: 3

Which ONE of the following techniques used in compiler code optimization uses live variable analysis?

A. Run-time function call management
B. Register assignment to variables

C. Strength reduction

D. Constant folding

gatecse2025-set1 compiler-design code-optimization easy one-mark

Answer key

3.5 Compilation Phases (12)

3.5.1 Compilation Phases: GATE CSE 1987 | Question: 1-xi

In a compiler the module that checks every character of the source text is called:

A. The code generator.

B. The code optimiser.

C. The lexical analyser.

D. The syntax analyser.

gate1987 compiler-design compilation-phases

Answer key

3.5.2 Compilation Phases: GATE CSE 1990 | Question: 2-ix

Match the pairs in the following questions:

(a)	Lexical analysis	(p)	DAG's
(b)	Code optimization	(q)	Syntax trees
(c)	Code generation	(r)	Push down automaton
(d)	Abelian groups	(s)	Finite automaton

gate1990 match-the-following compiler-design compilation-phases

Answer key

3.5.3 Compilation Phases: GATE CSE 2005 | Question: 61

Consider line number 3 of the following C-program.

```
int main() {              /*Line 1 */
  int I, N;             /*Line 2 */
  fro (I=0, I<N, I++); /*Line 3 */
}
```

Identify the compiler's response about this line while creating the object-module:

A. No compilation error

B. Only a lexical error

C. Only syntactic errors

D. Both lexical and syntactic errors

gatecse-2005 compiler-design compilation-phases normal

Answer key

3.5.4 Compilation Phases: GATE CSE 2009 | Question: 17

Match all items in Group 1 with the correct options from those given in Group 2.

Group 1		Group 2	
P.	Regular Expression	1.	Syntax analysis
Q.	Pushdown automata	2.	Code generation
R.	Dataflow analysis	3.	Lexical analysis
S.	Register allocation	4.	Code optimization

A. P-4, Q-1, R-2, S-3

B. P-3, Q-1, R-4, S-2

C. P-3, Q-4, R-1, S-2

D. P-2, Q-1, R-4, S-3

gatecse-2009 compiler-design easy compilation-phases match-the-following

Answer key

3.5.5 Compilation Phases: GATE CSE 2015 Set 2 | Question: 19

Match the following:

P.	Lexical analysis	1.	Graph coloring
Q.	Parsing	2.	DFA minimization
R.	Register allocation	3.	Post-order traversal
S.	Expression evaluation	4.	Production tree

A. P-2, Q-3, R-1, S-4
B. P-2, Q-1, R-4, S-3
C. P-2, Q-4, R-1, S-3
D. P-2, Q-3, R-4, S-1

gatecse-2015-set2 compiler-design normal compilation-phases match-the-following

Answer key

3.5.6 Compilation Phases: GATE CSE 2016 Set 2 | Question: 19

Match the following:

(P)	Lexical analysis	(i)	Leftmost derivation
(Q)	Top down parsing	(ii)	Type checking
(R)	Semantic analysis	(iii)	Regular expressions
(S)	Runtime environment	(iv)	Activation records

A. $P \leftrightarrow i, Q \leftrightarrow ii, R \leftrightarrow iv, S \leftrightarrow iii$
B. $P \leftrightarrow iii, Q \leftrightarrow i, R \leftrightarrow ii, S \leftrightarrow iv$
C. $P \leftrightarrow ii, Q \leftrightarrow iii, R \leftrightarrow i, S \leftrightarrow iv$
D. $P \leftrightarrow iv, Q \leftrightarrow i, R \leftrightarrow ii, S \leftrightarrow iii$

gatecse-2016-set2 compiler-design easy match-the-following compilation-phases

Answer key

3.5.7 Compilation Phases: GATE CSE 2017 Set 2 | Question: 05

Match the following according to input (from the left column) to the compiler phase (in the right column) that processes it:

P. Syntax tree	i. Code generator
Q. Character stream	ii. Syntax analyser
R. Intermediate representation	iii. Semantic analyser
S. Token stream	iv. Lexical analyser

A. P-ii; Q-iii; R-iv; S-i
B. P-ii; Q-i; R-iii; S-iv
C. P-iii; Q-iv; R-i; S-ii
D. P-i; Q-iv; R-ii; S-iii

gatecse-2017-set2 compiler-design match-the-following compilation-phases easy

Answer key

3.5.8 Compilation Phases: GATE CSE 2018 | Question: 8

Which one of the following statements is FALSE?

A. Context-free grammar can be used to specify both lexical and syntax rules
B. Type checking is done before parsing
C. High-level language programs can be translated to different Intermediate Representations
D. Arguments to a function can be passed using the program stack

gatecse-2018 compiler-design easy compilation-phases one-mark

Answer key

3.5.9 Compilation Phases: GATE CSE 2020 | Question: 9

Consider the following statements.

I. Symbol table is accessed only during lexical analysis and syntax analysis.
II. Compilers for programming languages that support recursion necessarily need heap storage for memory allocation in the run-time environment.
III. Errors violating the condition '*any variable must be declared before its use*' are detected during syntax analysis.

Which of the above statements is/are TRUE?

A. I only
B. I and III only
C. II only
D. None of I, II and III

gatecse-2020 compiler-design compilation-phases runtime-environment one-mark

Answer key

3.5.10 Compilation Phases: GATE CSE 2021 Set 2 | Question: 3

Consider the following ANSI C program:

```
int main () {
    Integer x;
    return 0;
}
```

Which one of the following phases in a seven-phase C compiler will throw an error?

A. Lexical analyzer
B. Syntax analyzer
C. Semantic analyzer
D. Machine dependent optimizer

gatecse-2021-set2 compilation-phases compiler-design one-mark

Answer key

3.5.11 Compilation Phases: GATE CSE 2023 | Question: 1

Consider the following statements regarding the front-end and back-end of a compiler.

S1: The front-end includes phases that are independent of the target hardware.
S2: The back-end includes phases that are specific to the target hardware.
S3: The back-end includes phases that are specific to the programming language used in the source code.

Identify the CORRECT option.

A. Only $\mathbf{S1}$ is TRUE.
B. Only $\mathbf{S1}$ and $\mathbf{S2}$ are TRUE.
C. $\mathbf{S1}, \mathbf{S2}$, and $\mathbf{S3}$ are all TRUE.
D. Only $\mathbf{S1}$ and $\mathbf{S3}$ are TRUE.

gatecse-2023 compiler-design compilation-phases one-mark

Answer key

3.5.12 Compilation Phases: GATE CSE 2024 | Set 2 | Question: 11

Consider the following two sets:

	Set X		Set Y
P.	Lexical Analyzer	1.	Abstract Syntax Tree
Q.	Syntax Analyzer	2.	Token
R.	Intermediate Code Generator	3.	Parse Tree
S.	Code Optimizer	4.	Constant Folding

Which one of the following options is the CORRECT match from ***Set X to Set Y***?

A. $\text{P} - 4; \text{Q} - 1; \text{R} - 3; \text{S} - 2$
B. $\text{P} - 2; \text{Q} - 3; \text{R} - 1; \text{S} - 4$
C. $\text{P} - 2; \text{Q} - 1; \text{R} - 3; \text{S} - 4$
D. $\text{P} - 4; \text{Q} - 3; \text{R} - 2; \text{S} - 1$

gatecse2024-set2 compiler-design compilation-phases match-the-following easy one-mark

Answer key

3.6 Expression Evaluation (2)

3.6.1 Expression Evaluation: GATE CSE 2002 | Question: 2.19

To evaluate an expression without any embedded function calls

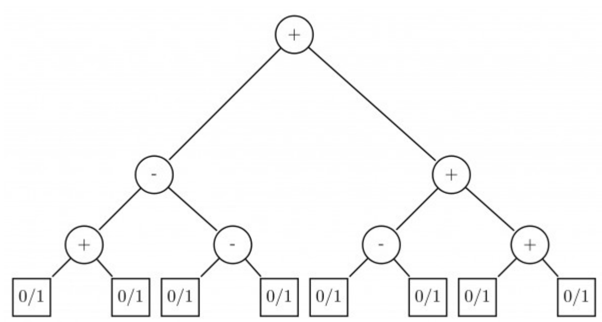
A. One stack is enough
B. Two stacks are needed
C. As many stacks as the height of the expression tree are needed
D. A Turing machine is needed in the general case

gatecse-2002 compiler-design expression-evaluation easy

Answer key

3.6.2 Expression Evaluation: GATE CSE 2014 Set 2 | Question: 39

Consider the expression tree shown. Each leaf represents a numerical value, which can either be 0 or 1. Over all possible choices of the values at the leaves, the maximum possible value of the expression represented by the tree is ___.



gatecse-2014-set2 compiler-design normal expression-evaluation numerical-answers

Answer key

3.7 First and Follow (6)

3.7.1 First and Follow: GATE CSE 1992 | Question: 02,xiii

For a context free grammar, FOLLOW(A) is the set of terminals that can appear immediately to the right of non-terminal A in some "sentential" form. We define two sets LFOLLOW(A) and RFOLLOW(A) by replacing the word "sentential" by "left sentential" and "right most sentential" respectively in the definition of FOLLOW (A).

A. FOLLOW(A) and LFOLLOW(A) may be different.
B. FOLLOW(A) and RFOLLOW(A) are always the same.
C. All the three sets are identical.
D. All the three sets are different.

gate1992 parsing compiler-design normal multiple-selects first-and-follow

Answer key

3.7.2 First and Follow: GATE CSE 2012 | Question: 52

For the grammar below, a partial $LL(1)$ parsing table is also presented along with the grammar. Entries that need to be filled are indicated as $E1, E2,$ and $E3$. ε is the empty string, $ indicates end of input, and, | separates alternate right hand sides of productions.

- $S \to aAbB \mid bAaB \mid \varepsilon$
- $A \to S$
- $B \to S$

	a	b	\$
S	E1	E2	$S \rightarrow \varepsilon$
A	$A \rightarrow S$	$A \rightarrow S$	error
B	$B \rightarrow S$	$B \rightarrow S$	$E3$

The FIRST and FOLLOW sets for the non-terminals A and B are

A. $\text{FIRST}(A) = \{a, b, \varepsilon\} = \text{FIRST}(B)$
$\text{FOLLOW}(A) = \{a, b\}$
$\text{FOLLOW}(B) = \{a, b, \$\}$

B. $\text{FIRST}(A) = \{a, b, \$\}$
$\text{FIRST}(B) = \{a, b, \varepsilon\}$
$\text{FOLLOW}(A) = \{a, b\}$
$\text{FOLLOW}(B) = \{\$\}$

C. $\text{FIRST}(A) = \{a, b, \varepsilon\} = \text{FIRST}(B)$
$\text{FOLLOW}(A) = \{a, b\}$
$\text{FOLLOW}(B) = \varnothing$

D. $\text{FIRST}(A) = \{a, b\} = \text{FIRST}(B)$
$\text{FOLLOW}(A) = \{a, b\}$
$\text{FOLLOW}(B) = \{a, b\}$

gatecse-2012 compiler-design parsing normal first-and-follow

Answer key☟

3.7.3 First and Follow: GATE CSE 2017 Set 1 | Question: 17

Consider the following grammar:

- $P \rightarrow xQRS$
- $Q \rightarrow yz \mid z$
- $R \rightarrow w \mid \varepsilon$
- $S \rightarrow y$

What is FOLLOW(Q)?

A. $\{R\}$ B. $\{w\}$ C. $\{w, y\}$ D. $\{w, \$\}$

gatecse-2017-set1 compiler-design parsing easy first-and-follow

Answer key☟

3.7.4 First and Follow: GATE CSE 2019 | Question: 19

Consider the grammar given below:

- $S \rightarrow Aa$
- $A \rightarrow BD$
- $B \rightarrow b \mid \epsilon$
- $D \rightarrow d \mid \epsilon$

Let a, b, d and $\$$ be indexed as follows:

a	b	d	\$
3	2	1	0

Compute the FOLLOW set of the non-terminal B and write the index values for the symbols in the FOLLOW set in the descending order.(For example, if the FOLLOW set is $(a, b, d, \$)$, then the answer should be 3210)

gatecse-2019 numerical-answers compiler-design parsing one-mark first-and-follow

Answer key

3.7.5 First and Follow: GATE CSE 2024 | Set 1 | Question: 28

Consider the following grammar G, with S as the start symbol. The grammar G has three incomplete productions denoted by $(1), (2)$, and (3).

$$\begin{aligned} &S \rightarrow daT \mid \quad (1) \\ &T \rightarrow aS|bT| \quad (2) \\ &R \rightarrow (3) \mid \epsilon \end{aligned}$$

The set of terminals is $\{a, b, c, d, f\}$. The FIRST and FOLLOW sets of the different non-terminals are as follows.

$$\text{FIRST}(S) = \{c, d, f\}, \text{FIRST}(T) = \{a, b, \epsilon\}, \text{FIRST}(R) = \{c, \epsilon\}$$
$$\text{FOLLOW}(S) = \text{FOLLOW}(T) = \{c, f, \$\}, \text{FOLLOW}(R) = \{f\}$$

Which one of the following options CORRECTLY fills in the incomplete productions?

A. (1) $S \rightarrow Rf$ (2) $T \rightarrow \epsilon$ (3) $R \rightarrow cTR$
B. (1) $S \rightarrow fR$ (2) $T \rightarrow \epsilon$ (3) $R \rightarrow cTR$
C. (1) $S \rightarrow fR$ (2) $T \rightarrow cT$ (3) $R \rightarrow cR$
D. (1) $S \rightarrow Rf$ (2) $T \rightarrow cT$ (3) $R \rightarrow cR$

gatecse2024-set1 compiler-design first-and-follow two-marks

Answer key

3.7.6 First and Follow: GATE CSE 2025 | Set 1 | Question: 36

Which of the following statement(s) is/are TRUE while computing First and Follow during top down parsing by a compiler?

A. For a production $A \rightarrow \epsilon, \epsilon$ will be added to $\text{First}(A)$.
B. If there is any input right end marker, it will be added to First(S), where S is the start symbol.
C. For a production $A \rightarrow \epsilon, \epsilon$ will be added to Follow (A).
D. If there is any input right end marker, it will be added to $\text{Follow}(S)$, where S is the start symbol.

gatecse2025-set1 compiler-design first-and-follow parsing multiple-selects two-marks

Answer key

3.8 Grammar (51)

3.8.1 Grammar: GATE CSE 1988 | Question: 10ia

Consider the following grammar:

- $S \rightarrow S$
- $S \rightarrow SS \mid a \mid \epsilon$

Construct the collection of sets of $\text{LR}\ (0)$ items for this grammar and draw its goto graph.

gate1988 compiler-design descriptive grammar parsing

Answer key

3.8.2 Grammar: GATE CSE 1988 | Question: 10ib

Consider the following grammar:

- $S \rightarrow S$

- $S \to SS \mid a \mid \epsilon$

Indicate the shift-reduce and reduce-reduce conflict (if any) in the various states of the $\mathrm{LR}(0)$ parser.

gate1988 compiler-design descriptive grammar parsing

Answer key☟

3.8.3 Grammar: GATE CSE 1990 | Question: 16a

Show that grammar G_1 is ambiguous using parse trees:

$G_1 : S \to$ if S then S else S

$S \to$ if S then S

gate1990 descriptive compiler-design grammar

Answer key☟

3.8.4 Grammar: GATE CSE 1991 | Question: 10a

Consider the following grammar for arithmetic expressions using binary operators $-$ and $/$ which are not associative

- $E \to E - T \mid T$
- $T \to T/F \mid F$
- $F \to (E) \mid id$

(E is the start symbol)

Is the grammar unambiguous? Is so, what is the relative precedence between $-$ and $/$? If not, give an unambiguous grammar that gives $/$ precedence over $-$.

gate1991 grammar compiler-design normal descriptive

Answer key☟

3.8.5 Grammar: GATE CSE 1991 | Question: 10b

Consider the following grammar for arithmetic expressions using binary operators $-$ and $/$ which are not associative

- $E \to E - T \mid T$
- $T \to T/F \mid F$
- $F \to (E) \mid id$

(E is the start symbol)

Does the grammar allow expressions with redundant parentheses as in (id/id) or in $id - (id/id)$? If so, convert the grammar into one which does not generate expressions with redundant parentheses. Do this with minimum number of changes to the given production rules and adding at most one more production rule.

gate1991 grammar compiler-design normal descriptive

Answer key☟

3.8.6 Grammar: GATE CSE 1991 | Question: 10c

Consider the following grammar for arithmetic expressions using binary operators $-$ and $/$ which are not associative

- $E \to E - T \mid T$
- $T \to T/F \mid F$
- $F \to (E) \mid id$

(E is the start symbol)

Does the grammar allow expressions with redundant parentheses as in (id/id) or in $id - (id/id)$? If so, convert the grammar into one which does not generate expressions with redundant parentheses. Do this with minimum number of changes to the given production rules and adding at most one more production rule.

Convert the grammar obtained above into one that is not left recursive.

gate1991 grammar compiler-design normal descriptive

Answer key

3.8.7 Grammar: GATE CSE 1992 | Question: 02,xviii

If G is a context free grammar and w is a string of length l in $L(G)$, how long is a derivation of w in G, if G is in Chomsky normal form?

A. $2l$
B. $2l + 1$
C. $2l - 1$
D. l

gate1992 compiler-design easy grammar

Answer key

3.8.8 Grammar: GATE CSE 1994 | Question: 1.18

Which of the following features cannot be captured by context-free grammars?

A. Syntax of if-then-else statements
B. Syntax of recursive procedures
C. Whether a variable has been declared before its use
D. Variable names of arbitrary length

gate1994 compiler-design grammar normal

Answer key

3.8.9 Grammar: GATE CSE 1994 | Question: 20

A grammar G is in Chomsky-Normal Form (CNF) if all its productions are of the form $A \to BC$ or $A \to a$, where A, B and C, are non-terminals and a is a terminal. Suppose G is a CFG in CNF and w is a string in $L(G)$ of length n, then how long is a derivation of w in G?

gate1994 compiler-design grammar normal descriptive

Answer key

3.8.10 Grammar: GATE CSE 1994 | Question: 3.5

Match the following items

(i)	Backus-Naur form	(a)	Regular expressions
(ii)	Lexical analysis	(b)	LALR(1) grammar
(iii)	YACC	(c)	LL(1) grammars
(iv)	Recursive descent parsing	(d)	General context-free grammars

gate1994 compiler-design grammar normal match-the-following

Answer key

3.8.11 Grammar: GATE CSE 1995 | Question: 1.10

Consider a grammar with the following productions

- $S \to a\alpha b \mid b\alpha c \mid aB$
- $S \to \alpha S \mid b$
- $S \to \alpha bb \mid ab$
- $S\alpha \to bdb \mid b$

The above grammar is:

A. Context free B. Regular C. Context sensitive D. $LR(k)$

gate1995 compiler-design grammar normal

Answer key

3.8.12 Grammar: GATE CSE 1995 | Question: 9

A. Translate the arithmetic expression $a^* - (b + c)$ into syntax tree.

B. A grammar is said to have cycles if it is the case that $A \overset{+}{\Rightarrow} A$

Show that no grammar that has cycles can be $\text{LL}(1)$.

gate1995 compiler-design grammar normal descriptive

Answer key

3.8.13 Grammar: GATE CSE 1996 | Question: 11

Let G be a context-free grammar where $G = (\{S, A, B, C\}, \{a, b, d\}, P, S)$ with the productions in P given below.

- $S \rightarrow ABAC$
- $A \rightarrow aA \mid \varepsilon$
- $B \rightarrow bB \mid \varepsilon$
- $C \rightarrow d$

(ε denotes the null string). Transform the grammar G to an equivalent context-free grammar G' that has no ε productions and no unit productions. (A unit production is of the form $x \rightarrow y$, and x and y are non terminals).

gate1996 compiler-design grammar normal descriptive

Answer key

3.8.14 Grammar: GATE CSE 1996 | Question: 2.10

The grammar whose productions are

- $\langle \text{stmt} \rangle \rightarrow$ if id then $\langle \text{stmt} \rangle$
- $\langle \text{stmt} \rangle \rightarrow$ if id then $\langle \text{stmt} \rangle$ else $\langle \text{stmt} \rangle$
- $\langle \text{stmt} \rangle \rightarrow$ id := id

is ambiguous because

(a) the sentence

```
if a then if b then c:= d
```

has more than two parse trees

(b) the left most and right most derivations of the sentence

```
if a then if b then c:= d
```

give rise to different parse trees

(c) the sentence

```
if a then if b then c:= d else c:= f
```

has more than two parse trees

(d) the sentence

```
if a then if b then c:= d else c:= f
```

has two parse trees

gate1996 compiler-design grammar normal

Answer key

3.8.15 Grammar: GATE CSE 1997 | Question: 1.6

In the following grammar

- $X ::= X \oplus Y \mid Y$
- $Y ::= Z * Y \mid Z$
- $Z ::= id$

Which of the following is true?

A. '$\oplus$' is left associative while '$*$' is right associative
B. Both '$\oplus$' and '$*$' are left associative
C. '$\oplus$' is right associative while '$*$' is left associative
D. None of the above

gate1997 compiler-design grammar normal

Answer key

3.8.16 Grammar: GATE CSE 1997 | Question: 11

Consider the grammar

- $S \to bSe$
- $S \to PQR$
- $P \to bPc$
- $P \to \varepsilon$
- $Q \to cQd$
- $Q \to \varepsilon$
- $R \to dRe$
- $R \to \varepsilon$

where S, P, Q, R are non-terminal symbols with S being the start symbol; b, c, d, e are terminal symbols and 'ε' is the empty string. This grammar generates strings of the form b^i, c^j, d^k, e^m for some $i, j, k, m \geq 0$.

a. What is the condition on the values of i, j, k, m?
b. Find the smallest string that has two parse trees.

gate1997 compiler-design grammar normal theory-of-computation descriptive

Answer key

3.8.17 Grammar: GATE CSE 1998 | Question: 14

A. Let $G_1 = (N, T, P, S_1)$ be a CFG where, $N = \{S_1, A, B\}, T = \{a, b\}$ and P is given by

$$\begin{array}{l|l} S_1 \to aS_1b & S_1 \to aBb \\ S_1 \to aAb & B \to Bb \\ A \to aA & B \to b \\ A \to a & \end{array}$$

What is $L(G_1)$?

B. Use the grammar in Part(a) to give a CFG for $L_2 = \{a^ib^ja^kb^l \mid i, j, k, l \geq 1, i = j \text{ or } k = l\}$ by adding not more than 5 production rules.
C. Is L_2 inherently ambiguous?

gate1998 compiler-design grammar descriptive

Answer key

3.8.18 Grammar: GATE CSE 1998 | Question: 6b

Consider the grammar

- S $\rightarrow Aa \mid b$
- A $\rightarrow Ac \mid Sd \mid \epsilon$

Construct an equivalent grammar with no left recursion and with minimum number of production rules.

gate1998 compiler-design grammar descriptive

Answer key

3.8.19 Grammar: GATE CSE 1999 | Question: 2.15

A grammar that is both left and right recursive for a non-terminal, is

A. Ambiguous
B. Unambiguous
C. Information is not sufficient to decide whether it is ambiguous or unambiguous
D. None of the above

gate1999 compiler-design grammar normal

Answer key

3.8.20 Grammar: GATE CSE 2001 | Question: 1.18

Which of the following statements is false?

A. An unambiguous grammar has same leftmost and rightmost derivation
B. An LL(1) parser is a top-down parser
C. LALR is more powerful than SLR
D. An ambiguous grammar can never be LR(k) for any k

gatecse-2001 compiler-design grammar normal

Answer key

3.8.21 Grammar: GATE CSE 2001 | Question: 18

A. Remove left-recursion from the following grammar: $S \rightarrow Sa \mid Sb \mid a \mid b$
B. Consider the following grammar:

$$S \rightarrow aSbS \mid bSaS \mid \epsilon$$

Construct all possible parse trees for the string abab. Is the grammar ambiguous?

gatecse-2001 compiler-design grammar descriptive

Answer key

3.8.22 Grammar: GATE CSE 2003 | Question: 56

Consider the grammar shown below

- $S \rightarrow iEtSS' \mid a$
- $S' \rightarrow eS \mid \epsilon$
- $E \rightarrow b$

In the predictive parse table, M, of this grammar, the entries $M[S', e]$ and $M[S', \$]$ respectively are

A. $\{S' \to eS\}$ and $\{S' \to \epsilon\}$
B. $\{S' \to eS\}$ and $\{\}$
C. $\{S' \to \epsilon\}$ and $\{S' \to \epsilon\}$
D. $\{S' \to eS, S' \to \varepsilon\}$ and $\{S' \to \epsilon\}$

gatecse-2003 compiler-design grammar normal parsing

Answer key

3.8.23 Grammar: GATE CSE 2003 | Question: 57

Consider the grammar shown below.

- $S \to C\,C$
- $C \to c\,C \mid d$

This grammar is

A. LL(1)
B. SLR(1) but not LL(1)
C. LALR(1) but not SLR(1)
D. LR(I) but not LALR(1)

gatecse-2003 compiler-design grammar parsing normal

Answer key

3.8.24 Grammar: GATE CSE 2003 | Question: 58

Consider the translation scheme shown below.

- $S \to T\ R$
- $R \to +T\{\text{print}(`+'); \}R \mid \varepsilon$
- $T \to$ **num** $\{\text{print}($**num**.val$); \}$

Here **num** is a token that represents an integer and **num**.val represents the corresponding integer value. For an input string '$9 + 5 + 2$', this translation scheme will print

A. $9 + 5 + 2$
B. $9\ 5 + 2 +$
C. $9\ 5\ 2 + +$
D. $+ + 9\ 5\ 2$

gatecse-2003 compiler-design grammar normal

Answer key

3.8.25 Grammar: GATE CSE 2004 | Question: 45

Consider the grammar with the following translation rules and E as the start symbol

$$\begin{array}{ll} E \to E_1 \# T & \{E.value = E_1.value * T.value\} \\ \quad |T & \{E.value = T.value\} \\ T \to T_1 \& F & \{T.value = T_1.value + F.value\} \\ \quad |F & \{T.value = F.value\} \\ F \to \text{num} & \{F.value = num.value\} \end{array}$$

Compute E.value for the root of the parse tree for the expression: 2 # 3 & 5 # 6 & 4

A. 200
B. 180
C. 160
D. 40

gatecse-2004 compiler-design grammar normal

Answer key

3.8.26 Grammar: GATE CSE 2004 | Question: 8

Which of the following grammar rules violate the requirements of an operator grammar? P, Q, R are nonterminals, and r, s, t are terminals.

I. $P \to QR$
II. $P \to QsR$
III. $P \to \varepsilon$
IV. $P \to QtRr$

A. (I) only B. (I) and (III) only C. (II) and (III) only D. (III) and (IV) only

gatecse-2004 compiler-design grammar normal

Answer key

3.8.27 Grammar: GATE CSE 2004 | Question: 88

Consider the following grammar G:

$S \to bS \mid aA \mid b$

$A \to bA \mid aB$

$B \to bB \mid aS \mid a$

Let $N_a(w)$ and $N_b(w)$ denote the number of a's and b's in a string ω respectively.

The language $L(G)$ over $\{a,b\}^+$ generated by G is

A. $\{w \mid N_a(w) > 3N_b(w)\}$
B. $\{w \mid N_b(w) > 3N_a(w)\}$
C. $\{w \mid N_a(w) = 3k, k \in \{0,1,2,\dots\}\}$
D. $\{w \mid N_b(w) = 3k, k \in \{0,1,2,\dots\}\}$

gatecse-2004 compiler-design grammar normal

Answer key

3.8.28 Grammar: GATE CSE 2005 | Question: 14

The grammar $A \to AA \mid (A) \mid \epsilon$ is not suitable for predictive-parsing because the grammar is:

A. ambiguous B. left-recursive C. right-recursive D. an operator-grammar

gatecse-2005 compiler-design parsing grammar easy

Answer key

3.8.29 Grammar: GATE CSE 2005 | Question: 59

Consider the grammar:

$$E \to E + n \mid E \times n \mid n$$

For a sentence $n + n \times n$, the handles in the right-sentential form of the reduction are:

A. $n, E + n$ and $E + n \times n$
B. $n, E + n$ and $E + E \times n$
C. $n, n + n$ and $n + n \times n$
D. $n, E + n$ and $E \times n$

gatecse-2005 compiler-design grammar normal

Answer key

3.8.30 Grammar: GATE CSE 2006 | Question: 32, ISRO2016-35

Consider the following statements about the context free grammar

$$G = \{S \to SS, S \to ab, S \to ba, S \to \epsilon\}$$

I. G is ambiguous
II. G produces all strings with equal number of a's and b's

III. G can be accepted by a deterministic PDA.

Which combination below expresses all the true statements about G?

A. I only
B. I and III only
C. II and III only
D. I, II and III

gatecse-2006 compiler-design grammar normal isro2016

Answer key

3.8.31 Grammar: GATE CSE 2006 | Question: 59

Consider the following translation scheme.

- $S \rightarrow ER$
- $R \rightarrow *E\,\{\text{print}(`*');\}\,R \mid \varepsilon$
- $E \rightarrow F + E\,\{\text{print}(`+');\} \mid F$
- $F \rightarrow (S) \mid id\,\{\text{print}(id.value);\}$

Here id is a token that represents an integer and $id.value$ represents the corresponding integer value. For an input '$2 * 3 + 4$', this translation scheme prints

A. $2 * 3 + 4$
B. $2 * +3\ 4$
C. $2\ 3 * 4+$
D. $2\ 3\ 4 + *$

gatecse-2006 compiler-design grammar normal

Answer key

3.8.32 Grammar: GATE CSE 2006 | Question: 84

Which one of the following grammars generates the language $L = \left\{a^i b^j \mid i \neq j\right\}$?

A. $S \rightarrow AC \mid CB$
$C \rightarrow aCb \mid a \mid b$
$A \rightarrow aA \mid \varepsilon$
$B \rightarrow Bb \mid \varepsilon$

B. $S \rightarrow aS \mid Sb \mid a \mid b$

C. $S \rightarrow AC \mid CB$
$C \rightarrow aCb \mid \varepsilon$
$A \rightarrow aA \mid \varepsilon$
$B \rightarrow Bb \mid \varepsilon$

D. $S \rightarrow AC \mid CB$
$C \rightarrow aCb \mid \varepsilon$
$A \rightarrow aA \mid a$
$B \rightarrow Bb \mid b$

gatecse-2006 compiler-design grammar normal theory-of-computation

Answer key

3.8.33 Grammar: GATE CSE 2006 | Question: 85

The grammar

- $S \rightarrow AC \mid CB$
- $C \rightarrow aCb \mid \epsilon$
- $A \rightarrow aA \mid a$
- $B \rightarrow Bb \mid b$

generates the language $L = \left\{a^i b^j \mid i \neq j\right\}$. In this grammar what is the length of the derivation (number of steps starting from S) to generate the string $a^l b^m$ with $l \neq m$

A. $\max(l, m) + 2$
B. $l + m + 2$
C. $l + m + 3$
D. $\max(l, m) + 3$

gatecse-2006 compiler-design grammar normal

Answer key

3.8.34 Grammar: GATE CSE 2007 | Question: 52

Consider the grammar with non-terminals $N = \{S, C, S_1\}$, terminals $T = \{a, b, i, t, e\}$, with S as the start symbol, and the following set of rules:

$S \rightarrow iCtSS_1 \mid a$

$S_1 \rightarrow eS \mid \epsilon$
$C \rightarrow b$

The grammar is NOT LL(1) because:

A. it is left recursive
B. it is right recursive
C. it is ambiguous
D. it is not context-free

gatecse-2007 compiler-design grammar normal

Answer key

3.8.35 Grammar: GATE CSE 2007 | Question: 53

Consider the following two statements:

- P: Every regular grammar is LL(1)
- Q: Every regular set has a LR(1) grammar

Which of the following is **TRUE**?

A. Both P and Q are true
B. P is true and Q is false
C. P is false and Q is true
D. Both P and Q are false

gatecse-2007 compiler-design grammar normal

Answer key

3.8.36 Grammar: GATE CSE 2007 | Question: 78

Consider the CFG with $\{S, A, B\}$ as the non-terminal alphabet, $\{a, b\}$ as the terminal alphabet, S as the start symbol and the following set of production rules:

$S \rightarrow aB \qquad S \rightarrow bA$
$B \rightarrow b \qquad A \rightarrow a$
$B \rightarrow bS \qquad A \rightarrow aS$
$B \rightarrow aBB \qquad S \rightarrow bAA$

Which of the following strings is generated by the grammar?

A. $aaaabb$
B. $aabbbb$
C. $aabbab$
D. $abbbba$

gatecse-2007 compiler-design grammar normal

Answer key

3.8.37 Grammar: GATE CSE 2007 | Question: 79

Consider the CFG with $\{S, A, B\}$ as the non-terminal alphabet, $\{a, b\}$ as the terminal alphabet, S as the start symbol and the following set of production rules:

$S \rightarrow aB \qquad S \rightarrow bA$
$B \rightarrow b \qquad A \rightarrow a$
$B \rightarrow bS \qquad A \rightarrow aS$
$B \rightarrow aBB \qquad S \rightarrow bAA$

For the string $aabbab$, how many derivation trees are there?

A. 1
B. 2
C. 3
D. 4

gatecse-2007 compiler-design grammar normal

Answer key

3.8.38 Grammar: GATE CSE 2008 | Question: 50

Which of the following statements are true?

I. Every left-recursive grammar can be converted to a right-recursive grammar and vice-versa
II. All ϵ-productions can be removed from any context-free grammar by suitable transformations

III. The language generated by a context-free grammar all of whose productions are of the form $X \to w$ or $X \to wY$ (where, w is a string of terminals and Y is a non-terminal), is always regular
IV. The derivation trees of strings generated by a context-free grammar in Chomsky Normal Form are always binary trees

A. I, II, III and IV
B. II, III and IV only
C. I, III and IV only
D. I, II and IV only

gatecse-2008 normal compiler-design grammar

Answer key

3.8.39 Grammar: GATE CSE 2010 | Question: 38

The grammar $S \to aSa \mid bS \mid c$ is

A. LL(1) but not LR(1)
B. LR(1) but not LL(1)
C. Both LL(1) and LR(1)
D. Neither LL(1) nor LR(1)

gatecse-2010 compiler-design grammar normal

Answer key

3.8.40 Grammar: GATE CSE 2014 Set 2 | Question: 17

Consider the grammar defined by the following production rules, with two operators $*$ and $+$

- $S \to T * P$
- $T \to U \mid T * U$
- $P \to Q + P \mid Q$
- $Q \to Id$
- $U \to Id$

Which one of the following is TRUE?

A. $+$ is left associative, while $*$ is right associative
B. $+$ is right associative, while $*$ is left associative
C. Both $+$ and $*$ are right associative
D. Both $+$ and $*$ are left associative

gatecse-2014-set2 compiler-design grammar normal

Answer key

3.8.41 Grammar: GATE CSE 2016 Set 2 | Question: 45

Which one of the following grammars is free from left recursion?

A. $S \to AB$
$A \to Aa \mid b$
$B \to c$

B. $S \to Ab \mid Bb \mid c$
$A \to Bd \mid \epsilon$
$B \to e$

C. $S \to Aa \mid B$
$A \to Bb \mid Sc \mid \epsilon$
$B \to d$

D. $S \to Aa \mid Bb \mid c$
$A \to Bd \mid \epsilon$
$B \to Ae \mid \epsilon$

gatecse-2016-set2 compiler-design grammar easy

Answer key

3.8.42 Grammar: GATE CSE 2016 Set 2 | Question: 46

A student wrote two context-free grammars G1 and G2 for generating a single C-like array declaration. The dimension of the array is at least one. For example,

```
int a[10] [3];
```

The grammars use D as the start symbol, and use six terminal symbols **int ; id [ ] num.**

Grammar **G1**	Grammar **G2**
D $\rightarrow$ **int L;**	D $\rightarrow$ **int L;**
L $\rightarrow$ **id** [**E**	L $\rightarrow$ **id E**
E $\rightarrow$ **num**]	E $\rightarrow$ **E** [**num**]
E $\rightarrow$ **num**] [**E**	E $\rightarrow$ [**num**]

Which of the grammars correctly generate the declaration mentioned above?

A. Both **G1** and **G2**
B. Only **G1**
C. Only **G2**
D. Neither **G1** nor **G2**

gatecse-2016-set2 compiler-design grammar normal

Answer key☟

3.8.43 Grammar: GATE CSE 2017 Set 2 | Question: 32

Consider the following expression grammar G:

- $E \rightarrow E - T \mid T$
- $T \rightarrow T + F \mid F$
- $F \rightarrow (E) \mid id$

Which of the following grammars is not left recursive, but is equivalent to G?

A. $E \rightarrow E - T \mid T$

$T \rightarrow T + F \mid F$

$F \rightarrow (E) \mid id$

B. $E \rightarrow TE'$

$E' \rightarrow -TE' \mid \epsilon$

$T \rightarrow T + F \mid F$

$F \rightarrow (E) \mid id$

C. $E \rightarrow TX$

$X \rightarrow -TX \mid \epsilon$

$T \rightarrow FY$

$Y \rightarrow +FY \mid \epsilon$

$F \rightarrow (E) \mid id$

D. $E \rightarrow TX \mid (TX)$

$X \rightarrow -TX \mid +TX \mid \epsilon$

$T \rightarrow id$

gatecse-2017-set2 grammar

Answer key☟

3.8.44 Grammar: GATE CSE 2019 | Question: 43

Consider the augmented grammar given below:

- $S' \rightarrow S$
- $S \rightarrow \langle L \rangle \mid id$
- $L \rightarrow L, S \mid S$

Let $I_0 = \text{CLOSURE}(\{[S' \rightarrow \cdot S]\})$. The number of items in the set $\text{GOTO}(I_0, \langle\ )$ is______

gatecse-2019 numerical-answers compiler-design grammar two-marks

Answer key☟

3.8.45 Grammar: GATE CSE 2021 Set 1 | Question: 31

Consider the following context-free grammar where the set of terminals is $\{a, b, c, d, f\}$.

$$\begin{array}{lcl} \mathrm{S} & \rightarrow & d\,a\,\mathrm{T} \mid \mathrm{R}\,f \\ \mathrm{T} & \rightarrow & a\,\mathrm{S} \mid b\,a\,\mathrm{T} \mid \epsilon \\ \mathrm{R} & \rightarrow & c\,a\,\mathrm{T\,R} \mid \epsilon \end{array}$$

The following is a partially-filled $\mathsf{LL(1)}$ parsing table.

	a	b	c	d	f	\$
S			$\boxed{1}$	$\mathrm{S} \rightarrow da\mathrm{T}$	$\boxed{2}$	
T	$\mathrm{T} \rightarrow a\mathrm{S}$	$\mathrm{T} \rightarrow ba\mathrm{T}$	$\boxed{3}$		$\mathrm{T} \rightarrow \varepsilon$	$\boxed{4}$
R			$\mathrm{R} \rightarrow ca\mathrm{TR}$		$\mathrm{R} \rightarrow \varepsilon$	

Which one of the following choices represents the correct combination for the numbered cells in the parsing table ("blank" denotes that the corresponding cell is empty)?

A. $\boxed{1}$ $\mathrm{S} \rightarrow \mathrm{R}f$ $\boxed{2}$ $\mathrm{S} \rightarrow \mathrm{R}f$ $\boxed{3}$ $\mathrm{T} \rightarrow \varepsilon$ $\boxed{4}$ $\mathrm{T} \rightarrow \varepsilon$
B. $\boxed{1}$ blank $\boxed{2}$ $\mathrm{S} \rightarrow \mathrm{R}f$ $\boxed{3}$ $\mathrm{T} \rightarrow \varepsilon$ $\boxed{4}$ $\mathrm{T} \rightarrow \varepsilon$
C. $\boxed{1}$ $\mathrm{S} \rightarrow \mathrm{R}f$ $\boxed{2}$ blank $\boxed{3}$ blank $\boxed{4}$ $\mathrm{T} \rightarrow \varepsilon$
D. $\boxed{1}$ blank $\boxed{2}$ $\mathrm{S} \rightarrow \mathrm{R}f$ $\boxed{3}$ blank $\boxed{4}$ blank

gatecse-2021-set1 compiler-design grammar two-marks

Answer key

3.8.46 Grammar: GATE CSE 2024 | Set 1 | Question: 49

Let $G = (V, \Sigma, S, P)$ be a context-free grammar in Chomsky Normal Form with $\Sigma = \{a, b, c\}$ and V containing 10 variable symbols including the start symbol S. The string $w = a^{30}b^{30}c^{30}$ is derivable from S. The number of steps (application of rules) in the derivation $S \rightarrow^* w$ is __________.

gatecse2024-set1 numerical-answers compiler-design grammar two-marks

Answer key

3.8.47 Grammar: GATE CSE 2024 | Set 2 | Question: 42

Consider a context-free grammar G with the following 3 rules.

$$S \rightarrow aS, S \rightarrow aSbS, S \rightarrow c$$

Let $w \in L(G)$. Let $n_a(w), n_b(w), n_c(w)$ denote the number of times a, b, c occur in w, respectively. Which of the following statements is/are TRUE?

A. $n_a(w) > n_b(w)$
B. $n_a(w) > n_c(w) - 2$
C. $n_c(w) = n_b(w) + 1$
D. $n_c(w) = n_b(w) * 2$

gatecse2024-set2 compiler-design multiple-selects grammar two-marks

Answer key

3.8.48 Grammar: GATE CSE 2025 | Set 2 | Question: 41

Consider two grammars G_1 and G_2 with the production rules given below:

$$G_1 : S \rightarrow if\ E\ then\ S \mid if\ E\ then\ S\ else\ S \mid a$$
$$E \rightarrow b$$
$$G_2 : S \rightarrow if\ E\ then\ S \mid M$$
$$M \rightarrow if\ E\ then\ M\ else\ S \mid c$$
$$E \rightarrow b$$

where $if, then, else, a, b, c$ are the terminals.
Which of the following option(s) is/are CORRECT?

A. G_1 is not $LL(1)$ and G_2 is $LL(1)$
B. G_1 is $LL(1)$ and G_2 is not $LL(1)$
C. G_1 and G_2 are not $LL(1)$
D. G_1 and G_2 are ambiguous.

gatecse2025-set2 compiler-design grammar multiple-selects easy two-marks

Answer key

3.8.49 Grammar: GATE IT 2005 | Question: 83a

Consider the context-free grammar

$E \rightarrow E + E$
$E \rightarrow (E * E)$
$E \rightarrow id$

where E is the starting symbol, the set of terminals is $\{id, (, +,), *\}$, and the set of nonterminals is $\{E\}$.

Which of the following terminal strings has more than one parse tree when parsed according to the above grammar?

A. $id + id + id + id$
B. $id + (id * (id * id))$
C. $(id * (id * id)) + id$
D. $((id * id + id) * id)$

gateit-2005 compiler-design grammar parsing easy

Answer key

3.8.50 Grammar: GATE IT 2007 | Question: 9

Consider an ambiguous grammar G and its disambiguated version D. Let the language recognized by the two grammars be denoted by $L(G)$ and $L(D)$ respectively. Which one of the following is true?

A. $L(D) \subset L(G)$
B. $L(D) \supset L(G)$
C. $L(D) = L(G)$
D. $L(D)$ is empty

gateit-2007 compiler-design grammar normal

Answer key

3.8.51 Grammar: GATE IT 2008 | Question: 78

A CFG G is given with the following productions where S is the start symbol, A is a non-terminal and a and b are terminals.

- $S \rightarrow aS \mid A$
- $A \rightarrow aAb \mid bAa \mid \epsilon$

Which of the following strings is generated by the grammar above?

A. $aabbaba$
B. $aabaaba$
C. $abababb$
D. $aabbaab$

gateit-2008 parsing normal grammar

Answer key

3.9 Intermediate Code (11)

3.9.1 Intermediate Code: GATE CSE 1988 | Question: 2xvii

Construct a DAG for the following set of quadruples:

- E:=A+B
- F:=E-C
- G:=F*D
- H:=A+B
- I:=I-C
- J:=I+G

gate1988 descriptive compiler-design intermediate-code

Answer key

3.9.2 Intermediate Code: GATE CSE 1989 | Question: 4-v

Is the following code template for the if-then-else statement correct? if not, correct it.

- if expression then statement 1
  else statement 2

Template:

Code for expression

- (*result in $E, E > O$ indicates true *)
- Branch on $E > O$ to $L1$
- Code for statement 1
- $L1$: Code for statement 2

descriptive gate1989 compiler-design intermediate-code

Answer key

3.9.3 Intermediate Code: GATE CSE 1992 | Question: 11b

Write 3 address intermediate code (quadruples) for the following boolean expression in the sequence as it would be generated by a compiler. Partial evaluation of boolean expressions is not permitted. Assume the usual rules of precedence of the operators.

$$(a+b) > (c+d) \text{ or } a > c \text{ and } b < d$$

gate1992 compiler-design syntax-directed-translation intermediate-code descriptive

Answer key

3.9.4 Intermediate Code: GATE CSE 1994 | Question: 1.12

Generation of intermediate code based on an abstract machine model is useful in compilers because

A. it makes implementation of lexical analysis and syntax analysis easier
B. syntax-directed translations can be written for intermediate code generation
C. it enhances the portability of the front end of the compiler
D. it is not possible to generate code for real machines directly from high level language programs

gate1994 compiler-design intermediate-code easy

Answer key

3.9.5 Intermediate Code: GATE CSE 2014 Set 2 | Question: 34

For a C program accessing $\mathbf{X[i][j][k]}$, the following intermediate code is generated by a compiler. Assume that the size of an **integer** is 32 bits and the size of a **character** is 8 bits.

```
t0 = i * 1024
t1 = j * 32
t2 = k * 4
t3 = t1 + t0
t4 = t3 + t2
t5 = X[t4]
```

Which one of the following statements about the source code for the C program is CORRECT?

A. $\mathbf{X}$ is declared as "**int** $\mathbf{X[32][32][8]}$".
B. $\mathbf{X}$ is declared as "**int** $\mathbf{X[4][1024][32]}$".
C. $\mathbf{X}$ is declared as "**char** $\mathbf{X[4][32][8]}$".
D. $\mathbf{X}$ is declared as "**char** $\mathbf{X[32][16][2]}$".

gatecse-2014-set2 compiler-design intermediate-code programming-in-c normal

Answer key

3.9.6 Intermediate Code: GATE CSE 2014 Set 3 | Question: 17

One of the purposes of using intermediate code in compilers is to

A. make parsing and semantic analysis simpler.
B. improve error recovery and error reporting.
C. increase the chances of reusing the machine-independent code optimizer in other compilers.
D. improve the register allocation.

gatecse-2014-set3 compiler-design intermediate-code easy

Answer key

3.9.7 Intermediate Code: GATE CSE 2015 Set 1 | Question: 8

For computer based on three-address instruction formats, each address field can be used to specify which of the following:

(S1) A memory operand

(S2) A processor register

(S3) An implied accumulator register

A. Either $S1$ or $S2$
B. Either $S2$ or $S3$
C. Only $S2$ and $S3$
D. All of $S1$, $S2$ and $S3$

gatecse-2015-set1 compiler-design intermediate-code normal

Answer key

3.9.8 Intermediate Code: GATE CSE 2015 Set 2 | Question: 29

Consider the intermediate code given below.

```
(1) i=1
(2) j=1
(3) t1 = 5 * i
(4) t2 = t1 + j
(5) t3 = 4 * t2
(6) t4 = t3
(7) a[t4] = -1
(8) j = j + 1
(9) if j <= 5 goto (3)
(10) i = i +1
(11) if i < 5 goto (2)
```

The number of nodes and edges in control-flow-graph constructed for the above code, respectively, are

A. 5 and 7
B. 6 and 7
C. 5 and 5
D. 7 and 8

gatecse-2015-set2 compiler-design intermediate-code normal

Answer key

3.9.9 Intermediate Code: GATE CSE 2021 Set 2 | Question: 13

In the context of compilers, which of the following is/are NOT an intermediate representation of the source program?

A. Three address code
B. Abstract Syntax Tree (AST)
C. Control Flow Graph (CFG)
D. Symbol table

gatecse-2021-set2 multiple-selects compiler-design easy intermediate-code one-mark

Answer key

3.9.10 Intermediate Code: GATE CSE 2024 | Set 1 | Question: 29

Consider the following pseudo-code.

```
L 1: t1 = -1

L 2: t2 = 0

L 3: t3 = 0
```

```
L 4: t4 = 4 * t3
L 5: t5 = 4 * t2
L 6: t6 = t5 * M
L 7: t7 = t4 + t6
L 8: t8 = a[t7]
L 9: if t8 <= max goto L11
L 10: t1 = t8
L 11: t3 = t3 + 1
L 12: if t3 < M   goto L4
L 13: t2 = t2 + 1
L 14: if t2 < N goto L3
L 15: max = t1
```

Which one of the following options CORRECTLY specifies the number of basic blocks and the number of instructions in the largest basic block, respectively?

A. 6 and 6 B. 6 and 7 C. 7 and 7 D. 7 and 6

gatecse2024-set1 compiler-design intermediate-code two-marks

Answer key☟

3.9.11 Intermediate Code: GATE CSE 2024 | Set 2 | Question: 33

Consider the following expression: $x[i] = (p + r) * -s[i] + u/w$. The following sequence shows the list of triples representing the given expression, with entries missing for triples (1), (3), and (6).

(0)	$+$	p	r
(1)			
(2)	uminus	(1)	
(3)			
(4)	$/$	u	w
(5)	$+$	(3)	(4)
(6)			
(7)	$=$	(6)	(5)

Which one of the following options fills in the missing entries CORRECTLY?

A. $(1) = []\,\mathrm{s}\; i$ $\quad (3) * (0)(2)$ $\quad (6)\ [] = xi$
B. (1)[ ]$= si$ $\quad (3) - (0)(2)$ $\quad (6) = []x(5)$
C. $(1) = []\,\mathrm{s}\; i$ $\quad (3) * (0)(2)$ $\quad (6)[] = x(5)$
D. (1) [ ]$= si$ $\quad (3) - (0)(2)$ $\quad (6) = []xi$

gatecse2024-set2 compiler-design intermediate-code two-marks

Answer key☟

3.10 LR Parser (20)

3.10.1 LR Parser: GATE CSE 1992 | Question: 02,xiv

Consider the $\mathrm{SLR}(1)$ and $\mathrm{LALR}\ (1)$ parsing tables for a context free grammar. Which of the following statement is/are true?

A. The *goto* part of both tables may be different.
B. The *shift* entries are identical in both the tables.
C. The *reduce* entries in the tables may be different.
D. The *error* entries in tables may be different

gate1992 compiler-design normal parsing multiple-selects lr-parser

Answer key☟

3.10.2 LR Parser: GATE CSE 1998 | Question: 1.26

Which of the following statements is true?

A. SLR parser is more powerful than LALR
B. LALR parser is more powerful than Canonical LR parser
C. Canonical LR parser is more powerful than LALR parser
D. The parsers SLR, Canonical CR, and LALR have the same power

gate1998 compiler-design parsing normal lr-parser

Answer key☟

3.10.3 LR Parser: GATE CSE 2003 | Question: 17

Assume that the SLR parser for a grammar G has n_1 states and the LALR parser for G has n_2 states. The relationship between n_1 and n_2 is

A. n_1 is necessarily less than n_2
B. n_1 is necessarily equal to n_2
C. n_1 is necessarily greater than n_2
D. None of the above

gatecse-2003 compiler-design parsing easy lr-parser

Answer key☟

3.10.4 LR Parser: GATE CSE 2005 | Question: 60

Consider the grammar:

$$S \rightarrow (S) \mid a$$

Let the number of states in SLR (1), LR(1) and LALR(1) parsers for the grammar be n_1, n_2 and n_3 respectively. The following relationship holds good:

A. $n_1 < n_2 < n_3$
B. $n_1 = n_3 < n_2$
C. $n_1 = n_2 = n_3$
D. $n_1 \geq n_3 \geq n_2$

gatecse-2005 compiler-design parsing normal lr-parser

Answer key☟

3.10.5 LR Parser: GATE CSE 2006 | Question: 7

Consider the following grammar

- $S \rightarrow S * E$
- $S \rightarrow E$
- $E \rightarrow F + E$
- $E \rightarrow F$
- $F \rightarrow id$

Consider the following LR(0) items corresponding to the grammar above

i. $S \rightarrow S * .E$
ii. $E \rightarrow F. + E$
iii. $E \rightarrow F + .E$

Given the items above, which two of them will appear in the same set in the canonical sets-of-items for the grammar?

A. i and ii B. ii and iii C. i and iii D. None of the above

gatecse-2006 compiler-design parsing normal lr-parser

Answer key

3.10.6 LR Parser: GATE CSE 2008 | Question: 55

An LALR(1) parser for a grammar G can have shift-reduce (S-R) conflicts if and only if

A. The SLR(1) parser for G has S-R conflicts
B. The LR(1) parser for G has S-R conflicts
C. The LR(0) parser for G has S-R conflicts
D. The LALR(1) parser for G has reduce-reduce conflicts

gatecse-2008 compiler-design parsing normal lr-parser

Answer key

3.10.7 LR Parser: GATE CSE 2013 | Question: 40

Consider the following two sets of LR(1) items of an LR(1) grammar.

$$\begin{array}{l|l} X \to c.X, c/d & X \to c.X, \$ \\ X \to .cX, c/d & X \to .cX, \$ \\ X \to .d, c/d & X \to .d, \$ \end{array}$$

Which of the following statements related to merging of the two sets in the corresponding LALR parser is/are **FALSE**?

1. Cannot be merged since look aheads are different.
2. Can be merged but will result in S-R conflict.
3. Can be merged but will result in R-R conflict.
4. Cannot be merged since goto on c will lead to two different sets.

A. 1 only B. 2 only
C. 1 and 4 only D. $1, 2, 3$ and 4

gatecse-2013 compiler-design parsing normal lr-parser

Answer key

3.10.8 LR Parser: GATE CSE 2013 | Question: 9

What is the maximum number of reduce moves that can be taken by a bottom-up parser for a grammar with no epsilon and unit-production (i.e., of type $A \to \epsilon$ and $A \to a$) to parse a string with n tokens?

A. $n/2$ B. $n-1$ C. $2n-1$ D. 2^n

gatecse-2013 compiler-design parsing normal lr-parser

Answer key

3.10.9 LR Parser: GATE CSE 2014 Set 1 | Question: 34

A canonical set of items is given below

- $S \to L. > R$
- $Q \to R.$

On input symbol $<$ the set has

A. a shift-reduce conflict and a reduce-reduce conflict.
B. a shift-reduce conflict but not a reduce-reduce conflict.
C. a reduce-reduce conflict but not a shift-reduce conflict.
D. neither a shift-reduce nor a reduce-reduce conflict.

gatecse-2014-set1 compiler-design parsing normal lr-parser

Answer key

3.10.10 LR Parser: GATE CSE 2015 Set 1 | Question: 13

Which one of the following is TRUE at any valid state in shift-reduce parsing?

A. Viable prefixes appear only at the bottom of the stack and not inside
B. Viable prefixes appear only at the top of the stack and not inside
C. The stack contains only a set of viable prefixes
D. The stack never contains viable prefixes

gatecse-2015-set1 compiler-design parsing normal viable-prefix lr-parser

Answer key

3.10.11 LR Parser: GATE CSE 2015 Set 3 | Question: 16

Among simple LR (SLR), canonical LR, and look-ahead LR (LALR), which of the following pairs identify the method that is very easy to implement and the method that is the most powerful, in that order?

A. SLR, LALR
B. Canonical LR, LALR
C. SLR, canonical LR
D. LALR, canonical LR

gatecse-2015-set3 compiler-design parsing normal lr-parser

Answer key

3.10.12 LR Parser: GATE CSE 2017 Set 2 | Question: 6

Which of the following statements about parser is/are CORRECT?

I. Canonical LR is more powerful than SLR
II. SLR is more powerful than LALR
III. SLR is more powerful than Canonical LR

A. I only
B. II only
C. III only
D. II and III only

gatecse-2017-set2 compiler-design parsing lr-parser

Answer key

3.10.13 LR Parser: GATE CSE 2019 | Question: 3

Which one of the following kinds of derivation is used by LR parsers?

A. Leftmost
B. Leftmost in reverse
C. Rightmost
D. Rightmost in reverse

gatecse-2019 compiler-design parsing one-mark lr-parser

Answer key

3.10.14 LR Parser: GATE CSE 2020 | Question: 24

Consider the following grammar.

- $S \rightarrow aSB \mid d$
- $B \rightarrow b$

The number of reduction steps taken by a bottom-up parser while accepting the string $aaadbbb$ is ___________.

gatecse-2020 numerical-answers compiler-design lr-parser one-mark

Answer key

3.10.15 LR Parser: GATE CSE 2021 Set 1 | Question: 5

Consider the following statements.

- S_1 : Every $\mathrm{SLR}(1)$ grammar is unambiguous but there are certain unambiguous grammars that are not $\mathrm{SLR}(1)$.
- S_2 : For any context-free grammar, there is a parser that takes at most $O(n^3)$ time to parse a string of length n.

Which one of the following options is correct?

A. S_1 is true and S_2 is false
B. S_1 is false and S_2 is true
C. S_1 is true and S_2 is true
D. S_1 is false and S_2 is false

gatecse-2021-set1 compiler-design lr-parser one-mark

Answer key☟

3.10.16 LR Parser: GATE CSE 2021 Set 2 | Question: 51

Consider the following augmented grammar with $\{\#, @, <, >, a, b, c\}$ as the set of terminals.

$$
\begin{aligned}
&S' \rightarrow S \\
&S \rightarrow S\#cS \\
&S \rightarrow SS \\
&S \rightarrow S@ \\
&S \rightarrow < S > \\
&S \rightarrow a \\
&S \rightarrow b \\
&S \rightarrow c
\end{aligned}
$$

Let $I_0 = \mathrm{CLOSURE}(\{S' \rightarrow \bullet S\})$. The number of items in the set $\mathrm{GOTO}(\mathrm{GOTO}(I_0 <), <)$ is ___________

gatecse-2021-set2 compiler-design lr-parser numerical-answers two-marks

Answer key☟

3.10.17 LR Parser: GATE CSE 2022 | Question: 19

Consider the augmented grammar with $\{+, *, (,), \mathrm{id}\}$ as the set of terminals.

- $S' \rightarrow S$
- $S \rightarrow S + R \mid R$
- $R \rightarrow R{*}P \mid P$
- $P \rightarrow (S) \mid \mathrm{id}$

If I_0 is the set of two $LR(0)$ items $\{[S' \rightarrow S.], [S \rightarrow S. + R]\}$, then $goto(closure(I_0), +)$ contains exactly ______________ items.

gatecse-2022 numerical-answers compiler-design parsing lr-parser one-mark

Answer key☟

3.10.18 LR Parser: GATE CSE 2022 | Question: 3

Which one of the following statements is TRUE?

A. The $LALR(1)$ parser for a grammar G cannot have reduce-reduce conflict if the $LR(1)$ parser for G does not have reduce-reduce conflict.
B. Symbol table is accessed only during the lexical analysis phase.
C. Data flow analysis is necessary for run-time memory management.
D. $LR(1)$ parsing is sufficient for deterministic context-free languages.

gatecse-2022 compiler-design parsing one-mark lr-parser

Answer key☟

3.10.19 LR Parser: GATE CSE 2024 | Set 2 | Question: 55

Consider the following augmented grammar, which is to be parsed with a SLR parser. The set of terminals is $\{a, b, c, d, \#, @\}$

$$S' \to S$$
$$S \to SS|Aa|bAc|Bc|bBa$$
$$A \to d\#$$
$$B \to @$$

Let $I_0 = \mathrm{CLOSURE}(\{S' \to \bullet S\})$. The number of items in the set $\mathrm{GOTO}(I_0, S)$ is __________.

gatecse2024-set2 numerical-answers compiler-design lr-parser two-marks

Answer key

3.10.20 LR Parser: GATE CSE 2025 | Set 2 | Question: 30

Given a Context-Free Grammar G as follows:

$$S \to Aa|bAc|dc \mid bda$$
$$A \to d$$

Which ONE of the following statements is TRUE?

A. G is neither $\mathrm{LALR}(1)$ nor $\mathrm{SLR}(1)$
B. G is $\mathrm{CLR}(1)$, not $\mathrm{LALR}(1)$
C. G is $\mathrm{LALR}(1)$, not $\mathrm{SLR}(1)$
D. G is $\mathrm{LALR}(1)$, also $\mathrm{SLR}(1)$

gatecse2025-set2 compiler-design context-free-grammar parsing lr-parser two-marks

3.11 Lexical Analysis (6)

3.11.1 Lexical Analysis: GATE CSE 1987 | Question: 1-xvii

Using longer identifiers in a program will necessarily lead to:

A. Somewhat slower compilation
B. A program that is easier to understand
C. An incorrect program
D. None of the above

gate1987 compiler-design lexical-analysis

Answer key

3.11.2 Lexical Analysis: GATE CSE 2000 | Question: 1.18, ISRO2015-25

The number of tokens in the following C statement is

```
printf("i=%d, &i=%x", i, &i);
```

A. 3
B. 26
C. 10
D. 21

gatecse-2000 compiler-design lexical-analysis easy isro2015

Answer key

3.11.3 Lexical Analysis: GATE CSE 2010 | Question: 13

Which data structure in a compiler is used for managing information about variables and their attributes?

A. Abstract syntax tree
B. Symbol table

C. Semantic stack

D. Parse table

gatecse-2010 compiler-design lexical-analysis easy

Answer key

3.11.4 Lexical Analysis: GATE CSE 2011 | Question: 1

In a compiler, keywords of a language are recognized during

A. parsing of the program
B. the code generation
C. the lexical analysis of the program
D. dataflow analysis

gatecse-2011 compiler-design lexical-analysis easy

Answer key

3.11.5 Lexical Analysis: GATE CSE 2011 | Question: 19

The lexical analysis for a modern computer language such as Java needs the power of which one of the following machine models in a necessary and sufficient sense?

A. Finite state automata
B. Deterministic pushdown automata
C. Non-deterministic pushdown automata
D. Turing machine

gatecse-2011 compiler-design lexical-analysis easy

Answer key

3.11.6 Lexical Analysis: GATE CSE 2018 | Question: 37

A lexical analyzer uses the following patterns to recognize three tokens T_1, T_2, and T_3 over the alphabet $\{a, b, c\}$.

- $T_1 : a?(b \mid c)^*a$
- $T_2 : b?(a \mid c)^*b$
- $T_3 : c?(b \mid a)^*c$

Note that '$x?$' means 0 or 1 occurrence of the symbol x. Note also that the analyzer outputs the token that matches the longest possible prefix.

If the string $bbaacabc$ is processed by the analyzer, which one of the following is the sequence of tokens it outputs?

A. $T_1T_2T_3$
B. $T_1T_1T_3$
C. $T_2T_1T_3$
D. T_3T_3

gatecse-2018 compiler-design lexical-analysis normal two-marks

Answer key

3.12 Linker (3)

3.12.1 Linker: GATE CSE 1991 | Question: 03,ix

A "link editor" is a program that:

A. matches the parameters of the macro-definition with locations of the parameters of the macro call
B. matches external names of one program with their location in other programs
C. matches the parameters of subroutine definition with the location of parameters of subroutine call.
D. acts as a link between text editor and the user
E. acts as a link between compiler and the user program

gate1991 compiler-design normal linker multiple-selects

Answer key

3.12.2 Linker: GATE CSE 2003 | Question: 76

Which of the following is NOT an advantage of using shared, dynamically linked libraries as opposed to using statistically linked libraries?

A. Smaller sizes of executable files

B. Lesser overall page fault rate in the system
C. Faster program startup
D. Existing programs need not be re-linked to take advantage of newer versions of libraries

gatecse-2003 compiler-design runtime-environment linker easy

Answer key

3.12.3 Linker: GATE CSE 2004 | Question: 9

Consider a program P that consists of two source modules M_1 and M_2 contained in two different files. If M_1 contains a reference to a function defined in M_2 the reference will be resolved at

A. Edit time
B. Compile time
C. Link time
D. Load time

gatecse-2004 compiler-design easy linker

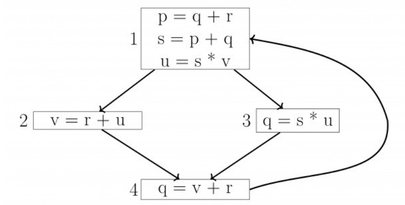
Answer key

3.13 Live Variable Analysis (3)

3.13.1 Live Variable Analysis: GATE CSE 2015 Set 1 | Question: 50

A variable x is said to be live at a statement s_i in a program if the following three conditions hold simultaneously:

i. There exists a statement S_j that uses x
ii. There is a path from S_i to S_j in the flow graph corresponding to the program
iii. The path has no intervening assignment to x including at S_i and S_j



The variables which are live both at the statement in basic block 2 and at the statement in basic block 3 of the above control flow graph are

A. $\mathrm{p, s, u}$
B. $\mathrm{r, s, u}$
C. $\mathrm{r, u}$
D. $\mathrm{q, v}$

gatecse-2015-set1 compiler-design live-variable-analysis normal

Answer key

3.13.2 Live Variable Analysis: GATE CSE 2021 Set 2 | Question: 38

For a statement S in a program, in the context of liveness analysis, the following sets are defined:

$\text{USE}(S)$: the set of variables used in S

$\text{IN}(S)$: the set of variables that are live at the entry of S

$\text{OUT}(S)$: the set of variables that are live at the exit of S

Consider a basic block that consists of two statements, S_1 followed by S_2. Which one of the following statements is correct?

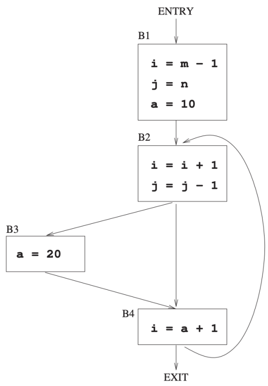
A. $\text{OUT}(S_1) = \text{IN}\ (S_2)$
B. $\text{OUT}\ (S_1) = \text{IN}\ (S_1) \cup\ \text{USE}\ (S_1)$
C. $\text{OUT}\ (S_1) = \text{IN}\ (S_2)\ \cup\ \text{OUT}\ (S_2)$
D. $\text{OUT}\ (S_1) = \text{USE}\ (S_1) \cup \text{IN}\ (S_2)$

gatecse-2021-set2 code-optimization live-variable-analysis compiler-design two-marks

Answer key

3.13.3 Live Variable Analysis: GATE CSE 2023 | Question: 27

Consider the control flow graph shown.



Which one of the following choices correctly lists the set of *live* variables at the exit point of each basic block?

A. $\mathrm{B1}$: $\{\ \}$, $\mathrm{B2}$: $\{\mathrm{a}\}$, $\mathrm{B3}$: $\{\mathrm{a}\}$, $\mathrm{B4}$: $\{\mathrm{a}\}$
B. $\mathrm{B1}$: $\{\mathrm{i}, \mathrm{j}\}$, $\mathrm{B2}$: $\{\mathrm{a}\}$, $\mathrm{B3}$: $\{\mathrm{a}\}$, $\mathrm{B4}$: $\{\mathrm{i}\}$
C. $\mathrm{B1}$: $\{\mathrm{a}, \mathrm{i}, \mathrm{j}\}$, $\mathrm{B2}$: $\{\mathrm{a}, \mathrm{i}, \mathrm{j}\}$, $\mathrm{B3}$: $\{\mathrm{a}, \mathrm{i}\}$, $\mathrm{B4}$: $\{\mathrm{a}\}$
D. $\mathrm{B1}$: $\{\mathrm{a}, \mathrm{i}, \mathrm{j}\}$, $\mathrm{B2}$: $\{\mathrm{a}, \mathrm{j}\}$, $\mathrm{B3}$: $\{\mathrm{a}, \mathrm{j}\}$, $\mathrm{B4}$: $\{\mathrm{a}, \mathrm{i}, \mathrm{j}\}$

gatecse-2023 compiler-design live-variable-analysis two-marks

Answer key☟

3.14 Macros (4)

3.14.1 Macros: GATE CSE 1992 | Question: 01,vii

Macro expansion is done in pass one instead of pass two in a two pass macro assembler because ________

gate1992 compiler-design macros easy fill-in-the-blanks

Answer key☟

3.14.2 Macros: GATE CSE 1995 | Question: 1.11

What are x and y in the following macro definition?

```
macro Add x, y
      Load y
      Mul x
      Store y
end macro
```

A. Variables
B. Identifiers
C. Actual parameters
D. Formal parameters

gate1995 compiler-design macros easy

Answer key☟

3.14.3 Macros: GATE CSE 1996 | Question: 2.16

Which of the following macros can put a macro assembler into an infinite loop?

i.
```
.MACRO M1, X
.IF EQ, X   ;if X=0 then
M1 X + 1
.ENDC
.IF NE, X   ;if X ≠ O then
.WORD X  ;address (X) is stored here
.ENDC
.ENDM
```

ii.
```
.MACRO M2, X
.IF EQ, X
M2 X
.ENDC
.IF NE, X
.WORD X + 1
```

```
.ENDC
.ENDM
```

A. (ii) only
B. (i) only
C. both (i) and (ii)
D. None of the above

gate1996 compiler-design macros normal

Answer key

3.14.4 Macros: GATE CSE 1997 | Question: 1.9

The conditional expansion facility of macro processor is provided to

A. test a condition during the execution of the expanded program
B. to expand certain model statements depending upon the value of a condition during the execution of the expanded program
C. to implement recursion
D. to expand certain model statements depending upon the value of a condition during the process of macro expansion

gate1997 compiler-design macros easy

Answer key

3.15 Operator Precedence (3)

3.15.1 Operator Precedence: GATE CSE 2000 | Question: 2.21, ISRO2015-24

Given the following expression grammar:

$$E \rightarrow E * F \mid F + E \mid F$$

$$F \rightarrow F - F \mid id$$

Which of the following is true?

A. $*$ has higher precedence than $+$
B. $-$ has higher precedence than $*$
C. $+$ and $-$ have same precedence
D. $+$ has higher precedence than $*$

gatecse-2000 operator-precedence normal compiler-design isro2015

Answer key

3.15.2 Operator Precedence: GATE CSE 2016 Set 1 | Question: 45

The attribute of three arithmetic operators in some programming language are given below.

OPERATOR	PRECEDENCE	ASSOCIATIVITY	ARITY
$+$	High	Left	Binary
$-$	Medium	Right	Binary
$*$	Low	Left	Binary

The value of the expression $2 - 5 + 1 - 7 * 3$ in this language is ________.

gatecse-2016-set1 compiler-design parsing normal numerical-answers operator-precedence

Answer key

3.15.3 Operator Precedence: GATE CSE 2024 | Set 1 | Question: 23

Consider the operator precedence and associativity rules for the *integer* arithmetic operators given in the table below.

Operator	Precedence	Associativity
$+$	Highest	Left
$-$	High	Right
$*$	Medium	Right
$/$	Low	Right

The value of the expression $3+1+5*2/7+2-4-7-6/2$ as per the above rules is ________.

gatecse2024-set1 numerical-answers compiler-design operator-precedence one-mark

Answer key

3.16 Parameter Passing (14)

3.16.1 Parameter Passing: GATE CSE 1988 | Question: 2xv

What is printed by following program, assuming call-by reference method of passing parameters for all variables in the parameter list of procedure P?

```
program    Main(inout, output);
var    a, b:integer;
      procedure P(x, y, z:integer);
      begin
         y:=y+1
         z:=x+x
      end P;
begin
   a:=2; b:=3;
   p(a+b, a, a);
   Write(a)
end.
```

gate1988 descriptive compiler-design runtime-environment parameter-passing numerical-answers

Answer key

3.16.2 Parameter Passing: GATE CSE 1988 | Question: 8i

Consider the procedure declaration:

```
Procedure
P (k: integer)
```

where the parameter passing mechanism is call-by-value-result. Is it correct if the call, P (A[i]), where A is an array and i an integer, is implemented as below.

a. create a new local variable, say z;
b. assign to z, the value of A [i];
c. execute the body of P using z for k;
d. set A [i] to z;
Explain your answer. If this is incorrect implementation, suggest a correct one.

gate1988 descriptive compiler-design runtime-environment parameter-passing

Answer key

3.16.3 Parameter Passing: GATE CSE 1989 | Question: 3-viii

In which of the following case(s) is it possible to obtain different results for call-by-reference and call-by-name parameter passing?

A. Passing an expression as a parameter
B. Passing an array as a parameter
C. Passing a pointer as a parameter
D. Passing as array element as a parameter

gate1989 parameter-passing runtime-environment compiler-design multiple-selects

Answer key

3.16.4 Parameter Passing: GATE CSE 1990 | Question: 11a

What does the following program output?

```
program module (input, output);
var
   a:array [1...5] of integer;
   i, j: integer;
procedure unknown (var b: integer, var c: integer);
var
   i:integer;
begin
   for i := 1 to 5 do a[i] := i;
   b:= 0; c := 0
   for i := 1 to 5 do write (a[i]);
   writeln();
   a[3]:=11; a[1]:=11;
   for i:=1 to 5 do a [i] := sqr(a[i]);
   writeln(c,b); b := 5; c := 6;
end;
begin
  i:=1; j:=3; unknown (a[i], a[j]);
  for i:=1 to 5 do write (a[i]);
end;
```

gate1990 descriptive compiler-design runtime-environment parameter-passing

Answer key

3.16.5 Parameter Passing: GATE CSE 1991 | Question: 03,x

Indicate all the true statements from the following:

A. Recursive descent parsing cannot be used for grammar with left recursion.
B. The intermediate form for representing expressions which is best suited for code optimization is the postfix form.
C. A programming language not supporting either recursion or pointer type does not need the support of dynamic memory allocation.
D. Although C does not support call-by-name parameter passing, the effect can be correctly simulated in C
E. No feature of Pascal typing violates strong typing in Pascal.

gate1991 compiler-design parameter-passing difficult multiple-selects

Answer key

3.16.6 Parameter Passing: GATE CSE 1991 | Question: 09a

Consider the following pseudo-code (all data items are of type integer):

```
procedure P(a, b, c);
   a := 2;
   c := a + b;
end {P}

begin
   x := 1;
   y := 5;
   z := 100;
   P(x, x*y, z);
   Write ('x = ', x, 'z = ', z);
end
```

Determine its output, if the parameters are passed to the Procedure P by

i. value
ii. reference
iii. name

gate1991 compiler-design parameter-passing normal runtime-environment descriptive

Answer key

3.16.7 Parameter Passing: GATE CSE 1991 | Question: 09b

For the following code, indicate the output if

a. static scope rules
b. dynamic scope rules

are used

```
var a,b : integer;

procedure P;
   a := 5;
   b := 10;
end {P};

procedure Q;
   var a, b : integer;
   P;
end {Q};

begin
   a := 1;
   b := 2;
   Q;
   Write ('a = ', a, 'b = ', b);
end
```

gate1991 runtime-environment normal compiler-design parameter-passing descriptive

Answer key

3.16.8 Parameter Passing: GATE CSE 1993 | Question: 26

A stack is used to pass parameters to procedures in a procedure call.

A. If a procedure P has two parameters as described in procedure definition:

```
procedure P (var x :integer; y: integer);
```

and if P is called by ; $P(a, b)$

State precisely in a sentence what is pushed on stack for parameters a and b

B. In the generated code for the body of procedure P, how will the addressing of formal parameters x and y differ?

gate1993 compiler-design parameter-passing runtime-environment normal descriptive

Answer key

3.16.9 Parameter Passing: GATE CSE 1995 | Question: 2.4

What is the value of X printed by the following program?

```
program COMPUTE (input, output);
var X:integer;
procedure FIND (X:real);
   begin
      X:=sqrt(X);
   end;
begin
   X:=2
   FIND(X);
   writeln(X);
end.
```

A. 2
B. $\sqrt{2}$
C. Run time error
D. None of the above

gate1995 compiler-design parameter-passing runtime-environment easy

Answer key

3.16.10 Parameter Passing: GATE CSE 1999 | Question: 15

What will be the output of the following program assuming that parameter passing is

i. call by value
ii. call by reference
iii. call by copy restore

```
    procedure P{x, y, z};
    begin
        y:y+1;
        z: x+x;
    end;
    begin
        a:= b:= 3;
        P(a+b, a, a);
        Print(a);
    end
```

gate1999 parameter-passing normal runtime-environment descriptive

Answer key

3.16.11 Parameter Passing: GATE CSE 2003 | Question: 74

The following program fragment is written in a programming language that allows global variables and does not allow nested declarations of functions.

```
global int i=100, j=5;
void P(x) {
 int i=10;
   print(x+10);
   i=200;
   j=20;
   print (x);
}
main() {P(i+j);}
```

If the programming language uses dynamic scoping and call by name parameter passing mechanism, the values printed by the above program are

A. $115, 220$
B. $25, 220$
C. $25, 15$
D. $115, 105$

gatecse-2003 programming compiler-design parameter-passing runtime-environment normal

Answer key

3.16.12 Parameter Passing: GATE CSE 2004 | Question: 2,ISRO2017-54

Consider the following function

```
void swap(int a, int b)
{
   int temp;
   temp = a;
   a = b;
   b = temp;
}
```

In order to exchange the values of two variables x and y.

A. call $swap(x, y)$
B. call $swap(\&x, \&y)$
C. $swap(x, y)$ cannot be used as it does not return any value
D. $swap(x, y)$ cannot be used as the parameters are passed by value

gatecse-2004 compiler-design programming-in-c parameter-passing easy isro2017 runtime-environment

Answer key

3.16.13 Parameter Passing: GATE CSE 2016 Set 1 | Question: 36

What will be the output of the following pseudo-code when parameters are passed by reference and dynamic scoping is assumed?

```
a = 3;
void n(x) { x = x * a; print (x); }
void m(y) { a = 1 ; a = y - a;  n(a); print (a); }
void main () { m(a); }
```

A. $6, 2$ B. $6, 6$ C. $4, 2$ D. $4, 4$

gatecse-2016-set1 parameter-passing normal

Answer key

3.16.14 Parameter Passing: GATE IT 2007 | Question: 33

Consider the program below in a hypothetical language which allows global variable and a choice of call by reference or call by value methods of parameter passing.

```
int i ;
program main ()
{
    int j = 60;
    i = 50;
    call f (i, j);
    print i, j;
}
procedure f (x, y)
{
    i = 100;
    x = 10;
    y = y + i ;
}
```

Which one of the following options represents the correct output of the program for the two parameter passing mechanisms?

A. Call by value : $i = 70, j = 10$; Call by reference : $i = 60, j = 70$
B. Call by value : $i = 50, j = 60$; Call by reference : $i = 50, j = 70$
C. Call by value : $i = 10, j = 70$; Call by reference : $i = 100, j = 60$
D. Call by value : $i = 100, j = 60$; Call by reference : $i = 10, j = 70$

gateit-2007 programming parameter-passing normal compiler-design runtime-environment

Answer key

3.17 Parsing (27)

3.17.1 Parsing: GATE CSE 1987 | Question: 1-xii

A context-free grammar is ambiguous if:

A. The grammar contains useless non-terminals.
B. It produces more than one parse tree for some sentence.
C. Some production has two non terminals side by side on the right-hand side.
D. None of the above.

gate1987 compiler-design parsing ambiguous-grammar

Answer key

3.17.2 Parsing: GATE CSE 1987 | Question: 1-xiv

An operator precedence parser is a

A. Bottom-up parser.
B. Top-down parser.
C. Back tracking parser.
D. None of the above.

gate1987 compiler-design parsing easy

Answer key

3.17.3 Parsing: GATE CSE 1989 | Question: 1-iii

Merging states with a common core may produce ___________ conflicts and does not produce ____________ conflicts in an LALR parser.

gate1989 descriptive compiler-design parsing

Answer key

3.17.4 Parsing: GATE CSE 1993 | Question: 25

A simple Pascal like language has only three statements.

i. assignment statement e.g. x:=expression
ii. loop construct e.g. for i:=expression to expression do statement
iii. sequencing e.g. begin statement ;…; statement end

A. Write a context-free grammar (CFG) for statements in the above language. Assume that expression has already been defined. Do not use optional parenthesis and * operator in CFG.
B. Show the parse tree for the following statements:

```
for j:=2 to 10 do
begin
   x:=expr1;
   y:=expr2;
end
```

gate1993 compiler-design parsing normal descriptive

Answer key

3.17.5 Parsing: GATE CSE 1995 | Question: 8

Construct the $\text{LL}(1)$ table for the following grammar.

1. $Expr \rightarrow \_Expr$
2. $Expr \rightarrow (Expr)$
3. $Expr \rightarrow Var\ ExprTail$
4. $ExprTail \rightarrow \_Expr$
5. $Expr \rightarrow \lambda$
6. $Var \rightarrow Id\ VarTail$
7. $VarTail \rightarrow (Expr)$
8. $VarTail \rightarrow \lambda$
9. $Goal \rightarrow Expr\$$

gate1995 compiler-design parsing normal descriptive

Answer key

3.17.6 Parsing: GATE CSE 1998 | Question: 1.27

Type checking is normally done during

A. lexical analysis
B. syntax analysis
C. syntax directed translation
D. code optimization

gate1998 compiler-design parsing easy

Answer key

3.17.7 Parsing: GATE CSE 1998 | Question: 22

A. An identifier in a programming language consists of up to six letters and digits of which the first character must be a letter. Derive a regular expression for the identifier.

B. Build an $LL(1)$ parsing table for the language defined by the $LL(1)$ grammar with productions

$\text{Program} \rightarrow \text{ begin } d \text{ semi } X \text{ end}$

$X \rightarrow d \text{ semi } X \mid sY$

$Y \rightarrow \text{ semi } sY \mid \epsilon$

gate1998 compiler-design parsing descriptive

Answer key

3.17.8 Parsing: GATE CSE 1999 | Question: 1.17

Which of the following is the most powerful parsing method?

A. LL (1)
B. Canonical LR
C. SLR
D. LALR

gate1999 compiler-design parsing easy

Answer key

3.17.9 Parsing: GATE CSE 2000 | Question: 1.19, UGCNET-Dec2013-II: 30

Which of the following derivations does a top-down parser use while parsing an input string? The input is scanned from left to right.

A. Leftmost derivation
B. Leftmost derivation traced out in reverse
C. Rightmost derivation
D. Rightmost derivation traced out in reverse

gatecse-2000 compiler-design parsing normal ugcnetcse-dec2013-paper2

Answer key

3.17.10 Parsing: GATE CSE 2001 | Question: 16

Consider the following grammar with terminal alphabet $\Sigma = \{a, (,), +, *\}$ and start symbol E. The production rules of the grammar are:

- $E \rightarrow aA$
- $E \rightarrow (E)$
- $A \rightarrow +E$
- $A \rightarrow *E$
- $A \rightarrow \epsilon$

a. Compute the FIRST and FOLLOW sets for E and A.
b. Complete the LL(1) parse table for the grammar.

gatecse-2001 compiler-design parsing normal descriptive

Answer key

3.17.11 Parsing: GATE CSE 2002 | Question: 22

A. Construct all the parse trees corresponding to $i + j * k$ for the grammar
$E \rightarrow E + E$
$E \rightarrow E * E$
$E \rightarrow id$
B. In this grammar, what is the precedence of the two operators $*$ and $+$?
C. If only one parse tree is desired for any string in the same language, what changes are to be made so that the resulting LALR(1) grammar is unambiguous?

gatecse-2002 compiler-design parsing normal descriptive

Answer key

3.17.12 Parsing: GATE CSE 2003 | Question: 16

Which of the following suffices to convert an arbitrary CFG to an LL(1) grammar?

A. Removing left recursion alone
B. Factoring the grammar alone
C. Removing left recursion and factoring the grammar
D. None of the above

gatecse-2003 compiler-design parsing easy

Answer key☟

3.17.13 Parsing: GATE CSE 2005 | Question: 83a

Statement for Linked Answer Questions 83a & 83b:

Consider the following expression grammar. The semantic rules for expression evaluation are stated next to each grammar production.

$$\begin{array}{r|l} E \rightarrow number & E.val = number.val \\ \mid E \text{ `+' } E & E^{(1)}.val = E^{(2)}.val + E^{(3)}.val \\ \mid E \text{ `}\times\text{' } E & E^{(1)}.val = E^{(2)}.val \times E^{(3)}.val \end{array}$$

The above grammar and the semantic rules are fed to a *yaac* tool (which is an LALR(1) parser generator) for parsing and evaluating arithmetic expressions. Which one of the following is true about the action of *yaac* for the given grammar?

A. It detects *recursion* and eliminates recursion

B. It detects *reduce-reduce* conflict, and resolves

C. It detects *shift-reduce* conflict, and resolves the conflict in favor of a *shift* over a *reduce* action

D. It detects *shift-reduce* conflict, and resolves the conflict in favor of a *reduce* over a *shift* action

gatecse-2005 compiler-design parsing difficult

Answer key☟

3.17.14 Parsing: GATE CSE 2005 | Question: 83b

Consider the following expression grammar. The semantic rules for expression evaluation are stated next to each grammar production.

$$\begin{array}{r|l} E \rightarrow number & E.val = number.val \\ \mid E \text{ `+' } E & E^{(1)}.val = E^{(2)}.val + E^{(3)}.val \\ \mid E \text{ `}\times\text{' } E & E^{(1)}.val = E^{(2)}.val \times E^{(3)}.val \end{array}$$

Assume the conflicts of this question are resolved using yacc tool and an LALR(1) parser is generated for parsing arithmetic expressions as per the given grammar. Consider an expression $3 \times 2 + 1$. What precedence and associativity properties does the generated parser realize?

A. Equal precedence and left associativity; expression is evaluated to 7

B. Equal precedence and right associativity; expression is evaluated to 9

C. Precedence of '$\times$' is higher than that of '$+$', and both operators are left associative; expression is evaluated to 7

D. Precedence of '$+$' is higher than that of '$\times$', and both operators are left associative; expression is evaluated to 9

gatecse-2005 compiler-design parsing normal

Answer key☟

3.17.15 Parsing: GATE CSE 2006 | Question: 58

Consider the following grammar:

- $S \rightarrow FR$
- $R \rightarrow *S \mid \varepsilon$
- $F \rightarrow id$

In the predictive parser table M of the grammar the entries $M[S, id]$ and $M[R, \$]$ respectively are

A. $\{S \rightarrow FR\}$ and $\{R \rightarrow \varepsilon\}$
B. $\{S \rightarrow FR\}$ and $\{\}$
C. $\{S \rightarrow FR\}$ and $\{R \rightarrow *S\}$
D. $\{F \rightarrow id\}$ and $\{R \rightarrow \varepsilon\}$

gatecse-2006 compiler-design parsing normal

Answer key☟

3.17.16 Parsing: GATE CSE 2007 | Question: 18

Which one of the following is a top-down parser?

A. Recursive descent parser.
B. Operator precedence parser.
C. An LR(k) parser.
D. An LALR(k) parser.

gatecse-2007 compiler-design parsing normal

Answer key☟

3.17.17 Parsing: GATE CSE 2008 | Question: 11

Which of the following describes a handle (as applicable to LR-parsing) appropriately?

A. It is the position in a sentential form where the next shift or reduce operation will occur
B. It is non-terminal whose production will be used for reduction in the next step
C. It is a production that may be used for reduction in a future step along with a position in the sentential form where the next shift or reduce operation will occur
D. It is the production p that will be used for reduction in the next step along with a position in the sentential form where the right hand side of the production may be found

gatecse-2008 compiler-design parsing normal

Answer key☟

3.17.18 Parsing: GATE CSE 2009 | Question: 42

Which of the following statements are TRUE?

I. There exist parsing algorithms for some programming languages whose complexities are less than $\Theta(n^3)$
II. A programming language which allows recursion can be implemented with static storage allocation.
III. No L-attributed definition can be evaluated in the framework of bottom-up parsing.
IV. Code improving transformations can be performed at both source language and intermediate code level.

A. I and II
B. I and IV
C. III and IV
D. I, III and IV

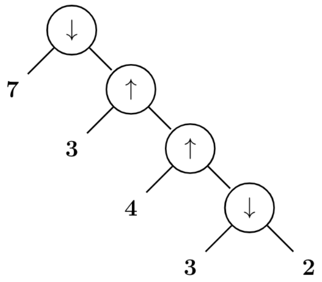
gatecse-2009 compiler-design parsing normal

Answer key☟

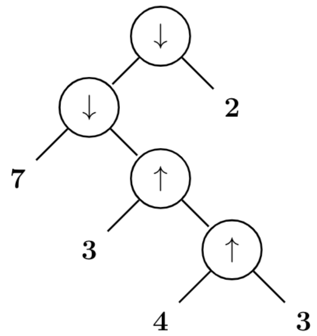
3.17.19 Parsing: GATE CSE 2011 | Question: 27

Consider two binary operators '$\uparrow$' and '$\downarrow$' with the precedence of operator $\downarrow$ being lower than that of the operator $\uparrow$. Operator $\uparrow$ is right associative while operator $\downarrow$ is left associative. Which one of the following represents the parse tree for expression $(7 \downarrow 3 \uparrow 4 \uparrow 3 \downarrow 2)$

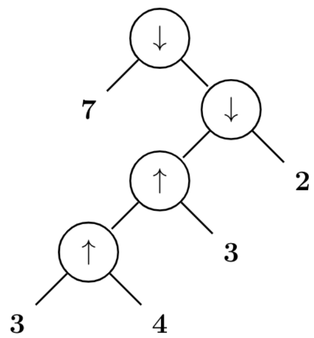
A.



B.



C.



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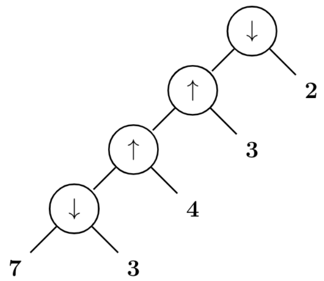


gatecse-2011 compiler-design parsing normal

Answer key

3.17.20 Parsing: GATE CSE 2012 | Question: 53

For the grammar below, a partial $LL(1)$ parsing table is also presented along with the grammar. Entries that need to be filled are indicated as $E1, E2,$ and $E3$. ε is the empty string, $ indicates end of input, and, $|$ separates alternate right hand sides of productions.

- $S \to aAbB \mid bAaB \mid \varepsilon$
- $A \to S$
- $B \to S$

	a	**b**	**$**
S	E1	E2	$S \to \varepsilon$
A	$A \to S$	$A \to S$	error
B	$B \to S$	$B \to S$	$E3$

The appropriate entries for $E1, E2,$ and $E3$ are

A. $E1 : S \to aAbB, A \to S$
$E2 : S \to bAaB, B \to S$
$E3 : B \to S$

B. $E1 : S \to aAbB, S \to \varepsilon$
$E2 : S \to bAaB, S \to \varepsilon$
$E3 : S \to \varepsilon$

C. $E1 : S \to aAbB, S \to \varepsilon$
$E2 : S \to bAaB, S \to \varepsilon$
$E3 : B \to S$

D. $E1 : A \to S, S \to \varepsilon$
$E2 : B \to S, S \to \varepsilon$
$E3 : B \to S$

normal gatecse-2012 compiler-design parsing

Answer key

3.17.21 Parsing: GATE CSE 2015 Set 3 | Question: 31

Consider the following grammar *G*

$S \to F \mid H$

$F \to p \mid c$

$H \to d \mid c$

Where S, F, and H are non-terminal symbols, $p, d,$ and c are terminal symbols. Which of the following statement(s) is/are correct?

S1: LL(1) can parse all strings that are generated using grammar *G*

S2: LR(1) can parse all strings that are generated using grammar *G*

A. Only S1   B. Only S2   C. Both S1 and S2   D. Neither S1 and S2

gatecse-2015-set3 compiler-design parsing normal

Answer key

3.17.22 Parsing: GATE CSE 2017 Set 1 | Question: 43

Consider the following grammar:

- stmt $\to$ **if** expr **then** expr **else** expr; stmt | Ò
- expr $\to$ term **relop** term | term
- term $\to$ id | number
- id $\to$ **a** | **b** | **c**
- number $\to$ $[0-9]$

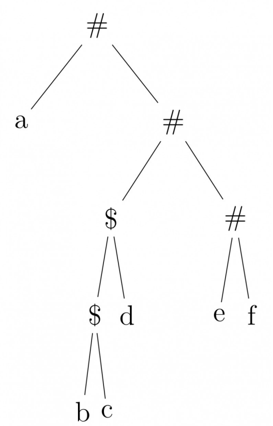
where **relop** is a relational operator (e.g., $<, >, \dots$), Ò refers to the empty statement, and **if**, **then**, **else** are terminals.
Consider a program P following the above grammar containing ten **if** terminals. The number of control flow paths in P is________ . For example. the program
if e_1 **then** e_2 **else** e_3
has 2 control flow paths. $e_1 \to e_2$ and $e_1 \to e_3$.

gatecse-2017-set1 compiler-design parsing normal numerical-answers

Answer key

3.17.23 Parsing: GATE CSE 2018 | Question: 38

Consider the following parse tree for the expression a#bcd#e#f, involving two binary operators $ and #.



Which one of the following is correct for the given parse tree?

A. $ has higher precedence and is left associative; # is right associative
B. # has higher precedence and is left associative; $ is right associative
C. $ has higher precedence and is left associative; # is left associative
D. $ has higher precedence and is right associative; # is left associative

gatecse-2018 compiler-design parsing normal two-marks

Answer key

3.17.24 Parsing: GATE CSE 2024 | Set 1 | Question: 16

Which of the following is/are Bottom-Up Parser(s)?

A. Shift-reduce Parser
B. Predictive Parser
C. LL(1) Parser
D. LR Parser

gatecse2024-set1 multiple-selects compiler-design parsing easy one-mark

Answer key

3.17.25 Parsing: GATE CSE 2024 | Set 2 | Question: 30

Consider the following context-free grammar where the start symbol is S and the set of terminals is $\{a, b, c, d\}$.

$$S \rightarrow AaAb \mid BbBa$$
$$A \rightarrow cS \mid \epsilon$$
$$B \rightarrow dS \mid \epsilon$$

The following is a partially-filled $\mathrm{LL}(1)$ parsing table.

	a	b	c	d	\$
S	$S \rightarrow AaAb$	$S \rightarrow BbBa$	(1)	(2)	
A	$A \rightarrow \epsilon$	(3)	$A \rightarrow cS$		
B	(4)	$B \rightarrow \epsilon$		$B \rightarrow dS$	

Which one of the following options represents the CORRECT combination for the numbered cells in the parsing table?

Note: In the options, "blank" denotes that the corresponding cell is empty.

A. $(1)\ S \rightarrow AaAb\ (2)\ S \rightarrow BbBa\ (3)\ A \rightarrow \epsilon\ (4)\ B \rightarrow \epsilon$
B. $(1)\ S \rightarrow BbBa\ (2)\ S \rightarrow AaAb\ (3)\ A \rightarrow \epsilon\ (4)\ B \rightarrow \epsilon$
C. $(1)\ S \rightarrow AaAb\ (2)\ S \rightarrow BbBa\ (3)$ blank (4) blank
D. $(1)\ S \rightarrow BbBa\ (2)\ S \rightarrow AaAb\ (3)$ blank (4) blank

gatecse2024-set2 compiler-design ll-parser parsing two-marks

Answer key

3.17.26 Parsing: GATE IT 2005 | Question: 83b

Consider the context-free grammar

- $E \rightarrow E + E$
- $E \rightarrow (E * E)$
- $E \rightarrow \mathrm{id}$

where E is the starting symbol, the set of terminals is $\{id, (, +,), *\}$, and the set of non-terminals is $\{E\}$.
For the terminal string $id + id + id + id$, how many parse trees are possible?

A. 5
B. 4
C. 3
D. 2

gateit-2005 compiler-design parsing normal

Answer key

3.17.27 Parsing: GATE IT 2008 | Question: 79

A CFG G is given with the following productions where S is the start symbol, A is a non-terminal and a and b are terminals.

- $S \to aS \mid A$
- $A \to aAb \mid bAa \mid \epsilon$

For the string "$aabbaab$" how many steps are required to derive the string and how many parse trees are there?

A. 6 and 1 B. 6 and 2 C. 7 and 2 D. 4 and 2

gateit-2008 compiler-design parsing normal

Answer key

3.18 Register Allocation (6)

3.18.1 Register Allocation: GATE CSE 1997 | Question: 4.9

The expression $(a * b) * c \; op \ldots$

where 'op' is one of '$+$', '$*$' and '$\uparrow$' (exponentiation) can be evaluated on a CPU with single register without storing the value of $(a * b)$ if

A. 'op' is '$+$' or '$*$'
B. 'op' is '$\uparrow$' or '$*$'
C. 'op' is '$\uparrow$' or '$+$'
D. not possible to evaluate without storing

gate1997 compiler-design register-allocation normal

Answer key

3.18.2 Register Allocation: GATE CSE 2004 | Question: 10

Consider the grammar rule $E \to E1 - E2$ for arithmetic expressions. The code generated is targeted to a CPU having a single user register. The subtraction operation requires the first operand to be in the register. If $E1$ and $E2$ do not have any common sub expression, in order to get the shortest possible code

A. $E1$ should be evaluated first
B. $E2$ should be evaluated first
C. Evaluation of $E1$ and $E2$ should necessarily be interleaved
D. Order of evaluation of $E1$ and $E2$ is of no consequence

gatecse-2004 compiler-design register-allocation normal

Answer key

3.18.3 Register Allocation: GATE CSE 2010 | Question: 37

The program below uses six temporary variables a, b, c, d, e, f.

```
a = 1
b = 10
c = 20
d = a + b
e = c + d
f = c + e
b = c + e
e = b + f
d = 5 + e
return d + f
```

Assuming that all operations take their operands from registers, what is the minimum number of registers needed to execute this program without spilling?

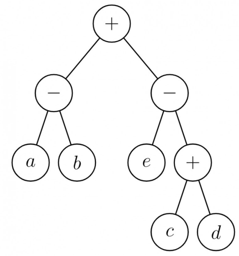
A. 2 B. 3 C. 4 D. 6

gatecse-2010 compiler-design register-allocation normal

Answer key

3.18.4 Register Allocation: GATE CSE 2011 | Question: 36

Consider evaluating the following expression tree on a machine with load-store architecture in which memory can be accessed only through load and store instructions. The variables $a, b, c, d,$ and e are initially stored in memory. The binary operators used in this expression tree can be evaluated by the machine only when operands are in registers. The instructions produce result only in a register. If no intermediate results can be stored in memory, what is the minimum number of registers needed to evaluate this expression?



A. 2 B. 9 C. 5 D. 3

gatecse-2011 compiler-design register-allocation normal

Answer key

3.18.5 Register Allocation: GATE CSE 2013 | Question: 48

The following code segment is executed on a processor which allows only register operands in its instructions. Each instruction can have atmost two source operands and one destination operand. Assume that all variables are dead after this code segment.

```
c = a + b;
d = c * a;
e = c + a;
x = c * c;
if (x > a) {
 y = a * a;
}
else {
 d = d * d;
 e = e * e;
}
```

Q.48 Suppose the instruction set architecture of the processor has only two registers. The only allowed compiler optimization is code motion, which moves statements from one place to another while preserving correctness. What is the minimum number of spills to memory in the compiled code?

A. 0 B. 1 C. 2 D. 3

gatecse-2013 normal compiler-design register-allocation

Answer key

3.18.6 Register Allocation: GATE CSE 2017 Set 1 | Question: 52

Consider the expression $(a-1) * (((b+c)/3)+d)$. Let X be the minimum number of registers required by an *optimal* code generation (without any register spill) algorithm for a load/store architecture, in which

A. only load and store instructions can have memory operands and
B. arithmetic instructions can have only register or immediate operands.

The value of X is _____________ .

gatecse-2017-set1 compiler-design register-allocation normal numerical-answers

Answer key

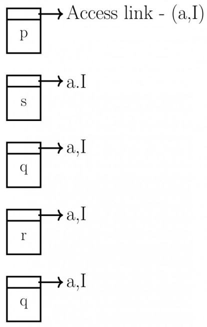
3.19 Runtime Environment (22)

3.19.1 Runtime Environment: GATE CSE 1988 | Question: 2xii

Consider the following program skeleton and below figure which shows activation records of procedures involved in the calling sequence.

$$p \rightarrow s \rightarrow q \rightarrow r \rightarrow q.$$

Write the access links of the activation records to enable correct access and variables in the procedures from other procedures involved in the calling sequence




```
procedure p;
 procedure q;
  procedure r;
   begin
    q
   end r;
  begin
   r
  end q;
 procedure s;
  begin
   q
  end s;
 begin
  s
 end p;
```

gate1988 normal descriptive runtime-environment compiler-design

Answer key☟

3.19.2 Runtime Environment: GATE CSE 1989 | Question: 10a

Will recursion work correctly in a language with static allocation of all variables? Explain.

gate1989 descriptive compiler-design runtime-environment

Answer key☟

3.19.3 Runtime Environment: GATE CSE 1989 | Question: 8b

Indicate the result of the following program if the language uses (i) static scope rules and (ii) dynamic scope rules.

```
var x, y:integer;
procedure A (var z:integer);
var x:integer;
begin x:=1; B; z:= x end;
procedure B;
begin x:=x+1 end;
begin
x:=5; A(y); write (y)
...end.
```

gate1989 descriptive compiler-design runtime-environment

Answer key☟

3.19.4 Runtime Environment: GATE CSE 1990 | Question: 2-v

Match the pairs in the following questions:

(a)	Pointer data type	(p)	Type conversion
(b)	Activation record	(q)	Dynamic data structure
(c)	Repeat-until	(r)	Recursion
(d)	Coercion	(s)	Nondeterministic loop

gate1990 match-the-following compiler-design runtime-environment recursion

Answer key

3.19.5 Runtime Environment: GATE CSE 1990 | Question: 4-v

State whether the following statements are TRUE or FALSE with reason:

The Link-load-and-go loading scheme required less storage space than the link-and-go loading scheme.

gate1990 true-false compiler-design runtime-environment

Answer key

3.19.6 Runtime Environment: GATE CSE 1993 | Question: 7.7

A part of the system software which under all circumstances must reside in the main memory is:

A. text editor
B. assembler
C. linker
D. loader
E. none of the above

gate1993 compiler-design runtime-environment easy

Answer key

3.19.7 Runtime Environment: GATE CSE 1995 | Question: 1.14

A linker is given object modules for a set of programs that were compiled separately. What information need to be included in an object module?

A. Object code
B. Relocation bits
C. Names and locations of all external symbols defined in the object module
D. Absolute addresses of internal symbols

gate1995 compiler-design runtime-environment normal

Answer key

3.19.8 Runtime Environment: GATE CSE 1996 | Question: 2.17

The correct matching for the following pairs is

(A)	Activation record	(1)	Linking loader
(B)	Location counter	(2)	Garbage collection
(C)	Reference counts	(3)	Subroutine call
(D)	Address relocation	(4)	Assembler

A. A-3 B-4 C-1 D-2
B. A-4 B-3 C-1 D-2
C. A-4 B-3 C-2 D-1
D. A-3 B-4 C-2 D-1

gate1996 compiler-design easy runtime-environment

Answer key

3.19.9 Runtime Environment: GATE CSE 1997 | Question: 1.10

Heap allocation is required for languages.

A. that support recursion
B. that support dynamic data structure
C. that use dynamic scope rules
D. None of the above

gate1997 compiler-design easy runtime-environment

Answer key

3.19.10 Runtime Environment: GATE CSE 1997 | Question: 1.8

A language L allows declaration of arrays whose sizes are not known during compilation. It is required to make efficient use of memory. Which one of the following is true?

A. A compiler using static memory allocation can be written for L
B. A compiler cannot be written for L; an interpreter must be used
C. A compiler using dynamic memory allocation can be written for L
D. None of the above

gate1997 compiler-design easy runtime-environment

Answer key

3.19.11 Runtime Environment: GATE CSE 1998 | Question: 1.25, ISRO2008-41

In a resident – OS computer, which of the following systems must reside in the main memory under all situations?

A. Assembler
B. Linker
C. Loader
D. Compiler

gate1998 compiler-design runtime-environment normal isro2008

Answer key

3.19.12 Runtime Environment: GATE CSE 1998 | Question: 1.28

A linker reads four modules whose lengths are $200, 800, 600$ and 500 words, respectively. If they are loaded in that order, what are the relocation constants?

A. $0, 200, 500, 600$
B. $0, 200, 1000, 1600$
C. $200, 500, 600, 800$
D. $200, 700, 1300, 2100$

gate1998 compiler-design runtime-environment normal

Answer key

3.19.13 Runtime Environment: GATE CSE 1998 | Question: 2.15

Faster access to non-local variables is achieved using an array of pointers to activation records called a

A. stack
B. heap
C. display
D. activation tree

gate1998 programming compiler-design normal runtime-environment

Answer key

3.19.14 Runtime Environment: GATE CSE 2001 | Question: 1.17

The process of assigning load addresses to the various parts of the program and adjusting the code and the data in the program to reflect the assigned addresses is called

A. Assembly
B. parsing
C. Relocation
D. Symbol resolution

gatecse-2001 compiler-design runtime-environment easy

Answer key

3.19.15 Runtime Environment: GATE CSE 2002 | Question: 2.20

Dynamic linking can cause security concerns because

A. Security is dynamic
B. The path for searching dynamic libraries is not known till runtime
C. Linking is insecure
D. Cryptographic procedures are not available for dynamic linking

gatecse-2002 compiler-design runtime-environment easy

Answer key

3.19.16 Runtime Environment: GATE CSE 2008 | Question: 54

Which of the following are true?

I. A programming language which does not permit global variables of any kind and has no nesting of procedures/functions, but permits recursion can be implemented with static storage allocation
II. Multi-level access link (or display) arrangement is needed to arrange activation records only if the programming language being implemented has nesting of procedures/functions
III. Recursion in programming languages cannot be implemented with dynamic storage allocation
IV. Nesting procedures/functions and recursion require a dynamic heap allocation scheme and cannot be implemented with a stack-based allocation scheme for activation records
V. Programming languages which permit a function to return a function as its result cannot be implemented with a stack-based storage allocation scheme for activation records

A. II and V only
B. I, III and IV only
C. I, II and V only
D. II, III and V only

gatecse-2008 compiler-design difficult runtime-environment

Answer key

3.19.17 Runtime Environment: GATE CSE 2010 | Question: 14

Which languages necessarily need heap allocation in the runtime environment?

A. Those that support recursion.
B. Those that use dynamic scoping.
C. Those that allow dynamic data structure.
D. Those that use global variables.

gatecse-2010 compiler-design easy runtime-environment

Answer key

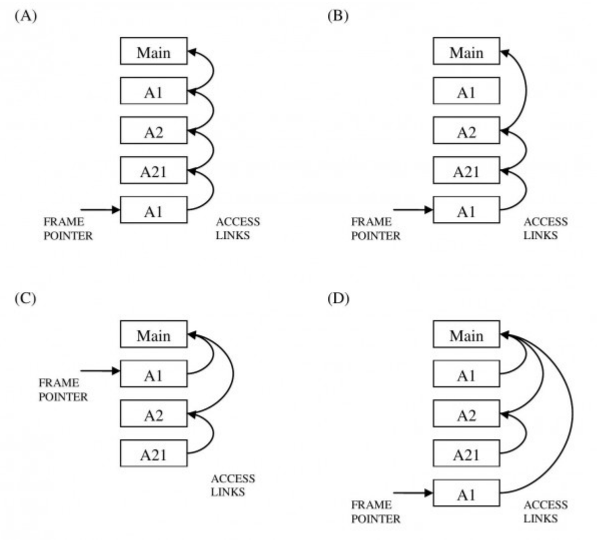
3.19.18 Runtime Environment: GATE CSE 2012 | Question: 36

Consider the program given below, in a block-structured pseudo-language with lexical scoping and nesting of procedures permitted.

```
Program main;
 Var ...

 Procedure A1;
  Var ...
  Call A2;
 End A1

 Procedure A2;
  Var ...

  Procedure A21;
   Var ...
   Call A1;
  End A21

  Call A21;
 End A2

 Call A1;
End main.
```

Consider the calling chain: $\text{Main} \rightarrow \text{A1} \rightarrow \text{A2} \rightarrow \text{A21} \rightarrow \text{A1}$

The correct set of activation records along with their access links is given by:



gatecse-2012 compiler-design runtime-environment normal

Answer key

3.19.19 Runtime Environment: GATE CSE 2014 Set 2 | Question: 18

Which one of the following is **NOT** performed during compilation?

A. Dynamic memory allocation
B. Type checking
C. Symbol table management
D. Inline expansion

gatecse-2014-set2 compiler-design easy runtime-environment

Answer key

3.19.20 Runtime Environment: GATE CSE 2014 Set 3 | Question: 18

Which of the following statements are CORRECT?

1. Static allocation of all data areas by a compiler makes it impossible to implement recursion.
2. Automatic garbage collection is essential to implement recursion.
3. Dynamic allocation of activation records is essential to implement recursion.
4. Both heap and stack are essential to implement recursion.

A. 1 and 2 only
B. 2 and 3 only
C. 3 and 4 only
D. 1 and 3 only

gatecse-2014-set3 compiler-design runtime-environment normal

Answer key

3.19.21 Runtime Environment: GATE CSE 2021 Set 1 | Question: 4

Consider the following statements.

- S_1 **:** The sequence of procedure calls corresponds to a preorder traversal of the activation tree.
- S_2 **:** The sequence of procedure returns corresponds to a postorder traversal of the activation tree.

Which one of the following options is correct?

A. S_1 is true and S_2 is false
B. S_1 is false and S_2 is true
C. S_1 is true and S_2 is true
D. S_1 is false and S_2 is false

gatecse-2021-set1 runtime-environment normal one-mark

Answer key

3.19.22 Runtime Environment: GATE CSE 2023 | Question: 26

Consider the following program:

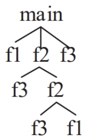
```
int main()
{
    f1 ();
    f2(2);
    f3();
    return (0);
}
```

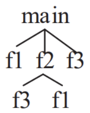
```
int f1 ()
{
    return(1);
}
```

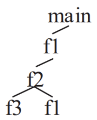
```
int f2 (int X)
{
    f3();
    if (X==1);
        return f1 ();
    else
        return (X * f2 (X - 1));

}
```

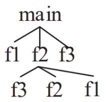
```
int f3 ()
{
    return (5);
}
```

Which one of the following options represents the activation tree corresponding to the main function?

A. 

B. 

C. 

D. 

gatecse-2023 compiler-design runtime-environment two-marks

Answer key

3.20 Static Single Assignment (3)

3.20.1 Static Single Assignment: GATE CSE 2015 Set 1 | Question: 55

The least number of temporary variables required to create a three-address code in static single assignment form for the expression $q + r/3 + s - t * 5 + u * v/w$ is__________________.

gatecse-2015-set1 compiler-design intermediate-code normal numerical-answers static-single-assignment

Answer key

3.20.2 Static Single Assignment: GATE CSE 2016 Set 1 | Question: 19

Consider the following code segment.

```
x = u - t;
y = x * v;
x = y + w;
y = t - z;
y = x * y;
```

The minimum number of *total* variables required to convert the above code segment to *static single assignment* form is ___________.

gatecse-2016-set1 compiler-design static-single-assignment normal numerical-answers

Answer key

3.20.3 Static Single Assignment: GATE CSE 2017 Set 1 | Question: 12

Consider the following intermediate program in three address code

```
p = a - b
q = p * c
p = u * v
q = p + q
```

Which one of the following corresponds to a *static single assignment* form of the above code?

A.		B.		C.		D.	
	p1 = a - b q1 = p1 * c p1 = u * v q1 = p1 + q1		p3 = a - b q4 = p3 * c p4 = u * v q5 = p4 + q4		p1 = a - b q1 = p2 * c p3 = u * v q2 = p4 + q3		p1 = a - b q1 = p * c p2 = u * v q2 = p + q

gatecse-2017-set1 compiler-design intermediate-code normal static-single-assignment

Answer key

3.21 Symbol Table (1)

3.21.1 Symbol Table: GATE CSE 2025 | Set 1 | Question: 2

Which ONE of the following statements is **FALSE** regarding the symbol table?

A. Symbol table is responsible for keeping track of the scope of variables.
B. Symbol table can be implemented using a binary search tree.
C. Symbol table is not required after the parsing phase.
D. Symbol table is created during the lexical analysis phase.

gatecse2025-set1 compiler-design symbol-table easy one-mark

Answer key

3.22 Syntax Directed Translation (17)

3.22.1 Syntax Directed Translation: GATE CSE 1992 | Question: 11a

Write syntax directed definitions (semantic rules) for the following grammar to add the type of each identifier to its entry in the symbol table during semantic analysis. Rewriting the grammar is not permitted and semantic rules are to be added to the ends of productions only.

- $D \rightarrow TL;$
- $T \rightarrow \text{int}$
- $T \rightarrow \text{real}$
- $L \rightarrow L, id$
- $L \rightarrow id$

gate1992 compiler-design syntax-directed-translation normal descriptive

Answer key

3.22.2 Syntax Directed Translation: GATE CSE 1995 | Question: 2.10

A shift reduce parser carries out the actions specified within braces immediately after reducing with the corresponding rule of grammar

- $S \rightarrow xxW \text{ \{print``1''\}}$
- $S \rightarrow y \text{ \{print``2''\}}$
- $W \rightarrow Sz \text{ \{print``3''\}}$

What is the translation of $xxxxyzz$ using the syntax directed translation scheme described by the above rules?

A. 23131 B. 11233 C. 11231 D. 33211

gate1995 compiler-design grammar syntax-directed-translation normal

Answer key

3.22.3 Syntax Directed Translation: GATE CSE 1996 | Question: 20

Consider the syntax-directed translation schema (SDTS) shown below:

- $E \rightarrow E + E$ {print "+"}
- $E \rightarrow E * E$ {print "."}
- $E \rightarrow id$ {print id.name}
- $E \rightarrow (E)$

An LR-parser executes the actions associated with the productions immediately after a reduction by the corresponding production. Draw the parse tree and write the translation for the sentence.

$(a + b) * (c + d)$, using SDTS given above.

gate1996 compiler-design syntax-directed-translation normal descriptive

Answer key

3.22.4 Syntax Directed Translation: GATE CSE 1998 | Question: 23

Let the attribute 'val' give the value of a binary number generated by S in the following grammar:

- $S \rightarrow L.L \mid L$
- $L \rightarrow LB \mid B$
- $B \rightarrow 0 \mid 1$

For example, an input 101.101 gives $S.val = 5.625$

Construct a syntax directed translation scheme using only synthesized attributes, to determine $S.val$.

gate1998 compiler-design syntax-directed-translation normal descriptive

Answer key

3.22.5 Syntax Directed Translation: GATE CSE 2000 | Question: 19

Consider the syntax directed translation scheme (SDTS) given in the following. Assume attribute evaluation with bottom-up parsing, i.e., attributes are evaluated immediately after a reduction.

- $E \rightarrow E_1 * T \quad \{E.val = E_1.val * T.val\}$
- $E \rightarrow T \quad \{E.val = T.val\}$
- $T \rightarrow F - T_1 \quad \{T.val = F.val - T_1.val\}$
- $T \rightarrow F \quad \{T.val = F.val\}$
- $F \rightarrow 2 \quad \{F.val = 2\}$
- $F \rightarrow 4 \quad \{F.val = 4\}$

A. Using this SDTS, construct a parse tree for the expression $4 - 2 - 4 * 2$ and also compute its $E.val$.
B. It is required to compute the total number of reductions performed to parse a given input. Using synthesized attributes only, modify the SDTS given, without changing the grammar, to find $E.red$, the number of reductions performed while reducing an input to E.

gatecse-2000 compiler-design syntax-directed-translation normal descriptive

Answer key

3.22.6 Syntax Directed Translation: GATE CSE 2001 | Question: 17

The syntax of the repeat-until statement is given by the following grammar

$S \rightarrow$ repeat S_1 until E

where E stands for expressions, S and S_1 stand for statements. The non-terminals S and S_1 have an attribute code that represents generated code. The non-terminal E has two attributes. The attribute code represents generated code to evaluate the expression and store its value in a distinct variable, and the attribute varName contains the name of the variable in which the truth value is stored. The truth-value stored in the variable is 1 if E is true, 0 if E is false.

Give a syntax-directed definition to generate three-address code for the repeat-until statement. Assume that you can call a function newlabel() that returns a distinct label for a statement. Use the operator '\\' to concatenate two strings and the function gen(s) to generate a line containing the string s.

gatecse-2001 compiler-design syntax-directed-translation normal descriptive

Answer key☟

3.22.7 Syntax Directed Translation: GATE CSE 2003 | Question: 18

In a bottom-up evaluation of a syntax directed definition, inherited attributes can

A. always be evaluated
B. be evaluated only if the definition is L-attributed
C. be evaluated only if the definition has synthesized attributes
D. never be evaluated

gatecse-2003 compiler-design syntax-directed-translation normal

Answer key☟

3.22.8 Syntax Directed Translation: GATE CSE 2003 | Question: 59

Consider the syntax directed definition shown below.

$$\begin{array}{ll} S \to \textbf{id} := E & \{gen(\textbf{id}.place = E.place;);\} \\ E \to E_1 + E_2 & \{t = newtemp(); \\ & gen(t = E_1.place + E_2.place;); \\ & E.place = t;\} \\ E \to id & \{E.place = \textbf{id}.place;\} \end{array}$$

Here, gen is a function that generates the output code, and $newtemp$ is a function that returns the name of a new temporary variable on every call. Assume that t_i's are the temporary variable names generated by $newtemp$. For the statement '$X := Y + Z$', the 3-address code sequence generated by this definition is

A. $X = Y + Z$
B. $t_1 = Y + Z; X = t_1$
C. $t_1 = Y; t_2 = t_1 + Z; X = t_2$
D. $t_1 = Y; t_2 = Z; t_3 = t_1 + t_2; X = t_3$

gatecse-2003 compiler-design syntax-directed-translation normal

Answer key☟

3.22.9 Syntax Directed Translation: GATE CSE 2016 Set 1 | Question: 46

Consider the following Syntax Directed Translation Scheme $(SDTS)$, with non-terminals $\{S, A\}$ and terminals $\{a, b\}$.

$$\begin{array}{ll} S \to aA & \{\text{print } 1\} \\ S \to a & \{\text{print } 2\} \\ A \to Sb & \{\text{print } 3\} \end{array}$$

Using the above $SDTS$, the output printed by a bottom-up parser, for the input aab is:

A. $1\ 3\ 2$
B. $2\ 2\ 3$
C. $2\ 3\ 1$
D. syntax error

gatecse-2016-set1 compiler-design syntax-directed-translation normal

Answer key☟

3.22.10 Syntax Directed Translation: GATE CSE 2019 | Question: 36

Consider the following grammar and the semantic actions to support the inherited type declaration attributes. Let $X_1, X_2, X_3, X_4, X_5,$ and X_6 be the placeholders for the non-terminals D, T, L or L_1 in the following table:

Production rule	Semantic action
$D \rightarrow TL$	$X_1.\text{type} = X_2.\text{type}$
$T \rightarrow \text{int}$	$T.\text{type} = \text{int}$
$T \rightarrow \text{float}$	$T.\text{type} = \text{float}$
$L \rightarrow L_1, id$	$X_3.\text{type} = X_4.\text{type}$ $\text{addType}(id.\text{entry}, X_5.\text{type})$
$L \rightarrow id$	$\text{addType}(id.\text{entry}, X_6.\text{type})$

Which one of the following are appropriate choices for X_1, X_2, X_3 and X_4?

A. $X_1 = L,\ X_2 = T,\ X_3 = L_1,\ X_4 = L$
B. $X_1 = T,\ X_2 = L,\ X_3 = L_1,\ X_4 = T$
C. $X_1 = L,\ X_2 = L,\ X_3 = L_1,\ X_4 = T$
D. $X_1 = T,\ X_2 = L,\ X_3 = T,\ X_4 = L_1$

gatecse-2019 compiler-design syntax-directed-translation two-marks

Answer key☟

3.22.11 Syntax Directed Translation: GATE CSE 2020 | Question: 33

Consider the productions $A \rightarrow PQ$ and $A \rightarrow XY$. Each of the five non-terminals $A, P, Q, X,$ and Y has two attributes: s is a synthesized attribute, and i is an inherited attribute. Consider the following rules.

- Rule $1: P.i = A.i + 2,\ Q.i = P.i + A.i,$ and $A.s = P.s + Q.s$
- Rule $2: X.i = A.i + Y.s$ and $Y.i = X.s + A.i$

Which one of the following is TRUE?

A. Both Rule 1 and Rule 2 are L-attributed.
B. Only Rule 1 is L-attributed.
C. Only Rule 2 is L-attributed.
D. Neither Rule 1 nor Rule 2 is L-attributed.

gatecse-2020 compiler-design syntax-directed-translation two-marks

Answer key☟

3.22.12 Syntax Directed Translation: GATE CSE 2021 Set 1 | Question: 26

Consider the following grammar (that admits a series of declarations, followed by expressions) and the associated syntax directed translation (SDT) actions, given as pseudo-code

$$
\begin{array}{lll}
P & \rightarrow & D^* E^* \\
D & \rightarrow & \textsf{int ID}\{\text{record that } \textsf{ID}.\text{lexeme is of type } \textsf{int}\} \\
D & \rightarrow & \textsf{bool ID}\{\text{record that } \textsf{ID}.\text{lexeme is of type } \textsf{bool}\} \\
E & \rightarrow & E_1 + E_2\{\text{check that } E_1.\text{type} = E_2.\text{type} = \textsf{int}; \text{set } E.\text{type} := \textsf{int}\} \\
E & \rightarrow & !E_1\{\text{check that } E_1.\text{type} = \textsf{bool};\ \text{set } E.\text{type} := \textsf{bool}\} \\
E & \rightarrow & \textsf{ID}\{\text{set } E.\text{type} := \textsf{int}\}
\end{array}
$$

With respect to the above grammar, which one of the following choices is correct?

A. The actions can be used to correctly type-check any syntactically correct program
B. The actions can be used to type-check syntactically correct integer variable declarations and integer expressions
C. The actions can be used to type-check syntactically correct boolean variable declarations and boolean

expressions.

D. The actions will lead to an infinite loop

gatecse-2021-set1 compiler-design syntax-directed-translation two-marks

Answer key

3.22.13 Syntax Directed Translation: GATE CSE 2022 | Question: 55

Consider the following grammar along with translation rules.

$$\begin{array}{ll} S \rightarrow S_1 \# T & \{S._{\text{val}} = S_{1}._{\text{val}}\ {}^{*}T._{\text{val}}\ \} \\ S \rightarrow T & \{S._{\text{val}} = T._{\text{val}}\ \} \\ T \rightarrow T_1 \% R & \{T._{\text{val}} = T_{1}._{\text{val}} \div R._{\text{val}}\ \} \\ T \rightarrow R & \{T._{\text{val}} = R._{\text{val}}\ \} \\ R \rightarrow \text{id} & \{R._{\text{val}} = \text{id}._{\text{val}}\ \} \end{array}$$

Here $\#$ and $\%$ are operators and id is a token that represents an integer and $\text{id}._{\text{val}}$ represents the corresponding integer value. The set of non-terminals is $\{\text{S}, \text{T}, \text{R}, \text{P}\}$ and a subscripted non-terminal indicates an instance of the non-terminal.

Using this translation scheme, the computed value of $S._{\text{val}}$ for root of the parse tree for the expression $20\#10\%5\#8\%2\%2$ is ________________.

gatecse-2022 numerical-answers compiler-design syntax-directed-translation two-marks

Answer key

3.22.14 Syntax Directed Translation: GATE CSE 2023 | Question: 50

Consider the syntax directed translation given by the following grammar and semantic rules. Here N, I, F and B are non-terminals. N is the starting non-terminal, and $\#, \mathbf{0}$ and $\mathbf{1}$ are lexical tokens corresponding to input letters "#", "0" and "1", respectively. $X.\mathit{val}$ denotes the synthesized attribute (a numeric value) associated with a non-terminal X. I_1 and F_1 denote occurrences of I and F on the right hand side of a production, respectively. For the tokens $\mathbf{0}$ and $\mathbf{1}, \mathbf{0}.\mathit{val} = 0$ and $\mathbf{1}.\mathit{val} = 1$.

$$\begin{array}{ll} N \rightarrow I \# F & N.\mathit{val} = I.\mathit{val} + F.\mathit{val} \\ I \rightarrow I_1 B & I.\mathit{val} = (2 I_1.\mathit{val}) + B.\mathit{val} \\ I \rightarrow B & I.\mathit{val} = \text{B.val} \\ F \rightarrow B F_1 & F.\mathit{val} = \frac{1}{2}(B.\mathit{val} + F_1.\mathit{val}) \\ F \rightarrow B & \text{F.val } = \frac{1}{2} B.\mathit{val} \\ B \rightarrow \mathbf{0} & B.\mathit{val} = \mathbf{0}.\mathit{val} \\ B \rightarrow \mathbf{1} & B.\mathit{val} = \mathbf{1}.\mathit{val} \end{array}$$

The value computed by the translation scheme for the input string

$$10\#011$$

is _____________. (Rounded off to three decimal places)

gatecse-2023 compiler-design syntax-directed-translation numerical-answers two-marks

Answer key

3.22.15 Syntax Directed Translation: GATE CSE 2024 | Set 1 | Question: 27

Consider the following syntax-directed definition (SDD).

$S \rightarrow DHTU$	$\{S.val = D.val + H.val + T.val + U.val;\}$
$D \rightarrow'' \text{M}'' D_1$	$\{D.val = 5 + D_1.val;\}$
$D \rightarrow \epsilon$	$\{D.val = -5;\}$
$H \rightarrow'' \text{L}'' H_1$	$\{H.val = 5{*}10 + H_1.val;\}$
$H \rightarrow \epsilon$	$\{H.val = -10;\}$
$T \rightarrow$ "C" T_1	$\{T.val = 5{*}100 + T_1.val;\}$
$T \rightarrow \epsilon$	$\{T.val = -5;\}$
$U \rightarrow$ "K"	$\{U.val = 5;\}$

Given "MMLK" as the input, which one of the following options is the CORRECT value computed by the SDD (in the attribute $S.val$)?

A. 45 B. 50 C. 55 D. 65

gatecse2024-set1 compiler-design syntax-directed-translation two-marks

Answer key

3.22.16 Syntax Directed Translation: GATE CSE 2024 | Set 2 | Question: 19

Which of the following statements is/are FALSE?

A. An attribute grammar is a syntax-directed definition (SDD) in which the functions in the semantic rules have no side effects
B. The attributes in a L-attributed definition cannot always be evaluated in a depth-first order
C. Synthesized attributes can be evaluated by a bottom-up parser as the input is parsed
D. All L-attributed definitions based on LR(1) grammar can be evaluated using a bottom-up parsing strategy

gatecse2024-set2 compiler-design syntax-directed-translation multiple-selects one-mark

Answer key

3.22.17 Syntax Directed Translation: GATE CSE 2025 | Set 2 | Question: 12

Given the following syntax directed translation rules:

- Rule 1: $R \rightarrow AB\{B.i = R.i - 1; A.i = B.i; R.i = A.i + 1;\}$
- Rule 2: $P \rightarrow CD\{P.i = C.i + D.i; D.i = C.i + 2;\}$
- Rule 3: $Q \rightarrow EF\{Q.i = E.i + F.i;\}$

Which ONE is the CORRECT option among the following?

A. Rule 1 is S-attributed and L-attributed; Rule 2 is S-attributed and not L-attributed; Rule 3 is neither S-attributed nor L-attributed.
B. Rule 1 is neither S-attributed not L-attributed; Rule 2 is S-attributed and L-attributed; Rule 3 is S-attributed and L-attributed.
C. Rule 1 is neither S-attributed nor L-attributed; Rule 2 is not S-attributed and is L-attributed; Rule 3 is S-attributed and L-attributed.
D. Rule 1 is S-attributed and not L-attributed; Rule 2 is not S-attributed and is L-attributed; Rule 3 is S-attributed and L-attributed.

gatecse2025-set2 compiler-design syntax-directed-translation one-mark

Answer key

3.23 Variable Scope (2)

3.23.1 Variable Scope: GATE CSE 1987 | Question: 1-xix

Study the following program written in a block-structured language:

```
Var x, y:interger;
procedure P(n:interger);
begin
    x:=(n+2)/(n-3);
end;

procedure Q
Var x, y:interger;
begin
   x:=3;
   y:=4;
   P(y);
   Write(x)                         __(1)
end;

begin
   x:=7;
   y:=8;
   Q;
Write(x);                           __(2)
end.
```

What will be printed by the write statements marked (1) and (2) in the program if the variables are statically scoped?

A. $3,6$ B. $6,7$ C. $3,7$ D. None of the above.

gate1987 compiler-design variable-scope runtime-environment

Answer key

3.23.2 Variable Scope: GATE CSE 1987 | Question: 1-xx

For the program given below what will be printed by the write statements marked (1) and (2) in the program if the variables are dynamically scoped?

```
Var x, y:interger;
procedure P(n:interger);
begin
    x := (n+2)/(n-3);
end;

procedure Q
Var x, y:interger;
begin
   x:=3;
   y:=4;
   P(y);
   Write(x);                         __(1)
end;

begin
   x:=7;
   y:=8;
   Q;
   Write(x);                           __(2)
end.
```

A. $3,6$ B. $6,7$ C. $3,7$ D. None of the above

gate1987 compiler-design variable-scope runtime-environment

Answer key

Answer Keys

3.1.1	N/A	3.1.2	Q-Q	3.1.3	N/A	3.1.4	A;B;C	3.1.5	True
3.1.6	N/A	3.1.7	True	3.1.8	False	3.1.9	B	3.2.1	C
3.3.1	6:6	3.4.1	A	3.4.2	D	3.4.3	A	3.4.4	D
3.4.5	7	3.4.6	A	3.4.7	C	3.4.8	6 : 6	3.4.9	D
3.4.10	B	3.5.1	C	3.5.2	N/A	3.5.3	A	3.5.4	B

3.5.5	C
3.5.10	C
3.7.1	A;B
3.7.6	A;D
3.8.5	N/A
3.8.10	N/A
3.8.15	A
3.8.20	A
3.8.25	C
3.8.30	B
3.8.35	C
3.8.40	B
3.8.45	A
3.8.50	C
3.9.4	C
3.9.9	D
3.10.3	B
3.10.8	B
3.10.13	D
3.10.18	D
3.11.3	B
3.12.2	C
3.14.1	N/A
3.15.2	9
3.16.4	N/A
3.16.9	A
3.16.14	D
3.17.5	N/A
3.17.10	N/A
3.17.15	A
3.17.20	C
3.17.25	A
3.18.3	B
3.19.2	N/A
3.19.7	C
3.19.12	B
3.19.17	C
3.19.22	A
3.22.1	N/A
3.22.6	N/A

3.5.6	B
3.5.11	B
3.7.2	A
3.8.1	N/A
3.8.6	N/A
3.8.11	X
3.8.16	N/A
3.8.21	N/A
3.8.26	B
3.8.31	D
3.8.36	C
3.8.41	B
3.8.46	179
3.8.51	D
3.9.5	A
3.9.10	D
3.10.4	B
3.10.9	D
3.10.14	7
3.10.19	9
3.11.4	C
3.12.3	C
3.14.2	D
3.15.3	6
3.16.5	A;D
3.16.10	N/A
3.17.1	B
3.17.6	C
3.17.11	N/A
3.17.16	A
3.17.21	D
3.17.26	A
3.18.4	D
3.19.3	N/A
3.19.8	D
3.19.13	C
3.19.18	D
3.20.1	8
3.22.2	A
3.22.7	B

3.5.7	C
3.5.12	B
3.7.3	C
3.8.2	N/A
3.8.7	C
3.8.12	N/A
3.8.17	N/A
3.8.22	D
3.8.27	C
3.8.32	D
3.8.37	B
3.8.42	A
3.8.47	B;C
3.9.1	N/A
3.9.6	C
3.9.11	A
3.10.5	D
3.10.10	C
3.10.15	C
3.10.20	C
3.11.5	A
3.13.1	C
3.14.3	A
3.16.1	10
3.16.6	N/A
3.16.11	X
3.17.2	A
3.17.7	N/A
3.17.12	D
3.17.17	D
3.17.22	1024
3.17.27	A
3.18.5	B
3.19.4	N/A
3.19.9	B
3.19.14	C
3.19.19	A
3.20.2	10
3.22.3	N/A
3.22.8	B

3.5.8	B
3.6.1	A
3.7.4	31
3.8.3	N/A
3.8.8	C
3.8.13	N/A
3.8.18	N/A
3.8.23	A
3.8.28	A
3.8.33	A
3.8.38	C
3.8.43	C
3.8.48	C;D
3.9.2	N/A
3.9.7	A
3.10.1	B;C;D
3.10.6	B
3.10.11	C
3.10.16	8 : 8
3.11.1	A
3.11.6	D
3.13.2	A
3.14.4	D
3.16.2	N/A
3.16.7	N/A
3.16.12	D
3.17.3	N/A
3.17.8	B
3.17.13	C
3.17.18	B
3.17.23	A
3.18.1	A
3.18.6	2
3.19.5	True
3.19.10	C
3.19.15	B
3.19.20	D
3.20.3	B
3.22.4	N/A
3.22.9	C

3.5.9	D
3.6.2	6
3.7.5	A
3.8.4	N/A
3.8.9	N/A
3.8.14	D
3.8.19	C
3.8.24	B
3.8.29	D
3.8.34	C
3.8.39	C
3.8.44	5
3.8.49	A
3.9.3	N/A
3.9.8	B
3.10.2	C
3.10.7	D
3.10.12	A
3.10.17	5
3.11.2	C
3.12.1	B
3.13.3	D
3.15.1	B
3.16.3	A;D
3.16.8	N/A
3.16.13	D
3.17.4	N/A
3.17.9	A
3.17.14	B
3.17.19	B
3.17.24	A;D
3.18.2	B
3.19.1	N/A
3.19.6	D
3.19.11	C
3.19.16	A
3.19.21	C
3.21.1	C
3.22.5	N/A
3.22.10	A

3.22.11	B	3.22.12	B	3.22.13	80	3.22.14	2.375	3.22.15	A
3.22.16	B;D	3.22.17	C	3.23.1	A	3.23.2	B		

4 Computer Networks (215)

Concept of layering.OSI and TCP/IP Protocol Stacks; Basics of packet, circuit and virtual circuit-switching; Data link layer: framing, error detection, Medium Access Control, Ethernet bridging; Routing protocols: shortest path, flooding, distance vector and link state routing; Fragmentation and IP addressing, IPv4, CIDR notation, Basics of IP support protocols (ARP, DHCP, ICMP), Network Address Translation (NAT); Transport layer: flow control and congestion control, UDP, TCP, sockets; Application layer protocols: DNS, SMTP, HTTP, FTP, **Email**.

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Mark Distribution in Previous GATE

Year	2025 - 1	2025 - 2	2024 - 1	2024 - 2	2023	2022	2021 - 1	2021 - 2	Minimum	Average	Maximu
1 Mark Count	2	4	3	3	2	2	1	1	1	2.25	4
2 Marks Count	3	1	3	3	3	4	4	3	1	3	4
Total Marks	8	6	9	9	8	10	9	7	**6**	**8.25**	**10**

4.0.1 GATE CSE 2024 | Set 1 | Question: 55

Consider sending an IP datagram of size 1420 bytes (including 20 bytes of IP header) from a sender to a receiver over a path of two links with a router between them. The first link (sender to router) has an MTU (Maximum Transmission Unit) size of 542 bytes, while the second link (router to receiver) has an MTU size of 360 bytes. The number of fragments that would be delivered at the receiver is ____________.

gatecse2024-set1 numerical-answers computer-networks two-marks

Answer key☟

4.1 Application Layer Protocols (12)

4.1.1 Application Layer Protocols: GATE CSE 2008 | Question: 14, ISRO2016-74

What is the maximum size of data that the application layer can pass on to the TCP layer below?

A. Any size

B. 2^{16} bytes - size of TCP header

C. 2^{16} bytes

D. 1500 bytes

gatecse-2008 easy computer-networks application-layer-protocols isro2016

Answer key☟

4.1.2 Application Layer Protocols: GATE CSE 2011 | Question: 4

Consider the different activities related to email.

- m1 : Send an email from mail client to mail server
- m2 : Download an email from mailbox server to a mail client
- m3 : Checking email in a web browser

Which is the application level protocol used in each activity?

A. m1 : HTTP m2 : SMTP m3 : POP
B. m1 : SMTP m2 : FTP m3 : HTTP
C. m1 : SMTP m2 : POP m3 : HTTP
D. m1 : POP m2 : SMTP m3 : IMAP

gatecse-2011 computer-networks application-layer-protocols easy

Answer key☟

4.1.3 Application Layer Protocols: GATE CSE 2012 | Question: 10

The protocol data unit (PDU) for the application layer in the Internet stack is:

A. Segment B. Datagram C. Message D. Frame gatecse-2012 computer-networks application-layer-protocols easy

Answer key

4.1.4 Application Layer Protocols: GATE CSE 2016 Set 1 | Question: 25

Which of the following is/are example(s) of stateful application layer protocol?

i. HTTP
ii. FTP
iii. TCP
iv. POP3

A. (i) and (ii) only B. (ii) and (iii) only C. (ii) and (iv) only D. (iv) only

gatecse-2016-set1 computer-networks application-layer-protocols normal

Answer key

4.1.5 Application Layer Protocols: GATE CSE 2019 | Question: 16

Which of the following protocol pairs can be used to send and retrieve e-mails (in that order)?

A. IMAP, POP3 B. SMTP, POP3 C. SMTP, MIME D. IMAP, SMTP

gatecse-2019 computer-networks application-layer-protocols one-mark

Answer key

4.1.6 Application Layer Protocols: GATE CSE 2020 | Question: 25

Assume that you have made a request for a web page through your web browser to a web server. Initially the browser cache is empty. Further, the browser is configured to send HTTP requests in non-persistent mode. The web page contains text and five very small images.The minimum number of TCP connections required to display the web page completely in your browser is__________.

gatecse-2020 numerical-answers computer-networks application-layer-protocols one-mark

Answer key

4.1.7 Application Layer Protocols: GATE CSE 2022 | Question: 25

Consider the resolution of the domain name www.gate.org.in by a DNS resolver. Assume that no resource records are cached anywhere across the DNS servers and that iterative query mechanism is used in the resolution. The number of DNS query-response pairs involved in completely resolving the domain name is ________________.

gatecse-2022 numerical-answers computer-networks one-mark application-layer-protocols

Answer key

4.1.8 Application Layer Protocols: GATE IT 2005 | Question: 25

Consider the three commands : PROMPT, HEAD and RCPT.
Which of the following options indicate a correct association of these commands with protocols where these are used?

A. HTTP, SMTP, FTP
B. FTP, HTTP, SMTP
C. HTTP, FTP, SMTP
D. SMTP, HTTP, FTP

gateit-2005 computer-networks application-layer-protocols normal

Answer key

4.1.9 Application Layer Protocols: GATE IT 2005 | Question: 26

Traceroute reports a possible route that is taken by packets moving from some host A to some other host B. Which of the following options represents the technique used by traceroute to identify these hosts:

A. By progressively querying routers about the next router on the path to B using ICMP packets, starting with the first router

B. By requiring each router to append the address to the ICMP packet as it is forwarded to B. The list of all routers en-route to B is returned by B in an ICMP reply packet
C. By ensuring that an ICMP reply packet is returned to A by each router en-route to B, in the ascending order of their hop distance from A
D. By locally computing the shortest path from A to B

gateit-2005 computer-networks icmp application-layer-protocols normal

Answer key

4.1.10 Application Layer Protocols: GATE IT 2005 | Question: 77

Assume that "host1.mydomain.dom" has an IP address of $145.128.16.8$. Which of the following options would be most appropriate as a subsequence of steps in performing the reverse lookup of $145.128.16.8$? In the following options "NS" is an abbreviation of "nameserver".

A. Query a NS for the root domain and then NS for the "dom" domains
B. Directly query a NS for "dom" and then a NS for "mydomain.dom" domains
C. Query a NS for in-addr.arpa and then a NS for 128.145.in-addr.arpa domains
D. Directly query a NS for 145.in-addr.arpa and then a NS for 128.145.in-addr.arpa domains

gateit-2005 computer-networks normal application-layer-protocols

Answer key

4.1.11 Application Layer Protocols: GATE IT 2006 | Question: 18

HELO and PORT, respectively, are commands from the protocols:

A. FTP and HTTP
B. TELNET and POP3
C. HTTP and TELNET
D. SMTP and FTP

gateit-2006 computer-networks application-layer-protocols normal

Answer key

4.1.12 Application Layer Protocols: GATE IT 2008 | Question: 20

Provide the best matching between the entries in the two columns given in the table below:

I.	Proxy Server	a.	Firewall
II.	Kazaa, DC++	b.	Caching
III.	Slip	c.	P2P
IV.	DNS	d.	PPP

A. I-a, II-d, III-c, IV-b
B. I-b, II-d, III-c, IV-a
C. I-a, II-c, III-d, IV-b
D. I-b, II-c, III-d, IV-a

gateit-2008 computer-networks normal application-layer-protocols

Answer key

4.2 Arp (1)

4.2.1 Arp: GATE CSE 2025 | Set 2 | Question: 6

Consider the following statements:

i. Address Resolution Protocol (ARP) provides a mapping from an IP address to the corresponding hardware (link-layer) address.
ii. A single TCP segment from a sender S to a receiver R cannot carry both data from S to R and acknowledgement for a segment frmo R to S

Which one of the following is CORRECT?

A. Both (i) and (ii) are TRUE
B. (i) is TRUE and (ii) is FALSE

C. (i) is FALSE and (ii) is TRUE

D. Both (i) and (ii) are FALSE

gatecse2025-set2 computer-networks tcp arp easy one-mark

Answer key☟

4.3 Bit Stuffing (2)

4.3.1 Bit Stuffing: GATE CSE 2014 Set 3 | Question: 24

A bit-stuffing based framing protocol uses an 8-bit delimiter pattern of $01111110.$ If the output bit-string after stuffing is $01111100101,$ then the input bit-string is:

A. 0111110100
B. 0111110101
C. 0111111101
D. 0111111111

gatecse-2014-set3 computer-networks error-detection bit-stuffing

Answer key☟

4.3.2 Bit Stuffing: GATE IT 2004 | Question: 80

In a data link protocol, the frame delimiter flag is given by $0111.$ Assuming that bit stuffing is employed, the transmitter sends the data sequence 01110110 as

A. 01101011
B. 011010110
C. 011101100
D. 0110101100

gateit-2004 computer-networks network-flow normal bit-stuffing

Answer key☟

4.4 Bridges (3)

4.4.1 Bridges: GATE CSE 2004 | Question: 16

Which of the following is NOT true with respect to a transparent bridge and a router?

A. Both bridge and router selectively forward data packets
B. A bridge uses IP addresses while a router uses MAC addresses
C. A bridge builds up its routing table by inspecting incoming packets
D. A router can connect between a LAN and a WAN

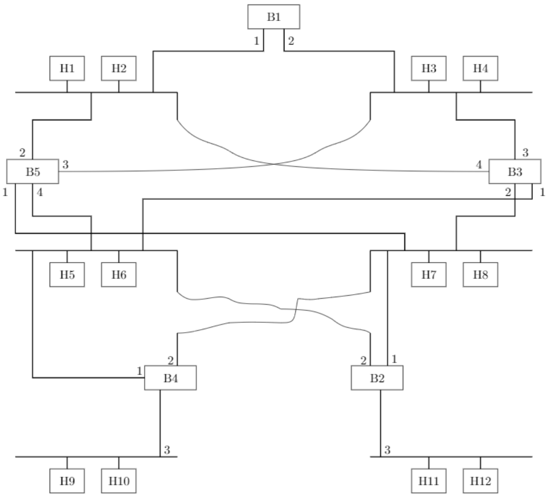
gatecse-2004 computer-networks bridges normal

Answer key☟

4.4.2 Bridges: GATE CSE 2006 | Question: 82

Consider the diagram shown below where a number of LANs are connected by (transparent) bridges. In order to avoid packets looping through circuits in the graph, the bridges organize themselves in a spanning tree. First, the root bridge is identified as the bridge with the least serial number. Next, the root sends out (one or more) data units to enable the setting up of the spanning tree of shortest paths from the root bridge to each bridge.

Each bridge identifies a port (the root port) through which it will forward frames to the root bridge. Port conflicts are always resolved in favour of the port with the lower index value. When there is a possibility of multiple bridges forwarding to the same LAN (but not through the root port), ties are broken as follows: bridges closest to the root get preference and between such bridges, the one with the lowest serial number is preferred.



For the given connection of LANs by bridges, which one of the following choices represents the depth first traversal of the spanning tree of bridges?

A. $\mathrm{B1, B5, B3, B4, B2}$
B. $\mathrm{B1, B3, B5, B2, B4}$
C. $\mathrm{B1, B5, B2, B3, B4}$
D. $\mathrm{B1, B3, B4, B5, B2}$

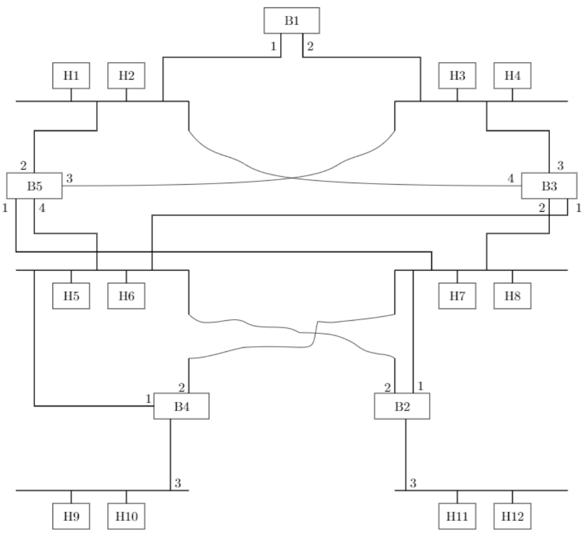
gatecse-2006 computer-networks bridges normal

Answer key

4.4.3 Bridges: GATE CSE 2006 | Question: 83

Consider the diagram shown below where a number of LANs are connected by (transparent) bridges. In order to avoid packets looping through circuits in the graph, the bridges organize themselves in a spanning tree. First, the root bridge is identified as the bridge with the least serial number. Next, the root sends out (one or more) data
units to enable the setting up of the spanning tree of shortest paths from the root bridge to each bridge.

Each bridge identifies a port (the root port) through which it will forward frames to the root bridge. Port conflicts are always resolved in favour of the port with the lower index value. When there is a possibility of multiple bridges forwarding to the same LAN (but not through the root port), ties are broken as follows: bridges closest to the root get preference and between such bridges, the one with the lowest serial number is preferred.



Consider the spanning tree $B1, B5, B3, B4, B2$ for the given connection of LANs by bridges, that represents the depth first traversal of the spanning tree of bridges. Let host $H1$ send out a broadcast ping packet. Which of the following options represents the correct forwarding table on $B3$?

a.

Hosts	Port
H1, H2, H3, H4	3
H5, H6, H9, H10	1
H7, H8, H11, H12	2

b.

Hosts	Port
H1, H2	4
H3, H4	3
H5, H6	1
H7, H8, H9, H10, H11, H12	2

c.

Hosts	Port
H3, H4	3
H5, H6, H9, H10	1
H1, H2	4
H7, H8, H11, H12	2

d.

Hosts	Port
H1, H2, H3, H4	3
H5, H7, H9, H10	1
H7, H8, H11, H12	4

gatecse-2006 computer-networks bridges normal

Answer key

4.5 CRC Polynomial (4)

4.5.1 CRC Polynomial: GATE CSE 2007 | Question: 68, ISRO2016-73

The message 11001001 is to be transmitted using the CRC polynomial $x^3 + 1$ to protect it from errors. The message that should be transmitted is:

A. 11001001000 B. 11001001011 C. 11001010 D. 110010010011

gatecse-2007 computer-networks error-detection crc-polynomial normal isro2016

Answer key

4.5.2 CRC Polynomial: GATE CSE 2017 Set 1 | Question: 32

A computer network uses polynomials over $GF(2)$ for error checking with 8 bits as information bits and uses $x^3 + x + 1$ as the generator polynomial to generate the check bits. In this network, the message 01011011 is transmitted as:

A. 01011011010 B. 01011011011 C. 01011011101 D. 01011011100

gatecse-2017-set1 computer-networks crc-polynomial normal

Answer key

4.5.3 CRC Polynomial: GATE CSE 2021 Set 2 | Question: 34

Consider the cyclic redundancy check (CRC) based error detecting scheme having the generator polynomial $X^3 + X + 1$. Suppose the message $m_4m_3m_2m_1m_0 = 11000$ is to be transmitted. Check bits $c_2c_1c_0$ are appended at the end of the message by the transmitter using the above CRC scheme. The transmitted bit string is denoted by $m_4m_3m_2m_1m_0c_2c_1c_0$. The value of the checkbit sequence $c_2c_1c_0$ is

A. 101 B. 110 C. 100 D. 111

gatecse-2021-set2 computer-networks crc-polynomial two-marks

Answer key

4.5.4 CRC Polynomial: GATE IT 2005 | Question: 78

Consider the following message $M = 1010001101$. The cyclic redundancy check (CRC) for this message using the divisor polynomial $x^5 + x^4 + x^2 + 1$ is :

A. 01110
B. 01011
C. 10101
D. 10110

gateit-2005 computer-networks crc-polynomial normal

Answer key

4.6 CSMA CD (6)

4.6.1 CSMA CD: GATE CSE 2015 Set 3 | Question: 6

Consider a CSMA/CD network that transmits data at a rate of 100 **Mbps** $(10^8$ bits per second) over a 1 **km** (kilometre) cable with no repeaters. If the minimum frame size required for this network is 1250 bytes, What is the signal speed $(\textbf{km/sec})$ in the cable?

A. 8000
B. 10000
C. 16000
D. 20000

gatecse-2015-set3 computer-networks congestion-control csma-cd normal

Answer key

4.6.2 CSMA CD: GATE CSE 2016 Set 2 | Question: 53

A network has a data transmission bandwidth of 20×10^6 bits per second. It uses **CSMA/CD** in the **MAC** layer. The maximum signal propagation time from one node to another node is 40 microseconds. The minimum size of a frame in the network is __________ bytes.

gatecse-2016-set2 computer-networks csma-cd numerical-answers normal

Answer key

4.6.3 CSMA CD: GATE CSE 2018 | Question: 55

Consider a simple communication system where multiple nodes are connected by a shared broadcast medium (like Ethernet or wireless). The nodes in the system use the following carrier-sense based medium access protocol. A node that receives a packet to transmit will carrier-sense the medium for 5 units of time. If the node does not detect any other transmission, it starts transmitting its packet in the next time unit. If the node detects another transmission, it waits until this other transmission finishes, and then begins to carrier-sense for 5 time units again. Once they start to transmit, nodes do not perform any collision detection and continue transmission even if a collision occurs. All transmissions last for 20 units of time. Assume that the transmission signal travels at the speed of 10 meters per unit time in the medium.

Assume that the system has two nodes P and Q, located at a distance d meters from each other. P start transmitting a packet at time $t = 0$ after successfully completing its carrier-sense phase. Node Q has a packet to transmit at time $t = 0$ and begins to carrier-sense the medium.

The maximum distance d (in meters, rounded to the closest integer) that allows Q to successfully avoid a collision between its proposed transmission and P's ongoing transmission is _______.

gatecse-2018 computer-networks csma-cd numerical-answers two-marks

Answer key

4.6.4 CSMA CD: GATE IT 2005 | Question: 27

Which of the following statements is TRUE about CSMA/CD:

A. IEEE 802.11 wireless LAN runs CSMA/CD protocol
B. Ethernet is not based on CSMA/CD protocol
C. CSMA/CD is not suitable for a high propagation delay network like satellite network
D. There is no contention in a CSMA/CD network

gateit-2005 computer-networks congestion-control csma-cd normal

Answer key

4.6.5 CSMA CD: GATE IT 2005 | Question: 71

A network with CSMA/CD protocol in the MAC layer is running at 1Gbps over a 1km cable with no repeaters. The signal speed in the cable is $2 \times 10^8 \text{m/sec}$. The minimum frame size for this network should be:

A. 10000bits
B. 10000bytes
C. 5000 bits
D. 5000bytes

gateit-2005 computer-networks congestion-control csma-cd normal

Answer key

4.6.6 CSMA CD: GATE IT 2008 | Question: 65

The minimum frame size required for a CSMA/CD based computer network running at 1Gbps on a $200m$ cable with a link speed of $2 \times 10^8 \text{m/sec}$ is:

A. 125bytes
B. 250bytes
C. 500bytes
D. None of the above

gateit-2008 computer-networks csma-cd normal

Answer key

4.7 Channel Utilization (1)

4.7.1 Channel Utilization: GATE CSE 2025 | Set 2 | Question: 26

Suppose we are transmitting frames between two nodes using Stop-and-Wait protocol. The frame size is 3000 bits. The transmission rate of the channel is 2000 bps (bits/second) and the propagation delay between the two nodes is 100 milliseconds. Assume that the processing times at the source and destination are negligible. Also, assume that the size of the acknowledgement packet is negligible. Which ONE of the following most accurately gives the channel utilization for the above scenario in percentage?

A. 88.23
B. 93.75
C. 85.44
D. 66.67

gatecse2025-set2 computer-networks stop-and-wait channel-utilization two-marks

Answer key

4.8 Communication (4)

4.8.1 Communication: GATE CSE 2012 | Question: 44

Consider a source computer (S) transmitting a file of size 10^6 bits to a destination computer (D) over a network of two routers $(R_1 \text{ and } R_2)$ and three links $(L_1, L_2, \text{ and } L_3)$. L_1 connects S to R_1; L_2 connects R_1 to R_2; and L_3 connects R_2 to D. Let each link be of length 100 km. Assume signals travel over each link at a speed of 10^8 meters per second. Assume that the link bandwidth on each link is 1 Mbps. Let the file be broken down into 1000 packets each of size 1000 bits. Find the total sum of transmission and propagation delays in transmitting the file from S to D?

A. 1005 ms
B. 1010 ms
C. 3000 ms
D. 3003 ms

gatecse-2012 computer-networks communication normal

Answer key

4.8.2 Communication: GATE CSE 2022 | Question: 49

Consider a 100 Mbps link between an earth station (sender) and a satellite (receiver) at an altitude of $2100 \text{ km}.$ The signal propagates at a speed of $3 \times 10^8 \text{ m/s}.$ The time taken $(\text{in milliseconds}, \textit{rounded off to two decimal places})$ for the receiver to completely receive a packet of 1000 bytes transmitted by the sender is _______________.

gatecse-2022 numerical-answers computer-networks two-marks communication

Answer key☟

4.8.3 Communication: GATE IT 2007 | Question: 62

Let us consider a statistical time division multiplexing of packets. The number of sources is 10. In a time unit, a source transmits a packet of 1000 bits. The number of sources sending data for the first 20 time units is $6, 9, 3, 7, 2, 2, 2, 3, 4, 6, 1, 10, 7, 5, 8, 3, 6, 2, 9, 5$ respectively. The output capacity of multiplexer is 5000 bits per time unit. Then the average number of backlogged of packets per time unit during the given period is

A. 5
B. 4.45
C. 3.45
D. 0

gateit-2007 computer-networks communication normal

Answer key☟

4.8.4 Communication: GATE IT 2007 | Question: 64

A broadcast channel has 10 nodes and total capacity of 10 Mbps. It uses polling for medium access. Once a node finishes transmission, there is a polling delay of 80 μs to poll the next node. Whenever a node is polled, it is allowed to transmit a maximum of 1000 bytes. The maximum throughput of the broadcast channel is:

A. 1 Mbps
B. $100/11$ Mbps
C. 10 Mbps
D. 100 Mbps

gateit-2007 computer-networks communication normal

Answer key☟

4.9 Congestion Control (6)

4.9.1 Congestion Control: GATE CSE 2008 | Question: 56

In the slow start phase of the TCP congestion algorithm, the size of the congestion window:

A. does not increase
B. increase linearly
C. increases quadratically
D. increases exponentially

gatecse-2008 computer-networks congestion-control normal

Answer key☟

4.9.2 Congestion Control: GATE CSE 2012 | Question: 45

Consider an instance of TCP's Additive Increase Multiplicative Decrease (AIMD) algorithm where the window size at the start of the slow start phase is 2 MSS and the threshold at the start of the first transmission is 8 MSS. Assume that a timeout occurs during the fifth transmission. Find the congestion window size at the end of the tenth transmission.

A. 8 MSS
B. 14 MSS
C. 7 MSS
D. 12 MSS

gatecse-2012 computer-networks congestion-control normal

Answer key☟

4.9.3 Congestion Control: GATE CSE 2014 Set 1 | Question: 27

Let the size of congestion window of a TCP connection be 32 KB when a timeout occurs. The round trip time of the connection is 100 msec and the maximum segment size used is 2 KB. The time taken **(in msec)** by the TCP connection to get back to 32 KB congestion window is _________.

gatecse-2014-set1 computer-networks tcp congestion-control numerical-answers normal

Answer key☟

4.9.4 Congestion Control: GATE CSE 2015 Set 1 | Question: 29

Consider a LAN with four nodes $S_1, S_2, S_3,$ and S_4. Time is divided into fixed-size slots, and a node can begin its transmission only at the beginning of a slot. A collision is said to have occurred if more than one node transmits in the same slot. The probabilities of generation of a frame in a time slot by $S_1, S_2, S_3,$ and S_4 are

$0.1, 0.2, 0.3$ and 0.4 respectively. The probability of sending a frame in the first slot without any collision by any of these four stations is__________________.

gatecse-2015-set1 computer-networks normal numerical-answers congestion-control

Answer key☟

4.9.5 Congestion Control: GATE CSE 2018 | Question: 14

Consider the following statements regarding the slow start phase of the TCP congestion control algorithm. Note that *cwnd* stands for the TCP congestion window and MSS window denotes the Maximum Segments Size:

i. The *cwnd* increases by 2 MSS on every successful acknowledgment
ii. The *cwnd* approximately doubles on every successful acknowledgment
iii. The *cwnd* increases by 1 MSS every round trip time
iv. The *cwnd* approximately doubles every round trip time

Which one of the following is correct?

A. Only (ii) and (iii) are true
B. Only (i) and (iii) are true
C. Only (iv) is true
D. Only (i) and (iv) are true

gatecse-2018 computer-networks tcp congestion-control normal one-mark

Answer key☟

4.9.6 Congestion Control: GATE IT 2005 | Question: 73

On a TCP connection, current congestion window size is Congestion Window = 4 KB. The window size advertised by the receiver is Advertise Window = 6 KB. The last byte sent by the sender is LastByteSent = 10240 and the last byte acknowledged by the receiver is LastByteAcked = 8192. The current window size at the sender is:

A. 2048 bytes
B. 4096 bytes
C. 6144 bytes
D. 8192 bytes

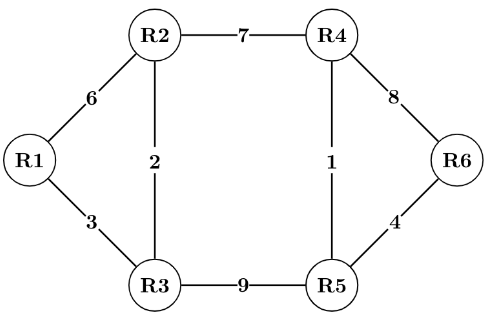
gateit-2005 computer-networks congestion-control normal

Answer key☟

4.10 Distance Vector Routing (8)

4.10.1 Distance Vector Routing: GATE CSE 2010 | Question: 54

Consider a network with 6 routers $\mathbf{R1}$ to $\mathbf{R6}$ connected with links having weights as shown in the following diagram.



All the routers use the distance vector based routing algorithm to update their routing tables. Each router starts with its routing table initialized to contain an entry for each neighbor with the weight of the respective connecting link. After all the routing tables stabilize, how many links in the network will never be used for carrying any data?

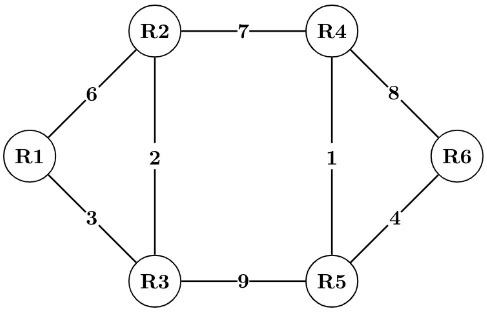
A. 4
B. 3
C. 2
D. 1

gatecse-2010 computer-networks routing distance-vector-routing normal

Answer key☟

4.10.2 Distance Vector Routing: GATE CSE 2010 | Question: 55

Consider a network with 6 routers $R1$ to $R6$ connected with links having weights as shown in the following diagram.



Suppose the weights of all unused links are changed to 2 and the distance vector algorithm is used again until all routing tables stabilize. How many links will now remain unused?

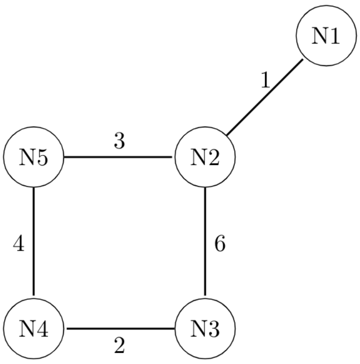
A. 0
B. 1
C. 2
D. 3

gatecse-2010 computer-networks routing distance-vector-routing normal

Answer key☟

4.10.3 Distance Vector Routing: GATE CSE 2011 | Question: 52

Consider a network with five nodes, $N1$ to $N5$, as shown as below.



The network uses a Distance Vector Routing protocol. Once the routes have been stabilized, the distance vectors at different nodes are as follows.

N1: $(0, 1, 7, 8, 4)$

N2: $(1, 0, 6, 7, 3)$

N3: $(7, 6, 0, 2, 6)$

N4: $(8, 7, 2, 0, 4)$

N5: $(4, 3, 6, 4, 0)$

Each distance vector is the distance of the best known path at that instance to nodes, $N1$ to $N5$, where the distance to itself is 0. Also, all links are symmetric and the cost is identical in both directions. In each round, all nodes exchange their distance vectors with their respective neighbors. Then all nodes update their distance vectors. In between two rounds, any change in cost of a link will cause the two incident nodes to change only that entry in their distance vectors.

The cost of link $N2 - N3$ reduces to 2 (in both directions). After the next round of updates, what will be the new distance vector at node, $N3$?

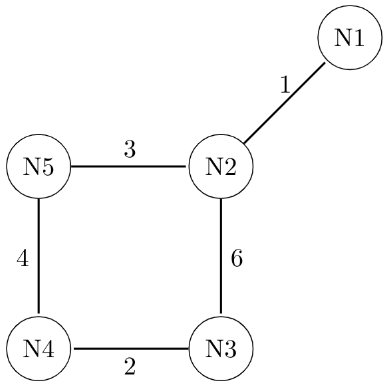
A. $(3, 2, 0, 2, 5)$
B. $(3, 2, 0, 2, 6)$
C. $(7, 2, 0, 2, 5)$
D. $(7, 2, 0, 2, 6)$

gatecse-2011 computer-networks routing distance-vector-routing normal

Answer key☟

4.10.4 Distance Vector Routing: GATE CSE 2011 | Question: 53

Consider a network with five nodes, $N1$ to $N5$, as shown as below.



The network uses a Distance Vector Routing protocol. Once the routes have been stabilized, the distance vectors at different nodes are as follows.

- **N1**: $(0, 1, 7, 8, 4)$
- **N2**: $(1, 0, 6, 7, 3)$
- **N3**: $(7, 6, 0, 2, 6)$
- **N4**: $(8, 7, 2, 0, 4)$
- **N5**: $(4, 3, 6, 4, 0)$

Each distance vector is the distance of the best known path at that instance to nodes, $N1$ to $N5$, where the distance to itself is 0. Also, all links are symmetric and the cost is identical in both directions. In each round, all nodes exchange their distance vectors with their respective neighbors. Then all nodes update their distance vectors. In between two rounds, any change in cost of a link will cause the two incident nodes to change only that entry in their distance vectors.

The cost of link $N2 - N3$ reduces to 2 (in both directions). After the next round of updates, the link $N1 - N2$ goes down. $N2$ will reflect this change immediately in its distance vector as cost, ∞. After the **NEXT ROUND** of update, what will be the cost to $N1$ in the distance vector of $N3$?

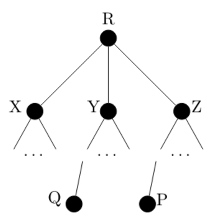
A. 3 B. 9 C. 10 D. ∞

gatecse-2011 computer-networks routing distance-vector-routing normal

Answer key

4.10.5 Distance Vector Routing: GATE CSE 2021 Set 2 | Question: 45

Consider a computer network using the distance vector routing algorithm in its network layer. The partial topology of the network is shown below.



The objective is to find the shortest-cost path from the router R to routers P and Q. Assume that R does not initially know the shortest routes to P and Q. Assume that R has three neighbouring routers denoted as X, Y and Z. During one iteration, R measures its distance to its neighbours X, Y, and Z as 3, 2 and 5, respectively. Router R gets routing vectors from its neighbours that indicate that the distance to router P from routers X, Y and Z are 7, 6 and 5, respectively. The routing vector also indicates that the distance to router Q from routers X, Y and Z are 4, 6 and 8 respectively. Which of the following statement(s) is/are correct with respect to the new routing table o R, after updation during this iteration?

A. The distance from R to P will be stored as 10
B. The distance from R to Q will be stored as 7

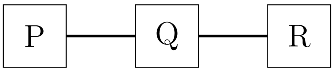
C. The next hop router for a packet from R to P is Y
D. The next hop router for a packet from R to Q is Z

gatecse-2021-set2 multiple-selects computer-networks distance-vector-routing two-marks

Answer key

4.10.6 Distance Vector Routing: GATE CSE 2022 | Question: 47

Consider a network with three routers $\mathrm{P}, \mathrm{Q}, \mathrm{R}$ shown in the figure below. All the links have cost of unity.



The routers exchange distance vector routing information and have converged on the routing tables, after which the link Q-R fails. Assume that P and Q send out routing updates at random times, each at the same average rate. The probability of a routing loop formation *(rounded off to one decimal place)* between P and Q, leading to count-to-infinity problem, is _______________.

gatecse-2022 numerical-answers computer-networks routing distance-vector-routing two-marks

Answer key

4.10.7 Distance Vector Routing: GATE IT 2005 | Question: 29

Count to infinity is a problem associated with:

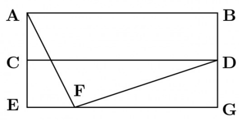
A. link state routing protocol.
B. distance vector routing protocol
C. DNS while resolving host name
D. TCP for congestion control

gateit-2005 computer-networks routing distance-vector-routing normal

Answer key

4.10.8 Distance Vector Routing: GATE IT 2007 | Question: 60

For the network given in the figure below, the routing tables of the four nodes A, E, D and G are shown. Suppose that F has estimated its delay to its neighbors, A, E, D and G as 8, 10, 12 and 6 msecs respectively and updates its routing table using distance vector routing technique.



Routing Table of A

A	0
B	40
C	14
D	17
E	21
F	9
G	24

Routing Table of D

A	20
B	8
C	30
D	0
E	14
F	7
G	22

Routing Table of E

A	24
B	27
C	7
D	20
E	0
F	11
G	22

Routing Table of G

A	21
B	24
C	22
D	19
E	22
F	10
G	0

A.

A	8
B	20
C	17
D	12
E	10
F	0
G	6

B.

A	21
B	8
C	7
D	19
E	14
F	0
G	22

C.

A	8
B	20
C	17
D	12
E	10
F	16
G	6

D.

A	8
B	8
C	7
D	12
E	10
F	0
G	6

gateit-2007 computer-networks distance-vector-routing normal

Answer key

4.11 Error Detection (10)

4.11.1 Error Detection: GATE CSE 1992 | Question: 01,ii

Consider a 3-bit error detection and 1-bit error correction hamming code for 4-bit data. The extra parity bits required would be _____ and the 3-bit error detection is possible because the code has a minimum distance of _______.

gate1992 computer-networks error-detection normal fill-in-the-blanks

Answer key

4.11.2 Error Detection: GATE CSE 1994 | Question: 9

Following 7 bit single error correcting hamming coded message is received.

7	6	5	4	3	2	1	bit No.
1	0	0	0	1	1	0	X

Determine if the message is correct (assuming that at most 1 bit could be corrupted). If the message contains an error find the bit which is erroneous and gives correct message.

gate1994 computer-networks error-detection hamming-code normal descriptive

Answer key

4.11.3 Error Detection: GATE CSE 1995 | Question: 1.12

What is the distance of the following code 000000, 010101, 000111, 011001, 111111?

A. 2

B. 3

C. 4

D. 1

gate1995 computer-networks error-detection normal

Answer key

4.11.4 Error Detection: GATE CSE 2009 | Question: 48

Let $G(x)$ be the generator polynomial used for CRC checking. What is the condition that should be satisfied by $G(x)$ to detect odd number of bits in error?

A. $G(x)$ contains more than two terms
B. $G(x)$ does not divide $1+x^k$, for any k not exceeding the frame length
C. $1+x$ is a factor of $G(x)$
D. $G(x)$ has an odd number of terms.

gatecse-2009 computer-networks error-detection normal

Answer key

4.11.5 Error Detection: GATE CSE 2017 Set 2 | Question: 34

Consider the binary code that consists of only four valid codewords as given below:

$00000, 01011, 10101, 11110$

Let the minimum Hamming distance of the code p and the maximum number of erroneous bits that can be corrected by the code be q. Then the values of p and q are

A. $p = 3$ and $q = 1$ B. $p = 3$ and $q = 2$ C. $p = 4$ and $q = 1$ D. $p = 4$ and $q = 2$

gatecse-2017-set2 computer-networks error-detection

Answer key

4.11.6 Error Detection: GATE CSE 2021 Set 1 | Question: 29

Assume that a 12-bit Hamming codeword consisting of 8-bit data and 4 check bits is $d_8 d_7 d_6 d_5 c_8 d_4 d_4 d_3 d_2 c_4 d_1 c_2 c_1$, where the data bits and the check bits are given in the following tables:

Data bits

d_8	d_7	d_6	d_5	d_4	d_3	d_2	d_1
1	1	0	x	0	1	0	1

Check bits

c_8	c_4	c_2	c_1
y	0	1	0

Which one of the following choices gives the correct values of x and y?

A. x is 0 and y is 0 B. x is 0 and y is 1 C. x is 1 and y is 0 D. x is 1 and y is 1

gatecse-2021-set1 computer-networks hamming-code two-marks error-detection

Answer key

4.11.7 Error Detection: GATE IT 2005 | Question: 74

In a communication network, a packet of length L bits takes link L_1 with a probability of p_1 or link L_2 with a probability of p_2. Link L_1 and L_2 have bit error probability of b_1 and b_2 respectively. The probability that the packet will be received without error via either L_1 or L_2 is

A. $(1 - b_1)^L p_1 + (1 - b_2)^L p_2$
B. $[1 - (b_1 + b_2)^L] p_1 p_2$
C. $(1 - b_1)^L (1 - b_2)^L p_1 p_2$
D. $1 - (b_1^L p_1 + b_2^L p_2)$

gateit-2005 computer-networks error-detection probability normal

Answer key

4.11.8 Error Detection: GATE IT 2007 | Question: 43

An error correcting code has the following code words: $00000000, 00001111, 01010101, 10101010, 11110000$. What is the maximum number of bit errors that can be corrected?

A. 0 B. 1 C. 2 D. 3

gateit-2007 computer-networks error-detection normal

Answer key

4.11.9 Error Detection: GATE IT 2008 | Question: 66

Data transmitted on a link uses the following $2D$ parity scheme for error detection:
Each sequence of 28 bits is arranged in a 4×7 matrix (rows r_0 through r_3, and columns d_7 through d_1) and is padded with a column d_0 and row r_4 of parity bits computed using the Even parity scheme. Each bit of column d_0 (respectively, row r_4) gives the parity of the corresponding row (respectively, column). These 40 bits are transmitted over the data link.

	$\mathbf{d_7}$	$\mathbf{d_6}$	$\mathbf{d_5}$	$\mathbf{d_4}$	$\mathbf{d_3}$	$\mathbf{d_2}$	$\mathbf{d_1}$	$\mathbf{d_0}$
$\mathbf{r_0}$	0	1	0	1	0	0	1	**1**
$\mathbf{r_1}$	1	1	0	0	1	1	1	**0**
$\mathbf{r_2}$	0	0	0	1	0	1	0	**0**
$\mathbf{r_3}$	0	1	1	0	1	0	1	**0**
$\mathbf{r_4}$	**1**	**1**	**0**	**0**	**0**	**1**	**1**	**0**

The table shows data received by a receiver and has n corrupted bits. What is the minimum possible value of n?

A. 1 B. 2 C. 3 D. 4

gateit-2008 computer-networks normal error-detection

Answer key

4.11.10 Error Detection: GATE1987-2-i

Match the pairs in the following questions:

(A) Cyclic Redundancy Code	(p) Error Correction
(B) Serial Communication	(q) Wired-OR
(C) Open Collector	(r) Error detection
(D) Hamming Code	(s) RS-232-C

gate1989 descriptive computer-networks error-detection

Answer key

4.12 Ethernet (7)

4.12.1 Ethernet: GATE CSE 2004 | Question: 54

A and B are the only two stations on an Ethernet. Each has a steady queue of frames to send. Both A and B attempt to transmit a frame, collide, and A wins the first backoff race. At the end of this successful transmission by A, both A and B attempt to transmit and collide. The probability that A wins the second backoff race is:

A. 0.5 B. 0.625 C. 0.75 D. 1.0

gatecse-2004 computer-networks ethernet probability normal

Answer key

4.12.2 Ethernet: GATE CSE 2013 | Question: 36

Determine the maximum length of the cable (in km) for transmitting data at a rate of 500 Mbps in an Ethernet LAN with frames of size $10,000$ bits. Assume the signal speed in the cable to be $2,00,000$ km/s.

A. 1 B. 2
C. 2.5 D. 5

gatecse-2013 computer-networks ethernet normal

Answer key

4.12.3 Ethernet: GATE CSE 2016 Set 2 | Question: 24

In an Ethernet local area network, which one of the following statements is **TRUE**?

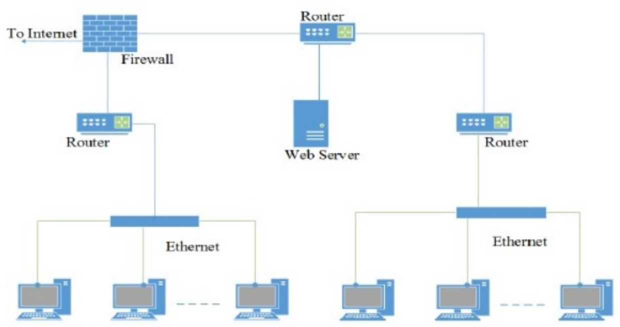
A. A station stops to sense the channel once it starts transmitting a frame.
B. The purpose of the jamming signal is to pad the frames that are smaller than the minimum frame size.
C. A station continues to transmit the packet even after the collision is detected.
D. The exponential back off mechanism reduces the probability of collision on retransmissions.

gatecse-2016-set2 computer-networks ethernet normal

Answer key

4.12.4 Ethernet: GATE CSE 2022 | Question: 12

Consider an enterprise network with two Ethernet segments, a web server and a firewall, connected via three routers as shown below.



What is the number of subnets inside the enterprise network?

A. 3 B. 12 C. 6 D. 8

gatecse-2022 computer-networks ethernet one-mark

Answer key

4.12.5 Ethernet: GATE CSE 2024 | Set 2 | Question: 13

Node X has a TCP connection open to node Y. The packets from X to Y go through an intermediate IP router R. Ethernet switch S is the first switch on the network path between X and R. Consider a packet sent from X to Y over this connection.

Which of the following statements is/are TRUE about the destination IP and MAC addresses on this packet at the time it leaves X?

A. The destination IP address is the IP address of R
B. The destination IP address is the IP address of Y
C. The destination MAC address is the MAC address of S
D. The destination MAC address is the MAC address of Y

gatecse2024-set2 computer-networks multiple-selects ethernet one-mark

Answer key

4.12.6 Ethernet: GATE CSE 2024 | Set 2 | Question: 45

Consider an Ethernet segment with a transmission speed of 10^8bits/sec and a maximum segment length of 500 meters. If the speed of propagation of the signal in the medium is 2×10^8 meters/sec, then the minimum frame size (*in bits*) required for collision detection is ___________.

gatecse2024-set2 numerical-answers computer-networks ethernet two-marks

Answer key

4.12.7 Ethernet: GATE IT 2006 | Question: 19

Which of the following statements is TRUE?

A. Both Ethernet frame and IP packet include checksum fields
B. Ethernet frame includes a checksum field and IP packet includes a CRC field
C. Ethernet frame includes a CRC field and IP packet includes a checksum field
D. Both Ethernet frame and IP packet include CRC fields

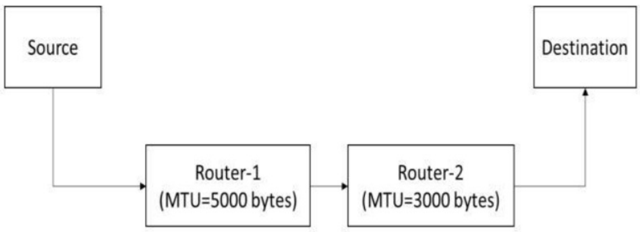
gateit-2006 computer-networks normal ethernet

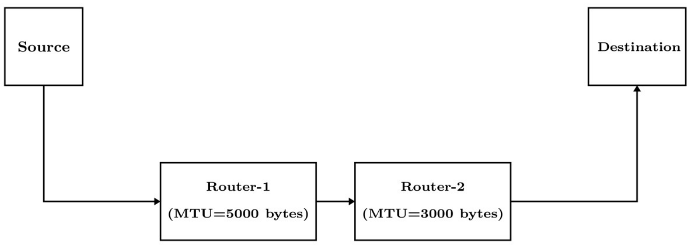
Answer key

4.13 Fragmentation (2)

4.13.1 Fragmentation: GATE CSE 2025 | Set 1 | Question: 47

Suppose a message of size 15000 bytes is transmitted from a source to a destination using IPv4 protocol via two routers as shown in the figure. Each router has a defined maximum transmission unit (MTU) as shown in the figure, including IP header. The number of fragments that will be delivered to the destination is _________. (Answer in integer)





gatecse2025-set1 computer-networks ip-addressing fragmentation numerical-answers two-marks

Answer key

4.13.2 Fragmentation: GATE CSE 2025 | Set 2 | Question: 13

Consider a network that uses Ethernet and $IPv4$. Assume that $IPv4$ headers do not use any options field. Each Ethernet frame can carry a maximum of 1500 bytes in its data field. A UDP segment is transmitted. The payload (data) in the UDPO segment is 7488 bytes.

Which ONE of the following choices has the CORRECT total number of fragments transmitted and the sixe of the last fragment including $IPv4$ header?

A. 5 fragments 1488 bytes
B. 6 fragments 88 bytes
C. 6 fragments 108 bytes
D. 6 fragments 116 bytes

gatecse2025-set2 computer-networks fragmentation ip-addressing one-mark

Answer key

4.14 IP Addressing (11)

4.14.1 IP Addressing: GATE CSE 2003 | Question: 27

Which of the following assertions is FALSE about the Internet Protocol (IP)?

A. It is possible for a computer to have multiple IP addresses
B. IP packets from the same source to the same destination can take different routes in the network
C. IP ensures that a packet is discarded if it is unable to reach its destination within a given number of hops
D. The packet source cannot set the route of an outgoing packets; the route is determined only by the routing tables in the routers on the way

gatecse-2003 computer-networks ip-addressing normal

Answer key

4.14.2 IP Addressing: GATE CSE 2004 | Question: 56

Consider three IP networks A, B and C. Host H_A in network A sends messages each containing 180 bytes of application data to a host H_C in network C. The TCP layer prefixes 20 byte header to the message.

This passes through an intermediate network B.The maximum packet size, including 20 byte IP header, in each network is:

- A: 1000 bytes
- B: 100 bytes
- C: 1000 bytes

The network A and B are connected through a 1 Mbps link, while B and C are connected by a 512 Kbps link (bps = bits per second).

Assuming that the packets are correctly delivered, how many bytes, including headers, are delivered to the IP layer at the destination for one application message, in the best case? Consider only data packets.

A. 200 B. 220 C. 240 D. 260

gatecse-2004 computer-networks ip-addressing tcp normal

Answer key

4.14.3 IP Addressing: GATE CSE 2004 | Question: 57

Consider three IP networks A, B and C. Host H_A in network A sends messages each containing 180 $bytes$ of application data to a host H_C in network C. The TCP layer prefixes 20 byte header to the message. This passes through an intermediate network B. The maximum packet size, including 20 byte IP header, in each network, is:

- $A : 1000 \text{ bytes}$
- $B : 100 \quad \text{bytes}$
- $C : 1000 \text{ bytes}$

The network A and B are connected through a $1 \ Mbps$ link, while B and C are connected by a $512 \ Kbps$ link (bps = bits per second).

What is the rate at which application data is transferred to host H_C? Ignore errors, acknowledgments, and other overheads.

A. 325.5 Kbps
B. 354.5 Kbps
C. 409.6 Kbps
D. 512.0 Kbps

gatecse-2004 computer-networks ip-addressing tcp normal

Answer key

4.14.4 IP Addressing: GATE CSE 2012 | Question: 23

In the IPv4 addressing format, the number of networks allowed under Class C addresses is:

A. 2^{14} B. 2^{7} C. 2^{21} D. 2^{24}

gatecse-2012 computer-networks ip-addressing easy

Answer key

4.14.5 IP Addressing: GATE CSE 2013 | Question: 37

In an IPv4 datagram, the M bit is 0, the value of $HLEN$ is 10, the value of total length is 400 and the fragment offset value is 300. The position of the datagram, the sequence numbers of the first and the last bytes of the payload, respectively are:

A. Last fragment, 2400 and 2789
B. First fragment, 2400 and 2759
C. Last fragment, 2400 and 2759
D. Middle fragment, 300 and 689

gatecse-2013 computer-networks ip-addressing normal

Answer key

4.14.6 IP Addressing: GATE CSE 2014 Set 3 | Question: 27

Every host in an IPv4 network has a 1-second resolution real-time clock with battery backup. Each host needs to generate up to 1000 unique identifiers per second. Assume that each host has a globally unique IPv4 address. Design a 50-bit globally unique ID for this purpose. After what period (in seconds) will the identifiers generated by a host wrap around?

gatecse-2014-set3 computer-networks ip-addressing numerical-answers normal

Answer key

4.14.7 IP Addressing: GATE CSE 2017 Set 2 | Question: 20

The maximum number of IPv4 router addresses that can be listed in the record route (RR) option field of an IPv4 header is______.

gatecse-2017-set2 computer-networks ip-addressing numerical-answers

Answer key

4.14.8 IP Addressing: GATE CSE 2018 | Question: 54

Consider an IP packet with a length of $4,500 \text{ bytes}$ that includes a 20-byte IPv4 header and a 40-byte TCP header. The packet is forwarded to an IPv4 router that supports a Maximum Transmission Unit (MTU) of 600 bytes. Assume that the length of the IP header in all the outgoing fragments of this packet is 20 bytes. Assume that the fragmentation offset value stored in the first fragment is 0.

The fragmentation offset value stored in the third fragment is ________.

gatecse-2018 computer-networks ip-addressing numerical-answers two-marks

Answer key

4.14.9 IP Addressing: GATE CSE 2023 | Question: 42

Suppose in a web browser, you click on the www. gate-2023.in URL. The browser cache is empty. The IP address for this URL is not cached in your local host, so a DNS lookup is triggered (by the local DNS server deployed on your local host) over the 3-tier DNS hierarchy in an iterative mode. No resource records are cached anywhere across all DNS servers.

Let RTT denote the round trip time between your local host and DNS servers in the DNS hierarchy. The round trip time between the local host and the web server hosting www.gate-2023.in is also equal to RTT. The HTML file associated with the URL is small enough to have negligible transmission time and negligible rendering time by your web browser, which references 10 equally small objects on the same web server.

Which of the following statements is/are CORRECT about the minimum elapsed time between clicking on the URL and your browser fully rendering it?

A. 7 RTTs, in case of non-persistent HTTP with 5 parallel TCP connections.
B. 5 RTTs, in case of persistent HTTP with pipelining.
C. 9 RTTs, in case of non-persistent HTTP with 5 parallel TCP connections.
D. 6 RTTs, in case of persistent HTTP with pipelining.

gatecse-2023 computer-networks ip-addressing multiple-selects two-marks

Answer key

4.14.10 IP Addressing: GATE CSE 2024 | Set 2 | Question: 28

Which one of the following CIDR prefixes exactly represents the range of IP addresses $10.12.2.0$ to $10.12.3.255$?

A. $10.12.2.0/23$
B. $10.12.2.0/24$
C. $10.12.0.0/22$
D. $10.12.2.0/22$

gatecse2024-set2 computer-networks ip-addressing two-marks

Answer key

4.14.11 IP Addressing: GATE CSE 2025 | Set 2 | Question: 8

A machine receives an $IPv4$ datagram. The protocol field of the $IPv4$ header has the protocol number of a protocol X.

Which ONE of the following is NOT a possible candidate for X?

A. Internet Control Message Protocol (ICMP)
B. Internet Group Management (IGMP)
C. Open Shortest Path First (OSPF)
D. Routing Information Protocol (RIP)

gatecse2025-set2 computer-networks ip-addressing one-mark

Answer key

4.15 IP Packet (11)

4.15.1 IP Packet: GATE CSE 2006 | Question: 5

For which one of the following reasons does internet protocol(IP) use the time-to-live(TTL) field in IP datagram header?

A. Ensure packets reach destination within that time
B. Discard packets that reach later than that time
C. Prevent packets from looping indefinitely
D. Limit the time for which a packet gets queued in intermediate routers

gatecse-2006 computer-networks ip-addressing ip-packet easy

Answer key

4.15.2 IP Packet: GATE CSE 2010 | Question: 15. PGEE 2018

One of the header fields in an IP datagram is the Time-to-Live (TTL) field. Which of the following statements best explains the need for this field?

A. It can be used to prioritize packets.
B. It can be used to reduce delays.
C. It can be used to optimize throughput.
D. It can be used to prevent packet looping.

gatecse-2010 computer-networks ip-packet easy

Answer key

4.15.3 IP Packet: GATE CSE 2014 Set 3 | Question: 25

Host A (on TCP/IP v4 network A) sends an IP datagram D to host B (also on TCP/IP v4 network B). Assume that no error occurred during the transmission of D. When D reaches B, which of the following IP header field(s) may be different from that of the original datagram D?

i. TTL
ii. Checksum
iii. Fragment Offset

A. i only
B. i and ii only
C. ii and iii only
D. i, ii and iii

gatecse-2014-set3 computer-networks ip-packet normal

Answer key

4.15.4 IP Packet: GATE CSE 2014 Set 3 | Question: 28

An IP router with a $\text{Maximum Transmission Unit (MTU)}$ of 1500 bytes has received an IP packet of size 4404 bytes with an IP header of length 20 bytes. The values of the relevant fields in the header of the third IP fragment generated by the router for this packet are:

A. $\text{MF bit: } 0,$ Datagram Length:$1444;$ Offset: 370
B. $\text{MF bit: } 1,$ Datagram Length: $1424;$ Offset: 185
C. $\text{MF bit: } 1,$ Datagram Length: $1500;$ Offset: 370
D. $\text{MF bit: } 0,$ Datagram Length: $1424;$ Offset: 2960

gatecse-2014-set3 computer-networks ip-packet normal

Answer key

4.15.5 IP Packet: GATE CSE 2015 Set 1 | Question: 22

Which of the following fields of an IP header is NOT modified by a typical IP router?

A. Check sum B. Source address C. Time to Live (TTL) D. Length

gatecse-2015-set1 computer-networks ip-packet easy

Answer key

4.15.6 IP Packet: GATE CSE 2015 Set 2 | Question: 52

Host A sends a UDP datagram containing 8880 bytes of user data to host B over an Ethernet LAN. Ethernet frames may carry data up to $1500 \text{ bytes (i.e. MTU} = 1500 \text{ bytes)}.$ Size of UDP header is 8 bytes and size of IP header is $20 \text{ bytes}.$ There is no option field in IP header. How many total number of IP fragments will be transmitted and what will be the contents of offset field in the last fragment?

A. 6 and 925 B. 6 and 7400 C. 7 and 1110 D. 7 and 8880

gatecse-2015-set2 computer-networks ip-packet normal

Answer key

4.15.7 IP Packet: GATE CSE 2016 Set 1 | Question: 53

An IP datagram of size 1000 bytes arrives at a router. The router has to forward this packet on a link whose MTU (maximum transmission unit) is 100 bytes . Assume that the size of the IP header is 20 bytes .

The number of fragments that the IP datagram will be divided into for transmission is________.

gatecse-2016-set1 computer-networks ip-packet normal numerical-answers

Answer key

4.15.8 IP Packet: GATE CSE 2024 | Set 1 | Question: 21

Which of the following fields is/are modified in the IP header of a packet going out of a network address translation (NAT) device from an internal network to an external network?

A. Source IP B. Destination IP
C. Header Checksum D. Total Length

gatecse2024-set1 multiple-selects computer-networks ip-packet one-mark

Answer key

4.15.9 IP Packet: GATE CSE 2024 | Set 2 | Question: 18

Which of the following statements about IPv4 fragmentation is/are TRUE?

A. The fragmentation of an IP datagram is performed *only* at the source of the datagram
B. The fragmentation of an IP datagram is performed at any IP router which finds that the size of the datagram

to be transmitted exceeds the MTU

C. The reassembly of fragments is performed *only* at the destination of the datagram
D. The reassembly of fragments is performed at all intermediate routers along the path from the source to the destination

gatecse2024-set2 computer-networks multiple-selects ip-packet one-mark

Answer key

4.15.10 IP Packet: GATE CSE 2024 | Set 2 | Question: 22

Which of the following fields of an IP header is/are *always* modified by any router before it forwards the IP packet?

A. Source IP Address
B. Protocol
C. Time to Live (TTL)
D. Header Checksum

gatecse2024-set2 computer-networks multiple-selects ip-packet one-mark

Answer key

4.15.11 IP Packet: GATE IT 2004 | Question: 86

In the TCP/IP protocol suite, which one of the following is NOT part of the IP header?

A. Fragment Offset
B. Source IP address
C. Destination IP address
D. Destination port number

gateit-2004 computer-networks ip-packet normal

Answer key

4.16 LAN Technologies (7)

4.16.1 LAN Technologies: GATE CSE 2003 | Question: 83

A $2\ km$ long broadcast LAN has 10^7 bps bandwidth and uses CSMA/CD. The signal travels along the wire at 2×10^8 m/s. What is the minimum packet size that can be used on this network?

A. 50 bytes
B. 100 bytes
C. 200 bytes
D. None of the above

gatecse-2003 computer-networks lan-technologies normal

Answer key

4.16.2 LAN Technologies: GATE CSE 2007 | Question: 65

There are n stations in slotted LAN. Each station attempts to transmit with a probability p in each time slot. What is the probability that **ONLY** one station transmits in a given time slot?

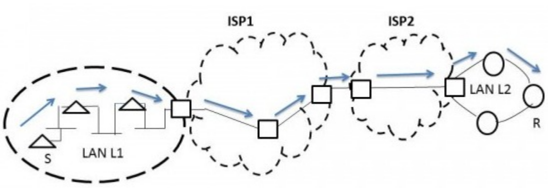
A. $np(1-p)^{n-1}$
B. $(1-p)^{n-1}$
C. $p(1-p)^{n-1}$
D. $1-(1-p)^{n-1}$

gatecse-2007 computer-networks lan-technologies probability normal

Answer key

4.16.3 LAN Technologies: GATE CSE 2014 Set 2 | Question: 25

In the diagram shown below, $L1$ is an Ethernet LAN and $L2$ is a Token-Ring LAN. An IP packet originates from sender S and traverses to R, as shown. The links within each ISP and across the two ISPs, are all point-to-point optical links. The initial value of the TTL field is 32. The maximum possible value of the TTL field when R receives the datagram is _______.



gatecse-2014-set2 computer-networks numerical-answers lan-technologies ethernet normal

Answer key

4.16.4 LAN Technologies: GATE CSE 2019 | Question: 49

Consider that 15 machines need to be connected in a LAN using 8-port Ethernet switches. Assume that these switches do not have any separate uplink ports. The minimum number of switches needed is ______

gatecse-2019 numerical-answers computer-networks lan-technologies two-marks

Answer key

4.16.5 LAN Technologies: GATE IT 2004 | Question: 27

A host is connected to a Department network which is part of a University network. The University network, in turn, is part of the Internet. The largest network in which the Ethernet address of the host is unique is

A. the subnet to which the host belongs
B. the Department network
C. the University network
D. the Internet

gateit-2004 computer-networks lan-technologies ethernet normal

Answer key

4.16.6 LAN Technologies: GATE IT 2005 | Question: 28

Which of the following statements is FALSE regarding a bridge?

A. Bridge is a layer 2 device
B. Bridge reduces collision domain
C. Bridge is used to connect two or more LAN segments
D. Bridge reduces broadcast domain

gateit-2005 computer-networks lan-technologies normal

Answer key

4.16.7 LAN Technologies: GATE IT 2006 | Question: 66

A router has two full-duplex Ethernet interfaces each operating at 100 Mb/s. Ethernet frames are at least 84 bytes long (including the Preamble and the Inter-Packet-Gap). The maximum packet processing time at the router for wirespeed forwarding to be possible is (in microseconds)

A. 0.01
B. 3.36
C. 6.72
D. 8

gateit-2006 computer-networks lan-technologies ethernet normal

Answer key

4.17 MAC Protocol (5)

4.17.1 MAC Protocol: GATE CSE 2005 | Question: 74

Suppose the round trip propagation delay for a 10 Mbps Ethernet having 48-bit jamming signal is $46.4 \; \mu s$. The minimum frame size is:

A. 94
B. 416
C. 464
D. 512

gatecse-2005 computer-networks mac-protocol ethernet

Answer key

4.17.2 MAC Protocol: GATE CSE 2015 Set 2 | Question: 8

A link has transmission speed of 10^6 bits/sec. It uses data packets of size 1000 bytes each. Assume that the acknowledgment has negligible transmission delay and that its propagation delay is the same as the data propagation delay. Also, assume that the processing delays at nodes are negligible. The efficiency of the stop-and-wait protocol in this setup is exactly 25%. The value of the one way propagation delay (in milliseconds) is_____.

gatecse-2015-set2 computer-networks mac-protocol stop-and-wait normal numerical-answers

Answer key☟

4.17.3 MAC Protocol: GATE CSE 2021 Set 2 | Question: 54

Consider a network using the pure ALOHA medium access control protocol, where each frame is of length $1,000$ bits. The channel transmission rate is 1 Mbps ($= 10^6$ bits per second). The aggregate number of transmissions across all the nodes (including new frame transmissions and retransmitted frames due to collisions) is modelled as a Poisson process with a rate of $1,000$ frames per second. Throughput is defined as the average number of frames successfully transmitted per second. The throughput of the network (rounded to the nearest integer) is _______________

gatecse-2021-set2 computer-networks mac-protocol pure-aloha numerical-answers two-marks

Answer key☟

4.17.4 MAC Protocol: GATE IT 2004 | Question: 85

Consider a simplified time slotted MAC protocol, where each host always has data to send and transmits with probability $p = 0.2$ in every slot. There is no backoff and one frame can be transmitted in one slot. If more than one host transmits in the same slot, then the transmissions are unsuccessful due to collision. What is the maximum number of hosts which this protocol can support if each host has to be provided a minimum throughput of 0.16 frames per time slot?

A. 1
B. 2
C. 3
D. 4

gateit-2004 computer-networks congestion-control mac-protocol normal

Answer key☟

4.17.5 MAC Protocol: GATE IT 2005 | Question: 75

In a TDM medium access control bus LAN, each station is assigned one time slot per cycle for transmission. Assume that the length of each time slot is the time to transmit 100 bits plus the end-to-end propagation delay. Assume a propagation speed of $2 \times 10^8 m/sec$. The length of the LAN is 1 km with a bandwidth of 10 Mbps. The maximum number of stations that can be allowed in the LAN so that the throughput of each station can be $2/3 \text{ Mbps}$ is

A. 3
B. 5
C. 10
D. 20

gateit-2005 computer-networks mac-protocol normal

Answer key☟

4.18 Network Flow (4)

4.18.1 Network Flow: GATE CSE 1992 | Question: 01,v

A simple and reliable data transfer can be accomplished by using the 'handshake protocol'. It accomplishes reliable data transfer because for every data item sent by the transmitter ________.

gate1992 computer-networks network-flow easy fill-in-the-blanks

Answer key☟

4.18.2 Network Flow: GATE CSE 2017 Set 2 | Question: 35

Consider two hosts X and Y, connected by a single direct link of rate 10^6 bits/sec. The distance between the two hosts is $10,000 \text{ km}$ and the propagation speed along the link is $2 \times 10^8 \text{ m/sec}$. Host X sends a file of $50,000 \text{ bytes}$ as one large message to host Y continuously. Let the transmission and propagation delays be p milliseconds and q milliseconds respectively. Then the value of p and q are

A. $p = 50$ and $q = 100$
B. $p = 50$ and $q = 400$
C. $p = 100$ and $q = 50$
D. $p = 400$ and $q = 50$

gatecse-2017-set2 computer-networks network-flow

Answer key☟

4.18.3 Network Flow: GATE IT 2004 | Question: 87

A TCP message consisting of $2100 \quad bytes$ is passed to IP for delivery across two networks. The first network can carry a maximum payload of $1200\ bytes$ per frame and the second network can carry a maximum payload of $400\ bytes$ per frame, excluding network overhead. Assume that IP overhead per packet is $20\ bytes$. What is the total IP overhead in the second network for this transmission?

A. 40 bytes B. 80 bytes C. 120 bytes D. 160 bytes

gateit-2004 computer-networks network-flow normal

Answer key

4.18.4 Network Flow: GATE IT 2006 | Question: 67

A link of capacity 100 Mbps is carrying traffic from a number of sources. Each source generates an on-off traffic stream; when the source is on, the rate of traffic is 10 Mbps, and when the source is off, the rate of traffic is zero. The duty cycle, which is the ratio of on-time to off-time, is $1 : 2$. When there is no buffer at the link, the minimum number of sources that can be multiplexed on the link so that link capacity is not wasted and no data loss occurs is $S1$. Assuming that all sources are synchronized and that the link is provided with a large buffer, the maximum number of sources that can be multiplexed so that no data loss occurs is $S2$. The values of $S1$ and $S2$ are, respectively,

A. 10 and 30 B. 12 and 25 C. 5 and 33 D. 15 and 22

gateit-2006 computer-networks network-flow normal

Answer key

4.19 Network Layering (6)

4.19.1 Network Layering: GATE CSE 2003 | Question: 28

Which of the following functionality *must* be implemented by a transport protocol over and above the network protocol?

A. Recovery from packet losses
B. Detection of duplicate packets
C. Packet delivery in the correct order
D. End to end connectivity

gatecse-2003 computer-networks network-layering easy

Answer key

4.19.2 Network Layering: GATE CSE 2004 | Question: 15

Choose the best matching between Group 1 and Group 2

Group-1	**Group-2**
P. Data link layer	1. Ensures reliable transport of data over a physical point-to-point link
Q. Network layer	2. Encodes/decodes data for physical transmission
R. Transport layer	3. Allows end-to-end communication between two processes
	4. Routes data from one network node to the next

A. P-1, Q-4, R-3 B. P-2, Q-4, R-1 C. P-2, Q-3, R-1 D. P-1, Q-3, R-2

gatecse-2004 computer-networks network-layering normal

Answer key

4.19.3 Network Layering: GATE CSE 2007 | Question: 70

Match the following:

(P)	SMTP	(1)	Application layer
(Q)	BGP	(2)	Transport layer
(R)	TCP	(3)	Data link layer
(S)	PPP	(4)	Network layer
		(5)	Physical layer

A. P - 2, Q - 1, R - 3, S - 5
B. P - 1, Q - 4, R - 2, S - 3
C. P - 1, Q - 4, R - 2, S - 5
D. P - 2, Q - 4, R - 1, S - 3

gatecse-2007 computer-networks network-layering network-protocols easy

Answer key

4.19.4 Network Layering: GATE CSE 2013 | Question: 14

Assume that source S and destination D are connected through two intermediate routers labeled R. Determine how many times each packet has to visit the network layer and the data link layer during a transmission from S to D.

A. Network layer – 4 times and Data link layer – 4 times
B. Network layer – 4 times and Data link layer – 3 times
C. Network layer – 4 times and Data link layer – 6 times
D. Network layer – 2 times and Data link layer – 6 times

gatecse-2013 computer-networks network-layering normal

Answer key

4.19.5 Network Layering: GATE CSE 2014 Set 3 | Question: 23

In the following pairs of OSI protocol layer/sub-layer and its functionality, the **INCORRECT** pair is

A. Network layer and Routing
B. Data Link Layer and Bit synchronization
C. Transport layer and End-to-end process communication
D. Medium Access Control sub-layer and Channel sharing

gatecse-2014-set3 computer-networks network-layering easy

Answer key

4.19.6 Network Layering: GATE CSE 2018 | Question: 13

Match the following:

Field	Length in bits
P. UDP Header's Port Number	I. 48
Q. Ethernet MAC Address	II. 8
R. IPv6 Next Header	III. 32
S. TCP Header's Sequence Number	IV. 16

A. P-III, Q-IV, R-II, S-I
B. P-II, Q-I, R-IV, S-III
C. P-IV, Q-I, R-II, S-III
D. P-IV, Q-I, R-III, S-II

gatecse-2018 computer-networks network-layering normal one-mark

Answer key

4.20 Network Protocols (10)

4.20.1 Network Protocols: GATE CSE 2005 | Question: 24

The address resolution protocol (ARP) is used for:

A. Finding the IP address from the DNS
B. Finding the IP address of the default gateway

C. Finding the IP address that corresponds to a MAC address
D. Finding the MAC address that corresponds to an IP address

gatecse-2005 computer-networks normal network-protocols

Answer key

4.20.2 Network Protocols: GATE CSE 2007 | Question: 20

Which one of the following uses UDP as the transport protocol?

A. HTTP B. Telnet C. DNS D. SMTP

gatecse-2007 computer-networks network-protocols application-layer-protocols easy

Answer key

4.20.3 Network Protocols: GATE CSE 2015 Set 1 | Question: 17

In one of the pairs of protocols given below , both the protocols can use multiple TCP connections between the same client and the server. Which one is that?

A. HTTP, FTP B. HTTP, TELNET C. FTP, SMTP D. HTTP, SMTP

gatecse-2015-set1 computer-networks network-protocols normal

Answer key

4.20.4 Network Protocols: GATE CSE 2016 Set 1 | Question: 24

Which one of the following protocols is **NOT** used to resolve one form of address to another one?

A. DNS B. ARP C. DHCP D. RARP

gatecse-2016-set1 computer-networks network-protocols normal

Answer key

4.20.5 Network Protocols: GATE CSE 2019 | Question: 29

Suppose that in an IP-over-Ethernet network, a machine X wishes to find the MAC address of another machine Y in its subnet. Which one of the following techniques can be used for this?

A. X sends an ARP request packet to the local gateway's IP address which then finds the MAC address of Y and sends to X
B. X sends an ARP request packet to the local gateway's MAC address which then finds the MAC address of Y and sends to X
C. X sends an ARP request packet with broadcast MAC address in its local subnet
D. X sends an ARP request packet with broadcast IP address in its local subnet

gatecse-2019 computer-networks network-protocols two-marks

Answer key

4.20.6 Network Protocols: GATE CSE 2021 Set 1 | Question: 49

Consider the sliding window flow-control protocol operating between a sender and a receiver over a full-duplex error-free link. Assume the following:

- The time taken for processing the data frame by the receiver is negligible.
- The time taken for processing the acknowledgement frame by the sender is negligible.
- The sender has infinite number of frames available for transmission.
- The size of the data frame is $2,000$ bits and the size of the acknowledgement frame is 10 bits.
- The link data rate in each direction is 1 Mbps ($= 10^6$ bits per second).
- One way propagation delay of the link is 100 milliseconds.

The minimum value of the sender's window size in terms of the number of frames, (rounded to the nearest integer) needed to achieve a link utilization of 50% is_____________.

gatecse-2021-set1 computer-networks network-protocols sliding-window numerical-answers two-marks

Answer key

4.20.7 Network Protocols: GATE CSE 2021 Set 1 | Question: 8

Consider the following two statements.

- S_1: Destination MAC address of an ARP reply is a broadcast address.
- S_2: Destination MAC address of an ARP request is a broadcast address.

Which one of the following choices is correct?

A. Both S_1 and S_2 are true
B. S_1 is true and S_2 is false
C. S_1 is false and S_2 is true
D. Both S_1 and S_2 are false

gatecse-2021-set1 computer-networks network-protocols one-mark

Answer key

4.20.8 Network Protocols: GATE CSE 2024 | Set 1 | Question: 6

A user starts browsing a webpage hosted at a remote server. The browser opens a single TCP connection to fetch the entire webpage from the server. The webpage consists of a top-level index page with multiple embedded image objects. Assume that all caches (e.g., DNS cache, browser cache) are all initially empty. The following packets leave the user's computer in some order.

i. HTTP GET request for the index page
ii. DNS request to resolve the web server's name to its IP address
iii. HTTP GET request for an image object
iv. TCP SYN to open a connection to the web server

Which one of the following is the CORRECT chronological order (earliest in time to latest) of the packets leaving the computer?

A. $(\text{iv}), (\text{ii}), (\text{iii}), (\text{i})$
B. $(\text{ii}), (\text{iv}), (\text{iii}), (\text{i})$
C. $(\text{ii}), (\text{iv}), (\text{i}), (\text{iii})$
D. $(\text{iv}), (\text{ii}), (\text{i}), (\text{iii})$

gatecse2024-set1 computer-networks network-protocols one-mark

Answer key

4.20.9 Network Protocols: GATE IT 2007 | Question: 69

Consider the following clauses:

i. Not inherently suitable for client authentication.
ii. Not a state sensitive protocol.
iii. Must be operated with more than one server.
iv. Suitable for structured message organization.
v. May need two ports on the serve side for proper operation.

The option that has the maximum number of correct matches is

A. IMAP-i; FTP-ii; HTTP-iii; DNS-iv; POP3-v
B. FTP-i; POP3-ii; SMTP-iii; HTTP-iv; IMAP-v
C. POP3-i; SMTP-ii; DNS-iii; IMAP-iv; HTTP-v
D. SMTP-i; HTTP-ii; IMAP-iii; DNS-iv; FTP-v

gateit-2007 computer-networks network-protocols normal

Answer key

4.20.10 Network Protocols: GATE IT 2008 | Question: 68

Which of the following statements are TRUE?

- **S1:** TCP handles both congestion and flow control
- **S2:** UDP handles congestion but not flow control

- **S3:** Fast retransmit deals with congestion but not flow control
- **S4:** Slow start mechanism deals with both congestion and flow control

A. $S1$, $S2$ and $S3$ only
B. $S1$ and $S3$ only
C. $S3$ and $S4$ only
D. $S1$, $S3$ and $S4$ only

gateit-2008 computer-networks network-protocols normal

Answer key☟

4.21 Network Switching (4)

4.21.1 Network Switching: GATE CSE 2005 | Question: 73

In a packet switching network, packets are routed from source to destination along a single path having two intermediate nodes. If the message size is 24 bytes and each packet contains a header of 3 bytes, then the optimum packet size is:

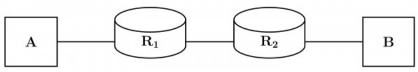
A. 4
B. 6
C. 7
D. 9

gatecse-2005 computer-networks network-switching normal

Answer key☟

4.21.2 Network Switching: GATE CSE 2014 Set 2 | Question: 26

Consider the store and forward packet switched network given below. Assume that the bandwidth of each link is 10^6 bytes / sec. A user on host A sends a file of size 10^3 bytes to host B through routers $R1$ and $R2$ in three different ways. In the first case a single packet containing the complete file is transmitted from A to B. In the second case, the file is split into 10 equal parts, and these packets are transmitted from A to B. In the third case, the file is split into 20 equal parts and these packets are sent from A to B. Each packet contains 100 bytes of header information along with the user data. Consider only transmission time and ignore processing, queuing and propagation delays. Also assume that there are no errors during transmission. Let $T1$, $T2$ and $T3$ be the times taken to transmit the file in the first, second and third case respectively. Which one of the following is CORRECT?



A. $T1 < T2 < T3$
B. $T1 > T2 > T3$
C. $T2 = T3, T3 < T1$
D. $T1 = T3, T3 > T2$

gatecse-2014-set2 computer-networks network-switching normal

Answer key☟

4.21.3 Network Switching: GATE CSE 2015 Set 3 | Question: 36

Two hosts are connected via a packet switch with 10^7 bits per second links. Each link has a propagation delay of 20 microseconds. The switch begins forwarding a packet 35 microseconds after it receives the same. If 10000 bits of data are to be transmitted between the two hosts using a packet size of 5000 bits, the time elapsed between the transmission of the first bit of data and the reception of the last bit of the data in microseconds is ______.

gatecse-2015-set3 computer-networks normal numerical-answers network-switching

Answer key☟

4.21.4 Network Switching: GATE IT 2004 | Question: 22

Which one of the following statements is FALSE?

A. Packet switching leads to better utilization of bandwidth resources than circuit switching
B. Packet switching results in less variation in delay than circuit switching
C. Packet switching requires more per-packet processing than circuit switching
D. Packet switching can lead to reordering unlike in circuit switching

gateit-2004 computer-networks network-switching normal

Answer key☟

4.22 Osi Model (1)

4.22.1 Osi Model: GATE CSE 2025 | Set 1 | Question: 6

Identify the ONE CORRECT matching between the OSI layers and their corresponding functionalities as shown.

	OSI Layers		**Functionalities**
(a)	Network Layer	(I)	Packet Routing
(b)	Transport Layer	(II)	Framing and error handling
(c)	Datalink layer	(III)	Host to host communication

A. (a)-(I), (b)-(II), (c)-(III)
B. (a)-(I), (b)-(III), (c)-(II)
C. (a)-(II), (b)-(I), (c)-(III)
D. (a)-(III), (b)-(II), (c)-(I)

gatecse2025-set1 computer-networks osi-model easy one-mark

Answer key

4.23 Probability (1)

4.23.1 Probability: GATE CSE 2025 | Set 1 | Question: 46

Suppose a 5-bit message is transmitted from a source to a destination through a noisy channel. The probability that a bit of the message gets flipped during transmission is 0.01. Flipping of each bit is independent of one another. The probability that the message is delivered error-free to the destination is ____________ (rounded off to three decimal places)

gatecse2025-set1 computer-networks probability numerical-answers easy two-marks

Answer key

4.24 Routing (13)

4.24.1 Routing: GATE CSE 2005 | Question: 26

In a network of LANs connected by bridges, packets are sent from one LAN to another through intermediate bridges. Since more than one path may exist between two LANs, packets may have to be routed through multiple bridges. Why is the *spanning tree algorithm* used for bridge-routing?

A. For shortest path routing between LANs
B. For avoiding loops in the routing paths
C. For fault tolerance
D. For minimizing collisions

gatecse-2005 computer-networks routing normal

Answer key

4.24.2 Routing: GATE CSE 2014 Set 1 | Question: 23

Consider the following three statements about link state and distance vector routing protocols, for a large network with 500 network nodes and 4000 links.

[S1]: The computational overhead in link state protocols is higher than in distance vector protocols.

[S2]: A distance vector protocol (with split horizon) avoids persistent routing loops, but not a link state protocol.

[S3]: After a topology change, a link state protocol will converge faster than a distance vector protocol.

Which one of the following is correct about $S1$, $S2$, and $S3$?

A. $S1$, $S2$, and $S3$ are all true.
B. $S1$, $S2$, and $S3$ are all false.
C. $S1$ and $S2$ are true, but $S3$ is false.
D. $S1$ and $S3$ are true, but $S2$ is false.

gatecse-2014-set1 computer-networks routing normal

Answer key

4.24.3 Routing: GATE CSE 2014 Set 2 | Question: 23

Which of the following is TRUE about the interior gateway routing protocols – Routing Information Protocol (RIP) and Open Shortest Path First $(OSPF)$

A. RIP uses distance vector routing and OSPF uses link state routing
B. OSPF uses distance vector routing and RIP uses link state routing
C. Both RIP and OSPF use link state routing
D. Both RIP and OSPF use distance vector routing

gatecse-2014-set2 computer-networks routing normal

Answer key☟

4.24.4 Routing: GATE CSE 2014 Set 3 | Question: 26

An IP router implementing Classless Inter-domain Routing (CIDR) receives a packet with address $131.23.151.76$. The router's routing table has the following entries:

Prefix	**Outer Interface Identifier**
$131.16.0.0/12$	3
$131.28.0.0/14$	5
$131.19.0.0/16$	2
$131.22.0.0/15$	1

The identifier of the output interface on which this packet will be forwarded is ______.

gatecse-2014-set3 computer-networks routing normal numerical-answers

Answer key☟

4.24.5 Routing: GATE CSE 2017 Set 2 | Question: 09

Consider the following statements about the routing protocols. Routing Information Protocol (RIP) and Open Shortest Path First (OSPF) in an IPv4 network.

I. RIP uses distance vector routing
II. RIP packets are sent using UDP
III. OSPF packets are sent using TCP
IV. OSPF operation is based on link-state routing

Which of the above statements are CORRECT?

A. I and IV only
B. I, II and III only
C. I, II and IV only
D. II, III and IV only

gatecse-2017-set2 computer-networks routing

Answer key☟

4.24.6 Routing: GATE CSE 2020 | Question: 15

Consider the following statements about the functionality of an IP based router.

I. A router does not modify the IP packets during forwarding.
II. It is not necessary for a router to implement any routing protocol.
III. A router should reassemble IP fragments if the MTU of the outgoing link is larger than the size of the incoming IP packet.

Which of the above statements is/are TRUE?

A. I and II only
B. I only
C. II and III only
D. II only

gatecse-2020 computer-networks routing one-mark

Answer key

4.24.7 Routing: GATE CSE 2023 | Question: 15

Which of the following statements is/are INCORRECT about the OSPF (Open Shortest Path First) routing protocol used in the Internet?

A. OSPF implements Bellman-Ford algorithm to find shortest paths.
B. OSPF uses Dijkstra's shortest path algorithm to implement least-cost path routing.
C. OSPF is used as an inter-domain routing protocol.
D. OSPF implements hierarchical routing.

gatecse-2023 computer-networks routing multiple-selects one-mark

Answer key

4.24.8 Routing: GATE CSE 2024 | Set 1 | Question: 26

Consider a network path $\text{P} - \text{Q} - \text{R}$ between nodes P and R via router Q. Node P sends a file of size 10^6 bytes to R via this path by splitting the file into chunks of 10^3 bytes each. Node P sends these chunks one after the other without any wait time between the successive chunk transmissions. Assume that the size of extra headers added to these chunks is negligible, and that the chunk size is less than the MTU.

Each of the links $\text{P} - \text{Q}$ and $\text{Q} - \text{R}$ has a bandwidth of 10^6bits/sec, and negligible propagation latency. Router Q immediately transmits every packet it receives from P to R, with negligible processing and queueing delays. Router Q can simultaneously receive on $\text{link P} - \text{Q}$ and transmit on $\text{link Q} - \text{R}$.

Assume P starts transmitting the chunks at time $t = 0$.

Which one of the following options gives the time (*in seconds, rounded off to* 3 *decimal places*) at which R receives all the chunks of the file?

A. 8.000 B. 8.008 C. 15.992 D. 16.000

gatecse2024-set1 computer-networks routing two-marks

Answer key

4.24.9 Routing: GATE CSE 2024 | Set 1 | Question: 48

Consider the entries shown below in the forwarding table of an IP router. Each entry consists of an IP prefix and the corresponding next hop router for packets whose destination IP address matches the prefix. The notation " $/\text{N}$ " in a prefix indicates a subnet mask with the most significant N bits set to 1.

Prefix	**Next hop router**
10.1.1.0 / 24	R1
10.1.1.128 / 25	R2
10.1.1.64 / 26	R3
10.1.1.192 / 26	R4

This router forwards 20 packets each to 5 hosts. The IP addresses of the hosts are $10.1.1.16, 10.1.1.72, 10.1.1.132, 10.1.1.191,$ and $10.1.1.205$. The number of packets forwarded via the next hop router R2 is __________.

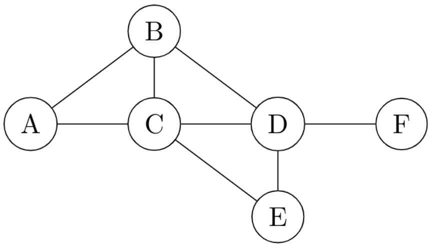
gatecse2024-set1 numerical-answers computer-networks routing two-marks

Answer key

4.24.10 Routing: GATE IT 2005 | Question: 85a

Consider a simple graph with unit edge costs. Each node in the graph represents a router. Each node maintains a routing table indicating the next hop router to be used to relay a packet to its destination and the cost of the path to the destination through that router. Initially, the routing table is empty. The routing table is synchronously updated as follows. In each updated interval, three tasks are performed.

i. A node determines whether its neighbours in the graph are accessible. If so, it sets the tentative cost to each accessible neighbour as 1. Otherwise, the cost is set to ∞.
ii. From each accessible neighbour, it gets the costs to relay to other nodes via that neighbour (as the next hop).
iii. Each node updates its routing table based on the information received in the previous two steps by choosing the minimum cost.



For the graph given above, possible routing tables for various nodes after they have stabilized, are shown in the following options. Identify the correct table.

A. Table for node A

A	-	-
B	B	1
C	C	1
D	B	3
E	C	3
F	C	4

B. Table for node C

A	A	1
B	B	1
C	-	-
D	D	1
E	E	1
F	E	3

C. Table for node B

A	A	1
B	-	-
C	C	1
D	D	1
E	C	2
F	D	2

D. Table for node D

A	B	3
B	B	1
C	C	1
D	-	-
E	E	1
F	F	1

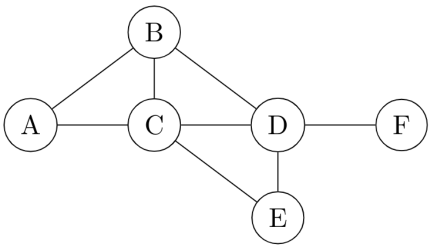
gateit-2005 computer-networks routing normal

Answer key☟

4.24.11 Routing: GATE IT 2005 | Question: 85b

Consider a simple graph with unit edge costs. Each node in the graph represents a router. Each node maintains a routing table indicating the next hop router to be used to relay a packet to its destination and the cost of the path to the destination through that router. Initially, the routing table is empty. The routing table is synchronously updated as follows. In each updated interval, three tasks are performed.

i. A node determines whether its neighbors in the graph are accessible. If so, it sets the tentative cost to each accessible neighbor as 1. Otherwise, the cost is set to ∞.
ii. From each accessible neighbor, it gets the costs to relay to other nodes via that neighbor (as the next hop).
iii. Each node updates its routing table based on the information received in the previous two steps by choosing the minimum cost.



Continuing from the earlier problem, suppose at some time t, when the costs have stabilized, node A goes down. The cost from node F to node A at time $(t+100)$ is :

A. >100 but finite
B. ∞
C. 3
D. >3 and ≤ 100

gateit-2005 computer-networks routing normal

Answer key☟

4.24.12 Routing: GATE IT 2007 | Question: 63

A group of 15 routers is interconnected in a centralized complete binary tree with a router at each tree node.

Router i communicates with router j by sending a message to the root of the tree. The root then sends the message back down to router j. The mean number of hops per message, assuming all possible router pairs are equally likely is

A. 3 B. 4.26 C. 4.53 D. 5.26

gateit-2007 computer-networks routing binary-tree normal

Answer key☟

4.24.13 Routing: GATE IT 2008 | Question: 67

Two popular routing algorithms are Distance Vector(DV) and Link State (LS) routing. Which of the following are true?

(S1): Count to infinity is a problem only with DV and not LS routing
(S2): In LS, the shortest path algorithm is run only at one node
(S3): In DV, the shortest path algorithm is run only at one node
(S4): DV requires lesser number of network messages than LS

A. S1, S2 and S4 only B. S1, S3 and S4 only C. S2 and S3 only D. S1 and S4 only

gateit-2008 computer-networks routing normal

Answer key☟

4.25 Routing Protocols (1)

4.25.1 Routing Protocols: GATE CSE 2025 | Set 2 | Question: 7

Consider the routing protocols given in **List I** and the names given in **List II**:

	List I		List II
(i)	Distance Vector routing	(a)	Bellman-Ford
(ii)	Link state routing	(b)	Dijkstra

For matching of items in **List I** with those in **List II**, which ONE of the following options is CORRECT?

A. (i) - (a) and (ii) - (b)
B. (i) - (a) and (ii) - (a)
C. (i) - (b) and (ii) - (a)
D. (i) - (b) and (ii) - (b)

gatecse2025-set2 computer-networks match-the-following routing-protocols easy one-mark

Answer key☟

4.26 Sliding Window (15)

4.26.1 Sliding Window: GATE CSE 2003 | Question: 84

Host A is sending data to host B over a full duplex link. A and B are using the sliding window protocol for flow control. The send and receive window sizes are 5 packets each. Data packets (sent only from A to B) are all 1000 bytes long and the transmission time for such a packet is 50 μs. Acknowledgment packets (sent only from B to A) are very small and require negligible transmission time. The propagation delay over the link is 200 μs. What is the maximum achievable throughput in this communication?

A. 7.69×10^6 Bps
B. 11.11×10^6 Bps
C. 12.33×10^6 Bps
D. 15.00×10^6 Bps

gatecse-2003 computer-networks sliding-window normal

Answer key☟

4.26.2 Sliding Window: GATE CSE 2005 | Question: 25

The maximum window size for data transmission using the selective reject protocol with $n\text{-bit}$ frame sequence numbers is:

A. 2^n B. 2^{n-1} C. $2^n - 1$ D. 2^{n-2}

gatecse-2005 computer-networks sliding-window easy

Answer key

4.26.3 Sliding Window: GATE CSE 2006 | Question: 44

Station A uses 32 byte packets to transmit messages to Station B using a sliding window protocol. The round trip delay between A and B is 80 milliseconds and the bottleneck bandwidth on the path between A and B is 128 kbps . What is the optimal window size that A should use?

A. 20 B. 40 C. 160 D. 320

gatecse-2006 computer-networks sliding-window normal

Answer key

4.26.4 Sliding Window: GATE CSE 2006 | Question: 46

Station A needs to send a message consisting of 9 packets to Station B using a sliding window (window size 3) and go-back-n error control strategy. All packets are ready and immediately available for transmission. If every 5th packet that A transmits gets lost (but no acks from B ever get lost), then what is the number of packets that A will transmit for sending the message to B?

A. 12 B. 14 C. 16 D. 18

gatecse-2006 computer-networks sliding-window normal

Answer key

4.26.5 Sliding Window: GATE CSE 2007 | Question: 69

The distance between two stations M and N is L kilometers. All frames are K bits long. The propagation delay per kilometer is t seconds. Let R bits/second be the channel capacity. Assuming that the processing delay is negligible, the minimum number of bits for the sequence number field in a frame for maximum utilization, when the $\text{sliding window protocol}$ is used, is:

A. $\lceil \log_2 \frac{2LtR+2K}{K} \rceil$ B. $\lceil \log_2 \frac{2LtR}{K} \rceil$

C. $\lceil \log_2 \frac{2LtR+K}{K} \rceil$ D. $\lceil \log_2 \frac{2LtR+2K}{2K} \rceil$

gatecse-2007 computer-networks sliding-window normal

Answer key

4.26.6 Sliding Window: GATE CSE 2009 | Question: 57, ISRO2016-75

Frames of 1000 bits are sent over a 10^6 bps duplex link between two hosts. The propagation time is 25 ms. Frames are to be transmitted into this link to maximally pack them in transit (within the link).

What is the minimum number of bits (I) that will be required to represent the sequence numbers distinctly? Assume that no time gap needs to be given between transmission of two frames.

A. $I = 2$ B. $I = 3$ C. $I = 4$ D. $I = 5$

gatecse-2009 computer-networks sliding-window normal isro2016

Answer key

4.26.7 Sliding Window: GATE CSE 2009 | Question: 58

Frames of 1000 bits are sent over a 10^6 bps duplex link between two hosts. The propagation time is $25ms$. Frames are to be transmitted into this link to maximally pack them in transit (within the link).

Let I be the minimum number of bits (I) that will be required to represent the sequence numbers distinctly assuming that no time gap needs to be given between transmission of two frames.

Suppose that the sliding window protocol is used with the sender window size of 2^I, where I is the numbers of bits as mentioned earlier and acknowledgements are always piggy backed. After sending 2^I frames, what is the minimum time the sender will have to wait before starting transmission of the next frame? (Identify the closest choice ignoring the frame processing time)

A. $16ms$ B. $18ms$ C. $20ms$ D. $22ms$

gatecse-2009 computer-networks sliding-window normal

Answer key

4.26.8 Sliding Window: GATE CSE 2014 Set 1 | Question: 28

Consider a selective repeat sliding window protocol that uses a frame size of 1 KB to send data on a 1.5 Mbps link with a one-way latency of 50 msec. To achieve a link utilization of 60%, the minimum number of bits required to represent the sequence number field is ________.

gatecse-2014-set1 computer-networks sliding-window numerical-answers normal

Answer key

4.26.9 Sliding Window: GATE CSE 2015 Set 3 | Question: 28

Consider a network connecting two systems located 8000 Km apart. The bandwidth of the network is $500 \times 10^6 \text{ bits}$ per second. The propagation speed of the media is $4 \times 10^6 \text{ meters}$ per second. It needs to design a Go-Back-N sliding window protocol for this network. The average packet size is 10^7 bits. The network is to be used to its full capacity. Assume that processing delays at nodes are negligible. Then, the minimum size in bits of the sequence number field has to be ______.

gatecse-2015-set3 computer-networks sliding-window normal numerical-answers

Answer key

4.26.10 Sliding Window: GATE CSE 2016 Set 2 | Question: 55

Consider a 128×10^3 bits/second satellite communication link with one way propagation delay of 150 milliseconds. Selective retransmission (repeat) protocol is used on this link to send data with a frame size of 1 kilobyte. Neglect the transmission time of acknowledgement. The minimum number of bits required for the sequence number field to achieve 100% utilization is ________.

gatecse-2016-set2 computer-networks sliding-window normal numerical-answers

Answer key

4.26.11 Sliding Window: GATE IT 2004 | Question: 81

In a sliding window ARQ scheme, the transmitter's window size is N and the receiver's window size is M. The minimum number of distinct sequence numbers required to ensure correct operation of the ARQ scheme is

A. $\min(M, N)$ B. $\max(M, N)$ C. $M + N$ D. MN

gateit-2004 computer-networks sliding-window normal

Answer key

4.26.12 Sliding Window: GATE IT 2004 | Question: 83

A 20 Kbps satellite link has a propagation delay of 400 ms. The transmitter employs the "go back n ARQ" scheme with n set to 10. Assuming that each frame is 100 byte long, what is the maximum data rate possible?

A. 5 Kbps B. 10 Kbps
C. 15 Kbps D. 20 Kbps

gateit-2004 computer-networks sliding-window normal

Answer key

4.26.13 Sliding Window: GATE IT 2004 | Question: 88

Suppose that the maximum transmit window size for a TCP connection is 12000 bytes. Each packet consists of 2000 bytes. At some point in time, the connection is in slow-start phase with a current transmit window of 4000 bytes. Subsequently, the transmitter receives two acknowledgments. Assume that no packets are lost and there are no time-outs. What is the maximum possible value of the current transmit window?

A. 4000 bytes
B. 8000 bytes
C. 10000 bytes
D. 12000 bytes

gateit-2004 computer-networks sliding-window normal

Answer key☟

4.26.14 Sliding Window: GATE IT 2006 | Question: 64

Suppose that it takes 1 unit of time to transmit a packet (of fixed size) on a communication link. The link layer uses a window flow control protocol with a window size of N packets. Each packet causes an ack or a nak to be generated by the receiver, and ack/nak transmission times are negligible. Further, the round trip time on the link is equal to N units. Consider time $i > N$. If only acks have been received till time i(no naks), then the goodput evaluated at the transmitter at time i(in packets per unit time) is

A. $1 - \frac{N}{i}$
B. $\frac{i}{(N+i)}$
C. 1
D. $1 - e^{\left(\frac{i}{N}\right)}$

gateit-2006 computer-networks sliding-window normal

Answer key☟

4.26.15 Sliding Window: GATE IT 2008 | Question: 64

A 1 Mbps satellite link connects two ground stations. The altitude of the satellite is $36,504$ km and speed of the signal is 3×10^8 m/s. What should be the packet size for a channel utilization of 25% for a satellite link using go-back-127 sliding window protocol? Assume that the acknowledgment packets are negligible in size and that there are no errors during communication.

A. 120 bytes
B. 60 bytes
C. 240 bytes
D. 90 bytes

gateit-2008 computer-networks sliding-window normal

Answer key☟

4.27 Sockets (4)

4.27.1 Sockets: GATE CSE 2008 | Question: 17

Which of the following system calls results in the sending of SYN packets?

A. socket
B. bind
C. listen
D. connect

gatecse-2008 normal computer-networks sockets

Answer key☟

4.27.2 Sockets: GATE CSE 2008 | Question: 59

A client process P needs to make a TCP connection to a server process S. Consider the following situation: the server process S executes a $\text{socket}()$, a $\text{bind}()$ and a $\text{listen}()$ system call in that order, following which it is preempted. Subsequently, the client process P executes a $\text{socket}()$ system call followed by $\text{connect}()$ system call to connect to the server process S. The server process has not executed any $\text{accept}()$ system call. Which one of the following events could take place?

A. $\text{connect}()$ system call returns successfully
B. $\text{connect}()$ system call blocks
C. $\text{connect}()$ system call returns an error
D. $\text{connect}()$ system call results in a core dump

gatecse-2008 computer-networks sockets normal

Answer key

4.27.3 Sockets: GATE CSE 2014 Set 2 | Question: 24

Which of the following socket API functions converts an unconnected active TCP socket into a passive socket?

A. connect B. bind C. listen D. accept

gatecse-2014-set2 computer-networks sockets easy

Answer key

4.27.4 Sockets: GATE CSE 2015 Set 2 | Question: 20

Identify the correct order in which a server process must invoke the function calls accept, bind, listen, and recv according to UNIX socket API.

A. listen, accept, bind, recv
B. bind, listen, accept, recv
C. bind, accept, listen, recv
D. accept, listen, bind, recv

gatecse-2015-set2 computer-networks sockets easy

Answer key

4.28 Stop and Wait (6)

4.28.1 Stop and Wait: GATE CSE 2015 Set 1 | Question: 53

Suppose that the stop-and-wait protocol is used on a link with a bit rate of 64 kilobits per second and 20 milliseconds propagation delay. Assume that the transmission time for the acknowledgment and the processing time at nodes are negligible. Then the minimum frame size in bytes to achieve a link utilization of at least $50\ \%$ is_________________.

gatecse-2015-set1 computer-networks stop-and-wait normal numerical-answers

Answer key

4.28.2 Stop and Wait: GATE CSE 2016 Set 1 | Question: 55

A sender uses the Stop-and-Wait ARQ protocol for reliable transmission of frames. Frames are of size 1000 bytes and the transmission rate at the sender is 80 Kbps$(1\text{Kbps} = 1000 \text{ bits/second})$. Size of an acknowledgment is 100 bytes and the transmission rate at the receiver is 8 Kbps. The one-way propagation delay is 100 milliseconds.

Assuming no frame is lost, the sender throughput is ________ bytes/ second.

gatecse-2016-set1 computer-networks stop-and-wait normal numerical-answers

Answer key

4.28.3 Stop and Wait: GATE CSE 2017 Set 1 | Question: 45

The values of parameters for the Stop-and-Wait ARQ protocol are as given below:

- Bit rate of the transmission channel $= 1$ Mbps.
- Propagation delay from sender to receiver $= 0.75$ ms.
- Time to process a frame $= 0.25$ ms.
- Number of bytes in the information frame $= 1980$.
- Number of bytes in the acknowledge frame $= 20$.
- Number of overhead bytes in the information frame $= 20$.

Assume there are no transmission errors. Then, the transmission efficiency (expressed in percentage) of the Stop-and-Wait ARQ protocol for the above parameters is _____________ (correct to 2 decimal places).

gatecse-2017-set1 computer-networks stop-and-wait numerical-answers normal

Answer key

4.28.4 Stop and Wait: GATE CSE 2023 | Question: 7

Suppose two hosts are connected by a point-to-point link and they are configured to use Stop-and-Wait protocol for reliable data transfer. Identify in which one of the following scenarios, the utilization of the link is the lowest.

A. Longer link length and lower transmission rate
B. Longer link length and higher transmission rate
C. Shorter link length and lower transmission rate
D. Shorter link length and higher transmission rate

gatecse-2023 computer-networks stop-and-wait one-mark

Answer key☟

4.28.5 Stop and Wait: GATE IT 2005 | Question: 72

A channel has a bit rate of $4\ kbps$ and one-way propagation delay of $20\ ms$. The channel uses stop and wait protocol. The transmission time of the acknowledgment frame is negligible. To get a channel efficiency of at least 50%, the minimum frame size should be

A. 80 bytes B. 80 bits C. 160 bytes D. 160 bits

gateit-2005 computer-networks stop-and-wait normal

Answer key☟

4.28.6 Stop and Wait: GATE IT 2006 | Question: 68

On a wireless link, the probability of packet error is 0.2. A stop-and-wait protocol is used to transfer data across the link. The channel condition is assumed to be independent of transmission to transmission. What is the average number of transmission attempts required to transfer 100 packets?

A. 100 B. 125 C. 150 D. 200

gateit-2006 computer-networks sliding-window stop-and-wait normal

Answer key☟

4.29 Subnetting (21)

4.29.1 Subnetting: GATE CSE 2003 | Question: 82, ISRO2009-1

The subnet mask for a particular network is $255.255.31.0.$ Which of the following pairs of IP addresses could belong to this network?

A. $172.57.88.62$ and $172.56.87.23$
B. $10.35.28.2$ and $10.35.29.4$
C. $191.203.31.87$ and $191.234.31.88$
D. $128.8.129.43$ and $128.8.161.55$

gatecse-2003 computer-networks subnetting normal isro2009

Answer key☟

4.29.2 Subnetting: GATE CSE 2004 | Question: 55

The routing table of a router is shown below:

Destination	Subnet Mask	Interface
128.75.43.0	255.255.255.0	Eth0
128.75.43.0	255.255.255.128	Eth1
192.12.17.5	255.255.255.255	Eth3
Default		Eth2

On which interface will the router forward packets addressed to destinations $128.75.43.16$ and $192.12.17.10$ respectively?

A. Eth1 and Eth2 B. Eth0 and Eth2 C. Eth0 and Eth3 D. Eth1 and Eth3

gatecse-2004 computer-networks subnetting normal

Answer key

4.29.3 Subnetting: GATE CSE 2005 | Question: 27

An organization has a class B network and wishes to form subnets for 64 departments. The subnet mask would be:

A. $255.255.0.0$ B. $255.255.64.0$ C. $255.255.128.0$ D. $255.255.252.0$

gatecse-2005 computer-networks subnetting normal

Answer key

4.29.4 Subnetting: GATE CSE 2006 | Question: 45

Two computers $C1$ and $C2$ are configured as follows. $C1$ has IP address $203.197.2.53$ and netmask $255.255.128.0$. $C2$ has IP address $203.197.75.201$ and netmask $255.255.192.0$. Which one of the following statements is true?

A. $C1$ and $C2$ both assume they are on the same network
B. $C2$ assumes $C1$ is on same network, but $C1$ assumes $C2$ is on a different network
C. $C1$ assumes $C2$ is on same network, but $C2$ assumes $C1$ is on a different network
D. $C1$ and $C2$ both assume they are on different networks.

gatecse-2006 computer-networks subnetting normal

Answer key

4.29.5 Subnetting: GATE CSE 2007 | Question: 67, ISRO2016-72

The address of a class B host is to be split into subnets with a 6-bit subnet number. What is the maximum number of subnets and the maximum number of hosts in each subnet?

A. 62 subnets and 262142 hosts.
B. 64 subnets and 262142 hosts.
C. 62 subnets and 1022 hosts.
D. 64 subnets and 1024 hosts.

gatecse-2007 computer-networks subnetting easy isro2016

Answer key

4.29.6 Subnetting: GATE CSE 2008 | Question: 57

If a class B network on the Internet has a subnet mask of $255.255.248.0$, what is the maximum number of hosts per subnet?

A. 1022 B. 1023 C. 2046 D. 2047

gatecse-2008 computer-networks subnetting easy

Answer key

4.29.7 Subnetting: GATE CSE 2010 | Question: 47

Suppose computers A and B have IP addresses $10.105.1.113$ and $10.105.1.91$ respectively and they both use same netmask N. Which of the values of N given below should not be used if A and B should belong to the same network?

A. $255.255.255.0$
B. $255.255.255.128$
C. $255.255.255.192$
D. $255.255.255.224$

gatecse-2010 computer-networks subnetting easy

Answer key

4.29.8 Subnetting: GATE CSE 2012 | Question: 34, ISRO-DEC2017-32

An Internet Service Provider (ISP) has the following chunk of CIDR-based IP addresses available with it: $245.248.128.0/20$. The ISP wants to give half of this chunk of addresses to Organization A, and a quarter to Organization B, while retaining the remaining with itself. Which of the following is a valid allocation of addresses to A and B?

A. $245.248.136.0/21$ and $245.248.128.0/22$
B. $245.248.128.0/21$ and $245.248.128.0/22$
C. $245.248.132.0/22$ and $245.248.132.0/21$
D. $245.248.136.0/24$ and $245.248.132.0/21$

gatecse-2012 computer-networks subnetting normal isrodec2017

Answer key

4.29.9 Subnetting: GATE CSE 2015 Set 2 | Question: 41

Consider the following routing table at an IP router:

Network No	Net Mask	Next Hop
128.96.170.0	255.255.254.0	Interface 0
128.96.168.0	255.255.254.0	Interface 1
128.96.166.0	255.255.254.0	R2
128.96.164.0	255.255.252.0	R3
0.0.0.0	Default	R4

For each IP address in Group I Identify the correct choice of the next hop from Group II using the entries from the routing table above.

Group I	Group II
i) 128.96.171.92	a) Interface 0
ii) 128.96.167.151	b) Interface 1
iii) 128.96.163.151	c) R2
iv) 128.96.164.121	d) R3
	e) R4

A. i-a, ii-c, iii-e, iv-d
B. i-a, ii-d, iii-b, iv-e
C. i-b, ii-c, iii-d, iv-e
D. i-b, ii-c, iii-e, iv-d

gatecse-2015-set2 computer-networks subnetting easy

Answer key

4.29.10 Subnetting: GATE CSE 2015 Set 3 | Question: 38

In the network $200.10.11.144/27$, the fourth octet (in decimal) of the last IP address of the network which can be assigned to a host is _______.

gatecse-2015-set3 computer-networks subnetting normal numerical-answers

Answer key

4.29.11 Subnetting: GATE CSE 2019 | Question: 28

Consider three machines M, N, and P with IP addresses $100.10.5.2$, $100.10.5.5$, and $100.10.5.6$ respectively. The subnet mask is set to $255.255.255.252$ for all the three machines. Which one of the following is true?

A. M, N, and P all belong to the same subnet
B. Only M and N belong to the same subnet

C. Only N and P belong to the same subnet

D. M, N, and P belong to three different subnets

gatecse-2019 computer-networks subnetting two-marks

Answer key

4.29.12 Subnetting: GATE CSE 2020 | Question: 38

An organization requires a range of IP address to assign one to each of its 1500 computers. The organization has approached an Internet Service Provider (ISP) for this task. The ISP uses CIDR and serves the requests from the available IP address space $202.61.0.0/17$. The ISP wants to assign an address space to the organization which will minimize the number of routing entries in the ISP's router using route aggregation. Which of the following address spaces are potential candidates from which the ISP can allot any one of the organization?

I. $202.61.84.0/21$
II. $202.61.104.0/21$
III. $202.61.64.0/21$
IV. $202.61.144.0/21$

A. I and II only
B. II and III only
C. III and IV only
D. I and IV only

gatecse-2020 computer-networks subnetting two-marks

Answer key

4.29.13 Subnetting: GATE CSE 2022 | Question: 45

Consider routing table of an organization's router shown below:

Subnet Number	Subnet Mask	Next Hop
12.20.164.0	255.255.252.0	R1
12.20.170.0	255.255.254.0	R2
12.20.168.0	255.255.254.0	Interface 0
12.20.166.0	255.255.254.0	Interface 1
default		R3

Which of the following prefixes in CIDR notation can be collectively used to correctly aggregate all of the subnets in the routing table?

A. $12.20.164.0/20$
B. $12.20.164.0/22$
C. $12.20.164.0/21$
D. $12.20.168.0/22$

gatecse-2022 computer-networks subnetting multiple-selects two-marks

Answer key

4.29.14 Subnetting: GATE CSE 2023 | Question: 55

The forwarding table of a router is shown below.

Subnet Number	**Subnet Mask**	**Interface ID**
200.150.0.0	255.255.0.0	1
200.150.64.0	255.255.224.0	2
200.150.68.0	255.255.255.0	3
200.150.68.64	255.255.255.224	4
Default		0

A packet addressed to a destination address $200.150.68.118$ arrives at the router. It will be forwarded to the interface with ID __________.

gatecse-2023 computer-networks subnetting numerical-answers two-marks

Answer key

4.29.15 Subnetting: GATE CSE 2025 | Set 1 | Question: 30

A packet with the destination IP address $145.36.109.70$ arrives at a router whose routing table is shown. Which interface will the packet be forwarded to?

Subnet Address	Subnet Mask (in CIDR notation)	Interface
$145.36.0.0$	$/16$	$E1$
$145.36.128.0$	$/17$	$E2$
$145.36.64.0$	$/18$	$E3$
$145.36.255.0$	$/24$	$E4$
Default	$-$	$E5$

A. E3
B. E1
C. E2
D. E5

gatecse2025-set1 computer-networks subnetting two-marks

Answer key

4.29.16 Subnetting: GATE IT 2004 | Question: 26

A subnet has been assigned a subnet mask of $255.255.255.192$. What is the maximum number of hosts that can belong to this subnet?

A. 14
B. 30
C. 62
D. 126

gateit-2004 computer-networks subnetting normal

Answer key

4.29.17 Subnetting: GATE IT 2005 | Question: 76

A company has a class C network address of $204.204.204.0$. It wishes to have three subnets, one with 100 hosts and two with 50 hosts each. Which one of the following options represents a feasible set of subnet address/subnet mask pairs?

A. $204.204.204.128/255.255.255.192$
$204.204.204.0/255.255.255.128$
$204.204.204.64/255.255.255.128$

B. $204.204.204.0/255.255.255.192$
$204.204.204.192/255.255.255.128$
$204.204.204.64/255.255.255.128$

C. $204.204.204.128/255.255.255.128$
$204.204.204.192/255.255.255.192$
$204.204.204.224/255.255.255.192$

D. $204.204.204.128/255.255.255.128$
$204.204.204.64/255.255.255.192$
$204.204.204.0/255.255.255.192$

gateit-2005 computer-networks subnetting normal

Answer key

4.29.18 Subnetting: GATE IT 2006 | Question: 63, ISRO2015-57

A router uses the following routing table:

Destination	Mask	Interface
144.16.0.0	255.255.0.0	eth0
144.16.64.0	255.255.224.0	eth1
144.16.68.0	255.255.255.0	eth2
144.16.68.64	255.255.255.224	eth3

Packet bearing a destination address $144.16.68.117$ arrives at the router. On which interface will it be forwarded?

A. eth0 B. eth1 C. eth2 D. eth3

gateit-2006 computer-networks subnetting normal isro2015

Answer key

4.29.19 Subnetting: GATE IT 2006 | Question: 70

A subnetted Class B network has the following broadcast address: $144.16.95.255$

Its subnet mask

A. is necessarily $255.255.224.0$
B. is necessarily $255.255.240.0$
C. is necessarily $255.255.248.0$
D. could be any one of $255.255.224.0$, $255.255.240.0$,$255.255.248.0$

gateit-2006 computer-networks subnetting normal

Answer key

4.29.20 Subnetting: GATE IT 2008 | Question: 84

Host X has IP address $192.168.1.97$ and is connected through two routers $R1$ and $R2$ to another host Y with IP address $192.168.1.80$. Router $R1$ has IP addresses $192.168.1.135$ and $192.168.1.110$. $R2$ has IP addresses $192.168.1.67$ and $192.168.1.155$. The netmask used in the network is $255.255.255.224$.

Given the information above, how many distinct subnets are guaranteed to already exist in the network?

A. 1 B. 2 C. 3 D. 6

gateit-2008 computer-networks subnetting normal

Answer key

4.29.21 Subnetting: GATE IT 2008 | Question: 85

Host X has IP address $192.168.1.97$ and is connected through two routers $R1$ and $R2$ to another host Y with IP address $192.168.1.80$. Router $R1$ has IP addresses $192.168.1.135$ and $192.168.1.110$. $R2$ has IP addresses $192.168.1.67$ and $192.168.1.155$. The netmask used in the network is $255.255.255.224$.

Which IP address should X configure its gateway as?

A. $192.168.1.67$ B. $192.168.1.110$
C. $192.168.1.135$ D. $192.168.1.155$

gateit-2008 computer-networks subnetting normal

Answer key

4.30 TCP (22)

4.30.1 TCP: GATE CSE 2009 | Question: 47

While opening a TCP connection, the initial sequence number is to be derived using a time-of-day (ToD) clock that keeps running even when the host is down. The low order 32 bits of the counter of the ToD clock is to be used for the initial sequence numbers. The clock counter increments once per milliseconds. The maximum packet lifetime is given to be 64s.

Which one of the choices given below is closest to the minimum permissible rate at which sequence numbers used for packets of a connection can increase?

A. 0.015/s
B. 0.064/s
C. 0.135/s
D. 0.327/s

gatecse-2009 computer-networks tcp difficult ambiguous

Answer key

4.30.2 TCP: GATE CSE 2012 | Question: 22

Which of the following transport layer protocols is used to support electronic mail?

A. SMTP
B. IP
C. TCP
D. UDP

gatecse-2012 computer-networks tcp easy

Answer key

4.30.3 TCP: GATE CSE 2015 Set 1 | Question: 19

Suppose two hosts use a TCP connection to transfer a large file. Which of the following statements is/are FALSE with respect to the TCP connection?

I. If the sequence number of a segment is m, then the sequence number of the subsequent segment is always $m+1$.
II. If the estimated round trip time at any given point of time is t sec, the value of the retransmission timeout is always set to greater than or equal to t sec.
III. The size of the advertised window never changes during the course of the TCP connection.
IV. The number of unacknowledged bytes at the sender is always less than or equal to the advertised window.

A. III only
B. I and III only
C. I and IV only
D. II and IV only

gatecse-2015-set1 computer-networks tcp normal

Answer key

4.30.4 TCP: GATE CSE 2015 Set 2 | Question: 34

Assume that the bandwidth for a TCP connection is 1048560 bits/sec. Let α be the value of RTT in milliseconds (rounded off to the nearest integer) after which the TCP window scale option is needed. Let β be the maximum possible window size with window scale option. Then the values of α and β are

A. 63 milliseconds, 65535×2^{14}
B. 63 milliseconds, 65535×2^{16}
C. 500 milliseconds, 65535×2^{14}
D. 500 milliseconds, 65535×2^{16}

gatecse-2015-set2 computer-networks difficult tcp

Answer key

4.30.5 TCP: GATE CSE 2015 Set 3 | Question: 22

Consider the following statements.

I. TCP connections are full duplex
II. TCP has no option for selective acknowledgement
III. TCP connections are message streams

A. Only I is correct
B. Only I and III are correct
C. Only II and III are correct
D. All of I, II and III are correct

gatecse-2015-set3 computer-networks tcp normal

Answer key

4.30.6 TCP: GATE CSE 2016 Set 2 | Question: 25

Identify the correct sequence in which the following packets are transmitted on the network by a host when a browser requests a webpage from a remote server, assuming that the host has just been restarted.

A. HTTP GET request, DNS query, TCP SYN
B. DNS query, HTTP GET request, TCP SYN
C. DNS query, TCP SYN, HTTP GET
D. TCP SYN, DNS query, HTTP GET

request. request.

gatecse-2016-set2 computer-networks normal tcp

Answer key

4.30.7 TCP: GATE CSE 2017 Set 1 | Question: 14

Consider a TCP client and a TCP server running on two different machines. After completing data transfer, the TCP client calls close to terminate the connection and a FIN segment is sent to the TCP server. Server-side TCP responds by sending an ACK, which is received by the client-side TCP. As per the TCP connection state diagram $(\text{RFC } 793)$, in which state does the client-side TCP connection wait for the FIN from the server-side TCP?

A. LAST-ACK B. TIME-WAIT C. FIN-WAIT-1 D. FIN-WAIT-2

gatecse-2017-set1 computer-networks tcp

Answer key

4.30.8 TCP: GATE CSE 2018 | Question: 25

Consider a long-lived TCP session with an end-to-end bandwidth of $1 \text{ Gbps } (= 10^9$ bits-per-second$)$. The session starts with a sequence number of 1234. The minimum time (in seconds, rounded to the closet integer) before this sequence number can be used again is _________.

gatecse-2018 computer-networks tcp normal numerical-answers one-mark

Answer key

4.30.9 TCP: GATE CSE 2020 | Question: 55

Consider a TCP connection between a client and a server with the following specifications; the round trip time is 6 ms, the size of the receiver advertised window is 50 KB, slow-start threshold at the client is 32 KB, and the maximum segment size is 2 KB. The connection is established at time $t = 0$. Assume that there are no timeouts and errors during transmission. Then the size of the congestion window (in KB) at time $t + 60$ ms after all acknowledgements are processed is _______

gatecse-2020 numerical-answers computer-networks tcp two-marks

Answer key

4.30.10 TCP: GATE CSE 2021 Set 1 | Question: 44

A TCP server application is programmed to listen on port number P on host S. A TCP client is connected to the TCP server over the network.

Consider that while the TCP connection was active, the server machine S crashed and rebooted. Assume that the client does not use the TCP keepalive timer. Which of the following behaviors is/are possible?

A. If the client was waiting to receive a packet, it may wait indefinitely
B. The TCP server application on S can listen on P after reboot
C. If the client sends a packet after the server reboot, it will receive a RST segment
D. If the client sends a packet after the server reboot, it will receive a FIN segment

gatecse-2021-set1 multiple-selects computer-networks tcp two-marks

Answer key

4.30.11 TCP: GATE CSE 2021 Set 1 | Question: 45

Consider two hosts P and Q connected through a router R. The maximum transfer unit (MTU) value of the link between P and R is 1500 bytes, and between R and Q is 820 bytes.

A TCP segment of size 1400 bytes was transferred from P to Q through R, with IP identification value as **0x1234**. Assume that the IP header size is 20 bytes. Further, the packet is allowed to be fragmented, i.e., **Don't Fragment (DF)** flag in the IP header is not set by P.

Which of the following statements is/are correct?

A. Two fragments are created at R and the IP datagram size carrying the second fragment is 620 bytes.
B. If the second fragment is lost, R will resend the fragment with the IP identification value 0x1234.
C. If the second fragment is lost, P is required to resend the whole TCP segment.
D. TCP destination port can be determined by analysing $only$ the second fragment.

gatecse-2021-set1 computer-networks tcp two-marks multiple-selects

Answer key

4.30.12 TCP: GATE CSE 2021 Set 2 | Question: 7

Consider the three-way handshake mechanism followed during TCP connection establishment between hosts P and Q. Let X and Y be two random 32-bit starting sequence numbers chosen by P and Q respectively. Suppose P sends a TCP connection request message to Q with a TCP segment having SYN bit $=1$, SEQ number $=X$, and ACK bit $=0$. Suppose Q accepts the connection request. Which one of the following choices represents the information present in the TCP segment header that is sent by Q to P?

A. SYN bit $=1$, SEQ number $=X+1$, ACK bit $=0$, ACK number $=Y$, FIN bit $=0$
B. SYN bit $=0$, SEQ number $=X+1$, ACK bit $=0$, ACK number $=Y$, FIN bit $=1$
C. SYN bit $=1$, SEQ number $=Y$, ACK bit $=1$, ACK number $=X+1$, FIN bit $=0$
D. SYN bit $=1$, SEQ number $=Y$, ACK bit $=1$, ACK number $=X$, FIN bit $=0$

gatecse-2021-set2 computer-networks tcp one-mark

Answer key

4.30.13 TCP: GATE CSE 2022 | Question: 50

Consider the data transfer using TCP over a 1 Gbps link. Assuming that the maximum segment lifetime (MSL) is set to 60 $\mathrm{seconds,}$ the minimum number of bits required for the sequence number field of the TCP header, to prevent the sequence number space from wrapping around during the MSL is ________________.

gatecse-2022 numerical-answers computer-networks tcp two-marks

Answer key

4.30.14 TCP: GATE CSE 2023 | Question: 40

Suppose you are asked to design a new reliable byte-stream transport protocol like TCP. This protocol, named myTCP, runs over a 100 Mbps network with Round Trip Time of 150 milliseconds and the maximum segment lifetime of 2 minutes.

Which of the following is/are valid lengths of the **Sequence Number** field in the myTCP header?

A. 30 bits B. 32 bits C. 34 bits D. 36 bits

gatecse-2023 computer-networks tcp multiple-selects two-marks

Answer key

4.30.15 TCP: GATE CSE 2024 | Set 1 | Question: 19

TCP client P successfully establishes a connection to TCP server Q. Let N_P denote the sequence number in the SYN sent from P to Q. Let N_Q denote the acknowledgement number in the SYN ACK from Q to P. Which of the following statements is/are CORRECT?

A. The sequence number N_P is chosen randomly by P
B. The sequence number N_P is always 0 for a new connection
C. The acknowledgement number N_Q is equal to N_P
D. The acknowledgement number N_Q is equal to N_P+1

gatecse2024-set1 multiple-selects computer-networks tcp one-mark

Answer key

4.30.16 TCP: GATE CSE 2024 | Set 2 | Question: 44

Consider a TCP connection operating at a point of time with the congestion window of size $12\ \text{MSS}$ (Maximum Segment Size), when a timeout occurs due to packet loss. Assuming that all the segments transmitted in the next two RTTs (Round Trip Time) are acknowledged correctly, the congestion window size (*in* MSS) during the third RTT will be __________.

gatecse2024-set2 numerical-answers computer-networks tcp two-marks

Answer key

4.30.17 TCP: GATE CSE 2025 | Set 1 | Question: 12

Consider the 3-way handshaking protocol for TCP connection establishment. Let the three packets exchanged during the connection establishment be denoted as $\text{P1}, \text{P2}$, and P3, in order. Which of the following option(s) is/are TRUE with respect to TCP header flags that are set in the packets?

A. $\text{P3} : \text{SYN} = 1, \text{ACK} = 1$
B. $\text{P2} : \text{SYN} = 1, \text{ACK} = 1$
C. P2: $\text{SYN} = 0, \text{ACK} = 1$
D. P1: $\text{SYN} = 1$

gatecse2025-set1 computer-networks tcp multiple-selects one-mark

Answer key

4.30.18 TCP: GATE IT 2004 | Question: 23

Which one of the following statements is FALSE?

A. TCP guarantees a minimum communication rate
B. TCP ensures in-order delivery
C. TCP reacts to congestion by reducing sender window size
D. TCP employs retransmission to compensate for packet loss

gateit-2004 computer-networks tcp normal

Answer key

4.30.19 TCP: GATE IT 2004 | Question: 28

In TCP, a unique sequence number is assigned to each

A. byte
B. word
C. segment
D. message

gateit-2004 computer-networks tcp normal

Answer key

4.30.20 TCP: GATE IT 2007 | Question: 13

Consider the following statements about the timeout value used in TCP.

i. The timeout value is set to the RTT (Round Trip Time) measured during TCP connection establishment for the entire duration of the connection.
ii. Appropriate RTT estimation algorithm is used to set the timeout value of a TCP connection.
iii. Timeout value is set to twice the propagation delay from the sender to the receiver.

Which of the following choices hold?

A. (i) is false, but (ii) and (iii) are true
B. (i) and (iii) are false, but (ii) is true
C. (i) and (ii) are false, but (iii) is true
D. $(i), (ii)$ and (iii) are false

gateit-2007 computer-networks tcp normal

Answer key

4.30.21 TCP: GATE IT 2007 | Question: 14

Consider a TCP connection in a state where there are no outstanding ACKs. The sender sends two

segments back to back. The sequence numbers of the first and second segments are 230 and 290 respectively. The first segment was lost, but the second segment was received correctly by the receiver. Let X be the amount of data carried in the first segment (in bytes), and Y be the ACK number sent by the receiver.
The values of X and Y (in that order) are

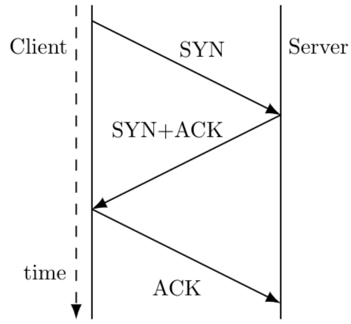
A. 60 and 290 B. 230 and 291 C. 60 and 231 D. 60 and 230

gateit-2007 computer-networks tcp normal

Answer key

4.30.22 TCP: GATE IT 2008 | Question: 69

The three way handshake for TCP connection establishment is shown below.



Which of the following statements are TRUE?

$S1:$ Loss of $\text{SYN} + \text{ACK}$ from the server will not establish a connection

$S2:$ Loss of ACK from the client cannot establish the connection

$S3:$ The server moves $\text{LISTEN} \rightarrow \text{SYN\_RCVD} \rightarrow \text{SYN\_SENT} \rightarrow \text{ESTABLISHED}$ in the state machine on no packet loss

$S4:$ The server moves $\text{LISTEN} \rightarrow \text{SYN\_RCVD} \rightarrow \text{ESTABLISHED}$ in the state machine on no packet loss

A. $S2$ and $S3$ only B. $S1$ and $S4$ only C. $S1$ and $S3$ only D. $S2$ and $S4$ only

gateit-2008 computer-networks tcp normal

Answer key

4.31 Token Bucket (2)

4.31.1 Token Bucket: GATE CSE 2008 | Question: 58

A computer on a 10Mbps network is regulated by a token bucket. The token bucket is filled at a rate of 2Mbps. It is initially filled to capacity with 16Megabits. What is the maximum duration for which the computer can transmit at the full 10Mbps?

A. 1.6 seconds B. 2 seconds C. 5 seconds D. 8 seconds

gatecse-2008 computer-networks token-bucket

Answer key

4.31.2 Token Bucket: GATE CSE 2016 Set 1 | Question: 54

For a host machine that uses the token bucket algorithm for congestion control, the token bucket has a capacity of 1 megabyte and the maximum output rate is 20 megabytes per second. Tokens arrive at a rate to sustain output at a rate of 10 megabytes per second. The token bucket is currently full and the machine needs to send 12 megabytes of data. The minimum time required to transmit the data is _____________ seconds.

gatecse-2016-set1 computer-networks token-bucket normal numerical-answers

Answer key

4.32 UDP (4)

4.32.1 UDP: GATE CSE 2005 | Question: 23

Packets of the same session may be routed through different paths in:

A. TCP, but not UDP
B. TCP and UDP
C. UDP, but not TCP
D. Neither TCP nor UDP

gatecse-2005 computer-networks tcp udp easy

Answer key

4.32.2 UDP: GATE CSE 2013 | Question: 12

The transport layer protocols used for real time multimedia, file transfer, DNS and email, respectively are

A. TCP, UDP, UDP and TCP
B. UDP, TCP, TCP and UDP
C. UDP, TCP, UDP and TCP
D. TCP, UDP, TCP and UDP

gatecse-2013 computer-networks tcp udp easy

Answer key

4.32.3 UDP: GATE CSE 2017 Set 2 | Question: 18

Consider socket API on a Linux machine that supports connected UDP sockets. A connected UDP socket is a UDP socket on which connect function has already been called. Which of the following statements is/are CORRECT?

I. A connected UDP socket can be used to communicate with multiple peers simultaneously.
II. A process can successfully call connect function again for an already connected UDP socket.

A. I only
B. II only
C. Both I and II
D. Neither I nor II

gatecse-2017-set2 computer-networks udp

Answer key

4.32.4 UDP: GATE IT 2006 | Question: 69

A program on machine X attempts to open a UDP connection to port 5376 on a machine Y, and a TCP connection to port 8632 on machine Z. However, there are no applications listening at the corresponding ports on Y and Z. An $ICMP$ Port Unreachable error will be generated by

A. Y but not Z
B. Z but not Y
C. Neither Y nor Z
D. Both Y and Z

gateit-2006 computer-networks tcp udp normal

Answer key

Answer Keys

4.0.1	6	4.1.1	A	4.1.2	C	4.1.3	C	4.1.4	C
4.1.5	B	4.1.6	6	4.1.7	4	4.1.8	B	4.1.9	A
4.1.10	C	4.1.11	D	4.1.12	C	4.2.1	B	4.3.1	B
4.3.2	D	4.4.1	B	4.4.2	A	4.4.3	A	4.5.1	B
4.5.2	C	4.5.3	C	4.5.4	A	4.6.1	D	4.6.2	200
4.6.3	50	4.6.4	C	4.6.5	A	4.6.6	B	4.7.1	A
4.8.1	A	4.8.2	7.07:7.09	4.8.3	B	4.8.4	B	4.9.1	D
4.9.2	C	4.9.3	1100 : 1300	4.9.4	0.4404	4.9.5	C	4.9.6	B
4.10.1	C	4.10.2	B	4.10.3	A	4.10.4	C	4.10.5	B;C
4.10.6	0.5	4.10.7	B	4.10.8	A	4.11.1	3 : 4	4.11.2	N/A
4.11.3	A	4.11.4	C	4.11.5	A	4.11.6	A	4.11.7	A

4.11.8	B	4.11.9	C	4.11.10	N/A	4.12.1	B	4.12.2	B
4.12.3	D	4.12.4	C	4.12.5	B	4.12.6	500	4.12.7	C
4.13.1	7:7	4.13.2	D	4.14.1	D	4.14.2	D	4.14.3	B
4.14.4	C	4.14.5	C	4.14.6	256	4.14.7	9	4.14.8	144
4.14.9	C;D	4.14.10	A	4.14.11	D	4.15.1	C	4.15.2	D
4.15.3	D	4.15.4	A	4.15.5	B	4.15.6	C	4.15.7	13
4.15.8	A;C	4.15.9	B;C	4.15.10	C;D	4.15.11	D	4.16.1	D
4.16.2	A	4.16.3	26	4.16.4	3	4.16.5	D	4.16.6	D
4.16.7	B	4.17.1	D	4.17.2	12	4.17.3	130 : 140	4.17.4	B
4.17.5	C	4.18.1	N/A	4.18.2	D	4.18.3	C	4.18.4	A
4.19.1	D	4.19.2	A	4.19.3	B	4.19.4	C	4.19.5	B
4.19.6	C	4.20.1	D	4.20.2	C	4.20.3	A	4.20.4	C
4.20.5	C	4.20.6	50 : 52	4.20.7	C	4.20.8	C	4.20.9	D
4.20.10	B	4.21.1	D	4.21.2	D	4.21.3	1575	4.21.4	B
4.22.1	B	4.23.1	0.949:0.952	4.24.1	B	4.24.2	D	4.24.3	A
4.24.4	1	4.24.5	C	4.24.6	D	4.24.7	A;C	4.24.8	B
4.24.9	40	4.24.10	C	4.24.11	A	4.24.12	C	4.24.13	D
4.25.1	A	4.26.1	B	4.26.2	B	4.26.3	B	4.26.4	C
4.26.5	C	4.26.6	D	4.26.7	C	4.26.8	5	4.26.9	8
4.26.10	4	4.26.11	C	4.26.12	B	4.26.13	B	4.26.14	A
4.26.15	A	4.27.1	D	4.27.2	C	4.27.3	C	4.27.4	B
4.28.1	320	4.28.2	2500	4.28.3	86.5 : 89.5	4.28.4	B	4.28.5	D
4.28.6	B	4.29.1	D	4.29.2	A	4.29.3	D	4.29.4	C
4.29.5	C	4.29.6	C	4.29.7	D	4.29.8	A	4.29.9	A
4.29.10	158	4.29.11	C	4.29.12	B	4.29.13	B;D	4.29.14	3
4.29.15	A	4.29.16	C	4.29.17	D	4.29.18	C	4.29.19	D
4.29.20	C	4.29.21	B	4.30.1	A	4.30.2	C	4.30.3	B
4.30.4	C	4.30.5	A	4.30.6	C	4.30.7	D	4.30.8	34 : 35
4.30.9	44	4.30.10	A;B;C	4.30.11	A;C	4.30.12	C	4.30.13	33
4.30.14	B;C;D	4.30.15	A;D	4.30.16	4	4.30.17	B;D	4.30.18	A
4.30.19	A	4.30.20	B	4.30.21	D	4.30.22	B	4.31.1	B
4.31.2	1.10:1.19	4.32.1	B	4.32.2	C	4.32.3	B	4.32.4	D

5 Databases (284)

ER-model. Relational model:Relational algebra, Tuple calculus, SQL. Integrity constraints, Normal forms. File organization, Indexing (e.g., B and B+ trees). Transactions and concurrency control.

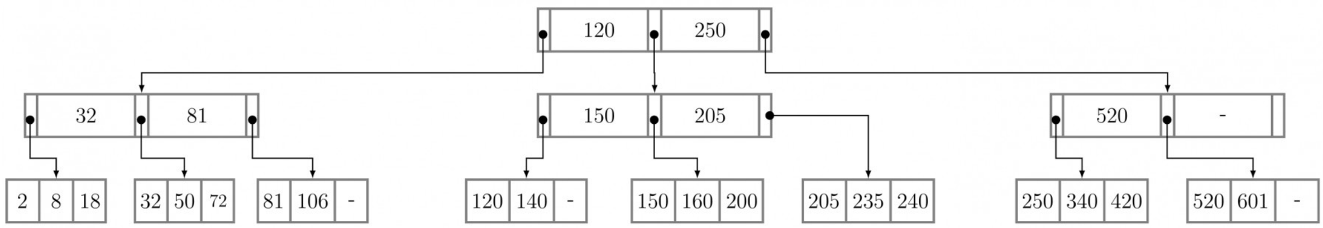
Mark Distribution in Previous GATE

Year	2025 - 1	2025 - 2	2024 - 1	2024 - 2	2023	2022	2021 - 1	2021 - 2	Minimum	Average	Maximu
1 Mark Count	1	1	4	4	1	3	2	1	1	2.13	4
2 Marks Count	3	4	2	2	2	2	3	3	2	2.63	4
Total Marks	8	9	8	8	5	7	8	7	**5**	**7.5**	**9**

5.1 B Tree (31)

5.1.1 B Tree: GATE CSE 1989 | Question: 12a

The below figure shows a B^+ tree where only key values are indicated in the records. Each block can hold upto three records. A record with a key value 34 is inserted into the B^+ tree. Obtain the modified B^+ tree after insertion.



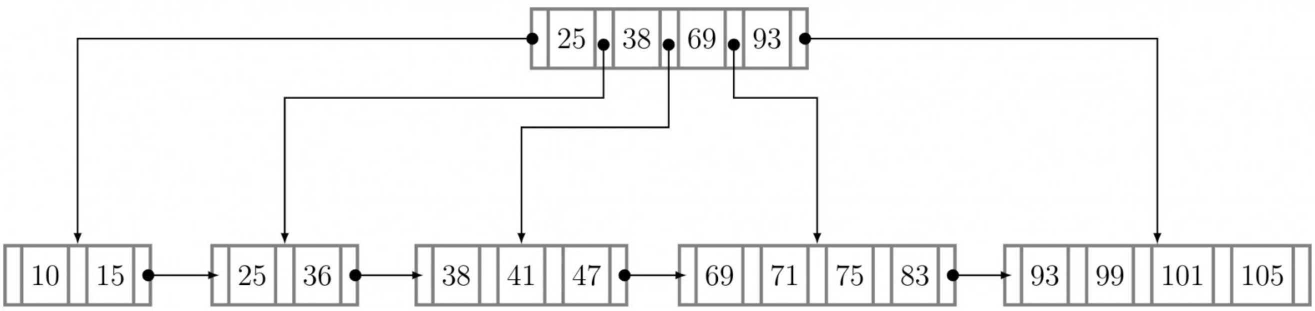
descriptive gate1989 databases b-tree

Answer key

5.1.2 B Tree: GATE CSE 1994 | Question: 14a

Consider B^+ - tree of order d shown in figure. (A B^+ - tree of order d contains between d and $2d$ keys in each node)

Draw the resulting B^+ - tree after 100 is inserted in the figure below.



gate1994 databases b-tree normal descriptive

Answer key

5.1.3 B Tree: GATE CSE 1994 | Question: 14b

For a B^+ - tree of order d with n leaf nodes, the number of nodes accessed during a search is $O(\_)$.

gate1994 databases b-tree normal descriptive

Answer key

5.1.4 B Tree: GATE CSE 1997 | Question: 19

A B^+ - tree of order d is a tree in which each internal node has between d and $2d$ key values. An internal node with M key values has $M+1$ children. The root (if it is an internal node) has between 1 and $2d$ key values. The distance of a node from the root is the length of the path from the root to the node. All leaves are at the same distance from the root. The height of the tree is the distance of a leaf from the root.

A. What is the total number of key values in the internal nodes of a B^+-tree with l leaves ($l \geq 2$)?
B. What is the maximum number of internal nodes in a B^+ - tree of order 4 with 52 leaves?
C. What is the minimum number of leaves in a B^+-tree of order d and height $h(h \geq 1)$?

gate1997 databases b-tree normal descriptive

Answer key

5.1.5 B Tree: GATE CSE 1999 | Question: 1.25

Which of the following is correct?

A. B-trees are for storing data on disk and B^+ trees are for main memory.
B. Range queries are faster on B^+ trees.
C. B-trees are for primary indexes and B^+ trees are for secondary indexes.
D. The height of a B^+ tree is independent of the number of records.

gate1999 databases b-tree normal

Answer key

5.1.6 B Tree: GATE CSE 1999 | Question: 21

Consider a B-tree with degree m, that is, the number of children, c, of any internal node (except the root) is such that $m \leq c \leq 2m-1$. Derive the maximum and minimum number of records in the leaf nodes for such a B-tree with height $h, h \geq 1.$(Assume that the root of a tree is at height 0).

gate1999 databases b-tree normal descriptive

Answer key

5.1.7 B Tree: GATE CSE 2000 | Question: 1.22, UGCNET-June2012-II: 11

B^+-trees are preferred to binary trees in databases because

A. Disk capacities are greater than memory capacities
B. Disk access is much slower than memory access
C. Disk data transfer rates are much less than memory data transfer rates
D. Disks are more reliable than memory

gatecse-2000 databases b-tree normal ugcnetcse-june2012-paper2

Answer key

5.1.8 B Tree: GATE CSE 2000 | Question: 21

(a) Suppose you are given an empty B^+ tree where each node (leaf and internal) can store up to 5 key values. Suppose values $1, 2, \dots 10$ are inserted, in order, into the tree. Show the tree pictorially

i. after 6 insertions, and
ii. after all 10 insertions

Do NOT show intermediate stages.

(b) Suppose instead of splitting a node when it is full, we try to move a value to the left sibling. If there is no left sibling, or the left sibling is full, we split the node. Show the tree after values $1, 2, \dots, 9$ have been inserted. Assume, as in (a) that each node can hold up to 5 keys.

(c) In general, suppose a B^+ tree node can hold a maximum of m keys,and you insert a long sequence of keys in increasing order. Then what approximately is the average number of keys in each leaf level node.

i. in the normal case, and
ii. with the insertion as in (b).

gatecse-2000 databases b-tree normal descriptive

Answer key

5.1.9 B Tree: GATE CSE 2001 | Question: 22

We wish to construct a B^+ tree with fan-out (the number of pointers per node) equal to 3 for the following set of key values:

$80, 50, 10, 70, 30, 100, 90$

Assume that the tree is initially empty and the values are added in the order given.

a. Show the tree after insertion of 10, after insertion of 30, and after insertion of 90. Intermediate trees need not be shown.
b. The key values 30 and 10 are now deleted from the tree in that order show the tree after each deletion.

gatecse-2001 databases b-tree normal descriptive

Answer key

5.1.10 B Tree: GATE CSE 2002 | Question: 17

a. The following table refers to search items for a key in B-trees and B^+ trees.

B-tree		**B^+-tree**	
Successful search	Unsuccessful search	Successful search	Unsuccessful search
X_1	X_2	X_3	X_4

A successful search means that the key exists in the database and unsuccessful means that it is not present in the database. Each of the entries X_1, X_2, X_3 and X_4 can have a value of either Constant or Variable. Constant means that the search time is the same, independent of the specific key value, where variable means that it is dependent on the specific key value chosen for the search.
Give the correct values for the entries X_1, X_2, X_3 and X_4 (for example $X_1 = \text{Constant}$, $X_2 = \text{Constant}$, $X_3 = \text{Constant}$, $X_4 = \text{Constant}$)

b. Relation $R(A, B)$ has the following view defined on it:

```
CREATE VIEW V AS
(SELECT R1.A,R2.B
FROM R AS R1, R as R2
WHERE R1.B=R2.A)
```

i. The current contents of relation R are shown below. What are the contents of the view V?

A	B
1	2
2	3
2	4
4	5
6	7
6	8
9	10

ii. The tuples $(2, 11)$ and $(11, 6)$ are now inserted into R. What are the *additional* tuples that are inserted in V?

gatecse-2002 databases b-tree normal descriptive

Answer key

5.1.11 B Tree: GATE CSE 2002 | Question: 2.23, UGCNET-June2012-II: 26

A B^+ - tree index is to be built on the *Name* attribute of the relation *STUDENT.* Assume that all the student names are of length 8 bytes, disk blocks are of size 512 bytes, and index pointers are of size 4 bytes. Given the scenario, what would be the best choice of the degree (i.e. number of pointers per node) of the B^+ - tree?

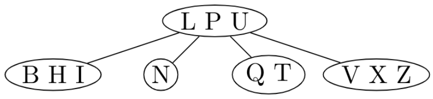
A. 16
B. 42
C. 43
D. 44

gatecse-2002 databases b-tree normal ugcnetcse-june2012-paper2

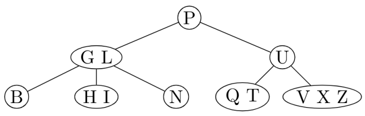
Answer key

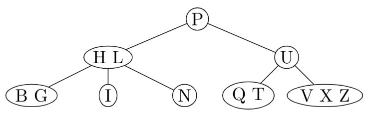
5.1.12 B Tree: GATE CSE 2003 | Question: 65

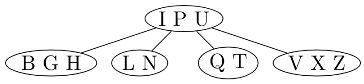
Consider the following $2-3-4$ tree (i.e., B-tree with a minimum degree of two) in which each data item is a letter. The usual alphabetical ordering of letters is used in constructing the tree.



What is the result of inserting G in the above tree?

A. 

B. 

C. 

D. None of the above

gatecse-2003 databases b-tree normal

Answer key

5.1.13 B Tree: GATE CSE 2004 | Question: 52

The order of an internal node in a $B+$ tree index is the maximum number of children it can have. Suppose that a child pointer takes 6 bytes, the search field value takes 14 bytes, and the block size is 512 bytes. What is the order of the internal node?

A. 24
B. 25
C. 26
D. 27

gatecse-2004 databases b-tree normal

Answer key

5.1.14 B Tree: GATE CSE 2005 | Question: 28

Which of the following is a key factor for preferring B^+-trees to binary search trees for indexing database relations?

A. Database relations have a large number of records
B. Database relations are sorted on the primary key
C. B^+-trees require less memory than binary search trees
D. Data transfer from disks is in blocks

gatecse-2005 databases b-tree normal

Answer key

5.1.15 B Tree: GATE CSE 2007 | Question: 63, ISRO2016-59

The order of a leaf node in a B^+ - tree is the maximum number of (value, data record pointer) pairs it can hold. Given that the block size is $1K$ bytes, data record pointer is 7 bytes long, the value field is 9 bytes long and a block pointer is 6 bytes long, what is the order of the leaf node?

A. 63 B. 64 C. 67 D. 68

gatecse-2007 databases b-tree normal isro2016

Answer key

5.1.16 B Tree: GATE CSE 2008 | Question: 41

A B-tree of order 4 is built from scratch by 10 successive insertions. What is the maximum number of node splitting operations that may take place?

A. 3 B. 4 C. 5 D. 6

gatecse-2008 databases b-tree normal

Answer key

5.1.17 B Tree: GATE CSE 2009 | Question: 44

The following key values are inserted into a B^+ - tree in which order of the internal nodes is 3, and that of the leaf nodes is 2, in the sequence given below. The order of internal nodes is the maximum number of tree pointers in each node, and the order of leaf nodes is the maximum number of data items that can be stored in it. The B^+ - tree is initially empty

$10, 3, 6, 8, 4, 2, 1$

The maximum number of times leaf nodes would get split up as a result of these insertions is

A. 2 B. 3 C. 4 D. 5

gatecse-2009 databases b-tree normal

Answer key

5.1.18 B Tree: GATE CSE 2010 | Question: 18

Consider a B^+-tree in which the maximum number of keys in a node is 5. What is the minimum number of keys in any non-root node?

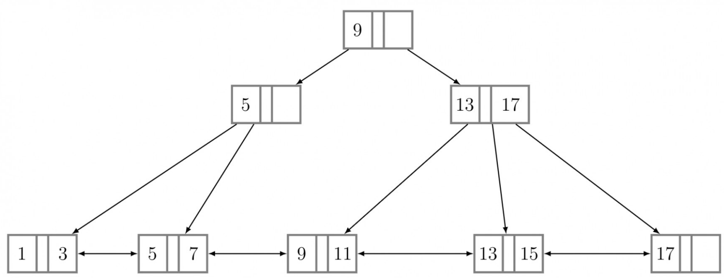
A. 1 B. 2 C. 3 D. 4

gatecse-2010 databases b-tree easy

Answer key

5.1.19 B Tree: GATE CSE 2015 Set 2 | Question: 6

With reference to the B^+ tree index of order 1 shown below, the minimum number of nodes (including the Root node) that must be fetched in order to satisfy the following query. "Get all records with a search key greater than or equal to 7 and less than 15 " is ______.



gatecse-2015-set2 databases b-tree normal numerical-answers

Answer key☟

5.1.20 B Tree: GATE CSE 2015 Set 3 | Question: 46

Consider a B^+ tree in which the search key is 12 bytes long, block size is 1024 bytes, record pointer is 10 bytes long and the block pointer is 8 bytes long. The maximum number of keys that can be accommodated in each non-leaf node of the tree is ______.

gatecse-2015-set3 databases b-tree normal numerical-answers

Answer key☟

5.1.21 B Tree: GATE CSE 2016 Set 2 | Question: 21

B+ Trees are considered BALANCED because.

A. The lengths of the paths from the root to all leaf nodes are all equal.
B. The lengths of the paths from the root to all leaf nodes differ from each other by at most 1.
C. The number of children of any two non-leaf sibling nodes differ by at most 1.
D. The number of records in any two leaf nodes differ by at most 1.

gatecse-2016-set2 databases b-tree normal

Answer key☟

5.1.22 B Tree: GATE CSE 2017 Set 2 | Question: 49

In a B^+ Tree , if the search-key value is 8 bytes long , the block size is 512 bytes and the pointer size is 2 B , then the maximum order of the B^+ Tree is ____

gatecse-2017-set2 databases b-tree numerical-answers normal

Answer key☟

5.1.23 B Tree: GATE CSE 2019 | Question: 14

Which one of the following statements is NOT correct about the B^+ tree data structure used for creating an index of a relational database table?

A. B^+ Tree is a height-balanced tree
B. Non-leaf nodes have pointers to data records
C. Key values in each node are kept in sorted order
D. Each leaf node has a pointer to the next leaf node

gatecse-2019 databases b-tree one-mark

Answer key☟

5.1.24 B Tree: GATE CSE 2024 | Set 1 | Question: 11

In a B^+ tree, the requirement of at least half-full (50%) node occupancy is relaxed for which one of the following cases?

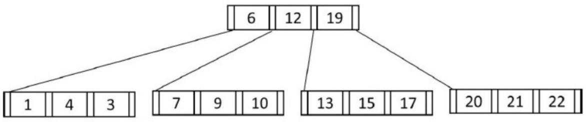
A. Only the root node
B. All leaf nodes
C. All internal nodes
D. Only the leftmost leaf node

gatecse2024-set1 databases b-tree one-mark

Answer key☟

5.1.25 B Tree: GATE CSE 2025 | Set 1 | Question: 11

Consider the following B^+tree with 5 nodes, in which a node can store at most 3 key values The value 23 is now inserted in the B^+tree. Which of the following options(s) is/are CORRECT?



A. None of the nodes will split.
B. At least one node will split and redistribute.
C. The total number of nodes will remain same.
D. The height of the tree will increase.

gatecse2025-set1 databases b-tree multiple-selects one-mark

Answer key

5.1.26 B Tree: GATE CSE 2025 | Set 2 | Question: 47

In a B^{+}- tree where each node can hold at most four key values, a root to leaf path consists of the following nodes:

$$\mathrm{A}=(49,77,83,-), \mathrm{B}=(7,19,33,44), \mathrm{C}=\left(20^{*}, 22^{*}, 25^{*}, 26^{*}\right)$$

The $*$-marked keys signify that these are data entries in a leaf.

Assume that a pointer between keys k_1 and k_2 points to a subtree containing keys in $[k_1, k_2)$, and that when a leaf is created, the smallest key in it is copied up into its parent.

A record with key value 23 is inserted into the B^{+}- tree.

The smallest key value in the parent of the leaf that contains 25^{*} is __________. (Answer in integer)

gatecse2025-set2 databases b-tree numerical-answers two-marks

Answer key

5.1.27 B Tree: GATE IT 2004 | Question: 79

Consider a table T in a relational database with a key field K. A B-tree of order p is used as an access structure on K, where p denotes the maximum number of tree pointers in a B-tree index node. Assume that K is 10 $bytes$ long; disk block size is 512 $bytes$; each data pointer P_D is 8 bytes long and each block pointer P_B is 5 bytes long. In order for each B-tree node to fit in a single disk block, the maximum value of p is

A. 20
B. 22
C. 23
D. 32

gateit-2004 databases b-tree normal

Answer key

5.1.28 B Tree: GATE IT 2005 | Question: 23, ISRO2017-67

A B-Tree used as an index for a large database table has four levels including the root node. If a new key is inserted in this index, then the maximum number of nodes that could be newly created in the process are

A. 5
B. 4
C. 3
D. 2

gateit-2005 databases b-tree normal isro2017

Answer key

5.1.29 B Tree: GATE IT 2006 | Question: 61

In a database file structure, the search key field is 9 $bytes$ long, the block size is 512 $bytes$, a record pointer is 7 $bytes$ and a block pointer is 6 $bytes$. The largest possible order of a non-leaf node in a B^{+} tree implementing this file structure is

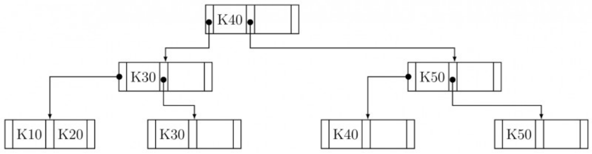
A. 23 B. 24 C. 34 D. 44

gateit-2006   databases   b-tree   normal

Answer key

5.1.30 B Tree: GATE IT 2007 | Question: 84

Consider the B^+ tree in the adjoining figure, where each node has at most two keys and three links.



Keys $K15$ and then $K25$ are inserted into this tree in that order. Exactly how many of the following nodes (disregarding the links) will be present in the tree after the two insertions?

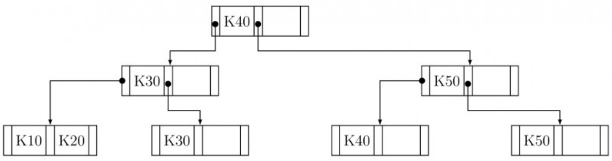
A. 1 B. 2 C. 3 D. 4

gateit-2007   databases   b-tree   normal

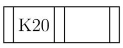
Answer key

5.1.31 B Tree: GATE IT 2007 | Question: 85

Consider the B^+ tree in the adjoining figure, where each node has at most two keys and three links.



Keys $K15$ and then $K25$ are inserted into this tree in that order. Now the key $K50$ is deleted from the B^+ tree resulting after the two insertions made earlier. Consider the following statements about the B^+ tree resulting after this deletion.

i. The height of the tree remains the same.
ii. The node 

(disregarding the links) is present in the tree.
iii. The root node remains unchanged (disregarding the links).

Which one of the following options is true?

A. Statements (i) and (ii) are true
B. Statements (ii) and (iii) are true
C. Statements (iii) and (i) are true
D. All the statements are false

gateit-2007   databases   b-tree   normal

Answer key

5.2 Candidate Key (5)

5.2.1 Candidate Key: GATE CSE 1994 | Question: 3.7

An instance of a relational scheme $R(A, B, C)$ has distinct values for attribute A. Can you conclude that A is a candidate key for R?

No

gate1994   databases   easy   database-normalization   candidate-key   descriptive

Answer key

5.2.2 Candidate Key: GATE CSE 2011 | Question: 12

Consider a relational table with a single record for each registered student with the following attributes:

1. Registration_Num: Unique registration number for each registered student
2. UID: Unique identity number, unique at the national level for each citizen
3. BankAccount_Num: Unique account number at the bank. A student can have multiple accounts or joint accounts. This attribute stores the primary account number.
4. Name: Name of the student
5. Hostel_Room: Room number of the hostel

Which of the following options is **INCORRECT**?

A. BankAccount_Num is a candidate key
B. Registration_Num can be a primary key
C. UID is a candidate key if all students are from the same country
D. If S is a super key such that $S \cap \text{UID}$ is NULL then $S \cup \text{UID}$ is also a superkey

gatecse-2011 databases normal candidate-key

Answer key

5.2.3 Candidate Key: GATE CSE 2014 Set 2 | Question: 21

The maximum number of superkeys for the relation schema $R(E, F, G, H)$ with E as the key is _____.

gatecse-2014-set2 databases numerical-answers easy candidate-key

8

Answer key

5.2.4 Candidate Key: GATE CSE 2014 Set 2 | Question: 22

Given an instance of the STUDENTS relation as shown as below

StudentID	StudentName	StudentEmail	StudentAge	CPI
2345	Shankar	shankar@math	X	9.4
1287	Swati	swati@ee	19	9.5
7853	Shankar	shankar@cse	19	9.4
9876	Swati	swati@mech	18	9.3
8765	Ganesh	ganesh@civil	19	8.7

For $(\text{StudentName}, \text{StudentAge})$ to be a key for this instance, the value X should NOT be equal to 19 _____.

gatecse-2014-set2 databases numerical-answers easy candidate-key

Answer key

5.2.5 Candidate Key: GATE CSE 2014 Set 3 | Question: 22

A *prime attribute* of a relation scheme R is an attribute that appears

A. in all candidate keys of R
B. in some candidate key of R
C. in a foreign key of R
D. only in the primary key of R

gatecse-2014-set3 databases easy candidate-key

Answer key

5.3 Conflict Serializable (9)

5.3.1 Conflict Serializable: GATE CSE 2014 Set 1 | Question: 29

Consider the following four schedules due to three transactions (indicated by the subscript) using *read* and *write* on a data item x, denoted by $r(x)$ and $w(x)$ respectively. Which one of them is conflict serializable?

A. $r_1(x); r_2(x); w_1(x); r_3(x); w_2(x);$
B. $r_2(x); r_1(x); w_2(x); r_3(x); w_1(x);$
C. $r_3(x); r_2(x); r_1(x); w_2(x); w_1(x);$
D. $r_2(x); w_2(x); r_3(x); r_1(x); w_1(x);$

gatecse-2014-set1 databases transaction-and-concurrency conflict-serializable normal

Answer key☟

5.3.2 Conflict Serializable: GATE CSE 2014 Set 2 | Question: 29

Consider the following schedule **S** of transactions $T1, T2, T3, T4$:

T1	**T2**	**T3**	**T4**
	Reads(X)		
		Writes(X)	
		Commit	
Writes(X)			
Commit			
	Writes(Y)		
	Reads(Z)		
	Commit		
			Reads(X)
			Reads(Y)
			Commit

Which one of the following statements is CORRECT?

A. **S** is conflict-serializable but not recoverable
B. **S** is not conflict-serializable but is recoverable
C. **S** is both conflict-serializable and recoverable
D. **S** is neither conflict-serializable not is it recoverable

gatecse-2014-set2 databases transaction-and-concurrency conflict-serializable normal

Answer key☟

5.3.3 Conflict Serializable: GATE CSE 2014 Set 3 | Question: 29

Consider the transactions $T1, T2,$ and $T3$ and the schedules $S1$ and $S2$ given below.

- $T1 : r1(X); r1(Z); w1(X); w1(Z)$
- $T2 : r2(Y); r2(Z); w2(Z)$
- $T3 : r3(Y); r3(X); w3(Y)$
- $S1 : r1(X); r3(Y); r3(X); r2(Y); r2(Z); w3(Y); w2(Z); r1(Z); w1(X); w1(Z)$
- $S2 : r1(X); r3(Y); r2(Y); r3(X); r1(Z); r2(Z); w3(Y); w1(X); w2(Z); w1(Z)$

Which one of the following statements about the schedules is **TRUE**?

A. Only $S1$ is conflict-serializable.
B. Only $S2$ is conflict-serializable.
C. Both $S1$ and $S2$ are conflict-serializable.
D. Neither $S1$ nor $S2$ is conflict-serializable.

gatecse-2014-set3 databases transaction-and-concurrency conflict-serializable normal

Answer key☟

5.3.4 Conflict Serializable: GATE CSE 2017 Set 2 | Question: 44

Two transactions T_1 and T_2 are given as

$T_1 : r_1(X)w_1(X)r_1(Y)w_1(Y)$

$T_2 : r_2(Y)w_2(Y)r_2(Z)w_2(Z)$

where $r_i(V)$ denotes a $read$ operation by transaction T_i on a variable V and $w_i(V)$ denotes a $write$ operation by transaction T_i on a variable V. The total number of conflict serializable schedules that can be formed by T_1 and T_2 is _______

gatecse-2017-set2 databases transaction-and-concurrency numerical-answers conflict-serializable

Answer key☟

5.3.5 Conflict Serializable: GATE CSE 2021 Set 1 | Question: 32

Let $r_i(z)$ and $w_i(z)$ denote read and write operations respectively on a data item z by a transaction T_i. Consider the following two schedules.

- $S_1 : r_1(x)r_1(y)r_2(x)r_2(y)w_2(y)w_1(x)$
- $S_2 : r_1(x)r_2(x)r_2(y)w_2(y)r_1(y)w_1(x)$

Which one of the following options is correct?

A. S_1 is conflict serializable, and S_2 is not conflict serializable
B. S_1 is not conflict serializable, and S_2 is conflict serializable
C. Both S_1 and S_2 are conflict serializable
D. Niether S_1 nor S_2 is conflict serializable

gatecse-2021-set1 databases transaction-and-concurrency conflict-serializable two-marks

Answer key☟

5.3.6 Conflict Serializable: GATE CSE 2021 Set 2 | Question: 32

Let S be the following schedule of operations of three transactions T_1, T_2 and T_3 in a relational database system:

$$R_2(Y), R_1(X), R_3(Z), R_1(Y)W_1(X), R_2(Z), W_2(Y), R_3(X), W_3(Z)$$

Consider the statements P and Q below:

- P: S is conflict-serializable.
- Q: If T_3 commits before T_1 finishes, then S is recoverable.

Which one of the following choices is correct?

A. Both P and Q are true
B. P is true and Q is false
C. P is false and Q is true
D. Both P and Q are false

gatecse-2021-set2 databases transaction-and-concurrency conflict-serializable two-marks

Answer key☟

5.3.7 Conflict Serializable: GATE CSE 2022 | Question: 29

Let $R_i(z)$ and $W_i(z)$ denote read and write operations on a data element z by a transaction T_i, respectively. Consider the schedule S with four transactions.

$S :\ R_4(x)R_2(x)R_3(x)R_1(y)W_1(y)W_2(x)W_3(y)R_4(y)$

Which one of the following serial schedules is conflict equivalent to S?

A. $T_1 \to T_3 \to T_4 \to T_2$
B. $T_1 \to T_4 \to T_3 \to T_2$
C. $T_4 \to T_1 \to T_3 \to T_2$
D. $T_3 \to T_1 \to T_4 \to T_2$

gatecse-2022 databases transaction-and-concurrency conflict-serializable two-marks

Answer key

5.3.8 Conflict Serializable: GATE CSE 2024 | Set 1 | Question: 36

Consider the following read-write schedule S over three transactions T_1, T_2, and T_3, where the subscripts in the schedule indicate transaction IDs:

$S: r_1(z); w_1(z); r_2(x); r_3(y); w_3(y); r_2(y); w_2(x); w_2(y);$

Which of the following transaction schedules is/are conflict equivalent to S?

A. $T_1T_2T_3$ B. $T_1T_3T_2$ C. $T_3T_2T_1$ D. $T_3T_1T_2$

gatecse2024-set1 databases conflict-serializable multiple-selects two-marks

Answer key

5.3.9 Conflict Serializable: GATE CSE 2025 | Set 2 | Question: 43

Consider the database transactions T1 and T2 , and data items X and Y . Which of the schedule(s) is/are conflict serializable?

Transaction T1
R1(X)
W1(Y)
R1(X)
W1(X)
COMMIT(T1)

Transaction T2
W2(X)
W2(Y)
COMMIT(T2)

A. R1(X), W2(X), W1(Y), W2(Y), R1(X), W1(X), COMMIT(T2), COMMIT(T1)
B. W2(X), R1(X), W2(Y), W1(Y), R1(X), COMMIT(T2), W1(X), COMMIT(T1)
C. R1(X), W1(Y), W2(X), W2(Y), R1(X), W1(X), COMMIT(T1), COMMIT(T2)
D. W2(X), R1(X), W1(Y), W2(Y), R1(X), COMMIT(T2), W1(X), COMMIT(T1)

gatecse2025-set2 databases conflict-serializable multiple-selects two-marks

Answer key

5.4 Database Design (1)

5.4.1 Database Design: GATE CSE 1994 | Question: 3.11

State True or False with reason

Logical data independence is easier to achieve than physical data independence.

gate1994 databases normal database-design true-false

Answer key

5.5 Database Normalization (56)

5.5.1 Database Normalization: GATE CSE 1987 | Question: 2n

State whether the following statements are TRUE or FALSE:

A relation r with schema (X, Y) satisfies the function dependency $X \rightarrow Y$, The tuples $\langle 1,2\rangle$ and $\langle 2,2\rangle$ can both be in r simultaneously.

gate1987 databases database-normalization T true-false

Answer key

5.5.2 Database Normalization: GATE CSE 1988 | Question: 12i

What are the three axioms of functional dependency for the relational databases given by Armstrong.

gate1988 normal descriptive databases database-normalization

Answer key

5.5.3 Database Normalization: GATE CSE 1988 | Question: 12iia

Using Armstrong's axioms of functional dependency derive the following rules:

$$\{x \to y,\ x \to z\} \models x \to yz$$

(Note: $x \to y$ denotes y is functionally dependent on x, $z \subseteq y$ denotes z is subset of y, and $\models$ means derives).

gate1988 easy descriptive databases database-normalization

Answer key

5.5.4 Database Normalization: GATE CSE 1988 | Question: 12iib

Using Armstrong's axioms of functional dependency derive the following rules:

$$\{x \to y,\ wy \to z\} \models xw \to z$$

(Note: $x \to y$ denotes y is functionally dependent on x, $z \subseteq y$ denotes z is subset of y, and $\models$ means derives).

gate1988 normal descriptive databases database-normalization

Answer key

5.5.5 Database Normalization: GATE CSE 1988 | Question: 12iic

Using Armstrong's axioms of functional dependency derive the following rules:

$$\{x \to y,\ z \subset y\} \models x \to z$$

(Note: $x \to y$ denotes y is functionally dependent on x, $z \subseteq y$ denotes z is subset of y, and $\models$ means derives).

gate1988 normal descriptive databases database-normalization

Answer key

5.5.6 Database Normalization: GATE CSE 1990 | Question: 2-iv

Match the pairs in the following questions:

(a)	Secondary index	(p)	Function dependency
(b)	Non-procedural query language	(q)	B-tree
(c)	Closure of a set of attributes	(r)	Domain calculus
(d)	Natural join	(s)	Relational algebraic operations

gate1990 match-the-following database-normalization databases

Answer key

5.5.7 Database Normalization: GATE CSE 1990 | Question: 3-ii

Indicate which of the following statements are true:

A relational database which is in 3NF may still have undesirable data redundancy because there may exist:

A. Transitive functional dependencies
B. Non-trivial functional dependencies involving prime attributes on the right-side.
C. Non-trivial functional dependencies involving prime attributes only on the left-side.
D. Non-trivial functional dependencies involving only prime attributes.

gate1990 normal databases database-normalization multiple-selects

Answer key

5.5.8 Database Normalization: GATE CSE 1994 | Question: 3.6

State True or False with reason

There is always a decomposition into Boyce-Codd normal form (BCNF) that is lossless and dependency preserving.

gate1994 databases database-normalization easy true-false

Answer key

5.5.9 Database Normalization: GATE CSE 1995 | Question: 26

Consider the relation scheme $R(A, B, C)$ with the following functional dependencies:

- $A, B \to C,$
- $C \to A$

A. Show that the scheme R is in 3NF but not in BCNF.
B. Determine the minimal keys of relation R.

gate1995 databases database-normalization normal descriptive

Answer key

5.5.10 Database Normalization: GATE CSE 1997 | Question: 6.9

For a database relation $R(a, b, c, d)$, where the domains a, b, c, d include only atomic values, only the following functional dependencies and those that can be inferred from them hold

- $a \to c$
- $b \to d$

This relation is

A. in first normal form but not in second normal form
B. in second normal form but not in first normal form
C. in third normal form
D. none of the above

gate1997 databases database-normalization normal

Answer key

5.5.11 Database Normalization: GATE CSE 1998 | Question: 1.34

Which normal form is considered adequate for normal relational database design?

A. $2NF$
B. $5NF$
C. $4NF$
D. $3NF$

gate1998 databases database-normalization easy

Answer key

5.5.12 Database Normalization: GATE CSE 1998 | Question: 26

Consider the following database relations containing the attributes

- Book_id
- Subject_Category_of_book
- Name_of_Author
- Nationality_of_Author

With Book_id as the primary key.

a. What is the highest normal form satisfied by this relation?

b. Suppose the attributes Book_title and Author_address are added to the relation, and the primary key is changed to {Name_of_Author, Book_title}, what will be the highest normal form satisfied by the relation?

gate1998 databases database-normalization normal descriptive

Answer key☟

5.5.13 Database Normalization: GATE CSE 1999 | Question: 1.24

Let $R=(A,B,C,D,E,F)$ be a relation scheme with the following dependencies $C \rightarrow F, E \rightarrow A, EC \rightarrow D, A \rightarrow B$. Which one of the following is a key for R?

A. CD
B. EC
C. AE
D. AC

gate1999 databases database-normalization easy

Answer key☟

5.5.14 Database Normalization: GATE CSE 1999 | Question: 2.7, UGCNET-June2014-III: 25

Consider the schema $R=(S,T,U,V)$ and the dependencies $S \rightarrow T, T \rightarrow U, U \rightarrow V$ and $V \rightarrow S$. Let $R = (R1 \text{ and } R2)$ be a decomposition such that $R1 \cap R2 \neq \phi$. The decomposition is

A. not in 2NF
B. in 2NF but not 3NF
C. in 3NF but not in 2NF
D. in both 2NF and 3NF

gate1999 databases database-normalization normal ugcnetjune2014iii

Answer key☟

5.5.15 Database Normalization: GATE CSE 2000 | Question: 2.24

Given the following relation instance.

X	Y	Z
1	4	2
1	5	3
1	6	3
3	2	2

Which of the following functional dependencies are satisfied by the instance?

A. $XY \rightarrow Z$ and $Z \rightarrow Y$
B. $YZ \rightarrow X$ and $Y \rightarrow Z$
C. $YZ \rightarrow X$ and $X \rightarrow Z$
D. $XZ \rightarrow Y$ and $Y \rightarrow X$

gatecse-2000 databases database-normalization easy

Answer key☟

5.5.16 Database Normalization: GATE CSE 2001 | Question: 2.23

$R(A,B,C,D)$ is a relation. Which of the following does not have a lossless join, dependency preserving $BCNF$ decomposition?

A. $A \rightarrow B, B \rightarrow CD$
B. $A \rightarrow B, B \rightarrow C, C \rightarrow D$
C. $AB \rightarrow C, C \rightarrow AD$
D. $A \rightarrow BCD$

gatecse-2001 databases database-normalization normal

Answer key☟

5.5.17 Database Normalization: GATE CSE 2002 | Question: 1.19

Relation R with an associated set of functional dependencies, F, is decomposed into BCNF. The redundancy (arising out of functional dependencies) in the resulting set of relations is

A. Zero
B. More than zero but less than that of an equivalent 3NF decomposition
C. Proportional to the size of F^+

D. Indeterminate

gatecse-2002 databases database-normalization normal

Answer key

5.5.18 Database Normalization: GATE CSE 2002 | Question: 16

For relation **R = (L, M, N, O, P),** the following dependencies hold:

$M \to O, NO \to P, P \to L$ and $L \to MN$

R is decomposed into **R1 = (L, M, N, P)** and **R2 = (M, O)**.

A. Is the above decomposition a lossless-join decomposition? Explain.
B. Is the above decomposition dependency-preserving? If not, list all the dependencies that are not preserved.
C. What is the highest normal form satisfied by the above decomposition?

gatecse-2002 databases database-normalization normal descriptive

Answer key

5.5.19 Database Normalization: GATE CSE 2002 | Question: 2.24

Relation R is decomposed using a set of functional dependencies, F, and relation S is decomposed using another set of functional dependencies, G. One decomposition is definitely BCNF, the other is definitely $3NF$, but it is not known which is which. To make a guaranteed identification, which one of the following tests should be used on the decompositions? (Assume that the closures of F and G are available).

A. Dependency-preservation
B. Lossless-join
C. BCNF definition
D. $3NF$ definition

gatecse-2002 databases database-normalization easy

Answer key

5.5.20 Database Normalization: GATE CSE 2002 | Question: 2.25

From the following instance of a relation schema $R(A, B, C)$, we can conclude that:

A	**B**	**C**
1	1	1
1	1	0
2	3	2
2	3	2

A. A functionally determines B and B functionally determines C
B. A functionally determines B and B does not functionally determine C
C. B does not functionally determine C
D. A does not functionally determine B and B does not functionally determine C

gatecse-2002 databases database-normalization

Answer key

5.5.21 Database Normalization: GATE CSE 2003 | Question: 85

Consider the following functional dependencies in a database.

Date_of_Birth $\to$ Age	Age $\to$ Eligibility
Name $\to$ Roll_number	Roll_number $\to$ Name
Course_number $\to$ Course_name	Course_number $\to$ Instructor
(Roll_number, Course_number) $\to$ Grade	

The relation (Roll_number, Name, Date_of_birth, Age) is

A. in second normal form but not in third normal form
B. in third normal form but not in BCNF
C. in BCNF
D. in none of the above

gatecse-2003 databases database-normalization normal

Answer key☟

5.5.22 Database Normalization: GATE CSE 2004 | Question: 50

The relation scheme $\text{Student Performance (name, courseNo, rollNo, grade)}$ has the following functional dependencies:

- name, courseNo, $\rightarrow$ grade
- rollNo, courseNo $\rightarrow$ grade
- name $\rightarrow$ rollNo
- rollNo $\rightarrow$ name

The highest normal form of this relation scheme is

A. 2NF
B. 3NF
C. BCNF
D. 4NF

gatecse-2004 databases database-normalization normal

Answer key☟

5.5.23 Database Normalization: GATE CSE 2005 | Question: 29, UGCNET-June2015-III: 9

Which one of the following statements about normal forms is FALSE?

A. BCNF is stricter than 3NF
B. Lossless, dependency-preserving decomposition into 3NF is always possible
C. Lossless, dependency-preserving decomposition into BCNF is always possible
D. Any relation with two attributes is in BCNF

gatecse-2005 databases database-normalization easy ugcnetcse-june2015-paper3

Answer key☟

5.5.24 Database Normalization: GATE CSE 2005 | Question: 78

Consider a relation scheme $R = (A, B, C, D, E, H)$ on which the following functional dependencies hold: $\{A \rightarrow B, BC \rightarrow D, E \rightarrow C, D \rightarrow A\}$. What are the candidate keys R?

A. AE, BE
B. AE, BE, DE
C. AEH, BEH, BCH
D. AEH, BEH, DEH

gatecse-2005 databases database-normalization easy

Answer key☟

5.5.25 Database Normalization: GATE CSE 2006 | Question: 70

The following functional dependencies are given:

$$AB \rightarrow CD, AF \rightarrow D, DE \rightarrow F, C \rightarrow G, F \rightarrow E, G \rightarrow A$$

Which one of the following options is false?

A. $\{CF\}^* = \{ACDEFG\}$
B. $\{BG\}^* = \{ABCDG\}$
C. $\{AF\}^* = \{ACDEFG\}$
D. $\{AB\}^* = \{ABCDG\}$

gatecse-2006 databases database-normalization normal

Answer key☟

5.5.26 Database Normalization: GATE CSE 2007 | Question: 62, UGCNET-June2014-II: 47

Which one of the following statements is FALSE?

A. Any relation with two attributes is in BCNF
B. A relation in which every key has only one attribute is in 2NF
C. A prime attribute can be transitively dependent on a key in a 3 NF relation
D. A prime attribute can be transitively dependent on a key in a BCNF relation

gatecse-2007 databases database-normalization normal ugcnetcse-june2014-paper2

Answer key

5.5.27 Database Normalization: GATE CSE 2008 | Question: 69

Consider the following relational schemes for a library database:

Book (Title, Author, Catalog_no, Publisher, Year, Price)
Collection(Title, Author, Catalog_no)

with the following functional dependencies:

I. $\text{Title Author} \rightarrow \text{Catalog\_no}$
II. $\text{Catalog\_no} \rightarrow \text{Title Author Publisher Year}$
III. $\text{Publisher Title Year} \rightarrow \text{Price}$

Assume $\{\text{Author, Title}\}$ is the key for both schemes. Which of the following statements is true?

A. Both Book and Collection are in BCNF
B. Both Book and Collection are in 3NF only
C. Book is in 2NF and Collection in 3NF
D. Both Book and Collection are in 2NF only

gatecse-2008 databases database-normalization normal

Answer key

5.5.28 Database Normalization: GATE CSE 2012 | Question: 2

Which of the following is **TRUE**?

A. Every relation in 3NF is also in BCNF
B. A relation R is in 3NF if every non-prime attribute of R is fully functionally dependent on every key of R
C. Every relation in BCNF is also in 3NF
D. No relation can be in both BCNF and 3NF

gatecse-2012 databases easy database-normalization

Answer key

5.5.29 Database Normalization: GATE CSE 2013 | Question: 54

Relation R has eight attributes ABCDEFGH. Fields of R contain only atomic values. $F=$ $\{\text{CH}\rightarrow\text{G, A}\rightarrow\text{BC, B}\rightarrow\text{CFH, E}\rightarrow\text{A, F}\rightarrow\text{EG}\}$ is a set of functional dependencies (FDs) so that F^+ is exactly the set of FDs that hold for R.

How many candidate keys does the relation R have?

A. 3
B. 4
C. 5
D. 6

gatecse-2013 databases database-normalization normal

Answer key

5.5.30 Database Normalization: GATE CSE 2013 | Question: 55

Relation R has eight attributes ABCDEFGH. Fields of R contain only atomic values. $F = \{\text{CH} \rightarrow \text{G, A} \rightarrow \text{BC, B} \rightarrow \text{CFH, E} \rightarrow \text{A, F} \rightarrow \text{EG}\}$ is a set of functional dependencies (FDs) so that F^+ is exactly the set of FDs that hold for R.

The relation R is

A. in 1NF, but not in 2NF.
B. in 2NF, but not in 3NF.
C. in 3NF, but not in BCNF.
D. in BCNF.

gatecse-2013 databases database-normalization normal

Answer key

5.5.31 Database Normalization: GATE CSE 2014 Set 1 | Question: 21

Consider the relation scheme $R = (E, F, G, H, I, J, K, L, M, N)$ and the set of functional dependencies

$$\{\{E, F\} \to \{G\}, \{F\} \to \{I, J\}, \{E, H\} \to \{K, L\}, \{K\} \to \{M\}, \{L\} \to \{N\}\}$$

on R. What is the key for R?

A. $\{E, F\}$
B. $\{E, F, H\}$
C. $\{E, F, H, K, L\}$
D. $\{E\}$

gatecse-2014-set1 databases database-normalization normal

Answer key

5.5.32 Database Normalization: GATE CSE 2014 Set 1 | Question: 30

Given the following two statements:

S1: Every table with two single-valued attributes is in 1NF, 2NF, 3NF and BCNF.

S2: $AB \to C, D \to E, E \to C$ is a minimal cover for the set of functional dependencies $AB \to C, D \to E, AB \to E, E \to C$.

Which one of the following is **CORRECT**?

A. S1 is TRUE and S2 is FALSE.
B. Both S1 and S2 are TRUE.
C. S1 is FALSE and S2 is TRUE.
D. Both S1 and S2 are FALSE.

gatecse-2014-set1 databases database-normalization normal

Answer key

5.5.33 Database Normalization: GATE CSE 2015 Set 3 | Question: 20

Consider the relation $X(P, Q, R, S, T, U)$ with the following set of functional dependencies

$F = \{$
$\{P, R\} \to \{S, T\},$
$\{P, S, U\} \to \{Q, R\}$
$\}$

Which of the following is the trivial functional dependency in F^+, where F^+ is closure to F?

A. $\{P, R\} \to \{S, T\}$
B. $\{P, R\} \to \{R, T\}$
C. $\{P, S\} \to \{S\}$
D. $\{P, S, U\} \to \{Q\}$

gatecse-2015-set3 databases database-normalization easy

Answer key

5.5.34 Database Normalization: GATE CSE 2016 Set 1 | Question: 21

Which of the following is NOT a superkey in a relational schema with attributes V, W, X, Y, Z and primary key $V\ Y$?

A. $VXYZ$
B. $VWXZ$
C. $VWXY$
D. $VWXYZ$

gatecse-2016-set1 databases database-normalization easy

Answer key

5.5.35 Database Normalization: GATE CSE 2016 Set 1 | Question: 23

A database of research articles in a journal uses the following schema.

$(\mathrm{VOLUME}, \mathrm{NUMBER}, \mathrm{STARTPAGE}, \mathrm{ENDPAGE}, \mathrm{TITLE}, \mathrm{YEAR}, \mathrm{PRICE})$

The primary key is '$(\mathrm{VOLUME}, \mathrm{NUMBER}, \mathrm{STARTPAGE}, \mathrm{ENDPAGE})$

and the following functional dependencies exist in the schema.

$$\begin{array}{ll} (\mathrm{VOLUME}, \mathrm{NUMBER}, \mathrm{STARTPAGE}, \mathrm{ENDPAGE}) & \rightarrow \mathrm{TITLE} \\ (\mathrm{VOLUME}, \mathrm{NUMBER}) & \rightarrow \mathrm{YEAR} \\ (\mathrm{VOLUME}, \mathrm{NUMBER}, \mathrm{STARTPAGE}, \mathrm{ENDPAGE}) & \rightarrow \mathrm{PRICE} \end{array}$$

The database is redesigned to use the following schemas

$(\mathrm{VOLUME}, \mathrm{NUMBER}, \mathrm{STARTPAGE}, \mathrm{ENDPAGE}, \mathrm{TITLE}, \mathrm{PRICE})$

$(\mathrm{VOLUME}, \mathrm{NUMBER}, \mathrm{YEAR})$

Which is the weakest normal form that the new database satisfies, but the old one does not?

A. $1\mathrm{NF}$
B. $2\mathrm{NF}$
C. $3\mathrm{NF}$
D. BCNF

gatecse-2016-set1 databases database-normalization normal

Answer key

5.5.36 Database Normalization: GATE CSE 2017 Set 1 | Question: 16

The following functional dependencies hold true for the relational schema $R\{V, W, X, Y, Z\}$:

- $V \rightarrow W$
- $VW \rightarrow X$
- $Y \rightarrow VX$
- $Y \rightarrow Z$

Which of the following is irreducible equivalent for this set of functional dependencies?

A. $V \rightarrow W$
$V \rightarrow X$
$Y \rightarrow V$
$Y \rightarrow Z$

B. $V \rightarrow W$
$W \rightarrow X$
$Y \rightarrow V$
$Y \rightarrow Z$

C. $V \rightarrow W$
$V \rightarrow X$
$Y \rightarrow V$
$Y \rightarrow X$
$Y \rightarrow Z$

D. $V \rightarrow W$
$W \rightarrow X$
$Y \rightarrow V$
$Y \rightarrow X$
$Y \rightarrow Z$

gatecse-2017-set1 databases database-normalization normal

Answer key

5.5.37 Database Normalization: GATE CSE 2018 | Question: 42

Consider the following four relational schemas. For each schema , all non-trivial functional dependencies are listed, The **bolded** attributes are the respective primary keys.

$\mathrm{Schema\ I:}$ Registration(rollno, courses)

Field 'courses' is a set-valued attribute containing the set of courses a student has registered for.

Non-trivial functional dependency

rollno $\rightarrow$ courses

$\mathrm{Schema\ II:}$ Registration (rollno, coursid, email)

Non-trivial functional dependencies:

rollno, courseid $\rightarrow$ email

email $\rightarrow$ rollno

$\mathrm{Schema\ III:}$ Registration (rollno, courseid, marks, grade)

Non-trivial functional dependencies:

rollno, courseid, $\rightarrow$ marks, grade marks $\rightarrow$ grade

Schema IV: Registration (rollno, courseid, credit)

Non-trivial functional dependencies:

rollno, courseid $\rightarrow$ credit

courseid $\rightarrow$ credit

Which one of the relational schemas above is in 3NF but not in BCNF?

A. Schema I
B. Schema II
C. Schema III
D. Schema IV

gatecse-2018 databases database-normalization normal two-marks

Answer key

5.5.38 Database Normalization: GATE CSE 2019 | Question: 32

Let the set of functional dependencies $F = \{QR \rightarrow S,\ R \rightarrow P,\ S \rightarrow Q\}$ hold on a relation schema $X = (PQRS)$. X is not in BCNF. Suppose X is decomposed into two schemas Y and Z, where $Y = (PR)$ and $Z = (QRS)$.

Consider the two statements given below.

I. Both Y and Z are in BCNF
II. Decomposition of X into Y and Z is dependency preserving and lossless

Which of the above statements is/are correct?

A. Both I and II
B. I only
C. II only
D. Neither I nor II

gatecse-2019 databases database-normalization two-marks

Answer key

5.5.39 Database Normalization: GATE CSE 2020 | Question: 36

Consider a relational table R that is in $3NF$, but not in BCNF. Which one of the following statements is TRUE?

A. R has a nontrivial functional dependency $X \rightarrow A$, where X is not a superkey and A is a prime attribute.
B. R has a nontrivial functional dependency $X \rightarrow A$, where X is not a superkey and A is a non-prime attribute and X is not a proper subset of any key.
C. R has a nontrivial functional dependency $X \rightarrow A$, where X is not a superkey and A is a non-prime attribute and X is a proper subset of some key
D. A cell in R holds a set instead of an atomic value.

gatecse-2020 databases database-normalization two-marks

Answer key

5.5.40 Database Normalization: GATE CSE 2021 Set 1 | Question: 33

Consider the relation $R(P,Q,S,T,X,Y,Z,W)$ with the following functional dependencies.

$$PQ \rightarrow X; \quad P \rightarrow YX; \quad Q \rightarrow Y; \quad Y \rightarrow ZW$$

Consider the decomposition of the relation R into the constituent relations according to the following two decomposition schemes.

- $D_1: \quad R = [(P,Q,S,T);\ (P,T,X);\ (Q,Y);\ (Y,Z,W)]$
- $D_2: \quad R = [(P,Q,S);\ (T,X);\ (Q,Y);\ (Y,Z,W)]$

Which one of the following options is correct?

A. D_1 is a lossless decomposition, but D_2 is a lossy decomposition
B. D_1 is a lossy decomposition, but D_2 is a lossless decomposition
C. Both D_1 and D_2 are lossless decompositions

D. Both D_1 and D_2 are lossy decompositions

gatecse-2021-set1 databases database-normalization two-marks

Answer key

5.5.41 Database Normalization: GATE CSE 2021 Set 2 | Question: 40

Suppose the following functional dependencies hold on a relation U with attributes P, Q, R, S, and T:

- $P \to QR$
- $RS \to T$

Which of the following functional dependencies can be inferred from the above functional dependencies?

A. $PS \to T$ B. $R \to T$ C. $P \to R$ D. $PS \to Q$

gatecse-2021-set2 multiple-selects databases database-normalization two-marks

Answer key

5.5.42 Database Normalization: GATE CSE 2022 | Question: 21

Consider a relation $R(A, B, C, D, E)$ with the following three functional dependencies.

$AB \to C;\ BC \to D;\ C \to E;$ 8

The number of superkeys in the relation R is ______________ .

gatecse-2022 numerical-answers databases database-normalization one-mark

Answer key

5.5.43 Database Normalization: GATE CSE 2022 | Question: 4

In a relational data model, which one of the following statements is TRUE?

A. A relation with only two attributes is always in BCNF.
B. If all attributes of a relation are prime attributes, then the relation is in BCNF.
C. Every relation has at least one non-prime attribute.
D. BCNF decompositions preserve functional dependencies.

gatecse-2022 databases database-normalization one-mark

Answer key

5.5.44 Database Normalization: GATE CSE 2024 | Set 1 | Question: 12

Which of the following statements about a relation $\mathbf{R}$ in first normal form (1NF) is/are TRUE?

A. $\mathbf{R}$ can have a multi-attribute key
B. $\mathbf{R}$ cannot have a foreign key
C. $\mathbf{R}$ cannot have a composite attribute
D. $\mathbf{R}$ cannot have more than one candidate key

gatecse2024-set1 multiple-selects databases database-normalization one-mark

Answer key

5.5.45 Database Normalization: GATE CSE 2024 | Set 1 | Question: 34

The symbol $\to$ indicates functional dependency in the context of a relational database. Which of the following options is/are TRUE?

A. $(X, Y) \to (Z, W)$ implies $X \to (Z, W)$ x
B. $(X, Y) \to (Z, W)$ implies $(X, Y) \to Z$

C. $((X, Y) \rightarrow Z$ and $W \rightarrow Y)$ implies $(X, W) \rightarrow Z$
D. $(X \rightarrow Y$ and $Y \rightarrow Z)$ implies $X \rightarrow Z$

gatecse2024-set1 multiple-selects databases database-normalization two-marks

Answer key

5.5.46 Database Normalization: GATE CSE 2024 | Set 2 | Question: 46

A functional dependency $F : X \rightarrow Y$ is termed as a useful functional dependency if and only if it satisfies all the following three conditions:

- X is not the empty set.
- Y is not the empty set.
- Intersection of X and Y is the empty set.

50

For a relation R with 4 attributes, the total number of possible useful functional dependencies is ___________.

gatecse2024-set2 numerical-answers databases database-normalization two-marks

Answer key

5.5.47 Database Normalization: GATE CSE 2025 | Set 2 | Question: 36

Consider the following relational schema along with all the functional dependencies that hold on them.

$$R1(A, B, C, D, E) : \{D \rightarrow E, EA \rightarrow B, EB \rightarrow C\}$$
$$R2(A, B, C, D) : \{A \rightarrow D, A \rightarrow B, C \rightarrow A\}$$

Which of the following statement(s) is/are TRUE?

A. $R1$ is in 3 NF
B. $R2$ is in 3 NF
C. $R1$ is NOT in 3 NF
D. $R2$ is NOT in 3 NF

gatecse2025-set2 databases database-normalization multiple-selects two-marks

Answer key

5.5.48 Database Normalization: GATE DS&AI 2024 | Question: 36

Given the relational schema $R = (U, V, W, X, Y, Z)$ and the set of functional dependencies:

$$\{U \rightarrow V, U \rightarrow W, WX \rightarrow Y, WX \rightarrow Z, V \rightarrow X\}$$

Which of the following functional dependencies can be derived from the above set?

A. $VW \rightarrow YZ$
B. $WX \rightarrow YZ$
C. $VW \rightarrow U$
D. $VW \rightarrow Y$

gate-ds-ai-2024 databases database-normalization multiple-selects two-marks

Answer key

5.5.49 Database Normalization: GATE Data Science and Artificial Intelligence 2024 | Sample Paper | Question: 26

Given the following relation instances

X	Y	Z
1	4	2
1	5	3
1	4	3
1	5	2
3	2	1

Which of the following conditions is/are **TRUE**?

A. $\mathrm{XY} -> \mathrm{Z}$ and $\mathrm{Z} -> \mathrm{Y}$
B. $\mathrm{YZ} -> \mathrm{X}$ and $\mathrm{X} ->> \mathrm{Y}$
C. $\mathrm{Y} -> \mathrm{X}$ and $\mathrm{Y} ->> \mathrm{X}$
D. $\mathrm{XZ} -> \mathrm{Y}$ and $\mathrm{Y} -> \mathrm{X}$

gateda-sample-paper-2024 database-normalization

Answer key

5.5.50 Database Normalization: GATE IT 2004 | Question: 75

A relation Empdtl is defined with attributes empcode (unique), name, street, city, state and pincode. For any pincode, there is only one city and state. Also, for any given street, city and state, there is just one pincode. In normalization terms, Empdtl is a relation in

A. 1NF only
B. 2NF and hence also in 1NF
C. 3NF and hence also in 2NF and 1NF
D. BCNF and hence also in 3NF, 2NF and 1NF

gateit-2004 databases database-normalization normal

Answer key

5.5.51 Database Normalization: GATE IT 2005 | Question: 22

A table has fields F_1, F_2, F_3, F_4, F_5 with the following functional dependencies

- $F_1 \rightarrow F_3, F_2 \rightarrow F_4, (F_1 . F_2) \rightarrow F_5$

In terms of Normalization, this table is in

A. $1\ \mathrm{NF}$
B. $2\ \mathrm{NF}$
C. $3\ \mathrm{NF}$
D. None of these

gateit-2005 databases database-normalization easy

Answer key

5.5.52 Database Normalization: GATE IT 2005 | Question: 70

In a schema with attributes A, B, C, D and E following set of functional dependencies are given

- $A \rightarrow B$
- $A \rightarrow C$
- $CD \rightarrow E$
- $B \rightarrow D$
- $E \rightarrow A$

Which of the following functional dependencies is NOT implied by the above set?

A. $CD \rightarrow AC$
B. $BD \rightarrow CD$
C. $BC \rightarrow CD$
D. $AC \rightarrow BC$

gateit-2005 databases database-normalization normal

Answer key

5.5.53 Database Normalization: GATE IT 2006 | Question: 60

Consider a relation R with five attributes V, W, X, Y, and Z. The following functional dependencies hold: $VY \rightarrow W, WX \rightarrow Z$, and $ZY \rightarrow V$.

Which of the following is a candidate key for R?

A. VXZ B. VXY C. $VWXY$ D. $VWXYZ$

gateit-2006 databases database-normalization normal

Answer key

5.5.54 Database Normalization: GATE IT 2008 | Question: 61

Let $R(A, B, C, D)$ be a relational schema with the following functional dependencies : $A \rightarrow B$, $B \rightarrow C$, $C \rightarrow D$ and $D \rightarrow B$. The decomposition of R into $(A, B), (B, C), (B, D)$

A. gives a lossless join, and is dependency preserving
B. gives a lossless join, but is not dependency preserving
C. does not give a lossless join, but is dependency preserving
D. does not give a lossless join and is not dependency preserving

gateit-2008 databases database-normalization normal

Answer key

5.5.55 Database Normalization: GATE IT 2008 | Question: 62

Let $R(A, B, C, D, E, P, G)$ be a relational schema in which the following functional dependencies are known to hold: $AB \rightarrow CD, DE \rightarrow P, C \rightarrow E, P \rightarrow C$ and $B \rightarrow G$. The relational schema R is

A. in BCNF
B. in 3NF, but not in BCNF
C. in 2NF, but not in 3NF
D. not in 2NF

gateit-2008 databases database-normalization normal

Answer key

5.5.56 Database Normalization: GATE2001-1.23, UGCNET-June2012-III: 18

Consider a schema $R(A, B, C, D)$ and functional dependencies $A \rightarrow B$ and $C \rightarrow D$. Then the decomposition of R into $R_1(A, B)$ and $R_2(C, D)$ is

A. dependency preserving and lossless join
B. lossless join but not dependency preserving
C. dependency preserving but not lossless join
D. not dependency preserving and not lossless join

gate1998 databases ugcnetcse-june2012-paper3 database-normalization

Answer key

5.6 Decomposition (1)

5.6.1 Decomposition: GATE DA 2025 | Question: 6

If a relational decomposition is not dependency-preserving, which one of the following relational operators will be executed more frequently in order to maintain the dependencies?

A. Selection B. Projection C. Join D. Set union

gateda-2025 databases decomposition relational-algebra easy one-mark

Answer key

5.7 ER Diagram (12)

5.7.1 ER Diagram: GATE CSE 2005 | Question: 75

Let E_1 and E_2 be two entities in an E/R diagram with simple-valued attributes. R_1 and R_2 are two relationships between E_1 and E_2, where R_1 is one-to-many and R_2 is many-to-many. R_1 and R_2 do not have any attributes of their own. What is the minimum number of tables required to represent this situation in the relational model?

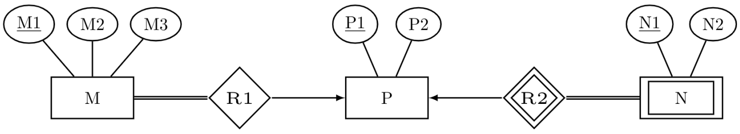
A. 2
B. 3
C. 4
D. 5

gatecse-2005 databases er-diagram normal

Answer key

5.7.2 ER Diagram: GATE CSE 2008 | Question: 82

Consider the following ER diagram



The minimum number of tables needed to represent M, N, P, $R1$, $R2$ is

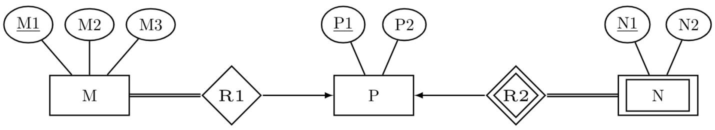
A. 2
B. 3
C. 4
D. 5

gatecse-2008 databases er-diagram normal

Answer key

5.7.3 ER Diagram: GATE CSE 2008 | Question: 83

Consider the following ER diagram



The minimum number of tables needed to represent M, N, P, $R1$, $R2$ is

Which of the following is a correct attribute set for one of the tables for the minimum number of tables needed to represent M, N, P, $R1$, $R2$?

A. $M1, M2, M3, P1$
B. $M1, P1, N1, N2$
C. $M1, P1, N1$
D. $M1, P1$

gatecse-2008 databases er-diagram normal

Answer key

5.7.4 ER Diagram: GATE CSE 2012 | Question: 14

Given the basic ER and relational models, which of the following is **INCORRECT**?

A. An attribute of an entity can have more than one value
B. An attribute of an entity can be composite
C. In a row of a relational table, an attribute can have more than one value
D. In a row of a relational table, an attribute can have exactly one value or a NULL value

gatecse-2012 databases normal er-diagram

Answer key

5.7.5 ER Diagram: GATE CSE 2015 Set 1 | Question: 41

Consider an Entity-Relationship (ER) model in which entity sets E_1 and E_2 are connected by an $m:n$ relationship R_{12}. E_1 and E_3 are connected by a $1:n$ (1 on the side of E_1 and n on the side of E_3) relationship R_{13}.

E_1 has two-singled attributes a_{11} and a_{12} of which a_{11} is the key attribute. E_2 has two singled-valued attributes a_{21} and a_{22} of which a_{21} is the key attribute. E_3 has two single-valued attributes a_{31} and a_{32} of which a_{31} is the key attribute. The relationships do not have any attributes.

If a relational model is derived from the above ER model, then the minimum number of relations that would be generated if all relation are in 3NF is________________.

gatecse-2015-set1 databases er-diagram normal numerical-answers

Answer key☟

5.7.6 ER Diagram: GATE CSE 2017 Set 2 | Question: 17

An ER model of a database consists of entity types A and B. These are connected by a relationship R which does not have its own attribute. Under which one of the following conditions, can the relational table for R be merged with that of A?

A. Relationship R is one-to-many and the participation of A in R is total
B. Relationship R is one-to-many and the participation of A in R is partial
C. Relationship R is many-to-one and the participation of A in R is total
D. Relationship R is many-to-one and the participation of A in R is partial

gatecse-2017-set2 databases er-diagram normal

Answer key☟

5.7.7 ER Diagram: GATE CSE 2018 | Question: 11

In an Entity-Relationship (ER) model, suppose R is a many-to-one relationship from entity set E1 to entity set E2. Assume that E1 and E2 participate totally in R and that the cardinality of E1 is greater than the cardinality of E2.

Which one of the following is true about R?

A. Every entity in E1 is associated with exactly one entity in E2
B. Some entity in E1 is associated with more than one entity in E2
C. Every entity in E2 is associated with exactly one entity in E1
D. Every entity in E2 is associated with at most one entity in E1

gatecse-2018 databases er-diagram normal one-mark

Answer key☟

5.7.8 ER Diagram: GATE CSE 2020 | Question: 14

Which one of the following is used to represent the supporting many-one relationships of a weak entity set in an entity-relationship diagram?

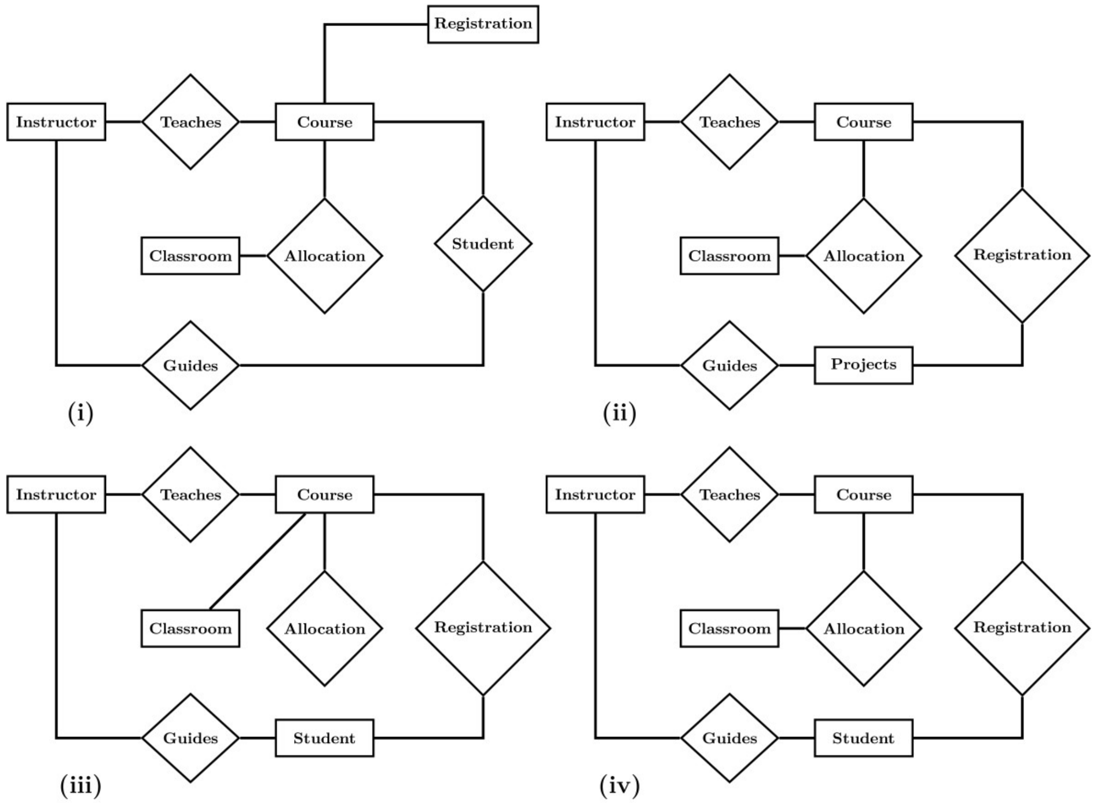
A. Diamonds with double/bold border
B. Rectangles with double/bold border
C. Ovals with double/bold border
D. Ovals that contain underlined identifiers

gatecse-2020 databases er-diagram one-mark

Answer key☟

5.7.9 ER Diagram: GATE CSE 2024 | Set 1 | Question: 10

Let S be the specification: "Instructors teach courses. Students register for courses. Courses are allocated classrooms. Instructors guide students." Which one of the following ER diagrams CORRECTLY represents S?



A. (i)
B. (ii)
C. (iii)
D. (iv)

gatecse2024-set1 databases er-diagram one-mark

Answer key☟

5.7.10 ER Diagram: GATE CSE 2024 | Set 2 | Question: 10

In the context of owner and weak entity sets in the ER (Entity-Relationship) data model, which one of the following statements is TRUE?

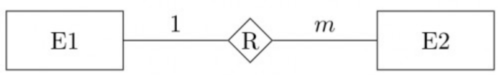
A. The weak entity set MUST have total participation in the identifying relationship
B. The owner entity set MUST have total participation in the identifying relationship
C. Both weak and owner entity sets MUST have total participation in the identifying relationship
D. Neither weak entity set nor owner entity set MUST have total participation in the identifying relationship

gatecse2024-set2 databases er-diagram one-mark

Answer key☟

5.7.11 ER Diagram: GATE IT 2004 | Question: 73

Consider the following entity relationship diagram (ERD), where two entities $E1$ and $E2$ have a relation R of cardinality 1:m.



The attributes of $E1$ are $A11$, $A12$ and $A13$ where $A11$ is the key attribute. The attributes of $E2$ are $A21$, $A22$ and $A23$ where $A21$ is the key attribute and $A23$ is a multi-valued attribute. Relation R does not have any attribute. A relational database containing minimum number of tables with each table satisfying the requirements of the third normal form ($3NF$) is designed from the above ERD. The number of tables in the database is

A. 2
B. 3
C. 5
D. 4

gateit-2004 databases er-diagram normal

Answer key

5.7.12 ER Diagram: GATE IT 2005 | Question: 21

Consider the entities 'hotel room', and 'person' with a many to many relationship 'lodging' as shown below:

If we wish to store information about the rent payment to be made by person (s) occupying different hotel rooms, then this information should appear as an attribute of

A. Person
B. Hotel Room
C. Lodging
D. None of these

gateit-2005 databases er-diagram easy

Answer key

5.8 Functional Dependency (2)

5.8.1 Functional Dependency: GATE CSE 2025 | Set 1 | Question: 37

Consider a relational schema team (name,city,owner), with functional dependencies $\{\text{name} \rightarrow \text{city}, \text{name} \rightarrow \text{owner}\}$.

The relation team is decomposed into two relations, $\text{t1}(\text{name,city})$ and $\text{t2}(\text{name, owner})$. Which of the following statement(s) is/are TRUE?

A. The relation team is NOT in BCNF
.
B. The relations $t1$ and $t2$ are in BCNF.
C. The decomposition constitutes a lossless join.
D. The relation team is NOT in 3 NF .

gatecse2025-set1 databases functional-dependency database-normalization multiple-selects two-marks

Answer key

5.8.2 Functional Dependency: GATE DA 2025 | Question: 47

Consider a database relation R with attributes ABCDEFG, and having the following functional dependencies:

$$\text{A} \rightarrow \text{BCEF} \quad \text{E} \rightarrow \text{DG} \quad \text{BC} \rightarrow \text{A}$$

Which of the following statements is/are correct?

A. A is the only candidate key of R
B. A, BC are the candidate keys of R
C. $\text{A}, \text{BC}, \text{E}$ are the candidate keys of R
D. Relation R is not in Boyce-Codd Normal Form (BCNF)

gateda-2025 databases functional-dependency multiple-selects two-marks

Answer key

5.9 Indexing (13)

5.9.1 Indexing: GATE CSE 1989 | Question: 4-xiv

For secondary key processing which of the following file organizations is preferred? Give a one line justification:

A. Indexed sequential file organization.
B. Two-way linked list.
C. Inverted file organization.
D. Sequential file organization.

gate1989 normal databases indexing descriptive

Answer key

5.9.2 Indexing: GATE CSE 1990 | Question: 10b

One giga bytes of data are to be organized as an indexed-sequential file with a uniform blocking factor 8. Assuming a block size of 1 Kilo bytes and a block refrencing pointer size of 32 bits, find out the number of levels of indexing that would be required and the size of the index at each level. Determine also the size of the master index. The referencing capability (fanout ratio) per block of index storage may be considered to be 32.

gate1990 databases indexing descriptive

Answer key

5.9.3 Indexing: GATE CSE 1993 | Question: 14

An ISAM (indexed sequential) file consists of records of size 64 bytes each, including key field of size 14 bytes. An address of a disk block takes 2 bytes. If the disk block size is 512 bytes and there are $16K$ records, compute the size of the data and index areas in terms of number blocks. How many levels of tree do you have for the index?

gate1993 databases indexing normal descriptive

Answer key

5.9.4 Indexing: GATE CSE 1998 | Question: 1.35

There are five records in a database.

Name	Age	Occupation	Category
Rama	27	CON	A
Abdul	22	ENG	A
Jennifer	28	DOC	B
Maya	32	SER	D
Dev	24	MUS	C

There is an index file associated with this and it contains the values $1, 3, 2, 5$ and 4. Which one of the fields is the index built from?

A. Age
B. Name
C. Occupation
D. Category

gate1998 databases indexing normal

Answer key

5.9.5 Indexing: GATE CSE 2008 | Question: 16, ISRO2016-60

A clustering index is defined on the fields which are of type

A. non-key and ordering
B. non-key and non-ordering
C. key and ordering
D. key and non-ordering

gatecse-2008 easy databases indexing isro2016

Answer key

5.9.6 Indexing: GATE CSE 2008 | Question: 70

Consider a file of 16384 records. Each record is 32 bytes long and its key field is of size 6 bytes. The file is ordered on a non-key field, and the file organization is unspanned. The file is stored in a file system with block size 1024 bytes, and the size of a block pointer is 10 bytes. If the secondary index is built on the key field of the file, and a multi-level index scheme is used to store the secondary index, the number of first-level and second-level blocks in the multi-level index are respectively

A. 8 and 0
B. 128 and 6
C. 256 and 4
D. 512 and 5

gatecse-2008 databases indexing normal

Answer key

5.9.7 Indexing: GATE CSE 2011 | Question: 39

Consider a relational table r with sufficient number of records, having attributes $A_1, A_2, \ldots, A_n$ and let $1 \leq p \leq n$. Two queries $Q1$ and $Q2$ are given below.

- $Q1 : \pi_{A_1,\ldots,A_p}\left(\sigma_{A_p=c}(r)\right)$ where c is a constant
- $Q2 : \pi_{A_1,\ldots,A_p}\left(\sigma_{c_1 \leq A_p \leq c_2}(r)\right)$ where c_1 and c_2 are constants.

The database can be configured to do ordered indexing on A_p or hashing on A_p. Which of the following statements is **TRUE**?

A. Ordered indexing will always outperform hashing for both queries
B. Hashing will always outperform ordered indexing for both queries
C. Hashing will outperform ordered indexing on $Q1$, but not on $Q2$
D. Hashing will outperform ordered indexing on $Q2$, but not on $Q1$

gatecse-2011 databases indexing normal

Answer key

5.9.8 Indexing: GATE CSE 2013 | Question: 15

An index is clustered, if

A. it is on a set of fields that form a candidate key
B. it is on a set of fields that include the primary key
C. the data records of the file are organized in the same order as the data entries of the index
D. the data records of the file are organized not in the same order as the data entries of the index

gatecse-2013 databases indexing normal

Answer key

5.9.9 Indexing: GATE CSE 2015 Set 1 | Question: 24

A file is organized so that the ordering of the data records is the same as or close to the ordering of data entries in some index. Then that index is called

A. Dense B. Sparse C. Clustered D. Unclustered

gatecse-2015-set1 databases indexing easy

Answer key

5.9.10 Indexing: GATE CSE 2020 | Question: 54

Consider a database implemented using B^+ tree for file indexing and installed on a disk drive with block size of 4 KB. The size of search key is 12 bytes and the size of tree/disk pointer is 8 bytes. Assume that the database has one million records. Also assume that no node of the B^+ tree and no records are present initially in main memory. Consider that each record fits into one disk block. The minimum number of disk accesses required to retrieve any record in the database is ________

gatecse-2020 numerical-answers databases b-tree indexing two-marks

Answer key

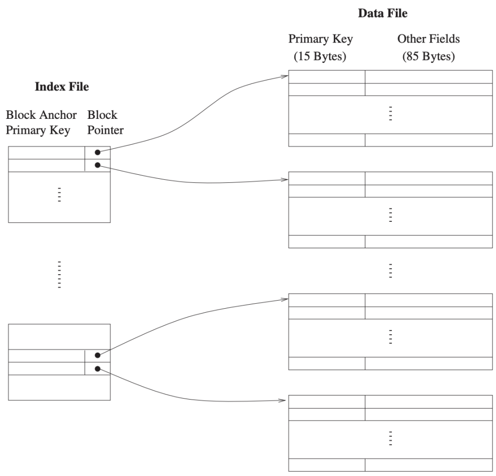
5.9.11 Indexing: GATE CSE 2021 Set 2 | Question: 21

A data file consisting of $1,50,000$ student-records is stored on a hard disk with block size of 4096 bytes. The data file is sorted on the primary key RollNo. The size of a record pointer for this disk is 7 bytes. Each student-record has a candidate key attribute called ANum of size 12 bytes. Suppose an index file with records consisting of two fields, ANum value and the record pointer the corresponding student record, is built and stored on the same disk. Assume that the records of data file and index file are not split across disk blocks. The number of blocks in the index file is ________ gatecse-2021-set2 numerical-answers databases indexing one-mark

Answer key

5.9.12 Indexing: GATE CSE 2023 | Question: 52

Consider a database of fixed-length records, stored as an ordered file. The database has $25,000$ records, with each record being 100 bytes, of which the primary key occupies 15 bytes. The data file is block-aligned in that each data record is fully contained within a block. The database is indexed by a primary index file, which is also stored as a block-aligned ordered file. The figure below depicts this indexing scheme.



Suppose the block size of the file system is 1024 bytes, and a pointer to a block occupies 5 bytes. The system uses binary search on the index file to search for a record with a given key. You may assume that a binary search on an index file of b blocks takes $\lceil \log_2 b \rceil$ block accesses in the worst case.

Given a key, the number of block accesses required to identify the block in the data file that may contain a record with the key, in the worst case, is _____________.

gatecse-2023 databases file-system indexing numerical-answers two-marks

Answer key

5.9.13 Indexing: GATE CSE 2024 | Set 2 | Question: 16

Which of the following file organizations is/are $\mathrm{I/O}$ efficient for the scan operation in DBMS?

A. Sorted
B. Heap
C. Unclustered tree index
D. Unclustered hash index

gatecse2024-set2 databases multiple-selects indexing one-mark

Answer key

5.10 Joins (7)

5.10.1 Joins: GATE CSE 2004 | Question: 14

Consider the following relation schema pertaining to a students database:

- Students (rollno, name, address)
- Enroll (rollno, courseno, coursename)

where the primary keys are shown underlined. The number of tuples in the student and Enroll tables are 120 and 8 respectively. What are the maximum and minimum number of tuples that can be present in (Student * Enroll), where '*' denotes natural join?

A. $8, 8$
B. $120, 8$
C. $960, 8$
D. $960, 120$

gatecse-2004 databases easy joins natural-join

Answer key

5.10.2 Joins: GATE CSE 2012 | Question: 50

Consider the following relations A, B and C :

A

ID	Name	Age
12	Arun	60
15	Shreya	24
99	Rohit	11

B

ID	Name	Age
15	Shreya	24
25	Hari	40
98	Rohit	20
99	Rohit	11

C

ID	Phone	Area
10	2200	02
99	2100	01

How many tuples does the result of the following relational algebra expression contain? Assume that the schema of $A \cup B$ is the same as that of A.

$$(A \cup B) \bowtie_{A.Id>40 \vee C.Id<15} C$$

A. 7 B. 4 C. 5 D. 9

gatecse-2012 databases joins normal

Answer key

5.10.3 Joins: GATE CSE 2014 Set 2 | Question: 30

Consider a join (relation algebra) between relations $r(R)$ and $s(S)$ using the nested loop method. There are 3 buffers each of size equal to disk block size, out of which one buffer is reserved for intermediate results. Assuming $\text{size}(r(R)) < \text{size}(s(S))$, the join will have fewer number of disk block accesses if

A. relation $r(R)$ is in the outer loop.
B. relation $s(S)$ is in the outer loop.
C. join selection factor between $r(R)$ and $s(S)$ is more than 0.5.
D. join selection factor between $r(R)$ and $s(S)$ is less than 0.5.

gatecse-2014-set2 databases normal joins

Answer key

5.10.4 Joins: GATE IT 2005 | Question: 82a

A database table T_1 has 2000 records and occupies 80 disk blocks. Another table T_2 has 400 records and occupies 20 disk blocks. These two tables have to be joined as per a specified join condition that needs to be evaluated for every pair of records from these two tables. The memory buffer space available can hold exactly one block of records for T_1 and one block of records for T_2 simultaneously at any point in time. No index is available on either table.

If Nested-loop join algorithm is employed to perform the join, with the most appropriate choice of table to be used in outer loop, the number of block accesses required for reading the data are

A. 800000 B. 40080 C. 32020 D. 100

gateit-2005 databases normal joins

Answer key

5.10.5 Joins: GATE IT 2005 | Question: 82b

A database table T_1 has 2000 records and occupies 80 disk blocks. Another table T_2 has 400 records and occupies 20 disk blocks. These two tables have to be joined as per a specified join condition that needs to be evaluated for every pair of records from these two tables. The memory buffer space available can hold exactly one block of records for T_1 and one block of records for T_2 simultaneously at any point in time. No index is available on either table.

If, instead of Nested-loop join, Block nested-loop join is used, again with the most appropriate choice of table in the outer loop, the reduction in number of block accesses required for reading the data will be

A. 0 B. 30400 C. 38400 D. 798400

gateit-2005 databases normal joins

Answer key☟

5.10.6 Joins: GATE IT 2006 | Question: 14

Consider the relations $r_1(\mathrm{P, Q, R})$ and $r_2(\mathrm{R, S, T})$ with primary keys P and R respectively. The relation r_1 contains 2000 tuples and r_2 contains 2500 tuples. The maximum size of the join $r_1 \bowtie r_2$ is :

A. 2000 B. 2500 C. 4500 D. 5000

gateit-2006 databases joins natural-join normal

Answer key☟

5.10.7 Joins: GATE IT 2007 | Question: 68

Consider the following relation schemas :

- b-Schema = (b-name, b-city, assets)
- a-Schema = (a-num, b-name, bal)
- d-Schema = (c-name, a-number)

Let branch, account and depositor be respectively instances of the above schemas. Assume that account and depositor relations are much bigger than the branch relation.

Consider the following query:

$\Pi_{\text{c-name}}$ ($\sigma_{\text{b-city = "Agra"} \wedge \text{ bal < 0}}$ (branch ⋈ (account ⋈ depositor)

Which one of the following queries is the most efficient version of the above query ?

A. $\Pi_{\text{c-name}}$ ($\sigma_{\text{bal < 0}}$ ($\sigma_{\text{b-city = "Agra"}}$ branch ⋈ account) ⋈ depositor)
B. $\Pi_{\text{c-name}}$ ($\sigma_{\text{b-city = "Agra"}}$ branch ⋈ ($\sigma_{\text{bal < 0}}$ account ⋈ depositor))
C. $\Pi_{\text{c-name}}$ (($\sigma_{\text{b-city = "Agra"}}$ branch ⋈ $\sigma_{\text{b-city = "Agra"} \wedge \text{ bal < 0}}$ account) ⋈ depositor)
D. $\Pi_{\text{c-name}}$ ($\sigma_{\text{b-city = "Agra"}}$ branch ⋈ ($\sigma_{\text{b-city = "Agra"} \wedge \text{ bal < 0}}$ account ⋈ depositor))

gateit-2007 databases joins relational-algebra normal

Answer key☟

5.11 Multivalued Dependency 4nf (1)

5.11.1 Multivalued Dependency 4nf: GATE IT 2007 | Question: 67

Consider the following implications relating to functional and multivalued dependencies given below, which may or may not be correct.

i. if $A \rightarrow\rightarrow B$ and $A \rightarrow\rightarrow C$ then $A \rightarrow BC$
ii. if $A \rightarrow B$ and $A \rightarrow C$ then $A \rightarrow\rightarrow BC$
iii. if $A \rightarrow\rightarrow BC$ and $A \rightarrow B$ then $A \rightarrow C$
iv. if $A \rightarrow BC$ and $A \rightarrow B$ then $A \rightarrow\rightarrow C$

Exactly how many of the above implications are valid?

A. 0 B. 1 C. 2 D. 3

gateit-2007 databases database-normalization multivalued-dependency-4nf normal

Answer key☟

5.12 Natural Join (3)

5.12.1 Natural Join: GATE CSE 2005 | Question: 30

Let r be a relation instance with schema R = (A, B, C, D). We define $r_1 = \pi_{A,B,C}(R)$ and $r_2 = \pi_{A,D}(r)$. Let $s = r_1 * r_2$ where $*$ denotes natural join. Given that the decomposition of r into r_1 and r_2 is lossy, which one of the following is TRUE?

A. $s \subset r$ B. $r \cup s = r$ C. $r \subset s$ D. $r * s = s$

gatecse-2005 databases relational-algebra natural-join normal

Answer key☟

5.12.2 Natural Join: GATE CSE 2010 | Question: 43

The following functional dependencies hold for relations $R(A, B, C)$ and $S(B, D, E)$.

- $B \rightarrow A$
- $A \rightarrow C$

The relation R contains 200 tuples and the relation S contains 100 tuples. What is the maximum number of tuples possible in the natural join $R \bowtie S$?

A. 100 B. 200 C. 300 D. 2000

gatecse-2010 databases normal natural-join database-normalization

Answer key☟

5.12.3 Natural Join: GATE CSE 2015 Set 2 | Question: 32

Consider two relations $R_1(A, B)$ with the tuples $(1, 5), (3, 7)$ and $R_2(A, C) = (1, 7), (4, 9)$.

Assume that $R(A, B, C)$ is the full natural outer join of R_1 and R_2. Consider the following tuples of the form (A, B, C) :

$a = (1, 5, null), b = (1, null, 7), c = (3, null, 9), d = (4, 7, null), e = (1, 5, 7),$

$f = (3, 7, null), g = (4, null, 9).$

Which one of the following statements is correct?

A. R contains a, b, e, f, g but not c, d.
B. R contains all a, b, c, d, e, f, g.
C. R contains e, f, g but not a, b.
D. R contains e but not f, g.

gatecse-2015-set2 databases normal natural-join

Answer key☟

5.13 Query (1)

5.13.1 Query: GATE CSE 1997 | Question: 76-b

Consider the following relational database schema:

- EMP (eno name, age)
- PROJ (pno name)
- INVOLVED (eno, pno)

EMP contains information about employees. PROJ about projects and involved about which employees involved in which projects. The underlined attributes are the primary keys for the respective relations.

State in English (in not more than 15 words)

What the following relational algebra expressions are designed to determine

i. $\Pi_{eno}(\text{INVOLVED}) - \Pi_{eno}((\Pi_{eno}(\text{INVOLVED}) \times \Pi_{pno}(\text{PROJ})) - \text{INVOLVED})$
ii. $\Pi_{age}(\text{EMP}) - \Pi_{age}(\sigma_{E.age<Emp.age}((\rho E(\text{EMP}) \times \text{EMP}))$

(Note: $\rho E(\text{EMP})$ conceptually makes a copy of EMP and names it E (ρ is called the rename operator))

gate1997 databases sql descriptive normal relational-algebra query

Answer key☟

5.14 Referential Integrity (5)

5.14.1 Referential Integrity: GATE CSE 1997 | Question: 6.10, ISRO2016-54

Let $R(a, b, c)$ and $S(d, e, f)$ be two relations in which d is the foreign key of S that refers to the primary key of R. Consider the following four operations R and S

I. Insert into R
II. Insert into S
III. Delete from R
IV. Delete from S

Which of the following can cause violation of the referential integrity constraint above?

A. Both I and IV
B. Both II and III
C. All of these
D. None of these

gate1997 databases referential-integrity easy isro2016

Answer key

5.14.2 Referential Integrity: GATE CSE 2005 | Question: 76

The following table has two attributes A and C where A is the primary key and C is the foreign key referencing A with on-delete cascade.

A	C
2	4
3	4
4	3
5	2
7	2
9	5
6	4

The set of all tuples that must be additionally deleted to preserve referential integrity when the tuple $(2, 4)$ is deleted is:

A. $(3,4)$ and $(6,4)$
B. $(5,2)$ and $(7,2)$
C. $(5,2), (7,2)$ and $(9,5)$
D. $(3,4), (4,3)$ and $(6,4)$

gatecse-2005 databases referential-integrity normal

Answer key

5.14.3 Referential Integrity: GATE CSE 2012 | Question: 43

Suppose $R_1(\underline{A}, B)$ and $R_2(\underline{C}, D)$ are two relation schemas. Let r_1 and r_2 be the corresponding relation instances. B is a foreign key that refers to C in R_2. If data in r_1 and r_2 satisfy referential integrity constraints, which of the following is **ALWAYS TRUE**?

A. $\prod_B(r_1) - \prod_C(r_2) = \varnothing$
B. $\prod_C(r_2) - \prod_B(r_1) = \varnothing$
C. $\prod_B(r_1) = \prod_C(r_2)$
D. $\prod_B(r_1) - \prod_C(r_2) \neq \varnothing$

gatecse-2012 databases relational-algebra normal referential-integrity

Answer key

5.14.4 Referential Integrity: GATE CSE 2017 Set 2 | Question: 19

Consider the following tables $T1$ and $T2$.

$T1$

P	Q
2	2
3	8
7	3
5	8
6	9
8	5
9	8

$T2$

R	S
2	2
8	3
3	2
9	7
5	7
7	2

In table $T1$ **P** is the primary key and **Q** is the foreign key referencing **R** in table $T2$ with on-delete cascade and on-update cascade. In table $T2$, **R** is the primary key and **S** is the foreign key referencing **P** in table $T1$ with on-delete set NULL and on-update cascade. In order to delete record $\langle 3, 8 \rangle$ from the table $T1$, the number of additional records that need to be deleted from table $T1$ is _______

gatecse-2017-set2 databases numerical-answers referential-integrity normal

Answer key

5.14.5 Referential Integrity: GATE CSE 2021 Set 2 | Question: 6

Consider the following statements $S1$ and $S2$ about the relational data model:

- $S1$: A relation scheme can have at most one foreign key.
- $S2$: A foreign key in a relation scheme R cannot be used to refer to tuples of R.

Which one of the following choices is correct?

A. Both $S1$ and $S2$ are true
B. $S1$ is true and $S2$ is false
C. $S1$ is false and $S2$ is true
D. Both $S1$ and $S2$ are false

gatecse-2021-set2 databases referential-integrity one-mark

Answer key

5.15 Relational Algebra (31)

5.15.1 Relational Algebra: GATE CSE 1992 | Question: 13b

Suppose we have a database consisting of the following three relations:

FREQUENTS	(CUSTOMER, HOTEL)
SERVES	(HOTEL, SNACKS)
LIKES	(CUSTOMER, SNACKS)

The first indicates the hotels each customer visits, the second tells which snacks each hotel serves and last indicates which snacks are liked by each customer. Express the following query in relational algebra:

Print the hotels the serve the snack that customer Rama likes.

gate1992 databases relational-algebra normal descriptive

Answer key

5.15.2 Relational Algebra: GATE CSE 1994 | Question: 13

Consider the following relational schema:

- COURSES (cno, cname)
- STUDENTS (rollno, sname, age, year)
- REGISTERED_FOR (cno, rollno)

The underlined attributes indicate the primary keys for the relations. The 'year' attribute for the STUDENTS relation indicates the year in which the student is currently studying (First year, Second year etc.)

A. Write a relational algebra query to print the roll number of students who have registered for cno 322.
B. Write a SQL query to print the age and year of the youngest student in each year.

gate1994 databases relational-algebra sql normal descriptive

Answer key☟

5.15.3 Relational Algebra: GATE CSE 1994 | Question: 3.8

Give a relational algebra expression using only the minimum number of operators from $(\cup, -)$ which is equivalent to $R \cap S$.

gate1994 databases relational-algebra normal descriptive

Answer key☟

5.15.4 Relational Algebra: GATE CSE 1995 | Question: 27

Consider the relation scheme.

AUTHOR	(ANAME, INSTITUTION, ACITY, AGE)
PUBLISHER	(PNAME, PCITY)
BOOK	(TITLE, ANAME, PNAME)

Express the following queries using (one or more of) SELECT, PROJECT, JOIN and DIVIDE operations.

A. Get the names of all publishers.
B. Get values of all attributes of all authors who have published a book for the publisher with PNAME='TECHNICAL PUBLISHERS'.
C. Get the names of all authors who have published a book for any publisher located in Madras

gate1995 databases relational-algebra normal descriptive

Answer key☟

5.15.5 Relational Algebra: GATE CSE 1996 | Question: 27

A library relational database system uses the following schema

- USERS (User#, User Name, Home Town)
- BOOKS (Book#, Book Title, Author Name)
- ISSUED (Book#, User#, Date)

Explain in one English sentence, what each of the following relational algebra queries is designed to determine

a. $\sigma_{\text{User}\#=6}\ (\pi_{\text{User}\#,\text{ Book Title}}\ ((\text{USERS} \bowtie \text{ISSUED}) \bowtie \text{BOOKS}))$
b. $\pi_{\text{Author Name}}\ (\text{BOOKS} \bowtie \sigma_{\text{Home Town=Delhi}}\ (\text{USERS} \bowtie \text{ISSUED}))$

gate1996 databases relational-algebra descriptive

Answer key☟

5.15.6 Relational Algebra: GATE CSE 1997 | Question: 76-a

Consider the following relational database schema:

- EMP (eno name, age)
- PROJ (pno name)
- INVOLVED (eno, pno)

EMP contains information about employees. PROJ about projects and involved about which employees involved in which projects. The underlined attributes are the primary keys for the respective relations.

What is the relational algebra expression containing one or more of $\{\sigma, \pi, \times, \rho, -\}$ which is equivalent to SQL query.

```
select eno  from EMP|INVOLVED where EMP.eno=INVOLVED.eno  and INVOLVED.pno=3
```

gate1997 databases sql relational-algebra descriptive

Answer key

5.15.7 Relational Algebra: GATE CSE 1998 | Question: 1.33

Given two union compatible relations $R_1(A, B)$ and $R_2(C, D)$, what is the result of the operation $R_1 \bowtie_{A=C \wedge B=D} R_2$?

A. $R_1 \cup R_2$
B. $R_1 \times R_2$
C. $R_1 - R_2$
D. $R_1 \cap R_2$

gate1998 normal relational-algebra

Answer key

5.15.8 Relational Algebra: GATE CSE 1998 | Question: 27

Consider the following relational database schemes:

- COURSES (Cno, Name)
- PRE_REQ(Cno, Pre_Cno)
- COMPLETED (Student_no, Cno)

COURSES gives the number and name of all the available courses.

PRE_REQ gives the information about which courses are pre-requisites for a given course.

COMPLETED indicates what courses have been completed by students

Express the following using relational algebra:

List all the courses for which a student with Student_no 2310 has completed all the pre-requisites.

gate1998 databases relational-algebra normal descriptive

Answer key

5.15.9 Relational Algebra: GATE CSE 1999 | Question: 1.18, ISRO2016-53

Consider the join of a relation R with a relation S. If R has m tuples and S has n tuples then the maximum and minimum sizes of the join respectively are

A. $m + n$ and 0
B. mn and 0
C. $m + n$ and $|m - n|$
D. mn and $m + n$

gate1999 databases relational-algebra easy isro2016

Answer key

5.15.10 Relational Algebra: GATE CSE 2000 | Question: 1.23, ISRO2016-57

Given the relations

- employee (name, salary, dept-no), and
- department (dept-no, dept-name,address),

Which of the following queries cannot be expressed using the basic relational algebra operations $(\sigma, \pi, \times, \bowtie, \cup, \cap, -)$?

A. Department address of every employee
B. Employees whose name is the same as their department name

C. The sum of all employees' salaries
D. All employees of a given department

gatecse-2000 databases relational-algebra easy isro2016

Answer key

5.15.11 Relational Algebra: GATE CSE 2001 | Question: 1.24

Suppose the adjacency relation of vertices in a graph is represented in a table Adj (X, Y). Which of the following queries cannot be expressed by a relational algebra expression of constant length?

A. List all vertices adjacent to a given vertex
B. List all vertices which have self loops
C. List all vertices which belong to cycles of less than three vertices
D. List all vertices reachable from a given vertex

gatecse-2001 databases relational-algebra normal

Answer key

5.15.12 Relational Algebra: GATE CSE 2001 | Question: 1.25

Let r and s be two relations over the relation schemes R and S respectively, and let A be an attribute in R. The relational algebra expression $\sigma_{A=a}(r \bowtie s)$ is always equal to

A. $\sigma_{A=a}(r)$
B. r
C. $\sigma_{A=a}(r) \bowtie s$
D. None of the above

gatecse-2001 databases relational-algebra

Answer key

5.15.13 Relational Algebra: GATE CSE 2002 | Question: 15

A university placement center maintains a relational database of companies that interview students on campus and make job offers to those successful in the interview. The schema of the database is given below:

$\text{COMPANY}(\underline{\text{cname}}, \text{clocation})$	$\text{STUDENT}(\underline{\text{srollno}}, \text{sname}, \text{sdegree})$
$\text{INTERVIEW}(\underline{\text{cname}, \text{srollno}}, \text{idate})$	$\text{OFFER}(\underline{\text{cname}, \text{srollno}}, \text{osalary})$

The COMPANY relation gives the name and location of the company. The STUDENT relation gives the student's roll number, name and the degree program for which the student is registered in the university. The INTERVIEW relation gives the date on which a student is interviewed by a company. The OFFER relation gives the salary offered to a student who is successful in a company's interview. The key for each relation is indicated by the underlined attributes

a. Write a **relational algebra** expressions (using only the operators $\bowtie, \sigma, \pi, \cup, -$) for the following queries.
   i. List the $rollnumbers$ and $names$ of students who attended at least one interview but did not receive any job offer.
   ii. List the $rollnumbers$ and $names$ of students who went for interviews and received job offers from $every$ company with which they interviewed.
b. Write an SQL query to list, for each degree program in which more than $five$ students were offered jobs, the name of the degree and the average offered salary of students in this degree program.

gatecse-2002 databases normal descriptive relational-algebra sql

Answer key

5.15.14 Relational Algebra: GATE CSE 2003 | Question: 30

Consider the following SQL query

Select distinct $a_1, a_2, \ldots, a_n$

from $r_1, r_2, \dots, r_m$

where P

For an arbitrary predicate P, this query is equivalent to which of the following relational algebra expressions?

A. $\Pi_{a_1, a_2, \dots a_n} \sigma_p \left(r_1 \times r_2 \times \dots \times r_m\right)$
B. $\Pi_{a_1, a_2, \dots a_n} \sigma_p \left(r_1 \bowtie r_2 \bowtie \dots \bowtie r_m\right)$
C. $\Pi_{a_1, a_2, \dots a_n} \sigma_p \left(r_1 \cup r_2 \cup \dots \cup r_m\right)$
D. $\Pi_{a_1, a_2, \dots a_n} \sigma_p \left(r_1 \cap r_2 \cap \dots \cap r_m\right)$

gatecse-2003 databases relational-algebra normal

Answer key☟

5.15.15 Relational Algebra: GATE CSE 2004 | Question: 51

Consider the relation Student (name, sex, marks), where the primary key is shown underlined, pertaining to students in a class that has at least one boy and one girl. What does the following relational algebra expression produce? (Note: ρ is the rename operator).

$\pi_{name} \{\sigma_{sex=female} \left(\text{Student}\right)\} - \pi_{name} \left(\text{Student} \bowtie_{(sex=female \wedge x=male \wedge marks \leq m)} \; \rho_{n,x,m} (\text{Student})\right)$

A. names of girl students with the highest marks
B. names of girl students with more marks than some boy student
C. names of girl students with marks not less than some boy student
D. names of girl students with more marks than all the boy students

gatecse-2004 databases relational-algebra normal

Answer key☟

5.15.16 Relational Algebra: GATE CSE 2007 | Question: 59

Information about a collection of students is given by the relation $\text{studInfo}(\underline{\text{studId}}, \text{ name}, \text{sex})$. The relation $\text{enroll}(\text{studId}, \text{ courseId})$ gives which student has enrolled for (or taken) what course(s). Assume that every course is taken by at least one male and at least one female student. What does the following relational algebra expression represent?

$\pi_{courceId} \left(\left(\pi_{\text{studId}} \left(\sigma_{sex='female'} \; \left(\text{studInfo}\right)\right) \times \pi_{courseId} \left(\text{enroll}\right)\right) - \text{enroll}\right)$

A. Courses in which all the female students are enrolled.
B. Courses in which a proper subset of female students are enrolled.
C. Courses in which only male students are enrolled.
D. None of the above

gatecse-2007 databases relational-algebra normal

Answer key☟

5.15.17 Relational Algebra: GATE CSE 2008 | Question: 68

Let R and S be two relations with the following schema

$R(\underline{P, Q}, R1, R2, R3)$

$S(\underline{P, Q}, S1, S2)$

where $\{P, Q\}$ is the key for both schemas. Which of the following queries are equivalent?

I. $\Pi_P \left(R \bowtie S\right)$
II. $\Pi_P \left(R\right) \bowtie \Pi_P \left(S\right)$
III. $\Pi_P \left(\Pi_{P,Q} \left(R\right) \cap \Pi_{P,Q} \left(S\right)\right)$
IV. $\Pi_P \left(\Pi_{P,Q} \left(R\right) - \left(\Pi_{P,Q} \left(R\right) - \Pi_{P,Q} \left(S\right)\right)\right)$

A. Only I and II B. Only I and III C. Only I, II and III D. Only I, III and IV

gatecse-2008 databases relational-algebra normal

Answer key

5.15.18 Relational Algebra: GATE CSE 2014 Set 3 | Question: 21

What is the optimized version of the relation algebra expression $\pi_{A1}(\pi_{A2}(\sigma_{F1}(\sigma_{F2}(r))))$, where $A1, A2$ are sets of attributes in r with $A1 \subset A2$ and $F1, F2$ are Boolean expressions based on the attributes in r?

A. $\pi_{A1}(\sigma_{(F1 \wedge F2)}(r))$
B. $\pi_{A1}(\sigma_{(F1 \vee F2)}(r))$
C. $\pi_{A2}(\sigma_{(F1 \wedge F2)}(r))$
D. $\pi_{A2}(\sigma_{(F1 \vee F2)}(r))$

gatecse-2014-set3 databases relational-algebra easy

Answer key

5.15.19 Relational Algebra: GATE CSE 2014 Set 3 | Question: 30

Consider the relational schema given below, where **eId** of the relation **dependent** is a foreign key referring to **empId** of the relation **employee**. Assume that every employee has at least one associated dependent in the **dependent** relation.

- **employee (empId, empName, empAge)**
- **dependent (depId, eId, depName, depAge)**

Consider the following relational algebra query:

$$\Pi_{empId}(employee) - \Pi_{empId}(employee \bowtie_{(empId=eID) \wedge (empAge \leq depAge)} dependent)$$

The above query evaluates to the set of **empId**s of employees whose age is greater than that of

A. some dependent.
B. all dependents.
C. some of his/her dependents.
D. all of his/her dependents.

gatecse-2014-set3 databases relational-algebra normal

Answer key

5.15.20 Relational Algebra: GATE CSE 2015 Set 1 | Question: 7

SELECT operation in SQL is equivalent to

A. The selection operation in relational algebra
B. The selection operation in relational algebra, except that SELECT in SQL retains duplicates
C. The projection operation in relational algebra
D. The projection operation in relational algebra, except that SELECT in SQL retains duplicates

gatecse-2015-set1 databases sql relational-algebra easy

Answer key

5.15.21 Relational Algebra: GATE CSE 2017 Set 1 | Question: 46

Consider a database that has the relation schema CR(StudentName, CourseName). An instance of the schema CR is as given below.

StudentName	CourseName
SA	CA
SA	CB
SA	CC
SB	CB
SB	CC
SC	CA
SC	CB
SC	CC
SD	CA
SD	CB
SD	CC
SD	CD
SE	CD
SE	CA
SE	CB
SF	CA
SF	CB
SF	CC

The following query is made on the database.

- $T1 \leftarrow \pi_{CourseName}\left(\sigma_{StudentName=SA}\ (CR)\right)$
- $T2 \leftarrow CR \div T1$

The number of rows in $T2$ is _____________ .

gatecse-2017-set1 databases relational-algebra normal numerical-answers

Answer key

5.15.22 Relational Algebra: GATE CSE 2018 | Question: 41

Consider the relations $r(A, B)$ and $s(B, C)$, where $s.B$ is a primary key and $r.B$ is a foreign key referencing $s.B$. Consider the query

$Q : r \bowtie (\sigma_{B<5}(s))$

Let LOJ denote the natural left outer-join operation. Assume that r and s contain no null values.

Which of the following is NOT equivalent to Q?

A. $\sigma_{B<5}(r \bowtie s)$
B. $\sigma_{B<5}(r\ LOJ\ s)$
C. $r\ LOJ\ (\sigma_{B<5}(s))$
D. $\sigma_{B<5}(r)\ LOJ\ s$

gatecse-2018 databases relational-algebra normal two-marks

Answer key

5.15.23 Relational Algebra: GATE CSE 2019 | Question: 55

Consider the following relations $P(X, Y, Z), Q(X, Y, T)$ and $R(Y, V)$.

Table: P

X	Y	Z
X1	Y1	Z1
X1	Y1	Z2
X2	Y2	Z2
X2	Y4	Z4

Table: Q

X	Y	T
X2	Y1	2
X1	Y2	5
X1	Y1	6
X3	Y3	1

Table: R

Y	V
Y1	V1
Y3	V2
Y2	V3
Y2	V2

How many tuples will be returned by the following relational algebra query?

$\Pi_x(\sigma_{(P.Y=R.Y \wedge R.V=V2))}\ (P \times R)) - \Pi_x(\sigma_{(Q.Y=R.Y \wedge Q.T>2))}\ (Q \times R))$

Answer: ________

gatecse-2019 numerical-answers databases relational-algebra two-marks

Answer key

5.15.24 Relational Algebra: GATE CSE 2021 Set 1 | Question: 27

The following relation records the age of 500 employees of a company, where $empNo$ (indicating the employee number) is the key:

$$empAge(\underline{empNo}, age)$$

Consider the following relational algebra expression:

$$\Pi_{empNo}(empAge \bowtie_{(age>age1)} \rho_{empNo1,age1}(empAge))$$

What does the above expression generate?

A. Employee numbers of only those employees whose age is the maximum
B. Employee numbers of only those employees whose age is more than the age of exactly one other employee
C. Employee numbers of all employees whose age is not the minimum
D. Employee numbers of all employees whose age is the minimum

gatecse-2021-set1 databases relational-algebra two-marks

Answer key

5.15.25 Relational Algebra: GATE CSE 2022 | Question: 15

Consider the following three relations in a relational database.

$\text{Employee}(\underline{\text{eId}}, \text{Name}),\ \text{Brand}(\underline{\text{bId}}, \text{bName}),\ \text{Own}(\underline{\text{eId}}, \underline{\text{bId}})$

Which of the following relational algebra expressions return the set of $eIds$ who own all the brands?

A. $\Pi_{eId}\ (\Pi_{eId,bId}(Own)/\Pi_{bId}(Brand))$
B. $\Pi_{eId}(Own) - \Pi_{eId}\ ((\Pi_{eId}(Own) \times \Pi_{bId}(Brand)) - \Pi_{eId,bId}(Own))$
C. $\Pi_{eId}\ (\Pi_{eId,bId}(Own)/\Pi_{bId}(Own))$
D. $\Pi_{eId}\ ((\Pi_{eId}(Own) \times \Pi_{bId}(Own))/\Pi_{bId}(Brand))$

gatecse-2022 databases relational-algebra multiple-selects one-mark

Answer key

5.15.26 Relational Algebra: GATE CSE 2024 | Set 1 | Question: 25

Consider the following two relations, $R(A, B)$ and $S(A, C)$:

R	
A	**B**
10	20
20	30
30	40
30	50
50	95

S	
A	**C**
10	90
30	45
40	80

The total number of tuples obtained by evaluating the following expression

$\sigma_{B<C}\left(R \bowtie_{R.A=S.A} S\right)$ is ___________.

gatecse2024-set1 numerical-answers databases relational-algebra one-mark

Answer key

5.15.27 Relational Algebra: GATE CSE 2024 | Set 2 | Question: 35

The relation schema, Person (pid, city), describes the city of residence for every person uniquely identified by pid. The following relational algebra operators are available: selection, projection, cross product, and rename.

To find the list of cities where at least 3 persons reside, using the above operators, the minimum number of cross product operations that must be used is

A. 1 B. 2 C. 3 D. 4

gatecse2024-set2 databases relational-algebra two-marks

Answer key

5.15.28 Relational Algebra: GATE DA 2025 | Question: 52

Consider the following tables, Loan and Borrower, of a bank.

Loan		
loan_number	**branch_name**	**amount**
L11	Banjara Hills	90000
L14	Kondapur	50000
L15	SR Nagar	40000
L22	SR Nagar	25000
L23	Balanagar	80000
L25	Kondapur	70000
L19	SR Nagar	65000

Borrower	
customer_name	**loan_num**
Anand	L11
Karteek	L11
Karteek	L14
Ankita	L15
Gopal	L19
Karteek	L22
Karteek	L23
Sunil	L23
Sunil	L25

Query: $\pi_{\text{branch\_name, customer\_name}}$ (**Loan** $\bowtie$ **Borrower**) $\div \pi_{\text{branch\_name}}$ (**Loan**) where $\bowtie$ denotes natural join.

The number of tuples returned by the above relational algebra query is ___________ (Answer in integer)

gateda-2025 databases relational-algebra numerical-answers two-marks

Answer key

5.15.29 Relational Algebra: GATE DA 2025 | Question: 7

Consider the following three relations:

$\text{Car}(\text{model}, \text{year}, \underline{\text{serial}}, \text{color})$
$\text{Make}(\text{maker}, \underline{\text{model}})$
$\text{Own}(\underline{\text{owner}}, \underline{\text{serial}})$

A tuple in Car represents a specific car of a given $\text{model},$ made in a given $\text{year},$ with a serial number and a $\text{color}.$ A tuple in Make specifies that a maker company makes cars of a certain $\text{model}.$ A tuple in Own specifies that an owner owns the car with a given serial number. Keys are underlined; $(\underline{\text{owner}}, \underline{\text{serial}})$ together form key for $\text{Own}.$ ($\bowtie$ denotes natural join)

$$\pi_{\text{owner}}\ (\text{Own} \bowtie (\sigma_{\text{color}=\text{"red"}}\ (\text{Car} \bowtie (\sigma_{\text{maker}=\text{"ABC"}}\ \text{Make}))))$$

Which one of the following options describes what the above expression computes?

A. All owners of a red car, a car made by $\text{ABC},$ or a red car made by ABC
B. All owners of more than one car, where at least one car is red and made by ABC
C. All owners of a red car made by ABC
D. All red cars made by ABC

gateda-2025 databases relational-algebra one-mark

Answer key☟

5.15.30 Relational Algebra: GATE DS&AI 2024 | Question: 16

Consider a database that includes the following relations:

Defender(name, rating, side, goals)
Forward(name, rating, assists, goals)
Team(name, club, price)

Which ONE of the following relational algebra expressions checks that every name occurring in Team appears in either Defender or Forward, where ϕ denotes the empty set?

A. Π_{name} (Team) $\setminus$ (Π_{name} (Defender) $\cap \Pi_{\text{name}}$ (Forward)) $= \phi$
B. (Π_{name} (Defender) $\cap \Pi_{\text{name}}$ (Forward)) $\setminus \Pi_{\text{name}}$ (Team) $= \phi$
C. Π_{name} (Team) $\setminus$ (Π_{name} (Defender) $\cup \Pi_{\text{name}}$ (Forward)) $= \phi$
D. (Π_{name} (Defender) $\cup \Pi_{\text{name}}$ (Forward)) $\setminus \Pi_{\text{name}}$ (Team) $= \phi$

gate-ds-ai-2024 relational-algebra databases one-mark

Answer key☟

5.15.31 Relational Algebra: GATE IT 2005 | Question: 68

A table 'student' with schema (roll, name, hostel, marks), and another table 'hobby' with schema (roll, hobbyname) contains records as shown below:

Table: student

Roll	Name	Hostel	Marks
1798	Manoj Rathor	7	95
2154	Soumic Banerjee	5	68
2369	Gumma Reddy	7	86
2581	Pradeep pendse	6	92
2643	Suhas Kulkarni	5	78
2711	Nitin Kadam	8	72
2872	Kiran Vora	5	92
2926	Manoj Kunkalikar	5	94
2959	Hemant Karkhanis	7	88
3125	Rajesh Doshi	5	82

Table: hobby

Roll	Hobby Name
1798	chess
1798	music
2154	music
2369	swimming
2581	cricket
2643	chess
2643	hockey
2711	volleyball
2872	football
2926	cricket
2959	photography
3125	music
3125	chess

The following SQL query is executed on the above tables:

```
select hostel
from student natural join hobby
where marks >= 75 and roll between 2000 and 3000;
```

Relations S and H with the same schema as those of these two tables respectively contain the same information as tuples. A new relation S' is obtained by the following relational algebra operation:

$$S' = \Pi_{\text{hostel}}((\sigma_{s.roll=H.roll}(\sigma_{marks>75 \text{ and } roll>2000 \text{ and } roll<3000}\ (S)) \times (H))$$

The difference between the number of rows output by the SQL statement and the number of tuples in S' is

A. 6
B. 4
C. 2
D. 0

gateit-2005 databases sql relational-algebra normal

Answer key

5.16 Relational Calculus (15)

5.16.1 Relational Calculus: GATE CSE 1993 | Question: 23

The following relations are used to store data about students, courses, enrollment of students in courses and teachers of courses. Attributes for primary key in each relation are marked by '*'.

```
Students (rollno*, sname, saddr)
courses (cno*, cname)
enroll(rollno*, cno*, grade)
teach(tno*, tname, cao*)
```

(cno is course number cname is course name, tno is teacher number, tname is teacher name, sname is student name, etc.)

Write a SQL query for retrieving roll number and name of students who got A grade in at least one course taught by teacher names Ramesh for the above relational database.

gate1993 databases sql relational-calculus normal descriptive

Answer key

5.16.2 Relational Calculus: GATE CSE 1993 | Question: 24

The following relations are used to store data about students, courses, enrollment of students in courses and teachers of courses. Attributes for primary key in each relation are marked by '*'.

- $\text{students(rollno*, sname, saddr)}$
- $\text{courses(cno*, cname)}$
- $\text{enroll(rollno*, cno*, grade)}$
- $\text{teach(tno*, tname, cao*)}$

(cno is course number, cname is course name, tno is teacher number, tname is teacher name, sname is student name, etc.)

For the relational database given above, the following functional dependencies hold:

- $\text{rollno} \rightarrow \text{sname, saddr}$
- $\text{cno} \rightarrow \text{cname}$
- $\text{tno} \rightarrow \text{tname}$
- $\text{rollno, cno} \rightarrow \text{grade}$

a. Is the database in 3^{rd} normal form $(3NF)$?
b. If yes, prove that it is in 3NF. If not, normalize the relations so that they are in 3NF (without proving).

gate1993 databases sql relational-calculus normal descriptive

Answer key

5.16.3 Relational Calculus: GATE CSE 1998 | Question: 2.19

Which of the following query transformations (i.e., replacing the l.h.s. expression by the r.h.s expression) is incorrect? R1 and R2 are relations, C1 and C2 are selection conditions and A1 and A2 are attributes of R1.

A. $\sigma_{C_1}(\sigma_{C_2}(R_1)) \rightarrow \sigma_{C_2}(\sigma_{C_1}(R_1))$
B. $\sigma_{C_1}(\pi_{A_1}(R_1)) \rightarrow \pi_{A_1}(\sigma_{C_1}(R_1))$
C. $\sigma_{C_1}(R_1 \cup R_2) \rightarrow \sigma_{C_1}(R_1) \cup \sigma_{C_1}(R_2)$
D. $\pi_{A_1}(\sigma_{C_1}(R_1)) \rightarrow \sigma_{C_1}(\pi_{A_1}(R_1))$

gate1998 databases relational-calculus normal

Answer key

5.16.4 Relational Calculus: GATE CSE 1999 | Question: 1.19

The relational algebra expression equivalent to the following tuple calculus expression:

$\{t \mid t \in r \wedge (t[A] = 10 \wedge t[B] = 20)\}$ is

A. $\sigma_{(A=10 \vee B=20)}(r)$
B. $\sigma_{(A=10)}(r) \cup \sigma_{(B=20)}(r)$
C. $\sigma_{(A=10)}(r) \cap \sigma_{(B=20)}(r)$
D. $\sigma_{(A=10)}(r) - \sigma_{(B=20)}(r)$

gate1999 databases relational-calculus normal

Answer key

5.16.5 Relational Calculus: GATE CSE 2001 | Question: 2.24

Which of the following relational calculus expression is not safe?

A. $\{t \mid \exists u \in R_1 (t[A] = u[A]) \wedge \neg \exists s \in R_2 (t[A] = s[A])\}$
B. $\{t \mid \forall u \in R_1 (u[A] =" x " \Rightarrow \exists s \in R_2 (t[A] = s[A] \wedge s[A] = u[A]))\}$
C. $\{t \mid \neg(t \in R_1)\}$
D. $\{t \mid \exists u \in R_1 (t[A] = u[A]) \wedge \exists s \in R_2 (t[A] = s[A])\}$

gatecse-2001 relational-calculus normal databases

Answer key

5.16.6 Relational Calculus: GATE CSE 2002 | Question: 1.20

With regards to the expressive power of the formal relational query languages, which of the following statements is true?

A. Relational algebra is more powerful than relational calculus
B. Relational algebra has the same power as relational calculus
C. Relational algebra has the same power as safe relational calculus
D. None of the above

gatecse-2002 databases relational-calculus normal

Answer key

5.16.7 Relational Calculus: GATE CSE 2004 | Question: 13

Let $R_1\left(\underline{A}, B, C\right)$ and $R_2\left(\underline{D}, E\right)$ be two relation schema, where the primary keys are shown underlined, and let C be a foreign key in R_1 referring to R_2. Suppose there is no violation of the above referential integrity constraint in the corresponding relation instances r_1 and r_2. Which of the following relational algebra expressions would necessarily produce an empty relation?

A. $\Pi_D(r_2) - \Pi_C(r_1)$
B. $\Pi_C(r_1) - \Pi_D(r_2)$
C. $\Pi_D\left(r_1 \bowtie_{C \neq D} r_2\right)$
D. $\Pi_C\left(r_1 \bowtie_{C=D} r_2\right)$

gatecse-2004 databases relational-calculus easy

Answer key

5.16.8 Relational Calculus: GATE CSE 2007 | Question: 60

Consider the relation **employee**(name, sex, supervisorName) with *name* as the key, *supervisorName* gives the name of the supervisor of the employee under consideration. What does the following Tuple Relational Calculus query produce?

$$\{e.name \mid employee(e) \wedge (\forall x)\left[\neg employee\left(x\right) \vee x.supervisorName \neq e.name \vee x.sex = \text{``}male\text{''}\right]\}$$

A. Names of employees with a male supervisor.
B. Names of employees with no immediate male subordinates.
C. Names of employees with no immediate female subordinates.
D. Names of employees with a female supervisor.

gatecse-2007 databases relational-calculus normal

Answer key

5.16.9 Relational Calculus: GATE CSE 2008 | Question: 15

Which of the following tuple relational calculus expression(s) is/are equivalent to $\forall t \in r\left(P\left(t\right)\right)$?

I. $\neg \exists t \in r\left(P\left(t\right)\right)$
II. $\exists t \notin r\left(P\left(t\right)\right)$
III. $\neg \exists t \in r\left(\neg P\left(t\right)\right)$
IV. $\exists t \notin r\left(\neg P\left(t\right)\right)$

A. I only
B. II only
C. III only
D. III and IV only

gatecse-2008 databases relational-calculus normal

Answer key

5.16.10 Relational Calculus: GATE CSE 2009 | Question: 45

Let R and S be relational schemes such that $R = \{a, b, c\}$ and $S = \{c\}$. Now consider the following queries on the database:

1. $\pi_{R-S}(r) - \pi_{R-S}\left(\pi_{R-S}(r) \times s - \pi_{R-S,S}(r)\right)$
2. $\{t \mid t \in \pi_{R-S}(r) \wedge \forall u \in s\left(\exists v \in r\left(u = v[S] \wedge t = v\left[R - S\right]\right)\right)\}$

3. $\{t \mid t \in \pi_{R-S}(r) \wedge \forall v \in r\,(\exists u \in s\,(u = v[S] \wedge t = v\,[R - S]))\}$

4.
```
Select R.a,R.b
  From R,S
  Where R.c = S.c
```

Which of the above queries are equivalent?

A. 1 and 2　　B. 1 and 3　　C. 2 and 4　　D. 3 and 4

gatecse-2009　databases　relational-calculus　difficult

Answer key

5.16.11 Relational Calculus: GATE CSE 2013 | Question: 35

Consider the following relational schema.

- Students(rollno: integer, sname: string)
- Courses(courseno: integer, cname: string)
- Registration(rollno: integer, courseno: integer, percent: real)

Which of the following queries are equivalent to this query in English?

"Find the distinct names of all students who score more than 90% in the course numbered 107"

I.
```
SELECT DISTINCT S.sname FROM Students as S, Registration
  as R WHERE
  R.rollno=S.rollno AND R.courseno=107 AND R.percent >90
```

II. $\prod_{sname}(\sigma_{courseno=107 \wedge percent>90}\,(Registration \bowtie Students))$

III. $\{T \mid \exists S \in Students, \exists R \in Registration(S.rollno = R.rollno$
$\wedge R.courseno = 107 \wedge R.percent > 90 \wedge T.sname = S.sname)\}$

IV.
$$\{\langle S_N \rangle \mid \exists S_R \exists R_P(\langle S_R, S_N \rangle \in Students \wedge$$
$$\langle S_R, 107, R_P \rangle \in Registration \wedge R_P > 90)\}$$

A. I, II, III and IV
B. I, II and III only
C. I, II and IV only
D. II, III and IV only

gatecse-2013　databases　sql　relational-calculus　normal

Answer key

5.16.12 Relational Calculus: GATE CSE 2017 Set 1 | Question: 41

Consider a database that has the relation schemas EMP(EmpId, EmpName, DeptId), and DEPT(DeptName, DeptId). Note that the DeptId can be permitted to be NULL in the relation EMP. Consider the following queries on the database expressed in tuple relational calculus.

I. $\{t \mid \exists$u $\in$ EMP(t[EmpName] = u[EmpName] $\wedge$ $\forall$v $\in$ DEPT(t[DeptId] $\neq$ v[DeptId]))$\}$
II. $\{t \mid \exists$u $\in$ EMP(t[EmpName] = u[EmpName] $\wedge$ $\exists$v $\in$ DEPT(t[DeptId] $\neq$ v[DeptId]))$\}$
III. $\{t \mid \exists$u $\in$ EMP(t[EmpName] = u[EmpName] $\wedge$ $\exists$v $\in$ DEPT(t[DeptId] $=$ v[DeptId]))$\}$

Which of the above queries are safe?

A. I and II only　　B. I and III only　　C. II and III only　　D. I, II and III

gatecse-2017-set1　databases　relational-calculus　safe-query　normal

Answer key

5.16.13 Relational Calculus: GATE IT 2006 | Question: 15

Which of the following relational query languages have the same expressive power?

I. Relational algebra
II. Tuple relational calculus restricted to safe expressions
III. Domain relational calculus restricted to safe expressions

A. II and III only
B. I and II only
C. I and III only
D. I, II and III

gateit-2006 databases relational-algebra relational-calculus easy

Answer key☟

5.16.14 Relational Calculus: GATE IT 2007 | Question: 65

Consider a selection of the form $\sigma_{A \leq 100}(r)$, where r is a relation with 1000 tuples. Assume that the attribute values for A among the tuples are uniformly distributed in the interval $[0, 500]$. Which one of the following options is the best estimate of the number of tuples returned by the given selection query ?

A. 50
B. 100
C. 150
D. 200

gateit-2007 databases relational-calculus probability normal

Answer key☟

5.16.15 Relational Calculus: GATE IT 2008 | Question: 75

Consider the following relational schema:

- $\text{Student}(\underline{\text{school-id}, \text{sch-roll-no}}, \text{sname}, \text{saddress})$
- $\text{School}(\underline{\text{school-id}}, \text{sch-name}, \text{sch-address}, \text{sch-phone})$
- $\text{Enrolment}(\underline{\text{school-id}, \text{sch-roll-no}}, \text{erollno}, \text{examname})$
- $\text{ExamResult}(\underline{\text{erollno}, \text{examname}}, \text{marks})$

Consider the following tuple relational calculus query.

$$\{t \mid \exists E \in \text{Enrolment} \quad t = E.\text{school-id} \land |\{x \mid x \in \text{Enrolment} \land x.\text{school-id} = t \land (\exists B \in \text{ExamResult} \quad B.\text{erc}$$

If a student needs to score more than 35 marks to pass an exam, what does the query return?

A. The empty set
B. schools with more than 35% of its students enrolled in some exam or the other
C. schools with a pass percentage above 35% over all exams taken together
D. schools with a pass percentage above 35% over each exam

gateit-2008 databases relational-calculus normal

Answer key☟

5.17 Relational Model (2)

5.17.1 Relational Model: GATE CSE 2023 | Question: 6

Which one of the options given below refers to the degree (or arity) of a relation in relational database systems?

A. Number of attributes of its relation schema.
B. Number of tuples stored in the relation.
C. Number of entries in the relation.
D. Number of distinct domains of its relation schema.

gatecse-2023 databases relational-model one-mark easy

Answer key☟

5.17.2 Relational Model: GATE DA 2025 | Question: 46

Consider the following two relations, named Customer and Person, in a database:

```
Person (
aadhaar CHAR(12) PRIMARY KEY,
name VARCHAR(32));

Customer (
name VARCHAR (32),
```

```
    email VARCHAR(32) PRIMARY KEY,
    phone CHAR(10),
    aadhaar CHAR(12),
      FOREIGN KEY (aadhaar) REFERENCES Person(aadhaar));
```

Which of the following statements is/are correct?

A. aadhaar is a candidate key in the Customer relation
B. phone can be NULL in the Customer relation
C. aadhaar is a candidate key in the Person relation
D. aadhaar can be NULL in the Person relation

gateda-2025 databases relational-model multiple-selects two-marks

Answer key

5.18 SQL (58)

5.18.1 SQL: GATE CSE 1988 | Question: 12iii

Describe the relational algebraic expression giving the relation returned by the following SQL query.

```
Select    SNAME
from      S
Where     SNOin
          (select   SNO
          from      SP
          where     PNOin
                    (select   PNO
                    from      P
                    Where     COLOUR='BLUE'))
```

gate1988 normal descriptive databases sql

Answer key

5.18.2 SQL: GATE CSE 1988 | Question: 12iv

```
Select    SNAME
from      S
Where     SNOin
          (select   SNO
          from      SP
          where     PNOin
                    (select   PNO
                    from      P
                    Where     COLOUR='BLUE'))
```

What relations are being used in the above SQL query? Given at least two attributes of each of these relations.

gate1988 normal descriptive databases sql

Answer key

5.18.3 SQL: GATE CSE 1990 | Question: 10-a

Consider the following relational database:

- employees (eno, ename, address, basic-salary)
- projects (pno, pname, nos-of-staffs-allotted)
- working (pno, eno, pjob)

The queries regarding data in the above database are formulated below in SQL. Describe in ENGLISH sentences the two queries that have been posted:

i.
```
SELECT ename
FROM employees
WHERE eno IN
  (SELECT eno
  FROM working
  GROUP BY eno
```

```
HAVING COUNT(*)=
   (SELECT COUNT(*)
   FROM projects))
```

ii.
```
SELECT pname
FROM projects
WHERE pno IN
   (SELECT pno
   FROM projects
   MINUS
   SELECT DISTINCT pno
   FROM working);
```

gate1990 descriptive databases sql

Answer key

5.18.4 SQL: GATE CSE 1991 | Question: 12,b

Suppose a database consist of the following relations:

```
SUPPLIER (SCODE,SNAME,CITY).

PART (PCODE,PNAME,PDESC,CITY).

PROJECTS (PRCODE,PRNAME,PRCITY).

SPPR (SCODE,PCODE,PRCODE,QTY).
```

Write algebraic solution to the following :

i. Get SCODE values for suppliers who supply to both projects PR1 and PR2.
ii. Get PRCODE values for projects supplied by at least one supplier not in the same city.

sql gate1991 normal databases descriptive

Answer key

5.18.5 SQL: GATE CSE 1991 | Question: 12-a

Suppose a database consist of the following relations:

```
SUPPLIER (SCODE,SNAME,CITY).
PART (PCODE,PNAME,PDESC,CITY).
PROJECTS (PRCODE,PRNAME,PRCITY).
SPPR (SCODE,PCODE,PRCODE,QTY).
```

Write SQL programs corresponding to the following queries:

i. Print PCODE values for parts supplied to any project in DEHLI by a supplier in DELHI.
ii. Print all triples <CITY, PCODE, CITY> such that a supplier in first city supplies the specified part to a project in the second city, but do not print the triples in which the two CITY values are same.

gate1991 databases sql normal descriptive

Answer key

5.18.6 SQL: GATE CSE 1998 | Question: 7-a

Suppose we have a database consisting of the following three relations.

- $\text{FREQUENTS (student, parlor)}$ giving the parlors each student visits.
- $\text{SERVES (parlor, ice-cream)}$ indicating what kind of ice-creams each parlor serves.
- $\text{LIKES (student, ice-cream)}$ indicating what ice-creams each student likes.

(Assume that each student likes at least one ice-cream and frequents at least one parlor)

Express the following in SQL:

Print the students that frequent at least one parlor that serves some ice-cream that they like.

gate1998 databases sql descriptive

Answer key

5.18.7 SQL: GATE CSE 1999 | Question: 2.25

Which of the following is/are correct?

A. An SQL query automatically eliminates duplicates
B. An SQL query will not work if there are no indexes on the relations
C. SQL permits attribute names to be repeated in the same relation
D. None of the above

gate1999 databases sql easy

Answer key

5.18.8 SQL: GATE CSE 1999 | Question: 22-a

Consider the set of relations

- EMP (Employee-no. Dept-no, Employee-name, Salary)
- DEPT (Dept-no. Dept-name, Location)

Write an SQL query to:

a. Find all employees names who work in departments located at ‘Calcutta’ and whose salary is greater than Rs.50,000.
b. Calculate, for each department number, the number of employees with a salary greater than Rs. 1,00,000.

gate1999 databases sql easy descriptive

Answer key

5.18.9 SQL: GATE CSE 1999 | Question: 22-b

Consider the set of relations

- EMP (Employee-no. Dept-no, Employee-name, Salary)
- DEPT (Dept-no. Dept-name, Location)

Write an SQL query to:

Calculate, for each department number, the number of employees with a salary greater than Rs. 1,00,000

gate1999 databases sql descriptive easy

Answer key

5.18.10 SQL: GATE CSE 2000 | Question: 2.25

Given relations r(w, x) and s(y, z) the result of

select distinct w, x
from r, s

is guaranteed to be same as r, provided.

A. r has no duplicates and s is non-empty
B. r and s have no duplicates
C. s has no duplicates and r is non-empty
D. r and s have the same number of tuples

gatecse-2000 databases sql

Answer key

5.18.11 SQL: GATE CSE 2000 | Question: 2.26

In SQL, relations can contain null values, and comparisons with null values are treated as unknown. Suppose all comparisons with a null value are treated as false. Which of the following pairs is not equivalent?

A. $x = 5 \quad not(not(x = 5))$
B. $x = 5 \quad x > 4$ and $x < 6,$ where x is an integer
C. $x \neq 5 \quad not(x = 5)$
D. none of the above

gatecse-2000 databases sql normal

Answer key

5.18.12 SQL: GATE CSE 2000 | Question: 22

Consider a bank database with only one relation

transaction (transno, acctno, date, amount)

The amount attribute value is positive for deposits and negative for withdrawals.

a. Define an SQL view TP containing the information
(acctno,T1.date,T2.amount)
for every pair of transaction T1,T2 and such that T1 and T2 are transaction on the same account and the date of T2 is $\leq$ the date of T1.
b. Using only the above view TP, write a query to find for each account the minimum balance it ever reached (not including the 0 balance when the account is created). Assume there is at most one transaction per day on each account and each account has at least one transaction since it was created. To simplify your query, break it up into 2 steps by defining an intermediate view V.

gatecse-2000 databases sql normal descriptive

Answer key

5.18.13 SQL: GATE CSE 2001 | Question: 2.25

Consider a relation geq which represents "greater than or equal to", that is, $(x, y) \in$ geq only if $y \geq x$.

```
create table geq
(
   ib integer not null,
   ub integer not null,
   primary key ib,
   foreign key (ub) references geq on delete cascade
);
```

Which of the following is possible if tuple (x,y) is deleted?

A. A tuple (z,w) with z > y is deleted
B. A tuple (z,w) with z > x is deleted
C. A tuple (z,w) with w < x is deleted
D. The deletion of (x,y) is prohibited

gatecse-2001 databases sql normal

Answer key

5.18.14 SQL: GATE CSE 2001 | Question: 21-a

Consider a relation examinee (regno, name, score), where regno is the primary key to score is a real number.

Write a relational algebra using $(\Pi, \sigma, \rho, \times)$ to find the list of names which appear more than once in examinee.

gatecse-2001 databases sql normal descriptive

Answer key

5.18.15 SQL: GATE CSE 2001 | Question: 21-b

Consider a relation examinee (regno, name, score), where regno is the primary key to score is a real number.

Write an SQL query to list the *regno* of examinees who have a score greater than the average score.

gatecse-2001 databases sql normal descriptive

Answer key

5.18.16 SQL: GATE CSE 2001 | Question: 21-c

Consider a relation $\text{examinee (regno, name, score)}$, where regno is the primary key to score is a real number.

Suppose the relation $\text{appears (regno, centr\_code)}$ specifies the center where an examinee appears. Write an SQL query to list the centr_code having an examinee of score greater than 80.

gatecse-2001 databases sql normal descriptive

Answer key

5.18.17 SQL: GATE CSE 2003 | Question: 86

Consider the set of relations shown below and the SQL query that follows.

Students: (Roll_number, Name, Date_of_birth)

Courses: (Course_number, Course_name, Instructor)

Grades: (Roll_number, Course_number, Grade)

```
Select distinct Name
from Students, Courses, Grades
where Students.Roll_number=Grades.Roll_number
 and Courses.Instructor = 'Korth'
 and Courses.Course_number = Grades.Course_number
 and Grades.Grade = 'A'
```

Which of the following sets is computed by the above query?

A. Names of students who have got an A grade in all courses taught by Korth
B. Names of students who have got an A grade in all courses
C. Names of students who have got an A grade in at least one of the courses taught by Korth
D. None of the above

gatecse-2003 databases sql easy

Answer key

5.18.18 SQL: GATE CSE 2004 | Question: 53

The employee information in a company is stored in the relation

- Employee (name, sex, salary, deptName)

Consider the following SQL query

```
Select deptName
  From Employee
  Where sex = 'M'
  Group by deptName
  Having avg(salary) >
    (select avg (salary) from Employee)
```

It returns the names of the department in which

A. the average salary is more than the average salary in the company
B. the average salary of male employees is more than the average salary of all male employees in the company

C. the average salary of male employees is more than the average salary of employees in same the department
D. the average salary of male employees is more than the average salary in the company

gatecse-2004 databases sql normal

Answer key

5.18.19 SQL: GATE CSE 2005 | Question: 77, ISRO2016-55

The relation **book** (title, price) contains the titles and prices of different books. Assuming that no two books have the same price, what does the following SQL query list?

```
select title
from book as B
where (select count(*)
  from book as T
  where T.price>B.price) < 5
```

A. Titles of the four most expensive books
B. Title of the fifth most inexpensive book
C. Title of the fifth most expensive book
D. Titles of the five most expensive books

gatecse-2005 databases sql easy isro2016

Answer key

5.18.20 SQL: GATE CSE 2006 | Question: 67

Consider the relation account (customer, balance) where the customer is a primary key and there are no null values. We would like to rank customers according to decreasing balance. The customer with the largest balance gets rank 1. Ties are not broke but ranks are skipped: if exactly two customers have the largest balance they each get rank 1 and rank 2 is not assigned.

Query1:

```
select A.customer, count(B.customer)
from account A, account B
where A.balance <=B.balance
group by A.customer
```

Query2:

```
select A.customer, 1+count(B.customer)
from account A, account B
where A.balance < B.balance
group by A.customer
```

Consider these statements about Query1 and Query2.

1. Query1 will produce the same row set as Query2 for some but not all databases.
2. Both Query1 and Query 2 are a correct implementation of the specification
3. Query1 is a correct implementation of the specification but Query2 is not
4. Neither Query1 nor Query2 is a correct implementation of the specification
5. Assigning rank with a pure relational query takes less time than scanning in decreasing balance order assigning ranks using ODBC.

Which two of the above statements are correct?

A. 2 and 5 B. 1 and 3 C. 1 and 4 D. 3 and 5

gatecse-2006 databases sql normal

Answer key

5.18.21 SQL: GATE CSE 2006 | Question: 68

Consider the relation enrolled (student, course) in which (student, course) is the primary key, and the relation paid (student, amount) where student is the primary key. Assume no null values and no foreign keys or

integrity constraints.
Given the following four queries:

Query1:

```
select student from enrolled where student in (select student from paid)
```

Query2:

```
select student from paid where student in (select student from enrolled)
```

Query3:

```
select E.student from enrolled E, paid P where E.student = P.student
```

Query4:

```
select student from paid where exists
   (select * from enrolled where enrolled.student = paid.student)
```

Which one of the following statements is correct?

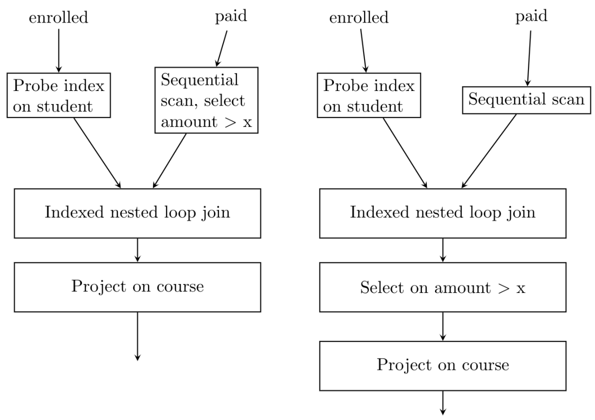
A. All queries return identical row sets for any database
B. Query2 and Query4 return identical row sets for all databases but there exist databases for which Query1 and Query2 return different row sets
C. There exist databases for which Query3 returns strictly fewer rows than Query2
D. There exist databases for which Query4 will encounter an integrity violation at runtime

gatecse-2006 databases sql normal

Answer key

5.18.22 SQL: GATE CSE 2006 | Question: 69

Consider the relation enrolled (student, course) in which (student, course) is the primary key, and the relation paid (student, amount) where student is the primary key. Assume no null values and no foreign keys or integrity constraints. Assume that amounts $6000, 7000, 8000, 9000$ and 10000 were each paid by 20% of the students. Consider these query plans (Plan 1 on left, Plan 2 on right) to *"list all courses taken by students who have paid more than x"*



A disk seek takes $4ms$, disk data transfer bandwidth is 300 MB/s and checking a tuple to see if amount is greater than x takes $10\mu s$. Which of the following statements is correct?

A. Plan 1 and Plan 2 will not output identical row sets for all databases
B. A course may be listed more than once in the output of Plan 1 for some databases
C. For $x = 5000$, Plan 1 executes faster than Plan 2 for all databases
D. For $x = 9000$, Plan I executes slower than Plan 2 for all databases

gatecse-2006 databases sql normal

Answer key

5.18.23 SQL: GATE CSE 2007 | Question: 61

Consider the table **employee**(empId, name, department, salary) and the two queries Q_1, Q_2 below. Assuming that department 5 has more than one employee, and we want to find the employees who get higher salary than anyone in the department $5,$ which one of the statements is **TRUE** for any arbitrary employee table?

Q_1 :

```
Select e.empId
From employee e
Where not exists
   (Select * From employee s Where s.department = "5" and s.salary >= e.salary)
```

Q_2 :

```
Select e.empId
From employee e
Where e.salary > Any
   (Select distinct salary From employee s Where s.department = "5")
```

A. Q_1 is the correct query
B. Q_2 is the correct query
C. Both Q_1 and Q_2 produce the same answer
D. Neither Q_1 nor Q_2 is the correct query

gatecse-2007 databases sql normal verbal-aptitude

Answer key

5.18.24 SQL: GATE CSE 2009 | Question: 55

Consider the following relational schema:

Suppliers($\underline{\text{sid:integer}}$, sname:string, city:string, street:string)

Parts($\underline{\text{pid:integer}}$, pname:string, color:string)

Catalog($\underline{\text{sid:integer, pid:integer}}$, cost:real)

Consider the following relational query on the above database:

```
SELECT S.sname
FROM    Suppliers S
WHERE S.sid NOT IN (SELECT C.sid
                FROM Catalog C
                WHERE C.pid NOT IN (SELECT P.pid
                                FROM Parts P
                                WHERE P.color<>'blue'))
```

Assume that relations corresponding to the above schema are not empty. Which one of the following is the correct interpretation of the above query?

A. Find the names of all suppliers who have supplied a non-blue part.
B. Find the names of all suppliers who have not supplied a non-blue part.
C. Find the names of all suppliers who have supplied only non-blue part.
D. Find the names of all suppliers who have not supplied only blue parts.

gatecse-2009 databases sql normal

Answer key

5.18.25 SQL: GATE CSE 2009 | Question: 56

Consider the following relational schema:

- Suppliers($\underline{\text{sid:integer}}$, sname:string, city:string, street:string)
- Parts($\underline{\text{pid:integer}}$, pname:string, color:string)
- Catalog($\underline{\text{sid:integer, pid:integer}}$, cost:real)

Assume that, in the suppliers relation above, each supplier and each street within a city has unique name, and (sname, city) forms a candidate key. No other functional dependencies are implied other than those implied by primary and candidate keys. Which one of the following is TRUE about the above schema?

A. The schema is in BCNF

B. The schema is in 3NF but not in BCNF

C. The schema is in 2NF but not in 3NF

D. The schema is not in 2NF

gatecse-2009 databases sql database-normalization normal

Answer key

5.18.26 SQL: GATE CSE 2010 | Question: 19

A relational schema for a train reservation database is given below.

- **passenger(pid, pname, age)**
- **reservation(pid, class, tid)**

Passenger

pid	pname	Age
0	Sachine	65
1	Rahul	66
2	Sourav	67
3	Anil	69

Reservation

pid	class	tid
0	AC	8200
1	AC	8201
2	SC	8201
5	AC	8203
1	SC	8204
3	AC	8202

What **pids** are returned by the following SQL query for the above instance of the tables?

```
SELECT pid
FROM Reservation
WHERE class='AC' AND
   EXISTS (SELECT *
         FROM Passenger
         WHERE age>65 AND
         Passenger.pid=Reservation.pid)
```

A. $1, 0$

B. $1, 2$

C. $1, 3$

D. $1, 5$

gatecse-2010 databases sql normal

Answer key

5.18.27 SQL: GATE CSE 2011 | Question: 32

Consider a database table T containing two columns X and Y each of type integer. After the creation of the table, one record $(\text{X}=1, \text{Y}=1)$ is inserted in the table.

Let MX and MY denote the respective maximum values of X and Y among all records in the table at any point in time. Using MX and MY, new records are inserted in the table 128 times with X and Y values being $\text{MX}+1, 2*\text{MY}+1$ respectively. It may be noted that each time after the insertion, values of MX and MY change.

What will be the output of the following SQL query after the steps mentioned above are carried out?

```
SELECT Y FROM T WHERE X=7;
```

A. 127

B. 255

C. 129

D. 257

gatecse-2011 databases sql normal

Answer key

5.18.28 SQL: GATE CSE 2011 | Question: 46

Database table by name Loan_Records is given below.

Borrower	Bank_Manager	Loan_Amount
Ramesh	Sunderajan	10000.00
Suresh	Ramgopal	5000.00
Mahesh	Sunderajan	7000.00

What is the output of the following SQL query?

```
SELECT count(*)
FROM (
   SELECT Borrower, Bank_Manager FROM Loan_Records) AS S
   NATURAL JOIN
   (SELECT Bank_Manager, Loan_Amount FROM Loan_Records) AS T
);
```

A. 3 B. 9 C. 5 D. 6

gatecse-2011 databases sql normal

Answer key

5.18.29 SQL: GATE CSE 2012 | Question: 15

Which of the following statements are **TRUE** about an SQL query?
P : An SQL query can contain a HAVING clause even if it does not have a GROUP BY clause
Q : An SQL query can contain a HAVING clause only if it has a GROUP BY clause
R : All attributes used in the GROUP BY clause must appear in the SELECT clause
S : Not all attributes used in the GROUP BY clause need to appear in the SELECT clause

A. P and R B. P and S C. Q and R D. Q and S

gatecse-2012 databases easy sql ambiguous

Answer key

5.18.30 SQL: GATE CSE 2012 | Question: 51

Consider the following relations A, B and C :

A

Id	Name	Age
12	Arun	60
15	Shreya	24
99	Rohit	11

B

Id	Name	Age
15	Shreya	24
25	Hari	40
98	Rohit	20
99	Rohit	11

C

Id	Phone	Area
10	2200	02
99	2100	01

How many tuples does the result of the following SQL query contain?

```
SELECT A.Id
FROM A
WHERE A.Age > ALL (SELECT B.Age
              FROM B
              WHERE B.Name = 'Arun')
```

A. 4 B. 3 C. 0 D. 1

gatecse-2012 databases sql normal

Answer key

5.18.31 SQL: GATE CSE 2014 Set 1 | Question: 22

Given the following statements:

S1: A foreign key declaration can always be replaced by an equivalent check assertion in SQL.

S2: Given the table $R(a, b, c)$ where a and b together form the primary key, the following is a valid table definition.

```
CREATE TABLE S (
   a INTEGER,
   d INTEGER,
   e INTEGER,
   PRIMARY KEY (d),
   FOREIGN KEY (a) references R)
```

Which one of the following statements is **CORRECT**?

A. S1 is TRUE and S2 is FALSE
B. Both S1 and S2 are TRUE
C. S1 is FALSE and S2 is TRUE
D. Both S1 and S2 are FALSE

gatecse-2014-set1 databases normal sql

Answer key

5.18.32 SQL: GATE CSE 2014 Set 1 | Question: 54

Given the following schema:

employees(emp-id, first-name, last-name, hire-date, dept-id, salary)

departments(dept-id, dept-name, manager-id, location-id)

You want to display the last names and hire dates of all latest hires in their respective departments in the location $\text{ID } 1700$. You issue the following query:

```
SQL>SELECT last-name, hire-date
  FROM employees
  WHERE (dept-id, hire-date) IN
  (SELECT dept-id, MAX(hire-date)
  FROM employees JOIN departments USING(dept-id)
  WHERE location-id =1700
  GROUP BY dept-id);
```

What is the outcome?

A. It executes but does not give the correct result
B. It executes and gives the correct result.
C. It generates an error because of pairwise comparison.
D. It generates an error because of the GROUP BY clause cannot be used with table joins in a sub-query.

gatecse-2014-set1 databases sql normal

Answer key

5.18.33 SQL: GATE CSE 2014 Set 2 | Question: 54

SQL allows duplicate tuples in relations, and correspondingly defines the multiplicity of tuples in the result of joins. Which one of the following queries always gives the same answer as the nested query shown below:

```
select * from R where a in (select S.a from S)
```

A. select R.* from R, S where R.a=S.a
B. select distinct R.* from R,S where R.a=S.a
C. select R.* from R,(select distinct a from S) as S1 where R.a=S1.a
D. select R.* from R,S where R.a=S.a and is unique R

gatecse-2014-set2 databases sql normal

Answer key

5.18.34 SQL: GATE CSE 2014 Set 3 | Question: 54

Consider the following relational schema:

employee (empId,empName,empDept)

customer (custId,custName,salesRepId,rating)

salesRepId is a foreign key referring to **empId** of the employee relation. Assume that each employee makes a sale to at least one customer. What does the following query return?

```
SELECT empName   FROM employee E
WHERE NOT EXISTS (SELECT custId
   FROM customer C
   WHERE C.salesRepId = E.empId
   AND C.rating <> 'GOOD');
```

A. Names of all the employees with at least one of their customers having a ‘GOOD’ rating.
B. Names of all the employees with at most one of their customers having a 'GOOD' rating.
C. Names of all the employees with none of their customers having a 'GOOD' rating.
D. Names of all the employees with all their customers having a 'GOOD' rating.

gatecse-2014-set3 databases sql easy

Answer key☟

5.18.35 SQL: GATE CSE 2015 Set 1 | Question: 27

Consider the following relation:

Student

Roll_No	Student_Name
1	Raj
2	Rohit
3	Raj

Performance

Roll_No	Course	Marks
1	Math	80
1	English	70
2	Math	75
3	English	80
2	Physics	65
3	Math	80

Consider the following SQL query.

```
SELECT S.Student_Name, Sum(P. Marks)
FROM Student S, Performance P
WHERE S.Roll_No= P.Roll_No
GROUP BY S.STUDENT_Name
```

The numbers of rows that will be returned by the SQL query is_________________.

gatecse-2015-set1 databases sql normal numerical-answers

Answer key☟

5.18.36 SQL: GATE CSE 2015 Set 3 | Question: 3

Consider the following relation

Cinema($theater, address, capacity$)

Which of the following options will be needed at the end of the SQL query

```
SELECT P1.address
FROM Cinema P1
```

such that it always finds the addresses of theaters with maximum capacity?

A. `WHERE P1.capacity >= All (select P2.capacity from Cinema P2)`

B. `WHERE P1.capacity >= Any (select P2.capacity from Cinema P2)`

C. `WHERE P1.capacity > All (select max(P2.capacity) from Cinema P2)`

D.
```
WHERE P1.capacity > Any (select max(P2.capacity) from Cinema P2)
```

gatecse-2015-set3 databases sql normal

Answer key

5.18.37 SQL: GATE CSE 2016 Set 2 | Question: 52

Consider the following database table named water_schemes:

Water_schemes

scheme_no	district_name	capacity
1	Ajmer	20
1	Bikaner	10
2	Bikaner	10
3	Bikaner	20
1	Churu	10
2	Churu	20
1	Dungargarh	10

The number of tuples returned by the following SQL query is _________.

```
with total (name, capacity) as
   select district_name, sum (capacity)
   from water_schemes
   group by district_name
with total_avg (capacity) as
   select avg (capacity)
   from total
select name
   from total, total_avg
   where total.capacity ≥ total_avg.capacity
```

gatecse-2016-set2 databases sql normal numerical-answers

Answer key

5.18.38 SQL: GATE CSE 2017 Set 1 | Question: 23

Consider a database that has the relation schema EMP (EmpId, EmpName, and DeptName). An instance of the schema EMP and a SQL query on it are given below:

EMP

EmpId	EmpName	DeptName
1	XYA	AA
2	XYB	AA
3	XYC	AA
4	XYD	AA
5	XYE	AB
6	XYF	AB
7	XYG	AB
8	XYH	AC
9	XYI	AC
10	XYJ	AC
11	XYK	AD
12	XYL	AD
13	XYM	AE

```
SELECT AVG(EC.Num)
FROM EC
WHERE (DeptName, Num) IN
```

```
(SELECT DeptName, COUNT(EmpId) AS
            EC(DeptName, Num)
FROM EMP
GROUP BY DeptName)
```

The output of executing the SQL query is _____________ .

gatecse-2017-set1 databases sql numerical-answers

Answer key

5.18.39 SQL: GATE CSE 2017 Set 2 | Question: 46

Consider the following database table named top_scorer.

top_scorer

player	country	goals
Klose	Germany	16
Ronaldo	Brazil	15
G Muller	Germany	14
Fontaine	France	13
Pele	Brazil	12
Klinsmann	Germany	11
Kocsis	Hungary	11
Batistuta	Argentina	10
Cubillas	Peru	10
Lato	Poland	10
Lineker	England	10
T Muller	Germany	10
Rahn	Germany	10

Consider the following SQL query:

```
SELECT ta.player FROM top_scorer AS ta
WHERE ta.goals >ALL (SELECT tb.goals
   FROM top_scorer AS tb
   WHERE tb.country = 'Spain')
AND ta.goals > ANY (SELECT tc.goals
   FROM top_scorer AS tc
   WHERE tc.country='Germany')
```

The number of tuples returned by the above SQL query is ______

gatecse-2017-set2 databases sql numerical-answers

Answer key

5.18.40 SQL: GATE CSE 2018 | Question: 12

Consider the following two tables and four queries in SQL.

Book (isbn, bname), Stock(isbn, copies)

Query 1:

```
SELECT B.isbn, S.copies FROM Book B INNER JOIN Stock S ON B.isbn=S.isbn;
```

Query 2:

```
SELECT B.isbn, S.copies FROM Book B LEFT OUTER JOIN Stock S ON B.isbn=S.isbn;
```

Query 3:

```
SELECT B.isbn, S,copies FROM Book B RIGHT OUTER JOIN Stock S ON B.isbn=S.isbn
```

Query 4:

```
SELECT B.isbn, S.copies FROM Book B FULL OUTER JOIN Stock S ON B.isbn=S.isbn
```

Which one of the queries above is certain to have an output that is a superset of the outputs of the other three queries?

A. Query 1 B. Query 2 C. Query 3 D. Query 4

gatecse-2018 databases sql easy one-mark

Answer key☟

5.18.41 SQL: GATE CSE 2019 | Question: 51

A relational database contains two tables Student and Performance as shown below:

Table: student

Roll_no	Student_name
1	Amit
2	Priya
3	Vinit
4	Rohan
5	Smita

Table: Performance

Roll_no	Subject_code	Marks
1	A	86
1	B	95
1	C	90
2	A	89
2	C	92
3	C	80

The primary key of the Student table is Roll_no. For the performance table, the columns Roll_no. and Subject_code together form the primary key. Consider the SQL query given below:

```
SELECT S.Student_name, sum(P.Marks)
FROM Student S, Performance P
WHERE P.Marks >84
GROUP BY S.Student_name;
```

The number of rows returned by the above SQL query is ____ 5

gatecse-2019 numerical-answers databases sql two-marks

Answer key☟

5.18.42 SQL: GATE CSE 2020 | Question: 13

Consider a relational database containing the following schemas.

Catalogue

sno	pno	cost
S1	P1	150
S1	P2	50
S1	P3	100
S2	P4	200
S2	P5	250
S3	P1	250
S3	P2	150
S3	P5	300
S3	P4	250

Suppliers

sno	sname	location
S1	M/s Royal furniture	Delhi
S2	M/s Balaji furniture	Bangalore
S3	M/s Premium furniture	Chennai

Parts

pno	pname	part_spec
P1	Table	Wood
P2	Chair	Wood
P3	Table	Steel
P4	Almirah	Steel
P5	Almirah	Wood

The primary key of each table is indicated by underlining the constituent fields.

```
SELECT s.sno, s.sname
FROM Suppliers s, Catalogue c
WHERE s.sno=c.sno AND
  cost > (SELECT AVG (cost)
```

```
        FROM Catalogue
        WHERE pno = 'P4'
        GROUP BY pno) ;
```

The number of rows returned by the above SQL query is

A. 4
B. 5
C. 0
D. 2

gatecse-2020 databases sql one-mark

Answer key

5.18.43 SQL: GATE CSE 2021 Set 1 | Question: 23

A relation $r(A, B)$ in a relational database has 1200 tuples. The attribute A has integer values ranging from 6 to 20, and the attribute B has integer values ranging from 1 to 20. Assume that the attributes A and B are independently distributed.

The estimated number of tuples in the output of $\sigma_{(A>10)\vee(B=18)}(r)$ is 820 ________.

gatecse-2021-set1 databases sql numerical-answers one-mark

Answer key

5.18.44 SQL: GATE CSE 2021 Set 2 | Question: 31

The relation scheme given below is used to store information about the employees of a company, where **empId** is the key and **deptId** indicates the department to which the employee is assigned. Each employee is assigned to exactly one department.

emp(<u>empId</u>, name, gender, salary, deptId)

Consider the following SQL query:

```
select deptId, count(*)
from emp
where gender = "female" and salary > (select avg(salary)from emp)
group by deptId;
```

The above query gives, for each department in the company, the number of female employees whose salary is greater than the average salary of

A. employees in the department
B. employees in the company
C. female employees in the department
D. female employees in the company

gatecse-2021-set2 databases sql easy two-marks

Answer key

5.18.45 SQL: GATE CSE 2022 | Question: 46

Consider the relational database with the following four schemas and their respective instances.

- Student(sNo, sName, dNo) Dept(dNo, dName)
- Course(cNo, cName, dNo) Register(sNo, cNo)

	Students	
sNo	sName	dNo
S01	James	D01
S02	Rocky	D01
S03	Jackson	D02
S04	Jane	D01
S05	Milli	D02

	Depth
dNo	dName
D01	CSE
D02	EEE

	Course	
cNo	cName	dNo
C11	DS	D01
C12	OS	D01
C21	DE	D02
C22	PT	D02
C23	CV	D03

	Register
sNo	cNo
S01	C11
S01	C12
S02	C11
S03	C21
S03	C22
S03	C23
S04	C11
S04	C12
S05	C11
S05	C21

SQL query

```
SELECT * FROM Student AS S WHERE NOT EXIST
 (SELECT cNo FROM Course WHERE dNo = “D01”
     EXCEPT
   SELECT cNo FROM Register WHERE sNo = S.sNo)
```

The number of rows returned by the above SQL query is 2 _______.

gatecse-2022 numerical-answers databases sql two-marks

Answer key

5.18.46 SQL: GATE CSE 2023 | Question: 51

Consider the following table named Student in a relational database. The primary key of this table is rollNum.

Student

rollNum	name	gender	marks
1	Naman	M	62
2	Aliya	F	70
3	Aliya	F	80
4	James	M	82
5	Swati	F	65

The SQL query below is executed on this database.

```
SELECT *
FROM Student
WHERE gender = 'F' AND
   marks > 65;
```

The number of rows returned by the query is 2 _______.

gatecse-2023 databases sql numerical-answers two-marks easy

Answer key

5.18.47 SQL: GATE CSE 2025 | Set 1 | Question: 45

Consider the following database tables of a sports league.

```
player (pid, pname, age)        team(tid, tname, city, cid)
coach (cid, cname)            members (pid,tid)
```

An instance of the table and an SQL query are given.

player

pid	pname	age
1	Jasprit	31
2	Atharva	24
3	Ishan	26
4	Axar	30

coach

cid	cname
101	Ricky
102	Mark
103	Trevor

team

tid	tname	city	cid
10	MI	Mumbai	102
20	DC	Delhi	101
30	PK	Mohali	103

members

pid	tid
1	10
2	30
3	10
4	20

```
SELECT MIN (P.age)
FROM player P
WHERE P.pid IN (
  SELECT M.pid
  FROM team T, coach C, members M
  WHERE C.cname = 'Mark'
       AND T.cid = C.cid
       AND M.tid = T.tid
  )
```

The value returned by the given SQL query is ______ 26. (Answer in integer)

gatecse2025-set1 databases sql numerical-answers easy two-marks

Answer key

5.18.48 SQL: GATE CSE 2025 | Set 2 | Question: 44

Consider the following relational schema:

Students (rollno: integer, name: string, age: integer, cgpa: real)

Courses (courseno: integer, cname: string, credits: integer)

Enrolled (rollno: integer, courseno: integer, grade: string)

Which of the following options is/are correct SQL query/queries to retrieve the names of the students enrolled in course number (i.e., courseno) 1470?

```
A. SELECT S.name
   FROM Students S
   WHERE EXISTS (SELECT * FROM Enrolled E
             WHERE E.courseno = 1470
                  AND E.rollno = S.rollno);
```

```
B. SELECT S.name
   FROM Students S
   WHERE SIZEOF (SELECT * FROM Enrolled E
             WHERE E.courseno = 1470
                  AND E.rollno = S.rollno) > 0;
```

```
C. SELECT S.name
   FROM Students S
   WHERE 0 < (SELECT COUNT(*)
          FROM Enrolled E
          WHERE E.courseno = 1470
               AND E.rollno = S.rollno);
```

```
D. SELECT S.name
   FROM Students S NATURAL JOIN Enrolled E
   WHERE E.courseno = 1470;
```

gatecse2025-set2 databases sql multiple-selects two-marks

Answer key

5.18.49 SQL: GATE DA 2025 | Question: 23

On a relation named Loan of a bank:

Loan		
loan_number	**branch_name**	**amount**
L11	Banjara Hills	90000
L14	Kondapur	50000
L15	SR Nagar	40000
L22	SR Nagar	25000
L23	Balanagar	80000
L25	Kondapur	70000
L19	SR Nagar	65000

the following SQL query is executed.

```
SELECT L1.loan_number
FROM Loan L1
WHERE L1.amount > (SELECT MAX (L2.amount)
            FROM Loan L2
            WHERE L2.branch_name = 'SR Nagar');
```

The number of rows returned by the query is __________ (Answer in integer).

gateda-2025 databases sql numerical-answers one-mark

Answer key

5.18.50 SQL: GATE DS&AI 2024 | Question: 21

Consider the following two tables named Raider and Team in a relational database maintained by a Kabaddi league. The attribute ID in table Team references the primary key of the Raider table, ID.

Raider			
ID	**Name**	**Raids**	**Raidpoints**
1	Arjun	200	250
2	Ankush	190	219
3	Sunil	150	200
4	Reza	150	190
5	Pratham	175	220
6	Gopal	193	215

Team		
City	**ID**	**BidPoints**
Jaipur	2	200
Patna	3	195
Hyderabad	5	175
Jaipur	1	250
Patna	4	200
Jaipur	6	200

The SQL query described below is executed on this database:

```
SELECT *
FROM Raider, Team
WHERE Raider.ID=Team.ID AND City="Jaipur" AND
RaidPoints > 200;
```

The number of rows returned by this query is _________.

gate-ds-ai-2024 numerical-answers databases sql one-mark

Answer key

5.18.51 SQL: GATE DS&AI 2024 | Question: 45

An OTT company is maintaining a large disk-based relational database of different movies with the following schema:

$$\text{Movie (ID, CustomerRating)}$$
$$\text{Genre (ID, Name)}$$
$$\text{Movie\_Genre (MovieID, GenreID)}$$

Consider the following SQL query on the relation database above:

```
SELECT *
FROM Movie, Genre, Movie_Genre
WHERE
   Movie.CustomerRating > 3.4 AND
   Genre.Name = "Comedy" AND
   Movie_Genre.MovieID = Movie.ID AND
   Movie_Genre.GenreID = Genre.ID;
```

This SQL query can be sped up using which of the following indexing options?

A. B^{+} tree on all the attributes.
B. Hash index on Genre.Name and B^{+} tree on the remaining attributes.
C. Hash index on Movie.CustomerRating and B^{+} tree on the remaining attributes.
D. Hash index on all the attributes.

gate-ds-ai-2024 sql databases multiple-selects two-marks

Answer key

5.18.52 SQL: GATE IT 2004 | Question: 74

A relational database contains two tables student and department in which student table has columns roll_no, name and dept_id and department table has columns dept_id and dept_name. The following insert statements were executed successfully to populate the empty tables:

```
Insert into department values (1, 'Mathematics')
Insert into department values (2, 'Physics')
Insert into student values (l, 'Navin', 1)
Insert into student values (2, 'Mukesh', 2)
Insert into student values (3, 'Gita', 1)
```

How many rows and columns will be retrieved by the following SQL statement?

```
Select * from student, department
```

A. 0 row and 4 columns
B. 3 rows and 4 columns
C. 3 rows and 5 columns
D. 6 rows and 5 columns

gateit-2004 databases sql normal

Answer key

5.18.53 SQL: GATE IT 2004 | Question: 76

A table T1 in a relational database has the following rows and columns:

Roll no.	Marks
1	10
2	20
3	30
4	NULL

The following sequence of SQL statements was successfully executed on table T1.

```
Update T1 set marks = marks + 5
Select avg(marks) from T1
```

What is the output of the select statement?

A. 18.75
B. 20
C. 25
D. Null

gateit-2004 databases sql normal

Answer key

5.18.54 SQL: GATE IT 2004 | Question: 78

Consider two tables in a relational database with columns and rows as follows:

Table: Student

Roll_no	Name	Dept_id
1	ABC	1
2	DEF	1
3	GHI	2
4	JKL	3

Table: Department

Dept_id	Dept_name
1	A
2	B
3	C

Roll_no is the primary key of the Student table, Dept_id is the primary key of the Department table and Student.Dept_id is a foreign key from Department.Dept_id
What will happen if we try to execute the following two SQL statements?

i. update Student set Dept_id = Null where Roll_on = 1
ii. update Department set Dept_id = Null where Dept_id = 1

A. Both i and ii will fail
B. i will fail but ii will succeed
C. i will succeed but ii will fail
D. Both i and ii will succeed

gateit-2004 databases sql normal

Answer key

5.18.55 SQL: GATE IT 2005 | Question: 69

In an inventory management system implemented at a trading corporation, there are several tables designed to hold all the information. Amongst these, the following two tables hold information on which items are supplied by which suppliers, and which warehouse keeps which items along with the stock-level of these items.

Supply = (supplierid, itemcode)
Inventory = (itemcode, warehouse, stocklevel)

For a specific information required by the management, following SQL query has been written

```
Select distinct STMP.supplierid
From Supply as STMP
Where not unique (Select ITMP.supplierid
                  From Inventory, Supply as ITMP
                  Where STMP.supplierid = ITMP.supplierid
                  And ITMP.itemcode = Inventory.itemcode
                  And Inventory.warehouse = 'Nagpur');
```

For the warehouse at Nagpur, this query will find all suppliers who

A. do not supply any item
B. supply exactly one item
C. supply one or more items
D. supply two or more items

gateit-2005 databases sql normal

Answer key

5.18.56 SQL: GATE IT 2006 | Question: 84

Consider a database with three relation instances shown below. The primary keys for the Drivers and Cars relation are *did* and *cid* respectively and the records are stored in ascending order of these primary keys as given in the tables. No indexing is available in the database.

D: Drivers relation

did	dname	rating	age
22	Karthikeyan	7	25
29	Salman	1	33
31	Boris	8	55
32	Amoldt	8	25
58	Schumacher	10	35
64	Sachin	7	35
71	Senna	10	16
74	Sachin	9	35
85	Rahul	3	25
95	Ralph	3	53

R: Reserves relation

did	Cid	day
22	101	10 / 10 / 06
22	102	10 / 10 / 06
22	103	08 / 10 / 06
22	104	07 / 10 / 06
31	102	10 / 11 / 16
31	103	06 / 11 / 16
31	104	12 / 11 / 16
64	101	05 / 09 / 06
64	102	08 / 09 / 06
74	103	08 / 09 / 06

C: Cars relation

Cid	Cname	colour
101	Renault	blue
102	Renault	red
103	Ferrari	green
104	Jaguar	red

What is the output of the following SQL query?

```
select D.dname
from Drivers D
where D.did in  (
                 select R.did
                 from Cars C, Reserves R
                 where R.cid = C.cid and C.colour = 'red'
                 intersect
                 select R.did
                 from Cars C, Reserves R
                 where R.cid  = C.cid and C.colour = 'green'
                 )
```

A. Karthikeyan, Boris
B. Sachin, Salman
C. Karthikeyan, Boris, Sachin
D. Schumacher, Senna

gateit-2006 databases sql normal

Answer key☟

5.18.57 SQL: GATE IT 2006 | Question: 85

Consider a database with three relation instances shown below. The primary keys for the Drivers and Cars relation are *did* and *cid* respectively and the records are stored in ascending order of these primary keys as given in the tables. No indexing is available in the database.

D: Drivers relation

did	dname	rating	age
22	Karthikeyan	7	25
29	Salman	1	33
31	Boris	8	55
32	Amoldt	8	25
58	Schumacher	10	35
64	Sachin	7	35
71	Senna	10	16
74	Sachin	9	35
85	Rahul	3	25
95	Ralph	3	53

R: Reserves relation

did	Cid	day
22	101	10 – 10 – 06
22	102	10 – 10 – 06
22	103	08 – 10 – 06
22	104	07 – 10 – 06
31	102	10 – 11 – 16
31	103	06 – 11 – 16
31	104	12 – 11 – 16
64	101	05 – 09 – 06
64	102	08 – 09 – 06
74	103	08 – 09 – 06

C: Cars relation

Cid	Cname	colour
101	Renault	blue
102	Renault	red
103	Ferrari	green
104	Jaguar	red

```
select D.dname
from Drivers D
where D.did in  (
                 select R.did
                 from Cars C, Reserves R
                 where R.cid = C.cid and C.colour = 'red'
                 intersect
                 select R.did
                 from Cars C, Reserves R
                 where R.cid  = C.cid and C.colour = 'green'
                  )
```

Let n be the number of comparisons performed when the above SQL query is optimally executed. If linear search is used to locate a tuple in a relation using primary key, then n lies in the range:

A. $36 - 40$
B. $44 - 48$
C. $60 - 64$
D. $100 - 104$

gateit-2006 databases sql normal

Answer key

5.18.58 SQL: GATE IT 2008 | Question: 74

Consider the following relational schema:

- $\text{Student}(\underline{\text{school-id, sch-roll-no}}, \text{sname, saddress})$
- $\text{School}(\underline{\text{school-id}}, \text{sch-name, sch-address, sch-phone})$
- $\text{Enrolment}(\underline{\text{school-id, sch-roll-no}}, \text{erollno, examname})$
- $\text{ExamResult}(\underline{\text{erollno, examname}}, \text{marks})$

What does the following SQL query output?

```
SELECT sch-name, COUNT (*)
FROM School C, Enrolment E, ExamResult R
WHERE E.school-id = C.school-id
AND
E.examname = R.examname AND E.erollno = R.erollno
AND
R.marks = 100 AND E.school-id IN (SELECT school-id
                        FROM student
                        GROUP BY school-id
                         HAVING COUNT (*) > 200)
GROUP By school-id
```

A. for each school with more than 200 students appearing in exams, the name of the school and the number of $100s$ scored by its students
B. for each school with more than 200 students in it, the name of the school and the number of $100s$ scored by its students
C. for each school with more than 200 students in it, the name of the school and the number of its students scoring 100 in at least one exam
D. nothing; the query has a syntax error

gateit-2008 databases sql normal

Answer key

5.19 Transaction and Concurrency (30)

5.19.1 Transaction and Concurrency: GATE CSE 1999 | Question: 2.6

For the schedule given below, which of the following is correct:

1	Read A	
2		Read B
3	Write A	
4		Read A
5		Write A
6		Write B
7	Read B	
8	Write B	

A. This schedule is serializable and can occur in a scheme using 2PL protocol
B. This schedule is serializable but cannot occur in a scheme using 2PL protocol
C. This schedule is not serializable but can occur in a scheme using 2PL protocol
D. This schedule is not serializable and cannot occur in a scheme using 2PL protocol

gate1999 databases transaction-and-concurrency normal

Answer key

5.19.2 Transaction and Concurrency: GATE CSE 2003 | Question: 29, ISRO2009-73

Which of the following scenarios may lead to an irrecoverable error in a database system?

A. A transaction writes a data item after it is read by an uncommitted transaction
B. A transaction reads a data item after it is read by an uncommitted transaction
C. A transaction reads a data item after it is written by a committed transaction
D. A transaction reads a data item after it is written by an uncommitted transaction

gatecse-2003 databases transaction-and-concurrency easy isro2009

Answer key

5.19.3 Transaction and Concurrency: GATE CSE 2003 | Question: 87

Consider three data items $D1, D2,$ and $D3,$ and the following execution schedule of transactions $T1, T2,$ and $T3.$ In the diagram, $R(D)$ and $W(D)$ denote the actions reading and writing the data item D respectively.

T1	T2	T3
	R(D3);	
	R(D2);	
	W(D2);	
		R(D2);
		R(D3);
R(D1);		
W(D1);		
		W(D2);
		W(D3);
	R(D1);	
R(D2);		
W(D2);		
	W(D1);	

Which of the following statements is correct?

A. The schedule is serializable as $T2; T3; T1$
B. The schedule is serializable as $T2; T1; T3$
C. The schedule is serializable as $T3; T2; T1$
D. The schedule is not serializable

gatecse-2003 databases transaction-and-concurrency normal

Answer key

5.19.4 Transaction and Concurrency: GATE CSE 2006 | Question: 20, ISRO2015-17

Consider the following log sequence of two transactions on a bank account, with initial balance $12000,$ that transfer 2000 to a mortgage payment and then apply a 5% interest.

1. T1 start
2. T1 B old $= 12000$ new $= 10000$
3. T1 M old $= 0$ new $= 2000$
4. T1 commit
5. T2 start
6. T2 B old $= 10000$ new $= 10500$
7. T2 commit

Suppose the database system crashes just before log record 7 is written. When the system is restarted, which one statement is true of the recovery procedure?

A. We must redo log record 6 to set B to 10500
B. We must undo log record 6 to set B to 10000 and then redo log records 2 and 3
C. We need not redo log records 2 and 3 because transaction T1 has committed
D. We can apply redo and undo operations in arbitrary order because they are idempotent

gatecse-2006 databases transaction-and-concurrency normal isro2015

Answer key

5.19.5 Transaction and Concurrency: GATE CSE 2007 | Question: 64

Consider the following schedules involving two transactions. Which one of the following statements is **TRUE**?

- $S_1 : r_1(X); r_1(Y); r_2(X); r_2(Y); w_2(Y); w_1(X)$
- $S_2 : r_1(X); r_2(X); r_2(Y); w_2(Y); r_1(Y); w_1(X)$

A. Both S_1 and S_2 are conflict serializable.

B. S_1 is conflict serializable and S_2 is not conflict serializable.

C. S_1 is not conflict serializable and S_2 is conflict serializable.

D. Both S_1 and S_2 are not conflict serializable.

gatecse-2007 databases transaction-and-concurrency normal

Answer key

5.19.6 Transaction and Concurrency: GATE CSE 2009 | Question: 43

Consider two transactions T_1 and T_2, and four schedules S_1, S_2, S_3, S_4, of T_1 and T_2 as given below:

$T_1 : R_1[x]W_1[x]W_1[y]$

$T_2 : R_2[x]R_2[y]W_2[y]$

$S_1 : R_1[x]R_2[x]R_2[y]W_1[x]W_1[y]W_2[y]$

$S_2 : R_1[x]R_2[x]R_2[y]W_1[x]W_2[y]W_1[y]$

$S_3 : R_1[x]W_1[x]R_2[x]W_1[y]R_2[y]W_2[y]$

$S_4 : R_2[x]R_2[y]R_1[x]W_1[x]W_1[y]W_2[y]$

Which of the above schedules are conflict-serializable?

A. $S_1 \text{ and } S_2$ B. $S_2 \text{ and } S_3$ C. S_3 only D. S_4 only

gatecse-2009 databases transaction-and-concurrency normal

Answer key

5.19.7 Transaction and Concurrency: GATE CSE 2010 | Question: 20

Which of the following concurrency control protocols ensure both conflict serializability and freedom from deadlock?

I. 2-phase locking
II. Time-stamp ordering

A. I only B. II only C. Both I and II D. Neither I nor II

gatecse-2010 databases transaction-and-concurrency normal

Answer key

5.19.8 Transaction and Concurrency: GATE CSE 2010 | Question: 42

Consider the following schedule for transactions $T1, T2$ and $T3$:

T1	T2	T3
Read(X)		
	Read(Y)	
		Read(Y)
	Write(Y)	
Write(X)		
		Write(X)
	Read(X)	
	Write(X)	

Which one of the schedules below is the correct serialization of the above?

A. $T1 \rightarrow T3 \rightarrow T2$
B. $T2 \rightarrow T1 \rightarrow T3$
C. $T2 \rightarrow T3 \rightarrow T1$
D. $T3 \rightarrow T1 \rightarrow T2$

gatecse-2010 databases transaction-and-concurrency normal

Answer key

5.19.9 Transaction and Concurrency: GATE CSE 2012 | Question: 27

Consider the following transactions with data items P and Q initialized to zero:

T_1	read (P); read (Q); if $\mathrm{P} = 0$ then $\mathrm{Q} := \mathrm{Q} + 1$; write (Q)
T_2	read (Q); read (P); if $\mathrm{Q} = 0$ then $\mathrm{P} := \mathrm{P} + 1$; write (P)

Any non-serial interleaving of **T1** and **T2** for concurrent execution leads to

A. a serializable schedule
B. a schedule that is not conflict serializable
C. a conflict serializable schedule
D. a schedule for which a precedence graph cannot be drawn

gatecse-2012 databases transaction-and-concurrency normal

Answer key

5.19.10 Transaction and Concurrency: GATE CSE 2015 Set 2 | Question: 1

Consider the following transaction involving two bank accounts x and y.

```
read(x); x:=x-50; write (x); read(y); y:=y+50; write(y)
```

The constraint that the sum of the accounts x and y should remain constant is that of

A. Atomicity
B. Consistency
C. Isolation
D. Durability

gatecse-2015-set2 databases transaction-and-concurrency easy

Answer key

5.19.11 Transaction and Concurrency: GATE CSE 2015 Set 2 | Question: 46

Consider a simple checkpointing protocol and the following set of operations in the log.

(start, T4); (write, T4, y, 2, 3); (start, T1); (commit, T4); (write, T1, z, 5, 7);

(checkpoint);

(start, T2); (write, T2, x, 1, 9); (commit, T2); (start, T3); (write, T3, z, 7, 2);

If a crash happens now and the system tries to recover using both undo and redo operations, what are the contents of the undo list and the redo list?

A. Undo: T3, T1; Redo: T2
B. Undo: T3, T1; Redo: T2, T4
C. Undo: none; Redo: T2, T4, T3, T1
D. Undo: T3, T1, T4; Redo: T2

gatecse-2015-set2 databases transaction-and-concurrency normal

Answer key

5.19.12 Transaction and Concurrency: GATE CSE 2015 Set 3 | Question: 29

Consider the partial Schedule S involving two transactions $T1$ and $T2$. Only the $read$ and the $write$ operations have been shown. The $read$ operation on data item P is denoted by $read(P)$ and $write$

operation on data item P is denoted by $write(P)$.

Schedule S

Time Instance	Transaction ID **T1**	**T2**
1	read(A)	
2	write(A)	
3		read(C)
4		write(C)
5		read(B)
6		write(B)
7		read(A)
8		commit
9	read(B)	

Suppose that the transaction $T1$ fails immediately after time instance 9. Which of the following statements is correct?

A. $T2$ must be aborted and then both $T1$ and $T2$ must be re-started to ensure transaction atomicity
B. Schedule S is non-recoverable and cannot ensure transaction atomicity
C. Only $T2$ must be aborted and then re-started to ensure transaction atomicity
D. Schedule S is recoverable and can ensure transaction atomicity and nothing else needs to be done

gatecse-2015-set3 databases transaction-and-concurrency normal

Answer key☟

5.19.13 Transaction and Concurrency: GATE CSE 2016 Set 1 | Question: 22

Which one of the following is NOT a part of the ACID properties of database transactions?

A. Atomicity B. Consistency C. Isolation D. Deadlock-freedom

gatecse-2016-set1 databases transaction-and-concurrency easy

Answer key☟

5.19.14 Transaction and Concurrency: GATE CSE 2016 Set 1 | Question: 51

Consider the following two phase locking protocol. Suppose a transaction T accesses (for read or write operations), a certain set of objects $\{O_1, \ldots, O_k\}$. This is done in the following manner:

- Step 1. T acquires exclusive locks to $O_1, \ldots, O_k$ in increasing order of their addresses.
- Step 2. The required operations are performed .
- Step 3. All locks are released

This protocol will

A. guarantee serializability and deadlock-freedom
B. guarantee neither serializability nor deadlock-freedom
C. guarantee serializability but not deadlock-freedom
D. guarantee deadlock-freedom but not serializability.

gatecse-2016-set1 databases transaction-and-concurrency normal

Answer key☟

5.19.15 Transaction and Concurrency: GATE CSE 2016 Set 2 | Question: 22

Suppose a database schedule S involves transactions $T_1, \ldots, T_n$. Construct the precedence graph of S

with vertices representing the transactions and edges representing the conflicts. If S is serializable, which one of the following orderings of the vertices of the precedence graph is guaranteed to yield a serial schedule?

A. Topological order
B. Depth-first order
C. Breadth-first order
D. Ascending order of the transaction indices

gatecse-2016-set2 databases transaction-and-concurrency normal

Answer key

5.19.16 Transaction and Concurrency: GATE CSE 2016 Set 2 | Question: 51

Consider the following database schedule with two transactions T_1 and T_2.

$S = r_2(X); r_1(X); r_2(Y); w_1(X); r_1(Y); w_2(X); a_1; a_2$

Where $r_i(Z)$ denotes a read operation by transaction T_i on a variable Z, $w_i(Z)$ denotes a write operation by T_i on a variable Z and a_i denotes an abort by transaction T_i.

Which one of the following statements about the above schedule is **TRUE**?

A. S is non-recoverable.
B. S is recoverable, but has a cascading abort.
C. S does not have a cascading abort.
D. S is strict.

gatecse-2016-set2 databases transaction-and-concurrency normal

Answer key

5.19.17 Transaction and Concurrency: GATE CSE 2017 Set 1 | Question: 42

In a database system, unique timestamps are assigned to each transaction using Lamport's logical clock. Let $TS(T_1)$ and $TS(T_2)$ be the timestamps of transactions T_1 and T_2 respectively. Besides, T_1 holds a lock on the resource R, and T_2 has requested a conflicting lock on the same resource R. The following algorithm is used to prevent deadlocks in the database system assuming that a killed transaction is restarted with the same timestamp.

if $TS(T_2) < TS(T_1)$ then

T_1 is killed

else T_2 waits.

Assume any transaction that is not killed terminates eventually. Which of the following is TRUE about the database system that uses the above algorithm to prevent deadlocks?

A. The database system is both deadlock-free and starvation-free.
B. The database system is deadlock-free, but not starvation-free.
C. The database system is starvation-free, but not deadlock-free.
D. The database system is neither deadlock-free nor starvation-free.

gatecse-2017-set1 databases timestamp-ordering normal transaction-and-concurrency

Answer key

5.19.18 Transaction and Concurrency: GATE CSE 2019 | Question: 11

Consider the following two statements about database transaction schedules:

I. Strict two-phase locking protocol generates conflict serializable schedules that are also recoverable.
II. Timestamp-ordering concurrency control protocol with Thomas' Write Rule can generate view serializable schedules that are not conflict serializable

Which of the above statements is/are TRUE?

A. I only
B. II only
C. Both I and II
D. Neither I nor II

gatecse-2019 databases transaction-and-concurrency one-mark

Answer key

5.19.19 Transaction and Concurrency: GATE CSE 2020 | Question: 37

Consider a schedule of transactions T_1 and T_2:

T_1	RA			RC		WD		WB	Commit	
T_2		RB	WB		RD		WC			Commit

Here, RX stands for "Read(X)" and WX stands for "Write(X)". Which one of the following schedules is conflict equivalent to the above schedule?

A.

T_1				RA	RC	WD	WB		Commit	
T_2	RB	WB	RD					WC		Commit

B.

T_1	RA	RC	WD	WB					Commit	
T_2					RB	WB	RD	WC		Commit

C.

T_1	RA	RC	WD				WB		Commit	
T_2				RB	WB	RD		WC		Commit

D.

T_1					RA	RC	WD	WB	Commit	
T_2	RB	WB	RD	WC						Commit

gatecse-2020 databases transaction-and-concurrency two-marks

Answer key

5.19.20 Transaction and Concurrency: GATE CSE 2021 Set 1 | Question: 13

Suppose a database system crashes again while recovering from a previous crash. Assume checkpointing is not done by the database either during the transactions or during recovery.

Which of the following statements is/are correct?

A. The same undo and redo list will be used while recovering again
B. The system cannot recover any further
C. All the transactions that are already undone and redone will not be recovered again
D. The database will become inconsistent

gatecse-2021-set1 multiple-selects databases transaction-and-concurrency one-mark

Answer key

5.19.21 Transaction and Concurrency: GATE CSE 2024 | Set 2 | Question: 17

Which of the following statements about the Two Phase Locking (2PL) protocol is/are TRUE?

A. 2PL permits only serializable schedules
B. With 2PL, a transaction always locks the data item being read or written just before every operation and always releases the lock just after the operation
C. With 2PL, once a lock is released on any data item inside a transaction, no more locks on any data item can be obtained inside that transaction
D. A deadlock is possible with 2PL

gatecse2024-set2 databases two-phase-locking-protocol multiple-selects transaction-and-concurrency one-mark

Answer key

5.19.22 Transaction and Concurrency: GATE CSE 2024 | Set 2 | Question: 9

Once the DBMS informs the user that a transaction has been successfully completed, its effect should persist even if the system crashes before all its changes are reflected on disk. This property is called

A. durability B. atomicity C. consistency D. isolation

gatecse2024-set2 databases transaction-and-concurrency one-mark

Answer key☟

5.19.23 Transaction and Concurrency: GATE CSE 2025 | Set 1 | Question: 5

A schedule of three database transactions $T_1, T_2,$ and T_3 is shown. $R_i(A)$ and $W_i(A)$ denote read and write of data item A by transaction $T_i, i = 1, 2, 3$. The transaction T_1 aborts at the end. Which other transaction(s) will be required to be rolled back?

$$R_1(X)W_1(Y)R_2(X)R_2(Y)R_3(Y)\,\text{ABORT}(T_1)$$

A. Only T_2 B. Only T_3 C. Both T_2 and T_3 D. Neither T_2 nor T_3

gatecse2025-set1 databases transaction-and-concurrency one-mark

Answer key☟

5.19.24 Transaction and Concurrency: GATE CSE 2025 | Set 2 | Question: 17

An audit of a banking transactions system has found that on an earlier occasion, two joint holders of account A attempted simultaneous transfers of Rs. 10000 each from account A to account B. Both transactions read the same value, Rs.11000, as the initial balance in A and were allowed to go through. B was credited Rs. 10000 twice. A was debited only once and ended up with a balance of Rs. 1000.

Which of the following properties is/are certain to have been violated by the system?

A. Atomicity B. Consistency C. Isolation D. Durability

gatecse2025-set2 databases transaction-and-concurrency multiple-selects one-mark

Answer key☟

5.19.25 Transaction and Concurrency: GATE IT 2004 | Question: 21

Which level of locking provides the highest degree of concurrency in a relational database ?

A. Page
B. Table
C. Row
D. Page, table and row level locking allow the same degree of concurrency

gateit-2004 databases normal transaction-and-concurrency

Answer key☟

5.19.26 Transaction and Concurrency: GATE IT 2004 | Question: 77

Consider the following schedule S of transactions $T1$ and $T2$:

T1	T2
Read(A)	
A = A – 10	
	Read(A)
	Temp = 0.2*A
	Write(A)
	Read(B)
Write(A)	
Read(B)	
B = B + 10	
Write(B)	
	B = B + Temp
	Write(B)

Which of the following is TRUE about the schedule S ?

A. S is serializable only as $T1, T2$
B. S is serializable only as $T2, T1$
C. S is serializable both as $T1, T2$ and $T2, T1$
D. S is not serializable either as $T1, T2$ or as $T2, T1$

gateit-2004 databases transaction-and-concurrency normal

Answer key

5.19.27 Transaction and Concurrency: GATE IT 2005 | Question: 24

Amongst the ACID properties of a transaction, the 'Durability' property requires that the changes made to the database by a successful transaction persist

A. Except in case of an Operating System crash
B. Except in case of a Disk crash
C. Except in case of a power failure
D. Always, even if there is a failure of any kind

gateit-2005 databases transaction-and-concurrency easy

Answer key

5.19.28 Transaction and Concurrency: GATE IT 2005 | Question: 67

A company maintains records of sales made by its salespersons and pays them commission based on each individual's total sales made in a year. This data is maintained in a table with following schema:

salesinfo = (salespersonid, totalsales, commission)

In a certain year, due to better business results, the company decides to further reward its salespersons by enhancing the commission paid to them as per the following formula:

If commission ≤ 50000, enhance it by 2%
If $50000 <$ commission ≤ 100000, enhance it by 4%
If commission > 100000, enhance it by 6%

The IT staff has written three different SQL scripts to calculate enhancement for each slab, each of these scripts is to run as a separate transaction as follows:

T1
```
Update salesinfo
Set commission = commission * 1.02
Where commission < = 50000;
```

T2

```
Update salesinfo
Set commission = commission * 1.04
Where commission > 50000 and
commission is < = 100000;
```

T3

```
Update salesinfo
Set commission = commission * 1.06
Where commission > 100000;
```

Which of the following options of running these transactions will update the commission of all salespersons correctly

A. Execute T1 followed by T2 followed by T3
B. Execute T2, followed by T3; T1 running concurrently throughout
C. Execute T3 followed by T2; T1 running concurrently throughout
D. Execute T3 followed by T2 followed by T1

gateit-2005 databases transaction-and-concurrency normal

Answer key

5.19.29 Transaction and Concurrency: GATE IT 2007 | Question: 66

Consider the following two transactions: $T1$ and $T2$.

$T1:$	read (A);	$T2:$	read (B);
	read (B);		read (A);
	If $A=0$ then $B \leftarrow B+1$;		If $B \neq 0$ then $A \leftarrow A-1$;
	write (B);		write (A);

Which of the following schemes, using shared and exclusive locks, satisfy the requirements for strict two phase locking for the above transactions?

A.

$S1:$	lock S(A);	$S2:$	lock S(B);
	read (A);		read (B);
	lock S(B);		lock S(A);
	read (B);		read (A);
	If $A=0$		If $B \neq 0$
	then $B \leftarrow B+1$;		then $A \leftarrow A-1$;
	write (B);		write (A);
	commit;		commit;
	unlock (A);		unlock (B);
	unlock (B);		unlock (A);

B.

$S1:$	lock X(A);	$S2:$	lock X(B);
	read (A);		read (B);
	lock X(B);		lock X(A);
	read (B);		read (A);
	If $A=0$		If $B \neq 0$
	then $B \leftarrow B+1$;		then $A \leftarrow A-1$;
	write (B);		write (A);
	unlock (A);		unlock (A);
	commit;		commit;
	unlock (B);		unlock (A);

C.

$S1:$	lock S(A);	$S2:$	lock S(B);
	read (A);		read (B);
	lock X(B);		lock X(A);
	read (B);		read (A);
	If $A = 0$		If $B \neq 0$
	then $B \leftarrow B + 1$;		then $A \leftarrow A - 1$;
	write (B);		write (A);
	unlock (A);		unlock (B);
	commit;		commit;
	unlock (B);		unlock (A);

D.

$S1:$	lock S(A);	$S2:$	lock S(B);
	read (A);		read (B);
	lock X(B);		lock X(A);
	read (B);		read (A);
	If $A = 0$		If $B \neq 0$
	then $B \leftarrow B + 1$;		then $A \leftarrow A - 1$;
	write (B);		write (A);
	unlock (A);		unlock (A);
	unlock (B);		unlock (A);
	commit;		commit;

gateit-2007 databases transaction-and-concurrency normal

Answer key

5.19.30 Transaction and Concurrency: GATE IT 2008 | Question: 63

Consider the following three schedules of transactions T1, T2 and T3. [Notation: In the following NYO represents the action Y (R for read, W for write) performed by transaction N on object O.]

$(S1)$	$2RA$	$2WA$	$3RC$	$2WB$	$3WA$	$3WC$	$1RA$	$1RB$	$1WA$	$1WB$
$(S2)$	$3RC$	$2RA$	$2WA$	$2WB$	$3WA$	$1RA$	$1RB$	$1WA$	$1WB$	$3WC$
$(S3)$	$2RA$	$3RC$	$3WA$	$2WA$	$2WB$	$3WC$	$1RA$	$1RB$	$1WA$	$1WB$

Which of the following statements is TRUE?

A. S1, S2 and S3 are all conflict equivalent to each other
B. No two of S1, S2 and S3 are conflict equivalent to each other
C. S2 is conflict equivalent to S3, but not to S1
D. S1 is conflict equivalent to S2, but not to S3

gateit-2008 databases transaction-and-concurrency normal

Answer key

5.20 Tuple Relational Calculus (1)

5.20.1 Tuple Relational Calculus: GATE CSE 2025 | Set 1 | Question: 29

Consider two relations describing teams and players in a sports league:

- teams(tid, tname): tid, tname are team-id and team-name, respectively
- players(pid,pname,tid): pid, pname, and tid denote player-id, playername and the team-id of the player,

respectively

Which ONE of the following tuple relational calculus queries returns the name of the players who play for the team having tname as ' MI' ?

A. $\{p.$ pname $|p \in$ players $\wedge \exists t\,(t \in$ teams $\wedge p.tid = t.tid \wedge t.tname =' MI')\}$
B. $\{p.$ pname $|p \in$ teams $\wedge \exists t\,(t \in$ players $\wedge p.tid = t.tid \wedge t.tname =' MI')\}$
C. $\{p.$ pname $|p \in$ players $\wedge \exists t\,(t \in$ teams $\wedge t.$ tname $=' MI')\}$
D. $\{p.$ pname $|p \in$ teams $\wedge \exists t\,(t \in$ players $\wedge t.$ tname $=' MI')\}$

gatecse2025-set1 databases tuple-relational-calculus two-marks

Answer key☟

Answer Keys

5.1.1	N/A	5.1.2	N/A	5.1.3	N/A	5.1.4	N/A	5.1.5	B
5.1.6	N/A	5.1.7	B	5.1.8	N/A	5.1.9	N/A	5.1.10	N/A
5.1.11	C	5.1.12	B	5.1.13	C	5.1.14	D	5.1.15	A
5.1.16	C	5.1.17	C	5.1.18	B	5.1.19	5	5.1.20	50
5.1.21	A	5.1.22	52	5.1.23	B	5.1.24	A	5.1.25	B;D
5.1.26	33:33	5.1.27	C	5.1.28	A	5.1.29	C	5.1.30	A
5.1.31	A	5.2.1	N/A	5.2.2	A	5.2.3	8	5.2.4	19
5.2.5	B	5.3.1	D	5.3.2	C	5.3.3	A	5.3.4	54
5.3.5	B	5.3.6	B	5.3.7	A	5.3.8	B;C;D	5.3.9	B
5.4.1	False	5.5.1	True	5.5.2	N/A	5.5.3	N/A	5.5.4	N/A
5.5.5	N/A	5.5.6	N/A	5.5.7	A;B;D	5.5.8	False	5.5.9	N/A
5.5.10	A	5.5.11	D	5.5.12	N/A	5.5.13	B	5.5.14	D
5.5.15	B	5.5.16	C	5.5.17	A	5.5.18	N/A	5.5.19	C
5.5.20	C	5.5.21	D	5.5.22	B	5.5.23	C	5.5.24	D
5.5.25	C	5.5.26	D	5.5.27	C	5.5.28	C	5.5.29	B
5.5.30	A	5.5.31	B	5.5.32	A	5.5.33	C	5.5.34	B
5.5.35	B	5.5.36	A	5.5.37	B	5.5.38	C	5.5.39	A
5.5.40	A	5.5.41	A;C;D	5.5.42	8	5.5.43	A	5.5.44	A;C
5.5.45	B;C;D	5.5.46	50	5.5.47	C;D	5.5.48	A;B;D	5.5.49	Q-Q
5.5.50	B	5.5.51	A	5.5.52	B	5.5.53	B	5.5.54	A
5.5.55	D	5.5.56	C	5.6.1	C	5.7.1	B	5.7.2	B
5.7.3	A	5.7.4	C	5.7.5	4	5.7.6	C	5.7.7	A
5.7.8	A	5.7.9	D	5.7.10	A	5.7.11	B	5.7.12	C
5.8.1	B;C	5.8.2	B;D	5.9.1	N/A	5.9.2	N/A	5.9.3	3
5.9.4	C	5.9.5	A	5.9.6	C	5.9.7	C	5.9.8	C
5.9.9	C	5.9.10	4	5.9.11	698 : 698	5.9.12	6	5.9.13	A;B
5.10.1	A	5.10.2	A	5.10.3	A	5.10.4	C	5.10.5	B
5.10.6	A	5.10.7	A	5.11.1	C	5.12.1	C	5.12.2	A
5.12.3	C	5.13.1	N/A	5.14.1	B	5.14.2	C	5.14.3	A

5.14.4	0.00
5.15.4	N/A
5.15.9	B
5.15.14	A
5.15.19	D
5.15.24	C
5.15.29	C
5.16.3	D
5.16.8	C
5.16.13	D
5.18.1	N/A
5.18.6	N/A
5.18.11	C
5.18.16	N/A
5.18.21	B
5.18.26	C
5.18.31	D
5.18.36	A
5.18.41	5
5.18.46	2
5.18.51	A;B
5.18.56	A
5.19.3	D
5.19.8	A
5.19.13	D
5.19.18	C
5.19.23	C
5.19.28	D

5.14.5	D
5.15.5	N/A
5.15.10	C
5.15.15	D
5.15.20	D
5.15.25	A;B
5.15.30	C
5.16.4	C
5.16.9	C
5.16.14	D
5.18.2	N/A
5.18.7	D
5.18.12	N/A
5.18.17	C
5.18.22	C
5.18.27	A
5.18.32	B
5.18.37	2
5.18.42	A
5.18.47	26:26
5.18.52	D
5.18.57	B
5.19.4	B
5.19.9	B
5.19.14	A
5.19.19	A
5.19.24	B;C
5.19.29	C

5.15.1	N/A
5.15.6	N/A
5.15.11	D
5.15.16	B
5.15.21	4
5.15.26	2
5.15.31	B
5.16.5	C
5.16.10	A
5.16.15	C
5.18.3	N/A
5.18.8	N/A
5.18.13	C
5.18.18	D
5.18.23	A
5.18.28	C
5.18.33	C
5.18.38	2.6
5.18.43	819 : 820 ; 205 : 205
5.18.48	A;C;D
5.18.53	C
5.18.58	D
5.19.5	C
5.19.10	B
5.19.15	A
5.19.20	A
5.19.25	C
5.19.30	D

5.15.2	N/A
5.15.7	D
5.15.12	C
5.15.17	D
5.15.22	C
5.15.27	B
5.16.1	N/A
5.16.6	C
5.16.11	A
5.17.1	A
5.18.4	N/A
5.18.9	N/A
5.18.14	N/A
5.18.19	D
5.18.24	X
5.18.29	C
5.18.34	D
5.18.39	7
5.18.44	B
5.18.49	3:3
5.18.54	C
5.19.1	D
5.19.6	B
5.19.11	A
5.19.16	C
5.19.21	A;C;D
5.19.26	X
5.20.1	A

5.15.3	N/A
5.15.8	N/A
5.15.13	N/A
5.15.18	A
5.15.23	1
5.15.28	1:1
5.16.2	N/A
5.16.7	B
5.16.12	D
5.17.2	B;C
5.18.5	N/A
5.18.10	A
5.18.15	N/A
5.18.20	C
5.18.25	A
5.18.30	B
5.18.35	2
5.18.40	D
5.18.45	2
5.18.50	3
5.18.55	D
5.19.2	D
5.19.7	B
5.19.12	B
5.19.17	A
5.19.22	A
5.19.27	D

6 Digital Logic (303)

Boolean algebra. Combinational and sequential circuits. Minimization. Number representations and computer arithmetic (fixed and floating point)

Mark Distribution in Previous GATE

Year	2025 - 1	2025 - 2	2024 - 1	2024 - 2	2023	2022	2021 - 1	2021 - 2	Minimum	Average	Maximu
1 Mark Count	2	3	2	2	2	1	2	3	1	2.13	3
2 Marks Count	2	3	2	2	2	2	2	2	2	2.13	3
Total Marks	6	9	6	6	6	5	6	7	**5**	**6.38**	**9**

6.1 Adder (9)

6.1.1 Adder: GATE CSE 1988 | Question: 4ii

Using binary full adders and other logic gates (if necessary), design an adder for adding 4-bit number (including sign) in $2's$ complement notation.

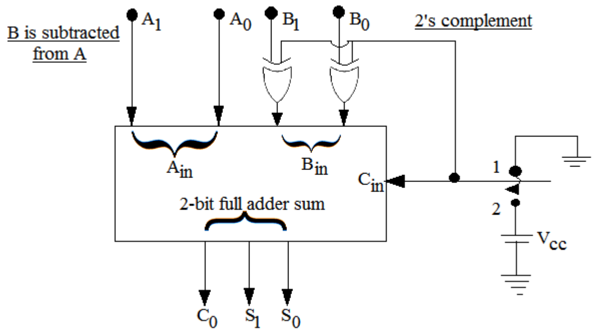
gate1988 digital-logic descriptive adder

Answer key

6.1.2 Adder: GATE CSE 1990 | Question: 1-i

Fill in the blanks:

In the two bit full-adder/subtractor unit shown in below figure, when the switch is in position 2 ___________ using __________ arithmetic.



gate1990 digital-logic adder fill-in-the-blanks

Answer key

6.1.3 Adder: GATE CSE 1997 | Question: 2.5

An N-bit carry lookahead adder, where N is a multiple of 4, employs ICs 74181 (4 bit ALU) and 74182 (4 bit carry lookahead generator).

The minimum addition time using the best architecture for this adder is

A. proportional to N

B. proportional to $\log N$

C. a constant

D. None of the above

gate1997 digital-logic normal adder

Answer key

6.1.4 Adder: GATE CSE 1999 | Question: 2.16

The number of full and half-adders required to add 16-bit numbers is

A. 8 half-adders, 8 full-adders

B. 1 half-adder, 15 full-adders

C. 16 half-adders, 0 full-adders

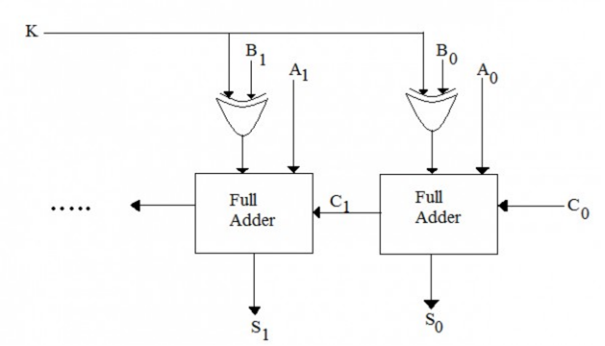
D. 4 half-adders, 12 full-adders

gate1999 digital-logic normal adder

Answer key

6.1.5 Adder: GATE CSE 2003 | Question: 46

Consider the ALU shown below.



If the operands are in $2's$ complement representation, which of the following operations can be performed by suitably setting the control lines K and C_0 only (+ and – denote addition and subtraction respectively)?

A. $A+B$, and $A–B$, but not $A+1$
B. $A+B$, and $A+1$, but not $A–B$
C. $A+B$, but not $A–B$ or $A+1$
D. $A+B$, and $A–B$, and $A+1$

gatecse-2003 digital-logic normal adder

Answer key

6.1.6 Adder: GATE CSE 2004 | Question: 62

A 4-bit carry look ahead adder, which adds two 4-bit numbers, is designed using AND, OR, NOT, NAND, NOR gates only. Assuming that all the inputs are available in both complemented and uncomplemented forms and the delay of each gate is one time unit, what is the overall propagation delay of the adder? Assume that the carry network has been implemented using two-level AND-OR logic.

A. 4 time units
B. 6 time units
C. 10 time units
D. 12 time units

gatecse-2004 digital-logic normal adder

Answer key

6.1.7 Adder: GATE CSE 2015 Set 2 | Question: 48

A half adder is implemented with XOR and AND gates. A full adder is implemented with two half adders and one OR gate. The propagation delay of an XOR gate is twice that of an AND/OR gate. The propagation delay of an AND/OR gate is 1.2 microseconds. A 4-bit-ripple-carry binary adder is implemented by using four full adders. The total propagation time of this 4-bit binary adder in microseconds is ______.

gatecse-2015-set2 digital-logic adder normal numerical-answers

Answer key

6.1.8 Adder: GATE CSE 2016 Set 1 | Question: 33

Consider a carry look ahead adder for adding two$n$-bit integers, built using gates of fan-in at most two. The time to perform addition using this adder is

A. $\Theta(1)$
B. $\Theta(\log(n))$
C. $\Theta(\sqrt{n})$
D. $\Theta(n)$)

gatecse-2016-set1 digital-logic adder normal

Answer key

6.1.9 Adder: GATE CSE 2016 Set 2 | Question: 07

Consider an eight-bit ripple-carry adder for computing the sum of A and $B,$ where A and B are integers represented in 2's complement form. If the decimal value of A is one, the decimal value of B that leads to the longest latency for the sum to stabilize is ___________ gatecse-2016-set2 digital-logic adder normal numerical-answers

Answer key

6.2 Array Multiplier (2)

6.2.1 Array Multiplier: GATE CSE 1999 | Question: 1.21

The maximum gate delay for any output to appear in an array multiplier for multiplying two n bit numbers is

A. $O(n^2)$ B. $O(n)$ C. $O(\log n)$ D. $O(1)$

gate1999 digital-logic normal array-multiplier

Answer key

6.2.2 Array Multiplier: GATE CSE 2003 | Question: 11

Consider an array multiplier for multiplying two n bit numbers. If each gate in the circuit has a unit delay, the total delay of the multiplier is

A. $\Theta(1)$ B. $\Theta(\log n)$ C. $\Theta(n)$ D. $\Theta(n^2)$

gatecse-2003 digital-logic normal array-multiplier

Answer key

6.3 Boolean Algebra (34)

6.3.1 Boolean Algebra: GATE CSE 1987 | Question: 1-II

The total number of Boolean functions which can be realised with four variables is:

A. 4 B. 17 C. 256 D. $65,536$

gate1987 digital-logic boolean-algebra functions combinatory

Answer key

6.3.2 Boolean Algebra: GATE CSE 1987 | Question: 12-a

The Boolean expression $A \oplus B \oplus A$ is equivalent to

A. $AB + \overline{A}\ \overline{B}$

B. $\overline{A}\,B + A\,\overline{B}$

C. B

D. $\overline{A}$

gate1987 digital-logic boolean-algebra easy

Answer key

6.3.3 Boolean Algebra: GATE CSE 1988 | Question: 2-iii

Let $*$ be defined as a Boolean operation given as $x * y = \overline{x}\ \overline{y} + xy$ and let $C = A * B.$ If $C = 1$ then prove that $A = B.$

gate1988 digital-logic descriptive boolean-algebra

Answer key

6.3.4 Boolean Algebra: GATE CSE 1989 | Question: 4-x

A switching function is said to be neutral if the number of input combinations for which its value is 1 is equal to the number of input combinations for which its value is $0.$ Compute the number of neutral switching functions of n variables (for a given n).

gate1989 descriptive digital-logic boolean-algebra

Answer key

6.3.5 Boolean Algebra: GATE CSE 1989 | Question: 5-a

Find values of Boolean variables A, B, C which satisfy the following equations:

- A+ B = 1
- AC = BC
- A + C = 1
- AB = 0

gate1989 descriptive digital-logic boolean-algebra

Answer key

6.3.6 Boolean Algebra: GATE CSE 1992 | Question: 02-i

The operation which is commutative but not associative is:

A. AND
B. OR
C. EX-OR
D. NAND

gate1992 easy digital-logic boolean-algebra multiple-selects

Answer key

6.3.7 Boolean Algebra: GATE CSE 1994 | Question: 4

A. Let $*$ be a Boolean operation defined as $A * B = AB + \overline{A}\,\overline{B}.$ If $C = A * B$ then evaluate and fill in the blanks:
   i. $A * A =$______
   ii. $C * A =$______
B. Solve the following boolean equations for the values of A, B and C :

$$AB + \overline{A}C = 1$$
$$AC + B = 0$$

gate1994 digital-logic normal boolean-algebra descriptive

Answer key

6.3.8 Boolean Algebra: GATE CSE 1995 | Question: 2.5

What values of A, B, C and D satisfy the following simultaneous Boolean equations?

$$\overline{A} + AB = 0, AB = AC, AB + A\overline{C} + CD = \overline{C}D$$

A. $A = 1, B = 0, C = 0, D = 1$
B. $A = 1, B = 1, C = 0, D = 0$
C. $A = 1, B = 0, C = 1, D = 1$
D. $A = 1, B = 0, C = 0, D = 0$

gate1995 digital-logic boolean-algebra easy

Answer key

6.3.9 Boolean Algebra: GATE CSE 1997 | Question: 2-1

Let $*$ be defined as $x * y = \bar{x} + y$. Let $z = x * y$. Value of $z * x$ is

A. $\bar{x} + y$
B. x
C. 0
D. 1

gate1997 digital-logic normal boolean-algebra

Answer key

6.3.10 Boolean Algebra: GATE CSE 1998 | Question: 1.13

What happens when a bit-string is XORed with itself n-times as shown:

$$[B \oplus (B \oplus (B \oplus (B \dots n \text{ times}]$$

A. complements when n is even
B. complements when n is odd

C. divides by 2^n always

D. remains unchanged when n is even

gate1998 digital-logic normal boolean-algebra

Answer key

6.3.11 Boolean Algebra: GATE CSE 1998 | Question: 2.8

Which of the following operations is commutative but not associative?

A. AND

B. OR

C. NAND

D. EXOR

gate1998 digital-logic easy boolean-algebra

Answer key

6.3.12 Boolean Algebra: GATE CSE 1999 | Question: 1.7

Which of the following expressions is not equivalent to $\bar{x}$?

A. $x \text{ NAND } x$

B. $x \text{ NOR } x$

C. $x \text{ NAND } 1$

D. $x \text{ NOR } 1$

gate1999 digital-logic easy boolean-algebra

Answer key

6.3.13 Boolean Algebra: GATE CSE 2000 | Question: 2.10

The simultaneous equations on the Boolean variables x, y, z and w,

- $x+y+z=1$
- $xy=0$
- $xz+w=1$
- $xy+\bar{z}\bar{w}=0$

have the following solution for x, y, z and w, respectively:

A. 0 1 0 0

B. 1 1 0 1

C. 1 0 1 1

D. 1 0 0 0

gatecse-2000 digital-logic boolean-algebra easy

Answer key

6.3.14 Boolean Algebra: GATE CSE 2002 | Question: 2-3

Let $f(A, B)=A'+B$. Simplified expression for function $f(f(x+y, y), z)$ is

A. $x'+z$

B. xyz

C. $xy'+z$

D. None of the above

gatecse-2002 digital-logic boolean-algebra normal

Answer key

6.3.15 Boolean Algebra: GATE CSE 2004 | Question: 17

A Boolean function $x'y'+xy+x'y$ is equivalent to

A. $x'+y'$

B. $x+y$

C. $x+y'$

D. $x'+y$

gatecse-2004 digital-logic easy boolean-algebra

Answer key

6.3.16 Boolean Algebra: GATE CSE 2007 | Question: 32

Let $f(w, x, y, z)=\sum(0,4,5,7,8,9,13,15)$. Which of the following expressions are NOT equivalent to f?

P: $x'y'z'+w'xy'+wy'z+xz$

Q: $w'y'z'+wx'y'+xz$

R: $w'y'z'+wx'y'+xyz+xy'z$

S: $x'y'z' + wx'y' + w'y$

A. P only
B. Q and S
C. R and S
D. S only

gatecse-2007 digital-logic normal boolean-algebra

Answer key

6.3.17 Boolean Algebra: GATE CSE 2007 | Question: 33

Define the connective $*$ for the Boolean variables X and Y as:

$$X * Y = XY + X'Y'.$$

Let $Z = X * Y$. Consider the following expressions P, Q and R.

$$P : X = Y * Z,$$
$$Q : Y = X * Z,$$
$$R : X * Y * Z = 1$$

Which of the following is **TRUE**?

A. Only P and Q are valid.
B. Only Q and R are valid.
C. Only P and R are valid.
D. All P, Q, R are valid.

gatecse-2007 digital-logic normal boolean-algebra

Answer key

6.3.18 Boolean Algebra: GATE CSE 2008 | Question: 26

If P, Q, R are Boolean variables, then
$(P + \bar{Q})(P.\bar{Q} + P.R)(\bar{P}.\bar{R} + \bar{Q})$ simplifies to

A. $P.\bar{Q}$
B. $P.\bar{R}$
C. $P.\bar{Q} + R$
D. $P.\bar{R} + Q$

gatecse-2008 easy digital-logic boolean-algebra

Answer key

6.3.19 Boolean Algebra: GATE CSE 2012 | Question: 6

The truth table

X	Y	(X,Y)
0	0	0
0	1	0
1	0	1
1	1	1

represents the Boolean function

A. X
B. $X + Y$
C. $X \oplus Y$
D. Y

gatecse-2012 digital-logic easy boolean-algebra

Answer key

6.3.20 Boolean Algebra: GATE CSE 2013 | Question: 21

Which one of the following expressions does **NOT** represent exclusive NOR of x and y?

A. $xy + x'y'$
B. $x \oplus y'$
C. $x' \oplus y$
D. $x' \oplus y'$

gatecse-2013 digital-logic easy boolean-algebra

Answer key

6.3.21 Boolean Algebra: GATE CSE 2014 Set 2 | Question: 6

The dual of a Boolean function $F(x_1, x_2, \ldots, x_n, +, ., ')$, written as F^D is the same expression as that of F with $+$ and $\cdot$ swapped. F is said to be self-dual if $F = F^D$. The number of self-dual functions with n Boolean variables is

A. 2^n B. 2^{n-1} C. 2^{2^n} D. $2^{2^{n-1}}$

gatecse-2014-set2 digital-logic normal dual-function boolean-algebra

Answer key☟

6.3.22 Boolean Algebra: GATE CSE 2014 Set 3 | Question: 55

Let $\oplus$ denote the exclusive OR (XOR) operation. Let '1' and '0' denote the binary constants. Consider the following Boolean expression for F over two variables P and Q:

$$F(P,Q) = ((1 \oplus P) \oplus (P \oplus Q)) \oplus ((P \oplus Q) \oplus (Q \oplus 0))$$

The equivalent expression for F is

A. $P+Q$
B. $\overline{P+Q}$
C. $P \oplus Q$
D. $\overline{P \oplus Q}$

gatecse-2014-set3 digital-logic normal boolean-algebra

Answer key☟

6.3.23 Boolean Algebra: GATE CSE 2015 Set 2 | Question: 37

The number of min-terms after minimizing the following Boolean expression is _______.

$[D' + AB' + A'C + AC'D + A'C'D]'$

gatecse-2015-set2 digital-logic boolean-algebra normal numerical-answers

Answer key☟

6.3.24 Boolean Algebra: GATE CSE 2016 Set 1 | Question: 06

Consider the Boolean operator # with the following properties :
$x\#0 = x, x\#1 = \bar{x}, x\#x = 0$ and $x\#\bar{x} = 1.$ Then $x\#y$ is equivalent to

A. $x\bar{y} + \bar{x}y$
B. $x\bar{y} + \bar{x}\,\bar{y}$
C. $\bar{x}y + xy$
D. $xy + \bar{x}\,\bar{y}$

gatecse-2016-set1 digital-logic boolean-algebra easy

Answer key☟

6.3.25 Boolean Algebra: GATE CSE 2016 Set 2 | Question: 08

Let, $x_1 \oplus x_2 \oplus x_3 \oplus x_4 = 0$ where x_1, x_2, x_3, x_4 are Boolean variables, and $\oplus$ is the XOR operator.
Which one of the following must always be **TRUE**?

A. $x_1x_2x_3x_4 = 0$
B. $x_1x_3 + x_2 = 0$
C. $\bar{x}_1 \oplus \bar{x}_3 = \bar{x}_2 \oplus \bar{x}_4$
D. $x_1 + x_2 + x_3 + x_4 = 0$

gatecse-2016-set2 digital-logic boolean-algebra normal

Answer key☟

6.3.26 Boolean Algebra: GATE CSE 2017 Set 2 | Question: 27

If w, x, y, z are Boolean variables, then which one of the following is INCORRECT?

A. $wx + w(x+y) + x(x+y) = x + wy$

B. $\overline{w\bar{x}(y+\bar{z})} + \bar{w}x = \bar{w} + x + \bar{y}z$

C. $(w\bar{x}(y+x\bar{z}) + \bar{w}\bar{x})y = x\bar{y}$

D. $(w+y)(wxy+wyz) = wxy + wyz$

gatecse-2017-set2 digital-logic boolean-algebra normal

Answer key

6.3.27 Boolean Algebra: GATE CSE 2018 | Question: 4

Let $\oplus$ and $\odot$ denote the Exclusive OR and Exclusive NOR operations, respectively. Which one of the following is NOT CORRECT?

A. $\overline{P \oplus Q} = P \odot Q$

B. $\overline{P} \oplus Q = P \odot Q$

C. $\overline{P} \oplus \overline{Q} = P \oplus Q$

D. $P \oplus \overline{P} \oplus Q = (P \odot \overline{P} \odot \overline{Q})$

gatecse-2018 digital-logic normal boolean-algebra one-mark

Answer key

6.3.28 Boolean Algebra: GATE CSE 2019 | Question: 6

Which one of the following is NOT a valid identity?

A. $(x \oplus y) \oplus z = x \oplus (y \oplus z)$

B. $(x+y) \oplus z = x \oplus (y+z)$

C. $x \oplus y = x + y$, if $xy = 0$

D. $x \oplus y = (xy + x'y')'$

gatecse-2019 digital-logic boolean-algebra one-mark

Answer key

6.3.29 Boolean Algebra: GATE CSE 2021 Set 1 | Question: 42

Consider the following Boolean expression.

$F = (X+Y+Z)(\overline{X}+Y)(\overline{Y}+Z)$

Which of the following Boolean expressions is/are equivalent to $\overline{F}$ (complement of F)?

A. $(\overline{X}+\overline{Y}+\overline{Z})(X+\overline{Y})(Y+\overline{Z})$

B. $X\overline{Y}+\overline{Z}$

C. $(X+\overline{Z})(\overline{Y}+\overline{Z})$

D. $X\overline{Y}+Y\overline{Z}+\overline{X}\ \overline{Y}\ \overline{Z}$

gatecse-2021-set1 multiple-selects digital-logic boolean-algebra two-marks

Answer key

6.3.30 Boolean Algebra: GATE CSE 2024 | Set 2 | Question: 20

For a Boolean variable x, which of the following statements is/are FALSE?

A. $x.1 = x$

B. $x + 1 = x$

C. $x \cdot x = 0$

D. $x + \bar{x} = 1$

gatecse2024-set2 digital-logic boolean-algebra easy multiple-selects one-mark

Answer key

6.3.31 Boolean Algebra: GATE CSE 2025 | Set 1 | Question: 14

Let X be a 3-variable Boolean function that produces output as $'1'$ when at least two of the input variables are $'1'$. Which of the following statement(s) is/are CORRECT, where a, b, c, d, e are Boolean variables?

A. $X(a,b,X(c,d,e)) = X(X(a,b,c),d,e)$

B. $X(a,b,X(a,b,c)) = X(a,b,c)$

C. $X(a,b,X(a,c,d)) = (X(a,b,a) \text{ AND } X(c,d,c))$
D. $X(a,b,c) = X(a, X(a,b,c), X(a,c,c))$

gatecse2025-set1 digital-logic boolean-algebra multiple-selects one-mark

Answer key

6.3.32 Boolean Algebra: GATE CSE 2025 | Set 2 | Question: 40

Which of the following Boolean algebraic equation(s) is/are CORRECT?

A. $\bar{A}BC + A\bar{B}\bar{C} + \bar{A}\bar{B}\bar{C} + A\bar{B}C + ABC = BC + \bar{B}\bar{C} + \bar{A}\bar{B}$
B. $AB + \bar{A}C + BC = AB + \bar{A}C$
C. $(A+C)(\bar{A}+B) = AB + \bar{A}C$
D. $\overline{(A+\bar{B}+\bar{D})(C+D)(\bar{A}+C+D)(A+B+\bar{D})} = \bar{A}D + \bar{C}\bar{D}$

gatecse2025-set2 digital-logic boolean-algebra multiple-selects easy two-marks

Answer key

6.3.33 Boolean Algebra: GATE IT 2004 | Question: 44

The function $A\bar{B}C + \bar{A}BC + AB\bar{C} + \bar{A}\bar{B}C + A\bar{B}\bar{C}$ is equivalent to

A. $A\bar{C} + AB + \bar{A}C$
B. $A\bar{B} + A\bar{C} + \bar{A}C$
C. $\bar{A}B + A\bar{C} + A\bar{B}$
D. $\bar{A}B + AC + A\bar{B}$

gateit-2004 digital-logic boolean-algebra easy

Answer key

6.3.34 Boolean Algebra: GATE IT 2005 | Question: 7

Which of the following expressions is equivalent to $(A \oplus B) \oplus C$

A. $(A+B+C)(\bar{A}+\bar{B}+\bar{C})$
B. $(A+B+C)(\bar{A}+\bar{B}+C)$
C. $ABC + \bar{A}(B \oplus C) + \bar{B}(A \oplus C)$
D. None of these

gateit-2005 digital-logic normal boolean-algebra

Answer key

6.4 Booths Algorithm (7)

6.4.1 Booths Algorithm: GATE CSE 1990 | Question: 8b

State the Booth's algorithm for multiplication of two numbers. Draw a block diagram for the implementation of the Booth's algorithm for determining the product of two 8-bit signed numbers.

gate1990 descriptive digital-logic booths-algorithm

Answer key

6.4.2 Booths Algorithm: GATE CSE 1996 | Question: 1.23

Booth's algorithm for integer multiplication gives worst performance when the multiplier pattern is

A. $101010\dots1010$
B. $100000\dots0001$
C. $111111\dots1111$
D. $011111\dots1110$

gate1996 digital-logic booths-algorithm normal

Answer key

6.4.3 Booths Algorithm: GATE CSE 1999 | Question: 1.20

Booth's coding in 8 bits for the decimal number -57 is:

A. $0-100+1000$
B. $0-100+100-1$
C. $0-1+100-10+1$
D. $00-10+100-1$

gate1999 digital-logic number-representation booths-algorithm normal

Answer key

6.4.4 Booths Algorithm: GATE CSE 2025 | Set 2 | Question: 22

The following two signed 2 's complement numbers (multiplicand M and multiplier Q) are being multiplied using Booth's algorithm:

M: 1100110111101101 and Q: 1010010010101010

The total number of addition and subtraction operations to be performed is______________. (Answer in integer)

gatecse2025-set2 digital-logic booths-algorithm numerical-answers one-mark

Answer key

6.4.5 Booths Algorithm: GATE IT 2005 | Question: 8

Using Booth's Algorithm for multiplication, the multiplier -57 will be recoded as

A. 0 -1 00 1 0 0 -1
B. 1 1 0 0 0 1 1 1
C. 0 -1 0 0 10 0 0
D. 0 1 0 0 -1 0 0 1

gateit-2005 digital-logic booths-algorithm normal

Answer key

6.4.6 Booths Algorithm: GATE IT 2006 | Question: 38

When multiplicand Y is multiplied by multiplier $X = x_{n-1}x_{n-2}\dots x_0$ using bit-pair recoding in Booth's algorithm, partial products are generated according to the following table.

Row	x_{i+1}	x_i	x_{i-1}	Partial Product
1	0	0	0	0
2	0	0	1	Y
3	0	1	0	Y
4	0	1	1	2Y
5	1	0	0	?
6	1	0	1	-Y
7	1	1	0	-Y
8	1	1	1	?

The partial products for rows 5 and 8 are

A. $2Y$ and Y
B. $-2Y$ and $2Y$
C. $-2Y$ and 0
D. 0 and Y

gateit-2006 digital-logic booths-algorithm difficult

Answer key

6.4.7 Booths Algorithm: GATE IT 2008 | Question: 42

The two numbers given below are multiplied using the Booth's algorithm.

Multiplicand : $0101\ 1010\ 1110\ 1110$
Multiplier: $0111\ 0111\ 1011\ 1101$

How many additions/Subtractions are required for the multiplication of the above two numbers?

A. 6
B. 8
C. 10
D. 12

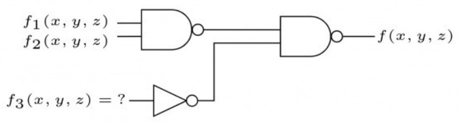
gateit-2008 digital-logic booths-algorithm normal

Answer key

6.5 Canonical Normal Form (9)

6.5.1 Canonical Normal Form: GATE CSE 2002 | Question: 2-1

Consider the following logic circuit whose inputs are functions f_1, f_2, f_3 and output is f



Given that

- $f_1(x, y, z) = \Sigma(0, 1, 3, 5)$
- $f_2(x, y, z) = \Sigma(6, 7)$, and
- $f(x, y, z) = \Sigma(1, 4, 5)$.

f_3 is

A. $\Sigma(1,4,5)$
B. $\Sigma(6,7)$
C. $\Sigma(0,1,3,5)$
D. None of the above

gatecse-2002 digital-logic normal canonical-normal-form circuit-output

Answer key

6.5.2 Canonical Normal Form: GATE CSE 2007 | Question: 48

Which of the following is TRUE about formulae in Conjunctive Normal Form?

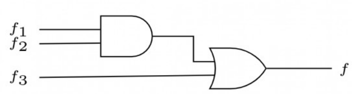
A. For any formula, there is a truth assignment for which at least half the clauses evaluate to true.
B. For any formula, there is a truth assignment for which all the clauses evaluate to true.
C. There is a formula such that for each truth assignment, at most one-fourth of the clauses evaluate to true.
D. None of the above.

gatecse-2007 digital-logic normal conjunctive-normal-form canonical-normal-form

Answer key

6.5.3 Canonical Normal Form: GATE CSE 2008 | Question: 8

Given f_1, f_3 and f in canonical sum of products form (in decimal) for the circuit



$f_1 = \Sigma m(4,5,6,7,8)$
$f_3 = \Sigma m(1,6,15)$
$f = \Sigma m(1,6,8,15)$
then f_2 is

A. $\Sigma m(4,6)$
B. $\Sigma m(4,8)$
C. $\Sigma m(6,8)$
D. $\Sigma m(4,6,8)$

gatecse-2008 digital-logic canonical-normal-form easy

Answer key

6.5.4 Canonical Normal Form: GATE CSE 2010 | Question: 6

The minterm expansion of $f(P,Q,R) = PQ + Q\bar{R} + P\bar{R}$ is

A. $m_2 + m_4 + m_6 + m_7$
B. $m_0 + m_1 + m_3 + m_5$
C. $m_0 + m_1 + m_6 + m_7$
D. $m_2 + m_3 + m_4 + m_5$

gatecse-2010 digital-logic canonical-normal-form normal

Answer key

6.5.5 Canonical Normal Form: GATE CSE 2015 Set 3 | Question: 43

The total number of prime implicants of the function $f(w, x, y, z) = \sum(0, 2, 4, 5, 6, 10)$ is ________

gatecse-2015-set3 digital-logic canonical-normal-form normal numerical-answers

Answer key

6.5.6 Canonical Normal Form: GATE CSE 2015 Set 3 | Question: 44

Given the function $F = P' + QR$, where F is a function in three Boolean variables P, Q and R and $P' = !P$, consider the following statements.

$(S1) F = \sum(4, 5, 6)$

$(S2) F = \sum(0, 1, 2, 3, 7)$

$(S3) F = \Pi(4, 5, 6)$

$(S4) F = \Pi(0, 1, 2, 3, 7)$

Which of the following is true?

A. (S1)-False, (S2)-True, (S3)-True, (S4)-False
B. (S1)-True, (S2)-False, (S3)-False, (S4)-True
C. (S1)-False, (S2)-False, (S3)-True, (S4)-True
D. (S1)-True, (S2)-True, (S3)-False, (S4)-False

gatecse-2015-set3 digital-logic canonical-normal-form normal

Answer key

6.5.7 Canonical Normal Form: GATE CSE 2019 | Question: 50

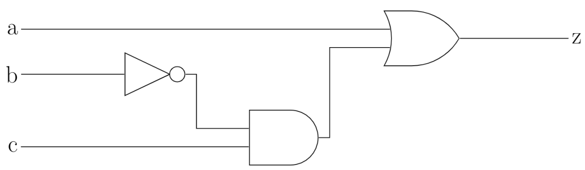
What is the minimum number of 2-input NOR gates required to implement a 4 -variable function expressed in sum-of-minterms form as $f = \Sigma(0, 2, 5, 7, 8, 10, 13, 15)$? Assume that all the inputs and their complements are available. Answer: _______

gatecse-2019 numerical-answers digital-logic canonical-normal-form two-marks

Answer key

6.5.8 Canonical Normal Form: GATE CSE 2020 | Question: 28

Consider the Boolean function $z(a, b, c)$.



Which one of the following minterm lists represents the circuit given above?

A. $z = \sum(0, 1, 3, 7)$
B. $z = \sum(1, 4, 5, 6, 7)$
C. $z = \sum(2, 4, 5, 6, 7)$
D. $z = \sum(2, 3, 5)$

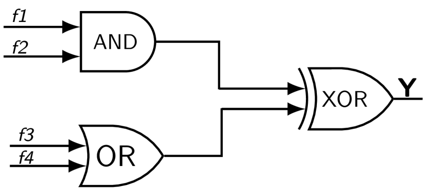
gatecse-2020 digital-logic canonical-normal-form two-marks

Answer key

6.5.9 Canonical Normal Form: GATE CSE 2024 | Set 2 | Question: 40

Consider 4-variable functions $f1, f2, f3, f4$ expressed in sum-of-minterms form as given below.

$$f1 = \sum(0,2,3,5,7,8,11,13)$$
$$f2 = \sum(1,3,5,7,11,13,15)$$
$$f3 = \sum(0,1,4,11)$$
$$f4 = \sum(0,2,6,13)$$



With respect to the circuit given above, which of the following options is/are CORRECT?

A. $\boldsymbol{Y} = \sum(0,1,2,11,13)$

B. $\boldsymbol{Y} = \Pi(3,4,5,6,7,8,9,10,12,14,15)$

C. $\boldsymbol{Y} = \sum(0,1,2,3,4,5,6,7)$

D. $\boldsymbol{Y} = \Pi(8,9,10,11,12,13,14,15)$

gatecse2024-set2 digital-logic canonical-normal-form multiple-selects two-marks

Answer key

6.6 Carry Generator (2)

6.6.1 Carry Generator: GATE CSE 2006 | Question: 36

Given two three bit numbers $a_2a_1a_0$ and $b_2b_1b_0$ and c the carry in, the function that represents the c*arry* generate function when these two numbers are added is:

A. $a_2b_2 + a_2a_1b_1 + a_2a_1a_0b_0 + a_2a_0b_1b_0 + a_1b_2b_1 + a_1a_0b_2b_0 + a_0b_2b_1b_0$

B. $a_2b_2 + a_2b_1b_0 + a_2a_1b_1b_0 + a_1a_0b_2b_1 + a_1a_0b_2 + a_1a_0b_2b_0 + a_2a_0b_1b_0$

C. $a_2 + b_2 + (a_2 \oplus b_2)(a_1 + b_1 + (a_1 \oplus b_1) + (a_0 + b_0))$

D. $a_2b_2 + \overline{a_2}a_1b_1 + \overline{a_2a_1}a_0b_0 + \overline{a_2}a_0\overline{b_1}b_0 + a_1\overline{b_2}b_1 + \overline{a_1}a_0\overline{b_2}b_0 + a_0\overline{b_2b_1}b_0$

gatecse-2006 digital-logic normal carry-generator adder

Answer key

6.6.2 Carry Generator: GATE CSE 2007 | Question: 35

In a look-ahead carry generator, the carry generate function G_i and the carry propagate function P_i for inputs A_i and B_i are given by:

$$P_i = A_i \oplus B_i \text{ and } G_i = A_iB_i$$

The expressions for the sum bit S_i and the carry bit C_{i+1} of the look ahead carry adder are given by:

$$S_i = P_i \oplus C_i \text{ and } C_{i+1} = G_i + P_iC_i, \text{ where } C_0 \text{ is the input carry.}$$

Consider a two-level logic implementation of the look-ahead carry generator. Assume that all P_i and G_i are available for the carry generator circuit and that the AND and OR gates can have any number of inputs. The number of AND gates and OR gates needed to implement the look-ahead carry generator for a 4-bit adder with S_3, S_2, S_1, S_0 and C_4 as its outputs are respectively:

A. $6,3$

B. $10,4$

C. $6,4$

D. $10,5$

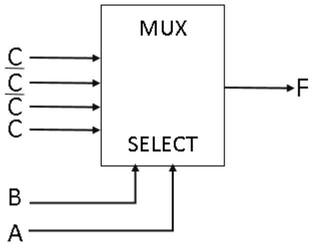
gatecse-2007 digital-logic normal carry-generator adder

Answer key

6.7 Circuit Output (40)

6.7.1 Circuit Output: GATE CSE 1987 | Question: 1-IV

The output F of the below multiplexer circuit can be represented by



A. $AB + B\bar{C} + \bar{C}A + \bar{B}\bar{C}$

B. $A \oplus B \oplus C$

C. $A \oplus B$

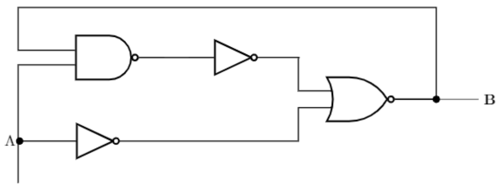
D. $\bar{A}\bar{B}C + \bar{A}B\bar{C} + A\bar{B}\bar{C}$

gate1987 digital-logic combinational-circuit multiplexer circuit-output

Answer key

6.7.2 Circuit Output: GATE CSE 1989 | Question: 4-ix

Explain the behaviour of the following logic circuit with level input A and output B.



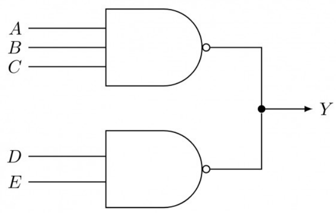
gate1989 descriptive digital-logic circuit-output

Answer key

6.7.3 Circuit Output: GATE CSE 1990 | Question: 3-i

Choose the correct alternatives (More than one may be correct).

Two NAND gates having open collector outputs are tied together as shown in below figure.



The logic function Y, implemented by the circuit is,

A. $Y = ABC + DE$

B. $Y = \overline{ABC + DE}$

C. $Y = ABC.DE$

D. $Y = \overline{ABC.DE}$

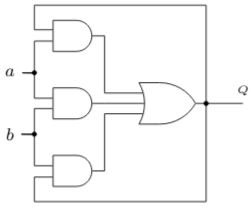
gate1990 normal digital-logic circuit-output

Answer key

6.7.4 Circuit Output: GATE CSE 1991 | Question: 5-a

Analyse the circuit in Fig below and complete the following table

a	b	Q_n
0	0	
0	1	
1	0	
1	1	

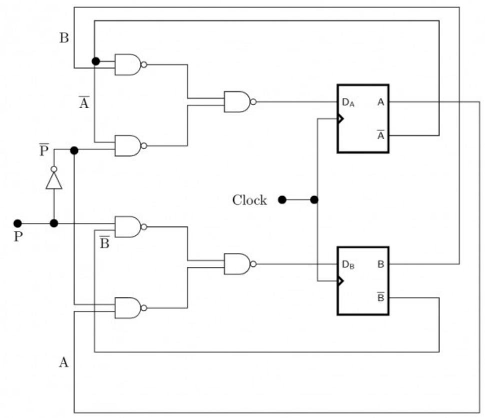


gate1991 digital-logic normal circuit-output sequential-circuit descriptive

Answer key

6.7.5 Circuit Output: GATE CSE 1993 | Question: 19

A control algorithm is implemented by the NAND – gate circuitry given in figure below, where A and B are state variable implemented by D flip-flops, and P is control input. Develop the state transition table for this controller.

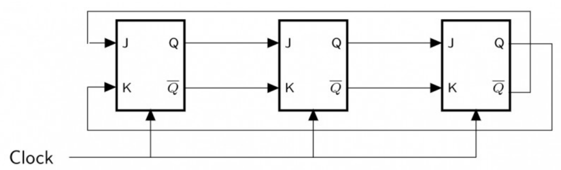


gate1993 digital-logic sequential-circuit flip-flop circuit-output normal descriptive

Answer key

6.7.6 Circuit Output: GATE CSE 1993 | Question: 6-3

For the initial state of 000, the function performed by the arrangement of the J-K flip-flops in figure is:



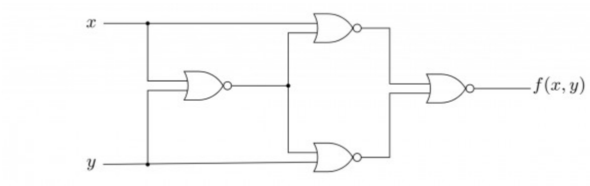
A. Shift Register
B. $\text{Mod-}\ 3$ Counter
C. $\text{Mod-}\ 6$ Counter
D. $\text{Mod-}\ 2$ Counter
E. None of the above

gate1993 digital-logic sequential-circuit flip-flop digital-counter circuit-output multiple-selects

Answer key

6.7.7 Circuit Output: GATE CSE 1993 | Question: 6.1

Identify the logic function performed by the circuit shown in figure.



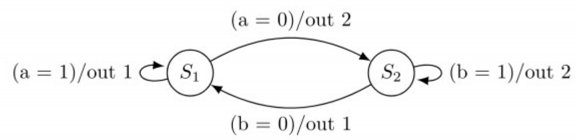
A. exclusive OR
B. exclusive NOR
C. NAND
D. NOR
E. None of the above

gate1993 digital-logic combinational-circuit circuit-output normal

Answer key☟

6.7.8 Circuit Output: GATE CSE 1993 | Question: 6.2

If the state machine described in figure should have a stable state, the restriction on the inputs is given by



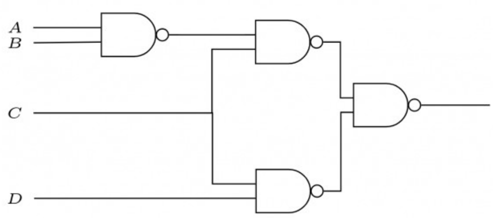
A. $a.b=1$
B. $a+b=1$
C. $\bar{a}+\bar{b}=0$
D. $\overline{a.b}=1$
E. $\overline{a+b}=1$

gate1993 digital-logic normal circuit-output sequential-circuit

Answer key☟

6.7.9 Circuit Output: GATE CSE 1994 | Question: 1.8

The logic expression for the output of the circuit shown in figure below is:



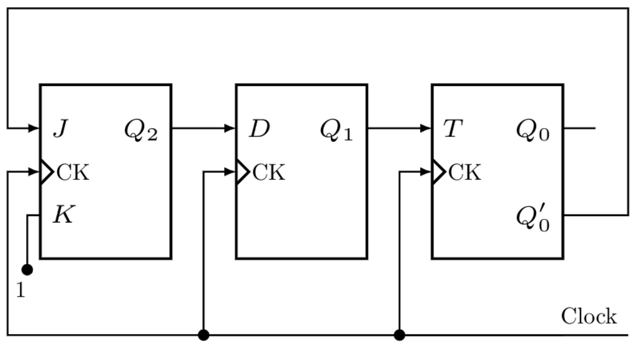
A. $\overline{AC}+\overline{BC}+CD$
B. $\overline{A}C+\overline{B}C+CD$
C. $ABC+\overline{C}\,\overline{D}$
D. $\overline{A}\,\overline{B}+\overline{B}\,\overline{C}+CD$

gate1994 digital-logic circuit-output normal

Answer key☟

6.7.10 Circuit Output: GATE CSE 1994 | Question: 11

Find the contents of the flip-flop Q_2, Q_1 and Q_0 in the circuit of figure, after giving four clock pulses to the clock terminal. Assume $Q_2Q_1Q_0 = 000$ initially.

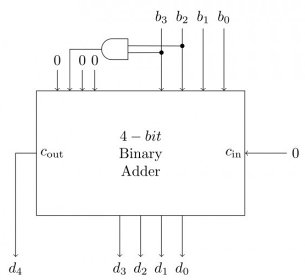


gate1994 digital-logic sequential-circuit digital-counter circuit-output normal descriptive

Answer key

6.7.11 Circuit Output: GATE CSE 1996 | Question: 2.21

Consider the circuit in below figure which has a four bit binary number $b_3b_2b_1b_0$ as input and a five bit binary number, $d_4d_3d_2d_1d_0$ as output.



A. Binary to Hex conversion

B. Binary to BCD conversion

C. Binary to Gray code conversion

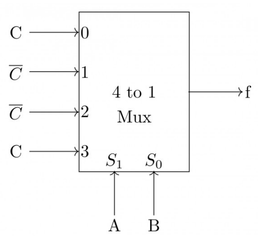
D. Binary to $radix - 12$ conversion

gate1996 digital-logic circuit-output normal

Answer key

6.7.12 Circuit Output: GATE CSE 1996 | Question: 2.22

Consider the circuit in figure. f implements



A. $\overline{A}\,\overline{B}C + \overline{A}B\overline{C} + ABC$

B. $A + B + C$

C. $A \oplus B \oplus C$

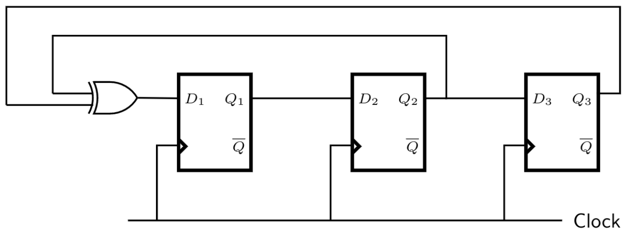
D. $AB + BC + CA$

gate1996 digital-logic circuit-output easy multiplexer

Answer key

6.7.13 Circuit Output: GATE CSE 1996 | Question: 24-a

Consider the synchronous sequential circuit in the below figure



Draw a state diagram, which is implemented by the circuit. Use the following names for the states corresponding to the values of flip-flops as given below.

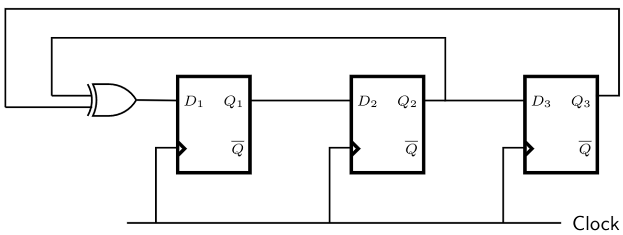
Q1	Q2	Q3	State
0	0	0	S_0
0	0	1	S_1
–	–	–	–
–	–	–	–
–	–	–	–
1	1	1	S_7

gate1996 digital-logic circuit-output normal descriptive

Answer key

6.7.14 Circuit Output: GATE CSE 1996 | Question: 24-b

Consider the synchronous sequential circuit in the below figure



Given that the initial state of the circuit is S_4, identify the set of states, which are not reachable.

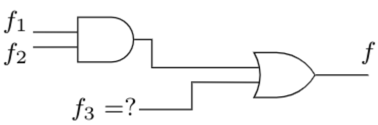
gate1996 normal digital-logic circuit-output descriptive

Answer key

6.7.15 Circuit Output: GATE CSE 1997 | Question: 5.5

Consider a logic circuit shown in figure below. The functions f_1, f_2 and f (in canonical sum of products form in decimal notation) are :

$f_1(w,x,y,z) = \sum 8,9,10$
$f_2(w,x,y,z) = \sum 7,8,12,13,14,15$
$f(w,x,y,z) = \sum 8,9$



The function f_3 is

A. $\sum 9,10$

B. $\sum 9$

C. $\sum 1,8,9$

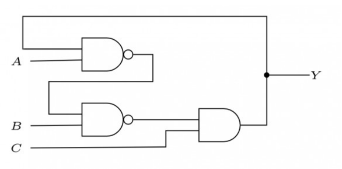
D. $\sum 8,10,15$

gate1997 digital-logic circuit-output normal

Answer key

6.7.16 Circuit Output: GATE CSE 1999 | Question: 2.8

Consider the circuit shown below. In a certain steady state, the line Y is at $'1'$. What are the possible values of A, B and C in this state?



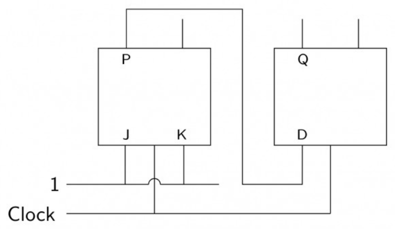
A. $A=0, B=0, C=1$
B. $A=0, B=1, C=1$
C. $A=1, B=0, C=1$
D. $A=1, B=1, C=1$

gate1999 digital-logic circuit-output normal

Answer key

6.7.17 Circuit Output: GATE CSE 2000 | Question: 2.12

The following arrangement of master-slave flip flops



has the initial state of P, Q as $0, 1$ (respectively). After three clock cycles the output state P, Q is (respectively),

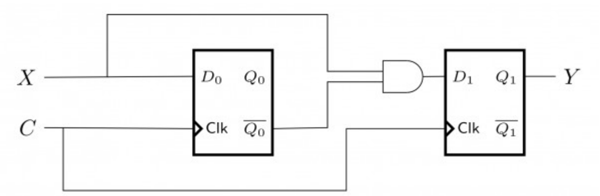
A. $1,0$
B. $1,1$
C. $0,0$
D. $0,1$

gatecse-2000 digital-logic circuit-output normal flip-flop

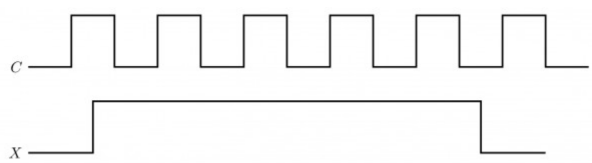
Answer key

6.7.18 Circuit Output: GATE CSE 2001 | Question: 2.8

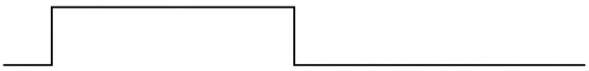
Consider the following circuit with initial state $Q_0 = Q_1 = 0$. The D Flip-flops are positive edged triggered and have set up times 20 nanosecond and hold times 0.

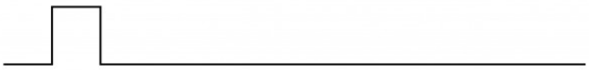


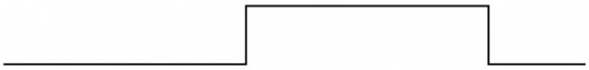
Consider the following timing diagrams of X and C. The clock period of $C \geq 40$ nanosecond. Which one is the correct plot of Y?



A. 

B. 

C. 

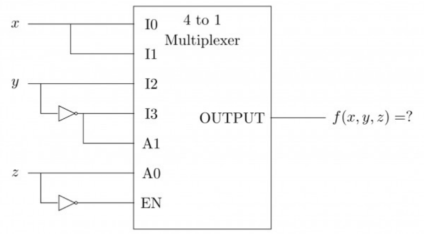
D. 

gatecse-2001 digital-logic circuit-output normal

Answer key☟

6.7.19 Circuit Output: GATE CSE 2002 | Question: 2.2

Consider the following multiplexer where $I0, I1, I2, I3$ are four data input lines selected by two address line combinations $A1A0 = 00, 01, 10, 11$ respectively and f is the output of the multiplexor. EN is the Enable input.



The function $f(x, y, z)$ implemented by the above circuit is

A. xyz'

B. $xy + z$

C. $x + y$

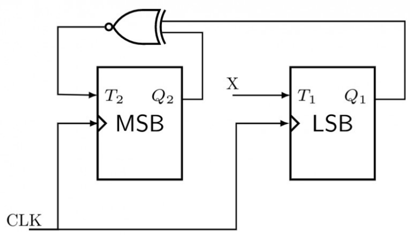
D. None of the above

gatecse-2002 digital-logic circuit-output normal

Answer key☟

6.7.20 Circuit Output: GATE CSE 2004 | Question: 61

Consider the partial implementation of a $2-bit$ counter using T flip-flops following the sequence $0-2-3-1-0$, as shown below.



To complete the circuit, the input X should be

A. Q_2^c

B. $Q_2 + Q_1$

C. $(Q_1 + Q_2)^c$

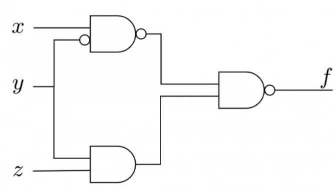
D. $Q_1 \oplus Q_2$

gatecse-2004 digital-logic circuit-output normal

Answer key☟

6.7.21 Circuit Output: GATE CSE 2005 | Question: 15

Consider the following circuit.



Which one of the following is TRUE?

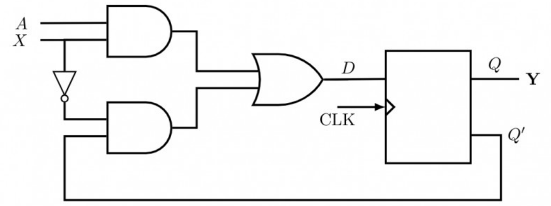
A. f is independent of x
B. f is independent of y
C. f is independent of z
D. None of x, y, z is redundant

gatecse-2005 digital-logic circuit-output normal

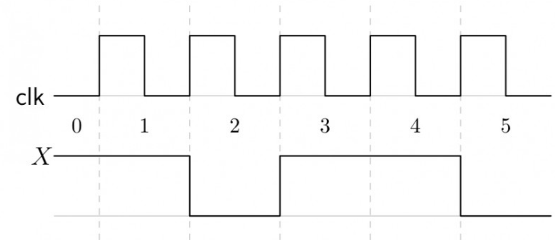
Answer key

6.7.22 Circuit Output: GATE CSE 2005 | Question: 62

Consider the following circuit involving a positive edge triggered D FF.



Consider the following timing diagram. Let A_i represents the logic level on the line A in the i-th clock period.



Let A' represent the complement of A. The correct output sequence on Y over the clock periods 1 through 5 is:

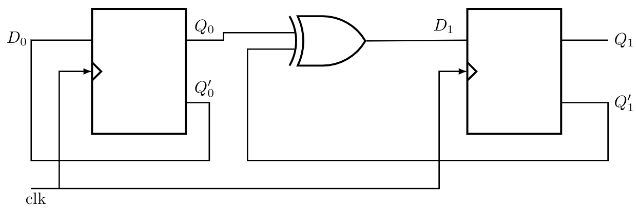
A. $A_0 A_1 A'_1 A_3 A_4$
B. $A_0 A_1 A'_2 A_3 A_4$
C. $A_1 A_2 A'_2 A_3 A_4$
D. $A_1 A'_2 A_3 A_4 A'_5$

gatecse-2005 digital-logic circuit-output normal

Answer key

6.7.23 Circuit Output: GATE CSE 2005 | Question: 64

Consider the following circuit:



The flip-flops are positive edge triggered D FFs. Each state is designated as a two-bit string $Q_0 Q_1$. Let the initial state be 00. The state transition sequence is

A. $00 \to 11 \to 01$

B. $00 \to 11$

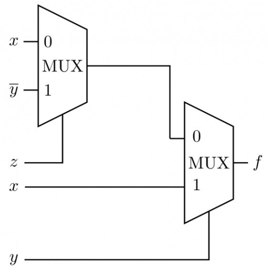
C. $00 \to 10 \to 01 \to 11$

D. $00 \to 11 \to 01 \to 10$

gatecse-2005 digital-logic circuit-output

Answer key

6.7.24 Circuit Output: GATE CSE 2006 | Question: 35



Consider the circuit above. Which one of the following options correctly represents $f(x, y, z)$

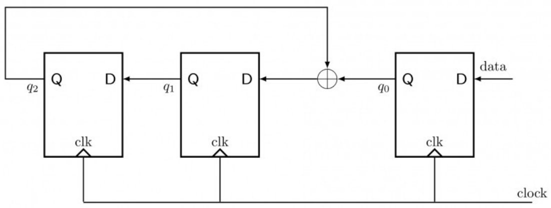
A. $x\bar{z} + xy + \bar{y}z$
B. $x\bar{z} + xy + \overline{yz}$
C. $xz + xy + \overline{yz}$
D. $xz + x\bar{y} + \bar{y}z$

gatecse-2006 digital-logic circuit-output normal

Answer key☟

6.7.25 Circuit Output: GATE CSE 2006 | Question: 37

Consider the circuit in the diagram. The $\oplus$ operator represents Ex-OR. The D flip-flops are initialized to zeroes (cleared).



The following data: 100110000 is supplied to the “data” terminal in nine clock cycles. After that the values of $q_2q_1q_0$ are:

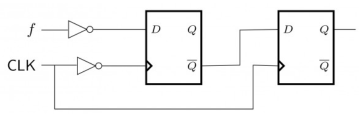
A. 000
B. 001
C. 010
D. 101

gatecse-2006 digital-logic circuit-output easy

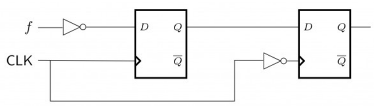
Answer key☟

6.7.26 Circuit Output: GATE CSE 2006 | Question: 8

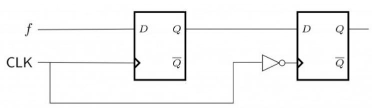
You are given a free running clock with a duty cycle of 50% and a digital waveform f which changes only at the negative edge of the clock. Which one of the following circuits (using clocked D flip-flops) will delay the phase of f by 180°?



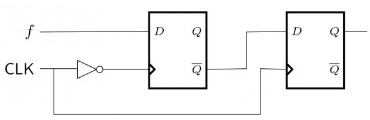
A.



B.



C.



D.

gatecse-2006 digital-logic normal circuit-output

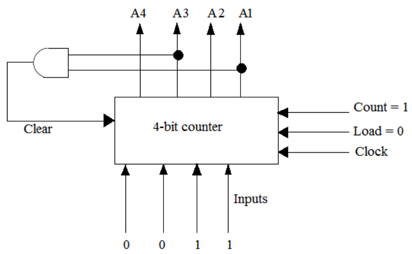
Answer key☟

6.7.27 Circuit Output: GATE CSE 2007 | Question: 36

The control signal functions of a $4\text{-}bit$ binary counter are given below (where X is "don't care"):

Clear	Clock	Load	Count	Function
1	X	X	X	Clear to 0
0	X	0	0	No Change
0	↑	1	X	Load Input
0	↑	0	1	Count Next

The counter is connected as follows:



Assume that the counter and gate delays are negligible. If the counter starts at 0, then it cycles through the following sequence:

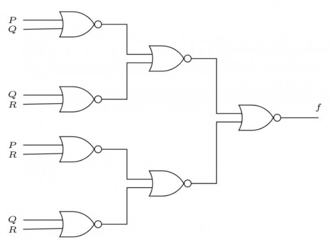
A. $0,3,4$ B. $0,3,4,5$ C. $0,1,2,3,4$ D. $0,1,2,3,4,5$

gatecse-2007 digital-logic circuit-output normal

Answer key☟

6.7.28 Circuit Output: GATE CSE 2010 | Question: 31

What is the boolean expression for the output f of the combinational logic circuit of NOR gates given below?



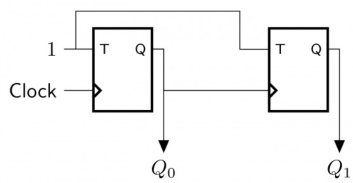
A. $\overline{Q+R}$
B. $\overline{P+Q}$
C. $\overline{P+R}$
D. $\overline{P+Q+R}$

gatecse-2010 digital-logic circuit-output normal

Answer key☟

6.7.29 Circuit Output: GATE CSE 2010 | Question: 32

In the sequential circuit shown below, if the initial value of the output Q_1Q_0 is 00. What are the next four values of Q_1Q_0?



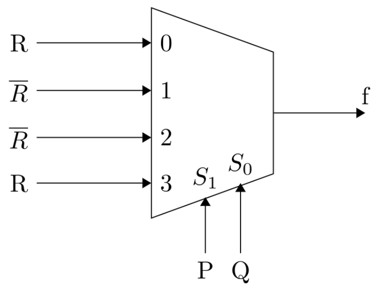
A. $11, 10, 01, 00$
B. $10, 11, 01, 00$
C. $10, 00, 01, 11$
D. $11, 10, 00, 01$

gatecse-2010 digital-logic circuit-output normal

Answer key☟

6.7.30 Circuit Output: GATE CSE 2010 | Question: 9

The Boolean expression of the output f of the multiplexer shown below is



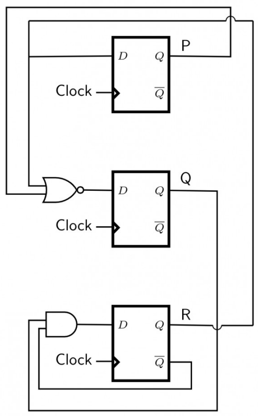
A. $\overline{P \oplus Q \oplus R}$
B. $P \oplus Q \oplus R$
C. $P + Q + R$
D. $\overline{P + Q + R}$

gatecse-2010 digital-logic circuit-output easy

Answer key☟

6.7.31 Circuit Output: GATE CSE 2011 | Question: 50

Consider the following circuit involving three D-type flip-flops used in a certain type of counter configuration.



If at some instance prior to the occurrence of the clock edge, P, Q and R have a value 0, 1 and 0 respectively, what shall be the value of PQR after the clock edge?

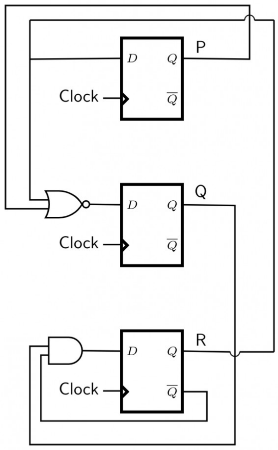
A. 000
B. 001
C. 010
D. 011

gatecse-2011 digital-logic circuit-output flip-flop normal

Answer key☟

6.7.32 Circuit Output: GATE CSE 2011 | Question: 51

Consider the following circuit involving three D-type flip-flops used in a certain type of counter configuration.



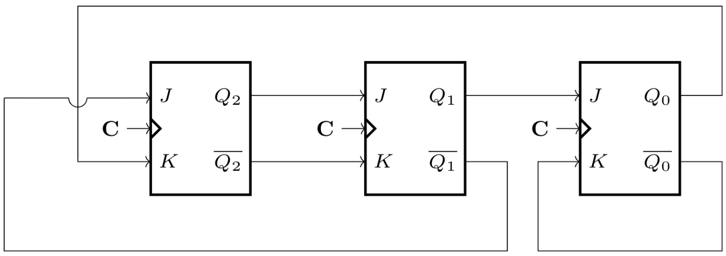
If all the flip-flops were reset to 0 at power on, what is the total number of distinct outputs (states) represented by PQR generated by the counter?

A. 3 B. 4 C. 5 D. 6

gatecse-2011 digital-logic circuit-output normal

Answer key

6.7.33 Circuit Output: GATE CSE 2014 Set 3 | Question: 45



The above synchronous sequential circuit built using JK flip-flops is initialized with $Q_2Q_1Q_0 = 000$. The state sequence for this circuit for the next 3 clock cycles is

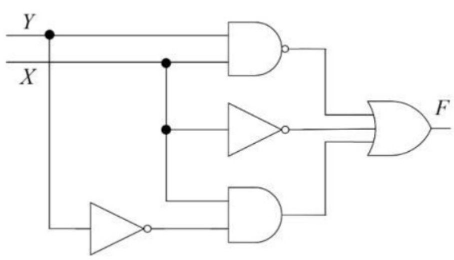
A. $001, 010, 011$
B. $111, 110, 101$
C. $100, 110, 111$
D. $100, 011, 001$

gatecse-2014-set3 digital-logic circuit-output normal

Answer key

6.7.34 Circuit Output: GATE CSE 2025 | Set 2 | Question: 21

Consider the following logic circuit diagram.



Which is/are the CORRECT option(s) for the output function F ?

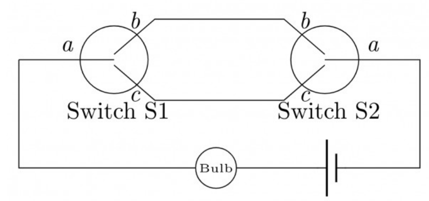
A. $\overline{XY}$
B. $\bar{X} + \bar{Y} + X\bar{Y}$
C. $\bar{X}\bar{Y} + \bar{X} + X\bar{Y}$
D. $X + \bar{Y}$

gatecse2025-set2 digital-logic circuit-output multiple-selects easy one-mark

Answer key

6.7.35 Circuit Output: GATE IT 2005 | Question: 10

A two-way switch has three terminals a, b and c. In ON position (logic value 1), a is connected to b, and in OFF position, a is connected to c. Two of these two-way switches $S1$ and $S2$ are connected to a bulb as shown below.



Which of the following expressions, if true, will always result in the lighting of the bulb ?

A. $S1.\overline{S2}$

B. $S1 + S2$

C. $\overline{S1 \oplus S2}$

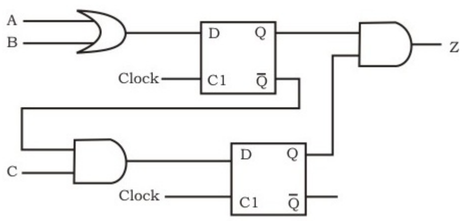
D. $S1 \oplus S2$

gateit-2005 digital-logic circuit-output normal

Answer key

6.7.36 Circuit Output: GATE IT 2005 | Question: 43

Which of the following input sequences will always generate a 1 at the output z at the end of the third cycle?



A.

A	B	C
0	0	0
1	0	1
1	1	1

B.

A	B	C
1	0	1
1	1	0
1	1	1

C.

A	B	C
0	1	1
1	0	1
1	1	1

D.

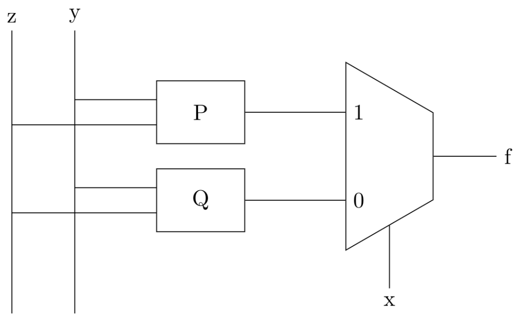
A	B	C
0	0	1
1	1	0
1	1	1

gateit-2005 digital-logic circuit-output normal

Answer key

6.7.37 Circuit Output: GATE IT 2006 | Question: 36

The majority function is a Boolean function $f(x, y, z)$ that takes the value 1 whenever a majority of the variables x, y, z are 1. In the circuit diagram for the majority function shown below, the logic gates for the boxes labeled P and Q are, respectively,



A. XOR, AND

B. XOR, XOR

C. OR, OR

D. OR, AND

gateit-2006 digital-logic circuit-output normal

Answer key

6.7.38 Circuit Output: GATE IT 2007 | Question: 38

The following expression was to be realized using 2-input AND and OR gates. However, during the fabrication all 2-input AND gates were mistakenly substituted by 2-input NAND gates. $(a.b).c+(a'.c).d+(b.c).d+a.d$

What is the function finally realized ?

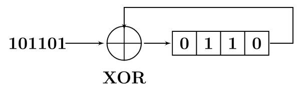
A. 1
B. $a'+b'+c'+d'$
C. $a'+b+c'+d'$
D. $a'+b'+c+d'$

gateit-2007 digital-logic circuit-output normal

Answer key

6.7.39 Circuit Output: GATE IT 2007 | Question: 40

What is the final value stored in the linear feedback shift register if the input is 101101?



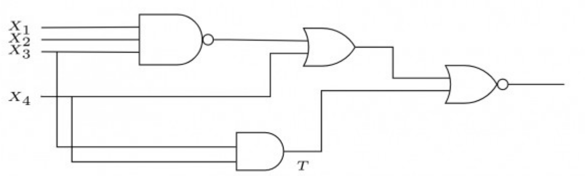
A. 0110
B. 1011
C. 1101
D. 1111

gateit-2007 digital-logic circuit-output normal

Answer key

6.7.40 Circuit Output: GATE IT 2007 | Question: 45

The line T in the following figure is permanently connected to the ground.



Which of the following inputs $(X_1X_2X_3X_4)$ will detect the fault ?

A. 0000
B. 0111
C. 1111
D. None of these

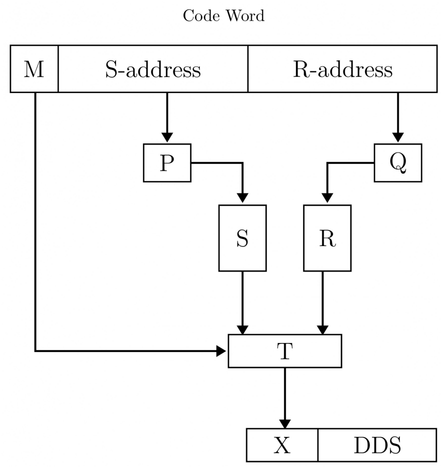
gateit-2007 digital-logic circuit-output normal

Answer key

6.8 Combinational Circuit (2)

6.8.1 Combinational Circuit: GATE CSE 2022 | Question: 30

Consider a digital display system (DDS) shown in the figure that displays the contents of register X. A $16-\text{bit}$ code word is used to load a word in X, either from S or from R. S is a $1024-$word memory segment and R is a $32-$word register file. Based on the value of mode bit M, T selects an input word to load in X. P and Q interface with the corresponding bits in the code word to choose the addressed word. Which one of the following represents the functionality of P, Q, and T?



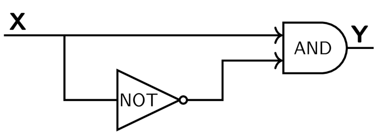
A. P is $10:1$ multiplexer; Q is $5:1$ multiplexer; T is $2:1$ multiplexer
B. P is $10:2^{10}$ decoder; Q is $5:2^{5}$ decoder; T is $2:1$ encoder
C. P is $10:2^{10}$ decoder; Q is $5:2^{5}$ decoder; T is $2:1$ multiplexer
D. P is $1:10$ de-multiplexer; Q is $1:5$ de-multiplexer; T is $2:1$ multiplexer

gatecse-2022 digital-logic combinational-circuit two-marks

Answer key

6.8.2 Combinational Circuit: GATE CSE 2024 | Set 1 | Question: 18

Consider the circuit shown below where the gates may have propagation delays. Assume that all signal transitions occur instantaneously and that wires have no delays. Which of the following statements about the circuit is/are CORRECT?



A. With no propagation delays, the output Y is always logic Zero
B. With no propagation delays, the output Y is always logic One
C. With propagation delays, the output Y can have a transient logic One after X transitions from logic Zero to logic One
D. With propagation delays, the output Y can have a transient logic Zero after X transitions from logic One to logic Zero

gatecse2024-set1 multiple-selects digital-logic combinational-circuit one-mark

Answer key

6.9 Decoder (3)

6.9.1 Decoder: GATE CSE 2007 | Question: 8, ISRO2011-31

How many 3-to-8 line decoders with an enable input are needed to construct a 6-to-64 line decoder without using any other logic gates?

A. 7 B. 8 C. 9 D. 10

gatecse-2007 digital-logic normal isro2011 decoder

Answer key

6.9.2 Decoder: GATE CSE 2020 | Question: 20

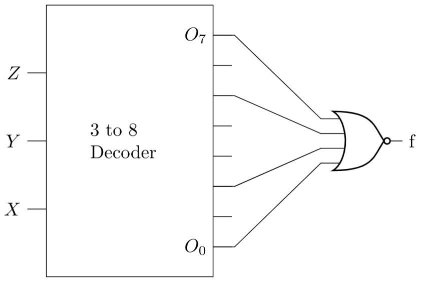
If there are m input lines and n output lines for a decoder that is used to uniquely address a byte addressable 1 KB RAM, then the minimum value of $m+n$ is ________ .

gatecse-2020 numerical-answers digital-logic decoder one-mark

Answer key

6.9.3 Decoder: GATE IT 2008 | Question: 9

What Boolean function does the circuit below realize?



A. $xz+\bar{x}\bar{z}$
B. $x\bar{z}+\bar{x}z$
C. $\bar{x}\bar{y}+yz$
D. $xy+\bar{y}\bar{z}$

gateit-2008 digital-logic circuit-output decoder normal

Answer key

6.10 Digital Circuits (6)

6.10.1 Digital Circuits: GATE CSE 1996 | Question: 5

A logic network has two data inputs A and B, and two control inputs C_0 and C_1. It implements the function F according to the following table.

C_1	C_0	**F**
0	0	$\overline{A+B}$
0	1	A + B
1	0	$A \oplus B$

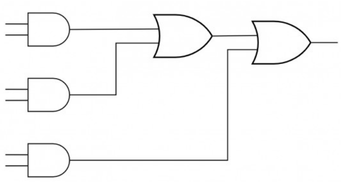
Implement the circuit using one 4 to 1 Multiplexer, one $2-$input Exclusive OR gate, one $2-$input AND gate, one $2-$input OR gate and one Inverter.

gate1996 digital-logic normal digital-circuits descriptive

Answer key

6.10.2 Digital Circuits: GATE CSE 2002 | Question: 7

A. Express the function $f(x,y,z)=xy'+yz'$ with only one complement operation and one or more AND/OR operations. Draw the logic circuit implementing the expression obtained, using a single NOT gate and one or more AND/OR gates.
B. Transform the following logic circuit (without expressing its switching function) into an equivalent logic circuit that employs only 6 NAND gates each with 2-inputs.

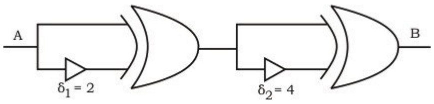


gatecse-2002 digital-logic normal descriptive digital-circuits

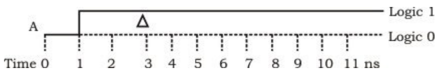
Answer key

6.10.3 Digital Circuits: GATE CSE 2003 | Question: 47

Consider the following circuit composed of XOR gates and non-inverting buffers.



The non-inverting buffers have delays $\delta_1 = 2ns$ and $\delta_2 = 4ns$ as shown in the figure. Both XOR gates and all wires have zero delays. Assume that all gate inputs, outputs, and wires are stable at logic level 0 at time 0. If the following waveform is applied at input A, how many transition(s) (change of logic levels) occur(s) at B during the interval from 0 to 10 ns?



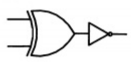
A. 1
B. 2
C. 3
D. 4

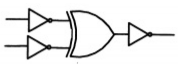
gatecse-2003 digital-logic digital-circuits

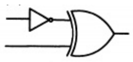
Answer key

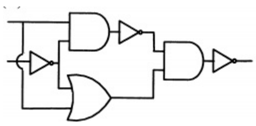
6.10.4 Digital Circuits: GATE CSE 2011 | Question: 13

Which one of the following circuits is **NOT** equivalent to a 2-input $XNOR$ (exclusive NOR) gate?

A. 

B. 

C. 

D. 

gatecse-2011 digital-logic normal digital-circuits

Answer key

6.10.5 Digital Circuits: GATE CSE 2013 | Question: 5

In the following truth table, $V = 1$ if and only if the input is valid.

Inputs				Outputs		
D_0	D_1	D_2	D_3	X_0	X_1	V
0	0	0	0	x	x	0
1	0	0	0	0	0	1
x	1	0	0	0	1	1
x	x	1	0	1	0	1
x	x	x	1	1	1	1

What function does the truth table represent?

A. Priority encoder
B. Decoder
C. Multiplexer
D. Demultiplexer

gatecse-2013 digital-logic normal digital-circuits

Answer key

6.10.6 Digital Circuits: GATE CSE 2014 Set 3 | Question: 8

Consider the following combinational function block involving four Boolean variables $x,\ y,\ a,\ b$ where $x,\ a,\ b$ are inputs and y is the output.

```
f(x, a, b, y)
{
   if(x is 1) y = a;
   else y = b;
}
```

Which one of the following digital logic blocks is the most suitable for implementing this function?

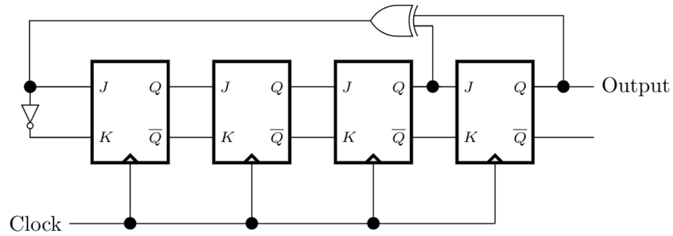
A. Full adder B. Priority encoder C. Multiplexor D. Flip-flop

gatecse-2014-set3 digital-logic easy digital-circuits

Answer key

6.11 Digital Counter (17)

6.11.1 Digital Counter: GATE CSE 1987 | Question: 1-III



The above circuit produces the output sequence:

A. $1111 \quad 1111 \quad 0000 \quad 0000$
B. $1111 \quad 0000 \quad 1111 \quad 0000$
C. $1111 \quad 0001 \quad 0011 \quad 0101$
D. $1010 \quad 1010 \quad 1010 \quad 1010$

gate1987 digital-logic sequential-circuit flip-flop digital-counter

Answer key

6.11.2 Digital Counter: GATE CSE 1987 | Question: 10c

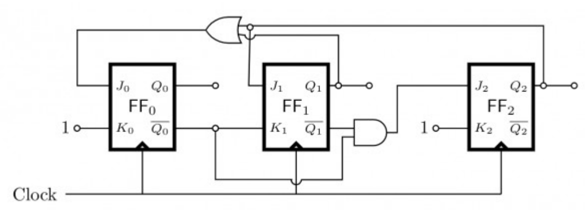
Give a minimal DFA that performs as a $\mod -3,\ 1$'s counter, i.e. outputs a 1 each time the number of 1's in the input sequence is a multiple of 3.

gate1987 digital-logic digital-counter descriptive

Answer key

6.11.3 Digital Counter: GATE CSE 1990 | Question: 5-c

For the synchronous counter shown in Fig.$3,$ write the truth table of $Q_0, Q_1,$ and Q_2 after each pulse, starting from $Q_0 = Q_1 = Q_2 = 0$ and determine the counting sequence and also the modulus of the counter.

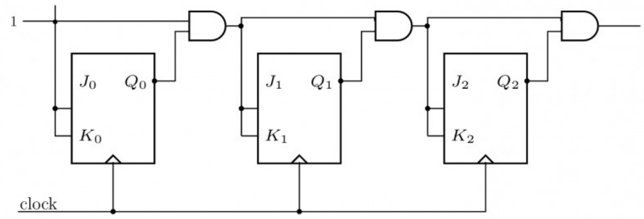


gate1990 descriptive digital-logic sequential-circuit flip-flop digital-counter

Answer key

6.11.4 Digital Counter: GATE CSE 1991 | Question: 5-c

Find the maximum clock frequency at which the counter in the figure below can be operated. Assume that the propagation delay through each flip flop and each AND gate is 10 ns. Also, assume that the setup time for the JK inputs of the flip flops is negligible.



gate1991 digital-logic sequential-circuit flip-flop digital-counter

Answer key

6.11.5 Digital Counter: GATE CSE 1994 | Question: 2-1

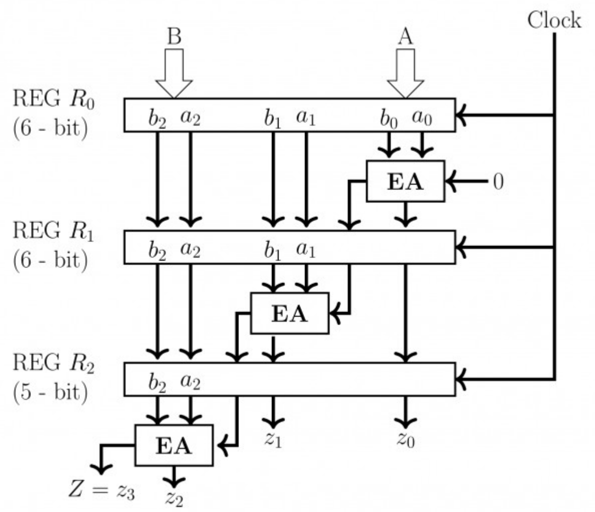
The number of flip-flops required to construct a binary modulo N counter is ___________

gate1994 digital-logic sequential-circuit flip-flop digital-counter fill-in-the-blanks

Answer key

6.11.6 Digital Counter: GATE CSE 2002 | Question: 8

Consider the following circuit. $A = a_2a_1a_0$ and $B = b_2b_1b_0$ are three bit binary numbers input to the circuit. The output is $Z = z_3z_2z_1z_0$. R0, R1 and R2 are registers with loading clock shown. The registers are loaded with their input data with the falling edge of a clock pulse (signal CLOCK shown) and appears as shown. The bits of input number A, B and the full adders are as shown in the circuit. Assume Clock period is greater than the settling time of all circuits.



a. For 8 clock pulses on the CLOCK terminal and the inputs A, B as shown, obtain the output Z (sequence of $4 - bit$ values of Z). Assume initial contents of R_0, R_1 and R_2 as all zeros.

A	110	011	111	101	000	000	000	000
B	101	101	011	110	000	000	000	000
Clock No	1	2	3	4	5	6	7	8

b. What does the circuit implement?

gatecse-2002 digital-logic normal descriptive digital-counter

Answer key

6.11.7 Digital Counter: GATE CSE 2011 | Question: 15

The minimum number of D flip-flops needed to design a mod-258 counter is

A. 9 B. 8 C. 512 D. 258

gatecse-2011 digital-logic normal digital-counter

Answer key

6.11.8 Digital Counter: GATE CSE 2014 Set 2 | Question: 7

Let $k = 2^n$. A circuit is built by giving the output of an n-bit binary counter as input to an n-to-2^n bit decoder. This circuit is equivalent to a

A. k-bit binary up counter.
B. k-bit binary down counter.
C. k--bit ring counter.
D. k-bit Johnson counter.

gatecse-2014-set2 digital-logic normal digital-counter

Answer key

6.11.9 Digital Counter: GATE CSE 2015 Set 1 | Question: 20

Consider a 4-bit Johnson counter with an initial value of $0000.$ The counting sequence of this counter is

A. $0, 1, 3, 7, 15, 14, 12, 8, 0$
B. $0, 1, 3, 5, 7, 9, 11, 13, 15, 0$
C. $0, 2, 4, 6, 8, 10, 12, 14, 0$
D. $0, 8, 12, 14, 15, 7, 3, 1, 0$

gatecse-2015-set1 digital-logic digital-counter easy

Answer key

6.11.10 Digital Counter: GATE CSE 2015 Set 2 | Question: 7

The minimum number of JK flip-flops required to construct a synchronous counter with the count sequence $(0, 0, 1, 1, 2, 2, 3, 3, 0, 0, \ldots)$ is _______.

gatecse-2015-set2 digital-logic digital-counter normal numerical-answers

Answer key

6.11.11 Digital Counter: GATE CSE 2016 Set 1 | Question: 8

We want to design a synchronous counter that counts the sequence $0-1-0-2-0-3$ and then repeats. The minimum number of $\mathrm{J\text{-}K}$ flip-flops required to implement this counter is _____________.

gatecse-2016-set1 digital-logic digital-counter flip-flop normal numerical-answers

Answer key

6.11.12 Digital Counter: GATE CSE 2017 Set 2 | Question: 42

The next state table of a $2-$bit saturating up-counter is given below.

Q_1	Q_0	Q_1^+	Q_0^+
0	0	0	1
0	1	1	0
1	0	1	1
1	1	1	1

The counter is built as a synchronous sequential circuit using T flip-flops. The expressions for T_1 and T_0 are

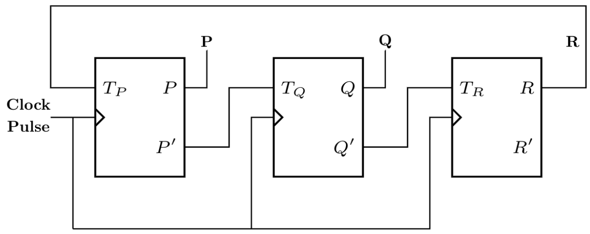
A. $T_1 = Q_1 Q_0, \quad T_0 = \bar{Q}_1 \bar{Q}_0$
B. $T_1 = \bar{Q}_1 Q_0, \quad T_0 = \bar{Q}_1 + \bar{Q}_0$
C. $T_1 = Q_1 + Q_0, \quad T_0 = \bar{Q}_1 \bar{Q}_0$
D. $T_1 = \bar{Q}_1 Q_0, \quad T_0 = Q_1 + Q_0$

gatecse-2017-set2 digital-logic digital-counter

Answer key

6.11.13 Digital Counter: GATE CSE 2021 Set 1 | Question: 28

Consider a 3-bit counter, designed using T flip-flops, as shown below:



Assuming the initial state of the counter given by PQR as 000, what are the next three states?

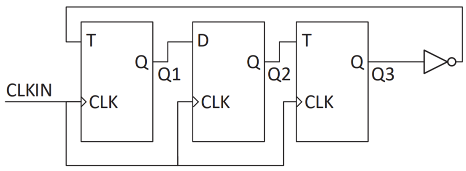
A. $011, 101, 000$ B. $001, 010, 111$ C. $011, 101, 111$ D. $001, 010, 000$

gatecse-2021-set1 digital-logic sequential-circuit digital-counter two-marks

Answer key

6.11.14 Digital Counter: GATE CSE 2023 | Question: 33

Consider a sequential digital circuit consisting of T flip-flops and D flip-flops as shown in the figure. CLKIN is the clock input to the circuit. At the beginning, $\mathrm{Q1}$, $\mathrm{Q2}$ and $\mathrm{Q3}$ have values $0, 1$ and 1, respectively.



Which one of the given values of $(\mathrm{Q1}, \mathrm{Q2}, \mathrm{Q3})$ can NEVER be obtained with this digital circuit?

A. $(0, 0, 1)$ B. $(1, 0, 0)$ C. $(1, 0, 1)$ D. $(1, 1, 1)$

gatecse-2023 digital-logic flip-flop two-marks digital-counter

Answer key

6.11.15 Digital Counter: GATE IT 2005 | Question: 11

How many pulses are needed to change the contents of a 8-bit up counter from 10101100 to 00100111 (rightmost bit is the LSB)?

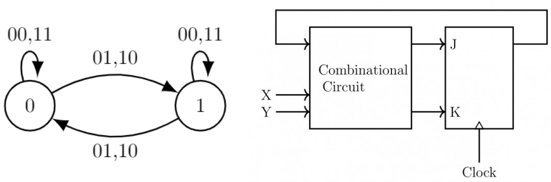
A. 134 B. 133 C. 124 D. 123

gateit-2005 digital-logic digital-counter normal

Answer key

6.11.16 Digital Counter: GATE IT 2008 | Question: 37

Consider the following state diagram and its realization by a JK flip flop



The combinational circuit generates J and K in terms of x, y and Q.
The Boolean expressions for J and K are :

A. $\overline{x \oplus y}$ and $\overline{x \oplus y}$ B. $\overline{x \oplus y}$ and $x \oplus y$

C. $x \oplus y$ and $\overline{x \oplus y}$

D. $x \oplus y$ and $x \oplus y$

gateit-2008 digital-logic boolean-algebra normal digital-counter

Answer key

6.11.17 Digital Counter: GATE1992-04-c

Design a 3-bit counter using D-flip flops such that not more than one flip-flop changes state between any two consecutive states.

gate1992 digital-logic sequential-circuit flip-flop digital-counter normal descriptive

Answer key

6.12 Finite State Machines (4)

6.12.1 Finite State Machines: GATE CSE 1994 | Question: 3.3

State True or False with one line explanation

A FSM (Finite State Machine) can be designed to add two integers of any arbitrary length (arbitrary number of digits).

gate1994 digital-logic normal true-false finite-state-machines

Answer key

6.12.2 Finite State Machines: GATE CSE 1995 | Question: 2.23

A finite state machine with the following state table has a single input x and a single out z.

present state	**next state, z**	
	x=1	x=0
A	D,0	B,0
B	B,1	C,1
C	B,0	D,1
D	B,1	C,0

If the initial state is unknown, then the shortest input sequence to reach the final state C is:

A. 01

B. 10

C. 101

D. 110

gate1995 digital-logic normal finite-state-machines

Answer key

6.12.3 Finite State Machines: GATE CSE 1996 | Question: 2.23

Consider the following state table for a sequential machine. The number of states in the minimized machine will be

		Input	
		0	1
Present State	**A**	D,0	B,1
	B	A,0	C,1
	C	A,0	B,1
	D	A,1	C,1
		Next state, Output	

A. 4

B. 3

C. 2

D. 1

gate1996 normal digital-logic finite-state-machines

Answer key☟

6.12.4 Finite State Machines: GATE CSE 2009 | Question: 27

Given the following state table of an FSM with two states A and B,one input and one output.

PRESENT STATE A	PRESENT STATE B	Input	Next State A	Next State B	Output
0	0	0	0	0	1
0	1	0	1	0	0
1	0	0	0	1	0
1	1	0	1	0	0
0	0	1	0	1	0
0	1	1	0	0	1
1	0	1	0	1	1
1	1	1	0	0	1

If the initial state is $A = 0, B = 0$ what is the minimum length of an input string which will take the machine to the state $A = 0, B = 1$ with $output = 1$.

A. 3 B. 4 C. 5 D. 6

gatecse-2009 digital-logic normal finite-state-machines

Answer key☟

6.13 Fixed Point Representation (2)

6.13.1 Fixed Point Representation: GATE CSE 2017 Set 1 | Question: 7

The n-bit fixed-point representation of an unsigned real number X uses f bits for the fraction part. Let $i = n - f$. The range of decimal values for X in this representation is

A. 2^{-f} to 2^i
B. 2^{-f} to $\left(2^i - 2^{-f}\right)$
C. 0 to 2^i
D. 0 to $\left(2^i - 2^{-f}\right)$

gatecse-2017-set1 digital-logic number-representation fixed-point-representation

Answer key☟

6.13.2 Fixed Point Representation: GATE CSE 2018 | Question: 33

Consider the unsigned 8-bit fixed point binary number representation, below,

$$b_7 \ b_6 \ b_5 \ b_4 \ b_3 \ \cdot b_2 \ b_1 \ b_0$$

where the position of the primary point is between b_3 and b_2 . Assume b_7 is the most significant bit. Some of the decimal numbers listed below **cannot** be represented **exactly** in the above representation:

i. 31.500
ii. 0.875
iii. 12.100
iv. 3.001

Which one of the following statements is true?

A. None of i, ii, iii, iv can be exactly represented
B. Only ii cannot be exactly represented
C. Only iii and iv cannot be exactly represented
D. Only i and ii cannot be exactly represented

gatecse-2018 digital-logic number-representation fixed-point-representation normal two-marks

Answer key☟

6.14.1 Flip Flop: GATE CSE 2001 | Question: 11

A sequential circuit takes an input stream of $0's$ and $1's$ and produces an output stream of $0's$ and $1's$. Initially it replicates the input on its output until two consecutive $0's$ are encountered on the input. From then onward, it produces an output stream, which is the bit-wise complement of input stream until it encounters two consecutive 1's, whereupon the process repeats. An example input and output stream is shown below.

$$\begin{array}{ll}\text{The input stream:} & 101100|01001011|011 \\ \text{The desired output:} & 101100|10110100|011\end{array}$$

J-K master-slave flip-flops are to be used to design the circuit.

a. Give the state transition diagram
b. Give the minimized sum-of-product expression for J and K inputs of one of its state flip-flops

gatecse-2001 digital-logic normal descriptive flip-flop

Answer key

6.14.2 Flip Flop: GATE CSE 2004 | Question: 18, ISRO2007-31

In an SR latch made by cross-coupling two NAND gates, if both S and R inputs are set to 0, then it will result in

A. $Q=0, Q'=1$
B. $Q=1, Q'=0$
C. $Q=1, Q'=1$
D. Indeterminate states

gatecse-2004 digital-logic easy isro2007 flip-flop

Answer key

6.14.3 Flip Flop: GATE CSE 2015 Set 1 | Question: 37

A positive edge-triggered D flip-flop is connected to a positive edge-triggered JK flip-flop as follows. The Q output of the D flip-flop is connected to both the J and K inputs of the JK flip-flop, while the Q output of the JK flip-flop is connected to the input of the D flip-flop. Initially, the output of the D flip-flop is set to logic one and the output of the JK flip-flop is cleared. Which one of the following is the bit sequence (including the initial state) generated at the Q output of the JK flip-flop when the flip-flops are connected to a free-running common clock? Assume that $J=K=1$ is the toggle mode and $J=K=0$ is the state holding mode of the JK flip-flops. Both the flip-flops have non-zero propagation delays.

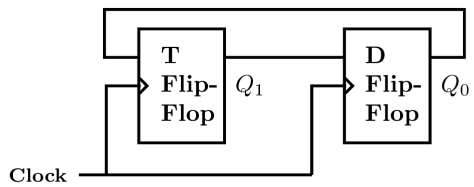
A. $0110110\ldots$
B. $0100100\ldots$
C. $011101110\ldots$
D. $011001100\ldots$

gatecse-2015-set1 digital-logic flip-flop normal

Answer key

6.14.4 Flip Flop: GATE CSE 2017 Set 1 | Question: 33

Consider a combination of T and D flip-flops connected as shown below. The output of the D flip-flop is connected to the input of the T flip-flop and the output of the T flip-flop is connected to the input of the D flip-flop.



Initially, both Q_0 and Q_1 are set to 1 (before the 1^{st} clock cycle). The outputs

A. Q_1Q_0 after the 3^{rd} cycle are 11 and after the 4^{th} cycle are 00 respectively.

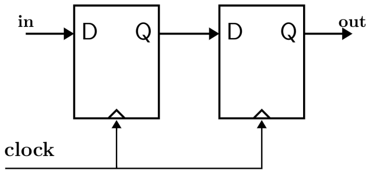
B. Q_1Q_0 after the 3^{rd} cycle are 11 and after the 4^{th} cycle are 01 respectively.
C. Q_1Q_0 after the 3^{rd} cycle are 00 and after the 4^{th} cycle are 11 respectively.
D. Q_1Q_0 after the 3^{rd} cycle are 01 and after the 4^{th} cycle are 01 respectively.

gatecse-2017-set1 digital-logic flip-flop normal

Answer key

6.14.5 Flip Flop: GATE CSE 2018 | Question: 22

Consider the sequential circuit shown in the figure, where both flip-flops used are positive edge-triggered D flip-flops.



The number of states in the state transition diagram of this circuit that have a transition back to the same state on some value of "in" is ____

gatecse-2018 digital-logic flip-flop numerical-answers normal one-mark

Answer key

6.14.6 Flip Flop: GATE IT 2007 | Question: 7

Which of the following input sequences for a cross-coupled $R-S$ flip-flop realized with two $NAND$ gates may lead to an oscillation?

A. $11, 00$
B. $01, 10$
C. $10, 01$
D. $00, 11$

gateit-2007 digital-logic normal flip-flop

Answer key

6.15 Floating Point Representation (12)

6.15.1 Floating Point Representation: GATE CSE 1987 | Question: 1-vii

The exponent of a floating-point number is represented in excess-N code so that:

A. The dynamic range is large.
B. The precision is high.
C. The smallest number is represented by all zeros.
D. Overflow is avoided.

gate1987 digital-logic number-representation floating-point-representation

Answer key

6.15.2 Floating Point Representation: GATE CSE 1989 | Question: 1-vi

Consider an excess -50 representation for floating point numbers with 4 BCD digit mantissa and 2 BCD digit exponent in normalised form. The minimum and maximum positive numbers that can be represented are __________ and _____________ respectively.

descriptive gate1989 digital-logic number-representation floating-point-representation

Answer key

6.15.3 Floating Point Representation: GATE CSE 1990 | Question: 1-iv-a

A 32-bit floating-point number is represented by a 7-bit signed exponent, and a 24-bit fractional mantissa. The base of the scale factor is 16,
The range of the exponent is ___________

gate1990 digital-logic number-representation floating-point-representation fill-in-the-blanks

Answer key

6.15.4 Floating Point Representation: GATE CSE 1990 | Question: 1-iv-b

A 32-bit floating-point number is represented by a 7-bit signed exponent, and a 24-bit fractional mantissa. The base of the scale factor is $16,$
The range of the exponent is ___________, if the scale factor is represented in excess-64 format.

gate1990 digital-logic number-representation floating-point-representation fill-in-the-blanks

Answer key

6.15.5 Floating Point Representation: GATE CSE 1997 | Question: 72

Following floating point number format is given

f is a fraction represented by a $6-bit$ mantissa (includes sign bit) in sign magnitude form, e is a $4-bit$ exponent (includes sign hit) in sign magnitude form and $n=(f,e)=f.2^e$ is a floating point number. Let $A=54.75$ in decimal and $B=9.75$ in decimal

a. Represent A and B as floating point numbers in the above format.
b. Show the steps involved in floating point addition of A and B.
c. What is the percentage error (up to one position beyond decimal point) in the addition operation in (b)?

gate1997 digital-logic floating-point-representation normal descriptive

Answer key

6.15.6 Floating Point Representation: GATE CSE 2003 | Question: 43

The following is a scheme for floating point number representation using 16 bits.

Bit Position	15	14 9	8 0
	s	e	m
	Sign	Exponent	Mantissa

Let $s, e,$ and m be the numbers represented in binary in the sign, exponent, and mantissa fields respectively. Then the floating point number represented is:

$$\begin{cases} (-1)^s\left(1+m\times 2^{-9}\right)2^{e-31}, & \text{if the exponent } \neq 111111 \\ 0, & \text{otherwise} \end{cases}$$

What is the maximum difference between two successive real numbers representable in this system?

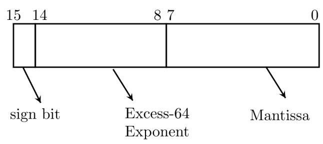
A. 2^{-40} B. 2^{-9} C. 2^{22} D. 2^{31}

gatecse-2003 digital-logic number-representation floating-point-representation normal

Answer key

6.15.7 Floating Point Representation: GATE CSE 2005 | Question: 85-a

Consider the following floating-point format.



Mantissa is a pure fraction in sign-magnitude form.

The decimal number 0.239×2^{13} has the following hexadecimal representation (without normalization and rounding off):

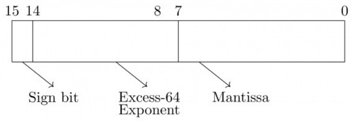
A. 0D 24 B. 0D 4D C. 4D 0D D. 4D 3D

gatecse-2005 digital-logic number-representation floating-point-representation normal

Answer key

6.15.8 Floating Point Representation: GATE CSE 2005 | Question: 85-b

Consider the following floating-point format.



Mantissa is a pure fraction in sign-magnitude form.

The normalized representation for the above format is specified as follows. The mantissa has an implicit 1 preceding the binary (radix) point. Assume that only $0's$ are padded in while shifting a field.

The normalized representation of the above number (0.239×2^{13}) is:

A. $0A\,20$ B. $11\,34$ C. $49\,D0$ D. $4A\,E8$

gatecse-2005 digital-logic number-representation floating-point-representation normal

Answer key

6.15.9 Floating Point Representation: GATE CSE 2008 | Question: 4

In the IEEE floating point representation the hexadecimal value $0x00000000$ corresponds to

A. The normalized value 2^{-127}
B. The normalized value 2^{-126}
C. The normalized value $+0$
D. The special value $+0$

gatecse-2008 digital-logic floating-point-representation ieee-representation easy

Answer key

6.15.10 Floating Point Representation: GATE CSE 2017 Set 2 | Question: 12

Given the following binary number in 32-bit (single precision) IEEE-754 format :

$$00111110011011010000000000000000$$

The decimal value closest to this floating-point number is :

A. $1.45 * 10^1$ B. $1.45 * 10^{-1}$ C. $2.27 * 10^{-1}$ D. $2.27 * 10^1$

gatecse-2017-set2 digital-logic number-representation floating-point-representation ieee-representation

Answer key

6.15.11 Floating Point Representation: GATE CSE 2020 | Question: 29

Consider three registers $R1$, $R2$, and $R3$ that store numbers in IEEE-754 single precision floating point format. Assume that $R1$ and $R2$ contain the values (in hexadecimal notation) 0x42200000 and 0xC1200000, respectively.

If $R3 = \frac{R1}{R2}$, what is the value stored in $R3$?

A. 0x40800000 B. 0xC0800000 C. 0x83400000 D. 0xC8500000

gatecse-2020 floating-point-representation digital-logic two-marks ieee-representation

Answer key

6.15.12 Floating Point Representation: GATE IT 2008 | Question: 7

The following bit pattern represents a floating point number in IEEE 754 single precision format

$1\ 10000011\ 101000000000000000000000$

The value of the number in decimal form is

A. -10 B. -13 C. -26 D. None of the above

gateit-2008 digital-logic number-representation floating-point-representation ieee-representation normal

Answer key

6.16 Functional Completeness (7)

6.16.1 Functional Completeness: GATE CSE 1989 | Question: 4-iii

Show that {NOR} is a functionally complete set of Boolean operations.

gate1989 descriptive digital-logic functional-completeness

Answer key

6.16.2 Functional Completeness: GATE CSE 1992 | Question: 02-ii

All digital circuits can be realized using only

A. Ex-OR gates B. Multiplexers C. Half adders D. OR gates

gate1992 normal digital-logic digital-circuits multiple-selects functional-completeness combinational-circuit

Answer key

6.16.3 Functional Completeness: GATE CSE 1993 | Question: 9

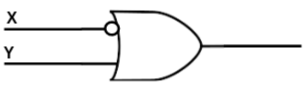
Assume that only half adders are available in your laboratory. Show that any binary function can be implemented using half adders only.

gate1993 digital-logic combinational-circuit adder descriptive functional-completeness

Answer key

6.16.4 Functional Completeness: GATE CSE 1998 | Question: 5

The implication gate, shown below has two inputs ($x \text{ and } y$); the output is 1 except when $x = 1 \text{ and } y = 0$, realize $f = \bar{x}y + x\bar{y}$ using only four implication gates.



Show that the implication gate is functionally complete.

gate1998 digital-logic functional-completeness descriptive

Answer key

6.16.5 Functional Completeness: GATE CSE 1999 | Question: 2.9

Which of the following sets of component(s) is/are sufficient to implement any arbitrary Boolean function?

A. XOR gates, NOT gates
B. 2 to 1 multiplexers
C. AND gates, XOR gates
D. Three-input gates that output $(A.B) + C$ for the inputs A, B and C.

gate1999 digital-logic normal functional-completeness multiple-selects

Answer key

6.16.6 Functional Completeness: GATE CSE 2015 Set 1 | Question: 39

Consider the operations

$f\ (X,\ Y,\ Z) = X'YZ + XY' + Y'Z'$ and $g\ (X,\ Y,\ Z) = X'YZ + X'YZ' + XY$

Which one of the following is correct?

A. Both $\{f\}$ and $\{g\}$ are functionally complete
B. Only $\{f\}$ is functionally complete
C. Only $\{g\}$ is functionally complete
D. Neither $\{f\}$ nor $\{g\}$ is functionally complete

gatecse-2015-set1 boolean-algebra difficult functional-completeness

Answer key

6.16.7 Functional Completeness: GATE IT 2008 | Question: 1

A set of Boolean connectives is functionally complete if all Boolean functions can be synthesized using those. Which of the following sets of connectives is NOT functionally complete?

A. EX-NOR
B. implication, negation
C. OR, negation
D. NAND

gateit-2008 digital-logic easy functional-completeness

Answer key

6.17 IEEE Representation (8)

6.17.1 IEEE Representation: GATE CSE 2012 | Question: 7

The decimal value 0.5 in IEEE single precision floating point representation has

A. fraction bits of $000\dots000$ and exponent value of 0
B. fraction bits of $000\dots000$ and exponent value of -1
C. fraction bits of $100\dots000$ and exponent value of 0
D. no exact representation

gatecse-2012 digital-logic normal number-representation ieee-representation

Answer key

6.17.2 IEEE Representation: GATE CSE 2014 Set 2 | Question: 45

The value of a float type variable is represented using the single-precision 32-bit floating point format of IEEE-754 standard that uses 1 bit for sign, 8 bits for biased exponent and 23 bits for the mantissa. A float type variable X is assigned the decimal value of -14.25. The representation of X in hexadecimal notation is

A. C1640000H
B. 416C0000H
C. 41640000H
D. C16C0000H

gatecse-2014-set2 digital-logic number-representation normal ieee-representation

Answer key

6.17.3 IEEE Representation: GATE CSE 2021 Set 1 | Question: 24

Consider the following representation of a number in IEEE 754 single-precision floating point format with a bias of 127.

$$S:1 \qquad E:\ 10000001 \qquad F:\ 11110000000000000000000$$

Here $S,\ E$ and F denote the sign, exponent, and fraction components of the floating point representation.

The decimal value corresponding to the above representation (rounded to 2 decimal places) is ____________.

gatecse-2021-set1 digital-logic number-representation ieee-representation numerical-answers one-mark floating-point-representation

Answer key

6.17.4 IEEE Representation: GATE CSE 2021 Set 2 | Question: 4

The format of the single-precision floating point representation of a real number as per the IEEE 754

standard is as follows:

sign	exponent	mantissa

Which one of the following choices is correct with respect to the *smallest* normalized positive number represented using the standard?

A. exponent $= 00000000$ and mantissa $= 00000000000000000000000$
B. exponent $= 00000000$ and mantissa $= 00000000000000000000001$
C. exponent $= 00000001$ and mantissa $= 00000000000000000000000$
D. exponent $= 00000001$ and mantissa $= 00000000000000000000001$

gatecse-2021-set2 digital-logic number-representation ieee-representation one-mark floating-point-representation

Answer key☟

6.17.5 IEEE Representation: GATE CSE 2022 | Question: 31

Consider three floating point numbers A, B and C stored in registers $\mathrm{R_A}, \mathrm{R_B}$ and $\mathrm{R_C}$, respectively as per IEEE-754 single precision floating point format. The 32-bit content stored in these registers $(\text{in hexadecimal form})$ are as follows.

$\mathrm{R_A} = \text{0xC1400000}$	$\mathrm{R_B} = \text{0x42100000}$	$\mathrm{R_C} = \text{0x41400000}$

Which one of the following is FALSE?

A. $A + C = 0$
B. $C = A + B$
C. $B = 3C$
D. $(B - C) > 0$

gatecse-2022 digital-logic ieee-representation number-representation two-marks floating-point-representation

Answer key☟

6.17.6 IEEE Representation: GATE CSE 2023 | Question: 35

Consider the IEEE-754 single precision floating point numbers $\mathrm{P} =$ 0xC1800000 and $\mathrm{Q} =$ 0x3F5C2EF4. Which one of the following corresponds to the product of these numbers $(\text{i.e.}, \mathrm{P} \times \mathrm{Q})$, represented in the IEEE-754 single precision format?

A. 0x404C2EF4
B. 0x405C2EF4
C. 0xC15C2EF4
D. 0xC14C2EF4

gatecse-2023 digital-logic number-representation ieee-representation two-marks floating-point-representation

Answer key☟

6.17.7 IEEE Representation: GATE CSE 2024 | Set 2 | Question: 4

The format of a single-precision floating-point number as per the IEEE 754 standard is:

Sign	Exponent	Mantissa
(1 bit)	(8 bits)	(23 bits)

Choose the largest floating-point number among the following options.

A.

Sign	Exponent	Mantissa
0	01111111	11111111111111111111111

B.

Sign	Exponent	Mantissa
0	11111110	11111111111111111111111

C.

Sign	Exponent	Mantissa
0	11111111	11111111111111111111111

D.

Sign	Exponent	Mantissa
0	01111111	00000000000000000000000

gatecse2024-set2 digital-logic number-representation ieee-representation floating-point-representation one-mark

Answer key

6.17.8 IEEE Representation: GATE CSE 2025 | Set 2 | Question: 39

Three floating point numbers $X, Y,$ and Z are stored in three registers $\mathrm{R_X}, \mathrm{R_Y},$ and $\mathrm{R_Z}$, respectively in $IEEE\ 754$ single precision format as given below in hexadecimal:

$$\mathrm{R_X} = 0\mathrm{xC1100000}, \mathrm{R_Y} = 0\mathrm{x40C00000}, \text{ and } \mathrm{R_Z} = 0\mathrm{x41400000}$$

Which of the following option(s) is/are CORRECT?

A. $4(X+Y)+Z=0$ B. $2Y-Z=0$ C. $4X+3Z=0$ D. $X+Y+Z=0$

gatecse2025-set2 digital-logic number-representation ieee-representation multiple-selects two-marks

Answer key

6.18 K Map (20)

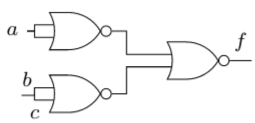
6.18.1 K Map: GATE CSE 1987 | Question: 16-a

A Boolean function f is to be realized only by NOR gates. Its K-map is given below:

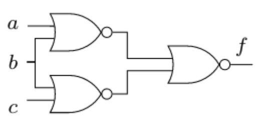
$c \backslash ab$	00	01	11	10
0	0	0	1	1
1	0	1	1	1

The realization is

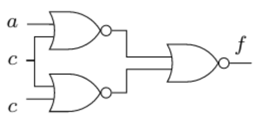
A.



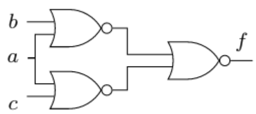
B.



C.



D.



gate1987 digital-logic k-map

Answer key

6.18.2 K Map: GATE CSE 1988 | Question: 3a-b

$A \backslash BC$	00	01	11	10
0	1		1	1
1		1	1	

$A \backslash B$	0	1
0	$\overline{C}$	1
1	C	C

The Karnaugh map of a function of (A, B, C) is shown on the left hand side of the above figure.

The reduced form of the same map is shown on the right hand side, in which the variable C is entered in the map itself. Discuss,

a. The methodology by which the reduced map has been derived and
b. the rules (or steps) by which the boolean function can be derived from the entries in the reduced map.

gate1988 descriptive digital-logic k-map

Answer key

6.18.3 K Map: GATE CSE 1992 | Question: 01-i

The Boolean function in sum of products form where K-map is given below (figure) is _______

$B \backslash C$	0	1
0	1	0
1	$\overline{A}$	A

gate1992 digital-logic k-map normal fill-in-the-blanks

Answer key

6.18.4 K Map: GATE CSE 1995 | Question: 15-a

Implement a circuit having the following output expression using an inverter and a nand gate

$$Z = \overline{A} + \overline{B} + C$$

gate1995 digital-logic k-map normal descriptive

Answer key

6.18.5 K Map: GATE CSE 1995 | Question: 15-b

What is the equivalent minimal Boolean expression (in sum of products form) for the Karnaugh map given below?

$CD \backslash AB$	00	01	11	10
00	1			1
01		1	1	
11		1	1	
10	1			1

gate1995 digital-logic boolean-algebra k-map normal descriptive

Answer key

6.18.6 K Map: GATE CSE 1996 | Question: 2.24

What is the equivalent Boolean expression in product-of-sums form for the Karnaugh map given in Fig

$CD \backslash AB$	00	01	11	10
00		1	1	
01	1			1
11	1			1
10		1	1	

A. $B\overline{D} + \overline{B}D$

B. $(B + \overline{C} + D)(\overline{B} + C + \overline{D})$

C. $(B + D)(\overline{B} + \overline{D})$

D. $(B + \overline{D})(\overline{B} + D)$

gate1996 digital-logic k-map easy

Answer key

6.18.7 K Map: GATE CSE 1998 | Question: 2.7

The function represented by the Karnaugh map given below is

A \ BC	00	01	10	11
0	1	0	0	1
1	1	0	0	1

A. $A.B$ B. $AB+BC+CA$ C. $\overline{B \oplus C}$ D. $A.BC$

gate1998 digital-logic k-map normal

Answer key

6.18.8 K Map: GATE CSE 1999 | Question: 1.8

Which of the following functions implements the Karnaugh map shown below?

AB \ CD	00	01	11	10
00	0	0	1	0
01	X	X	1	X
11	0	1	1	0
10	0	1	1	0

A. $\bar{A}B+CD$
B. $D(C+A)$
C. $AD+\bar{A}B$
D. $(C+D)(\bar{C}+D)+(A+B)$

gate1999 digital-logic k-map easy

Answer key

6.18.9 K Map: GATE CSE 2000 | Question: 2.11

Which functions does NOT implement the Karnaugh map given below?

xy \ wz	00	01	11	10
00	0	X	0	0
01	0	X	1	1
11	1	1	1	1
10	0	X	0	0

A. $(w+x)y$
B. $xy+yw$
C. $(w+x)(\bar{w}+y)(\bar{x}+y)$
D. None of the above

gatecse-2000 digital-logic k-map normal

Answer key

6.18.10 K Map: GATE CSE 2001 | Question: 1.11

Given the following karnaugh map, which one of the following represents the minimal Sum-Of-Products of the map?

yz \ wx	00	01	11	10
00	0	X	0	X
01	X	1	X	1
11	0	X	1	0
10	0	1	X	0

A. $XY+Y'Z$ B. $WX'Y'+XY+XZ$ C. $W'X+Y'Z+XY$ D. $XZ+Y$

gatecse-2001 k-map digital-logic normal

Answer key

6.18.11 K Map: GATE CSE 2002 | Question: 1.12

Minimum sum of product expression for $f(w,x,y,z)$ shown in Karnaugh-map below

yz \ wx	00	01	11	10
00	0	1	1	0
01	X	0	0	1
11	X	0	0	1
10	0	1	1	X

A. $xz + y'z$

B. $xz' + zx'$

C. $x'y + zx'$

D. None of the above

gatecse-2002 digital-logic k-map normal

Answer key

6.18.12 K Map: GATE CSE 2003 | Question: 45

The literal count of a Boolean expression is the sum of the number of times each literal appears in the expression. For example, the literal count of $(xy + xz')$ is 4. What are the minimum possible literal counts of the product-of-sum and sum-of-product representations respectively of the function given by the following Karnaugh map? Here, X denotes "don't care"

xy \ zw	00	01	11	10
00	X	1	0	1
01	0	1	X	0
11	1	X	X	0
10	X	0	0	X

A. $(11,9)$

B. $(9,13)$

C. $(9,10)$

D. $(11,11)$

gatecse-2003 digital-logic k-map normal

Answer key

6.18.13 K Map: GATE CSE 2008 | Question: 5

In the Karnaugh map shown below, X denotes a don’t care term. What is the minimal form of the function represented by the Karnaugh map?

cd \ ab	00	01	11	10
00	1	1		1
01	X			
11	X			
10	1	1		X

A. $\bar{b}.\bar{d} + \bar{a}.\bar{d}$

B. $\bar{a}.\bar{b} + \bar{b}.\bar{d} + \bar{a}.b.\bar{d}$

C. $\bar{b}.\bar{d} + \bar{a}.b.\bar{d}$

D. $\bar{a}.\bar{b} + \bar{b}.\bar{d} + \bar{a}.\bar{d}$

gatecse-2008 digital-logic k-map easy

Answer key

6.18.14 K Map: GATE CSE 2012 | Question: 30

What is the minimal form of the Karnaugh map shown below? Assume that X denotes a don't care term

cd \ ab	00	01	11	10
00	1	X	X	1
01	X			1
11				
10	1			X

A. $\bar{b}\bar{d}$
B. $\bar{b}\bar{d} + \bar{b}\bar{c}$
C. $\bar{b}\bar{d} + a\bar{b}\bar{c}d$
D. $\bar{b}\bar{d} + \bar{b}\bar{c} + \bar{c}\bar{d}$

gatecse-2012 digital-logic k-map easy

Answer key

6.18.15 K Map: GATE CSE 2017 Set 1 | Question: 21

Consider the Karnaugh map given below, where X represents *"don't care"* and blank represents 0.

dc \ ba	00	01	11	10
00		X	X	
01	1			X
11	1			1
10		X	X	

Assume for all inputs (a, b, c, d), the respective complements $\left(\bar{a}, \bar{b}, \bar{c}, \bar{d}\right)$ are also available. The above logic is implemented using 2-input NOR gates only. The minimum number of gates required is ____________ .

gatecse-2017-set1 digital-logic k-map numerical-answers normal

Answer key

6.18.16 K Map: GATE CSE 2019 | Question: 30

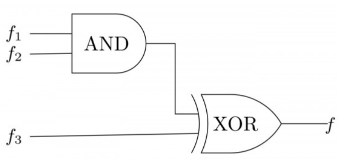
Consider three 4-variable functions f_1, f_2, and f_3, which are expressed in sum-of-minterms as

$f_1 = \Sigma(0, 2, 5, 8, 14)$,

$f_2 = \Sigma(2, 3, 6, 8, 14, 15)$,

$f_3 = \Sigma(2, 7, 11, 14)$

For the following circuit with one AND gate and one XOR gate the output function f can be expressed as:



A. $\Sigma(7, 8, 11)$
B. $\Sigma(2, 7, 8, 11, 14)$
C. $\Sigma(2, 14)$
D. $\Sigma(0, 2, 3, 5, 6, 7, 8, 11, 14, 15)$

gatecse-2019 digital-logic k-map digital-circuits two-marks

Answer key

6.18.17 K Map: GATE CSE 2025 | Set 2 | Question: 33

Given the following Karnaugh Map for a Boolean function $F(w, x, y, z)$:

wx \ yz				
	1	0	0	1
	0	1	1	0
	0	1	1	0
	1	0	0	1

Which one or more of the following Boolean expression(s) represent(s) F ?

A. $\bar{w}\bar{x}\bar{y}\bar{z} + w\bar{x}\bar{y}\bar{z} + \bar{w}\bar{x}y\bar{z} + w\bar{x}y\bar{z} + xz$
B. $\bar{w}\bar{x}\bar{y}\bar{z} + \bar{w}\bar{x}y\bar{z} + w\bar{x}yz + xz$
C. $\bar{w}\bar{x}\bar{y}\bar{z} + w\bar{x}\bar{y}\bar{z} + w\bar{x}\bar{y}z + xz$
D. $\bar{x}\bar{z} + xz$

gatecse2025-set2 digital-logic k-map multiple-selects two-marks

Answer key

6.18.18 K Map: GATE IT 2006 | Question: 35

The boolean function for a combinational circuit with four inputs is represented by the following Karnaugh map.

RS \ PQ	00	01	11	10
00	1	0	0	1
01	0	0	1	1
11	1	1	1	0
10	1	0	0	1

Which of the product terms given below is an essential prime implicant of the function?

A. QRS B. PQS C. PQ'S' D. Q'S'

gateit-2006 digital-logic k-map normal

Answer key

6.18.19 K Map: GATE IT 2007 | Question: 78

Consider the following expression

$a\bar{d} + \bar{a}\bar{c} + b\bar{c}d$

Which of the following Karnaugh Maps correctly represents the expression?

A.

ab \ cd	00	01	11	10
00	X	X		
01	X	X		
11	X	X		X
10	X			X

B.

ab \ cd	00	01	11	10
00	X	X		
01	X			
11	X	X		X
10	X	X		X

C.

ab \ cd	00	01	11	10
00	X	X		
01	X	X		X
11	X	X		X
10	X			X

D.

ab \ cd	00	01	11	10
00	X	X		
01	X	X		X
11	X	X		X
10	X		X	X

gateit-2007 digital-logic k-map normal

Answer key

6.18.20 K Map: GATE IT 2007 | Question: 79

Consider the following expression

$a\bar{d} + \bar{a}\bar{c} + b\bar{c}d$

Which of the following expressions does not correspond to the Karnaugh Map obtained for the given expression?

A. $\bar{c}\bar{d} + a\bar{d} + ab\bar{c} + \bar{a}\bar{c}d$
B. $\bar{a}\bar{c} + \bar{c}\bar{d} + a\bar{d} + ab\bar{c}d$
C. $\bar{a}\bar{c} + a\bar{d} + ab\bar{c} + \bar{c}d$
D. $\bar{b}\bar{c}\bar{d} + ac\bar{d} + \bar{a}\bar{c} + ab\bar{c}$

gateit-2007 digital-logic k-map normal

Answer key

6.19 Memory Interfacing (5)

6.19.1 Memory Interfacing: GATE CSE 1995 | Question: 2.2

The capacity of a memory unit is defined by the number of words multiplied by the number of bits/word. How many separate address and data lines are needed for a memory of $4K \times 16$?

A. 10 address, 16 data lines
B. 11 address, 8 data lines
C. 12 address, 16 data lines
D. 12 address, 12 data lines

gate1995 digital-logic memory-interfacing normal

Answer key

6.19.2 Memory Interfacing: GATE CSE 2009 | Question: 7, ISRO2015-3

How many $32K \times 1$ RAM chips are needed to provide a memory capacity of $256K$ bytes?

A. 8
B. 32
C. 64
D. 128

gatecse-2009 digital-logic memory-interfacing easy isro2015

Answer key

6.19.3 Memory Interfacing: GATE CSE 2010 | Question: 7

The main memory unit with a capacity of 4 megabytes is built using $1\text{M} \times 1\text{-bit}$ DRAM chips. Each DRAM chip has 1K rows of cells with 1K cells in each row. The time taken for a single refresh operation is 100 nanoseconds. The time required to perform one refresh operation on all the cells in the memory unit is

A. 100 nanoseconds
B. 100×2^{10} nanoseconds
C. 100×2^{20} nanoseconds
D. 3200×2^{20} nanoseconds

gatecse-2010 digital-logic memory-interfacing normal

Answer key

6.19.4 Memory Interfacing: GATE CSE 2013 | Question: 46

A RAM chip has a capacity of 1024 words of 8 bits each (1K × 8). The number of 2 × 4 decoders with enable line needed to construct a 16K × 16 RAM from 1K × 8 RAM is

(A) 4 (B) 5 (C) 6 (D) 7

gatecse-2013 digital-logic normal memory-interfacing

Answer key

6.19.5 Memory Interfacing: GATE IT 2005 | Question: 9

A dynamic RAM has a memory cycle time of 64 nsec. It has to be refreshed 100 times per msec and each refresh takes 100 nsec . What percentage of the memory cycle time is used for refreshing?

A. 10
B. 6.4
C. 1
D. 0.64

gateit-2005 digital-logic memory-interfacing normal

Answer key

6.20 Min No Gates (4)

6.20.1 Min No Gates: GATE CSE 2000 | Question: 9

Design a logic circuit to convert a single digit BCD number to the number modulo six as follows (Do not detect illegal input):

A. Write the truth table for all bits. Label the input bits $I_1, I_2, \dots$ with I_1 as the least significant bit. Label the output bits $R_1, R_2 \dots$ with R_1 as the least significant bit. Use 1 to signify truth.
B. Draw one circuit for each output bit using, ***altogether***, two two-input AND gates, one two-input OR gate and two NOT gates.

gatecse-2000 digital-logic min-no-gates descriptive

Answer key

6.20.2 Min No Gates: GATE CSE 2004 | Question: 58

A circuit outputs a digit in the form of 4 bits. 0 is represented by $0000, 1$ by $0001, \dots, 9$ by 1001. A combinational circuit is to be designed which takes these 4 bits as input and outputs 1 if the digit ≥ 5, and 0 otherwise. If only AND, OR and NOT gates may be used, what is the minimum number of gates required?

A. 2
B. 3
C. 4
D. 5

gatecse-2004 digital-logic normal min-no-gates

Answer key

6.20.3 Min No Gates: GATE CSE 2009 | Question: 6

What is the minimum number of gates required to implement the Boolean function (AB+C) if we have to use only 2-input NOR gates?

A. 2
B. 3
C. 4
D. 5

gatecse-2009 digital-logic min-no-gates normal

Answer key

6.20.4 Min No Gates: GATE IT 2004 | Question: 8

What is the minimum number of NAND gates required to implement a $2\text{-input EXCLUSIVE-OR}$ function without using any other logic gate?

A. 2
B. 4
C. 5
D. 6

gateit-2004 digital-logic min-no-gates normal

Answer key

6.21 Min Products of Sum Form (2)

6.21.1 Min Products of Sum Form: GATE CSE 1990 | Question: 5-a

Find the minimum product of sums of the following expression

$$f = ABC + \overline{A}\ \overline{B}\ \overline{C}$$

gate1990 digital-logic boolean-algebra min-products-of-sum-form canonical-normal-form descriptive

Answer key

6.21.2 Min Products of Sum Form: GATE CSE 2017 Set 2 | Question: 28

Given $f(w,x,y,z) = \Sigma_m(0,1,2,3,7,8,10) + \Sigma_d(5,6,11,15)$; where d represents the '*don't-care*' condition in Karnaugh maps. Which of the following is a minimum product-of-sums (POS) form of $f(w,x,y,z)$?

A. $f=(\bar{w}+\bar{z})(\bar{x}+z)$
B. $f=(\bar{w}+z)(x+z)$
C. $f=(w+z)(\bar{x}+z)$
D. $f=(w+\bar{z})(\bar{x}+z)$

gatecse-2017-set2 digital-logic min-products-of-sum-form

Answer key

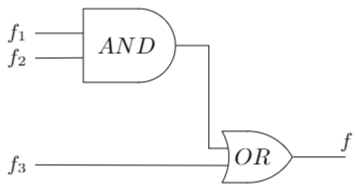
6.22 Min Sum of Products Form (15)

6.22.1 Min Sum of Products Form: GATE CSE 1988 | Question: 2-v

Three switching functions $f_1,\ f_2$ and f_3 are expressed below as sum of minterms.

- $f_1(w,x,y,z)=\sum 0,1,2,3,5,12$
- $f_2(w,x,y,z)=\sum 0,1,2,10,13,14,15$
- $f_3(w,x,y,z)=\sum 2,4,5,8$

Express the function f realised by the circuit shown in the below figure as the sum of minterms (in decimal notation).



gate1988 descriptive digital-logic easy circuit-output min-sum-of-products-form

Answer key

6.22.2 Min Sum of Products Form: GATE CSE 1991 | Question: 5-b

Find the minimum sum of products form of the logic function $f(A,B,C,D)=\Sigma_m(0,2,8,10,15)+\Sigma_d(3,11,12,14)$ where m and d represent minterm and don't care term respectively.

gate1991 digital-logic boolean-algebra min-sum-of-products-form descriptive

Answer key

6.22.3 Min Sum of Products Form: GATE CSE 1997 | Question: 71

Let $f=(\bar{w}+y)(\bar{x}+y)(w+\bar{x}+z)(\bar{w}+z)(\bar{x}+z)$

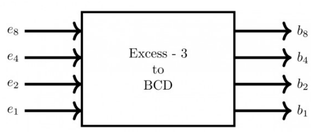
A. Express f as the minimal sum of products. Write only the answer.
B. If the output line is stuck at 0, for how many input combinations will the value of f be correct?

gate1997 digital-logic min-sum-of-products-form numerical-answers

Answer key

6.22.4 Min Sum of Products Form: GATE CSE 2001 | Question: 10

a. Is the 3-variable function $f=\Sigma(0,1,2,4)$ its self-dual? Justify your answer.
b. Give a minimal product-of-sum form of the b output of the following $\text{excess-}3$ to BCD converter.



gatecse-2001 digital-logic normal descriptive min-sum-of-products-form

Answer key

6.22.5 Min Sum of Products Form: GATE CSE 2005 | Question: 18

The switching expression corresponding to $f(A,B,C,D) = \Sigma(1,4,5,9,11,12)$ is:

A. $BC'D' + A'C'D + AB'D$
B. $ABC' + ACD + B'C'D$
C. $ACD' + A'BC' + AC'D'$
D. $A'BD + ACD' + BCD'$

gatecse-2005 digital-logic normal min-sum-of-products-form

Answer key

6.22.6 Min Sum of Products Form: GATE CSE 2007 | Question: 9

Consider the following Boolean function of four variables:

$$f(w,x,y,z) = \Sigma(1,3,4,6,9,11,12,14)$$

The function is

A. independent of one variables.
B. independent of two variables.
C. independent of three variables.
D. dependent on all variables

gatecse-2007 digital-logic normal min-sum-of-products-form k-map

Answer key

6.22.7 Min Sum of Products Form: GATE CSE 2011 | Question: 14

The simplified SOP (Sum of Product) from the Boolean expression

$$(P+\bar{Q}+\bar{R}).(P+\bar{Q}+R).(P+Q+\bar{R})$$

is

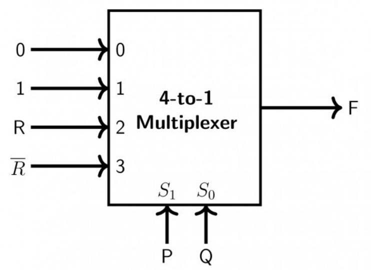
A. $(\bar{P}.Q+\bar{R})$
B. $(P+\bar{Q}.\bar{R})$
C. $(\bar{P}.Q+R)$
D. $(P.Q+R)$

gatecse-2011 digital-logic normal min-sum-of-products-form

Answer key

6.22.8 Min Sum of Products Form: GATE CSE 2014 Set 1 | Question: 45

Consider the 4-to-1 multiplexer with two select lines S_1 and S_0 given below



The minimal sum-of-products form of the Boolean expression for the output F of the multiplexer is

A. $\bar{P}Q+Q\bar{R}+P\bar{Q}R$
B. $\bar{P}Q+\bar{P}Q\bar{R}+PQ\bar{R}+P\bar{Q}R$
C. $\bar{P}QR+\bar{P}Q\bar{R}+Q\bar{R}+P\bar{Q}R$
D. $PQ\bar{R}$

gatecse-2014-set1 digital-logic normal multiplexer min-sum-of-products-form

Answer key

6.22.9 Min Sum of Products Form: GATE CSE 2014 Set 1 | Question: 7

Consider the following Boolean expression for F:

$F(P,Q,R,S) = PQ + \bar{P}QR + \bar{P}Q\bar{R}S$

The minimal sum—of—products form of F is

A. $PQ+QR+QS$
B. $P+Q+R+S$
C. $\bar{P}+\bar{Q}+\bar{R}+\bar{S}$
D. $\bar{P}R+\bar{R}\bar{P}S+P$

gatecse-2014-set1 digital-logic normal min-sum-of-products-form

Answer key

6.22.10 Min Sum of Products Form: GATE CSE 2014 Set 3 | Question: 7

Consider the following minterm expression for F:

$$F(P,Q,R,S)=\sum 0,2,5,7,8,10,13,15$$

The minterms 2, 7, 8 and 13 are 'do not care' terms. The minimal sum-of-products form for F is

A. $Q\bar{S}+\bar{Q}S$
B. $\bar{Q}\bar{S}+QS$
C. $\bar{Q}\bar{R}\bar{S}+\bar{Q}R\bar{S}+Q\bar{R}S+QRS$
D. $\bar{P}\bar{Q}\bar{S}+\bar{P}QS+PQS+P\bar{Q}\bar{S}$

gatecse-2014-set3 digital-logic min-sum-of-products-form normal

Answer key

6.22.11 Min Sum of Products Form: GATE CSE 2018 | Question: 49

Consider the minterm list form of a Boolean function F given below.

$$F(P,Q,R,S)=\Sigma m(0,2,5,7,9,11)+d(3,8,10,12,14)$$

Here, m denotes a minterm and d denotes a don't care term. The number of essential prime implicants of the function F is ___

gatecse-2018 digital-logic min-sum-of-products-form numerical-answers two-marks

Answer key

6.22.12 Min Sum of Products Form: GATE CSE 2021 Set 2 | Question: 52

Consider a Boolean function $f(w,x,y,z)$ such that

$$\begin{aligned} f(w,0,0,z) &= 1 \\ f(1,x,1,z) &= x+z \\ f(w,1,y,z) &= wz+y \end{aligned}$$

The number of literals in the minimal sum-of-products expression of f is _________

gatecse-2021-set2 digital-logic boolean-algebra min-sum-of-products-form numerical-answers two-marks

Answer key

6.22.13 Min Sum of Products Form: GATE CSE 2024 | Set 1 | Question: 37

Consider a Boolean expression given by $\mathrm{F(X,Y,Z)}=\sum(3,5,6,7)$.
Which of the following statements is/are CORRECT?

A. $\mathrm{F(X,Y,Z)}=\Pi(0,1,2,4)$
B. $\mathrm{F(X,Y,Z)}$=$\mathrm{X\,Y+Y\,Z+X\,Z}$
C. $\mathrm{F(X,Y,Z)}$ is independent of input Y
D. $\mathrm{F(X,Y,Z)}$ is independent of input X

gatecse2024-set1 multiple-selects digital-logic min-sum-of-products-form two-marks

Answer key

6.22.14 Min Sum of Products Form: GATE CSE 2025 | Set 1 | Question: 32

Consider the following four variable Boolean function in sum-of-product form

$$F\left(b_3,b_2,b_1,b_0\right)=\sum(0,2,4,8,10,11,12)$$

where the value of the function is computed by considering $b_3b_2b_1b_0$ as a 4-bit binary number, where b_3 denotes the most significant bit and b_0 denotes the least significant bit. Note that there are no don't care terms. Which ONE of the following options is the CORRECT minimized Boolean expression for F ?

A. $\bar{b}_1\bar{b}_0 + \bar{b}_2\bar{b}_0 + b_1\bar{b}_2b_3$
B. $\bar{b}_1\bar{b}_0 + \bar{b}_2\bar{b}_0$
C. $\bar{b}_2\bar{b}_0 + b_1b_2b_3$
D. $\bar{b}_0\bar{b}_2 + \bar{b}_3$

gatecse2025-set1 digital-logic min-sum-of-products-form easy two-marks

Answer key

6.22.15 Min Sum of Products Form: GATE IT 2008 | Question: 8

Consider the following Boolean function of four variables

$f(A, B, C, D) = \Sigma(2, 3, 6, 7, 8, 9, 10, 11, 12, 13)$

The function is

A. independent of one variable
B. independent of two variables
C. independent of three variable
D. dependent on all the variables

gateit-2008 digital-logic normal min-sum-of-products-form

Answer key

6.23 Multiplexer (14)

6.23.1 Multiplexer: GATE CSE 1990 | Question: 5-b

Show with the help of a block diagram how the Boolean function :

$$f = AB + BC + CA$$

can be realised using only a $4:1$ multiplexer.

gate1990 descriptive digital-logic combinational-circuit multiplexer

Answer key

6.23.2 Multiplexer: GATE CSE 1998 | Question: 1.14

A multiplexer with a $4-bit$ data select input is a

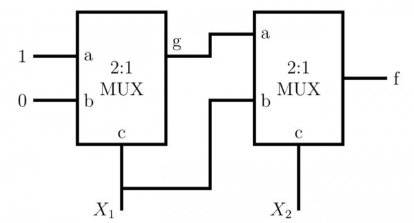
A. $4:1$ multiplexer
B. $2:1$ multiplexer
C. $16:1$ multiplexer
D. $8:1$ multiplexer

gate1998 digital-logic multiplexer easy

Answer key

6.23.3 Multiplexer: GATE CSE 2001 | Question: 2.11

Consider the circuit shown below. The output of a $2:1$ MUX is given by the function $(ac' + bc)$.



Which of the following is true?

A. $f = X_1' + X_2$
B. $f = X_1'X_2 + X_1X_2'$
C. $f = X_1X_2 + X_1'X_2'$
D. $f = X_1 + X_2'$

gatecse-2001 digital-logic normal multiplexer

Answer key

6.23.4 Multiplexer: GATE CSE 2004 | Question: 60

Consider a multiplexer with X and Y as data inputs and Z the as the control input. $Z = 0$ selects input X, and $Z = 1$ selects input Y. What are the connections required to realize the 2-variable Boolean function $f = T + R$, without using any additional hardware?

A. $\text{R to X, 1 to Y, T to Z}$
B. $\text{T to X, R to Y, T to Z}$
C. $\text{T to X, R to Y, 0 to Z}$
D. $\text{R to X, 0 to Y, T to Z}$

gatecse-2004 digital-logic normal multiplexer

Answer key

6.23.5 Multiplexer: GATE CSE 2007 | Question: 34

Suppose only one multiplexer and one inverter are allowed to be used to implement any Boolean function of n variables. What is the minimum size of the multiplexer needed?

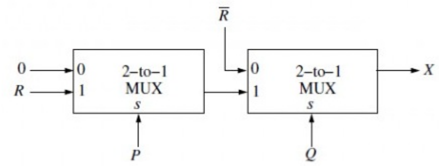
A. 2^n line to 1 line
B. 2^{n+1} line to 1line
C. 2^{n-1} line to 1line
D. 2^{n-2} line to 1line

gatecse-2007 digital-logic normal multiplexer

Answer key

6.23.6 Multiplexer: GATE CSE 2016 Set 1 | Question: 30

Consider the two cascade 2 to 1 multiplexers as shown in the figure .



The minimal sum of products form of the output X is

A. $\overline{P}\,\overline{Q} + PQR$
B. $\overline{P}\,Q + QR$
C. $PQ + \overline{P}\,\overline{Q}R$
D. $\overline{Q}\,\overline{R} + PQR$

gatecse-2016-set1 digital-logic multiplexer normal

Answer key

6.23.7 Multiplexer: GATE CSE 2020 | Question: 19

A multiplexer is placed between a group of 32 registers and an accumulator to regulate data movement such that at any given point in time the content of only one register will move to the accumulator. The number of select lines needed for the multiplexer is ______.

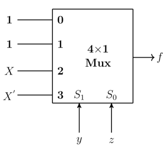
gatecse-2020 numerical-answers digital-logic multiplexer one-mark

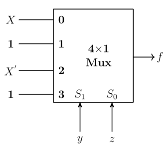
Answer key

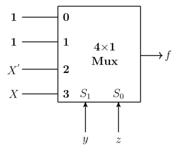
6.23.8 Multiplexer: GATE CSE 2021 Set 2 | Question: 5

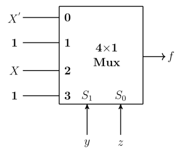
Which one of the following circuits implements the Boolean function given below?

$f(x, y, z) = m_0 + m_1 + m_3 + m_4 + m_5 + m_6$, where m_i is the i^{th} minterm.

A. 

B. 

C. 

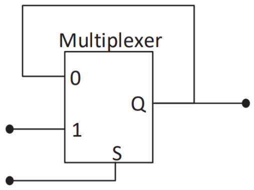
D. 

gatecse-2021-set2 digital-logic combinational-circuit multiplexer one-mark

Answer key

6.23.9 Multiplexer: GATE CSE 2023 | Question: 11

The output of a 2-input multiplexer is connected back to one of its inputs as shown in the figure.



Match the functional equivalence of this circuit to one of the following options.

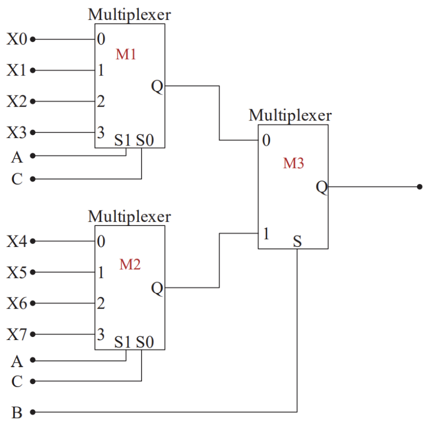
A. D Flip-flop
B. D Latch
C. Half-adder
D. Demultiplexer

gatecse-2023 digital-logic combinational-circuit multiplexer one-mark

Answer key

6.23.10 Multiplexer: GATE CSE 2023 | Question: 34

A Boolean digital circuit is composed using two 4-input multiplexers (M1 and M2) and one 2-input multiplexer (M3) as shown in the figure. X0-X7 are the inputs of the multiplexers M1 and M2 and could be connected to either 0 or 1. The select lines of the multiplexers are connected to Boolean variables A, B and C as shown.



Which one of the following set of values of $(\text{X0, X1, X2, X3, X4, X5, X6, X7})$ will realise the Boolean function $\overline{\text{A}} + \overline{\text{A}} \cdot \overline{\text{C}} + \text{A} \cdot \overline{\text{B}} \cdot \text{C}$?

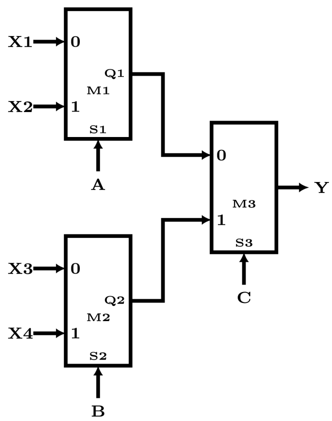
A. $(1,1,0,0,1,1,1,0)$
B. $(1,1,0,0,1,1,0,1)$
C. $(1,1,0,1,1,1,0,0)$
D. $(0,0,1,1,0,1,1,1)$

gatecse-2023 digital-logic combinational-circuit multiplexer two-marks

Answer key

6.23.11 Multiplexer: GATE CSE 2024 | Set 1 | Question: 54

Consider a digital logic circuit consisting of three 2-to-1 multiplexers M1, M2, and M3 as shown below. X1 and X2 are inputs of M1. X3 and X4 are inputs of M2. A, B, and C are select lines of M1, M2, and M3, respectively.



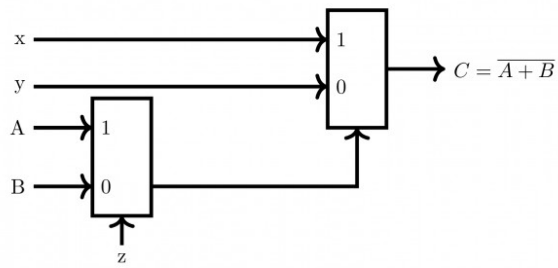
For an instance of inputs $\mathbf{X1 = 1, X2 = 1, X3 = 0}$, and $\mathbf{X4 = 0}$, the number of combinations of $\mathrm{A, B, C}$ that give the output $\mathbf{Y = 1}$ is ________.

gatecse2024-set1 numerical-answers digital-logic multiplexer two-marks

Answer key

6.23.12 Multiplexer: GATE IT 2005 | Question: 48

The circuit shown below implements a 2-input NOR gate using two $2-4$ MUX (control signal 1 selects the upper input). What are the values of signals x, y and z?



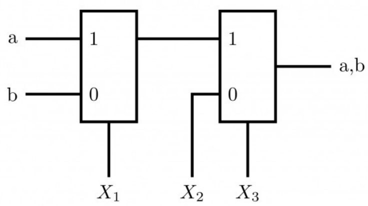
A. $1, 0, B$
B. $1, 0, A$
C. $0, 1, B$
D. $0, 1, A$

gateit-2005 digital-logic normal multiplexer

Answer key

6.23.13 Multiplexer: GATE IT 2007 | Question: 8

The following circuit implements a two-input AND gate using two $2-1$ multiplexers.



What are the values of X_1, X_2, X_3?

A. $X_1 = b, X_2 = 0, X_3 = a$
B. $X_1 = b, X_2 = 1, X_3 = b$
C. $X_1 = a, X_2 = b, X_3 = 1$
D. $X_1 = a, X_2 = 0, X_3 = b$

gateit-2007 digital-logic normal multiplexer

Answer key

6.23.14 Multiplexer: GATE1992-04-b

A priority encoder accepts three input signals $(\mathrm{A, B \text{ and } C})$ and produces a two-bit output (X_1, X_0) corresponding to the highest priority active input signal. Assume A has the highest priority followed by B

and C has the lowest priority. If none of the inputs are active the output should be 00, design the priority encoder using $4:1$ multiplexers as the main components.

gate1992 digital-logic combinational-circuit multiplexer descriptive

Answer key

6.24 Number Representation (58)

6.24.1 Number Representation: GATE CSE 1988 | Question: 2-vi

Define the value of r in the following: $\sqrt{(41)_r} = (7)_{10}$

gate1988 digital-logic normal number-representation descriptive

Answer key

6.24.2 Number Representation: GATE CSE 1990 | Question: 1-viii

The condition for overflow in the addition of two $2's$ complement numbers in terms of the carry generated by the two most significant bits is ___________.

gate1990 digital-logic number-representation fill-in-the-blanks

Answer key

6.24.3 Number Representation: GATE CSE 1991 | Question: 01-iii

Consider the number given by the decimal expression:

$$16^3 * 9 + 16^2 * 7 + 16 * 5 + 3$$

The number of $1's$ in the unsigned binary representation of the number is ______

gate1991 digital-logic number-representation normal numerical-answers

Answer key

6.24.4 Number Representation: GATE CSE 1991 | Question: 01-v

When two 4-bit numbers $A = a_3a_2a_1a_0$ and $B = b_3b_2b_1b_0$ are multiplied, the bit c_1 of the product C is given by ________

gate1991 digital-logic normal number-representation fill-in-the-blanks

Answer key

6.24.5 Number Representation: GATE CSE 1992 | Question: 4-a

Consider addition in two's complement arithmetic. A carry from the most significant bit does not always correspond to an overflow. Explain what is the condition for overflow in two's complement arithmetic.

gate1992 digital-logic normal number-representation descriptive

Answer key

6.24.6 Number Representation: GATE CSE 1993 | Question: 6.5

Convert the following numbers in the given bases into their equivalents in the desired bases:

A. $(110.101)_2 = (x)_{10}$
B. $(1118)_{10} = (y)_H$

gate1993 digital-logic number-representation normal descriptive

Answer key

6.24.7 Number Representation: GATE CSE 1994 | Question: 2.7

Consider n-bit (including sign bit) $2's$ complement representation of integer numbers. The range of integer values, N, that can be represented is _____ $\leq N \leq$_____ .

gatel994 digital-logic number-representation easy fill-in-the-blanks

Answer key

6.24.8 Number Representation: GATE CSE 1995 | Question: 18

The following is an incomplete Pascal function to convert a given decimal integer (in the range -8 to $+7$) into a binary integer in 2's complement representation. Determine the expressions A, B, C that complete program.

```
function TWOSCOMP (N:integer):integer;
  var
  REM, EXPONENT:integer;
  BINARY :integer;
  begin
    if(N>=-8) and (N<=+7) then
    begin
      if N<0 then
        N:=A;
      BINARY:=0;
      EXPONENT:=1;
      while N<>0 do
      begin
        REM:=N mod 2;
        BINARY:=BINARY + B*EXPONENT;
        EXPONENT:=EXPONENT*10;
        N:=C
      end
      TWOSCOMP:=BINARY
    end
  end;
```

gate1995 digital-logic number-representation normal descriptive

Answer key

6.24.9 Number Representation: GATE CSE 1995 | Question: 2.12, ISRO2015-9

The number of 1's in the binary representation of $(3 * 4096 + 15 * 256 + 5 * 16 + 3)$ are:

A. 8 B. 9 C. 10 D. 12

gate1995 digital-logic number-representation normal isro2015

Answer key

6.24.10 Number Representation: GATE CSE 1996 | Question: 1.25

Consider the following floating-point number representation.

31 24	23 0
Exponent	Mantissa

The exponent is in $2's$ complement representation and the mantissa is in the sign-magnitude representation. The range of the magnitude of the normalized numbers in this representation is

A. 0 to 1 B. 0.5 to 1 C. 2^{-23} to 0.5 D. 0.5 to $(1 - 2^{-23})$

gate1996 digital-logic number-representation normal

Answer key

6.24.11 Number Representation: GATE CSE 1997 | Question: 5.4

Given $\sqrt{(224)_r} = (13)_r$.

The value of the radix r is:

A. 10 B. 8 C. 5 D. 6

gate1997 digital-logic number-representation normal

Answer key

6.24.12 Number Representation: GATE CSE 1998 | Question: 1.17

The octal representation of an integer is $(342)_8$. If this were to be treated as an eight-bit integer in an 8085 based computer, its decimal equivalent is

A. 226 B. -98 C. 76 D. -30

gate1998 digital-logic number-representation normal

Answer key

6.24.13 Number Representation: GATE CSE 1998 | Question: 2.20

Suppose the domain set of an attribute consists of signed four digit numbers. What is the percentage of reduction in storage space of this attribute if it is stored as an integer rather than in character form?

A. 80% B. 20% C. 60% D. 40%

gate1998 digital-logic number-representation normal

Answer key

6.24.14 Number Representation: GATE CSE 1999 | Question: 2.17

Zero has two representations in

A. Sign-magnitude
B. $2's$ complement
C. $1's$ complement
D. None of the above

gate1999 digital-logic number-representation easy multiple-selects

Answer key

6.24.15 Number Representation: GATE CSE 2000 | Question: 1.6

The number 43 in $2's$ complement representation is

A. 01010101 B. 11010101 C. 00101011 D. 10101011

gatecse-2000 digital-logic number-representation easy

Answer key

6.24.16 Number Representation: GATE CSE 2000 | Question: 2.14

Consider the values of $A = 2.0 \times 10^{30}, B = -2.0 \times 10^{30}, C = 1.0$, and the sequence

```
X:= A + B       Y:= A + C
X:= X + C       Y:= Y + B
```

executed on a computer where floating point numbers are represented with 32 bits. The values for X and Y will be

A. $X = 1.0, Y = 1.0$
B. $X = 1.0, Y = 0.0$
C. $X = 0.0, Y = 1.0$
D. $X = 0.0, Y = 0.0$

gatecse-2000 digital-logic number-representation normal

Answer key

6.24.17 Number Representation: GATE CSE 2001 | Question: 2.10

The $2's$ complement representation of (-539)$_{10}$ in hexadecimal is

A. ABE B. DBC C. $DE5$ D. $9E7$

gatecse-2001 digital-logic number-representation easy

Answer key

6.24.18 Number Representation: GATE CSE 2002 | Question: 1.14

The decimal value 0.25

A. is equivalent to the binary value 0.1
B. is equivalent to the binary value 0.01
C. is equivalent to the binary value 0.00111
D. cannot be represented precisely in binary

gatecse-2002 digital-logic number-representation easy

Answer key

6.24.19 Number Representation: GATE CSE 2002 | Question: 1.15

The $2's$ complement representation of the decimal value -15 is

A. 1111
B. 11111
C. 111111
D. 10001

gatecse-2002 digital-logic number-representation easy

Answer key

6.24.20 Number Representation: GATE CSE 2002 | Question: 1.16

Sign extension is a step in

A. floating point multiplication
B. signed 16 bit integer addition
C. arithmetic left shift
D. converting a signed integer from one size to another

gatecse-2002 digital-logic easy number-representation

Answer key

6.24.21 Number Representation: GATE CSE 2002 | Question: 1.21

In $2's$ complement addition, overflow

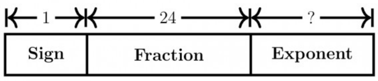
A. is flagged whenever there is carry from sign bit addition
B. cannot occur when a positive value is added to a negative value
C. is flagged when the carries from sign bit and previous bit match
D. None of the above

gatecse-2002 digital-logic number-representation normal

Answer key

6.24.22 Number Representation: GATE CSE 2002 | Question: 9

Consider the following 32-bit floating-point representation scheme as shown in the format below. A value is specified by 3 fields, a one bit sign field (with 0 for positive and 1 for negative values), a 24 bit fraction field (with the binary point is at the left end of the fraction bits), and a 7 bit exponent field (in $\text{excess-}64$ signed integer representation, with 16 is the base of exponentiation). The sign bit is the most significant bit.



A. It is required to represent the decimal value -7.5 as a normalized floating point number in the given format. Derive the values of the various fields. Express your final answer in the hexadecimal.
B. What is the largest value that can be represented using this format? Express your answer as the nearest power of 10.

gatecse-2002 digital-logic number-representation normal descriptive

Answer key

6.24.23 Number Representation: GATE CSE 2003 | Question: 9

Assuming all numbers are in $2's$ complement representation, which of the following numbers is divisible by 11111011?

A. 11100111 B. 11100100 C. 11010111 D. 11011011

gatecse-2003 digital-logic number-representation normal

Answer key

6.24.24 Number Representation: GATE CSE 2004 | Question: 19

If 73_x (in base-x number system) is equal to 54_y (in base y-number system), the possible values of x and y are

A. $8,16$ B. $10,12$ C. $9,13$ D. $8,11$

gatecse-2004 digital-logic number-representation easy

Answer key

6.24.25 Number Representation: GATE CSE 2004 | Question: 28

What is the result of evaluating the following two expressions using three-digit floating point arithmetic with rounding?

$(113. + -111.) + 7.51$

$113. + (-111. + 7.51)$

A. 9.51 and 10.0 respectively
B. 10.0 and 9.51 respectively
C. 9.51 and 9.51 respectively
D. 10.0 and 10.0 respectively

gatecse-2004 digital-logic number-representation normal

Answer key

6.24.26 Number Representation: GATE CSE 2004 | Question: 66

Let $A = 11111010$ and $B = 00001010$ be two $8-bit$ $2's$ complement numbers. Their product in $2's$ complement is

A. 11000100 B. 10011100 C. 10100101 D. 11010101

gatecse-2004 digital-logic number-representation easy

Answer key

6.24.27 Number Representation: GATE CSE 2005 | Question: 16, ISRO2009-18, ISRO2015-2

The range of integers that can be represented by an n bit $2's$ complement number system is:

A. -2^{n-1} to $(2^{n-1}-1)$
B. $-(2^{n-1}-1)$ to $(2^{n-1}-1)$
C. -2^{n-1} to 2^{n-1}
D. $-(2^{n-1}+1)$ to $(2^{n-1}-1)$

gatecse-2005 digital-logic number-representation easy isro2009 isro2015

Answer key

6.24.28 Number Representation: GATE CSE 2005 | Question: 17

The hexadecimal representation of $(657)_8$ is:

A. $1AF$ B. $D78$ C. $D71$ D. $32F$

gatecse-2005 digital-logic number-representation easy

Answer key

6.24.29 Number Representation: GATE CSE 2006 | Question: 39

We consider the addition of two $2's$ complement numbers $b_{n-1}b_{n-2}\dots b_0$ and $a_{n-1}a_{n-2}\dots a_0$. A binary adder for adding unsigned binary numbers is used to add the two numbers. The sum is denoted by $c_{n-1}c_{n-2}\dots c_0$ and the carry-out by c_{out}. Which one of the following options correctly identifies the overflow condition?

A. $c_{out}\left(\overline{a_{n-1}\oplus b_{n-1}}\right)$

B. $a_{n-1}b_{n-1}\overline{c_{n-1}}+\overline{a_{n-1}}\overline{b_{n-1}}c_{n-1}$

C. $c_{out}\oplus c_{n-1}$

D. $a_{n-1}\oplus b_{n-1}\oplus c_{n-1}$

gatecse-2006 digital-logic number-representation normal

Answer key

6.24.30 Number Representation: GATE CSE 2006 | Question: 40

Consider numbers represented in 4-bit Gray code. Let $h_3h_2h_1h_0$ be the Gray code representation of a number n and let $g_3g_2g_1g_0$ be the Gray code of $(n+1)(modulo 16)$ value of the number. Which one of the following functions is correct?

A. $g_0(h_3h_2h_1h_0)=\sum(1,2,3,6,10,13,14,15)$
B. $g_1(h_3h_2h_1h_0)=\sum(4,9,10,11,12,13,14,15)$
C. $g_2(h_3h_2h_1h_0)=\sum(2,4,5,6,7,12,13,15)$
D. $g_3(h_3h_2h_1h_0)=\sum(0,1,6,7,10,11,12,13)$

gatecse-2006 digital-logic number-representation binary-codes normal

Answer key

6.24.31 Number Representation: GATE CSE 2008 | Question: 6

Let r denote number system radix. The only value(s) of r that satisfy the equation $\sqrt{121_r}=11_r$ is/are

A. decimal 10

B. decimal 11

C. decimal 10 and 11

D. any value >2

gatecse-2008 digital-logic number-representation normal

Answer key

6.24.32 Number Representation: GATE CSE 2009 | Question: 5, ISRO2017-57

$(1217)_8$ is equivalent to

A. $(1217)_{16}$

B. $(028F)_{16}$

C. $(2297)_{10}$

D. $(0B17)_{16}$

gatecse-2009 digital-logic number-representation isro2017

Answer key

6.24.33 Number Representation: GATE CSE 2010 | Question: 8

P is a 16-bit signed integer. The 2's complement representation of P is $(F87B)_{16}$. The 2's complement representation of $8\times P$ is

A. $(C3D8)_{16}$

B. $(187B)_{16}$

C. $(F878)_{16}$

D. $(987B)_{16}$

gatecse-2010 digital-logic number-representation normal

Answer key

6.24.34 Number Representation: GATE CSE 2013 | Question: 4

The smallest integer that can be represented by an 8-bit number in $2's$ complement form is

A. -256

B. -128

C. -127

D. 0

gatecse-2013 digital-logic number-representation easy

Answer key

6.24.35 Number Representation: GATE CSE 2014 Set 1 | Question: 8

The base (or radix) of the number system such that the following equation holds is____________.

$\frac{312}{20} = 13.1$

gatecse-2014-set1 digital-logic number-representation numerical-answers normal

Answer key

6.24.36 Number Representation: GATE CSE 2014 Set 2 | Question: 8

Consider the equation $(123)_5 = (x8)_y$ with x and y as unknown. The number of possible solutions is _____ .

gatecse-2014-set2 digital-logic number-representation numerical-answers normal

Answer key

6.24.37 Number Representation: GATE CSE 2015 Set 3 | Question: 35

Consider the equation $(43)_x = (y3)_8$ where x and y are unknown. The number of possible solutions is _____

gatecse-2015-set3 digital-logic number-representation normal numerical-answers

Answer key

6.24.38 Number Representation: GATE CSE 2016 Set 1 | Question: 07

The $16\text{-bit } 2's$ complement representation of an integer is $1111 \quad 1111 \quad 1111 \quad 0101;$ its decimal representation is ____________

gatecse-2016-set1 digital-logic number-representation normal numerical-answers

Answer key

6.24.39 Number Representation: GATE CSE 2016 Set 2 | Question: 09

Let X be the number of distinct 16-bit integers in $2's$ complement representation. Let Y be the number of distinct 16-bit integers in sign magnitude representation Then $X - Y$ is______.

gatecse-2016-set2 digital-logic number-representation normal numerical-answers

Answer key

6.24.40 Number Representation: GATE CSE 2017 Set 1 | Question: 9

When two 8-bit numbers $A_7 \cdots A_0$ and $B_7 \cdots B_0$ in 2's complement representation (with A_0 and B_0 as the least significant bits) are added using a **ripple-carry adder,** the sum bits obtained are $S_7 \cdots S_0$ and the carry bits are $C_7 \cdots C_0$. An overflow is said to have occurred if

A. the carry bit C_7 is 1
B. all the carry bits $(C_7, \cdots, C_0)$ are 1
C. $\left(A_7 \cdot B_7 \cdot \overline{S_7} + \overline{A_7} \cdot \overline{B_7} \cdot S_7\right)$ is 1
D. $\left(A_0 \cdot B_0 \cdot \overline{S_0} + \overline{A_0} \cdot \overline{B_0} \cdot S_0\right)$ is 1

gatecse-2017-set1 digital-logic number-representation

Answer key

6.24.41 Number Representation: GATE CSE 2017 Set 2 | Question: 1

The representation of the value of a 16-bit unsigned integer X in hexadecimal number system is BCA9. The representation of the value of X in octal number system is

A. 571244 B. 736251 C. 571247 D. 136251

gatecse-2017-set2 digital-logic number-representation

Answer key

6.24.42 Number Representation: GATE CSE 2019 | Question: 22

Two numbers are chosen independently and uniformly at random from the set $\{1, 2, \ldots, 13\}$. The probability (rounded off to 3 decimal places) that their 4-bit (unsigned) binary representations have the same most significant bit is ___________.

gatecse-2019 numerical-answers digital-logic number-representation probability one-mark

Answer key

6.24.43 Number Representation: GATE CSE 2019 | Question: 4

In 16-bit 2's complement representation, the decimal number -28 is:

A. $1111\ 1111\ 0001\ 1100$
B. $0000\ 0000\ 1110\ 0100$
C. $1111\ 1111\ 1110\ 0100$
D. $1000\ 0000\ 1110\ 0100$

gatecse-2019 digital-logic number-representation one-mark

Answer key

6.24.44 Number Representation: GATE CSE 2019 | Question: 8

Consider $Z = X - Y$ where X, Y and Z are all in sign-magnitude form. X and Y are each represented in n bits. To avoid overflow, the representation of Z would require a minimum of:

A. n bits
B. $n-1$ bits
C. $n+1$ bits
D. $n+2$ bits

gatecse-2019 digital-logic number-representation one-mark

Answer key

6.24.45 Number Representation: GATE CSE 2021 Set 1 | Question: 6

Let the representation of a number in base 3 be 210. What is the hexadecimal representation of the number?

A. 15
B. 21
C. $D2$
D. 528

gatecse-2021-set1 digital-logic number-representation normal one-mark

Answer key

6.24.46 Number Representation: GATE CSE 2021 Set 2 | Question: 18

If x and y are two decimal digits and $(0.1101)_2 = (0.8xy5)_{10}$, the decimal value of $x+y$ is ___________

gatecse-2021-set2 numerical-answers digital-logic number-representation one-mark

Answer key

6.24.47 Number Representation: GATE CSE 2021 Set 2 | Question: 44

If the numerical value of a 2-byte unsigned integer on a little endian computer is 255 more than that on a big endian computer, which of the following choices represent(s) the unsigned integer on a little endian computer?

A. $0x6665$
B. $0x0001$
C. $0x4243$
D. $0x0100$

gatecse-2021-set2 multiple-selects digital-logic number-representation little-endian-big-endian two-marks

Answer key

6.24.48 Number Representation: GATE CSE 2022 | Question: 8

Let $\mathrm{R1}$ and $\mathrm{R2}$ be two $4-\mathrm{bit}$ registers that store numbers in 2's complement form. For the operation $\mathrm{R1} + \mathrm{R2}$, which one of the following values of $\mathrm{R1}$ and $\mathrm{R2}$ gives an arithmetic overflow?

A. $\mathrm{R1} = 1011$ and $\mathrm{R2} = 1110$
B. $\mathrm{R1} = 1100$ and $\mathrm{R2} = 1010$

C. $\mathrm{R1}=0011$ and $\mathrm{R2}=0100$

D. $\mathrm{R1}=1001$ and $\mathrm{R2}=1111$

gatecse-2022 digital-logic number-representation one-mark

Answer key

6.24.49 Number Representation: GATE CSE 2023 | Question: 22

A particular number is written as 132 in radix-4 representation. The same number in radix-5 representation is ____________.

gatecse-2023 digital-logic number-representation numerical-answers one-mark

Answer key

6.24.50 Number Representation: GATE CSE 2024 | Set 1 | Question: 3

Consider a system that uses 5 bits for representing signed integers in 2 's complement format. In this system, two integers A and B are represented as A=01010 and B=11010. Which one of the following operations will result in either an arithmetic overflow or an arithmetic underflow?

A. $A+B$

B. $A-B$

C. $B-A$

D. $2*B$

gatecse2024-set1 digital-logic number-representation one-mark

Answer key

6.24.51 Number Representation: GATE CSE 2024 | Set 2 | Question: 39

Which of the following is/are EQUAL to 224 in radix - 5 (*i.e.*, base - 5) notation?

A. 64 in radix -10

B. 100 in radix -8

C. 50 in radix -16

D. 121 in radix -7

gatecse2024-set2 digital-logic number-representation multiple-selects two-marks

Answer key

6.24.52 Number Representation: GATE CSE 2025 | Set 1 | Question: 15

The number -6 can be represented as 1010 in 4-bit 2's complement representation. Which of the following is/are CORRECT 2 's complement representation(s) of -6?

A. $1000\,1010$ in 8 -bits

B. $1111\,1010$ in 8-bits

C. $1000\,0000\,0000\,1010$ in 16-bits

D. $1111\,1111\,1111\,1010$ in 16-bits

gatecse2025-set1 digital-logic number-representation multiple-selects easy one-mark

Answer key

6.24.53 Number Representation: GATE IT 2004 | Question: 42

Using a $4-bit\ 2's$ complement arithmetic, which of the following additions will result in an overflow?

i. $1100+1100$
ii. $0011+0111$
iii. $1111+0111$

A. i only

B. ii only

C. iii only

D. i and iii only

gateit-2004 digital-logic number-representation normal

Answer key

6.24.54 Number Representation: GATE IT 2004 | Question: 43

The number $(123456)_8$ is equivalent to

A. $(\mathrm{A72E})_{16}$ and $(22130232)_4$

B. $(\mathrm{A72E})_{16}$ and $(22131122)_4$

C. $(\mathrm{A73E})_{16}$ and $(22130232)_4$

D. $(\mathrm{A62E})_{16}$ and $(22120232)_4$

gateit-2004 digital-logic number-representation normal

Answer key

6.24.55 Number Representation: GATE IT 2005 | Question: 47

$(34.4)_8 \times (23.4)_8$ evaluates to

A. $(1053.6)_8$ B. $(1053.2)_8$ C. $(1024.2)_8$ D. None of these

gateit-2005 digital-logic number-representation normal

Answer key☟

6.24.56 Number Representation: GATE IT 2006 | Question: 7, ISRO2009-41

The addition of $4-bit$, two's complement, binary numbers 1101 and 0100 results in

A. 0001 and an overflow
B. 1001 and no overflow
C. 0001 and no overflow
D. 1001 and an overflow

gateit-2006 digital-logic number-representation normal isro2009

Answer key☟

6.24.57 Number Representation: GATE IT 2007 | Question: 42

$(C012.25)_H - (10111001110.101)_B =$

A. $(135103.412)_o$
B. $(564411.412)_o$
C. $(564411.205)_o$
D. $(135103.205)_o$

gateit-2007 digital-logic number-representation normal

Answer key☟

6.24.58 Number Representation: GATE IT 2008 | Question: 15

A processor that has the carry, overflow and sign flag bits as part of its program status word (PSW) performs addition of the following two $2's$ complement numbers 01001101 and 11101001. After the execution of this addition operation, the status of the carry, overflow and sign flags, respectively will be:

A. $1,1,0$ B. $1,0,0$ C. $0,1,0$ D. $1,0,1$

gateit-2008 digital-logic number-representation normal

Answer key☟

6.25 Prime Implicants (2)

6.25.1 Prime Implicants: GATE CSE 1997 | Question: 5.1

Let $f(x,y,z) = \bar{x} + \bar{y}x + xz$ be a switching function. Which one of the following is valid?

A. $\bar{y}x$ is a prime implicant of f
B. xz is a minterm of f
C. xz is an implicant of f
D. y is a prime implicant of f

gate1997 digital-logic normal prime-implicants

Answer key☟

6.25.2 Prime Implicants: GATE CSE 2004 | Question: 59

Which are the essential prime implicants of the following Boolean function?

$f(a,b,c) = a'c + ac' + b'c$

A. $a'c$ and ac' B. $a'c$ and $b'c$ C. $a'c$ only. D. ac' and bc'

gatecse-2004 digital-logic normal prime-implicants

Answer key☟

6.26 ROM (4)

6.26.1 ROM: GATE CSE 1993 | Question: 6.6

A ROM is used to store the Truth table for binary multiple units that will multiply two 4-bit numbers. The size of the ROM (number of words $\times$ number of bits) that is required to accommodate the Truth table is $\text{M words} \times \text{ N bits}$. Write the values of M and N.

gate1993 digital-logic normal rom descriptive

Answer key☟

6.26.2 ROM: GATE CSE 1996 | Question: 1.21

A ROM is used to store the table for multiplication of two 8-bit unsigned integers. The size of ROM required is

A. 256×16
B. $64K \times 8$
C. $4K \times 16$
D. $64K \times 16$

gate1996 digital-logic normal rom

Answer key☟

6.26.3 ROM: GATE CSE 2012 | Question: 19

The amount of ROM needed to implement a 4-bit multiplier is

A. 64 bits
B. 128 bits
C. 1 Kbits
D. 2 Kbits

gatecse-2012 digital-logic normal rom

Answer key☟

6.26.4 ROM: GATE IT 2004 | Question: 10

What is the minimum size of ROM required to store the complete truth table of an $8-bit \times 8-bit$ multiplier?

A. $32K \times 16$ bits
B. $64K \times 16$ bits
C. $16K \times 32$ bits
D. $64K \times 32$ bits

gateit-2004 digital-logic normal rom

Answer key☟

6.27 Ripple Counter Operation (1)

6.27.1 Ripple Counter Operation: GATE CSE 2025 | Set 2 | Question: 24

In a 4-bit ripple counter, if the period of the waveform at the last flip-flop is 64 microseconds, then the frequency of the ripple counter in kHz is __________. (Answer in integer)

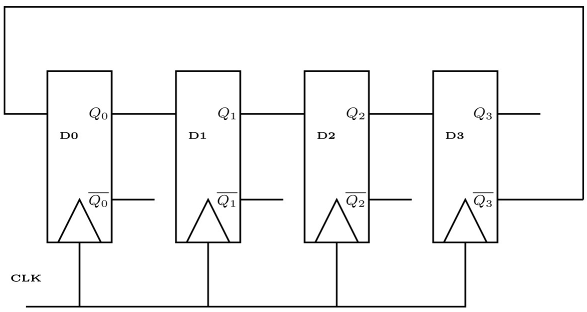
gatecse2025-set2 digital-logic ripple-counter-operation numerical-answers one-mark

Answer key☟

6.28 Sequential Circuit (1)

6.28.1 Sequential Circuit: GATE CSE 2025 | Set 1 | Question: 50

Consider the given sequential circuit designed using D-Flip-flops. The circuit is initialized with some value (initial state). The number of distinct states the circuit will go through before returning back to the initial state is ____________. (Answer in integer)



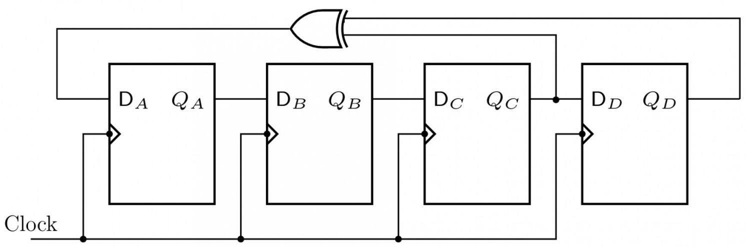
gatecse2025-set1 digital-logic sequential-circuit numerical-answers two-marks

Answer key

6.29 Shift Registers (2)

6.29.1 Shift Registers: GATE CSE 1987 | Question: 13-a

The below figure shows four D-type flip-flops connected as a shift register using a XOR gate. The initial state and three subsequent states for three clock pulses are also given.



State	Q_A	Q_B	Q_C	Q_D
Initial	1	1	1	1
After the first clock	0	1	1	1
After the second clock	0	0	1	1
After the third clock	0	0	0	1

The state $Q_A Q_B Q_C Q_D$ after the fourth clock pulse is

A. 0000 B. 1111 C. 1001 D. 1000

gate1987 digital-logic circuit-output sequential-circuit digital-counter shift-registers

Answer key

6.29.2 Shift Registers: GATE CSE 1991 | Question: 06,a

Using D flip-flop gates, design a parallel-in/serial-out shift register that shifts data from left to right with the following input lines:

i. Clock CLK
ii. Three parallel data inputs A, B, C
iii. Serial input S
iv. Control input $\mathrm{LOAD}/\overline{\mathrm{SHIFT}}$.

gate1991 digital-logic difficult sequential-circuit flip-flop shift-registers descriptive

Answer key

6.30 Static Hazard (1)

6.30.1 Static Hazard: GATE CSE 2006 | Question: 38

Consider a Boolean function $f(w,x,y,z)$. Suppose that exactly one of its inputs is allowed to change at a time. If the function happens to be true for two input vectors $i_1 = \langle w_1, x_1, y_1, z_1 \rangle$ and $i_2 = \langle w_2, x_2, y_2, z_2 \rangle$, we would like the function to remain true as the input changes from i_1 to i_2 (i_1 and i_2 differ in exactly one bit position) without becoming false momentarily. Let $f(w,x,y,z) = \sum(5,7,11,12,13,15)$. Which of the following cube covers of f will ensure that the required property is satisfied?

A. $\overline{w}xz, wx\overline{y}, x\overline{y}z, xyz, wyz$
B. $wxy, \overline{w}xz, wyz$
C. $wx\overline{yz}, xz, w\overline{x}yz$
D. $wx\overline{y}, wyz, wxz, \overline{w}xz, x\overline{y}z, xyz$

gatecse-2006 digital-logic min-sum-of-products-form difficult static-hazard

Answer key

6.31 Synchronous Asynchronous Circuits (4)

6.31.1 Synchronous Asynchronous Circuits: GATE CSE 1991 | Question: 03-ii

Advantage of synchronous sequential circuits over asynchronous ones is:

A. faster operation
B. ease of avoiding problems due to hazards
C. lower hardware requirement
D. better noise immunity
E. none of the above

gate1991 digital-logic normal sequential-circuit synchronous-asynchronous-circuits multiple-selects

Answer key

6.31.2 Synchronous Asynchronous Circuits: GATE CSE 1998 | Question: 16

Design a synchronous counter to go through the following states:

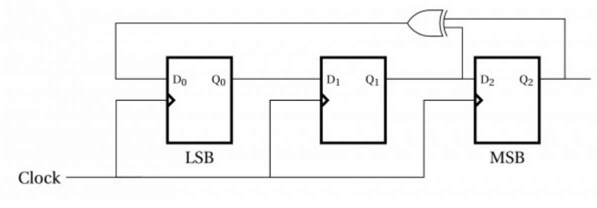
$$1,4,2,3,1,4,2,3,1,4\dots$$

gate1998 digital-logic normal descriptive synchronous-asynchronous-circuits

Answer key

6.31.3 Synchronous Asynchronous Circuits: GATE CSE 2001 | Question: 2.12

Consider the circuit given below with initial state $Q_0 = 1, Q_1 = Q_2 = 0$. The state of the circuit is given by the value $4Q_2 + 2Q_1 + Q_0$



Which one of the following is correct state sequence of the circuit?

A. $1,3,4,6,7,5,2$
B. $1,2,5,3,7,6,4$
C. $1,2,7,3,5,6,4$
D. $1,6,5,7,2,3,4$

gatecse-2001 digital-logic normal synchronous-asynchronous-circuits

Answer key

6.31.4 Synchronous Asynchronous Circuits: GATE CSE 2003 | Question: 44

A 1-input, 2-output synchronous sequential circuit behaves as follows:

Let z_k, n_k denote the number of $0's$ and $1's$ respectively in initial k bits of the input

$(z_k + n_k = k)$. The circuit outputs 00 until one of the following conditions holds.

- $z_k - n_k = 2$. In this case, the output at the k-th and all subsequent clock ticks is 10.
- $n_k - z_k = 2$. In this case, the output at the k-th and all subsequent clock ticks is 01.

What is the minimum number of states required in the state transition graph of the above circuit?

A. 5 B. 6 C. 7 D. 8

gatecse-2003 digital-logic synchronous-asynchronous-circuits normal

Answer key☟

Answer Keys

6.1.1	N/A	6.1.2	N/A	6.1.3	B	6.1.4	B	6.1.5	A
6.1.6	B	6.1.7	19.2	6.1.8	B	6.1.9	-1	6.2.1	B
6.2.2	C	6.3.1	D	6.3.2	C	6.3.3	N/A	6.3.4	N/A
6.3.5	N/A	6.3.6	D	6.3.7	N/A	6.3.8	A	6.3.9	B
6.3.10	D	6.3.11	C	6.3.12	D	6.3.13	C	6.3.14	C
6.3.15	D	6.3.16	D	6.3.17	D	6.3.18	A	6.3.19	A
6.3.20	D	6.3.21	D	6.3.22	D	6.3.23	1	6.3.24	A
6.3.25	C	6.3.26	C	6.3.27	D	6.3.28	B	6.3.29	B;C;D
6.3.30	B;C	6.3.31	B;D	6.3.32	B;C;D	6.3.33	B	6.3.34	C
6.4.1	N/A	6.4.2	A	6.4.3	B	6.4.4	13:13	6.4.5	A
6.4.6	C	6.4.7	B	6.5.1	A	6.5.2	A	6.5.3	C
6.5.4	A	6.5.5	3	6.5.6	A	6.5.7	3	6.5.8	B
6.5.9	C;D	6.6.1	A	6.6.2	B	6.7.1	B	6.7.2	N/A
6.7.3	C	6.7.4	N/A	6.7.5	N/A	6.7.6	A;C	6.7.7	B
6.7.8	B	6.7.9	B	6.7.10	011	6.7.11	D	6.7.12	C
6.7.13	N/A	6.7.14	N/A	6.7.15	B	6.7.16	B	6.7.17	A
6.7.18	A	6.7.19	A	6.7.20	D	6.7.21	A	6.7.22	A
6.7.23	D	6.7.24	A	6.7.25	C	6.7.26	C	6.7.27	C
6.7.28	A	6.7.29	A	6.7.30	B	6.7.31	D	6.7.32	B
6.7.33	C	6.7.34	A;B;C	6.7.35	C	6.7.36	X	6.7.37	D
6.7.38	C	6.7.39	A	6.7.40	D	6.8.1	C	6.8.2	A;C
6.9.1	C	6.9.2	1034	6.9.3	B	6.10.1	N/A	6.10.2	N/A
6.10.3	D	6.10.4	D	6.10.5	A	6.10.6	C	6.11.1	C
6.11.2	N/A	6.11.3	N/A	6.11.4	33.33	6.11.5	N/A	6.11.6	N/A
6.11.7	A	6.11.8	C	6.11.9	D	6.11.10	3	6.11.11	3:4
6.11.12	B	6.11.13	A	6.11.14	A	6.11.15	D	6.11.16	D
6.11.17	N/A	6.12.1	True	6.12.2	B	6.12.3	B	6.12.4	A
6.13.1	D	6.13.2	C	6.14.1	N/A	6.14.2	C	6.14.3	A
6.14.4	B	6.14.5	2	6.14.6	D	6.15.1	C	6.15.2	N/A
6.15.3	N/A	6.15.4	N/A	6.15.5	N/A	6.15.6	C	6.15.7	D
6.15.8	D	6.15.9	D	6.15.10	C	6.15.11	B	6.15.12	C

6.16.1	N/A	6.16.2	B;C	6.16.3	N/A	6.16.4	N/A	6.16.5	B;C
6.16.6	B	6.16.7	A	6.17.1	B	6.17.2	A	6.17.3	-7.75 : -7.75
6.17.4	C	6.17.5	B	6.17.6	C	6.17.7	B	6.17.8	A;B;C
6.18.1	D	6.18.2	N/A	6.18.3	N/A	6.18.4	N/A	6.18.5	N/A
6.18.6	C	6.18.7	C	6.18.8	B	6.18.9	D	6.18.10	A
6.18.11	B	6.18.12	C	6.18.13	A	6.18.14	B	6.18.15	1
6.18.16	A	6.18.17	A;D	6.18.18	D	6.18.19	A	6.18.20	C
6.19.1	C	6.19.2	C	6.19.3	B	6.19.4	B	6.19.5	C
6.20.1	N/A	6.20.2	B	6.20.3	B	6.20.4	B	6.21.1	N/A
6.21.2	A	6.22.1	N/A	6.22.2	N/A	6.22.3	9	6.22.4	N/A
6.22.5	A	6.22.6	B	6.22.7	B	6.22.8	A	6.22.9	A
6.22.10	B	6.22.11	3	6.22.12	6 : 6	6.22.13	A;B	6.22.14	A
6.22.15	A	6.23.1	N/A	6.23.2	C	6.23.3	C	6.23.4	A
6.23.5	C	6.23.6	D	6.23.7	5	6.23.8	A	6.23.9	B
6.23.10	C	6.23.11	4	6.23.12	D	6.23.13	A	6.23.14	N/A
6.24.1	12	6.24.2	N/A	6.24.3	9	6.24.4	N/A	6.24.5	N/A
6.24.6	N/A	6.24.7	N/A	6.24.8	N/A	6.24.9	C	6.24.10	D
6.24.11	C	6.24.12	D	6.24.13	C	6.24.14	A;C	6.24.15	C
6.24.16	B	6.24.17	C	6.24.18	B	6.24.19	D	6.24.20	D
6.24.21	B	6.24.22	N/A	6.24.23	A	6.24.24	D	6.24.25	A
6.24.26	A	6.24.27	A	6.24.28	A	6.24.29	B	6.24.30	C
6.24.31	D	6.24.32	B	6.24.33	A	6.24.34	B	6.24.35	5
6.24.36	3	6.24.37	5	6.24.38	-11	6.24.39	1	6.24.40	C
6.24.41	D	6.24.42	0.502 : 0.504	6.24.43	C	6.24.44	C	6.24.45	A
6.24.46	3 : 3	6.24.47	A;D	6.24.48	B	6.24.49	110	6.24.50	B
6.24.51	A;B;D	6.24.52	B;D	6.24.53	B	6.24.54	A	6.24.55	A
6.24.56	C	6.24.57	A	6.24.58	B	6.25.1	C	6.25.2	A
6.26.1	N/A	6.26.2	D	6.26.3	D	6.26.4	B	6.27.1	250:250
6.28.1	7:8	6.29.1	D	6.29.2	N/A	6.30.1	D	6.31.1	B
6.31.2	N/A	6.31.3	B	6.31.4	A				

7 Operating System (335)

System calls, Processes, Threads, Inter-process communication, Concurrency and synchronization. Deadlock. CPU scheduling. Memory management and Virtual memory. File systems. Disks is also under this

Mark Distribution in Previous GATE

Year	2025 - 1	2025 - 2	2024 - 1	2024 - 2	2023	2022	2021 - 1	2021 - 2	Minimum	Average	Maximu
1 Mark Count	2	1	2	2	3	2	4	2	1	2.25	4
2 Marks Count	3	3	4	4	3	4	1	3	1	3.13	4
Total Marks	8	7	10	10	9	10	6	8	**6**	**8.5**	**10**

7.0.1 GATE CSE 2025 | Set 1 | Question: 4

Consider a demand paging memory management system with 32-bit logical address, 20-bit physical address, and page size of 2048 bytes. Assuming that the memory is byte addressable, what is the maximum number of entries in the page table?

A. 2^{21} B. 2^{20} C. 2^{22} D. 2^{24}

gatecse2025-set1 operating-system demand-paging paging easy one-mark

Answer key

7.1 Context Switch (4)

7.1.1 Context Switch: GATE CSE 1999 | Question: 2.12

Which of the following actions is/are typically not performed by the operating system when switching context from process A to process B?

A. Saving current register values and restoring saved register values for process B.
B. Changing address translation tables.
C. Swapping out the memory image of process A to the disk.
D. Invalidating the translation look-aside buffer.

gate1999 operating-system context-switch normal

Answer key

7.1.2 Context Switch: GATE CSE 2000 | Question: 1.20, ISRO2008-47

Which of the following need not necessarily be saved on a context switch between processes?

A. General purpose registers
B. Translation look-aside buffer
C. Program counter
D. All of the above

gatecse-2000 operating-system easy isro2008 context-switch

Answer key

7.1.3 Context Switch: GATE CSE 2011 | Question: 6, UGCNET-June2013-III: 62

Let the time taken to switch from user mode to kernel mode of execution be $T1$ while time taken to switch between two user processes be $T2$. Which of the following is correct?

A. $T1 > T2$
B. $T1 = T2$
C. $T1 < T2$
D. Nothing can be said about the relation between $T1$ and $T2$

gatecse-2011 operating-system context-switch easy ugcnetcse-june2013-paper3

Answer key

7.1.4 Context Switch: GATE CSE 2024 | Set 2 | Question: 15

Consider a process P running on a CPU. Which one or more of the following events will *always* trigger a context switch by the OS that results in process P moving to a non-running state (e.g., ready, blocked)?

A. P makes a blocking system call to read a block of data from the disk
B. P tries to access a page that is in the swap space, triggering a page fault
C. An interrupt is raised by the disk to deliver data requested by some other process
D. A timer interrupt is raised by the hardware

gatecse2024-set2 operating-system multiple-selects context-switch one-mark

Answer key☟

7.2 Deadlock Prevention Avoidance Detection (4)

7.2.1 Deadlock Prevention Avoidance Detection: GATE CSE 2018 | Question: 24

Consider a system with 3 processes that share 4 instances of the same resource type. Each process can request a maximum of K instances. Resources can be requested and releases only one at a time. The largest value of K that will always avoid deadlock is ___

gatecse-2018 operating-system deadlock-prevention-avoidance-detection easy numerical-answers one-mark

Answer key☟

7.2.2 Deadlock Prevention Avoidance Detection: GATE CSE 2018 | Question: 39

In a system, there are three types of resources: E, F and G. Four processes P_0, P_1, P_2 and P_3 execute concurrently. At the outset, the processes have declared their maximum resource requirements using a matrix named Max as given below. For example, Max[P_2, F] is the maximum number of instances of F that P_2 would require. The number of instances of the resources allocated to the various processes at any given state is given by a matrix named Allocation.

Consider a state of the system with the Allocation matrix as shown below, and in which 3 instances of E and 3 instances of F are only resources available.

Allocation	E	F	G
P_0	1	0	1
P_1	1	1	2
P_2	1	0	3
P_3	2	0	0

Max	E	F	G
P_0	4	3	1
P_1	2	1	4
P_2	1	3	3
P_3	5	4	1

From the perspective of deadlock avoidance, which one of the following is true?

A. The system is in $safe$ state
B. The system is not in $safe$ state, but would be $safe$ if one more instance of E were available
C. The system is not in $safe$ state, but would be $safe$ if one more instance of F were available
D. The system is not in $safe$ state, but would be $safe$ if one more instance of G were available

gatecse-2018 operating-system deadlock-prevention-avoidance-detection normal two-marks

Answer key☟

7.2.3 Deadlock Prevention Avoidance Detection: GATE CSE 2021 Set 2 | Question: 43

Consider a computer system with multiple shared resource types, with one instance per resource type. Each instance can be owned by only one process at a time. Owning and freeing of resources are done by holding a global lock (L). The following scheme is used to own a resource instance:

```
function OWNRESOURCE(Resource R)
    Acquire lock L // a global lock
    if R is available then
        Acquire R
        Release lock L
    else
        if R is owned by another process P then
        Terminate P, after releasing all resources owned by P
        Acquire R
```

```
        Restart P
        Release lock L
        end if
    end if
end function
```

Which of the following choice(s) about the above scheme is/are correct?

A. The scheme ensures that deadlocks will not occur
B. The scheme may lead to live-lock
C. The scheme may lead to starvation
D. The scheme violates the mutual exclusion property

gatecse-2021-set2 multiple-selects operating-system deadlock-prevention-avoidance-detection two-marks

Answer key

7.2.4 Deadlock Prevention Avoidance Detection: GATE IT 2004 | Question: 63

In a certain operating system, deadlock prevention is attempted using the following scheme. Each process is assigned a unique timestamp, and is restarted with the same timestamp if killed. Let P_h be the process holding a resource R, P_r be a process requesting for the same resource R, and $T(P_h)$ and $T(P_r)$ be their timestamps respectively. The decision to wait or preempt one of the processes is based on the following algorithm.

```
if T(Pr) < T(Ph) then
   kill Pr
else wait
```

Which one of the following is TRUE?

A. The scheme is deadlock-free, but not starvation-free
B. The scheme is not deadlock-free, but starvation-free
C. The scheme is neither deadlock-free nor starvation-free
D. The scheme is both deadlock-free and starvation-free

gateit-2004 operating-system normal deadlock-prevention-avoidance-detection

Answer key

7.3 Disk (31)

7.3.1 Disk: GATE CSE 1990 | Question: 7-c

A certain moving arm disk-storage device has the following specifications:

- Number of tracks per surface $= 404$
- Track storage capacity $= 130030$ bytes.
- Disk speed $= 3600$ rpm
- Average seek time $= 30$ m secs.

Estimate the average latency, the disk storage capacity, and the data transfer rate.

gate1990 operating-system disk descriptive

Answer key

7.3.2 Disk: GATE CSE 1993 | Question: 6.7

A certain moving arm disk storage, with one head, has the following specifications:

- Number of tracks/recording surface $= 200$
- Disk rotation speed $= 2400$ rpm
- Track storage capacity $= 62,500$ bits

The average latency of this device is P ms and the data transfer rate is Q bits/sec. Write the values of P and Q.

gate1993 operating-system disk normal descriptive

Answer key

7.3.3 Disk: GATE CSE 1993 | Question: 7.8

The root directory of a disk should be placed

A. at a fixed address in main memory
B. at a fixed location on the disk
C. anywhere on the disk
D. at a fixed location on the system disk
E. anywhere on the system disk

gate1993 operating-system disk normal

Answer key

7.3.4 Disk: GATE CSE 1995 | Question: 14

If the overhead for formatting a disk is 96 bytes for a 4000 byte sector,

A. Compute the unformatted capacity of the disk for the following parameters:
   - Number of surfaces: 8
   - Outer diameter of the disk: 12 cm
   - Inner diameter of the disk: 4 cm
   - Inner track space: 0.1 mm
   - Number of sectors per track: 20
B. If the disk in (A) is rotating at 360 rpm, determine the effective data transfer rate which is defined as the number of bytes transferred per second between disk and memory.

gate1995 operating-system disk normal descriptive

Answer key

7.3.5 Disk: GATE CSE 1997 | Question: 74

A program P reads and processes 1000 consecutive records from a sequential file F stored on device D without using any file system facilities. Given the following

- Size of each record $= 3200$ bytes
- Access time of $D = 10$ msecs
- Data transfer rate of $D = 800 \times 10^3$ bytes/second
- CPU time to process each record $= 3$ msecs

What is the elapsed time of P if

A. F contains unblocked records and P does not use buffering?

B. F contains unblocked records and P uses one buffer (i.e., it always reads ahead into the buffer)?

C. records of F are organized using a blocking factor of 2 (i.e., each block on D contains two records of F) and P uses one buffer?

gate1997 operating-system disk

Answer key

7.3.6 Disk: GATE CSE 1998 | Question: 2-9

Formatting for a floppy disk refers to

A. arranging the data on the disk in contiguous fashion

B. writing the directory

C. erasing the system data

D. writing identification information on all tracks and sectors gate1998 operating-system disk normal

Answer key

7.3.7 Disk: GATE CSE 1998 | Question: 25-a

Free disk space can be used to keep track of using a free list or a bit map. Disk addresses require d bits. For a disk with B blocks, F of which are free, state the condition under which the free list uses less space than the bit map.

gate1998 operating-system disk descriptive

Answer key

7.3.8 Disk: GATE CSE 1998 | Question: 25b

Consider a disk with c cylinders, t tracks per cylinder, s sectors per track and a sector length s_l. A logical file d_l with fixed record length r_l is stored continuously on this disk starting at location (c_L, t_L, s_L), where c_L, t_L and S_L are the cylinder, track and sector numbers, respectively. Derive the formula to calculate the disk address (i.e. cylinder, track and sector) of a logical record n assuming that $r_l = s_l$.

gate1998 operating-system disk descriptive

Answer key

7.3.9 Disk: GATE CSE 1999 | Question: 2-18, ISRO2008-46

Raid configurations of the disks are used to provide

A. Fault-tolerance
B. High speed
C. High data density
D. (A) & (B)

gate1999 operating-system disk easy isro2008

Answer key

7.3.10 Disk: GATE CSE 2001 | Question: 1.22

Which of the following requires a device driver?

A. Register
B. Cache
C. Main memory
D. Disk

gatecse-2001 operating-system disk easy

Answer key

7.3.11 Disk: GATE CSE 2001 | Question: 20

Consider a disk with the 100 tracks numbered from 0 to 99 rotating at 3000 rpm. The number of sectors per track is 100 and the time to move the head between two successive tracks is 0.2 millisecond.

A. Consider a set of disk requests to read data from tracks $32, 7, 45, 5$ and 10. Assuming that the elevator algorithm is used to schedule disk requests, and the head is initially at track 25 moving up (towards larger track numbers), what is the total seek time for servicing the requests?
B. Consider an initial set of 100 arbitrary disk requests and assume that no new disk requests arrive while servicing these requests. If the head is initially at track 0 and the elevator algorithm is used to schedule disk requests, what is the worse case time to complete all the requests?

gatecse-2001 operating-system disk normal descriptive

Answer key

7.3.12 Disk: GATE CSE 2001 | Question: 8

Consider a disk with the following specifications: 20 surfaces, 1000 tracks/surface, 16 sectors/track, data density 1 KB/sector, rotation speed 3000 rpm. The operating system initiates the transfer between the disk and the memory sector-wise. Once the head has been placed on the right track, the disk reads a sector in a single scan. It reads bits from the sector while the head is passing over the sector. The read bits are formed into bytes in a serial-in-parallel-out buffer and each byte is then transferred to memory. The disk writing is exactly a complementary process.

For parts (C) and (D) below, assume memory read-write time = 0.1 microseconds/byte, interrupt driven transfer has an interrupt overhead = 0.4 microseconds, the DMA initialization, and termination overhead is negligible compared to the total sector transfer time. DMA requests are always granted.

A. What is the total capacity of the desk?
B. What is the data transfer rate?
C. What is the percentage of time the CPU is required for this disk I/O for byte-wise interrupts driven transfer?
D. What is the maximum percentage of time the CPU is held up for this disk I/O for cycle-stealing DMA transfer?

gatecse-2001 operating-system disk normal descriptive

Answer key☟

7.3.13 Disk: GATE CSE 2003 | Question: 25, ISRO2009-12

Using a larger block size in a fixed block size file system leads to

A. better disk throughput but poorer disk space utilization
B. better disk throughput and better disk space utilization
C. poorer disk throughput but better disk space utilization
D. poorer disk throughput and poorer disk space utilization

gatecse-2003 operating-system disk normal isro2009

Answer key☟

7.3.14 Disk: GATE CSE 2004 | Question: 49

A unix-style I-nodes has 10 direct pointers and one single, one double and one triple indirect pointers. Disk block size is 1 Kbyte, disk block address is 32 bits, and 48-bit integers are used. What is the maximum possible file size?

A. 2^{24} bytes B. 2^{32} bytes C. 2^{34} bytes D. 2^{48} bytes

gatecse-2004 operating-system disk normal

Answer key☟

7.3.15 Disk: GATE CSE 2005 | Question: 21

What is the swap space in the disk used for?

A. Saving temporary html pages
B. Saving process data
C. Storing the super-block
D. Storing device drivers

gatecse-2005 operating-system disk easy

Answer key☟

7.3.16 Disk: GATE CSE 2007 | Question: 11, ISRO2009-36, ISRO2016-21

Consider a disk pack with 16 surfaces, 128 tracks per surface and 256 sectors per track. 512 bytes of data are stored in a bit serial manner in a sector. The capacity of the disk pack and the number of bits required to specify a particular sector in the disk are respectively:

A. 256 Mbyte, 19 bits
B. 256 Mbyte, 28 bits
C. 512 Mbyte, 20 bits
D. 64 Gbyte, 28 bits

gatecse-2007 operating-system disk normal isro2016

Answer key☟

7.3.17 Disk: GATE CSE 2008 | Question: 32

For a magnetic disk with concentric circular tracks, the seek latency is not linearly proportional to the seek distance due to

A. non-uniform distribution of requests

B. arm starting and stopping inertia
C. higher capacity of tracks on the periphery of the platter
D. use of unfair arm scheduling policies

gatecse-2008 operating-system disk normal

Answer key

7.3.18 Disk: GATE CSE 2009 | Question: 51

A hard disk has 63 sectors per track, 10 platters each with 2 recording surfaces and 1000 cylinders. The address of a sector is given as a triple $\langle c, h, s \rangle$, where c is the cylinder number, h is the surface number and s is the sector number. Thus, the 0^{th} sector is addresses as $\langle 0, 0, 0 \rangle$, the 1^{st} sector as $\langle 0, 0, 1 \rangle$, and so on

The address $\langle 400, 16, 29 \rangle$ corresponds to sector number:

A. 505035
B. 505036
C. 505037
D. 505038

gatecse-2009 operating-system disk normal

Answer key

7.3.19 Disk: GATE CSE 2009 | Question: 52

A hard disk has 63 sectors per track, 10 platters each with 2 recording surfaces and 1000 cylinders. The address of a sector is given as a triple $\langle c, h, s \rangle$, where c is the cylinder number, h is the surface number and s is the sector number. Thus, the 0^{th} sector is addresses as $\langle 0, 0, 0 \rangle$, the 1^{st} sector as $\langle 0, 0, 1 \rangle$, and so on

The address of the 1039^{th} sector is

A. $\langle 0,15,31 \rangle$
B. $\langle 0,16,30 \rangle$
C. $\langle 0,16,31 \rangle$
D. $\langle 0,17,31 \rangle$

gatecse-2009 operating-system disk normal

Answer key

7.3.20 Disk: GATE CSE 2011 | Question: 44

An application loads 100 libraries at startup. Loading each library requires exactly one disk access. The seek time of the disk to a random location is given as 10 ms. Rotational speed of disk is 6000 rpm. If all 100 libraries are loaded from random locations on the disk, how long does it take to load all libraries? (The time to transfer data from the disk block once the head has been positioned at the start of the block may be neglected.)

A. $0.50\ s$
B. $1.50\ s$
C. $1.25\ s$
D. $1.00\ s$

gatecse-2011 operating-system disk normal

Answer key

7.3.21 Disk: GATE CSE 2012 | Question: 41

A file system with 300 GByte disk uses a file descriptor with 8 direct block addresses, 1 indirect block address and 1 doubly indirect block address. The size of each disk block is 128 Bytes and the size of each disk block address is 8 Bytes. The maximum possible file size in this file system is

A. 3 KBytes
B. 35 KBytes
C. 280 KBytes
D. dependent on the size of the disk

gatecse-2012 operating-system disk normal

Answer key

7.3.22 Disk: GATE CSE 2013 | Question: 29

Consider a hard disk with 16 recording surfaces $(0-15)$ having 16384 cylinders $(0-16383)$ and each cylinder contains 64 sectors $(0-63)$. Data storage capacity in each sector is 512 bytes. Data are organized cylinder-wise and the addressing format is $\langle \text{cylinder no.}, \text{surface no.}, \text{sector no.} \rangle$. A file of size 42797 KB is stored in the disk and the starting disk location of the file is $\langle 1200, 9, 40 \rangle$. What is the cylinder number of the last sector of the file, if it is stored in a contiguous manner?

A. 1281 B. 1282 C. 1283 D. 1284

gatecse-2013 operating-system disk normal

Answer key

7.3.23 Disk: GATE CSE 2015 Set 1 | Question: 48

Consider a disk pack with a seek time of 4 milliseconds and rotational speed of 10000 rotations per minute (RPM). It has 600 sectors per track and each sector can store 512 bytes of data. Consider a file stored in the disk. The file contains 2000 sectors. Assume that every sector access necessitates a seek, and the average rotational latency for accessing each sector is half of the time for one complete rotation. The total time (in milliseconds) needed to read the entire file is ______ 14020

gatecse-2015-set1 operating-system disk normal numerical-answers

Answer key

7.3.24 Disk: GATE CSE 2015 Set 2 | Question: 49

Consider a typical disk that rotates at 15000 rotations per minute (RPM) and has a transfer rate of 50×10^6 bytes/sec. If the average seek time of the disk is twice the average rotational delay and the controller's transfer time is 10 times the disk transfer time, the average time (in milliseconds) to read or write a 512-byte sector of the disk is ______

gatecse-2015-set2 operating-system disk normal numerical-answers

Answer key

7.3.25 Disk: GATE CSE 2018 | Question: 53

Consider a storage disk with 4 platters (numbered as $0, 1, 2$ and 3), 200 cylinders (numbered as $0, 1, \dots, 199$), and 256 sectors per track (numbered as $0, 1, \dots 255$). The following 6 disk requests of the form [sector number, cylinder number, platter number] are received by the disk controller at the same time:

$$[120, 72, 2], [180, 134, 1], [60, 20, 0], [212, 86, 3], [56, 116, 2], [118, 16, 1]$$

Currently head is positioned at sector number 100 of cylinder 80, and is moving towards higher cylinder numbers. The average power dissipation in moving the head over 100 cylinders is 20 milliwatts and for reversing the direction of the head movement once is 15 milliwatts. Power dissipation associated with rotational latency and switching of head between different platters is negligible.

The total power consumption in milliwatts to satisfy all of the above disk requests using the Shortest Seek Time First disk scheduling algorithm is ______ 515

gatecse-2018 operating-system disk numerical-answers two-marks

Answer key

7.3.26 Disk: GATE CSE 2024 | Set 1 | Question: 44

Consider a 512 GB hard disk with 32 storage surfaces. There are 4096 sectors per track and each sector holds 1024 bytes of data. The number of cylinders in the hard disk is ______. 4096

gatecse2024-set1 numerical-answers operating-system disk two-marks

Answer key

7.3.27 Disk: GATE CSE 2024 | Set 2 | Question: 43

Consider a disk with the following specifications: rotation speed of 6000 RPM, average seek time of 5 milliseconds, 500 sectors/track, 512-byte sectors. A file has content stored in 3000 sectors located *randomly* on the disk. Assuming average rotational latency, the total time (*in seconds, rounded off to 2 decimal places*) to read the entire file from the disk is ______. 30.06

gatecse2024-set2 numerical-answers operating-system disk two-marks

Answer key

7.3.28 Disk: GATE IT 2005 | Question: 63

In a computer system, four files of size 11050 bytes, 4990 bytes, 5170 bytes and 12640 bytes need to be stored. For storing these files on disk, we can use either 100 byte disk blocks or 200 byte disk blocks (but can't mix block sizes). For each block used to store a file, 4 bytes of bookkeeping information also needs to be stored on the disk. Thus, the total space used to store a file is the sum of the space taken to store the file and the space taken to store the book keeping information for the blocks allocated for storing the file. A disk block can store either bookkeeping information for a file or data from a file, but not both.
What is the total space required for storing the files using 100 byte disk blocks and 200 byte disk blocks respectively?

A. 35400 and 35800 bytes
B. 35800 and 35400 bytes
C. 35600 and 35400 bytes
D. 35400 and 35600 bytes

gateit-2005 operating-system disk normal

Answer key

7.3.29 Disk: GATE IT 2005 | Question: 81-a

A disk has 8 equidistant tracks. The diameters of the innermost and outermost tracks are 1 cm and 8 cm respectively. The innermost track has a storage capacity of 10 MB.

What is the total amount of data that can be stored on the disk if it is used with a drive that rotates it with

I. Constant Linear Velocity
II. Constant Angular Velocity?

A. I. 80 MB; II. 2040 MB
B. I. 2040 MB; II 80 MB
C. I. 80 MB; II. 360 MB
D. I. 360 MB; II. 80 MB

gateit-2005 operating-system disk normal

Answer key

7.3.30 Disk: GATE IT 2005 | Question: 81-b

A disk has 8 equidistant tracks. The diameters of the innermost and outermost tracks are 1 cm and 8 cm respectively. The innermost track has a storage capacity of 10 MB.

If the disk has 20 sectors per track and is currently at the end of the 5^{th} sector of the inner-most track and the head can move at a speed of 10 meters/sec and it is rotating at constant angular velocity of 6000 RPM, how much time will it take to read 1 MB contiguous data starting from the sector 4 of the outer-most track?

A. $13.5\ ms$
B. $10\ ms$
C. $9.5\ ms$
D. $20\ ms$

gateit-2005 operating-system disk normal

Answer key

7.3.31 Disk: GATE IT 2007 | Question: 44, ISRO2015-34

A hard disk system has the following parameters :

- Number of tracks $= 500$
- Number of sectors/track $= 100$
- Number of bytes /sector $= 500$
- Time taken by the head to move from one track to adjacent track $= 1\ ms$
- Rotation speed $= 600\ rpm$.

What is the average time taken for transferring 250 bytes from the disk ?

A. $300.5\ ms$
B. $255.5\ ms$
C. $255\ ms$
D. $300\ ms$

gateit-2007 operating-system disk normal isro2015

Answer key

7.4 Disk Scheduling (14)

7.4.1 Disk Scheduling: GATE CSE 1989 | Question: 4-xii

Disk requests come to disk driver for cylinders $10, 22, 20, 2, 40, 6$ and 38, in that order at a time when the disk drive is reading from cylinder 20. The seek time is 6 msec per cylinder. Compute the total seek time if the disk arm scheduling algorithm is.

A. First come first served.
B. Closest cylinder next.

gate1989 descriptive operating-system disk-scheduling

Answer key

7.4.2 Disk Scheduling: GATE CSE 1990 | Question: 9b

Assuming the current disk cylinder to be 50 and the sequence for the cylinders to be $1, 36, 49, 65, 53, 12, 3, 20, 55, 16, 65$ and 78 find the sequence of servicing using

1. Shortest seek time first (SSTF) and
2. Elevator disk scheduling policies.

gate1990 descriptive operating-system disk-scheduling

Answer key

7.4.3 Disk Scheduling: GATE CSE 1995 | Question: 20

The head of a moving head disk with 100 tracks numbered 0 to 99 is currently serving a request at track 55. If the queue of requests kept in FIFO order is

$$10, 70, 75, 23, 65$$

which of the two disk scheduling algorithms FCFS (First Come First Served) and SSTF (Shortest Seek Time First) will require less head movement? Find the head movement for each of the algorithms.

gate1995 operating-system disk-scheduling normal descriptive

Answer key

7.4.4 Disk Scheduling: GATE CSE 1997 | Question: 3.6

The correct matching for the following pairs is:

(A)	Disk Scheduling	(1)	Round robin
(B)	Batch Processing	(2)	SCAN
(C)	Time-sharing	(3)	LIFO
(D)	Interrupt processing	(4)	FIFO

A. A-3 B-4 C-2 D-1
B. A-4 B-3 C-2 D-1
C. A-2 B-4 C-1 D-3
D. A-3 B-4 C-3 D-2

gate1997 operating-system normal disk-scheduling match-the-following

Answer key

7.4.5 Disk Scheduling: GATE CSE 1999 | Question: 1.10

Which of the following disk scheduling strategies is likely to give the best throughput?

A. Farthest cylinder next
B. Nearest cylinder next
C. First come first served
D. Elevator algorithm

gate1999 operating-system disk-scheduling normal

Answer key

7.4.6 Disk Scheduling: GATE CSE 2004 | Question: 12

Consider an operating system capable of loading and executing a single sequential user process at a time. The disk head scheduling algorithm used is First Come First Served (FCFS). If FCFS is replaced by Shortest Seek Time First (SSTF), claimed by the vendor to give 50% better benchmark results, what is the expected improvement in the I/O performance of user programs?

A. 50% B. 40% C. 25% D. 0%

gatecse-2004 operating-system disk-scheduling normal

Answer key

7.4.7 Disk Scheduling: GATE CSE 2009 | Question: 31

Consider a disk system with 100 cylinders. The requests to access the cylinders occur in following sequence:

$4, 34, 10, 7, 19, 73, 2, 15, 6, 20$

Assuming that the head is currently at cylinder 50, what is the time taken to satisfy all requests if it takes 1 ms to move from one cylinder to adjacent one and shortest seek time first policy is used?

A. 95 ms B. 119 ms C. 233 ms D. 276 ms

gatecse-2009 operating-system disk-scheduling normal

Answer key

7.4.8 Disk Scheduling: GATE CSE 2014 Set 1 | Question: 19

Suppose a disk has 201 cylinders, numbered from 0 to 200. At some time the disk arm is at cylinder 100, and there is a queue of disk access requests for cylinders $30, 85, 90, 100, 105, 110, 135$ and 145. If Shortest-Seek Time First (SSTF) is being used for scheduling the disk access, the request for cylinder 90 is serviced after servicing ____________ number of requests.

gatecse-2014-set1 operating-system disk-scheduling numerical-answers normal

Answer key

7.4.9 Disk Scheduling: GATE CSE 2015 Set 1 | Question: 30

Suppose the following disk request sequence (track numbers) for a disk with 100 tracks is given:

$45, 20, 90, 10, 50, 60, 80, 25, 70.$

Assume that the initial position of the R/W head is on track 50. The additional distance that will be traversed by the R/W head when the Shortest Seek Time First (SSTF) algorithm is used compared to the SCAN (Elevator) algorithm (assuming that SCAN algorithm moves towards 100 when it starts execution) is________________tracks.

gatecse-2015-set1 operating-system disk-scheduling normal numerical-answers

Answer key

7.4.10 Disk Scheduling: GATE CSE 2016 Set 1 | Question: 48

Cylinder a disk queue with requests for I/O to blocks on cylinders $47, 38, 121, 191, 87, 11, 92, 10$. The C-LOOK scheduling algorithm is used. The head is initially at cylinder number 63, moving towards larger cylinder numbers on its servicing pass. The cylinders are numbered from 0 to 199. The total head movement (in number of cylinders) incurred while servicing these requests is__________.

gatecse-2016-set1 operating-system disk-scheduling normal numerical-answers

Answer key

7.4.11 Disk Scheduling: GATE CSE 2020 | Question: 35

Consider the following five disk access requests of the form (request id, cylinder number) that are present in the disk scheduler queue at a given time.

$(P, 155), (Q, 85), (R, 110), (S, 30), (T, 115)$

Assume the head is positioned at cylinder 100. The scheduler follows Shortest Seek Time First scheduling to service the requests.

Which one of the following statements is FALSE?

A. T is serviced before P.
B. Q is serviced after S,but before T.
C. The head reverses its direction of movement between servicing of Q and P.
D. R is serviced before P.

gatecse-2020 operating-system disk-scheduling two-marks

Answer key

7.4.12 Disk Scheduling: GATE IT 2004 | Question: 62

A disk has 200 tracks (numbered 0 through 199). At a given time, it was servicing the request of reading data from track 120, and at the previous request, service was for track 90. The pending requests (in order of their arrival) are for track numbers.

$30\ 70\ 115\ 130\ 110\ 80\ 20\ 25.$

How many times will the head change its direction for the disk scheduling policies SSTF(Shortest Seek Time First) and FCFS (First Come First Serve)?

A. 2 and 3
B. 3 and 3
C. 3 and 4
D. 4 and 4

gateit-2004 operating-system disk-scheduling normal

Answer key

7.4.13 Disk Scheduling: GATE IT 2007 | Question: 82

The head of a hard disk serves requests following the shortest seek time first (SSTF) policy. The head is initially positioned at track number 180.

Which of the request sets will cause the head to change its direction after servicing every request assuming that the head does not change direction if there is a tie in SSTF and all the requests arrive before the servicing starts?

A. $11, 139, 170, 178, 181, 184, 201, 265$
B. $10, 138, 170, 178, 181, 185, 201, 265$
C. $10, 139, 169, 178, 181, 184, 201, 265$
D. $10, 138, 170, 178, 181, 185, 200, 265$

gateit-2007 operating-system disk-scheduling normal

Answer key

7.4.14 Disk Scheduling: GATE IT 2007 | Question: 83

The head of a hard disk serves requests following the shortest seek time first (SSTF) policy.

What is the maximum cardinality of the request set, so that the head changes its direction after servicing every request if the total number of tracks are 2048 and the head can start from any track?

A. 9
B. 10
C. 11
D. 12

gateit-2007 operating-system disk-scheduling normal

Answer key

7.5 File System (9)

7.5.1 File System: GATE CSE 1996 | Question: 23

A file system with a one-level directory structure is implemented on a disk with disk block size of $4K$ bytes. The disk is used as follows:

Disk-block 0	File Allocation Table, consisting of one 8-bit entry per data block, representing the data block address of the next data block in the file
Disk-block 1	Directory, with one 32 bit entry per file:
Disk-block 2	Data-block 1;
Disk-block 3	Data-block 2; etc.

a. What is the maximum possible number of files?
b. What is the maximum possible file size in blocks

gate1996 operating-system disk normal file-system descriptive

Answer key☟

7.5.2 File System: GATE CSE 2002 | Question: 2.22

In the index allocation scheme of blocks to a file, the maximum possible size of the file depends on

A. the size of the blocks, and the size of the address of the blocks.
B. the number of blocks used for the index, and the size of the blocks.
C. the size of the blocks, the number of blocks used for the index, and the size of the address of the blocks.
D. None of the above

gatecse-2002 operating-system normal file-system

Answer key☟

7.5.3 File System: GATE CSE 2008 | Question: 20

The data blocks of a very large file in the Unix file system are allocated using

A. continuous allocation
B. linked allocation
C. indexed allocation
D. an extension of indexed allocation

gatecse-2008 file-system operating-system normal

Answer key☟

7.5.4 File System: GATE CSE 2014 Set 2 | Question: 20

A FAT (file allocation table) based file system is being used and the total overhead of each entry in the FAT is 4 bytes in size. Given a 100×10^6 bytes disk on which the file system is stored and data block size is 10^3 bytes, the maximum size of a file that can be stored on this disk in units of 10^6 bytes is _________.

gatecse-2014-set2 operating-system disk numerical-answers normal file-system

Answer key☟

7.5.5 File System: GATE CSE 2017 Set 2 | Question: 08

In a file allocation system, which of the following allocation scheme(s) can be used if no external fragmentation is allowed?

1. Contiguous
2. Linked
3. Indexed

A. 1 and 3 only
B. 2 only
C. 3 only
D. 2 and 3 only

gatecse-2017-set2 operating-system file-system normal

Answer key☟

7.5.6 File System: GATE CSE 2019 | Question: 42

The index node (inode) of a Unix -like file system has 12 direct, one single-indirect and one double-indirect pointers. The disk block size is 4 kB, and the disk block address is 32-bits long. The maximum possible file size is (rounded off to 1 decimal place) ____ GB

gatecse-2019 numerical-answers operating-system file-system two-marks

Answer key

7.5.7 File System: GATE CSE 2021 Set 1 | Question: 15

Consider a linear list based directory implementation in a file system. Each directory is a list of nodes, where each node contains the file name along with the file metadata, such as the list of pointers to the data blocks. Consider a given directory foo.

Which of the following operations will necessarily require a full scan of foo for successful completion?

A. Creation of a new file in foo
B. Deletion of an existing file from foo
C. Renaming of an existing file in foo
D. Opening of an existing file in foo

gatecse-2021-set1 multiple-selects operating-system file-system one-mark

Answer key

7.5.8 File System: GATE CSE 2022 | Question: 53

Consider two files systems A and B, that use contiguous allocation and linked allocation, respectively. A file of size 100 blocks is already stored in A and also in B. Now, consider inserting a new block in the middle of the file (between 50^{th} and 51^{st} block), whose data is already available in the memory. Assume that there are enough free blocks at the end of the file and that the file control blocks are already in memory. Let the number of disk accesses required to insert a block in the middle of the file in A and B are n_A and n_B, respectively, then the value of $n_A + n_B$ is__________________.

gatecse-2022 numerical-answers operating-system file-system two-marks

Answer key

7.5.9 File System: GATE IT 2004 | Question: 67

In a particular Unix OS, each data block is of size 1024 bytes, each node has 10 direct data block addresses and three additional addresses: one for single indirect block, one for double indirect block and one for triple indirect block. Also, each block can contain addresses for 128 blocks. Which one of the following is approximately the maximum size of a file in the file system?

A. 512 MB
B. 2 GB
C. 8 GB
D. 16 GB

gateit-2004 operating-system file-system normal

Answer key

7.6 Fork System Call (7)

7.6.1 Fork System Call: GATE CSE 2005 | Question: 72

```
Consider the following code fragment:
if (fork() == 0)
{
  a = a + 5;
  printf("%d, %p n", a, &a);
}
else
{
  a = a - 5;
  printf ("%d, %p n", a,& a);
}
```

Let u, v be the values printed by the parent process and x, y be the values printed by the child process. Which one of the following is **TRUE**?

A. $u = x + 10 \text{ and } v = y$
B. $u = x + 10 \text{ and } v != y$

C. $u + 10 = x$ and $v = y$

D. $u + 10 = x$ and $v! = y$

gatecse-2005 operating-system fork-system-call normal

Answer key

7.6.2 Fork System Call: GATE CSE 2008 | Question: 66

A process executes the following code

```
for(i=0; i<n; i++) fork();
```

The total number of child processes created is

A. n

B. $2^n - 1$

C. 2^n

D. $2^{n+1} - 1$

gatecse-2008 operating-system fork-system-call normal

Answer key

7.6.3 Fork System Call: GATE CSE 2012 | Question: 8

A process executes the code

```
fork();
fork();
fork();
```

The total number of child processes created is

A. 3

B. 4

C. 7

D. 8

gatecse-2012 operating-system easy fork-system-call

Answer key

7.6.4 Fork System Call: GATE CSE 2019 | Question: 17

The following C program is executed on a Unix/Linux system :

```
#include<unistd.h>
int main()
{
    int i;
    for(i=0; i<10; i++)
        if(i%2 == 0)
            fork();
    return 0;
}
```

The total number of child processes created is _________________ .

gatecse-2019 numerical-answers operating-system fork-system-call one-mark

Answer key

7.6.5 Fork System Call: GATE CSE 2023 | Question: 13

Which one or more of the following options guarantee that a computer system will transition from user mode to kernel mode?

A. Function Call

B. malloc Call

C. Page Fault

D. System Call

gatecse-2023 operating-system fork-system-call multiple-selects one-mark

Answer key

7.6.6 Fork System Call: GATE CSE 2024 | Set 1 | Question: 47

Consider the following code snippet using the fork () and wait () system calls. Assume that the code compiles and runs correctly, and that the system calls run successfully without any errors.

```
int x=3;
```

```
while (x>0){
fork ();
printf("hello");
wait (NULL) ;
X-- ;
}
```

The total number of times the printf statement is executed is __________.

gatecse2024-set1 numerical-answers operating-system fork-system-call two-marks

Answer key

7.6.7 Fork System Call: GATE IT 2004 | Question: 64

A process executes the following segment of code :

```
for(i = 1; i <= n; i++)
   fork ();
```

The number of new processes created is

A. n
B. $((n(n+1))/2)$
C. $2^n - 1$
D. $3^n - 1$

gateit-2004 operating-system fork-system-call easy

Answer key

7.7 IO Handling (7)

7.7.1 IO Handling: GATE CSE 1996 | Question: 1.20, ISRO2008-56

Which of the following is an example of spooled device?

A. A line printer used to print the output of a number of jobs
B. A terminal used to enter input data to a running program
C. A secondary storage device in a virtual memory system
D. A graphic display device

gate1996 operating-system io-handling normal isro2008

Answer key

7.7.2 IO Handling: GATE CSE 1998 | Question: 1.29

Which of the following is an example of a spooled device?

A. The terminal used to enter the input data for the C program being executed
B. An output device used to print the output of a number of jobs
C. The secondary memory device in a virtual storage system
D. The swapping area on a disk used by the swapper

gate1998 operating-system io-handling easy

Answer key

7.7.3 IO Handling: GATE CSE 2005 | Question: 19

Which one of the following is true for a CPU having a single interrupt request line and a single interrupt grant line?

A. Neither vectored interrupt nor multiple interrupting devices are possible

B. Vectored interrupts are not possible but multiple interrupting devices are possible
C. Vectored interrupts and multiple interrupting devices are both possible
D. Vectored interrupts are possible but multiple interrupting devices are not possible

gatecse-2005 operating-system io-handling normal

Answer key

7.7.4 IO Handling: GATE CSE 2005 | Question: 20

Normally user programs are prevented from handling I/O directly by I/O instructions in them. For CPUs having explicit I/O instructions, such I/O protection is ensured by having the I/O instruction privileged. In a CPU with memory mapped I/O, there is no explicit I/O instruction. Which one of the following is true for a CPU with memory mapped I/O?

A. I/O protection is ensured by operating system routine(s)
B. I/O protection is ensured by a hardware trap
C. I/O protection is ensured during system configuration
D. I/O protection is not possible

gatecse-2005 operating-system io-handling normal

Answer key

7.7.5 IO Handling: GATE CSE 2018 | Question: 9

The following are some events that occur after a device controller issues an interrupt while process L is under execution.

- P. The processor pushes the process status of L onto the control stack
- Q. The processor finishes the execution of the current instruction
- R. The processor executes the interrupt service routine
- S. The processor pops the process status of L from the control stack
- T. The processor loads the new PC value based on the interrupt

Which of the following is the correct order in which the events above occur?

A. QPTRS
B. PTRSQ
C. TRPQS
D. QTPRS

gatecse-2018 operating-system interrupts normal one-mark co-and-architecture io-handling

Answer key

7.7.6 IO Handling: GATE IT 2004 | Question: 11, ISRO2011-33

What is the bit rate of a video terminal unit with 80 characters/line, 8 bits/character and horizontal sweep time of 100 µs (including 20 µs of retrace time)?

A. 8 Mbps
B. 6.4 Mbps
C. 0.8 Mbps
D. 0.64 Mbps

gateit-2004 operating-system io-handling easy isro2011

Answer key

7.7.7 IO Handling: GATE IT 2006 | Question: 8

Which of the following DMA transfer modes and interrupt handling mechanisms will enable the highest I/O band-width?

A. Transparent DMA and Polling interrupts
B. Cycle-stealing and Vectored interrupts
C. Block transfer and Vectored interrupts
D. Block transfer and Polling interrupts

gateit-2006 operating-system io-handling dma normal

Answer key

7.8 Input Output (1)

7.8.1 Input Output: GATE CSE 2025 | Set 1 | Question: 19

Suppose in a multiprogramming environment, the following C program segment is executed. A process goes into I/O queue whenever an I/O related operation is performed. Assume that there will always be a context switch whenever a process requests for an I/O, and also whenever the process returns from an I/O. The number of times the process will enter the ready queue during its lifetime (not counting the time the process enters the ready queue when it is run initially) is ___________ . Answer in integer)

```
int main()
{
int x=0,i=0;
scanf("%d",&x);
for(i=0; i<20; i++)
{
x = x+20;
printf("%d\n",x);
}
return 0;
}
```

gatecse2025-set1 operating-system process-scheduling input-output numerical-answers one-mark

Answer key☟

7.9 Inter Process Communication (1)

7.9.1 Inter Process Communication: GATE CSE 1997 | Question: 3.7

I/O redirection

A. implies changing the name of a file
B. can be employed to use an existing file as input file for a program
C. implies connecting 2 programs through a pipe
D. None of the above

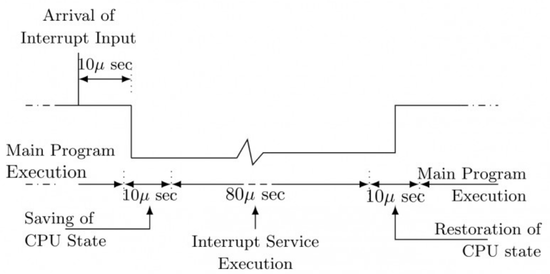
gate1997 operating-system normal inter-process-communication

Answer key☟

7.10 Interrupts (6)

7.10.1 Interrupts: GATE CSE 1993 | Question: 6.8

The details of an interrupt cycle are shown in figure.



Given that an interrupt input arrives every 1 msec, what is the percentage of the total time that the CPU devotes for the main program execution.

gate1993 operating-system interrupts normal descriptive

Answer key☟

7.10.2 Interrupts: GATE CSE 1997 | Question: 3.8

When an interrupt occurs, an operating system

A. ignores the interrupt
B. always changes state of interrupted process after processing the interrupt
C. always resumes execution of interrupted process after processing the interrupt
D. may change state of interrupted process to 'blocked' and schedule another process.

gate1997 operating-system interrupts normal

Answer key

7.10.3 Interrupts: GATE CSE 1998 | Question: 1.18

Which of the following devices should get higher priority in assigning interrupts?

A. Hard disk
B. Printer
C. Keyboard
D. Floppy disk

gate1998 operating-system interrupts normal

Answer key

7.10.4 Interrupts: GATE CSE 1999 | Question: 1.9

Listed below are some operating system abstractions (in the left column) and the hardware components (in the right column)

(A)	Thread	1.	Interrupt
(B)	Virtual address space	2.	Memory
(C)	File system	3.	CPU
(D)	Signal	4.	Disk

A. (A) – 2 (B) – 4 (C) – 3 (D) – 1
B. (A) – 1 (B) – 2 (C) – 3 (D) – 4
C. (A) – 3 (B) – 2 (C) – 4 (D) – 1
D. (A) – 4 (B) – 1 (C) – 2 (D) – 3

gate1999 operating-system easy interrupts virtual-memory disk

Answer key

7.10.5 Interrupts: GATE CSE 2001 | Question: 1.12

A processor needs software interrupt to

A. test the interrupt system of the processor
B. implement co-routines
C. obtain system services which need execution of privileged instructions
D. return from subroutine

gatecse-2001 operating-system interrupts easy

Answer key

7.10.6 Interrupts: GATE CSE 2011 | Question: 11

A computer handles several interrupt sources of which of the following are relevant for this question.

- Interrupt from CPU temperature sensor (raises interrupt if CPU temperature is too high)
- Interrupt from Mouse (raises Interrupt if the mouse is moved or a button is pressed)
- Interrupt from Keyboard (raises Interrupt if a key is pressed or released)
- Interrupt from Hard Disk (raises Interrupt when a disk read is completed)

Which one of these will be handled at the **HIGHEST** priority?

A. Interrupt from Hard Disk
B. Interrupt from Mouse
C. Interrupt from Keyboard
D. Interrupt from CPU temperature sensor

gatecse-2011 operating-system interrupts normal

Answer key

7.11 Linked Allocation (1)

7.11.1 Linked Allocation: GATE CSE 2025 | Set 1 | Question: 41

A disk of size $512\,\mathrm{M}$ bytes is divided into blocks of $64\,\mathrm{K}$ bytes. A file is stored in the disk using linked allocation. In linked allocation, each data block reserves 4 bytes to store the pointer to the next data block. The link part of the last data block contains a NULL pointer (also of 4 bytes). Suppose a file of $1\,\mathrm{M}$ bytes needs to be stored in the disk. Assume, $1\,\mathrm{K} = 2^{10}$ and $1\mathrm{M} = 2^{20}$. The amount of space in bytes that will be wasted due to internal fragmentation is ___________. (Answer in integer)

gatecse2025-set1 operating-system linked-allocation internal-fragmentation numerical-answers two-marks

Answer key

7.12 Memory Management (10)

7.12.1 Memory Management: GATE CSE 1992 | Question: 12-b

Let the page reference and the working set window be $c\,c\,d\,b\,c\,e\,c\,e\,a\,d$ and 4, respectively. The initial working set at time $t=0$ contains the pages $\{a, d, e\}$, where a was referenced at time $t=0$, d was referenced at time $t=-1$, and e was referenced at time $t=-2$. Determine the total number of page faults and the average number of page frames used by computing the working set at each reference.

gate1992 operating-system memory-management normal descriptive

Answer key

7.12.2 Memory Management: GATE CSE 1995 | Question: 5

A computer installation has $1000k$ of main memory. The jobs arrive and finish in the following sequences.

```
Job 1 requiring 200k arrives
Job 2 requiring 350k arrives
Job 3 requiring 300k arrives
Job 1 finishes
Job 4 requiring 120k arrives
Job 5 requiring 150k arrives
Job 6 requiring 80k arrives
```

A. Draw the memory allocation table using Best Fit and First Fit algorithms.

B. Which algorithm performs better for this sequence?

gate1995 operating-system memory-management normal descriptive

Answer key

7.12.3 Memory Management: GATE CSE 1996 | Question: 2.18

A 1000 Kbyte memory is managed using variable partitions but no compaction. It currently has two partitions of sizes 200 Kbyte and 260 Kbyte respectively. The smallest allocation request in Kbyte that could be denied is for

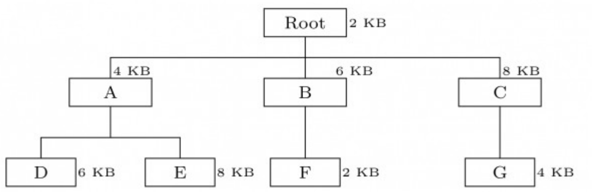
A. 151
B. 181
C. 231
D. 541

gate1996 operating-system memory-management normal

Answer key

7.12.4 Memory Management: GATE CSE 1998 | Question: 2.16

The overlay tree for a program is as shown below:



What will be the size of the partition (in physical memory) required to load (and run) this program?

A. 12 KB B. 14 KB C. 10 KB D. 8 KB

gate1998 operating-system normal memory-management

Answer key

7.12.5 Memory Management: GATE CSE 2014 Set 2 | Question: 55

Consider the main memory system that consists of 8 memory modules attached to the system bus, which is one word wide. When a write request is made, the bus is occupied for 100 nanoseconds (ns) by the data, address, and control signals. During the same 100 ns, and for 500 ns thereafter, the addressed memory module executes one cycle accepting and storing the data. The (internal) operation of different memory modules may overlap in time, but only one request can be on the bus at any time. The maximum number of stores (of one word each) that can be initiated in 1 millisecond is ________

gatecse-2014-set2 operating-system memory-management numerical-answers normal

Answer key

7.12.6 Memory Management: GATE CSE 2015 Set 2 | Question: 30

Consider 6 memory partitions of sizes 200 KB, 400 KB, 600 KB, 500 KB, 300 KB and 250 KB, where KBrefers to kilobyte. These partitions need to be allotted to four processes of sizes 357 KB, 210 KB, 468 KB, 491 KB in that order. If the best-fit algorithm is used, which partitions are NOT allotted to any process?

A. 200 KB and 300 KB
B. 200 KB and 250 KB
C. 250 KB and 300 KB
D. 300 KB and 400 KB

gatecse-2015-set2 operating-system memory-management easy

Answer key

7.12.7 Memory Management: GATE CSE 2020 | Question: 11

Consider allocation of memory to a new process. Assume that none of the existing holes in the memory will exactly fit the process's memory requirement. Hence, a new hole of smaller size will be created if allocation is made in any of the existing holes. Which one of the following statement is TRUE?

A. The hole created by first fit is always larger than the hole created by next fit.
B. The hole created by worst fit is always larger than the hole created by first fit.
C. The hole created by best fit is never larger than the hole created by first fit.
D. The hole created by next fit is never larger than the hole created by best fit.

gatecse-2020 operating-system memory-management one-mark

Answer key

7.12.8 Memory Management: GATE CSE 2022 | Question: 28

Which one of the following statements is FALSE?

A. The TLB performs an associative search in parallel on all its valid entries using page number of incoming virtual address.
B. If the virtual address of a word given by CPU has a TLB hit, but the subsequent search for the word results in a cache miss, then the word will always be present in the main memory.
C. The memory access time using a given inverted page table is always same for all incoming virtual addresses.
D. In a system that uses hashed page tables, if two distinct virtual addresses V1 and V2 map to the same value while hashing, then the memory access time of these addresses will not be the same.

gatecse-2022 operating-system memory-management translation-lookaside-buffer two-marks

Answer key

7.12.9 Memory Management: GATE IT 2006 | Question: 56

For each of the four processes $P_1, P_2, P_3,$ and P_4. The total size in kilobytes (KB) and the number of segments are given below.

Process	Total size (in KB)	Number of segments
P_1	195	4
P_2	254	5
P_3	45	3
P_4	364	8

The page size is 1 KB. The size of an entry in the page table is 4 bytes. The size of an entry in the segment table is 8 bytes. The maximum size of a segment is 256 KB. The paging method for memory management uses two-level paging, and its storage overhead is P. The storage overhead for the segmentation method is S. The storage overhead for the segmentation and paging method is T. What is the relation among the overheads for the different methods of memory management in the concurrent execution of the above four processes?

A. $\text{P} < \text{S} < \text{T}$
B. $\text{S} < \text{P} < \text{T}$
C. $\text{S} < \text{T} < \text{P}$
D. $\text{T} < \text{S} < \text{P}$

gateit-2006 operating-system memory-management difficult

Answer key

7.12.10 Memory Management: GATE IT 2007 | Question: 11

Let a memory have four free blocks of sizes $4k$, $8k$, $20k$, $2k$. These blocks are allocated following the best-fit strategy. The allocation requests are stored in a queue as shown below.

Request No	J1	J2	J3	J4	J5	J6	J7	J8
Request Sizes	2k	14k	3k	6k	6k	10k	7k	20k
Usage Time	4	10	2	8	4	1	8	6

The time at which the request for $J7$ will be completed will be

A. 16
B. 19
C. 20
D. 37

gateit-2007 operating-system memory-management normal

Answer key

7.13 Multilevel Paging (1)

7.13.1 Multilevel Paging: GATE CSE 2025 | Set 2 | Question: 48

A computer system supports a logical address space of 2^{32} bytes. It uses two-level hierarchical paging with a page size of 4096 bytes. A logical address is divided into a b-bit index to the outer page table, an offset within the page of the inner page table, and an offset within the desired page. Each entry of the inner page table uses eight bytes. All the pages in the system have the same size.

The value of b is _________. (Answer in integer)

gatecse2025-set2 operating-system paging multilevel-paging numerical-answers two-marks

Answer key

7.14 OS Protection (3)

7.14.1 OS Protection: GATE CSE 1999 | Question: 1.11, UGCNET-Dec2015-II: 44

System calls are usually invoked by using

A. a software interrupt
B. polling
C. an indirect jump
D. a privileged instruction

gate1999 operating-system normal ugcnetcse-dec2015-paper2 os-protection

Answer key

7.14.2 OS Protection: GATE CSE 2001 | Question: 1.13

A CPU has two modes -- privileged and non-privileged. In order to change the mode from privileged to non-privileged

A. a hardware interrupt is needed
B. a software interrupt is needed
C. a privileged instruction (which does not generate an interrupt) is needed
D. a non-privileged instruction (which does not generate an interrupt) is needed

gatecse-2001 operating-system normal os-protection

Answer key

7.14.3 OS Protection: GATE IT 2005 | Question: 19, UGCNET-June2012-III: 57

A user level process in Unix traps the signal sent on a Ctrl-C input, and has a signal handling routine that saves appropriate files before terminating the process. When a Ctrl-C input is given to this process, what is the mode in which the signal handling routine executes?

A. User mode
B. Kernel mode
C. Superuser mode
D. Privileged mode

gateit-2005 operating-system os-protection normal ugcnetcse-june2012-paper3

Answer key

7.15 Optimal Page Replacement (1)

7.15.1 Optimal Page Replacement: GATE CSE 2025 | Set 1 | Question: 44

In optimal page replacement algorithm, information about all future page references is available to the operating system (OS). A modification of the optimal page replacement algorithm is as follows:

The OS correctly predicts only up to next 4 page references (including the current page) at the time of allocating a frame to a page.

A process accesses the pages in the following order of page numbers:

$$1, 3, 2, 4, 2, 3, 1, 2, 4, 3, 1, 4$$

If the system has three memory frames that are initially empty, the number of page faults that will occur during execution of the process is __________. (Answer in integer)

gatecse2025-set1 operating-system page-fault optimal-page-replacement numerical-answers two-marks

Answer key

7.16 Page Replacement (33)

7.16.1 Page Replacement: GATE CSE 1993 | Question: 21

The following page addresses, in the given sequence, were generated by a program:

$1\ 2\ 3\ 4\ 1\ 3\ 5\ 2\ 1\ 5\ 4\ 3\ 2\ 3$

This program is run on a demand paged virtual memory system, with main memory size equal to 4 pages. Indicate the page references for which page faults occur for the following page replacement algorithms.

A. LRU
B. FIFO

Assume that the main memory is initially empty.

gate1993 operating-system page-replacement normal descriptive

Answer key

7.16.2 Page Replacement: GATE CSE 1994 | Question: 1.13

A memory page containing a heavily used variable that was initialized very early and is in constant use is removed then

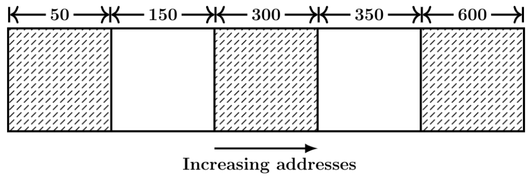
A. LRU page replacement algorithm is used
B. FIFO page replacement algorithm is used
C. LFU page replacement algorithm is used
D. None of the above

gate1994 operating-system page-replacement easy

Answer key

7.16.3 Page Replacement: GATE CSE 1994 | Question: 1.24

Consider the following heap (figure) in which blank regions are not in use and hatched region are in use.



The sequence of requests for blocks of sizes $300, 25, 125, 50$ can be satisfied if we use

A. either first fit or best fit policy (any one)
B. first fit but not best fit policy
C. best fit but not first fit policy
D. None of the above

gate1994 operating-system page-replacement normal

Answer key

7.16.4 Page Replacement: GATE CSE 1995 | Question: 1.8

Which of the following page replacement algorithms suffers from Belady's anamoly?

A. Optimal replacement
B. LRU
C. FIFO
D. Both (A) and (C)

gate1995 operating-system page-replacement normal

Answer key

7.16.5 Page Replacement: GATE CSE 1995 | Question: 2.7

The address sequence generated by tracing a particular program executing in a pure demand based paging system with 100 records per page with 1 free main memory frame is recorded as follows. What is the number of page faults?

$0100, 0200, 0430, 0499, 0510, 0530, 0560, 0120, 0220, 0240, 0260, 0320, 0370$

A. 13
B. 8
C. 7
D. 10

gate1995 operating-system page-replacement normal

Answer key

7.16.6 Page Replacement: GATE CSE 1997 | Question: 3.10, ISRO2008-57, ISRO2015-64

Dirty bit for a page in a page table

A. helps avoid unnecessary writes on a paging device
B. helps maintain LRU information
C. allows only read on a page
D. None of the above

gate1997 operating-system page-replacement easy isro2008 isro2015

Answer key

7.16.7 Page Replacement: GATE CSE 1997 | Question: 3.5

Locality of reference implies that the page reference being made by a process

A. will always be to the page used in the previous page reference
B. is likely to be to one of the pages used in the last few page references
C. will always be to one of the pages existing in memory
D. will always lead to a page fault

gate1997 operating-system page-replacement easy

Answer key

7.16.8 Page Replacement: GATE CSE 1997 | Question: 3.9

Thrashing

A. reduces page I/O
B. decreases the degree of multiprogramming
C. implies excessive page I/O
D. improve the system performance

gate1997 operating-system page-replacement easy

Answer key

7.16.9 Page Replacement: GATE CSE 2001 | Question: 1.21

Consider a virtual memory system with FIFO page replacement policy. For an arbitrary page access pattern, increasing the number of page frames in main memory will

A. always decrease the number of page faults
B. always increase the number of page faults
C. sometimes increase the number of page faults
D. never affect the number of page faults

gatecse-2001 operating-system page-replacement normal

Answer key

7.16.10 Page Replacement: GATE CSE 2002 | Question: 1.23

The optimal page replacement algorithm will select the page that

A. Has not been used for the longest time in the past
B. Will not be used for the longest time in the future
C. Has been used least number of times
D. Has been used most number of times

gatecse-2002 operating-system page-replacement easy

Answer key

7.16.11 Page Replacement: GATE CSE 2004 | Question: 21, ISRO2007-44

The minimum number of page frames that must be allocated to a running process in a virtual memory environment is determined by

A. the instruction set architecture
B. page size
C. number of processes in memory
D. physical memory size

gatecse-2004 operating-system virtual-memory page-replacement normal isro2007

Answer key

7.16.12 Page Replacement: GATE CSE 2005 | Question: 22, ISRO2015-36

Increasing the RAM of a computer typically improves performance because:

A. Virtual Memory increases
B. Larger RAMs are faster
C. Fewer page faults occur
D. Fewer segmentation faults occur

gatecse-2005 operating-system page-replacement easy isro2015

Answer key

7.16.13 Page Replacement: GATE CSE 2007 | Question: 56

A virtual memory system uses First In First Out (FIFO) page replacement policy and allocates a fixed number of frames to a process. Consider the following statements:

P: Increasing the number of page frames allocated to a process sometimes increases the page fault rate.

Q: Some programs do not exhibit locality of reference.

Which one of the following is TRUE?

A. Both P and Q are true, and Q is the reason for P
B. Both P and Q are true, but Q is not the reason for P.
C. P is false but Q is true
D. Both P and Q are false.

gatecse-2007 operating-system page-replacement normal

Answer key

7.16.14 Page Replacement: GATE CSE 2007 | Question: 82

A process has been allocated 3 page frames. Assume that none of the pages of the process are available in the memory initially. The process makes the following sequence of page references (reference string): $\mathbf{1, 2, 1, 3, 7, 4, 5, 6, 3, 1}$

If optimal page replacement policy is used, how many page faults occur for the above reference string?

A. 7
B. 8
C. 9
D. 10

gatecse-2007 operating-system page-replacement normal

Answer key

7.16.15 Page Replacement: GATE CSE 2007 | Question: 83

A process, has been allocated 3 page frames. Assume that none of the pages of the process are available in the memory initially. The process makes the following sequence of page references (reference string): $1, 2, 1, 3, 7, 4, 5, 6, 3, 1$

Least Recently Used (LRU) page replacement policy is a practical approximation to optimal page replacement. For the above reference string, how many more page faults occur with LRU than with the optimal page replacement policy?

A. 0
B. 1
C. 2
D. 3

gatecse-2007 normal operating-system page-replacement

Answer key

7.16.16 Page Replacement: GATE CSE 2009 | Question: 9, ISRO2016-52

In which one of the following page replacement policies, Belady's anomaly may occur?

A. FIFO
B. Optimal
C. LRU
D. MRU

gatecse-2009 operating-system page-replacement normal isro2016

Answer key

7.16.17 Page Replacement: GATE CSE 2010 | Question: 24

A system uses FIFO policy for system replacement. It has 4 page frames with no pages loaded to begin with. The system first accesses 100 distinct pages in some order and then accesses the same 100 pages but now in the reverse order. How many page faults will occur?

A. 196
B. 192
C. 197
D. 195

gatecse-2010 operating-system page-replacement normal

Answer key

7.16.18 Page Replacement: GATE CSE 2012 | Question: 42

Consider the virtual page reference string

$$1, 2, 3, 2, 4, 1, 3, 2, 4, 1$$

on a demand paged virtual memory system running on a computer system that has main memory size of 3 page frames which are initially empty. Let LRU, FIFO and OPTIMAL denote the number of page faults under the corresponding page replacement policy. Then

A. $\text{OPTIMAL} < \text{LRU} < \text{FIFO}$
B. $\text{OPTIMAL} < \text{FIFO} < \text{LRU}$
C. $\text{OPTIMAL} = \text{LRU}$
D. $\text{OPTIMAL} = \text{FIFO}$

gatecse-2012 operating-system page-replacement normal

Answer key

7.16.19 Page Replacement: GATE CSE 2014 Set 1 | Question: 33

Assume that there are 3 page frames which are initially empty. If the page reference string is $1, 2, 3, 4, 2, 1, 5, 3, 2, 4, 6$ the number of page faults using the optimal replacement policy is__________.

gatecse-2014-set1 operating-system page-replacement numerical-answers

Answer key

7.16.20 Page Replacement: GATE CSE 2014 Set 2 | Question: 33

A computer has twenty physical page frames which contain pages numbered 101 through 120. Now a program accesses the pages numbered $1, 2, \ldots, 100$ in that order, and repeats the access sequence **THRICE**. Which one of the following page replacement policies experiences the same number of page faults as the optimal page replacement policy for this program?

A. Least-recently-used
B. First-in-first-out
C. Last-in-first-out
D. Most-recently-used

gatecse-2014-set2 operating-system page-replacement ambiguous

Answer key

7.16.21 Page Replacement: GATE CSE 2014 Set 3 | Question: 20

A system uses 3 page frames for storing process pages in main memory. It uses the Least Recently Used (**LRU**) page replacement policy. Assume that all the page frames are initially empty. What is the total number of page faults that will occur while processing the page reference string given below?

$4, 7, 6, 1, 7, 6, 1, 2, 7, 2$

gatecse-2014-set3 operating-system page-replacement numerical-answers normal

Answer key

7.16.22 Page Replacement: GATE CSE 2015 Set 1 | Question: 47

Consider a main memory with five-page frames and the following sequence of page references: $3, 8, 2, 3, 9, 1, 6, 3, 8, 9, 3, 6, 2, 1, 3$. Which one of the following is true with respect to page replacement policies First In First Out (FIFO) and Least Recently Used (LRU)?

A. Both incur the same number of page faults
B. FIFO incurs 2 more page faults than LRU
C. LRU incurs 2 more page faults than FIFO
D. FIFO incurs 1 more page faults than LRU

gatecse-2015-set1 operating-system page-replacement normal

Answer key

7.16.23 Page Replacement: GATE CSE 2016 Set 1 | Question: 49

Consider a computer system with ten physical page frames. The system is provided with an access sequence $(a_1, a_2, \ldots, a_{20}, a_1, a_2, \ldots a_{20})$, where each a_i is a distinct virtual page number. The difference in the number of page faults between the last-in-first-out page replacement policy and the optimal page replacement policy is_________.

gatecse-2016-set1 operating-system page-replacement normal numerical-answers

Answer key

7.16.24 Page Replacement: GATE CSE 2016 Set 2 | Question: 20

In which one of the following page replacement algorithms it is possible for the page fault rate to increase even when the number of allocated frames increases?

A. LRU (Least Recently Used)
B. OPT (Optimal Page Replacement)
C. MRU (Most Recently Used)
D. FIFO (First In First Out)

gatecse-2016-set2 operating-system page-replacement easy

Answer key

7.16.25 Page Replacement: GATE CSE 2017 Set 1 | Question: 40

Recall that Belady's anomaly is that the page-fault rate may *increase* as the number of allocated frames increases. Now, consider the following statements:

- S_1: *Random page replacement* algorithm (where a page chosen at random is replaced) suffers from Belady's anomaly.
- S_2: *LRU page replacement* algorithm suffers from Belady's anomaly.

Which of the following is CORRECT?

A. S_1 is true, S_2 is true
B. S_1 is true, S_2 is false
C. S_1 is false, S_2 is true
D. S_1 is false, S_2 is false

gatecse-2017-set1 page-replacement operating-system normal

Answer key

7.16.26 Page Replacement: GATE CSE 2021 Set 1 | Question: 11

In the context of operating systems, which of the following statements is/are correct with respect to paging?

A. Paging helps solve the issue of external fragmentation
B. Page size has no impact on internal fragmentation
C. Paging incurs memory overheads
D. Multi-level paging is necessary to support pages of different sizes

gatecse-2021-set1 multiple-selects operating-system page-replacement one-mark

Answer key

7.16.27 Page Replacement: GATE CSE 2021 Set 2 | Question: 48

Consider a three-level page table to translate a $39-$bit virtual address to a physical address as shown below:

$\longleftarrow$ 39 – bit virtual address $\longrightarrow$

Level 1 offset	Level 2 offset	Level 3 offset	Page offset
9 bits	9 bits	9 bits	12 bits

The page size is $4\,\text{KB}$ $(1\text{KB} = 2^{10}$ bytes$)$ and page table entry size at every level is 8 bytes. A process P is currently using 2GB $(1\text{GB} = 2^{30}$ bytes$)$ virtual memory which is mapped to 2GB of physical memory. The minimum amount of memory required for the page table of P across all levels is _________ KB.

gatecse-2021-set2 numerical-answers operating-system memory-management page-replacement two-marks

Answer key

7.16.28 Page Replacement: GATE CSE 2022 | Question: 54

Consider a demand paging system with four page frames (initially empty) and LRU page replacement policy. For the following page reference string

$$7, 2, 7, 3, 2, 5, 3, 4, 6, 7, 7, 1, 5, 6, 1$$

the page fault rate, defined as the ratio of number of page faults to the number of memory accesses $(rounded\ off\ to\ one\ decimal\ place)$ is ____________.

gatecse-2022 numerical-answers operating-system page-replacement demand-paging two-marks

Answer key

7.16.29 Page Replacement: GATE CSE 2023 | Question: 47

Consider the following two-dimensional array D in the C programming language, which is stored in row-major order:

```
int D[128][128];
```

Demand paging is used for allocating memory and each physical page frame holds 512 elements of the array D. The Least Recently Used (LRU) page-replacement policy is used by the operating system. A total of 30 physical page frames are allocated to a process which executes the following code snippet:

```
for (int i = 0; i < 128; i++)
  for (int j = 0; j < 128; j++)
    D[j][i] *= 10;
```

The number of page faults generated during the execution of this code snippet is _______________.

gatecse-2023 operating-system page-replacement least-recently-used page-fault numerical-answers two-marks

Answer key

7.16.30 Page Replacement: GATE CSE 2025 | Set 2 | Question: 37

Consider a demand paging system with three frames, and the following page reference string: 1 2 3 4 5 4 1 6 4 5 1 3 2 . The contents of the frames are as follows initially and after each reference (from left to right):

initially	after												
–	1*	2*	3*	4*	5*	4	1	6*	4	5	1*	3*	2*
–	1	1	1	1	1	1	1	6	6	6	6	6	2
–	–	2	2	4	4	4	4	4	4	4	1	1	1
–	–	–	3	3	5	5	5	5	5	5	5	3	3

The *-marked references cause page replacements.

Which one or more of the following could be the page replacement policy/policies in use?

A. Least Recently Used page replacement policy
B. Least Frequently Used page replacement policy
C. Most Frequently Used page replacement policy
D. Optimal page replacement policy

gatecse2025-set2 operating-system page-replacement demand-paging multiple-selects two-marks

Answer key

7.16.31 Page Replacement: GATE IT 2007 | Question: 12

The address sequence generated by tracing a particular program executing in a pure demand paging system with 100 bytes per page is

$$0100, 0200, 0430, 0499, 0510, 0530, 0560, 0120, 0220, 0240, 0260, 0320, 0410.$$

Suppose that the memory can store only one page and if x is the address which causes a page fault then the bytes from addresses x to $\mathrm{x}+99$ are loaded on to the memory.
How many page faults will occur?

A. 0 B. 4 C. 7 D. 8

gateit-2007 operating-system virtual-memory page-replacement normal

Answer key☟

7.16.32 Page Replacement: GATE IT 2007 | Question: 58

A demand paging system takes 100 time units to service a page fault and 300 time units to replace a dirty page. Memory access time is 1 time unit. The probability of a page fault is p. In case of a page fault, the probability of page being dirty is also p. It is observed that the average access time is 3 time units. Then the value of p is

A. 0.194 B. 0.233 C. 0.514 D. 0.981

gateit-2007 operating-system page-replacement probability normal

Answer key☟

7.16.33 Page Replacement: GATE IT 2008 | Question: 41

Assume that a main memory with only 4 pages, each of 16 bytes, is initially empty. The CPU generates the following sequence of virtual addresses and uses the Least Recently Used (LRU) page replacement policy.

$$0, 4, 8, 20, 24, 36, 44, 12, 68, 72, 80, 84, 28, 32, 88, 92$$

How many page faults does this sequence cause? What are the page numbers of the pages present in the main memory at the end of the sequence?

A. 6 and $1,2,3,4$ B. 7 and $1,2,4,5$ C. 8 and $1,2,4,5$ D. 9 and $1,2,3,5$

gateit-2008 operating-system page-replacement normal

Answer key☟

7.17 Precedence Graph (3)

7.17.1 Precedence Graph: GATE CSE 1989 | Question: 11b

Consider the following precedence graph $(\mathrm{Fig.} 6)$ of processes where a node denotes a process and a directed edge from node P_i to node P_j implies; that P_i must complete before P_j commences. Implement the graph using FORK and JOIN constructs. The actual computation done by a process may be indicated by a comment line.

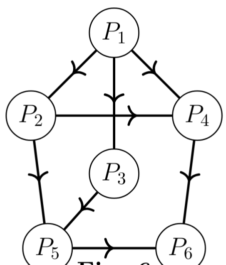


Fig. 6

gate1989 descriptive operating-system precedence-graph process-synchronization

Answer key☟

7.17.2 Precedence Graph: GATE CSE 1991 | Question: 01-xii

A given set of processes can be implemented by using only **parbegin/parend** statement, if the precedence graph of these processes is ______ gate1991 operating-system normal precedence-graph fill-in-the-blanks

Answer key

7.17.3 Precedence Graph: GATE CSE 1992 | Question: 12-a

Draw the precedence graph for the concurrent program given below

```
S1
parbegin
   begin
      S2:S4
   end;
   begin
      S3;
      parbegin
         S5;
         begin
            S6:S8
         end
      parend
   end;
   S7
parend;
S9
```

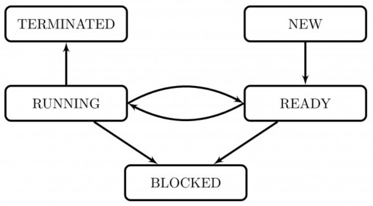
gate1992 operating-system normal concurrency precedence-graph descriptive

Answer key

7.18 Process (5)

7.18.1 Process: GATE CSE 1996 | Question: 1.18

The process state transition diagram in the below figure is representative of



A. a batch operating system
B. an operating system with a preemptive scheduler
C. an operating system with a non-preemptive scheduler
D. a uni-programmed operating system

gate1996 operating-system normal process

Answer key

7.18.2 Process: GATE CSE 2001 | Question: 2.20

Which of the following does not interrupt a running process?

A. A device B. Timer C. Scheduler process D. Power failure

gatecse-2001 operating-system easy process

Answer key

7.18.3 Process: GATE CSE 2002 | Question: 2.21

Which combination of the following features will suffice to characterize an OS as a multi-programmed OS?

a. More than one program may be loaded into main memory at the same time for execution
b. If a program waits for certain events such as I/O, another program is immediately scheduled for execution
c. If the execution of a program terminates, another program is immediately scheduled for execution.

A. (a)
B. (a) and (b)
C. (a) and (c)
D. (a), (b) and (c)

gatecse-2002 operating-system normal process

Answer key

7.18.4 Process: GATE CSE 2023 | Question: 12

Which one or more of the following need to be saved on a context switch from one thread $(\mathrm{T1})$ of a process to another thread $(\mathrm{T2})$ of the same process?

A. Page table base register
B. Stack pointer
C. Program counter
D. General purpose registers

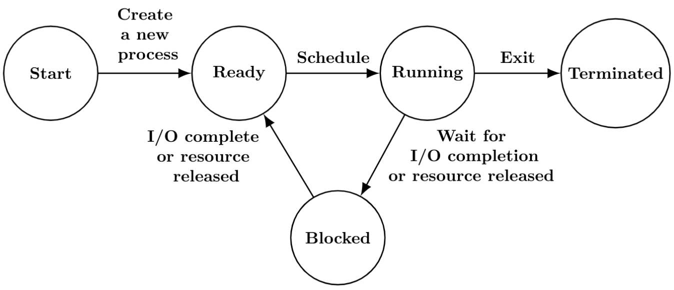
gatecse-2023 operating-system process multiple-selects one-mark

Answer key

7.18.5 Process: GATE IT 2006 | Question: 13

The process state transition diagram of an operating system is as given below.

Which of the following must be FALSE about the above operating system?



A. It is a multiprogrammed operating system
B. It uses preemptive scheduling
C. It uses non-preemptive scheduling
D. It is a multi-user operating system

gateit-2006 operating-system normal process

Answer key

7.19 Process Scheduling (48)

7.19.1 Process Scheduling: GATE CSE 1988 | Question: 2xa

State any undesirable characteristic of the following criteria for measuring performance of an operating system:

Turn around time

gate1988 normal descriptive operating-system process-scheduling

Answer key

7.19.2 Process Scheduling: GATE CSE 1988 | Question: 2xb

State any undesirable characteristic of the following criteria for measuring performance of an operating system:

Waiting time

gate1988 normal descriptive operating-system process-scheduling

Answer key

7.19.3 Process Scheduling: GATE CSE 1990 | Question: 1-vi

The highest-response ratio next scheduling policy favours ___________ jobs, but it also limits the waiting time of _________ jobs.

gate1990 operating-system process-scheduling fill-in-the-blanks

Answer key

7.19.4 Process Scheduling: GATE CSE 1993 | Question: 7.10

Assume that the following jobs are to be executed on a single processor system

Job Id	CPU Burst Time
p	4
q	1
r	8
s	1
t	2

The jobs are assumed to have arrived at time 0^+ and in the order p, q, r, s, t. Calculate the departure time (completion time) for job p if scheduling is round robin with time slice 1

A. 4
B. 10
C. 11
D. 12
E. None of the above

gate1993 operating-system process-scheduling normal

Answer key

7.19.5 Process Scheduling: GATE CSE 1995 | Question: 1.15

Which scheduling policy is most suitable for a time shared operating system?

A. Shortest Job First
B. Round Robin
C. First Come First Serve
D. Elevator

gate1995 operating-system process-scheduling easy

Answer key

7.19.6 Process Scheduling: GATE CSE 1995 | Question: 2.6

The sequence __________ is an optimal non-preemptive scheduling sequence for the following jobs which leaves the CPU idle for ________ unit(s) of time.

Job	Arrival Time	Burst Time
1	0.0	9
2	0.6	5
3	1.0	1

A. $\{3,2,1\},1$
B. $\{2,1,3\},0$
C. $\{3,2,1\},0$
D. $\{1,2,3\},5$

gate1995 operating-system process-scheduling normal

Answer key

7.19.7 Process Scheduling: GATE CSE 1996 | Question: 2.20, ISRO2008-15

Four jobs to be executed on a single processor system arrive at time 0 in the order A, B, C, D. Their burst CPU time requirements are $4, 1, 8, 1$ time units respectively. The completion time of A under round robin scheduling with time slice of one time unit is

A. 10
B. 4
C. 8
D. 9

gate1996 operating-system process-scheduling normal isro2008

Answer key

7.19.8 Process Scheduling: GATE CSE 1998 | Question: 2.17, UGCNET-Dec2012-III: 43

Consider n processes sharing the CPU in a round-robin fashion. Assuming that each process switch takes s seconds, what must be the quantum size q such that the overhead resulting from process switching is minimized but at the same time each process is guaranteed to get its turn at the CPU at least every t seconds?

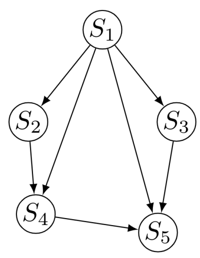
A. $q \leq \frac{t-ns}{n-1}$
B. $q \geq \frac{t-ns}{n-1}$
C. $q \leq \frac{t-ns}{n+1}$
D. $q \geq \frac{t-ns}{n+1}$

gate1998 operating-system process-scheduling normal ugcnetcse-dec2012-paper3

Answer key

7.19.9 Process Scheduling: GATE CSE 1998 | Question: 24

a. Four jobs are waiting to be run. Their expected run times are $6, 3, 5$ and x. In what order should they be run to minimize the average response time?
b. Write a concurrent program using par begin-par end to represent the precedence graph shown below.



gate1998 operating-system process-scheduling descriptive

Answer key

7.19.10 Process Scheduling: GATE CSE 1998 | Question: 7-b

In a computer system where the 'best-fit' algorithm is used for allocating 'jobs' to 'memory partitions', the following situation was encountered:

Partitions size in KB	$4K$ $8K$ $20K$ $2K$
Job sizes in KB	$2K$ $14K$ $3K$ $6K$ $6K$ $10K$ $20K$ $2K$
Time for execution	4 10 2 1 4 1 8 6

When will the $20K$ job complete?

gate1998 operating-system process-scheduling normal

Answer key

7.19.11 Process Scheduling: GATE CSE 2002 | Question: 1.22

Which of the following scheduling algorithms is non-preemptive?

A. Round Robin
B. First-In First-Out
C. Multilevel Queue Scheduling
D. Multilevel Queue Scheduling with Feedback

gatecse-2002 operating-system process-scheduling easy

Answer key

7.19.12 Process Scheduling: GATE CSE 2003 | Question: 77

A uni-processor computer system only has two processes, both of which alternate 10 ms CPU bursts with 90 ms I/O bursts. Both the processes were created at nearly the same time. The I/O of both processes can proceed in parallel. Which of the following scheduling strategies will result in the *least* CPU utilization (over a long period of time) for this system?

A. First come first served scheduling
B. Shortest remaining time first scheduling
C. Static priority scheduling with different priorities for the two processes
D. Round robin scheduling with a time quantum of 5 ms

gatecse-2003 operating-system process-scheduling normal

Answer key☟

7.19.13 Process Scheduling: GATE CSE 2004 | Question: 46

Consider the following set of processes, with the arrival times and the CPU-burst times gives in milliseconds.

Process	Arrival Time	Burst Time
P1	0	5
P2	1	3
P3	2	3
P4	4	1

What is the average turnaround time for these processes with the preemptive shortest remaining processing time first (SRPT) algorithm?

A. 5.50 B. 5.75 C. 6.00 D. 6.25

gatecse-2004 operating-system process-scheduling normal

Answer key☟

7.19.14 Process Scheduling: GATE CSE 2006 | Question: 06, ISRO2009-14

Consider three CPU-intensive processes, which require 10, 20 and 30 time units and arrive at times 0, 2 and 6, respectively. How many context switches are needed if the operating system implements a shortest remaining time first scheduling algorithm? Do not count the context switches at time zero and at the end.

A. 1 B. 2 C. 3 D. 4

gatecse-2006 operating-system process-scheduling normal isro2009

Answer key☟

7.19.15 Process Scheduling: GATE CSE 2006 | Question: 64

Consider three processes (process id 0, 1, 2 respectively) with compute time bursts 2, 4 and 8 time units. All processes arrive at time zero. Consider the longest remaining time first (LRTF) scheduling algorithm. In LRTF ties are broken by giving priority to the process with the lowest process id. The average turn around time is:

A. 13 units B. 14 units C. 15 units D. 16 units

gatecse-2006 operating-system process-scheduling normal

Answer key☟

7.19.16 Process Scheduling: GATE CSE 2006 | Question: 65

Consider three processes, all arriving at time zero, with total execution time of 10, 20 and 30 units, respectively. Each process spends the first 20% of execution time doing I/O, the next 70% of time doing computation, and the last 10% of time doing I/O again. The operating system uses a shortest remaining compute time first scheduling algorithm and schedules a new process either when the running process gets blocked on I/O or when the running process finishes its compute burst. Assume that all I/O operations can be overlapped as much as possible. For what percentage of time does the CPU remain idle?

A. 0% B. 10.6% C. 30.0% D. 89.4%

gatecse-2006 operating-system process-scheduling normal

Answer key

7.19.17 Process Scheduling: GATE CSE 2007 | Question: 16

Group 1 contains some CPU scheduling algorithms and Group 2 contains some applications. Match entries in Group 1 to entries in Group 2.

Group I		Group II	
(P)	Gang Scheduling	(1)	Guaranteed Scheduling
(Q)	Rate Monotonic Scheduling	(2)	Real-time Scheduling
(R)	Fair Share Scheduling	(3)	Thread Scheduling

A. $P-3; Q-2; R-1$ B. $P-1; Q-2; R-3$ C. $P-2; Q-3; R-1$ D. $P-1; Q-3; R-2$

gatecse-2007 operating-system process-scheduling normal

Answer key

7.19.18 Process Scheduling: GATE CSE 2007 | Question: 55

An operating system used Shortest Remaining System Time first (SRT) process scheduling algorithm. Consider the arrival times and execution times for the following processes:

Process	Execution Time	Arrival Time
P1	20	0
P2	25	15
P3	10	30
P4	15	45

What is the total waiting time for process $P2$?

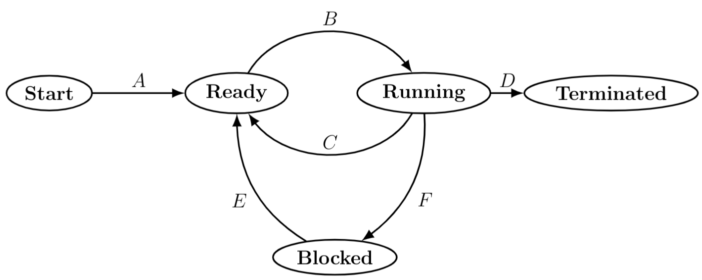
A. 5 B. 15 C. 40 D. 55

gatecse-2007 operating-system process-scheduling normal

Answer key

7.19.19 Process Scheduling: GATE CSE 2009 | Question: 32

In the following process state transition diagram for a uniprocessor system, assume that there are always some processes in the ready state:



Now consider the following statements:

I. If a process makes a transition D, it would result in another process making transition A immediately.
II. A process P_2 in blocked state can make transition E while another process P_1 is in running state.
III. The OS uses preemptive scheduling.
IV. The OS uses non-preemptive scheduling.

Which of the above statements are TRUE?

A. I and II B. I and III C. II and III D. II and IV

gatecse-2009 operating-system process-scheduling normal

Answer key

7.19.20 Process Scheduling: GATE CSE 2010 | Question: 25

Which of the following statements are true?

I. Shortest remaining time first scheduling may cause starvation
II. Preemptive scheduling may cause starvation
III. Round robin is better than FCFS in terms of response time

A. I only
B. I and III only
C. II and III only
D. I, II and III

gatecse-2010 operating-system process-scheduling easy

Answer key

7.19.21 Process Scheduling: GATE CSE 2011 | Question: 35

Consider the following table of arrival time and burst time for three processes $P0, P1$ and $P2.$

Process	Arrival Time	Burst Time
P0	0 ms	9
P1	1 ms	4
P2	2 ms	9

The pre-emptive shortest job first scheduling algorithm is used. Scheduling is carried out only at arrival or completion of processes. What is the average waiting time for the three processes?

A. 5.0 ms
B. 4.33 ms
C. 6.33 ms
D. 7.33 ms

gatecse-2011 operating-system process-scheduling normal

Answer key

7.19.22 Process Scheduling: GATE CSE 2012 | Question: 31

Consider the 3 processes, $P1, P2$ and $P3$ shown in the table.

Process	Arrival Time	Time Units Required
P1	0	5
P2	1	7
P3	3	4

The completion order of the 3 processes under the policies FCFS and RR2 (round robin scheduling with CPU quantum of 2 time units) are

A. **FCFS**: $P1, P2, P3$ **RR2**: $P1, P2, P3$
B. **FCFS**: $P1, P3, P2$ **RR2**: $P1, P3, P2$
C. **FCFS**: $P1, P2, P3$ **RR2**: $P1, P3, P2$
D. **FCFS**: $P1, P3, P2$ **RR2**: $P1, P2, P3$

gatecse-2012 operating-system process-scheduling normal

Answer key

7.19.23 Process Scheduling: GATE CSE 2013 | Question: 10

A scheduling algorithm assigns priority proportional to the waiting time of a process. Every process starts with zero (the lowest priority). The scheduler re-evaluates the process priorities every T time units and decides the next process to schedule. Which one of the following is **TRUE** if the processes have no I/O operations and all arrive at time zero?

A. This algorithm is equivalent to the first-come-first-serve algorithm.
B. This algorithm is equivalent to the round-robin algorithm.
C. This algorithm is equivalent to the shortest-job-first algorithm.
D. This algorithm is equivalent to the shortest-remaining-time-first algorithm.

gatecse-2013 operating-system process-scheduling normal

Answer key

7.19.24 Process Scheduling: GATE CSE 2014 Set 1 | Question: 32

Consider the following set of processes that need to be scheduled on a single CPU. All the times are given in milliseconds.

Process Name	Arrival Time	Execution Time
A	0	6
B	3	2
C	5	4
D	7	6
E	10	3

Using the *shortest remaining time first* scheduling algorithm, the average process turnaround time (in msec) is ____________________.

gatecse-2014-set1 operating-system process-scheduling numerical-answers normal

Answer key

7.19.25 Process Scheduling: GATE CSE 2014 Set 2 | Question: 32

Three processes A, B and C each execute a loop of 100 iterations. In each iteration of the loop, a process performs a single computation that requires t_c CPU milliseconds and then initiates a single I/O operation that lasts for t_{io} milliseconds. It is assumed that the computer where the processes execute has sufficient number of I/O devices and the OS of the computer assigns different I/O devices to each process. Also, the scheduling overhead of the OS is negligible. The processes have the following characteristics:

Process id	t_c	t_{io}
A	100 ms	500 ms
B	350 ms	500 ms
C	200 ms	500 ms

The processes A, B, and C are started at times 0, 5 and 10 milliseconds respectively, in a pure time sharing system (round robin scheduling) that uses a time slice of 50 milliseconds. The time in milliseconds at which process C would ***complete*** its first I/O operation is ___________.

gatecse-2014-set2 operating-system process-scheduling numerical-answers normal

Answer key

7.19.26 Process Scheduling: GATE CSE 2014 Set 3 | Question: 32

An operating system uses *shortest remaining time first* scheduling algorithm for pre-emptive scheduling of processes. Consider the following set of processes with their arrival times and CPU burst times (in milliseconds):

Process	Arrival Time	Burst Time
P1	0	12
P2	2	4
P3	3	6
P4	8	5

The average waiting time (in milliseconds) of the processes is ______.

gatecse-2014-set3 operating-system process-scheduling numerical-answers normal

Answer key

7.19.27 Process Scheduling: GATE CSE 2015 Set 1 | Question: 46

Consider a uniprocessor system executing three tasks T_1, T_2 and T_3 each of which is composed of an infinite sequence of jobs (or instances) which arrive periodically at intervals of $3, 7$ and 20 milliseconds, respectively. The priority of each task is the inverse of its period, and the available tasks are scheduled in order of priority, which is the highest priority task scheduled first. Each instance of T_1, T_2 and T_3 requires an execution time of $1, 2$ and 4 milliseconds, respectively. Given that all tasks initially arrive at the beginning of the 1^{st} millisecond and task preemptions are allowed, the first instance of T_3 completes its execution at the end of_____________________milliseconds.

gatecse-2015-set1 operating-system process-scheduling normal numerical-answers

Answer key

7.19.28 Process Scheduling: GATE CSE 2015 Set 3 | Question: 1

The maximum number of processes that can be in $Ready$ state for a computer system with n CPUs is :

A. n
B. n^2
C. 2^n
D. Independent of n

gatecse-2015-set3 operating-system process-scheduling easy

Answer key

7.19.29 Process Scheduling: GATE CSE 2015 Set 3 | Question: 34

For the processes listed in the following table, which of the following scheduling schemes will give the lowest average turnaround time?

Process	Arrival Time	Process Time
A	0	3
B	1	6
C	4	4
D	6	2

A. First Come First Serve
B. Non-preemptive Shortest job first
C. Shortest Remaining Time
D. Round Robin with Quantum value two

gatecse-2015-set3 operating-system process-scheduling normal

Answer key

7.19.30 Process Scheduling: GATE CSE 2016 Set 1 | Question: 20

Consider an arbitrary set of CPU-bound processes with unequal CPU burst lengths submitted at the same time to a computer system. Which one of the following process scheduling algorithms would minimize the average waiting time in the ready queue?

A. Shortest remaining time first
B. Round-robin with the time quantum less than the shortest CPU burst
C. Uniform random
D. Highest priority first with priority proportional to CPU burst length

gatecse-2016-set1 operating-system process-scheduling normal

Answer key

7.19.31 Process Scheduling: GATE CSE 2016 Set 2 | Question: 47

Consider the following processes, with the arrival time and the length of the CPU burst given in milliseconds. The scheduling algorithm used is preemptive shortest remaining-time first.

Process	Arrival Time	Burst Time
P_1	0	10
P_2	3	6
P_3	7	1
P_4	8	3

The average turn around time of these processes is ___________ milliseconds.

gatecse-2016-set2 operating-system process-scheduling normal numerical-answers

Answer key

7.19.32 Process Scheduling: GATE CSE 2017 Set 1 | Question: 24

Consider the following CPU processes with arrival times (in milliseconds) and length of CPU bursts (in milliseconds) as given below:

Process	Arrival Time	Burst Time
P_1	0	7
P_2	3	3
P_3	5	5
P_4	6	2

If the pre-emptive shortest remaining time first scheduling algorithm is used to schedule the processes, then the average waiting time across all processes is _____________ milliseconds.

gatecse-2017-set1 operating-system process-scheduling numerical-answers

Answer key

7.19.33 Process Scheduling: GATE CSE 2017 Set 2 | Question: 51

Consider the set of process with arrival time (in milliseonds), CPU burst time (in millisecods) and priority (0 is the highest priority) shown below. None of the process have I/O burst time

Process	Arrival Time	Burst Time	Priority
P_1	0	11	2
P_2	5	28	0
P_3	12	2	3
P_4	2	10	1
P_5	9	16	4

The average waiting time (in milli seconds) of all the process using premtive priority scheduling algorithm is ______

gatecse-2017-set2 operating-system process-scheduling numerical-answers

Answer key

7.19.34 Process Scheduling: GATE CSE 2019 | Question: 41

Consider the following four processes with arrival times (in milliseconds) and their length of CPU bursts (in milliseconds) as shown below:

Process	$P1$	$P2$	$P3$	$P4$
Arrival Time	0	1	3	4
CPU burst time	3	1	3	Z

These processes are run on a single processor using preemptive Shortest Remaining Time First scheduling algorithm. If the average waiting time of the processes is 1 millisecond, then the value of Z is _____

gatecse-2019 numerical-answers operating-system process-scheduling two-marks

Answer key

7.19.35 Process Scheduling: GATE CSE 2020 | Question: 12

Consider the following statements about process state transitions for a system using preemptive scheduling.

I. A running process can move to ready state.
II. A ready process can move to running state.
III. A blocked process can move to running state.
IV. A blocked process can move to ready state.

Which of the above statements are TRUE?

A. I, II, and III only
B. II and III only
C. I, II, and IV only
D. I, II, III and IV only

gatecse-2020 operating-system process-scheduling one-mark easy

Answer key

7.19.36 Process Scheduling: GATE CSE 2020 | Question: 50

Consider the following set of processes, assumed to have arrived at time 0. Consider the CPU scheduling algorithms Shortest Job First (SJF) and Round Robin (RR). For RR, assume that the processes are scheduled in the order P_1, P_2, P_3, P_4.

Processes	P_1	P_2	P_3	P_4
Burst time (in ms)	8	7	2	4

If the time quantum for RR is 4 ms, then the absolute value of the difference between the average turnaround times (in ms) of SJF and RR (round off to 2 decimal places is_______

gatecse-2020 numerical-answers operating-system process-scheduling two-marks

Answer key

7.19.37 Process Scheduling: GATE CSE 2021 Set 1 | Question: 25

Three processes arrive at time zero with CPU bursts of $16,\ 20$ and 10 milliseconds. If the scheduler has prior knowledge about the length of the CPU bursts, the minimum achievable average waiting time for these three processes in a non-preemptive scheduler (rounded to nearest integer) is _____________ milliseconds.

gatecse-2021-set1 operating-system process-scheduling numerical-answers one-mark

Answer key

7.19.38 Process Scheduling: GATE CSE 2021 Set 2 | Question: 14

Which of the following statement(s) is/are correct in the context of CPU scheduling?

A. Turnaround time includes waiting time
B. The goal is to only maximize CPU utilization and minimize throughput
C. Round-robin policy can be used even when the CPU time required by each of the processes is not known apriori
D. Implementing preemptive scheduling needs hardware support

gatecse-2021-set2 multiple-selects operating-system process-scheduling one-mark

Answer key

7.19.39 Process Scheduling: GATE CSE 2022 | Question: 32

Consider four processes P, Q, R, and S scheduled on a CPU as per round robin algorithm with a time quantum of $4 \text{ units}.$ The processes arrive in the order $\text{P, Q, R, S},$ all at time $\text{t} = 0.$ There is exactly one context switch from S to $\text{Q},$ exactly one context switch from R to $\text{Q},$ and exactly two context switches from Q to $\text{R}.$ There is no context switch from S to $\text{P}.$ Switching to a ready process after the termination of another process is also considered a context switch. Which one of the following is NOT possible as CPU burst time (in time units) of these processes?

A. $\mathrm{P}=4, \mathrm{Q}=10, \mathrm{R}=6, \mathrm{S}=2$
B. $\mathrm{P}=2, \mathrm{Q}=9, \mathrm{R}=5, \mathrm{S}=1$
C. $\mathrm{P}=4, \mathrm{Q}=12, \mathrm{R}=5, \mathrm{S}=4$
D. $\mathrm{P}=3, \mathrm{Q}=7, \mathrm{R}=7, \mathrm{S}=3$

gatecse-2022 operating-system process-scheduling round-robin-scheduling two-marks

Answer key

7.19.40 Process Scheduling: GATE CSE 2023 | Question: 17

Which one or more of the following CPU scheduling algorithms can potentially cause starvation?

A. First-in First-Out
B. Round Robin
C. Priority Scheduling
D. Shortest Job First

gatecse-2023 operating-system process-scheduling multiple-selects one-mark

Answer key

7.19.41 Process Scheduling: GATE CSE 2024 | Set 1 | Question: 15

Which of the following process state transitions is/are NOT possible?

A. Running to Ready
B. Waiting to Running
C. Ready to Waiting
D. Running to Terminated

gatecse2024-set1 operating-system process-scheduling multiple-selects one-mark

Answer key

7.19.42 Process Scheduling: GATE CSE 2024 | Set 2 | Question: 27

Consider a single processor system with four processes $\mathrm{A}, \mathrm{B}, \mathrm{C},$ and D, represented as given below, where for each process the first value is its arrival time, and the second value is its CPU burst time.

$\mathrm{A}(0,10), \mathrm{B}(2,6), \mathrm{C}(4,3)$, and $\mathrm{D}(6,7)$.

Which one of the following options gives the average waiting times when preemptive Shortest Remaining Time First (SRTF) and Non-Preemptive Shortest Job First $(\mathrm{NP\text{-}SJF})$ CPU scheduling algorithms are applied to the processes?

A. $\mathrm{SRTF}=6, \mathrm{NP}-\mathrm{SJF}=7$
B. $\mathrm{SRTF}=6, \mathrm{NP}-\mathrm{SJF}=7.5$
C. $\mathrm{SRTF}=7, \mathrm{NP}-\mathrm{SJF}=7.5$
D. $\mathrm{SRTF}=7, \mathrm{NP}-\mathrm{SJF}=8.5$

gatecse2024-set2 operating-system process-scheduling two-marks

Answer key

7.19.43 Process Scheduling: GATE CSE 2025 | Set 1 | Question: 28

A computer has two processors, M_1 and M_2. Four processes P_1, P_2, P_3, P_4 with CPU bursts of $20, 16, 25$, and 10 milliseconds, respectively, arrive at the same time and these are the only processes in the system. The scheduler uses non-preemptive priority scheduling, with priorities decided as follows:

- M_1 uses priority of execution for the processes as, $P_1 > P_3 > P_2 > P_4$, i.e., P_1 and P_4 have highest and lowest priorities, respectively.
- M_2 uses priority of execution for the processes as, $P_2 > P_3 > P_4 > P_1$, i.e., P_2 and P_1 have highest and lowest priorities, respectively.

A process P_i is scheduled to a processor M_k, if the processor is free and no other process P_j is waiting with higher priority. At any given point of time, a process can be allocated to any one of the free processors without violating the execution priority rules. Ignore the context switch time. What will be the average waiting time of the processes in milliseconds?

A. 9.00
B. 8.75
C. 6.50
D. 7.50

gatecse2025-set1 operating-system process-scheduling two-marks

Answer key

7.19.44 Process Scheduling: GATE IT 2005 | Question: 60

We wish to schedule three processes $P1$, $P2$ and $P3$ on a uniprocessor system. The priorities, CPU time requirements and arrival times of the processes are as shown below.

Process	Priority	CPU time required	Arrival time (hh:mm:ss)
P1	10 (highest)	20 sec	00 : 00 : 05
P2	9	10 sec	00 : 00 : 03
P3	8 (lowest)	15 sec	00 : 00 : 00

We have a choice of preemptive or non-preemptive scheduling. In preemptive scheduling, a late-arriving higher priority process can preempt a currently running process with lower priority. In non-preemptive scheduling, a late-arriving higher priority process must wait for the currently executing process to complete before it can be scheduled on the processor.
What are the turnaround times (time from arrival till completion) of $P2$ using preemptive and non-preemptive scheduling respectively?

A. 30 sec, 30 sec
B. 30 sec, 10 sec
C. 42 sec, 42 sec
D. 30 sec, 42 sec

gateit-2005 operating-system process-scheduling normal

Answer key

7.19.45 Process Scheduling: GATE IT 2006 | Question: 12

In the working-set strategy, which of the following is done by the operating system to prevent thrashing?

I. It initiates another process if there are enough extra frames.
II. It selects a process to suspend if the sum of the sizes of the working-sets exceeds the total number of available frames.

A. I only
B. II only
C. Neither I nor II
D. Both I and II

gateit-2006 operating-system process-scheduling normal

Answer key

7.19.46 Process Scheduling: GATE IT 2006 | Question: 54

The arrival time, priority, and duration of the CPU and I/O bursts for each of three processes P_1, P_2 and P_3 are given in the table below. Each process has a CPU burst followed by an I/O burst followed by another CPU burst. Assume that each process has its own I/O resource.

Process	Arrival Time	Priority	Burst duration (CPU)	Burst duration (I/O)	Burst duration) (CPU)
P_1	0	2	1	5	3
P_2	2	3 (lowest)	3	3	1
P_3	3	1 (highest)	2	3	1

The multi-programmed operating system uses preemptive priority scheduling. What are the finish times of the processes P_1, P_2 and P_3?

A. $11, 15, 9$
B. $10, 15, 9$
C. $11, 16, 10$
D. $12, 17, 11$

gateit-2006 operating-system process-scheduling normal

Answer key

7.19.47 Process Scheduling: GATE IT 2007 | Question: 26

Consider n jobs $J_1, J_2 \dots J_n$ such that job J_i has execution time t_i and a non-negative integer weight w_i. The weighted mean completion time of the jobs is defined to be $\frac{\sum_{i=1}^{n} w_i T_i}{\sum_{i=1}^{n} w_i}$, where T_i is the completion time of job J_i. Assuming that there is only one processor available, in what order must the jobs be executed in order to minimize the weighted mean completion time of the jobs?

A. Non-decreasing order of t_i
B. Non-increasing order of w_i
C. Non-increasing order of $w_i t_i$
D. Non-increasing order of w_i/t_i

gateit-2007 operating-system process-scheduling normal

Answer key

7.19.48 Process Scheduling: GATE IT 2008 | Question: 55

If the time-slice used in the round-robin scheduling policy is more than the maximum time required to execute any process, then the policy will

A. degenerate to shortest job first
B. degenerate to priority scheduling
C. degenerate to first come first serve
D. none of the above

gateit-2008 operating-system process-scheduling easy

Answer key

7.20 Process Synchronization (52)

7.20.1 Process Synchronization: GATE CSE 1987 | Question: 1-xvi

A critical region is

A. One which is enclosed by a pair of P and V operations on semaphores.
B. A program segment that has not been proved bug-free.
C. A program segment that often causes unexpected system crashes.
D. A program segment where shared resources are accessed.

gate1987 operating-system process-synchronization

Answer key

7.20.2 Process Synchronization: GATE CSE 1987 | Question: 8a

Consider the following proposal to the "readers and writers problem."

Shared variables and semaphores:

```
aw, ar, rw, rr : interger;
mutex, reading, writing: semaphore:
initial values of variables and states of semaphores:
ar=rr=aw=rw=0
reading_value = writing_value = 0
mutex_value = 1.                    Process writer;
Process reader;                       begin
begin                               while true do
repeat                              begin
       P(mutex);                          P(mutex);
       ar := ar+1;                        aw := aw + 1;
       grantread;                         grantwrite;
       V(mutex);                          V(mutex);
       P(reading);                        P(writing);
       read;                        Write;
       P(mutex);                       P(mutex);
       rr := rr - 1;                rw := rw - 1;
       ar := ar - 1;                 ar := aw - 1;
       grantwrite;                    grantread;
       V(mutex);                       V(mutex);
       other-work;                     other-work;
until false                   end
end.                         end.

Procedure grantread;
begin
   if aw = 0
```

```
  then while (rr < ar) do
     begin rr := rr + 1;
        V (reading)
     end
end;
Procedure grantwrite;
begin
  if rr = 0
  then while (rw < aw) do
     begin rw := rw + 1;
        V (writing)
     end
end;
```

a. Give the value of the shared variables and the states of semaphores when 12 readers are reading and writers are writing.
b. Can a group of readers make waiting writers starve? Can writers starve readers?
c. Explain in two sentences why the solution is incorrect.

gate1987 operating-system process-synchronization descriptive

Answer key

7.20.3 Process Synchronization: GATE CSE 1988 | Question: 10iib

Given below is solution for the critical section problem of two processes P_0 and P_1 sharing the following variables:

```
  var flag :array [0..1] of boolean; (initially false)
    turn: 0 .. 1;
```

The program below is for process $P_i (i = 0 \text{ or } 1)$ where process $P_j (j = 1 \text{ or } 0)$ being the other one.

```
repeat
    flag[i]:= true;
    while turn != i
    do begin
        while flag [j] do skip
        turn:=i;
    end

    critical section

    flag[i]:=false;
until false
```

Determine of the above solution is correct. If it is incorrect, demonstrate with an example how it violates the conditions.

gate1988 descriptive operating-system process-synchronization

Answer key

7.20.4 Process Synchronization: GATE CSE 1990 | Question: 2-iii

Match the pairs:

(a)	Critical region	(p)	Hoare's monitor
(b)	Wait/Signal	(q)	Mutual exclusion
(c)	Working Set	(r)	Principle of locality
(d)	Deadlock	(s)	Circular Wait

match-the-following gate1990 operating-system process-synchronization

Answer key

7.20.5 Process Synchronization: GATE CSE 1991 | Question: 11,a

Consider the following scheme for implementing a critical section in a situation with three processes P_i, P_j

and P_k.

```
Pi;
repeat
   flag[i] := true;
   while flag [j] or flag[k] do
      case turn of
      j: if flag [j] then
      begin
         flag [i] := false;
         while turn != i do skip;
         flag [i] := true;
      end;
      k: if flag [k] then
      begin
         flag [i] := false,
         while turn != i do skip;
         flag [i] := true
      end
   end
   critical section
   if turn = i then turn := j;
      flag [i] := false
   non-critical section
until false;
```

a. Does the scheme ensure mutual exclusion in the critical section? Briefly explain.

gate1991 process-synchronization normal operating-system descriptive

Answer key☟

7.20.6 Process Synchronization: GATE CSE 1991 | Question: 11,b

Consider the following scheme for implementing a critical section in a situation with three processes P_i, P_j and P_k.

Pi;

```
repeat
   flag[i] := true;
   while flag [j] or flag[k] do
      case turn of
      j: if flag [j] then
      begin
         flag [i] := false;
         while turn != i do skip;
         flag [i] := true;
      end;
      k: if flag [k] then
      begin
         flag [i] := false,
         while turn != i do skip;
         flag [i] := true
      end
   end
   critical section
   if turn = i then turn := j;
      flag [i] := false
   non-critical section
until false;
```

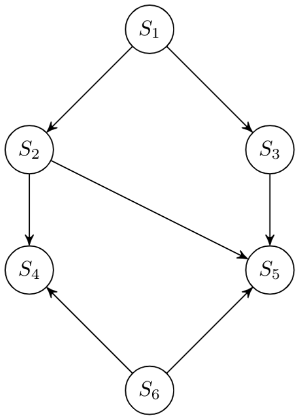
Is there a situation in which a waiting process can never enter the critical section? If so, explain and suggest modifications to the code to solve this problem

gate1991 process-synchronization normal operating-system descriptive

Answer key☟

7.20.7 Process Synchronization: GATE CSE 1993 | Question: 22

Write a concurrent program using parbegin-parend and semaphores to represent the precedence constraints of the statements S_1 to S_6, as shown in figure below.



gate1993 operating-system process-synchronization normal descriptive

Answer key

7.20.8 Process Synchronization: GATE CSE 1994 | Question: 27

A. Draw a precedence graph for the following sequential code. The statements are numbered from S_1 to S_6

S_1	read n
S_2	i := 1
S_3	if i > n next
S_4	a(i) := i+1
S_5	i := i+1
S_6	next : write a(i)

B. Can this graph be converted to a concurrent program using parbegin-parend construct only?

gate1994 operating-system process-synchronization normal descriptive

Answer key

7.20.9 Process Synchronization: GATE CSE 1995 | Question: 19

Consider the following program segment for concurrent processing using semaphore operators P and V for synchronization. Draw the precedence graph for the statements S_1 to S_9.

```
var
a,b,c,d,e,f,g,h,i,j,k : semaphore;
begin
cobegin
   begin S1; V(a); V(b) end;
   begin P(a); S2; V(c); V(d) end;
   begin P(c); S4; V(e) end;
   begin P(d); S5; V(f) end;
   begin P(e); P(f); S7; V(k) end
   begin P(b); S3; V(g); V(h) end;
   begin P(g); S6; V(i) end;
   begin P(h); P(i); S8; V(j) end;
   begin P(j); P(k); S9 end;
coend
end;
```

gate1995 operating-system process-synchronization normal descriptive

Answer key

7.20.10 Process Synchronization: GATE CSE 1996 | Question: 1.19, ISRO2008-61

A critical section is a program segment

A. which should run in a certain amount of time
B. which avoids deadlocks

C. where shared resources are accessed
D. which must be enclosed by a pair of semaphore operations, P and V

gate1996 operating-system process-synchronization easy isro2008

Answer key

7.20.11 Process Synchronization: GATE CSE 1996 | Question: 2.19

A solution to the Dining Philosophers Problem which avoids deadlock is to

A. ensure that all philosophers pick up the left fork before the right fork
B. ensure that all philosophers pick up the right fork before the left fork
C. ensure that one particular philosopher picks up the left fork before the right fork, and that all other philosophers pick up the right fork before the left fork
D. None of the above

gate1996 operating-system process-synchronization normal

Answer key

7.20.12 Process Synchronization: GATE CSE 1996 | Question: 21

The concurrent programming constructs fork and join are as below:

Fork <label> which creates a new process executing from the specified label

Join <variable> which decrements the specified synchronization variable (by 1) and terminates the process if the new value is not 0.

Show the precedence graph for $S1$, $S2$, $S3$, $S4$, and $S5$ of the concurrent program below.

```
N=2
M=2
Fork L3
Fork L4
S1
L1 : join N
S3
L2 : join M
S5
L3:S2
Goto L1
L4:S4
Goto L2
Next:
```

gate1996 operating-system process-synchronization normal descriptive

Answer key

7.20.13 Process Synchronization: GATE CSE 1997 | Question: 6.8

Each Process $P_i, i = 1 \dots 9$ is coded as follows

repeat
  P(mutex)
  {Critical section}
  V(mutex)
forever

The code for P_{10} is identical except it uses V(mutex) in place of P(mutex). What is the largest number of processes that can be inside the critical section at any moment?

A. 1 B. 2 C. 3 D. None

gate1997 operating-system process-synchronization normal

Answer key

7.20.14 Process Synchronization: GATE CSE 1997 | Question: 73

A concurrent system consists of 3 processes using a shared resource R in a non-preemptible and mutually exclusive manner. The processes have unique priorities in the range $1\dots 3$, 3 being the highest priority. It is required to synchronize the processes such that the resource is always allocated to the highest priority requester. The pseudo code for the system is as follows.

Shared data

```
mutex:semaphore = 1:/* initialized to 1*/

process[3]:semaphore = 0; /*all initialized to 0 */

R_requested [3]:boolean = false; /*all initialized to flase */

busy: boolean = false; /*initialized to false */
```

Code for processes

```
begin process
my-priority:integer;
my-priority:=___; /*in the range 1..3*/
repeat
    request_R(my-priority);
    P (proceed [my-priority]);
    {use shared resource R}
    release_R (my-priority);
forever
end process;
```

Procedures

```
procedure request_R(priority);
P(mutex);
if busy = true then
    R_requested [priority]:=true;
else
begin
    V(proceed [priority]);
    busy:=true;
end
V(mutex)
```

Give the pseudo code for the procedure release_R.

gate1997 operating-system process-synchronization descriptive

Answer key

7.20.15 Process Synchronization: GATE CSE 1998 | Question: 1.30

When the result of a computation depends on the speed of the processes involved, there is said to be

A. cycle stealing B. race condition C. a time lock D. a deadlock

gate1998 operating-system easy process-synchronization

Answer key

7.20.16 Process Synchronization: GATE CSE 1999 | Question: 20-a

A certain processor provides a 'test and set' instruction that is used as follows:

```
TSET register, flag
```

This instruction atomically copies flag to register and sets flag to 1. Give pseudo-code for implementing the entry and exit code to a critical region using this instruction.

gate1999 operating-system process-synchronization normal descriptive

Answer key

7.20.17 Process Synchronization: GATE CSE 1999 | Question: 20-b

Consider the following solution to the producer-consumer problem using a buffer of size 1. Assume that the initial value of count is 0. Also assume that the testing of count and assignment to count are atomic operations.

```
Producer:
Repeat
    Produce an item;
    if count = 1 then sleep;
    place item in buffer.
    count = 1;
    Wakeup(Consumer);
Forever

Consumer:
Repeat
    if count = 0 then sleep;
    Remove item from buffer;
    count = 0;
    Wakeup(Producer);
    Consume item;
Forever;
```

Show that in this solution it is possible that both the processes are sleeping at the same time.

gate1999 operating-system process-synchronization normal descriptive

Answer key

7.20.18 Process Synchronization: GATE CSE 2000 | Question: 1.21

Let $m[0] \ldots m[4]$ be mutexes (binary semaphores) and $P[0] \ldots P[4]$ be processes.
Suppose each process $P[i]$ executes the following:

```
wait (m[i]); wait (m(i+1) mod 4]);
...........
release (m[i]); release (m(i+1) mod 4]);
```

This could cause

A. Thrashing
B. Deadlock
C. Starvation, but not deadlock
D. None of the above

gatecse-2000 operating-system process-synchronization normal

Answer key

7.20.19 Process Synchronization: GATE CSE 2000 | Question: 20

a. Fill in the boxes below to get a solution for the reader-writer problem, using a single binary semaphore, mutex (initialized to 1) and busy waiting. Write the box numbers (1, 2 and 3), and their contents in your answer book.

```
int R = 0, W = 0;

Reader () {
 L1:   wait (mutex);
    if (W == 0) {
        R = R + 1;
        ▭ ________________(1)
    }
    else {
      ▭ ________________(2)
        goto L1;
    }
    ..../* do the read*/
    wait (mutex);
    R = R - 1;
    signal (mutex);
}
```

```
Writer () {
 L2:    wait (mutex);
    if (▭) { __________ (3)
        signal (mutex);
        goto L2;
    }
    W=1;
    signal (mutex);
    ...../*do the write*/
    wait( mutex);
    W=0;
    signal (mutex);
}
```

b. Can the above solution lead to starvation of writers?

gatecse-2000 operating-system process-synchronization normal descriptive

Answer key

7.20.20 Process Synchronization: GATE CSE 2001 | Question: 2.22

Consider Peterson's algorithm for mutual exclusion between two concurrent processes i and j. The program executed by process is shown below.

```
repeat
    flag[i] = true;
    turn = j;
    while (P) do no-op;
    Enter critical section, perform actions, then
    exit critical section
    Flag[i] = false;
    Perform other non-critical section actions.
Until false;
```

For the program to guarantee mutual exclusion, the predicate P in the while loop should be

A. flag[j] = true and turn = i
B. flag[j] = true and turn = j
C. flag[i] = true and turn = j
D. flag[i] = true and turn = i

gatecse-2001 operating-system process-synchronization normal

Answer key

7.20.21 Process Synchronization: GATE CSE 2002 | Question: 18-a

Draw the process state transition diagram of an OS in which (i) each process is in one of the five states: created, ready, running, blocked (i.e., sleep or wait), or terminated, and (ii) only non-preemptive scheduling is used by the OS. Label the transitions appropriately.

gatecse-2002 operating-system process-synchronization normal descriptive

Answer key

7.20.22 Process Synchronization: GATE CSE 2002 | Question: 18-b

The functionality of atomic TEST-AND-SET assembly language instruction is given by the following C function

```
int TEST-AND-SET (int *x)
{
    int y;
    A1: y=*x;
    A2: *x=1;
    A3: return y;
}
```

i. Complete the following C functions for implementing code for entering and leaving critical sections on the above TEST-AND-SET instruction.

```
int mutex=0;
void enter-cs()
{
    while(.....................);

}
void leave-cs()
{ .........................;

}
```

ii. Is the above solution to the critical section problem deadlock free and starvation-free?

iii. For the above solution, show by an example that mutual exclusion is not ensured if TEST-AND-SET instruction is not atomic?

gatecse-2002 operating-system process-synchronization normal descriptive

Answer key☟

7.20.23 Process Synchronization: GATE CSE 2002 | Question: 20

The following solution to the single producer single consumer problem uses semaphores for synchronization.

```
#define BUFFSIZE 100
buffer buf[BUFFSIZE];
int first = last = 0;
semaphore b_full = 0;
semaphore b_empty = BUFFSIZE

void producer()
{
while(1) {
    produce an item;
    p1:.................;
    put the item into buff (first);
    first = (first+1)%BUFFSIZE;
    p2: ...............;
    }
}

void consumer()
{
while(1) {
    c1:............
    take the item from buf[last];
    last = (last+1)%BUFFSIZE;
    c2:............;
    consume the item;
    }
}
```

A. Complete the dotted part of the above solution.

B. Using another semaphore variable, insert one line statement each immediately after $p1$, immediately before $p2$, immediately after $c1$ and immediately before $c2$ so that the program works correctly for multiple producers and consumers.

gatecse-2002 operating-system process-synchronization normal descriptive

Answer key

7.20.24 Process Synchronization: GATE CSE 2003 | Question: 80

Suppose we want to synchronize two concurrent processes P and Q using binary semaphores S and T. The code for the processes P and Q is shown below.

Process P:	Process Q:
`while(1){` `W:` `print '0';` `print '0';` `X:` `}`	`while(1){` `Y:` `print '1';` `print '1';` `Z:` `}`

Synchronization statements can be inserted only at points W, X, Y, and Z

Which of the following will always lead to an output staring with '001100110011'?

A. $P(S)$ at $W, V(S)$ at $X, P(T)$ at $Y, V(T)$ at Z, S and T initially 1
B. $P(S)$ at $W, V(T)$ at $X, P(T)$ at $Y, V(S)$ at Z, S initially 1, and T initially 0
C. $P(S)$ at $W, V(T)$ at $X, P(T)$ at $Y, V(S)$ at Z, S and T initially 1
D. $P(S)$ at $W, V(S)$ at $X, P(T)$ at $Y, V(T)$ at Z, S initially 1 , and T initially 0

gatecse-2003 operating-system process-synchronization normal

Answer key

7.20.25 Process Synchronization: GATE CSE 2003 | Question: 81

Suppose we want to synchronize two concurrent processes P and Q using binary semaphores S and T. The code for the processes P and Q is shown below.

Process P:	Process Q:
while(1) {	while(1) {
W:	Y:
print '0';	print '1';
print '0';	print '1';
X:	Z:
}	}

Synchronization statements can be inserted only at points W, X, Y, and Z

Which of the following will ensure that the output string never contains a substring of the form 01^n0 and 10^n1 where n is odd?

A. $P(S)$ at $W, V(S)$ at $X, P(T)$ at $Y, V(T)$ at Z, S and T initially 1
B. $P(S)$ at $W, V(T)$ at $X, P(T)$ at $Y, V(S)$ at Z, S and T initially 1
C. $P(S)$ at $W, V(S)$ at $X, P(S)$ at $Y, V(S)$ at Z, S initially 1
D. $V(S)$ at $W, V(T)$ at $X, P(S)$ at $Y, P(T)$ at Z, S and T initially 1

gatecse-2003 operating-system process-synchronization normal

Answer key

7.20.26 Process Synchronization: GATE CSE 2004 | Question: 48

Consider two processes P_1 and P_2 accessing the shared variables X and Y protected by two binary semaphores S_X and S_Y respectively, both initialized to 1. P and V denote the usual semaphore operators, where P decrements the semaphore value, and V increments the semaphore value. The pseudo-code of P_1 and P_2 is as follows:

P_1:	P_2:
While true do {	While true do {
$L_1 : \ldots\ldots$	$L_3 : \ldots\ldots$
$L_2 : \ldots\ldots$	$L_4 : \ldots\ldots$
$\mathrm{X} = \mathrm{X} + 1;$	$\mathrm{Y} = \mathrm{Y} + 1;$
$Y = Y - 1;$	$X = Y - 1;$
$V(S_X);$	$V(S_Y);$
$V(S_Y);$	$V(S_X);$
}	}

In order to avoid deadlock, the correct operators at L_1, L_2, L_3 and L_4 are respectively.

A. $P(S_Y), P(S_X); P(S_X), P(S_Y)$

B. $P(S_X), P(S_Y); P(S_Y), P(S_X)$

C. $P(S_X), P(S_X); P(S_Y), P(S_Y)$

D. $P(S_X), P(S_Y); P(S_X), P(S_Y)$

gatecse-2004 operating-system process-synchronization normal

Answer key

7.20.27 Process Synchronization: GATE CSE 2006 | Question: 61

The atomic *fetch-and-set* x, y instruction unconditionally sets the memory location x to 1 and fetches the old value of x in y without allowing any intervening access to the memory location x. Consider the following implementation of P and V functions on a binary semaphore S.

```
void P (binary_semaphore *s) {
   unsigned y;
   unsigned *x = &(s->value);
   do {
      fetch-and-set x, y;
   } while (y);
}

void V (binary_semaphore *s) {
   S->value = 0;
}
```

Which one of the following is true?

A. The implementation may not work if context switching is disabled in P
B. Instead of using *fetch-and –set*, a pair of normal load/store can be used
C. The implementation of V is wrong
D. The code does not implement a binary semaphore

gatecse-2006 operating-system process-synchronization normal

Answer key

7.20.28 Process Synchronization: GATE CSE 2006 | Question: 78

Barrier is a synchronization construct where a set of processes synchronizes globally i.e., each process in the set arrives at the barrier and waits for all others to arrive and then all processes leave the barrier. Let the number of processes in the set be three and S be a binary semaphore with the usual P and V functions. Consider the following C implementation of a barrier with line numbers shown on left.

void barrier (void) {

```
1: P(S);
2: process_arrived++;
3: V(S);
```

```
4: while (process_arrived !=3);
5: P(S);
6: process_left++;
7: if (process_left==3) {
8:     process_arrived = 0;
9:     process_left = 0;
10: }
11: V(S);
```

}

The variables *process_arrived* and *process_left* are shared among all processes and are initialized to zero. In a concurrent program all the three processes call the barrier function when they need to synchronize globally.

The above implementation of barrier is incorrect. Which one of the following is true?

A. The barrier implementation is wrong due to the use of binary semaphore S
B. The barrier implementation may lead to a deadlock if two barrier in invocations are used in immediate succession.
C. Lines 6 to 10 need not be inside a critical section
D. The barrier implementation is correct if there are only two processes instead of three.

gatecse-2006 operating-system process-synchronization normal

Answer key

7.20.29 Process Synchronization: GATE CSE 2006 | Question: 79

Barrier is a synchronization construct where a set of processes synchronizes globally i.e., each process in the set arrives at the barrier and waits for all others to arrive and then all processes leave the barrier. Let the number of processes in the set be three and S be a binary semaphore with the usual P and V functions. Consider the following C implementation of a barrier with line numbers shown on left.

void barrier (void) {

```
1 P(S);
2 process_arrived++;
3 V(S);
4 while (process_arrived !=3);
5   P(S);
6   process_left++;
7   if (process_left==3) {
8     process_arrived = 0;
9     process_left = 0;
10  }
11 V(S);
```

}

The variables process_arrived and process_left are shared among all processes and are initialized to zero. In a concurrent program all the three processes call the barrier function when they need to synchronize globally.

Which one of the following rectifies the problem in the implementation?

A. Lines 6 to 10 are simply replaced by process_arrived--
B. At the beginning of the barrier the first process to enter the barrier waits until process_arrived becomes zero before proceeding to execute $P(S)$.
C. Context switch is disabled at the beginning of the barrier and re-enabled at the end.
D. The variable process_left is made private instead of shared

gatecse-2006 operating-system process-synchronization normal

Answer key

7.20.30 Process Synchronization: GATE CSE 2007 | Question: 58

Two processes, $P1$ and $P2$, need to access a critical section of code. Consider the following synchronization construct used by the processes:

/* P1 */	/* P2 */

while (true) {
  wants1 = true;
  while (wants2 == true);
  /* Critical Section */
  wants1 = false;
}
/* Remainder section */
	while (true) {
	  wants2 = true;
	  while (wants1 == true);
	  /* Critical Section */
	  wants2=false;
	}
	/* Remainder section */

Here, wants1 and wants2 are shared variables, which are initialized to false.

Which one of the following statements is TRUE about the construct?

A. It does not ensure mutual exclusion.
B. It does not ensure bounded waiting.
C. It requires that processes enter the critical section in strict alteration.
D. It does not prevent deadlocks, but ensures mutual exclusion.

gatecse-2007 operating-system process-synchronization normal

Answer key

7.20.31 Process Synchronization: GATE CSE 2009 | Question: 33

The **enter_CS()** and **leave_CS()** functions to implement critical section of a process are realized using test-and-set instruction as follows:

```
void enter_CS(X)
{
   while(test-and-set(X));
}

void leave_CS(X)
{
   X = 0;
}
```

In the above solution, X is a memory location associated with the CS and is initialized to 0. Now consider the following statements:

I. The above solution to CS problem is deadlock-free
II. The solution is starvation free
III. The processes enter CS in FIFO order
IV. More than one process can enter CS at the same time

Which of the above statements are TRUE?

A. (I) only
B. (I) and (II)
C. (II) and (III)
D. (IV) only

gatecse-2009 operating-system process-synchronization normal

Answer key

7.20.32 Process Synchronization: GATE CSE 2010 | Question: 23

Consider the methods used by processes $P1$ and $P2$ for accessing their critical sections whenever needed, as given below. The initial values of shared boolean variables $S1$ and $S2$ are randomly assigned.

Method used by P1	Method used by P2
while (S1 == S2); Critical Section S1 = S2;	while (S1 != S2); Critical Section S2 = not(S1);

Which one of the following statements describes the properties achieved?

A. Mutual exclusion but not progress
B. Progress but not mutual exclusion
C. Neither mutual exclusion nor progress
D. Both mutual exclusion and progress

gatecse-2010 operating-system process-synchronization normal

Answer key

7.20.33 Process Synchronization: GATE CSE 2010 | Question: 45

The following program consists of 3 concurrent processes and 3 binary semaphores. The semaphores are initialized as $S0 = 1, S1 = 0$ and $S2 = 0.$

Process P0	Process P1	Process P2

while (true) {
wait (S0);
print '0';
release (S1);
release (S2);
}
	wait (S1);
	release (S0);
		wait (S2);
		release (S0);

How many times will process $P0$ print '0'?

A. At least twice
B. Exactly twice
C. Exactly thrice
D. Exactly once

gatecse-2010 operating-system process-synchronization normal

Answer key

7.20.34 Process Synchronization: GATE CSE 2012 | Question: 32

Fetch_And_Add(X,i) is an atomic Read-Modify-Write instruction that reads the value of memory location X, increments it by the value i, and returns the old value of X. It is used in the pseudocode shown below to implement a busy-wait lock. L is an unsigned integer shared variable initialized to 0. The value of 0 corresponds to lock being available, while any non-zero value corresponds to the lock being not available.

```
AcquireLock(L){
  while (Fetch_And_Add(L,1))
    L = 1;
}

ReleaseLock(L){
  L = 0;
}
```

This implementation

A. fails as L can overflow
B. fails as L can take on a non-zero value when the lock is actually available
C. works correctly but may starve some processes
D. works correctly without starvation

gatecse-2012 operating-system process-synchronization normal

Answer key

7.20.35 Process Synchronization: GATE CSE 2013 | Question: 34

A shared variable x, initialized to zero, is operated on by four concurrent processes W, X, Y, Z as follows. Each of the processes W and X reads x from memory, increments by one, stores it to memory, and then terminates. Each of the processes Y and Z reads x from memory, decrements by two, stores it to memory, and then terminates. Each process before reading x invokes the P operation (i.e., wait) on a counting semaphore S and invokes the V operation (i.e., signal) on the semaphore S after storing x to memory. Semaphore S is initialized to two. What is the maximum possible value of x after all processes complete execution?

A. -2
B. -1
C. 1
D. 2

gatecse-2013 operating-system process-synchronization normal

Answer key

7.20.36 Process Synchronization: GATE CSE 2013 | Question: 39

A certain computation generates two arrays a and b such that $a[i] = f(i)$ for $0 \leq i < n$ and $b[i] = g(a[i])$ for $0 \leq i < n$. Suppose this computation is decomposed into two concurrent processes X and Y such that X computes the array a and Y computes the array b. The processes employ two binary semaphores R and S, both initialized to zero. The array a is shared by the two processes. The structures of the processes are shown below.

Process X:

```
private i;
for (i=0; i< n; i++) {
 a[i] = f(i);
 ExitX(R, S);
}
```

Process Y:

```
private i;
for (i=0; i< n; i++) {
  EntryY(R, S);
  b[i] = g(a[i]);
}
```

Which one of the following represents the **CORRECT** implementations of ExitX and EntryY?

A.
```
ExitX(R, S) {
 P(R);
 V(S);
}
EntryY(R, S) {
 P(S);
 V(R);
}
```

B.
```
ExitX(R, S) {
 V(R);
 V(S);
}
EntryY(R, S) {
 P(R);
 P(S);
}
```

C.
```
ExitX(R, S) {
 P(S);
 V(R);
}
EntryY(R, S) {
 V(S);
 P(R);
}
```

D.
```
ExitX(R, S) {
 V(R);
 P(S);
}
EntryY(R, S) {
 V(S);
 P(R);
}
```

gatecse-2013 operating-system process-synchronization normal

Answer key

7.20.37 Process Synchronization: GATE CSE 2014 Set 2 | Question: 31

Consider the procedure below for the *Producer-Consumer* problem which uses semaphores:

```
semaphore n = 0;
semaphore s = 1;
```

```
void producer()
{
   while(true)
   {
      produce();
      semWait(s);
      addToBuffer();
      semSignal(s);
      semSignal(n);
   }
}
```

```
void consumer()
{
   while(true)
   {
      semWait(s);
      semWait(n);
      removeFromBuffer();
      semSignal(s);
      consume();
   }
}
```

Which one of the following is **TRUE**?

A. The producer will be able to add an item to the buffer, but the consumer can never consume it.
B. The consumer will remove no more than one item from the buffer.
C. Deadlock occurs if the consumer succeeds in acquiring semaphore s when the buffer is empty.
D. The starting value for the semaphore n must be 1 and not 0 for deadlock-free operation.

gatecse-2014-set2 operating-system process-synchronization normal

Answer key

7.20.38 Process Synchronization: GATE CSE 2015 Set 1 | Question: 9

The following two functions $P1$ and $P2$ that share a variable B with an initial value of 2 execute concurrently.

P1() {	P2(){
C = B - 1;	D = 2 * B;
B = 2 * C;	B = D - 1;
}	}

The number of distinct values that B can possibly take after the execution is________________________.

gatecse-2015-set1 operating-system process-synchronization normal numerical-answers

Answer key

7.20.39 Process Synchronization: GATE CSE 2015 Set 3 | Question: 10

Two processes X and Y need to access a critical section. Consider the following synchronization construct used by both the processes

Process X	Process Y
/* other code for process X*/	/* other code for process Y */
while (true)	while (true)
{	{
varP = true;	varQ = true;
while (varQ == true)	while (varP == true)
{	{
/* Critical Section */	/* Critical Section */
varP = false;	varQ = false;
}	}
}	}
/* other code for process X */	/* other code for process Y */

Here *varP* and *varQ* are shared variables and both are initialized to false. Which one of the following statements is true?

A. The proposed solution prevents deadlock but fails to guarantee mutual exclusion
B. The proposed solution guarantees mutual exclusion but fails to prevent deadlock
C. The proposed solution guarantees mutual exclusion and prevents deadlock
D. The proposed solution fails to prevent deadlock and fails to guarantee mutual exclusion

gatecse-2015-set3 operating-system process-synchronization normal

Answer key

7.20.40 Process Synchronization: GATE CSE 2016 Set 1 | Question: 50

Consider the following proposed solution for the critical section problem. There are n processes : $P_0 \dots P_{n-1}$. In the code, function pmax returns an integer not smaller than any of its arguments .For all $i, t[i]$ is initialized to zero.

Code for P_i;

```
do {
   c[i]=1; t[i]= pmax (t[0],....,t[n-1])+1; c[i]=0;
   for every j != i in {0,....,n-1} {
      while (c[j]);
      while (t[j] != 0 && t[j] <=t[i]);
   }
   Critical Section;
   t[i]=0;

   Remainder Section;

}  while (true);
```

Which of the following is TRUE about the above solution?

A. At most one process can be in the critical section at any time
B. The bounded wait condition is satisfied
C. The progress condition is satisfied
D. It cannot cause a deadlock

gatecse-2016-set1 operating-system process-synchronization difficult ambiguous

Answer key

7.20.41 Process Synchronization: GATE CSE 2016 Set 2 | Question: 48

Consider the following two-process synchronization solution.

PROCESS 0	Process 1
Entry: loop while (turn == 1); (critical section) Exit: turn = 1;	Entry: loop while (turn == 0); (critical section) Exit turn = 0;

The shared variable turn is initialized to zero. Which one of the following is TRUE?

A. This is a correct two- process synchronization solution.
B. This solution violates mutual exclusion requirement.
C. This solution violates progress requirement.
D. This solution violates bounded wait requirement.

gatecse-2016-set2 operating-system process-synchronization normal

Answer key

7.20.42 Process Synchronization: GATE CSE 2017 Set 1 | Question: 27

A multithreaded program P executes with x number of threads and uses y number of locks for ensuring mutual exclusion while operating on shared memory locations. All locks in the program are *non-reentrant*, i.e., if a thread holds a lock l, then it cannot re-acquire lock l without releasing it. If a thread is unable to acquire a lock, it blocks until the lock becomes available. The *minimum* value of x and the *minimum* value of y together for which execution of P can result in a deadlock are:

A. $x = 1, y = 2$
B. $x = 2, y = 1$
C. $x = 2, y = 2$
D. $x = 1, y = 1$

gatecse-2017-set1 operating-system process-synchronization normal

Answer key

7.20.43 Process Synchronization: GATE CSE 2018 | Question: 40

Consider the following solution to the producer-consumer synchronization problem. The shared buffer size is N. Three semaphores $empty$, $full$ and $mutex$ are defined with respective initial values of $0, N$ and 1. Semaphore $empty$ denotes the number of available slots in the buffer, for the consumer to read from. Semaphore $full$ denotes the number of available slots in the buffer, for the producer to write to. The placeholder variables, denoted by P, Q, R and S, in the code below can be assigned either $empty$ or $full$. The valid semaphore operations are: $wait()$ and $sigmal()$.

Producer:	Consumer:

do {
wait (P);
wait (mutex);
//Add item to buffer
signal (mutex);
signal (Q);
}while (1);
	do {
	wait (R);
	wait (mutex);
	//consume item from buffer
	signal (mutex);
	signal (S);
	}while (1);

Which one of the following assignments tp P, Q, R and S will yield the correct solution?

A. $P : full, \quad Q : full, \quad R : empty, \quad S : empty$
B. $P : empty, \quad Q : empty, \quad R : full, \quad S : full$
C. $P : full, \quad Q : empty, \quad R : empty, \quad S : full$
D. $P : empty, \quad Q : full, \quad R : full, \quad S : empty$

gatecse-2018 operating-system process-synchronization normal two-marks

Answer key

7.20.44 Process Synchronization: GATE CSE 2019 | Question: 23

Consider three concurrent processes P_1, P_2 and P_3 as shown below, which access a shared variable D that has been initialized to 100.

P_1	P_2	P_3
:	:	:
:	:	:
$D = D + 20$	$D = D - 50$	$D = D + 10$
:	:	:
:	:	:

The processes are executed on a uniprocessor system running a time-shared operating system. If the minimum and maximum possible values of D after the three processes have completed execution are X and Y respectively, then the value of $Y - X$ is ______

gatecse-2019 numerical-answers operating-system process-synchronization one-mark

Answer key

7.20.45 Process Synchronization: GATE CSE 2024 | Set 2 | Question: 36

Consider a multi-threaded program with two threads $\mathrm{T1}$ and $\mathrm{T2}$. The threads share two semaphores: $s1$ (initialized to 1) and $s2$ (initialized to 0). The threads also share a global variable x (initialized to 0). The threads execute the code shown below.

```
//code of T 1
wait (s1);
x = x+1;
print (x);
wait (s2);
signal(s1);
```

```
// code of T2
wait (s1);
x= x+1;
print (x) ;
signal (s2);
signal (s1);
```

Which of the following outcomes is/are possible when threads $\mathrm{T1}$ and $\mathrm{T2}$ execute concurrently?

A. $\mathrm{T1}$ runs first and prints 1, $\mathrm{T2}$ runs next and prints 2
B. $\mathrm{T2}$ runs first and prints 1, $\mathrm{T1}$ runs next and prints 2
C. $\mathrm{T1}$ runs first and prints 1, $\mathrm{T}\ 2$ does not print anything (deadlock)
D. $\mathrm{T2}$ runs first and prints 1, $\mathrm{T1}$ does not print anything (deadlock)

gatecse2024-set2 operating-system multiple-selects process-synchronization two-marks

Answer key

7.20.46 Process Synchronization: GATE IT 2004 | Question: 65

The semaphore variables full, empty and mutex are initialized to 0, n and 1, respectively. Process P_1 repeatedly adds one item at a time to a buffer of size n, and process P_2 repeatedly removes one item at a time from the same buffer using the programs given below. In the programs, K, L, M and N are unspecified statements.

P_1

```
while (1) {
   K;
   P(mutex);
   Add an item to the buffer;
   V(mutex);
   L;
}
```

P_2

```
while (1) {
   M;
   P(mutex);
   Remove an item from the buffer;
   V(mutex);
   N;
}
```

The statements K, L, M and N are respectively

A. P(full), V(empty), P(full), V(empty)
B. P(full), V(empty), P(empty), V(full)
C. P(empty), V(full), P(empty), V(full)
D. P(empty), V(full), P(full), V(empty)

gateit-2004 operating-system process-synchronization normal

Answer key

7.20.47 Process Synchronization: GATE IT 2005 | Question: 41

Given below is a program which when executed spawns two concurrent processes :
semaphore $X := 0;$
/* Process now forks into concurrent processes $P1$ & $P2$ */

$P1$	$P2$
repeat forever	repeat forever
$V(X);$	$P(X);$
Compute;	Compute;
$P(X);$	$V(X);$

Consider the following statements about processes $P1$ and $P2$:

I. It is possible for process $P1$ to starve.
II. It is possible for process $P2$ to starve.

Which of the following holds?

A. Both (I) and (II) are true.
B. (I) is true but (II) is false.
C. (II) is true but (I) is false
D. Both (I) and (II) are false

gateit-2005 operating-system process-synchronization normal

Answer key

7.20.48 Process Synchronization: GATE IT 2005 | Question: 42

Two concurrent processes $P1$ and $P2$ use four shared resources $R1, R2, R3$ and $R4$, as shown below.

P1	**P2**
Compute:	Compute;
Use R1;	Use R1;
Use R2;	Use R2;
Use R3;	Use R3;
Use R4;	Use R4;

Both processes are started at the same time, and each resource can be accessed by only one process at a time The following scheduling constraints exist between the access of resources by the processes:

- $P2$ must complete use of $R1$ before $P1$ gets access to $R1$.
- $P1$ must complete use of $R2$ before $P2$ gets access to $R2$.
- $P2$ must complete use of $R3$ before $P1$ gets access to $R3$.
- $P1$ must complete use of $R4$ before $P2$ gets access to $R4$.

There are no other scheduling constraints between the processes. If only binary semaphores are used to enforce the above scheduling constraints, what is the minimum number of binary semaphores needed?

A. 1 B. 2 C. 3 D. 4

gateit-2005 operating-system process-synchronization normal

Answer key

7.20.49 Process Synchronization: GATE IT 2006 | Question: 55

Consider the solution to the bounded buffer producer/consumer problem by using general semaphores $S, F,$ and E. The semaphore S is the mutual exclusion semaphore initialized to 1. The semaphore F corresponds to the number of free slots in the buffer and is initialized to N. The semaphore E corresponds to the number of elements in the buffer and is initialized to 0.

Producer Process	**Consumer Process**
Produce an item;	Wait(E);
Wait(F);	Wait(S);
Wait(S);	Remove an item from the buffer;
Append the item to the buffer;	Signal(S);
Signal(S);	Signal(F);
Signal(E);	Consume the item;

Which of the following interchange operations may result in a deadlock?

I. Interchanging Wait (F) and Wait (S) in the Producer process
II. Interchanging Signal (S) and Signal (F) in the Consumer process

A. (I) only
B. (II) only
C. Neither (I) nor (II)
D. Both (I) and (II)

gateit-2006 operating-system process-synchronization normal

Answer key

7.20.50 Process Synchronization: GATE IT 2007 | Question: 10

Processes $P1$ and $P2$ use critical_flag in the following routine to achieve mutual exclusion. Assume that critical_flag is initialized to FALSE in the main program.

```
get_exclusive_access ( )
{
   if (critical _flag == FALSE) {
       critical_flag = TRUE ;
       critical_region () ;
       critical_flag = FALSE;
   }
}
```

Consider the following statements.

i. It is possible for both $P1$ and $P2$ to access critical_region concurrently.
ii. This may lead to a deadlock.

Which of the following holds?

A. (i) is false (ii) is true
B. Both (i) and (ii) are false
C. (i) is true (ii) is false
D. Both (i) and (ii) are true

gateit-2007 operating-system process-synchronization normal

Answer key☟

7.20.51 Process Synchronization: GATE IT 2007 | Question: 56

Synchronization in the classical readers and writers problem can be achieved through use of semaphores. In the following incomplete code for readers-writers problem, two binary semaphores mutex and wrt are used to obtain synchronization

```
wait (wrt)
writing is performed
signal (wrt)
wait (mutex)
readcount = readcount + 1
if readcount = 1 then S1
S2
reading is performed
S3
readcount = readcount - 1
if readcount = 0 then S4
signal (mutex)
```

The values of $S1, S2, S3, S4,$ (in that order) are

A. signal (mutex), wait (wrt), signal (wrt), wait (mutex)
B. signal (wrt), signal (mutex), wait (mutex), wait (wrt)
C. wait (wrt), signal (mutex), wait (mutex), signal (wrt)
D. signal (mutex), wait (mutex), signal (mutex), wait (mutex)

gateit-2007 operating-system process-synchronization normal

Answer key☟

7.20.52 Process Synchronization: GATE IT 2008 | Question: 53

The following is a code with two threads, producer and consumer, that can run in parallel. Further, S and Q are binary semaphores quipped with the standard P and V operations.

```
semaphore S = 1, Q = 0;
integer x;

producer:                consumer:
while (true) do           while (true) do
   P(S);                  P(Q);
   x = produce ();            consume (x);
   V(Q);                   V(S);
done                     done
```

Which of the following is TRUE about the program above?

A. The process can deadlock
B. One of the threads can starve
C. Some of the items produced by the producer may be lost
D. Values generated and stored in 'x' by the producer will always be consumed before the producer can generate a new value

gateit-2008 operating-system process-synchronization normal

Answer key☟

7.21 Resource Allocation (27)

7.21.1 Resource Allocation: GATE CSE 1988 | Question: 11

A number of processes could be in a deadlock state if none of them can execute due to non-availability of sufficient resources. Let $P_i, 0 \leq i \leq 4$ represent five processes and let there be four resources types $r_j, 0 \leq j \leq 3$. Suppose the following data structures have been used.

Available: A vector of length 4 such that if Available $[i] = k$, there are k instances of resource type r_j available in the system.

Allocation. A 5×4 matrix defining the number of each type currently allocated to each process. If Allocation

$[i, j] = k$ then process p_i is currently allocated k instances of resource type r_j.

Max. A 5×4 matrix indicating the maximum resource need of each process. If $Max[i, j] = k$ then process p_i, may need a maximum of k instances of resource type r_j in order to complete the task.

Assume that system allocated resources only when it does not lead into an unsafe state such that resource requirements in future never cause a deadlock state. Now consider the following snapshot of the system.

Allocation

	r_0	r_1	r_2	r_3
p_0	0	0	1	2
p_1	1	0	0	0
p_2	1	3	5	4
p_3	0	6	3	2
p_4	0	0	1	4

Max

r_0	r_1	r_2	r_3
0	0	1	2
1	7	5	0
2	3	5	6
0	6	5	2
0	6	5	6

Available

r_0	r_1	r_2	r_3
1	5	2	0

Is the system currently in a safe state? If yes, explain why.

gate1988 normal descriptive operating-system resource-allocation

Answer key☟

7.21.2 Resource Allocation: GATE CSE 1989 | Question: 11a

i. A system of four concurrent processes, P, Q, R and S, use shared resources A, B and C. The sequences in which processes, P, Q, R and S request and release resources are as follows:

Process P:	1.	P requests A
	2.	P requests B
	3.	P releases A
	4.	P releases B
Process Q:	1.	Q requests C
	2.	Q requests A
	3.	Q releases C
	4.	P releases A
Process R:	1.	R requests B
	2.	R requests C
	3.	R releases B
	4.	R releases C
Process S:	1.	S requests A
	2.	S requests C
	3.	S releases A
	4.	S releases C

If a resource is free, it is granted to a requesting process immediately. There is no preemption of granted resources. A resource is taken back from a process only when the process explicitly releases it.

Can the system of four processes get into a deadlock? If yes, give a sequence (ordering) of operations (for requesting and releasing resources) of these processes which leads to a deadlock.

ii. Will the processes always get into a deadlock? If your answer is no, give a sequence of these operations which leads to completion of all processes.
iii. What strategies can be used to prevent deadlocks in a system of concurrent processes using shared resources if preemption of granted resources is not allowed?

descriptive gate1989 operating-system resource-allocation

Answer key

7.21.3 Resource Allocation: GATE CSE 1992 | Question: 02-xi

A computer system has 6 tape devices, with n processes competing for them. Each process may need 3 tape drives. The maximum value of n for which the system is guaranteed to be deadlock-free is:

A. 2　B. 3　C. 4　D. 1

gate1992 operating-system resource-allocation normal multiple-selects

Answer key

7.21.4 Resource Allocation: GATE CSE 1993 | Question: 7.9, UGCNET-Dec2012-III: 41

Consider a system having m resources of the same type. These resources are shared by 3 processes A, B, and C which have peak demands of $3, 4$, and 6 respectively. For what value of m deadlock will not occur?

A. 7　B. 9　C. 10　D. 13

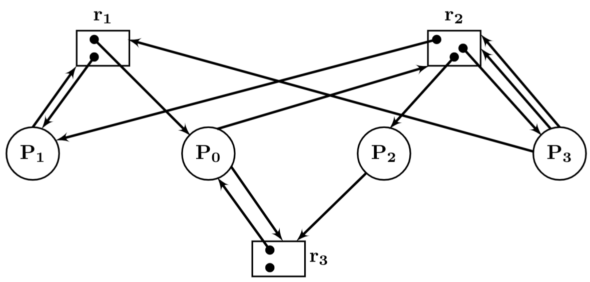
E. 15

gate1993 operating-system resource-allocation normal ugcnetcse-dec2012-paper3 multiple-selects

Answer key

7.21.5 Resource Allocation: GATE CSE 1994 | Question: 28

Consider the resource allocation graph in the figure.



A. Find if the system is in a deadlock state
B. Otherwise, find a safe sequence

gate1994 operating-system resource-allocation normal descriptive

Answer key

7.21.6 Resource Allocation: GATE CSE 1996 | Question: 22

A computer system uses the Banker's Algorithm to deal with deadlocks. Its current state is shown in the table below, where $P0$, $P1$, $P2$ are processes, and $R0$, $R1$, $R2$ are resources types.

Maximum Need

	$R0$	$R1$	$R2$
$P0$	4	1	2
$P1$	1	5	1
$P2$	1	2	3

Current Allocation

	$R0$	$R1$	$R2$
$P0$	1	0	2
$P1$	0	3	1
$P2$	1	0	2

Available

$R0$	$R1$	$R2$
2	2	0

A. Show that the system can be in this state
B. What will the system do on a request by process $P0$ for one unit of resource type $R1$?

gate1996 operating-system resource-allocation normal descriptive

Answer key

7.21.7 Resource Allocation: GATE CSE 1997 | Question: 6.7

An operating system contains 3 user processes each requiring 2 units of resource R. The minimum number of units of R such that no deadlocks will ever arise is

A. 3 B. 5 C. 4 D. 6

gate1997 operating-system resource-allocation normal

Answer key

7.21.8 Resource Allocation: GATE CSE 1997 | Question: 75

An operating system handles requests to resources as follows.

A process (which asks for some resources, uses them for some time and then exits the system) is assigned a unique timestamp are when it starts. The timestamps are monotonically increasing with time. Let us denote the timestamp of a process P by $TS(P)$.

When a process P requests for a resource the OS does the following:

i. If no other process is currently holding the resource, the OS awards the resource to P.
ii. If some process Q with $TS(Q) < TS(P)$ is holding the resource, the OS makes P wait for the resources.
iii. If some process Q with $TS(Q) > TS(P)$ is holding the resource, the OS restarts Q and awards the resources to P. (Restarting means taking back the resources held by a process, killing it and starting it again with the same timestamp)

When a process releases a resource, the process with the smallest timestamp (if any) amongst those waiting for the resource is awarded the resource.

A. Can a deadlock over arise? If yes, show how. If not prove it.
B. Can a process P ever starve? If yes, show how. If not prove it.

gate1997 operating-system resource-allocation normal descriptive

Answer key

7.21.9 Resource Allocation: GATE CSE 1998 | Question: 1.32

A computer has six tape drives, with n processes competing for them. Each process may need two drives. What is the maximum value of n for the system to be deadlock free?

A. 6 B. 5 C. 4 D. 3

gate1998 operating-system resource-allocation normal

Answer key

7.21.10 Resource Allocation: GATE CSE 2000 | Question: 2.23

Which of the following is not a valid deadlock prevention scheme?

A. Release all resources before requesting a new resource.
B. Number the resources uniquely and never request a lower numbered resource than the last one requested.
C. Never request a resource after releasing any resource.
D. Request and all required resources be allocated before execution.

gatecse-2000 operating-system resource-allocation normal

Answer key

7.21.11 Resource Allocation: GATE CSE 2001 | Question: 19

Two concurrent processes $P1$ and $P2$ want to use resources $R1$ and $R2$ in a mutually exclusive manner. Initially, $R1$ and $R2$ are free. The programs executed by the two processes are given below.

Program for P1:		Program for P2:	
S1:	While ($R1$ is busy) do no-op;	Q1:	While ($R1$ is busy) do no-op;
S2:	Set $R1 \leftarrow$ busy;	Q2:	Set $R1 \leftarrow$ busy;
S3:	While ($R2$ is busy) do no-op;	Q3:	While ($R2$ is busy) do no-op;
S4:	Set $R2 \leftarrow$ busy;	Q4:	Set $R2 \leftarrow$ busy;
S5:	Use $R1$ and $R2$;	Q5:	Use $R1$ and $R2$;
S6:	Set $R1 \leftarrow$ free;	Q6:	Set $R2 \leftarrow$ free;
S7:	Set $R2 \leftarrow$ free;	Q7:	Set $R1 \leftarrow$ free;

A. Is mutual exclusion guaranteed for $R1$ and $R2$? If not show a possible interleaving of the statements of $P1$ and $P2$ such mutual exclusion is violated (i.e., both $P1$ and $P2$ use $R1$ and $R2$ at the same time).
B. Can deadlock occur in the above program? If yes, show a possible interleaving of the statements of $P1$ and $P2$ leading to deadlock.
C. Exchange the statements $Q1$ and $Q3$ and statements $Q2$ and $Q4$. Is mutual exclusion guaranteed now? Can deadlock occur?

gatecse-2001 operating-system resource-allocation normal descriptive

Answer key☟

7.21.12 Resource Allocation: GATE CSE 2005 | Question: 71

Suppose n processes, $P_1, \dots P_n$ share m identical resource units, which can be reserved and released one at a time. The maximum resource requirement of process P_i is s_i, where $s_i > 0$. Which one of the following is a sufficient condition for ensuring that deadlock does not occur?

A. $\forall i,\ s_i, < m$
B. $\forall i,\ s_i < n$
C. $\sum_{i=1}^{n} s_i < (m+n)$
D. $\sum_{i=1}^{n} s_i < (m \times n)$

gatecse-2005 operating-system resource-allocation normal

Answer key☟

7.21.13 Resource Allocation: GATE CSE 2006 | Question: 66

Consider the following snapshot of a system running n processes. Process i is holding x_i instances of a resource R, $1 \leq i \leq n$. Currently, all instances of R are occupied. Further, for all i, process i has placed a request for an additional y_i instances while holding the x_i instances it already has. There are exactly two processes p and q and such that $y_p = y_q = 0$. Which one of the following can serve as a necessary condition to guarantee that the system is not approaching a deadlock?

A. $\min(x_p, x_q) < \max_{k \neq p,q} y_k$
B. $x_p + x_q \geq \min_{k \neq p,q} y_k$
C. $\max(x_p, x_q) > 1$
D. $\min(x_p, x_q) > 1$

gatecse-2006 operating-system resource-allocation normal

Answer key☟

7.21.14 Resource Allocation: GATE CSE 2007 | Question: 57

A single processor system has three resource types X, Y and Z, which are shared by three processes. There are 5 units of each resource type. Consider the following scenario, where the column **alloc** denotes the number of units of each resource type allocated to each process, and the column **request** denotes the number of units of each resource type requested by a process in order to complete execution. Which of these processes will finish **LAST**?

	alloc			**request**		
	X	Y	Z	X	Y	Z
P0	1	2	1	1	0	3
P1	2	0	1	0	1	2
P2	2	2	1	1	2	0

A. $P0$

B. $P1$

C. $P2$

D. None of the above, since the system is in a deadlock

gatecse-2007 operating-system resource-allocation normal

Answer key☟

7.21.15 Resource Allocation: GATE CSE 2008 | Question: 65

Which of the following is NOT true of deadlock prevention and deadlock avoidance schemes?

A. In deadlock prevention, the request for resources is always granted if the resulting state is safe

B. In deadlock avoidance, the request for resources is always granted if the resulting state is safe

C. Deadlock avoidance is less restrictive than deadlock prevention

D. Deadlock avoidance requires knowledge of resource requirements *apriori..*

gatecse-2008 operating-system easy resource-allocation

Answer key☟

7.21.16 Resource Allocation: GATE CSE 2009 | Question: 30

Consider a system with 4 types of resources $R1$ (3 units), $R2$ (2 units), $R3$ (3 units), $R4$ (2 units). A non-preemptive resource allocation policy is used. At any given instance, a request is not entertained if it cannot be completely satisfied. Three processes $P1$, $P2$, $P3$ request the resources as follows if executed independently.

Process P1:	**Process P2:**	**Process P3:**
$t = 0$: requests 2 units of $R2$	$t = 0$: requests 2 units of $R3$	$t = 0$: requests 1 unit of $R4$
$t = 1$: requests 1 unit of $R3$	$t = 2$: requests 1 unit of $R4$	$t = 2$: requests 2 units of $R1$
$t = 3$: requests 2 units of $R1$	$t = 4$: requests 1 unit of $R1$	$t = 5$: releases 2 units of $R1$
$t = 5$: releases 1 unit of $R2$ and 1 unit of $R1$	$t = 6$: releases 1 unit of $R3$	$t = 7$: requests 1 unit of $R2$
$t = 7$: releases 1 unit of $R3$	$t = 8$: Finishes	$t = 8$: requests 1 unit of $R3$
$t = 8$: requests 2 units of $R4$		$t = 9$: Finishes
$t = 10$: Finishes		

Which one of the following statements is TRUE if all three processes run concurrently starting at time $t = 0$?

A. All processes will finish without any deadlock

B. Only $P1$ and $P2$ will be in deadlock

C. Only $P1$ and $P3$ will be in deadlock

D. All three processes will be in deadlock

gatecse-2009 operating-system resource-allocation normal

Answer key☟

7.21.17 Resource Allocation: GATE CSE 2010 | Question: 46

A system has n resources $R_0, \ldots, R_{n-1}$, and k processes $P_0, \ldots, P_{k-1}$. The implementation of the resource request logic of each process P_i is as follows:

$$\begin{array}{l}\text{if}(i\%2 == 0)\{\\ \quad \text{if}(i < n) \text{ request } R_i;\\ \quad \text{if}(i+2 < n) \text{ request } R_{i+2};\}\\ \text{else}\{\\ \quad \text{if}(i < n) \text{ request } R_{n-i};\\ \quad \text{if}(i+2 < n) \text{ request } R_{n-i-2};\}\end{array}$$

In which of the following situations is a deadlock possible?

A. $n = 40,\ k = 26$ B. $n = 21,\ k = 12$ C. $n = 20,\ k = 10$ D. $n = 41,\ k = 19$

gatecse-2010 operating-system resource-allocation normal

Answer key☟

7.21.18 Resource Allocation: GATE CSE 2013 | Question: 16

Three concurrent processes X, Y, and Z execute three different code segments that access and update certain shared variables. Process X executes the P operation (i.e., $wait$) on semaphores a, b, and c; process Y executes the P operation on semaphores b, c, and d; process Z executes the P operation on semaphores c, d, and a before entering the respective code segments. After completing the execution of its code segment, each process invokes the V operation (i.e., $signal$) on its three semaphores. All semaphores are binary semaphores initialized to one. Which one of the following represents a deadlock-free order of invoking the P operations by the processes?

A. $X : P(a)P(b)P(c)\ Y : P(b)P(c)P(d)\ Z : P(c)P(d)P(a)$
B. $X : P(b)P(a)P(c)\ Y : P(b)P(c)P(d)\ Z : P(a)P(c)P(d)$
C. $X : P(b)P(a)P(c)\ Y : P(c)P(b)P(d)\ Z : P(a)P(c)P(d)$
D. $X : P(a)P(b)P(c)\ Y : P(c)P(b)P(d)\ Z : P(c)P(d)P(a)$

gatecse-2013 operating-system resource-allocation normal

Answer key☟

7.21.19 Resource Allocation: GATE CSE 2014 Set 1 | Question: 31

An operating system uses the *Banker's algorithm* for deadlock avoidance when managing the allocation of three resource types X, Y, and Z to three processes $P0, P1$, and $P2$. The table given below presents the current system state. Here, the *Allocation matrix* shows the current number of resources of each type allocated to each process and the *Max matrix* shows the maximum number of resources of each type required by each process during its execution.

	Allocation			Max		
	X	Y	Z	X	Y	Z
P0	0	0	1	8	4	3
P1	3	2	0	6	2	0
P2	2	1	1	3	3	3

There are 3 units of type $X, 2$ units of type Y and 2 units of type Z still available. The system is currently in a **safe** state. Consider the following independent requests for additional resources in the current state:

REQ1: $P0$ requests 0 units of $X, 0$ units of Y and 2 units of Z

REQ2: $P1$ requests 2 units of $X, 0$ units of Y and 0 units of Z

Which one of the following is **TRUE**?

A. Only REQ1 can be permitted.
B. Only REQ2 can be permitted.
C. Both REQ1 and REQ2 can be
D. Neither REQ1 nor REQ2 can be

permitted. permitted.

gatecse-2014-set1 operating-system resource-allocation normal

Answer key

7.21.20 Resource Allocation: GATE CSE 2014 Set 3 | Question: 31

A system contains three programs and each requires three tape units for its operation. The minimum number of tape units which the system must have such that deadlocks never arise is _________.

gatecse-2014-set3 operating-system resource-allocation numerical-answers easy

Answer key

7.21.21 Resource Allocation: GATE CSE 2015 Set 2 | Question: 23

A system has 6 identical resources and N processes competing for them. Each process can request at most 2 resources. Which one of the following values of N could lead to a deadlock?

A. 1
B. 2
C. 3
D. 4

gatecse-2015-set2 operating-system resource-allocation easy

Answer key

7.21.22 Resource Allocation: GATE CSE 2015 Set 3 | Question: 52

Consider the following policies for preventing deadlock in a system with mutually exclusive resources.

I. Process should acquire all their resources at the beginning of execution. If any resource is not available, all resources acquired so far are released.
II. The resources are numbered uniquely, and processes are allowed to request for resources only in increasing resource numbers
III. The resources are numbered uniquely, and processes are allowed to request for resources only in deccreasing resource numbers
IV. The resources are numbered uniquely. A processes is allowed to request for resources only for a resource with resource number larger than its currently held resources

Which of the above policies can be used for preventing deadlock?

A. Any one of (I) and (III) but not (II) or (IV)
B. Any one of (I), (III) and (IV) but not (II)
C. Any one of (II) and (III) but not (I) or (IV)
D. Any one of (I), (II), (III) and (IV)

gatecse-2015-set3 operating-system resource-allocation normal

Answer key

7.21.23 Resource Allocation: GATE CSE 2017 Set 2 | Question: 33

A system shares 9 tape drives. The current allocation and maximum requirement of tape drives for that processes are shown below:

Process	Current Allocation	Maximum Requirement
P1	3	7
P2	1	6
P3	3	5

Which of the following best describes current state of the system?

A. Safe, Deadlocked
B. Safe, Not Deadlocked
C. Not Safe, Deadlocked
D. Not Safe, Not Deadlocked

gatecse-2017-set2 operating-system resource-allocation normal

Answer key

7.21.24 Resource Allocation: GATE CSE 2019 | Question: 39

Consider the following snapshot of a system running n concurrent processes. Process i is holding X_i instances of a resource R, $1 \leq i \leq n$. Assume that all instances of R are currently in use. Further, for all i, process i can place a request for at most Y_i additional instances of R while holding the X_i instances it already has. Of the n processes, there are exactly two processes p and q such that $Y_p = Y_q = 0$. Which one of the following conditions guarantees that no other process apart from p and q can complete execution?

A. $X_p + X_q < \text{Min}\{Y_k \mid 1 \leq k \leq n, k \neq p, k \neq q\}$
B. $X_p + X_q < \text{Max}\{Y_k \mid 1 \leq k \leq n, k \neq p, k \neq q\}$
C. $\text{Min}(X_p, X_q) \geq \text{Min}\{Y_k \mid 1 \leq k \leq n, k \neq p, k \neq q\}$
D. $\text{Min}(X_p, X_q) \leq \text{Max}\{Y_k \mid 1 \leq k \leq n, k \neq p, k \neq q\}$

gatecse-2019 operating-system two-marks resource-allocation

Answer key☟

7.21.25 Resource Allocation: GATE CSE 2022 | Question: 16

Which of the following statements is/are TRUE with respect to deadlocks?

A. Circular wait is a necessary condition for the formation of deadlock.
B. In a system where each resource has more than one instance, a cycle in its wait-for graph indicates the presence of a deadlock.
C. If the current allocation of resources to processes leads the system to unsafe state, then deadlock will necessarily occur.
D. In the resource-allocation graph of a system, if every edge is an assignment edge, then the system is not in deadlock state.

gatecse-2022 operating-system resource-allocation multiple-selects one-mark

Answer key☟

7.21.26 Resource Allocation: GATE IT 2005 | Question: 62

Two shared resources R_1 and R_2 are used by processes P_1 and P_2. Each process has a certain priority for accessing each resource. Let T_{ij} denote the priority of P_i for accessing R_j. A process P_i can snatch a resource R_k from process P_j if T_{ik} is greater than T_{jk}.
Given the following :

I. $T_{11} > T_{21}$
II. $T_{12} > T_{22}$
III. $T_{11} < T_{21}$
IV. $T_{12} < T_{22}$

Which of the following conditions ensures that P_1 and P_2 can never deadlock?

A. (I) and (IV) B. (II) and (III) C. (I) and (II) D. None of the above

gateit-2005 operating-system resource-allocation normal

Answer key☟

7.21.27 Resource Allocation: GATE IT 2008 | Question: 54

An operating system implements a policy that requires a process to release all resources before making a request for another resource. Select the TRUE statement from the following:

A. Both starvation and deadlock can occur
B. Starvation can occur but deadlock cannot occur
C. Starvation cannot occur but deadlock can occur
D. Neither starvation nor deadlock can occur

gateit-2008 operating-system resource-allocation normal

Answer key

7.22 Resource Allocation Graph (1)

7.22.1 Resource Allocation Graph: GATE CSE 2025 | Set 2 | Question: 38

$P = \{P_1, P_2, P_3, P_4\}$ consists of all active processes in an operating system.

$R = \{R_1, R_2, R_3, R_4\}$ consists of single instances of distinct types of resources in the system.

The resource allocation graph has the following assignment and claim edges.

Assignment edges: $R_1 \rightarrow P_1, R_2 \rightarrow P_2, R_3 \rightarrow P_3, R_4 \rightarrow P_4$ (the assignment edge $R_1 \rightarrow P_1$ means resource R_1 is assigned to process P_1, and so on for others)

Claim edges: $P_1 \rightarrow R_2, P_2 \rightarrow R_3, P_3 \rightarrow R_1, P_2 \rightarrow R_4, P_4 \rightarrow R_2$ (the claim edge $P_1 \rightarrow R_2$ means process P_1 is waiting for resource R_2, and so on for others)

Which of the following statement(s) is/are CORRECT?

A. Aborting P_1 makes the system deadlock free.
B. Aborting P_3 makes the system deadlock free.
C. Aborting P_2 makes the system deadlock free.
D. Aborting P_1 and P_4 makes the system deadlock free.

gatecse2025-set2 operating-system resource-allocation-graph multiple-selects two-marks

Answer key

7.23 Semaphore (10)

7.23.1 Semaphore: GATE CSE 1990 | Question: 1-vii

Semaphore operations are atomic because they are implemented within the OS _________.

gate1990 operating-system semaphore process-synchronization fill-in-the-blanks

Answer key

7.23.2 Semaphore: GATE CSE 1992 | Question: 02,x, ISRO2015-35

At a particular time of computation, the value of a counting semaphore is 7. Then 20 P operations and 15 V operations were completed on this semaphore. The resulting value of the semaphore is :

A. 42 B. 2 C. 7 D. 12

gate1992 operating-system semaphore easy isro2015 process-synchronization

Answer key

7.23.3 Semaphore: GATE CSE 1998 | Question: 1.31

A counting semaphore was initialized to 10. Then $6P$ (wait) operations and $4V$ (signal) operations were completed on this semaphore. The resulting value of the semaphore is

A. 0 B. 8 C. 10 D. 12

gate1998 operating-system process-synchronization semaphore easy

Answer key

7.23.4 Semaphore: GATE CSE 2008 | Question: 63

The P and V operations on counting semaphores, where s is a counting semaphore, are defined as follows:

$P(s):$ $s = s - 1;$
If $s < 0$ then wait;

$V(s):$ $s = s + 1;$
If $s \leq 0$ then wake up process waiting on s;

Assume that P_b and V_b the wait and signal operations on binary semaphores are provided. Two binary semaphores

x_b and y_b are used to implement the semaphore operations $P(s)$ and $V(s)$ as follows:

$$
P(s): \quad \begin{array}{l} P_b(x_b); \\ s = s - 1; \\ \text{if } (s < 0) \\ \{ \\ \quad V_b(x_b); \\ \quad P_b(y_b); \\ \} \\ \text{ else } V_b(x_b); \end{array}
$$

$$
V(s): \quad \begin{array}{l} P_b(x_b); \\ s = s + 1; \\ \text{if } (s \leq 0) V_b(y_b); \\ V_b(x_b); \end{array}
$$

The initial values of x_b and y_b are respectively

A. 0 and 0 B. 0 and 1 C. 1 and 0 D. 1 and 1

gatecse-2008 operating-system normal semaphore

Answer key☟

7.23.5 Semaphore: GATE CSE 2016 Set 2 | Question: 49

Consider a non-negative counting semaphore S. The operation $P(S)$ decrements S, and $V(S)$ increments S. During an execution, 20 $P(S)$ operations and 12 $V(S)$ operations are issued in some order. The largest initial value of S for which at least one $P(S)$ operation will remain blocked is _______

gatecse-2016-set2 operating-system semaphore normal numerical-answers

Answer key☟

7.23.6 Semaphore: GATE CSE 2020 | Question: 34

Each of a set of n processes executes the following code using two semaphores a and b initialized to 1 and 0, respectively. Assume that count is a shared variable initialized to 0 and not used in CODE SECTION P.

CODE SECTION P

```
wait(a); count=count+1;
if (count==n) signal (b);
signal (a); wait (b) ; signal (b);
```

CODE SECTION Q

What does the code achieve?

A. It ensures that no process executes CODE SECTION Q before every process has finished CODE SECTION P.
B. It ensures that atmost two processes are in CODE SECTION Q at any time.
C. It ensures that all processes execute CODE SECTION P mutually exclusively.
D. It ensures that at most $n-1$ processes are in CODE SECTION P at any time.

gatecse-2020 operating-system semaphore two-marks

Answer key☟

7.23.7 Semaphore: GATE CSE 2021 Set 1 | Question: 46

Consider the following pseudocode, where S is a semaphore initialized to 5 in line $\#2$ and **counter** is a shared variable initialized to 0 in line $\#1$. Assume that the increment operation in line $\#7$ is not atomic.

```
1.  int counter = 0;
2.  Semaphore S = init(5);
3.  void parop(void)
4.  {
5.        wait(S);
6.        wait(S);
7.        counter++;
```

```
    signal(S);
    signal(S);
}
```

If five threads execute the function **parop** concurrently, which of the following program behavior(s) is/are possible?

A. The value of **counter** is 5 after all the threads successfully complete the execution of **parop**
B. The value of **counter** is 1 after all the threads successfully complete the execution of **parop**
C. The value of **counter** is 0 after all the threads successfully complete the execution of **parop**
D. There is a deadlock involving all the threads

gatecse-2021-set1 multiple-selects operating-system process-synchronization semaphore two-marks

Answer key

7.23.8 Semaphore: GATE CSE 2022 | Question: 9

Consider the following threads, T_1, T_2, and T_3 executing on a single processor, synchronized using three binary semaphore variables, S_1, S_2, and S_3, operated upon using standard **wait**() and **signal**(). The threads can be context switched in any order and at any time.

T_1	T_2	T_3
while(true){	while(true){	while(true){
wait(S_3);	wait(S_1);	wait(S_2);
print("C");	print("B");	print("A");
signal(S_2); }	signal(S_3); }	signal(S_1); }

Which initialization of the semaphores would print the sequence $\text{BCABCABCA}\ldots$?

A. $S_1 = 1; S_2 = 1; S_3 = 1$
B. $S_1 = 1; S_2 = 1; S_3 = 0$
C. $S_1 = 1; S_2 = 0; S_3 = 0$
D. $S_1 = 0; S_2 = 1; S_3 = 1$

gatecse-2022 operating-system process-synchronization semaphore one-mark

Answer key

7.23.9 Semaphore: GATE CSE 2023 | Question: 28

Consider the two functions **incr** and **decr** shown below.

```
incr(){          decr(){
  wait(s);         wait(s);
  X = X+1;          X = X-1;
  signal(s);        signal(s);
}              }
```

There are 5 threads each invoking **incr** once, and 3 threads each invoking **decr** once, on the same shared variable X. The initial value of X is 10.

Suppose there are two implementations of the semaphore s, as follows:

I-1: s is a binary semaphore initialized to 1.
I-2: s is a counting semaphore initialized to 2.

Let $V1, V2$ be the values of X at the end of execution of all the threads with implementations **I-1, I-2**, respectively.

Which one of the following choices corresponds to the minimum possible values of $V1, V2$, respectively?

A. $15, 7$
B. $7, 7$
C. $12, 7$
D. $12, 8$

gatecse-2023 operating-system semaphore two-marks

Answer key

7.23.10 Semaphore: GATE IT 2006 | Question: 57

The wait and signal operations of a monitor are implemented using semaphores as follows. In the following,

- x is a condition variable,
- mutex is a semaphore initialized to 1,
- x_sem is a semaphore initialized to 0,
- x_count is the number of processes waiting on semaphore x_sem, initially 0,
- next is a semaphore initialized to 0,
- next_count is the number of processes waiting on semaphore next, initially 0.

The body of each procedure that is visible outside the monitor is replaced with the following:

```
P(mutex);
...
body of procedure
...
if (next_count > 0)
   V(next);
else
   V(mutex);
```

Each occurrence of x.wait is replaced with the following:

```
x_count = x_count + 1;
if (next_count > 0)
   V(next);
else
   V(mutex);
------------------------------------------------------------ E1;
x_count = x_count - 1;
```

Each occurrence of x.signal is replaced with the following:

```
if (x_count > 0)
{
   next_count = next_count + 1;
   ------------------- E2;
   P(next);
   next_count = next_count - 1;
}
```

For correct implementation of the monitor, statements $E1$ and $E2$ are, respectively,

A. $P(x\_sem), V(next)$
B. $V(next), P(x\_sem)$
C. $P(next), V(x\_sem)$
D. $P(x\_sem), V(x\_sem)$

gateit-2006 operating-system process-synchronization semaphore normal

Answer key

7.24 Srtf (1)

7.24.1 Srtf: GATE CSE 2025 | Set 2 | Question: 16

Processes $P1, P2, P3, P4$ arrive in that order at times $0, 1, 2$, and 8 milliseconds respectively, and have execution times of $10, 13, 6$, and 9 milliseconds respectively. Shortest Remaining Time First (SRTF) algorithm is used as the CPU scheduling policy. Ignore context switching times.

Which ONE of the following correctly gives the average turnaround time of the four processes in milliseconds?

A. 22
B. 15
C. 37
D. 19

gatecse2025-set2 operating-system srtf process-scheduling average-turnaround-time one-mark

Answer key

7.25 System Calls (1)

7.25.1 System Calls: GATE CSE 2021 Set 1 | Question: 14

Which of the following standard C library functions will *always* invoke a system call when executed from a single-threaded process in a $\mathrm{UNIX/Linux}$ operating system?

A. **exit** B. **malloc** C. **sleep** D. **strlen**

gatecse-2021-set1 multiple-selects operating-system system-calls one-mark

Answer key

7.26 Threads (10)

7.26.1 Threads: GATE CSE 2004 | Question: 11

Consider the following statements with respect to user-level threads and kernel-supported threads

I. context switch is faster with kernel-supported threads
II. for user-level threads, a system call can block the entire process
III. Kernel supported threads can be scheduled independently
IV. User level threads are transparent to the kernel

Which of the above statements are true?

A. (II), (III) and (IV) only
B. (II) and (III) only
C. (I) and (III) only
D. (I) and (II) only

gatecse-2004 operating-system threads normal

Answer key

7.26.2 Threads: GATE CSE 2007 | Question: 17

Consider the following statements about user level threads and kernel level threads. Which one of the following statements is FALSE?

A. Context switch time is longer for kernel level threads than for user level threads.
B. User level threads do not need any hardware support.
C. Related kernel level threads can be scheduled on different processors in a multi-processor system.
D. Blocking one kernel level thread blocks all related threads.

gatecse-2007 operating-system threads normal

Answer key

7.26.3 Threads: GATE CSE 2011 | Question: 16, UGCNET-June2013-III: 65

A thread is usually defined as a "light weight process" because an Operating System (OS) maintains smaller data structure for a thread than for a process. In relation to this, which of the following statement is TRUE?

A. On per- thread basis , the OS maintains only CPU register state .
B. The OS does not maintain a separate stack for each thread .
C. On per- thread basis , the OS does not maintain virtual memory state .
D. On per- thread basis , the OS maintains only scheduling and accounting information .

gatecse-2011 operating-system threads normal ugcnetcse-june2013-paper3

Answer key

7.26.4 Threads: GATE CSE 2014 Set 1 | Question: 20

Which one of the following is **FALSE**?

A. User level threads are not scheduled by the kernel.
B. When a user level thread is blocked, all other threads of its process are blocked.
C. Context switching between user level threads is faster than context switching between kernel level threads.

D. Kernel level threads cannot share the code segment.

gatecse-2014-set1 operating-system threads normal

Answer key

7.26.5 Threads: GATE CSE 2017 Set 1 | Question: 18

Threads of a process share

A. global variables but not heap
B. heap but not global variables
C. neither global variables nor heap
D. both heap and global variables

gatecse-2017-set1 operating-system threads

Answer key

7.26.6 Threads: GATE CSE 2017 Set 2 | Question: 07

Which of the following is/are shared by all the threads in a process?

I. Program counter
II. Stack
III. Address space
IV. Registers

A. (I) and (II) only
B. (III) only
C. (IV) only
D. (III) and (IV) only

gatecse-2017-set2 operating-system threads

Answer key

7.26.7 Threads: GATE CSE 2021 Set 2 | Question: 42

Consider the following multi-threaded code segment (in a mix of C and pseudo-code), invoked by two processes P_1 and P_2, and each of the processes spawns two threads T_1 and T_2:

```
int x = 0;  // global
Lock L1;    // global
main () {
   create a thread to execute foo(); // Thread T1
   create a thread to execute foo(); // Thread T2
   wait for the two threads to finish execution;
   print(x);}


foo() {
   int y = 0;
   Acquire L1;
   x = x + 1;
   y = y + 1;
   Release L1;
   print (y);}
```

Which of the following statement(s) is/are correct?

A. Both P_1 and P_2 will print the value of x as 2.
B. At least of P_1 and P_2 will print the value of x as 4.
C. At least one of the threads will print the value of y as 2.
D. Both T_1 and T_2, in both the processes, will print the value of y as 1.

gatecse-2021-set2 multiple-selects operating-system threads two-marks

Answer key

7.26.8 Threads: GATE CSE 2024 | Set 1 | Question: 14

Which of the following statements about threads is/are TRUE?

A. Threads can only be implemented in kernel space
B. Each thread has its own file descriptor table for open files

C. All the threads belonging to a process share a common stack
D. Threads belonging to a process are by default not protected from each other

gatecse2024-set1 multiple-selects operating-system threads one-mark

Answer key

7.26.9 Threads: GATE CSE 2024 | Set 1 | Question: 30

Consider the following two threads $\mathrm{T1}$ and $\mathrm{T2}$ that update two shared variables a and b. Assume that initially $\mathrm{a} = \mathrm{b} = 1$. Though context switching between threads can happen at any time, each statement of $\mathrm{T1}$ or $\mathrm{T2}$ is executed atomically without interruption.

$$\begin{array}{ll} \mathrm{T1} & \mathrm{T2} \\ \mathrm{a} = \mathrm{a} + 1; & \mathrm{b} = 2 * \mathrm{b}; \\ \mathrm{b} = \mathrm{b} + 1; & \mathrm{a} = 2 * a; \end{array}$$

Which one of the following options lists all the possible combinations of values of a and b after both T1 and T2 finish execution?

A. $(\mathrm{a} = 4,\ \mathrm{b} = 4); (\mathrm{a} = 3,\ \mathrm{b} = 3); (\mathrm{a} = 4,\ \mathrm{b} = 3)$
B. $(\mathrm{a} = 3,\ \mathrm{b} = 4); (\mathrm{a} = 4,\ \mathrm{b} = 3); (\mathrm{a} = 3,\ \mathrm{b} = 3)$
C. $(\mathrm{a} = 4,\ \mathrm{b} = 4); (\mathrm{a} = 4,\ \mathrm{b} = 3); (\mathrm{a} = 3,\ \mathrm{b} = 4)$
D. $(\mathrm{a} = 2,\ \mathrm{b} = 2); (\mathrm{a} = 2,\ \mathrm{b} = 3); (\mathrm{a} = 3,\ \mathrm{b} = 4)$

gatecse2024-set1 operating-system threads two-marks

Answer key

7.26.10 Threads: GATE IT 2004 | Question: 14

Which one of the following is NOT shared by the threads of the same process ?

A. Stack
B. Address Space
C. File Descriptor Table
D. Message Queue

gateit-2004 operating-system easy threads

Answer key

7.27 Virtual Memory (43)

7.27.1 Virtual Memory: GATE CSE 1989 | Question: 2-iv

Match the pairs in the following:

(A)	Virtual memory	(p)	Temporal Locality
(B)	Shared memory	(q)	Spatial Locality
(C)	Look-ahead buffer	(r)	Address Translation
(D)	Look-aside buffer	(s)	Mutual Exclusion

match-the-following gate1989 operating-system virtual-memory

Answer key

7.27.2 Virtual Memory: GATE CSE 1990 | Question: 1-v

Under paged memory management scheme, simple lock and key memory protection arrangement may still be required if the __________ processors do not have address mapping hardware.

gate1990 operating-system virtual-memory fill-in-the-blanks

Answer key

7.27.3 Virtual Memory: GATE CSE 1990 | Question: 7-b

In a two-level virtual memory, the memory access time for main memory, $t_M = 10^{-8}$ sec, and the memory access time for the secondary memory, $t_D = 10^{-3}$ sec. What must be the hit ratio, H such that the access efficiency is within 80 percent of its maximum value?

gate1990 descriptive operating-system virtual-memory

Answer key☟

7.27.4 Virtual Memory: GATE CSE 1991 | Question: 03-xi

Indicate all the false statements from the statements given below:

A. The amount of virtual memory available is limited by the availability of the secondary memory
B. Any implementation of a critical section requires the use of an indivisible machine- instruction ,such as test-and-set.
C. The use of monitors ensure that no dead-locks will be caused .
D. The LRU page-replacement policy may cause thrashing for some type of programs.
E. The best fit techniques for memory allocation ensures that memory will never be fragmented.

gate1991 operating-system virtual-memory normal multiple-selects

Answer key☟

7.27.5 Virtual Memory: GATE CSE 1994 | Question: 1.21

Which one of the following statements is true?

A. Macro definitions cannot appear within other macro definitions in assembly language programs
B. Overlaying is used to run a program which is longer than the address space of a computer
C. Virtual memory can be used to accommodate a program which is longer than the address space of a computer
D. It is not possible to write interrupt service routines in a high level language

gate1994 operating-system normal virtual-memory

Answer key☟

7.27.6 Virtual Memory: GATE CSE 1995 | Question: 1.7

In a paged segmented scheme of memory management, the segment table itself must have a page table because

A. The segment table is often too large to fit in one page
B. Each segment is spread over a number of pages
C. Segment tables point to page tables and not to the physical locations of the segment
D. The processor's description base register points to a page table

gate1995 operating-system virtual-memory normal

Answer key☟

7.27.7 Virtual Memory: GATE CSE 1995 | Question: 2.16

In a virtual memory system the address space specified by the address lines of the CPU must be _____ than the physical memory size and ____ than the secondary storage size.

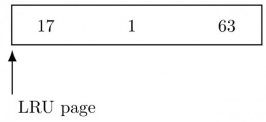
A. smaller, smaller
B. smaller, larger
C. larger, smaller
D. larger, larger

gate1995 operating-system virtual-memory normal

Answer key☟

7.27.8 Virtual Memory: GATE CSE 1996 | Question: 7

A demand paged virtual memory system uses 16 bit virtual address, page size of 256 bytes, and has 1 Kbyte of main memory. LRU page replacement is implemented using the list, whose current status (page number is decimal) is



For each hexadecimal address in the address sequence given below,

$$\text{00FF}, \text{010D}, \text{10FF}, \text{11B0}$$

indicate

i. the new status of the list
ii. page faults, if any, and
iii. page replacements, if any.

gate1996 operating-system virtual-memory normal descriptive

Answer key

7.27.9 Virtual Memory: GATE CSE 1998 | Question: 2.18, UGCNET-June2012-III: 48

If an instruction takes i microseconds and a page fault takes an additional j microseconds, the effective instruction time if on the average a page fault occurs every k instruction is:

A. $i + \frac{j}{k}$
B. $i + (j \times k)$
C. $\frac{i+j}{k}$
D. $(i+j) \times k$

gate1998 operating-system virtual-memory easy ugcnetcse-june2012-paper3

Answer key

7.27.10 Virtual Memory: GATE CSE 1999 | Question: 19

A certain computer system has the segmented paging architecture for virtual memory. The memory is byte addressable. Both virtual and physical address spaces contain 2^{16} bytes each. The virtual address space is divided into 8 non-overlapping equal size segments. The memory management unit (MMU) has a hardware segment table, each entry of which contains the physical address of the page table for the segment. Page tables are stored in the main memory and consists of 2 byte page table entries.

a. What is the minimum page size in bytes so that the page table for a segment requires at most one page to store it? Assume that the page size can only be a power of 2.
b. Now suppose that the pages size is 512 bytes. It is proposed to provide a TLB (Transaction look-aside buffer) for speeding up address translation. The proposed TLB will be capable of storing page table entries for 16 recently referenced virtual pages, in a fast cache that will use the direct mapping scheme. What is the number of tag bits that will need to be associated with each cache entry?
c. Assume that each page table entry contains (besides other information) 1 valid bit, 3 bits for page protection and 1 dirty bit. How many bits are available in page table entry for storing the aging information for the page? Assume that the page size is 512 bytes.

gate1999 operating-system virtual-memory normal descriptive

Answer key

7.27.11 Virtual Memory: GATE CSE 1999 | Question: 2.10

A multi-user, multi-processing operating system cannot be implemented on hardware that does not support

A. Address translation
B. DMA for disk transfer
C. At least two modes of CPU execution (privileged and non-privileged)

D. Demand paging

gate1999 operating-system normal virtual-memory

Answer key

7.27.12 Virtual Memory: GATE CSE 1999 | Question: 2.11

Which of the following is/are advantage(s) of virtual memory?

A. Faster access to memory on an average.
B. Processes can be given protected address spaces.
C. Linker can assign addresses independent of where the program will be loaded in physical memory.
D. Program larger than the physical memory size can be run.

gate1999 operating-system virtual-memory easy

Answer key

7.27.13 Virtual Memory: GATE CSE 2000 | Question: 2.22

Suppose the time to service a page fault is on the average 10 milliseconds, while a memory access takes 1 microsecond. Then a 99.99% hit ratio results in average memory access time of

A. 1.9999 milliseconds
B. 1 millisecond
C. 9.999 microseconds
D. 1.9999 microseconds

gatecse-2000 operating-system easy virtual-memory

Answer key

7.27.14 Virtual Memory: GATE CSE 2001 | Question: 1.20

Where does the swap space reside?

A. RAM
B. Disk
C. ROM
D. On-chip cache

gatecse-2001 operating-system easy virtual-memory

Answer key

7.27.15 Virtual Memory: GATE CSE 2001 | Question: 1.8

Which of the following statements is false?

A. Virtual memory implements the translation of a program's address space into physical memory address space
B. Virtual memory allows each program to exceed the size of the primary memory
C. Virtual memory increases the degree of multiprogramming
D. Virtual memory reduces the context switching overhead

gatecse-2001 operating-system virtual-memory normal

Answer key

7.27.16 Virtual Memory: GATE CSE 2001 | Question: 2.21

Consider a machine with 64 MB physical memory and a 32-bit virtual address space. If the page size s 4 KB, what is the approximate size of the page table?

A. 16 MB
B. 8 MB
C. 2 MB
D. 24 MB

gatecse-2001 operating-system virtual-memory normal

Answer key

7.27.17 Virtual Memory: GATE CSE 2002 | Question: 19

A computer uses $32-bit$ virtual address, and $32-bit$ physical address. The physical memory is byte addressable, and the page size is 4 Kbytes. It is decided to use two level page tables to translate from virtual address to physical address. Equal number of bits should be used for indexing first level and second level page table, and the size of each table entry is 4 bytes.

A. Give a diagram showing how a virtual address would be translated to a physical address.
B. What is the number of page table entries that can be contained in each page?
C. How many bits are available for storing protection and other information in each page table entry?

gatecse-2002 operating-system virtual-memory normal descriptive

Answer key

7.27.18 Virtual Memory: GATE CSE 2003 | Question: 26

In a system with 32 bit virtual addresses and 1 KB page size, use of one-level page tables for virtual to physical address translation is not practical because of

A. the large amount of internal fragmentation
B. the large amount of external fragmentation
C. the large memory overhead in maintaining page tables
D. the large computation overhead in the translation process

gatecse-2003 operating-system virtual-memory normal

Answer key

7.27.19 Virtual Memory: GATE CSE 2003 | Question: 78

A processor uses $2-level$ page tables for virtual to physical address translation. Page tables for both levels are stored in the main memory. Virtual and physical addresses are both 32 bits wide. The memory is byte addressable. For virtual to physical address translation, the 10 most significant bits of the virtual address are used as index into the first level page table while the next 10 bits are used as index into the second level page table. The 12 least significant bits of the virtual address are used as offset within the page. Assume that the page table entries in both levels of page tables are 4 bytes wide. Further, the processor has a translation look-aside buffer (TLB), with a hit rate of 96%. The TLB caches recently used virtual page numbers and the corresponding physical page numbers. The processor also has a physically addressed cache with a hit rate of 90%. Main memory access time is 10 ns, cache access time is 1 ns, and TLB access time is also 1 ns.

Assuming that no page faults occur, the average time taken to access a virtual address is approximately (to the nearest 0.5 ns)

A. 1.5 ns
B. 2 ns
C. 3 ns
D. 4 ns

gatecse-2003 operating-system normal virtual-memory

Answer key

7.27.20 Virtual Memory: GATE CSE 2003 | Question: 79

A processor uses 2-level page tables for virtual to physical address translation. Page tables for both levels are stored in the main memory. Virtual and physical addresses are both 32 bits wide. The memory is byte addressable. For virtual to physical address translation, the 10 most significant bits of the virtual address are used as index into the first level page table while the next 10 bits are used as index into the second level page table. The 12 least significant bits of the virtual address are used as offset within the page. Assume that the page table entries in both levels of page tables are 4 bytes wide. Further, the processor has a translation look-aside buffer (TLB), with a hit rate of 96%. The TLB caches recently used virtual page numbers and the corresponding physical page numbers. The processor also has a physically addressed cache with a hit rate of 90%. Main memory access time is 10 ns, cache access time is 1 ns, and TLB access time is also 1 ns.

Suppose a process has only the following pages in its virtual address space: two contiguous code pages starting at virtual address $0x00000000$, two contiguous data pages starting at virtual address $0x00400000$, and a stack page starting at virtual address $0xFFFFF000$. The amount of memory required for storing the page tables of this process is

A. 8 KB
B. 12 KB
C. 16 KB
D. 20 KB

gatecse-2003 operating-system normal virtual-memory

Answer key

7.27.21 Virtual Memory: GATE CSE 2006 | Question: 62, ISRO2016-50

A CPU generates 32-bit virtual addresses. The page size is 4 KB. The processor has a translation look-aside buffer (TLB) which can hold a total of 128 page table entries and is 4-way set associative. The minimum size of the TLB tag is:

A. 11 bits
B. 13 bits
C. 15 bits
D. 20 bits

gatecse-2006 operating-system virtual-memory normal isro2016

Answer key

7.27.22 Virtual Memory: GATE CSE 2006 | Question: 63, UGCNET-June2012-III: 45

A computer system supports 32-bit virtual addresses as well as 32-bit physical addresses. Since the virtual address space is of the same size as the physical address space, the operating system designers decide to get rid of the virtual memory entirely. Which one of the following is true?

A. Efficient implementation of multi-user support is no longer possible
B. The processor cache organization can be made more efficient now
C. Hardware support for memory management is no longer needed
D. CPU scheduling can be made more efficient now

gatecse-2006 operating-system virtual-memory normal ugcnetcse-june2012-paper3

Answer key

7.27.23 Virtual Memory: GATE CSE 2008 | Question: 67

A processor uses 36 bit physical address and 32 bit virtual addresses, with a page frame size of 4 Kbytes. Each page table entry is of size 4 bytes. A three level page table is used for virtual to physical address translation, where the virtual address is used as follows:

- Bits $30-31$ are used to index into the first level page table.
- Bits $21-29$ are used to index into the 2nd level page table.
- Bits $12-20$ are used to index into the 3rd level page table.
- Bits $0-11$ are used as offset within the page.

The number of bits required for addressing the next level page table(or page frame) in the page table entry of the first, second and third level page tables are respectively

A. $20,20,20$
B. $24,24,24$
C. $24,24,20$
D. $25,25,24$

gatecse-2008 operating-system virtual-memory normal

Answer key

7.27.24 Virtual Memory: GATE CSE 2009 | Question: 10

The essential content(s) in each entry of a page table is / are

A. Virtual page number
B. Page frame number
C. Both virtual page number and page frame number
D. Access right information

gatecse-2009 operating-system virtual-memory easy

Answer key

7.27.25 Virtual Memory: GATE CSE 2009 | Question: 34

A multilevel page table is preferred in comparison to a single level page table for translating virtual address to physical address because

A. It reduces the memory access time to read or write a memory location.
B. It helps to reduce the size of page table needed to implement the virtual address space of a process
C. It is required by the translation lookaside buffer.

D. It helps to reduce the number of page faults in page replacement algorithms.

gatecse-2009 operating-system virtual-memory easy

Answer key

7.27.26 Virtual Memory: GATE CSE 2011 | Question: 20, UGCNET-June2013-II: 48

Let the page fault service time be 10 milliseconds(ms) in a computer with average memory access time being 20 nanoseconds (ns). If one page fault is generated every 10^6 memory accesses, what is the effective access time for memory?

A. 21 ns
B. 30 ns
C. 23 ns
D. 35 ns

gatecse-2011 operating-system virtual-memory normal ugcnetcse-june2013-paper2

Answer key

7.27.27 Virtual Memory: GATE CSE 2013 | Question: 52

A computer uses 46-bit virtual address, 32-bit physical address, and a three–level paged page table organization. The page table base register stores the base address of the first-level table (T1), which occupies exactly one page. Each entry of T1 stores the base address of a page of the second-level table (T2). Each entry of T2 stores the base address of a page of the third-level table (T3). Each entry of T3 stores a page table entry (PTE). The PTE is 32 bits in size. The processor used in the computer has a 1 MB 16 way set associative virtually indexed physically tagged cache. The cache block size is 64 bytes.

What is the size of a page in KB in this computer?

A. 2
B. 4
C. 8
D. 16

gatecse-2013 operating-system virtual-memory normal

Answer key

7.27.28 Virtual Memory: GATE CSE 2013 | Question: 53

A computer uses 46-bit virtual address, 32-bit physical address, and a three–level paged page table organization. The page table base register stores the base address of the first-level table (T1), which occupies exactly one page. Each entry of T1 stores the base address of a page of the second-level table (T2). Each entry of T2 stores the base address of a page of the third-level table (T3). Each entry of T3 stores a page table entry (PTE). The PTE is 32 bits in size. The processor used in the computer has a 1 MB 16 way set associative virtually indexed physically tagged cache. The cache block size is 64 bytes.

What is the minimum number of page colours needed to guarantee that no two synonyms map to different sets in the processor cache of this computer?

A. 2
B. 4
C. 8
D. 16

gatecse-2013 normal operating-system virtual-memory

Answer key

7.27.29 Virtual Memory: GATE CSE 2014 Set 3 | Question: 33

Consider a paging hardware with a TLB. Assume that the entire page table and all the pages are in the physical memory. It takes 10 milliseconds to search the TLB and 80 milliseconds to access the physical memory. If the TLB hit ratio is 0.6, the effective memory access time (in milliseconds) is _________.

gatecse-2014-set3 operating-system virtual-memory numerical-answers normal

Answer key

7.27.30 Virtual Memory: GATE CSE 2015 Set 1 | Question: 12

Consider a system with byte-addressable memory, 32-bit logical addresses, 4 kilobyte page size and page table entries of 4 bytes each. The size of the page table in the system in megabytes is___________.

gatecse-2015-set1 operating-system virtual-memory easy numerical-answers

Answer key

7.27.31 Virtual Memory: GATE CSE 2015 Set 2 | Question: 25

A computer system implements a 40 -bit virtual address, page size of 8 kilobytes, and a 128-entry translation look-aside buffer (TLB) organized into 32 sets each having 4 ways. Assume that the TLB tag does not store any process id. The minimum length of the TLB tag in bits is ______.

gatecse-2015-set2 operating-system virtual-memory easy numerical-answers

Answer key

7.27.32 Virtual Memory: GATE CSE 2015 Set 2 | Question: 47

A computer system implements 8 kilobyte pages and a 32-bit physical address space. Each page table entry contains a valid bit, a dirty bit, three permission bits, and the translation. If the maximum size of the page table of a process is 24 megabytes, the length of the virtual address supported by the system is _______ bits.

gatecse-2015-set2 operating-system virtual-memory normal numerical-answers

Answer key

7.27.33 Virtual Memory: GATE CSE 2016 Set 1 | Question: 47

Consider a computer system with 40-bit virtual addressing and page size of sixteen kilobytes. If the computer system has a one-level page table per process and each page table entry requires 48 bits, then the size of the per-process page table is __________ megabytes.

gatecse-2016-set1 operating-system virtual-memory easy numerical-answers

Answer key

7.27.34 Virtual Memory: GATE CSE 2018 | Question: 10

Consider a process executing on an operating system that uses demand paging. The average time for a memory access in the system is M units if the corresponding memory page is available in memory, and D units if the memory access causes a page fault. It has been experimentally measured that the average time taken for a memory access in the process is X units.

Which one of the following is the correct expression for the page fault rate experienced by the process.

A. $(D-M)/(X-M)$ B. $(X-M)/(D-M)$ C. $(D-X)/(D-M)$ D. $(X-M)/(D-X)$

gatecse-2018 operating-system virtual-memory normal one-mark

Answer key

7.27.35 Virtual Memory: GATE CSE 2019 | Question: 33

Assume that in a certain computer, the virtual addresses are 64 bits long and the physical addresses are 48 bits long. The memory is word addressible. The page size is 8 kB and the word size is 4 bytes. The Translation Look-aside Buffer (TLB) in the address translation path has 128 valid entries. At most how many distinct virtual addresses can be translated without any TLB miss?

A. 16×2^{10}
B. 256×2^{10}
C. 4×2^{20}
D. 8×2^{20}

gatecse-2019 operating-system virtual-memory two-marks

Answer key

7.27.36 Virtual Memory: GATE CSE 2020 | Question: 53

Consider a paging system that uses 1-level page table residing in main memory and a TLB for address translation. Each main memory access takes 100 ns and TLB lookup takes 20 ns. Each page transfer to/from the disk takes 5000 ns. Assume that the TLB hit ratio is 95%, page fault rate is 10%. Assume that for 20% of the total page faults, a dirty page has to be written back to disk before the required page is read from disk.

TLB update time is negligible. The average memory access time in ns (round off to 1 decimal places) is ___________

gatecse-2020 numerical-answers operating-system virtual-memory two-marks

Answer key

7.27.37 Virtual Memory: GATE CSE 2023 | Question: 48

Consider a computer system with 57-bit virtual addressing using multi-level tree-structured page tables with L levels for virtual to physical address translation. The page size is $4\,\text{KB}(1\,\text{KB}=1024\,\text{B})$ and a page table entry at any of the levels occupies 8 bytes.

The value of L is ______________.

gatecse-2023 operating-system virtual-memory numerical-answers two-marks

Answer key

7.27.38 Virtual Memory: GATE CSE 2024 | Set 1 | Question: 52

Consider a memory management system that uses a page size of $2\,\text{KB}$. Assume that both the physical and virtual addresses start from 0. Assume that the pages $0, 1, 2,$ and 3 are stored in the page frames $1, 3, 2,$ and 0, respectively. The physical address *(in decimal format)* corresponding to the virtual address 2500 *(in decimal format)* is ___________.

gatecse2024-set1 numerical-answers operating-system virtual-memory two-marks

Answer key

7.27.39 Virtual Memory: GATE CSE 2024 | Set 2 | Question: 14

Which of the following tasks is/are the responsibility/responsibilities of the memory management unit (MMU) in a system with paging-based memory management?

A. Allocate a new page table for a newly created process
B. Translate a virtual address to a physical address using the page table
C. Raise a trap when a virtual address is not found in the page table
D. Raise a trap when a process tries to write to a page marked with read-only permission in the page table

gatecse2024-set2 operating-system multiple-selects virtual-memory one-mark

Answer key

7.27.40 Virtual Memory: GATE CSE 2024 | Set 2 | Question: 54

Consider a 32-bit system with $4\,\text{KB}$ page size and page table entries of size 4 bytes each. Assume $1\,\text{KB}=2^{10}$ bytes. The OS uses a 2-level page table for memory management, with the page table containing an outer page directory and an inner page table. The OS allocates a page for the outer page directory upon process creation. The OS uses demand paging when allocating memory for the inner page table, i.e., a page of the inner page table is allocated only if it contains at least one valid page table entry.

An active process in this system accesses 2000 unique pages during its execution, and none of the pages are swapped out to disk. After it completes the page accesses, let X denote the minimum and Y denote the maximum number of pages across the two levels of the page table of the process.

The value of X+Y is ___________.

gatecse2024-set2 numerical-answers operating-system virtual-memory two-marks

Answer key

7.27.41 Virtual Memory: GATE IT 2004 | Question: 66

In a virtual memory system, size of the virtual address is 32-bit, size of the physical address is 30-bit, page size is 4 Kbyte and size of each page table entry is 32-bit. The main memory is byte addressable. Which one of the following is the maximum number of bits that can be used for storing protection and other information in each page table entry?

A. 2 B. 10 C. 12 D. 14

gateit-2004 operating-system virtual-memory normal

Answer key☟

7.27.42 Virtual Memory: GATE IT 2008 | Question: 16

A paging scheme uses a Translation Look-aside Buffer (TLB). A TLB-access takes 10 ns and the main memory access takes 50 ns. What is the effective access time(in ns) if the TLB hit ratio is 90% and there is no page-fault?

A. 54 B. 60 C. 65 D. 75

gateit-2008 operating-system virtual-memory normal

Answer key☟

7.27.43 Virtual Memory: GATE IT 2008 | Question: 56

Match the following flag bits used in the context of virtual memory management on the left side with the different purposes on the right side of the table below.

Name of the bit		Purpose	
I.	Dirty	a.	Page initialization
II.	R/W	b.	Write-back policy
III.	Reference	c.	Page protection
IV.	Valid	d.	Page replacement policy

A. I-d, II-a, III-b, IV-c
B. I-b, II-c, III-a, IV-d
C. I-c, II-d, III-a, IV-b
D. I-b, II-c, III-d, IV-a

gateit-2008 operating-system virtual-memory easy

Answer key☟

Answer Keys

7.0.1	A	7.1.1	C	7.1.2	B	7.1.3	C	7.1.4	A;B
7.2.1	2	7.2.2	A	7.2.3	A;B;C	7.2.4	A	7.3.1	N/A
7.3.2	N/A	7.3.3	B	7.3.4	N/A	7.3.5	9.006	7.3.6	D
7.3.7	N/A	7.3.8	N/A	7.3.9	D	7.3.10	D	7.3.11	A
7.3.12	800	7.3.13	A	7.3.14	C	7.3.15	B	7.3.16	A
7.3.17	B	7.3.18	C	7.3.19	C	7.3.20	B	7.3.21	B
7.3.22	D	7.3.23	14020	7.3.24	6.1 : 6.2	7.3.25	85	7.3.26	4096
7.3.27	30.06	7.3.28	C	7.3.29	D	7.3.30	B	7.3.31	D
7.4.1	N/A	7.4.2	N/A	7.4.3	N/A	7.4.4	C	7.4.5	B
7.4.6	D	7.4.7	B	7.4.8	3	7.4.9	10	7.4.10	346
7.4.11	B	7.4.12	C	7.4.13	B	7.4.14	C	7.5.1	N/A
7.5.2	C	7.5.3	D	7.5.4	99.55 : 99.65	7.5.5	D	7.5.6	4.0 : 4.1
7.5.7	A;C	7.5.8	153	7.5.9	B	7.6.1	C	7.6.2	B
7.6.3	C	7.6.4	31	7.6.5	C;D	7.6.6	14	7.6.7	C
7.7.1	A	7.7.2	B	7.7.3	C	7.7.4	A	7.7.5	A

7.7.6	B	7.7.7	C	7.8.1	21:21	7.9.1	B	7.10.1	90.00
7.10.2	D	7.10.3	A	7.10.4	C	7.10.5	C	7.10.6	D
7.11.1	65468:65468	7.12.1	3.2	7.12.2	N/A	7.12.3	B	7.12.4	B
7.12.5	10000	7.12.6	A	7.12.7	C	7.12.8	C	7.12.9	B
7.12.10	B	7.13.1	11:11	7.14.1	A	7.14.2	C	7.14.3	B
7.15.1	6:6	7.16.1	N/A	7.16.2	B	7.16.3	B	7.16.4	C
7.16.5	C	7.16.6	A	7.16.7	B	7.16.8	C	7.16.9	C
7.16.10	B	7.16.11	A	7.16.12	C	7.16.13	B	7.16.14	A
7.16.15	C	7.16.16	A	7.16.17	A	7.16.18	B	7.16.19	7
7.16.20	D	7.16.21	6	7.16.22	A	7.16.23	1	7.16.24	D
7.16.25	B	7.16.26	A;C	7.16.27	4108 : 4108	7.16.28	0.6	7.16.29	4096
7.16.30	D	7.16.31	C	7.16.32	A	7.16.33	B	7.17.1	N/A
7.17.2	N/A	7.17.3	N/A	7.18.1	B	7.18.2	C	7.18.3	B
7.18.4	B;C;D	7.18.5	B	7.19.1	N/A	7.19.2	N/A	7.19.3	N/A
7.19.4	C	7.19.5	B	7.19.6	A	7.19.7	D	7.19.8	A
7.19.9	N/A	7.19.10	19	7.19.11	B	7.19.12	D	7.19.13	A
7.19.14	B	7.19.15	A	7.19.16	B	7.19.17	A	7.19.18	B
7.19.19	C	7.19.20	D	7.19.21	A	7.19.22	C	7.19.23	B
7.19.24	7.2	7.19.25	1000	7.19.26	5.5	7.19.27	12	7.19.28	D
7.19.29	C	7.19.30	A	7.19.31	8.25	7.19.32	3	7.19.33	29
7.19.34	2	7.19.35	C	7.19.36	5.25:5.26	7.19.37	12 : 12	7.19.38	A;C;D
7.19.39	D	7.19.40	C;D	7.19.41	B;C	7.19.42	B	7.19.43	A
7.19.44	D	7.19.45	D	7.19.46	B	7.19.47	D	7.19.48	C
7.20.1	D	7.20.2	N/A	7.20.3	N/A	7.20.4	N/A	7.20.5	N/A
7.20.6	N/A	7.20.7	N/A	7.20.8	N/A	7.20.9	N/A	7.20.10	C
7.20.11	C	7.20.12	N/A	7.20.13	D	7.20.14	N/A	7.20.15	B
7.20.16	N/A	7.20.17	N/A	7.20.18	B	7.20.19	N/A	7.20.20	B
7.20.21	N/A	7.20.22	N/A	7.20.23	N/A	7.20.24	B	7.20.25	C
7.20.26	D	7.20.27	A	7.20.28	B	7.20.29	B	7.20.30	D
7.20.31	A	7.20.32	A	7.20.33	A	7.20.34	B	7.20.35	D
7.20.36	C	7.20.37	C	7.20.38	3	7.20.39	A	7.20.40	A
7.20.41	C	7.20.42	D	7.20.43	C	7.20.44	80	7.20.45	B;C
7.20.46	D	7.20.47	A	7.20.48	B	7.20.49	A	7.20.50	C
7.20.51	C	7.20.52	D	7.21.1	N/A	7.21.2	N/A	7.21.3	A
7.21.4	D;E	7.21.5	N/A	7.21.6	N/A	7.21.7	C	7.21.8	N/A
7.21.9	B	7.21.10	C	7.21.11	N/A	7.21.12	C	7.21.13	B
7.21.14	C	7.21.15	A	7.21.16	A	7.21.17	B	7.21.18	B
7.21.19	B	7.21.20	7	7.21.21	D	7.21.22	D	7.21.23	B
7.21.24	A	7.21.25	A;D	7.21.26	C	7.21.27	B	7.22.1	C;D
7.23.1	N/A	7.23.2	B	7.23.3	B	7.23.4	C	7.23.5	7

7.23.6	A	7.23.7	A;B;D	7.23.8	C	7.23.9	C	7.23.10	D
7.24.1	D	7.25.1	A;C	7.26.1	A	7.26.2	D	7.26.3	C
7.26.4	D	7.26.5	D	7.26.6	B	7.26.7	A;D	7.26.8	D
7.26.9	A	7.26.10	A	7.27.1	N/A	7.27.2	N/A	7.27.3	99.99
7.27.4	B;C;E	7.27.5	A	7.27.6	A	7.27.7	C	7.27.8	N/A
7.27.9	A	7.27.10	N/A	7.27.11	A;C	7.27.12	B;D	7.27.13	D
7.27.14	B	7.27.15	D	7.27.16	C	7.27.17	N/A	7.27.18	C
7.27.19	D	7.27.20	C	7.27.21	C	7.27.22	C	7.27.23	D
7.27.24	B	7.27.25	B	7.27.26	B	7.27.27	C	7.27.28	C
7.27.29	122	7.27.30	4	7.27.31	22	7.27.32	36	7.27.33	384
7.27.34	B	7.27.35	B	7.27.36	155:156	7.27.37	5	7.27.38	6596
7.27.39	B;C;D	7.27.40	1028	7.27.41	D	7.27.42	C	7.27.43	D

8 Programming and DS: Data Structures (236)

Webpage

Stacks, Queues, Linked lists, Trees, Binary search trees, Binary heaps, Graphs.

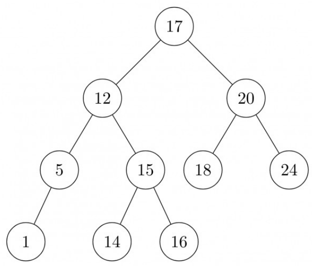
Mark Distribution in Previous GATE

Year	2025 - 1	2025 - 2	2024 - 1	2024 - 2	2023	2022	2021 - 1	2021 - 2	Minimum	Average	Maximu
1 Mark Count	3	2	0	0	2	2	4	2	0	1.88	4
2 Marks Count	1	2	1	2	3	1	1	0	0	1.38	3
Total Marks	5	6	2	4	8	4	6	2	**2**	**4.63**	**8**

8.1 AVL Tree (6)

8.1.1 AVL Tree: GATE CSE 1988 | Question: 7ii

Mark the balance factor of each node on the tree given in the below figure and state whether it is height-balanced.

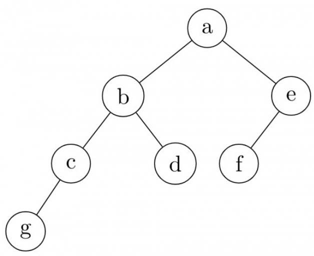


gate1988 data-structures normal descriptive avl-tree binary-tree

Answer key☟

8.1.2 AVL Tree: GATE CSE 1996 | Question: 1.14

In the balanced binary tree in the below figure, how many nodes will become unbalanced when a node is inserted as a child of the node "g"?



A. 1 B. 3 C. 7 D. 8

gate1996 data-structures binary-tree avl-tree normal

Answer key☟

8.1.3 AVL Tree: GATE CSE 1998 | Question: 21

A. Derive a recurrence relation for the size of the smallest AVL tree with height h.
B. What is the size of the smallest AVL tree with height 8?

gate1998 data-structures avl-tree descriptive numerical-answers

Answer key☟

8.1.4 AVL Tree: GATE CSE 2009 | Question: 37,ISRO-DEC2017-55

What is the maximum height of any AVL-tree with 7 nodes? Assume that the height of a tree with a single node is 0.

A. 2 B. 3 C. 4 D. 5

gatecse-2009 data-structures binary-search-tree normal isrodec2017 avl-tree

Answer key☟

8.1.5 AVL Tree: GATE CSE 2020 | Question: 6

What is the worst case time complexity of inserting n^2 elements into an AVL-tree with n elements initially?

A. $\Theta(n^4)$
B. $\Theta(n^2)$
C. $\Theta(n^2 \log n)$
D. $\Theta(n^3)$

gatecse-2020 binary-tree avl-tree one-mark

Answer key☟

8.1.6 AVL Tree: GATE IT 2008 | Question: 12

Which of the following is TRUE?

A. The cost of searching an AVL tree is $\Theta(\log n)$ but that of a binary search tree is $O(n)$
B. The cost of searching an AVL tree is $\Theta(\log n)$ but that of a complete binary tree is $\Theta(n \log n)$
C. The cost of searching a binary search tree is $O(\log n)$ but that of an AVL tree is $\Theta(n)$
D. The cost of searching an AVL tree is $\Theta(n \log n)$ but that of a binary search tree is $O(n)$

gateit-2008 data-structures binary-search-tree easy avl-tree

Answer key☟

8.2 Array (13)

8.2.1 Array: GATE CSE 1993 | Question: 12

The following Pascal program segments finds the largest number in a two-dimensional integer array $A[0 \dots n-1, 0 \dots n-1]$ using a single loop. Fill up the boxes to complete the program and write against $\boxed{\text{A}}, \boxed{\text{B}}, \boxed{\text{C}}$ and $\boxed{\text{D}}$ in your answer book Assume that max is a variable to store the largest value and i, j are the indices to the array.

```
begin
   max:=|A|, i:=0, j:=0;
   while |B| do
   begin
      if A[i, j]>max then max:=A[i, j];
      if |C| then j:=j+1;
      else begin
         j:=0;
         i:=|D|
      end
   end
end
```

gate1993 data-structures array normal descriptive

Answer key☟

8.2.2 Array: GATE CSE 1994 | Question: 1.11

In a compact single dimensional array representation for lower triangular matrices (i.e all the elements above the diagonal are zero) of size $n \times n$, non-zero elements, (i.e elements of lower triangle) of each row are stored one after another, starting from the first row, the index of the $(i, j)^{th}$ element of the lower triangular matrix in this new representation is:

A. $i + j$ B. $i + j - 1$ C. $(j-1) + \frac{i(i-1)}{2}$ D. $i + \frac{j(j-1)}{2}$

gate1994 data-structures array normal

Answer key

8.2.3 Array: GATE CSE 1994 | Question: 25

An array A contains n integers in non-decreasing order, $A[1] \leq A[2] \leq \cdots \leq A[n]$. Describe, using Pascal like pseudo code, a linear time algorithm to find i, j, such that $A[i]+A[j]=a$ given integer M, if such i, j exist.

gate1994 data-structures array normal descriptive

Answer key

8.2.4 Array: GATE CSE 1997 | Question: 17

An array A contains $n \geq 1$ positive integers in the locations $A[1], A[2], \ldots A[n]$. The following program fragment prints the length of a shortest sequence of consecutive elements of A, $A[i], A[i+1], \ldots, A[j]$ such that the sum of their values is $\geq M$, a given positive number. It prints '$n+1$' if no such sequence exists. Complete the program by filling in the boxes. In each case use the simplest possible expression. Write only the line number and the contents of the box.

```
begin
i:=1;j:=1;
sum := □
min:=n; finish:=false;
while not finish do
   if □ then
      if j=n then finish:=true
      else
      begin
         j:=j+1;
         sum:= □
      end
   else
   begin
      if(j-i) < min then min:=j-i;
      sum:=sum –A[i];
      i:=i+1;
   end
   writeln (min +1);
end.
```

gate1997 data-structures array normal descriptive

Answer key

8.2.5 Array: GATE CSE 1998 | Question: 2.14

Let A be a two dimensional array declared as follows:

```
A: array [1 .... 10] [1 ..... 15] of integer;
```

Assuming that each integer takes one memory location, the array is stored in row-major order and the first element of the array is stored at location 100, what is the address of the element $A[i][j]$?

A. $15i+j+84$

B. $15j+i+84$

C. $10i+j+89$

D. $10j+i+89$

gate1998 data-structures array easy

Answer key

8.2.6 Array: GATE CSE 2000 | Question: 1.2

An $n \times n$ array v is defined as follows:

$v[i, j]=i-j$ for all $i, j, i \leq n, 1 \leq j \leq n$

The sum of the elements of the array v is

A. 0

B. $n-1$

C. n^2-3n+2

D. $n^2 \frac{(n+1)}{2}$

gatecse-2000 data-structures array easy

Answer key

8.2.7 Array: GATE CSE 2000 | Question: 15

Suppose you are given arrays $p[1......N]$ and $q[1......N]$ both uninitialized, that is, each location may contain an arbitrary value), and a variable count, initialized to 0. Consider the following procedures set and is_set:

```
set(i) {
   count = count + 1;
   q[count] = i;
   p[i] = count;
}
is_set(i) {
   if (p[i] ≤ 0 or p[i] > count)
      return false;
   if (q[p[i]] ≠ i)
      return false;
   return true;
}
```

A. Suppose we make the following sequence of calls:
   $set(7); set(3); set(9);$
   After these sequence of calls, what is the value of count, and what do $q[1], q[2], q[3], p[7], p[3]$ and $p[9]$ contain?
B. Complete the following statement "The first count elements of ___________contain values i such that set (__________________) has been called".
C. Show that if $set(i)$ has not been called for some i, then regardless of what $p[i]$ contains, $is\_set(i)$ will return false.

gatecse-2000 data-structures array easy descriptive

Answer key

8.2.8 Array: GATE CSE 2005 | Question: 5

A program P reads in 500 integers in the range $[0, 100]$ representing the scores of 500 students. It then prints the frequency of each score above 50. What would be the best way for P to store the frequencies?

A. An array of 50 numbers
B. An array of 100 numbers
C. An array of 500 numbers
D. A dynamically allocated array of 550 numbers

gatecse-2005 data-structures array easy

Answer key

8.2.9 Array: GATE CSE 2013 | Question: 50

The procedure given below is required to find and replace certain characters inside an input character string supplied in array A. The characters to be replaced are supplied in array $oldc$, while their respective replacement characters are supplied in array $newc$. Array A has a fixed length of five characters, while arrays $oldc$ and $newc$ contain three characters each. However, the procedure is flawed.

```
void find_and_replace (char *A, char *oldc, char *newc) {
   for (int i=0; i<5; i++)
      for (int j=0; j<3; j++)
         if (A[i] == oldc[j])
            A[i] = newc[j];
}
```

The procedure is tested with the following four test cases.

1. $oldc = “abc”, newc = “dab”$
2. $oldc = “cde”, newc = “bcd”$
3. $oldc = “bca”, newc = “cda”$
4. $oldc = “abc”, newc = “bac”$

The tester now tests the program on all input strings of length five consisting of characters ‘a’, ‘b’, ‘c’, ‘d’ and ‘e’ with duplicates allowed. If the tester carries out this testing with the four test cases given above, how many test cases will be able to capture the flaw?

A. Only one
B. Only two
C. Only three
D. All four

gatecse-2013 data-structures array normal

Answer key

8.2.10 Array: GATE CSE 2013 | Question: 51

The procedure given below is required to find and replace certain characters inside an input character string supplied in array A. The characters to be replaced are supplied in array $oldc$, while their respective replacement characters are supplied in array $newc$. Array A has a fixed length of five characters, while arrays $oldc$ and $newc$ contain three characters each. However, the procedure is flawed.

```
void find_and_replace (char *A, char *oldc, char *newc) {
    for (int i=0; i<5; i++)
       for (int j=0; j<3; j++)
           if (A[i] == oldc[j])
              A[i] = newc[j];
}
```

The procedure is tested with the following four test cases.

1. $oldc = \text{“}abc\text{”}, newc = \text{“}dab\text{”}$
2. $oldc = \text{“}cde\text{”}, newc = \text{“}bcd\text{”}$
3. $oldc = \text{“}bca\text{”}, newc = \text{“}cda\text{”}$
4. $oldc = \text{“}abc\text{”}, newc = \text{“}bac\text{”}$

If array A is made to hold the string “$abcde$”, which of the above four test cases will be successful in exposing the flaw in this procedure?

A. None
B. 2 only
C. 3 and 4 only
D. 4 only

gatecse-2013 data-structures array normal

Answer key

8.2.11 Array: GATE CSE 2014 Set 3 | Question: 42

Consider the C function given below. Assume that the array $listA$ contains $n(>0)$ elements, sorted in ascending order.

```
int ProcessArray(int *listA, int x, int n)
{
      int i, j, k;
      i = 0;    j = n-1;
       do {
            k = (i+j)/2;
            if (x <= listA[k]) j = k-1;
            if (listA[k] <= x) i = k+1;
          }
      while (i <= j);
      if (listA[k] == x) return(k);
      else   return -1;
}
```

Which one of the following statements about the function $ProcessArray$ is **CORRECT**?

A. It will run into an infinite loop when x is not in $listA$.
B. It is an implementation of binary search.
C. It will always find the maximum element in $listA$.
D. It will return -1 even when x is present in $listA$.

gatecse-2014-set3 data-structures array easy

Answer key

8.2.12 Array: GATE CSE 2015 Set 2 | Question: 31

A Young tableau is a $2D$ array of integers increasing from left to right and from top to bottom. Any unfilled entries are marked with ∞, and hence there cannot be any entry to the right of, or below a ∞. The following Young tableau consists of unique entries.

1	2	5	14
3	4	6	23
10	12	18	25
31	∞	∞	∞

When an element is removed from a Young tableau, other elements should be moved into its place so that the resulting table is still a Young tableau (unfilled entries may be filled with a ∞). The minimum number of entries (other than 1) to be shifted, to remove 1 from the given Young tableau is _____.

gatecse-2015-set2 databases array normal numerical-answers

Answer key☟

8.2.13 Array: GATE CSE 2021 Set 1 | Question: 2

Let P be an array containing n integers. Let t be the lowest upper bound on the number of comparisons of the array elements, required to find the minimum and maximum values in an arbitrary array of n elements. Which one of the following choices is correct?

A. $t > 2n - 2$
B. $t > 3\lceil \frac{n}{2} \rceil$ and $t \leq 2n - 2$
C. $t > n$ and $t \leq 3\lceil \frac{n}{2} \rceil$
D. $t > \lceil \log_2(n) \rceil$ and $t \leq n$

gatecse-2021-set1 data-structures array one-mark

Answer key☟

8.3 Binary Heap (29)

8.3.1 Binary Heap: GATE CSE 1990 | Question: 2-viii

Match the pairs in the following questions:

(a)	A heap construction	(p)	$\Omega(n \log_{10} n)$
(b)	Constructing Hashtable with linear probing	(q)	$O(n)$
(c)	AVL tree construction	(r)	$O(n^2)$
(d)	Digital trie construction	(s)	$O(n \log_2 n)$

gate1990 match-the-following data-structures binary-heap

Answer key☟

8.3.2 Binary Heap: GATE CSE 1996 | Question: 2.11

The minimum number of interchanges needed to convert the array into a max-heap is

$$89, 19, 40, 17, 12, 10, 2, 5, 7, 11, 6, 9, 70$$

A. 0
B. 1
C. 2
D. 3

gate1996 data-structures binary-heap easy

Answer key☟

8.3.3 Binary Heap: GATE CSE 1999 | Question: 12

A. In binary tree, a full node is defined to be a node with 2 children. Use induction on the height of the binary tree to prove that the number of full nodes plus one is equal to the number of leaves.

B. Draw the min-heap that results from insertion of the following elements in order into an initially empty min-heap: $7, 6, 5, 4, 3, 2, 1$. Show the result after the deletion of the root of this heap.

gate1999 data-structures binary-heap normal descriptive

Answer key

8.3.4 Binary Heap: GATE CSE 2001 | Question: 1.15

Consider any array representation of an n element binary heap where the elements are stored from index 1 to index n of the array. For the element stored at index i of the array $(i \leq n)$, the index of the parent is

A. $i-1$
B. $\lfloor \frac{i}{2} \rfloor$
C. $\lceil \frac{i}{2} \rceil$
D. $\frac{(i+1)}{2}$

gatecse-2001 data-structures binary-heap easy

Answer key

8.3.5 Binary Heap: GATE CSE 2003 | Question: 23

In a min-heap with n elements with the smallest element at the root, the 7^{th} smallest element can be found in time

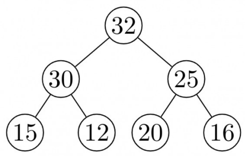
A. $\Theta(n \log n)$
B. $\Theta(n)$
C. $\Theta(\log n)$
D. $\Theta(1)$

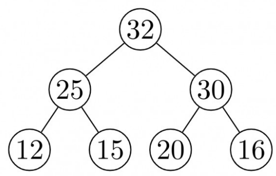
gatecse-2003 data-structures binary-heap

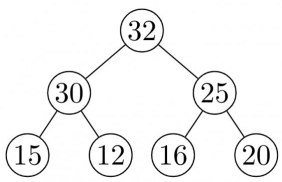
Answer key

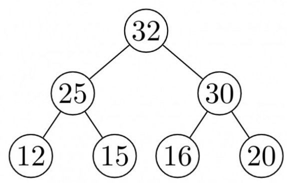
8.3.6 Binary Heap: GATE CSE 2004 | Question: 37

The elements $32, 15, 20, 30, 12, 25, 16,$ are inserted one by one in the given order into a maxHeap. The resultant maxHeap is

A. 

B. 

C. 

D. 

gatecse-2004 data-structures binary-heap easy

Answer key

8.3.7 Binary Heap: GATE CSE 2005 | Question: 34

A priority queue is implemented as a Max-Heap. Initially, it has 5 elements. The level-order traversal of the heap is: $10, 8, 5, 3, 2$. Two new elements 1 and 7 are inserted into the heap in that order. The level-order traversal of the heap after the insertion of the elements is:

A. $10, 8, 7, 5, 3, 2, 1$
B. $10, 8, 7, 2, 3, 1, 5$
C. $10, 8, 7, 1, 2, 3, 5$
D. $10, 8, 7, 3, 2, 1, 5$

gatecse-2005 data-structures binary-heap normal

Answer key

8.3.8 Binary Heap: GATE CSE 2006 | Question: 10

In a binary max heap containing n numbers, the smallest element can be found in time

A. $O(n)$
B. $O(\log n)$
C. $O(\log \log n)$
D. $O(1)$

gatecse-2006 data-structures binary-heap easy

Answer key

8.3.9 Binary Heap: GATE CSE 2006 | Question: 76

Statement for Linked Answer Questions 76 & 77:

A 3-ary max heap is like a binary max heap, but instead of 2 children, nodes have 3 children. A 3-ary heap can be represented by an array as follows: The root is stored in the first location, $a[0]$, nodes in the next level, from left to right, is stored from $a[1]$ to $a[3]$. The nodes from the second level of the tree from left to right are stored from $a[4]$ location onward. An item x can be inserted into a 3-ary heap containing n items by placing x in the location $a[n]$ and pushing it up the tree to satisfy the heap property.

76. Which one of the following is a valid sequence of elements in an array representing 3-ary max heap?

A. $1, 3, 5, 6, 8, 9$
B. $9, 6, 3, 1, 8, 5$
C. $9, 3, 6, 8, 5, 1$
D. $9, 5, 6, 8, 3, 1$

gatecse-2006 data-structures binary-heap normal

Answer key

8.3.10 Binary Heap: GATE CSE 2006 | Question: 77

Statement for Linked Answer Questions 76 & 77:

A 3-ary max heap is like a binary max heap, but instead of 2 children, nodes have 3 children. A 3-ary heap can be represented by an array as follows: The root is stored in the first location, $a[0]$, nodes in the next level, from left to right, is stored from $a[1]$ to $a[3]$. The nodes from the second level of the tree from left to right are stored from $a[4]$ location onward. An item x can be inserted into a 3-ary heap containing n items by placing x in the location $a[n]$ and pushing it up the tree to satisfy the heap property.

76. Which one of the following is a valid sequence of elements in an array representing $3-$ary max heap?

A. $1, 3, 5, 6, 8, 9$
B. $9, 6, 3, 1, 8, 5$
C. $9, 3, 6, 8, 5, 1$
D. $9, 5, 6, 8, 3, 1$

77. Suppose the elements $7, 2, 10$ and 4 are inserted, in that order, into the valid 3-ary max heap found in the previous question, Q.76. Which one of the following is the sequence of items in the array representing the resultant heap?

A. $10, 7, 9, 8, 3, 1, 5, 2, 6, 4$
B. $10, 9, 8, 7, 6, 5, 4, 3, 2, 1$
C. $10, 9, 4, 5, 7, 6, 8, 2, 1, 3$
D. $10, 8, 6, 9, 7, 2, 3, 4, 1, 5$

gatecse-2006 data-structures binary-heap normal

Answer key

8.3.11 Binary Heap: GATE CSE 2007 | Question: 47

Consider the process of inserting an element into a $Max\ Heap$, where the $Max\ Heap$ is represented by an $array$. Suppose we perform a binary search on the path from the new leaf to the root to find the position for the newly inserted element, the number of $comparisons$ performed is:

A. $\Theta(\log_2 n)$
B. $\Theta(\log_2 \log_2 n)$
C. $\Theta(n)$
D. $\Theta(n \log_2 n)$

gatecse-2007 data-structures binary-heap normal

Answer key

8.3.12 Binary Heap: GATE CSE 2009 | Question: 59

Consider a binary max-heap implemented using an array.
Which one of the following array represents a binary max-heap?

A. $\{25, 12, 16, 13, 10, 8, 14\}$
B. $\{25, 14, 13, 16, 10, 8, 12\}$

C. $\{25, 14, 16, 13, 10, 8, 12\}$

D. $\{25, 14, 12, 13, 10, 8, 16\}$

gatecse-2009 data-structures binary-heap easy

Answer key

8.3.13 Binary Heap: GATE CSE 2009 | Question: 60

Consider a binary max-heap implemented using an array.
What is the content of the array after two delete operations on $\{25, 14, 16, 13, 10, 8, 12\}$

A. $\{14, 13, 12, 10, 8\}$

B. $\{14, 12, 13, 8, 10\}$

C. $\{14, 13, 8, 12, 10\}$

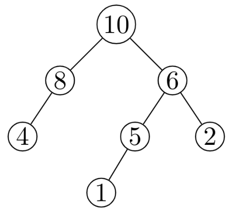
D. $\{14, 13, 12, 8, 10\}$

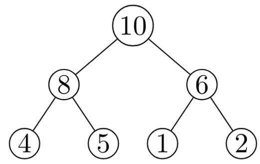
gatecse-2009 data-structures binary-heap normal

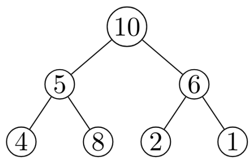
Answer key

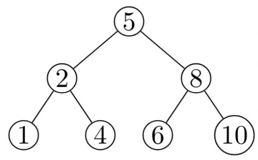
8.3.14 Binary Heap: GATE CSE 2011 | Question: 23

A max-heap is a heap where the value of each parent is greater than or equal to the value of its children. Which of the following is a max-heap?

A. 

B. 

C. 

D. 

gatecse-2011 data-structures binary-heap easy

Answer key

8.3.15 Binary Heap: GATE CSE 2014 Set 2 | Question: 12

A priority queue is implemented as a Max-Heap. Initially, it has 5 elements. The level-order traversal of the heap is: $10, 8, 5, 3, 2$. Two new elements 1 and 7 are inserted into the heap in that order. The level-order traversal of the heap after the insertion of the elements is:

A. $10, 8, 7, 3, 2, 1, 5$

B. $10, 8, 7, 2, 3, 1, 5$

C. $10, 8, 7, 1, 2, 3, 5$

D. $10, 8, 7, 5, 3, 2, 1$

gatecse-2014-set2 data-structures binary-heap normal

Answer key

8.3.16 Binary Heap: GATE CSE 2015 Set 1 | Question: 32

Consider a max heap, represented by the array: $40, 30, 20, 10, 15, 16, 17, 8, 4$.

Array index	1	2	3	4	5	6	7	8	9
Value	40	30	20	10	15	16	17	8	4

Now consider that a value 35 is inserted into this heap. After insertion, the new heap is

A. $40, 30, 20, 10, 15, 16, 17, 8, 4, 35$

B. $40, 35, 20, 10, 30, 16, 17, 8, 4, 15$

C. $40, 30, 20, 10, 35, 16, 17, 8, 4, 15$

D. $40, 35, 20, 10, 15, 16, 17, 8, 4, 30$

gatecse-2015-set1 data-structures binary-heap easy

Answer key

8.3.17 Binary Heap: GATE CSE 2015 Set 2 | Question: 17

Consider a complete binary tree where the left and right subtrees of the root are max-heaps. The lower bound for the number of operations to convert the tree to a heap is

A. $\Omega(\log n)$
B. $\Omega(n)$
C. $\Omega(n \log n)$
D. $\Omega(n^2)$

gatecse-2015-set2 data-structures binary-heap normal

Answer key

8.3.18 Binary Heap: GATE CSE 2015 Set 3 | Question: 19

Consider the following array of elements.

$\langle 89, 19, 50, 17, 12, 15, 2, 5, 7, 11, 6, 9, 100 \rangle$

The minimum number of interchanges needed to convert it into a max-heap is

A. 4
B. 5
C. 2
D. 3

gatecse-2015-set3 data-structures binary-heap easy

Answer key

8.3.19 Binary Heap: GATE CSE 2016 Set 1 | Question: 37

An operator $delete(i)$ for a binary heap data structure is to be designed to delete the item in the i-th node. Assume that the heap is implemented in an array and i refers to the i-th index of the array. If the heap tree has depth d (number of edges on the path from the root to the farthest leaf), then what is the time complexity to re-fix the heap efficiently after the removal of the element?

A. $O(1)$
B. $O(d)$ but not $O(1)$
C. $O(2^d)$ but not $O(d)$
D. $O(d\,2^d)$ but not $O(2^d)$

gatecse-2016-set1 data-structures binary-heap normal

Answer key

8.3.20 Binary Heap: GATE CSE 2016 Set 2 | Question: 34

A complete binary min-heap is made by including each integer in $[1, 1023]$ exactly once. The depth of a node in the heap is the length of the path from the root of the heap to that node. Thus, the root is at depth 0. The maximum depth at which integer 9 can appear is _________.

gatecse-2016-set2 data-structures binary-heap normal numerical-answers

Answer key

8.3.21 Binary Heap: GATE CSE 2018 | Question: 46

The number of possible min-heaps containing each value from $\{1, 2, 3, 4, 5, 6, 7\}$ exactly once is _______

gatecse-2018 binary-heap numerical-answers combinatory two-marks

Answer key

8.3.22 Binary Heap: GATE CSE 2019 | Question: 40

Consider the following statements:

I. The smallest element in a max-heap is always at a leaf node
II. The second largest element in a max-heap is always a child of a root node
III. A max-heap can be constructed from a binary search tree in $\Theta(n)$ time
IV. A binary search tree can be constructed from a max-heap in $\Theta(n)$ time

Which of the above statements are TRUE?

A. I, II and III
B. I, II and IV
C. I, III and IV
D. II, III and IV

gatecse-2019 data-structures binary-heap two-marks

Answer key

8.3.23 Binary Heap: GATE CSE 2020 | Question: 47

Consider the array representation of a binary min-heap containing 1023 elements. The minimum number of comparisons required to find the maximum in the heap is ___________.

gatecse-2020 numerical-answers binary-heap two-marks

Answer key

8.3.24 Binary Heap: GATE CSE 2021 Set 2 | Question: 2

Let H be a binary min-heap consisting of n elements implemented as an array. What is the worst case time complexity of an optimal algorithm to find the maximum element in H?

A. $\Theta(1)$
B. $\Theta(\log n)$
C. $\Theta(n)$
D. $\Theta(n \log n)$

gatecse-2021-set2 data-structures binary-heap time-complexity one-mark

Answer key

8.3.25 Binary Heap: GATE CSE 2023 | Question: 2

Which one of the following sequences when stored in an array at locations $A[1], \ldots, A[10]$ forms a max-heap?

A. $23, 17, 10, 6, 13, 14, 1, 5, 7, 12$
B. $23, 17, 14, 7, 13, 10, 1, 5, 6, 12$
C. $23, 17, 14, 6, 13, 10, 1, 5, 7, 15$
D. $23, 14, 17, 1, 10, 13, 16, 12, 7, 5$

gatecse-2023 data-structures binary-heap one-mark

Answer key

8.3.26 Binary Heap: GATE CSE 2024 | Set 1 | Question: 33

Consider a binary min-heap containing 105 distinct elements. Let k be the index (in the underlying array) of the maximum element stored in the heap. The number of possible values of k is

A. 53
B. 52
C. 27
D. 1

gatecse2024-set1 data-structures binary-heap two-marks

Answer key

8.3.27 Binary Heap: GATE IT 2004 | Question: 53

An array of integers of size n can be converted into a heap by adjusting the heaps rooted at each internal node of the complete binary tree starting at the node $\lfloor (n-1)/2 \rfloor$, and doing this adjustment up to the root node (root node is at index 0) in the order $\lfloor (n-1)/2 \rfloor$, $\lfloor (n-3)/2 \rfloor$, ..., 0. The time required to construct a heap in this manner is

A. $O(\log n)$
B. $O(n)$
C. $O(n \log \log n)$
D. $O(n \log n)$

gateit-2004 data-structures binary-heap normal

Answer key

8.3.28 Binary Heap: GATE IT 2006 | Question: 44

Which of the following sequences of array elements forms a heap?

A. $\{23, 17, 14, 6, 13, 10, 1, 12, 7, 5\}$
B. $\{23, 17, 14, 6, 13, 10, 1, 5, 7, 12\}$
C. $\{23, 17, 14, 7, 13, 10, 1, 5, 6, 12\}$
D. $\{23, 17, 14, 7, 13, 10, 1, 12, 5, 7\}$

gateit-2006 data-structures binary-heap easy

Answer key

8.3.29 Binary Heap: GATE IT 2006 | Question: 72

An array X of n distinct integers is interpreted as a complete binary tree. The index of the first element of the array is 0. If only the root node does not satisfy the heap property, the algorithm to convert the complete binary tree into a heap has the best asymptotic time complexity of

A. $O(n)$ B. $O(\log n)$ C. $O(n \log n)$ D. $O(n \log \log n)$

gateit-2006 data-structures binary-heap easy

Answer key

8.4 Binary Search Tree (36)

8.4.1 Binary Search Tree: GATE CSE 1996 | Question: 2.14

A binary search tree is generated by inserting in order the following integers:

$$50, 15, 62, 5, 20, 58, 91, 3, 8, 37, 60, 24$$

The number of nodes in the left subtree and right subtree of the root respectively is

A. $(4,7)$ B. $(7,4)$ C. $(8,3)$ D. $(3,8)$

gate1996 data-structures binary-search-tree easy

Answer key

8.4.2 Binary Search Tree: GATE CSE 1996 | Question: 4

A binary search tree is used to locate the number 43. Which of the following probe sequences are possible and which are not? Explain.

(a)	61	52	14	17	40	43
(b)	2	3	50	40	60	43
(c)	10	65	31	48	37	43
(d)	81	61	52	14	41	43
(e)	17	77	27	66	18	43

gate1996 data-structures binary-search-tree normal descriptive

Answer key

8.4.3 Binary Search Tree: GATE CSE 1997 | Question: 4.5

A binary search tree contains the value $1, 2, 3, 4, 5, 6, 7, 8$. The tree is traversed in pre-order and the values are printed out. Which of the following sequences is a valid output?

A. 5 3 1 2 4 7 8 6
B. 5 3 1 2 6 4 8 7
C. 5 3 2 4 1 6 7 8
D. 5 3 1 2 4 7 6 8

gate1997 data-structures binary-search-tree normal

Answer key

8.4.4 Binary Search Tree: GATE CSE 2001 | Question: 14

A. Insert the following keys one by one into a binary search tree in the order specified.

$$15, 32, 20, 9, 3, 25, 12, 1$$

Show the final binary search tree after the insertions.

B. Draw the binary search tree after deleting 15 from it.

C. Complete the statements $S1$, $S2$ and $S3$ in the following function so that the function computes the depth of a binary tree rooted at t.

```
typedef struct tnode{
    int key;
    struct tnode *left, *right;
} *Tree;
```

```
int depth (Tree t)
{
   int x, y;
   if (t == NULL) return 0;
   x = depth (t -> left);
S1:    ___________;

S2:    if (x > y) return __________;

S3:    else return _______;

}
```

gatecse-2001 data-structures binary-search-tree normal descriptive

Answer key

8.4.5 Binary Search Tree: GATE CSE 2003 | Question: 19, ISRO2009-24

Suppose the numbers $7, 5, 1, 8, 3, 6, 0, 9, 4, 2$ are inserted in that order into an initially empty binary search tree. The binary search tree uses the usual ordering on natural numbers. What is the in-order traversal sequence of the resultant tree?

A. $7\ 5\ 1\ 0\ 3\ 2\ 4\ 6\ 8\ 9$
B. $0\ 2\ 4\ 3\ 1\ 6\ 5\ 9\ 8\ 7$
C. $0\ 1\ 2\ 3\ 4\ 5\ 6\ 7\ 8\ 9$
D. $9\ 8\ 6\ 4\ 2\ 3\ 0\ 1\ 5\ 7$

gatecse-2003 binary-search-tree easy isro2009

Answer key

8.4.6 Binary Search Tree: GATE CSE 2003 | Question: 6

Let $T(n)$ be the number of different binary search trees on n distinct elements.

Then $T(n) = \sum_{k=1}^{n} T(k-1)T(x)$, where x is

A. $n-k+1$ B. $n-k$ C. $n-k-1$ D. $n-k-2$

gatecse-2003 normal binary-search-tree

Answer key

8.4.7 Binary Search Tree: GATE CSE 2003 | Question: 63, ISRO2009-25

A data structure is required for storing a set of integers such that each of the following operations can be done in $O(\log n)$ time, where n is the number of elements in the set.

I. Deletion of the smallest element
II. Insertion of an element if it is not already present in the set

Which of the following data structures can be used for this purpose?

A. A heap can be used but not a balanced binary search tree
B. A balanced binary search tree can be used but not a heap
C. Both balanced binary search tree and heap can be used
D. Neither balanced search tree nor heap can be used

gatecse-2003 data-structures easy isro2009 binary-search-tree

Answer key

8.4.8 Binary Search Tree: GATE CSE 2004 | Question: 4, ISRO2009-26

The following numbers are inserted into an empty binary search tree in the given order: $10, 1, 3, 5, 15, 12, 16$. What is the height of the binary search tree (the height is the maximum distance of a leaf node from the root)?

A. 2 B. 3 C. 4 D. 6

gatecse-2004 data-structures binary-search-tree easy isro2009

Answer key☟

8.4.9 Binary Search Tree: GATE CSE 2004 | Question: 85

A program takes as input a balanced binary search tree with n leaf nodes and computes the value of a function $g(x)$ for each node x. If the cost of computing $g(x)$ is:

$$\min \left(\begin{array}{c} \text{number of leaf-nodes} \\ \text{in left-subtree of } x \end{array} , \begin{array}{c} \text{number of leaf-nodes} \\ \text{in right-subtree of } x \end{array} \right)$$

Then the worst-case time complexity of the program is?

A. $\Theta(n)$
B. $\Theta(n \log n)$
C. $\Theta(n^2)$
D. $\Theta(n^2 \log n)$

gatecse-2004 binary-search-tree normal data-structures

Answer key☟

8.4.10 Binary Search Tree: GATE CSE 2005 | Question: 33

Postorder traversal of a given binary search tree, T produces the following sequence of keys

$10, 9, 23, 22, 27, 25, 15, 50, 95, 60, 40, 29$

Which one of the following sequences of keys can be the result of an in-order traversal of the tree T?

A. $9, 10, 15, 22, 23, 25, 27, 29, 40, 50, 60, 95$
B. $9, 10, 15, 22, 40, 50, 60, 95, 23, 25, 27, 29$
C. $29, 15, 9, 10, 25, 22, 23, 27, 40, 60, 50, 95$
D. $95, 50, 60, 40, 27, 23, 22, 25, 10, 9, 15, 29$

gatecse-2005 data-structures binary-search-tree easy

Answer key☟

8.4.11 Binary Search Tree: GATE CSE 2005 | Question: 35

How many distinct binary search trees can be created out of 4 distinct keys?

A. 5 B. 14 C. 24 D. 42

gatecse-2005 data-structures binary-search-tree counting normal

Answer key☟

8.4.12 Binary Search Tree: GATE CSE 2008 | Question: 46

You are given the postorder traversal, P, of a binary search tree on the n elements $1, 2, \dots, n$. You have to determine the unique binary search tree that has P as its postorder traversal. What is the time complexity of the most efficient algorithm for doing this?

A. $\Theta(\log n)$
B. $\Theta(n)$
C. $\Theta(n \log n)$
D. None of the above, as the tree cannot be uniquely determined

gatecse-2008 data-structures binary-search-tree normal

Answer key☟

8.4.13 Binary Search Tree: GATE CSE 2012 | Question: 5

The worst case running time to search for an element in a balanced binary search tree with $n2^n$ elements is

A. $\Theta(n \log n)$
B. $\Theta(n2^n)$
C. $\Theta(n)$
D. $\Theta(\log n)$

gatecse-2012 data-structures normal binary-search-tree

Answer key☟

8.4.14 Binary Search Tree: GATE CSE 2013 | Question: 43

The preorder traversal sequence of a binary search tree is $30, 20, 10, 15, 25, 23, 39, 35, 42$. Which one of the following is the postorder traversal sequence of the same tree?

A. $10, 20, 15, 23, 25, 35, 42, 39, 30$
B. $15, 10, 25, 23, 20, 42, 35, 39, 30$
C. $15, 20, 10, 23, 25, 42, 35, 39, 30$
D. $15, 10, 23, 25, 20, 35, 42, 39, 30$

gatecse-2013 data-structures binary-search-tree normal

Answer key☟

8.4.15 Binary Search Tree: GATE CSE 2013 | Question: 7

Which one of the following is the tightest upper bound that represents the time complexity of inserting an object into a binary search tree of n nodes?

A. $O(1)$
B. $O(\log n)$
C. $O(n)$
D. $O(n \log n)$

gatecse-2013 data-structures easy binary-search-tree

Answer key☟

8.4.16 Binary Search Tree: GATE CSE 2014 Set 3 | Question: 39

Suppose we have a balanced binary search tree T holding n numbers. We are given two numbers L and H and wish to sum up all the numbers in T that lie between L and H. Suppose there are m such numbers in T. If the tightest upper bound on the time to compute the sum is $O(n^a \log^b n + m^c \log^d n)$, the value of $a + 10b + 100c + 1000d$ is ______.

gatecse-2014-set3 data-structures binary-search-tree numerical-answers normal

Answer key☟

8.4.17 Binary Search Tree: GATE CSE 2015 Set 1 | Question: 10

Which of the following is/are correct in order traversal sequence(s) of binary search tree(s)?

I. $3, 5, 7, 8, 15, 19, 25$
II. $5, 8, 9, 12, 10, 15, 25$
III. $2, 7, 10, 8, 14, 16, 20$
IV. $4, 6, 7, 9, 18, 20, 25$

A. I and IV only
B. II and III only
C. II and IV only
D. II only

gatecse-2015-set1 data-structures binary-search-tree easy

Answer key☟

8.4.18 Binary Search Tree: GATE CSE 2015 Set 1 | Question: 23

What are the worst-case complexities of insertion and deletion of a key in a binary search tree?

A. $\Theta(\log n)$ for both insertion and deletion
B. $\Theta(n)$ for both insertion and deletion
C. $\Theta(n)$ for insertion and $\Theta(\log n)$ for deletion

D. $\Theta(\log n)$ for insertion and $\Theta(n)$ for deletion

gatecse-2015-set1 data-structures binary-search-tree easy

Answer key

8.4.19 Binary Search Tree: GATE CSE 2015 Set 3 | Question: 13

While inserting the elements $71, 65, 84, 69, 67, 83$ in an empty binary search tree (BST) in the sequence shown, the element in the lowest level is

A. 65
B. 67
C. 69
D. 83

gatecse-2015-set3 data-structures binary-search-tree easy

Answer key

8.4.20 Binary Search Tree: GATE CSE 2016 Set 2 | Question: 40

The number of ways in which the numbers $1, 2, 3, 4, 5, 6, 7$ can be inserted in an empty binary search tree, such that the resulting tree has height 6, is _________.

Note: The height of a tree with a single node is 0.

gatecse-2016-set2 data-structures binary-search-tree normal numerical-answers

Answer key

8.4.21 Binary Search Tree: GATE CSE 2017 Set 1 | Question: 6

Let T be a binary search tree with 15 nodes. The minimum and maximum possible heights of T are:

Note: The height of a tree with a single node is 0.

A. 4 and 15 respectively.
B. 3 and 14 respectively.
C. 4 and 14 respectively.
D. 3 and 15 respectively.

gatecse-2017-set1 data-structures binary-search-tree easy

Answer key

8.4.22 Binary Search Tree: GATE CSE 2017 Set 2 | Question: 36

The pre-order traversal of a binary search tree is given by $12, 8, 6, 2, 7, 9, 10, 16, 15, 19, 17, 20$. Then the post-order traversal of this tree is

A. $2, 6, 7, 8, 9, 10, 12, 15, 16, 17, 19, 20$
B. $2, 7, 6, 10, 9, 8, 15, 17, 20, 19, 16, 12$
C. $7, 2, 6, 8, 9, 10, 20, 17, 19, 15, 16, 12$
D. $7, 6, 2, 10, 9, 8, 15, 16, 17, 20, 19, 12$

gatecse-2017-set2 data-structures binary-search-tree

Answer key

8.4.23 Binary Search Tree: GATE CSE 2020 | Question: 41

In a balanced binary search tree with n elements, what is the worst case time complexity of reporting all elements in range $[a, b]$? Assume that the number of reported elements is k.

A. $\Theta(\log n)$
B. $\Theta(\log n + k)$
C. $\Theta(k \log n)$
D. $\Theta(n \log k)$

gatecse-2020 data-structures binary-search-tree two-marks

Answer key

8.4.24 Binary Search Tree: GATE CSE 2020 | Question: 5

The preorder traversal of a binary search tree is $15, 10, 12, 11, 20, 18, 16, 19$. Which one of the following is the postorder traversal of the tree?

A. $10, 11, 12, 15, 16, 18, 19, 20$
B. $11, 12, 10, 16, 19, 18, 20, 15$
C. $20, 19, 18, 16, 15, 12, 11, 10$
D. $19, 16, 18, 20, 11, 12, 10, 15$

gatecse-2020 binary-search-tree one-mark

Answer key

8.4.25 Binary Search Tree: GATE CSE 2021 Set 1 | Question: 10

A binary search tree T contains n distinct elements. What is the time complexity of picking an element in T that is smaller than the maximum element in T?

A. $\Theta(n \log n)$
B. $\Theta(n)$
C. $\Theta(\log n)$
D. $\Theta(1)$

gatecse-2021-set1 data-structures binary-search-tree time-complexity one-mark

Answer key

8.4.26 Binary Search Tree: GATE CSE 2022 | Question: 18

Suppose a binary search tree with 1000 distinct elements is also a complete binary tree. The tree is stored using the array representation of binary heap trees. Assuming that the array indices start with $0,$ the 3^{rd} largest element of the tree is stored at index ______________ .

gatecse-2022 numerical-answers data-structures binary-search-tree one-mark

Answer key

8.4.27 Binary Search Tree: GATE CSE 2024 | Set 2 | Question: 29

You are given a set V of distinct integers. A binary search tree T is created by inserting all elements of V one by one, starting with an empty tree. The tree T follows the convention that, at each node, all values stored in the left subtree of the node are smaller than the value stored at the node. You are not aware of the sequence in which these values were inserted into T, and you do not have access to T.

Which one of the following statements is TRUE?

A. Inorder traversal of T can be determined from V
B. Root node of T can be determined from V
C. Preorder traversal of T can be determined from V
D. Postorder traversal of T can be determined from V

gatecse2024-set2 binary-search-tree two-marks

Answer key

8.4.28 Binary Search Tree: GATE CSE 2025 | Set 1 | Question: 16

Which of the following statement(s) is/are TRUE for any binary search tree (BST) having n distinct integers?

A. The maximum length of a path from the root node to any other node is $(n-1)$.
B. An inorder traversal will always produce a sorted sequence of elements.
C. Finding an element takes $O(\log_2 n)$ time in the worst case.
D. Every BST is also a Min-Heap.

gatecse2025-set1 data-structures binary-search-tree multiple-selects one-mark

Answer key

8.4.29 Binary Search Tree: GATE CSE 2025 | Set 2 | Question: 25

Suppose the values $10, -4, 15, 30, 20, 5, 60, 19$ are inserted in that order into an initially empty binary search tree. Let T be the resulting binary search tree. The number of edges in the path from the node containing 19 to the root node of T is _________. (Answer in integer)

gatecse2025-set2 data-structures binary-search-tree numerical-answers easy one-mark

Answer key

8.4.30 Binary Search Tree: GATE IT 2005 | Question: 12

The numbers $1, 2, \dots n$ are inserted in a binary search tree in some order. In the resulting tree, the right subtree of the root contains p nodes. The first number to be inserted in the tree must be

A. p
B. $p+1$
C. $n-p$
D. $n-p+1$

gateit-2005 data-structures normal binary-search-tree

Answer key

8.4.31 Binary Search Tree: GATE IT 2005 | Question: 55

A binary search tree contains the numbers $1, 2, 3, 4, 5, 6, 7, 8.$ When the tree is traversed in pre-order and the values in each node printed out, the sequence of values obtained is $5, 3, 1, 2, 4, 6, 8, 7.$ If the tree is traversed in post-order, the sequence obtained would be

A. $8,7,6,5,4,3,2,1$
B. $1,2,3,4,8,7,6,5$
C. $2,1,4,3,6,7,8,5$
D. $2,1,4,3,7,8,6,5$

gateit-2005 data-structures binary-search-tree normal

Answer key

8.4.32 Binary Search Tree: GATE IT 2006 | Question: 45

Suppose that we have numbers between 1 and 100 in a binary search tree and want to search for the number 55. Which of the following sequences CANNOT be the sequence of nodes examined?

A. $\{10,75,64,43,60,57,55\}$
B. $\{90,12,68,34,62,45,55\}$
C. $\{9,85,47,68,43,57,55\}$
D. $\{79,14,72,56,16,53,55\}$

gateit-2006 data-structures binary-search-tree normal

Answer key

8.4.33 Binary Search Tree: GATE IT 2007 | Question: 29

When searching for the key value 60 in a binary search tree, nodes containing the key values $10, 20, 40, 50, 70, 80, 90$ are traversed, not necessarily in the order given. How many different orders are possible in which these key values can occur on the search path from the root to the node containing the value 60?

A. 35
B. 64
C. 128
D. 5040

gateit-2007 data-structures binary-search-tree normal

Answer key

8.4.34 Binary Search Tree: GATE IT 2008 | Question: 71

A Binary Search Tree (BST) stores values in the range 37 to 573. Consider the following sequence of keys.

I. $81, 537, 102, 439, 285, 376, 305$
II. $52, 97, 121, 195, 242, 381, 472$
III. $142, 248, 520, 386, 345, 270, 307$
IV. $550, 149, 507, 395, 463, 402, 270$

Suppose the BST has been unsuccessfully searched for key 273. Which all of the above sequences list nodes in the order in which we could have encountered them in the search?

A. II and III only
B. I and III only
C. III and IV only
D. III only

gateit-2008 data-structures binary-search-tree normal

Answer key

8.4.35 Binary Search Tree: GATE IT 2008 | Question: 72

A Binary Search Tree (BST) stores values in the range 37 to 573. Consider the following sequence of keys.

I. $81, 537, 102, 439, 285, 376, 305$
II. $52, 97, 121, 195, 242, 381, 472$

III. $142, 248, 520, 386, 345, 270, 307$
IV. $550, 149, 507, 395, 463, 402, 270$

Which of the following statements is TRUE?

A. I, II and IV are inorder sequences of three different BSTs
B. I is a preorder sequence of some BST with 439 as the root
C. II is an inorder sequence of some BST where 121 is the root and 52 is a leaf
D. IV is a postorder sequence of some BST with 149 as the root

gateit-2008 data-structures binary-search-tree easy

Answer key

8.4.36 Binary Search Tree: GATE IT 2008 | Question: 73

How many distinct BSTs can be constructed with 3 distinct keys?

A. 4 B. 5 C. 6 D. 9

gateit-2008 data-structures binary-search-tree normal

Answer key

8.5 Binary Tree (53)

8.5.1 Binary Tree: GATE CSE 1987 | Question: 2c

State whether the following statements are TRUE or FALSE:

It is possible to construct a binary tree uniquely whose pre-order and post-order traversals are given?

gate1987 binary-tree data-structures normal true-false

Answer key

8.5.2 Binary Tree: GATE CSE 1987 | Question: 2g

State whether the following statements are TRUE or FALSE:

If the number of leaves in a tree is not a power of $2,$ then the tree is not a binary tree.

gate1987 data-structures binary-tree true-false

Answer key

8.5.3 Binary Tree: GATE CSE 1987 | Question: 7b

Construct a binary tree whose preorder traversal is

- $K\ L\ N\ M\ P\ R\ Q\ S\ T$

and inorder traversal is

- $N\ L\ K\ P\ R\ M\ S\ Q\ T$

gate1987 data-structures binary-tree descriptive

Answer key

8.5.4 Binary Tree: GATE CSE 1988 | Question: 7i

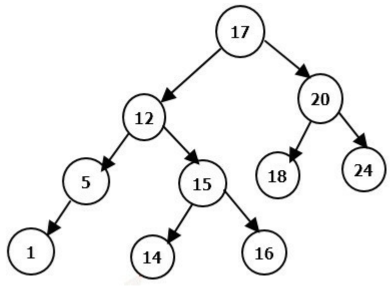
Define the height of a binary tree or subtree and also define a height-balanced (AVL) tree.

gate1988 normal descriptive data-structures binary-tree

Answer key

8.5.5 Binary Tree: GATE CSE 1988 | Question: 7iii

Consider the tree given in the below figure, insert 13 and show the new balance factors that would arise if the tree is not rebalanced. Finally, carry out the required rebalancing of the tree and show the new tree with the balance factors on each mode.



gate1988 normal descriptive data-structures binary-tree

Answer key

8.5.6 Binary Tree: GATE CSE 1989 | Question: 3-ixa

Which one of the following statements (s) is/are FALSE?

A. Overlaying is used to run a program, which is longer than the address space of the computer.
B. Optimal binary search tree construction can be performed efficiently by using dynamic programming.
C. Depth first search cannot be used to find connected components of a graph.
D. Given the prefix and postfix walls over a binary tree, the binary tree can be uniquely constructed.

normal gate1989 binary-tree multiple-selects

Answer key

8.5.7 Binary Tree: GATE CSE 1990 | Question: 3-iv

The total external path length, $\text{EPL},$ of a binary tree with n external nodes is, $\text{EPL} = \sum_{w} I_w,$ where I_w is the path length of external node w),

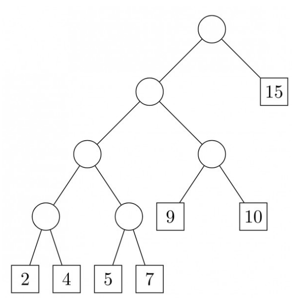
A. $\leq n^2$ always.
B. $\geq n \log_2 n$ always.
C. Equal to n^2 always.
D. $O(n)$ for some special trees.

gate1990 normal data-structures binary-tree multiple-selects

Answer key

8.5.8 Binary Tree: GATE CSE 1991 | Question: 01,viii

The weighted external path length of the binary tree in figure is ______

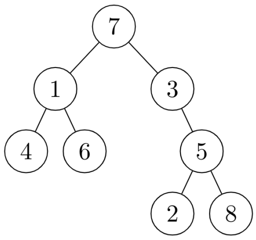


gate1991 binary-tree data-structures normal numerical-answers

Answer key

8.5.9 Binary Tree: GATE CSE 1991 | Question: 1,ix

If the binary tree in figure is traversed in inorder, then the order in which the nodes will be visited is ______

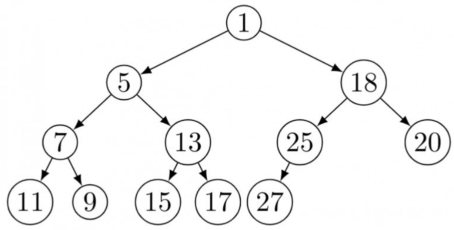


gate1991 binary-tree easy data-structures descriptive

Answer key☟

8.5.10 Binary Tree: GATE CSE 1991 | Question: 14,a

Consider the binary tree in the figure below:



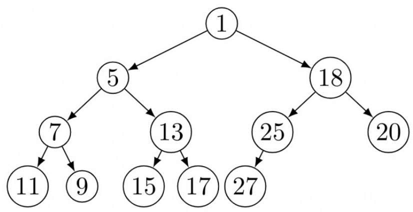
What structure is represented by the binary tree?

gate1991 data-structures binary-tree time-complexity easy descriptive

Answer key☟

8.5.11 Binary Tree: GATE CSE 1991 | Question: 14,b

Consider the binary tree in the figure below:



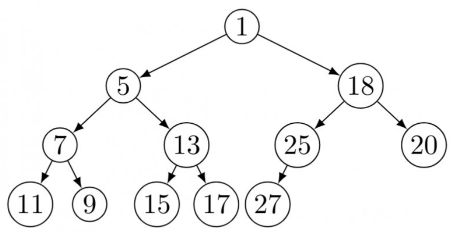
Give different steps for deleting the node with key 5 so that the structure is preserved.

gate1991 data-structures binary-tree normal descriptive

Answer key☟

8.5.12 Binary Tree: GATE CSE 1991 | Question: 14,c

Consider the binary tree in the figure below:



Outline a procedure in Pseudo-code to delete an arbitrary node from such a binary tree with n nodes that preserves the structures. What is the worst-case time complexity of your procedure?

gate1991 normal data-structures binary-tree time-complexity descriptive

Answer key

8.5.13 Binary Tree: GATE CSE 1993 | Question: 16

Prove by the principal of mathematical induction that for any binary tree, in which every non-leaf node has 2-descendants, the number of leaves in the tree is one more than the number of non-leaf nodes.

gate1993 data-structures binary-tree normal descriptive

Answer key

8.5.14 Binary Tree: GATE CSE 1994 | Question: 8

A rooted tree with 12 nodes has its nodes numbered 1 to 12 in pre-order. When the tree is traversed in post-order, the nodes are visited in the order $3, 5, 4, 2, 7, 8, 6, 10, 11, 12, 9, 1$.

Reconstruct the original tree from this information, that is, find the parent of each node, and show the tree diagrammatically.

gate1994 data-structures binary-tree normal descriptive

Answer key

8.5.15 Binary Tree: GATE CSE 1995 | Question: 1.17

A binary tree T has n leaf nodes. The number of nodes of degree 2 in T is

A. $\log_2 n$
B. $n-1$
C. n
D. 2^n

gate1995 data-structures binary-tree normal

Answer key

8.5.16 Binary Tree: GATE CSE 1995 | Question: 6

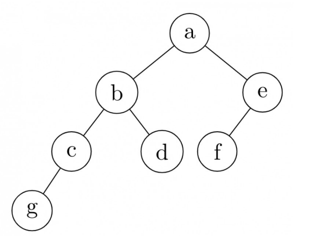
What is the number of binary trees with 3 nodes which when traversed in post-order give the sequence A, B, C? Draw all these binary trees.

gate1995 data-structures binary-tree normal descriptive

Answer key

8.5.17 Binary Tree: GATE CSE 1996 | Question: 1.15

Which of the following sequences denotes the post order traversal sequence of the below tree?



A. $f\,e\,g\,c\,d\,b\,a$
B. $g\,c\,b\,d\,a\,f\,e$
C. $g\,c\,d\,b\,f\,e\,a$
D. $f\,e\,d\,g\,c\,b\,a$

gate1996 data-structures binary-tree easy

Answer key

8.5.18 Binary Tree: GATE CSE 1997 | Question: 16

A size-balanced binary tree is a binary tree in which for every node the difference between the number of nodes in the left and right subtree is at most 1. The distance of a node from the root is the length of the path from the root to the node. The height of a binary tree is the maximum distance of a leaf node from the root.

A. Prove, by using induction on h, that a size-balance binary tree of height h contains at least 2^h nodes.
B. In a size-balanced binary tree of height $h \geqslant 1$, how many nodes are at distance $h-1$ from the root? Write only

the answer without any explanations.

gate1997 data-structures binary-tree normal descriptive proof

Answer key

8.5.19 Binary Tree: GATE CSE 1998 | Question: 20

Draw the binary tree with node labels $\mathrm{a, b, c, d, e, f}$ and g for which the inorder and postorder traversals result in the following sequences:

Inorder: $\mathrm{a\ f\ b\ c\ d\ g\ e}$

Postorder: $\mathrm{a\ f\ c\ g\ e\ d\ b}$

gate1998 data-structures binary-tree descriptive

Answer key

8.5.20 Binary Tree: GATE CSE 2000 | Question: 1.14

Consider the following nested representation of binary trees: $(X\ Y\ Z)$ indicates Y and Z are the left and right subtrees, respectively, of node X. Note that Y and Z may be $NULL$, or further nested. Which of the following represents a valid binary tree?

A. $(1\ 2\ (4\ 5\ 6\ 7))$
B. $(1\ (2\ 3\ 4)\ 5\ 6)\ 7)$
C. $(1\ (2\ 3\ 4)\ (5\ 6\ 7))$
D. $(1\ (2\ 3\ NULL)\ (4\ 5))$

gatecse-2000 data-structures binary-tree easy

Answer key

8.5.21 Binary Tree: GATE CSE 2000 | Question: 2.16

Let LASTPOST, LASTIN and LASTPRE denote the last vertex visited `in a postorder, inorder and preorder traversal respectively, of a complete binary tree. Which of the following is always true?

A. LASTIN = LASTPOST
B. LASTIN = LASTPRE
C. LASTPRE = LASTPOST
D. None of the above

gatecse-2000 data-structures binary-tree normal

Answer key

8.5.22 Binary Tree: GATE CSE 2002 | Question: 2.12

A weight-balanced tree is a binary tree in which for each node, the number of nodes in the left sub tree is at least half and at most twice the number of nodes in the right sub tree. The maximum possible height (number of nodes on the path from the root to the furthest leaf) of such a tree on n nodes is best described by which of the following?

A. $\log_2 n$
B. $\log_{\frac{4}{3}} n$
C. $\log_3 n$
D. $\log_{\frac{3}{2}} n$

gatecse-2002 data-structures binary-tree normal

Answer key

8.5.23 Binary Tree: GATE CSE 2002 | Question: 6

Draw all binary trees having exactly three nodes labeled A, B and C on which preorder traversal gives the sequence C, B, A.

gatecse-2002 data-structures binary-tree easy descriptive

Answer key

8.5.24 Binary Tree: GATE CSE 2004 | Question: 35

Consider the label sequences obtained by the following pairs of traversals on a labeled binary tree. Which of these pairs identify a tree uniquely?

I. preorder and postorder
II. inorder and postorder
III. preorder and inorder
IV. level order and postorder

A. I only
B. II, III
C. III only
D. IV only

gatecse-2004 data-structures binary-tree normal

Answer key

8.5.25 Binary Tree: GATE CSE 2004 | Question: 43

Consider the following C program segment

```
struct CellNode{
   struct CellNode *leftChild
   int element;
   struct CellNode *rightChild;
   };

int Dosomething (struct CellNode *ptr)
{
   int value = 0;
   if(ptr != NULL)
   {
      if (ptr -> leftChild != NULL)
         value = 1 + DoSomething (ptr -> leftChild);
      if (ptr -> rightChild != NULL)
         value = max(value, 1 + Dosomething (ptr -> rightChild));
   }
   return(value);
}
```

The value returned by the function DoSomething when a pointer to the root of a non-empty tree is passed as argument is

A. The number of leaf nodes in the tree
B. The number of nodes in the tree
C. The number of internal nodes in the tree
D. The height of the tree

gatecse-2004 data-structures binary-tree normal

Answer key

8.5.26 Binary Tree: GATE CSE 2006 | Question: 13

A scheme for storing binary trees in an array X is as follows. Indexing of X starts at 1 instead of 0. the root is stored at $X[1]$. For a node stored at $X[i]$, the left child, if any, is stored in $X[2i]$ and the right child, if any, in $X[2i+1]$. To be able to store any binary tree on n vertices the minimum size of X should be

A. $\log_2 n$
B. n
C. $2n+1$
D. $2^n - 1$

gatecse-2006 data-structures binary-tree normal

Answer key

8.5.27 Binary Tree: GATE CSE 2007 | Question: 12

The height of a binary tree is the maximum number of edges in any root to leaf path. The maximum number of nodes in a binary tree of height h is:

A. $2^h - 1$
B. $2^{h-1} - 1$
C. $2^{h+1} - 1$
D. 2^{h+1}

gatecse-2007 data-structures binary-tree easy

Answer key

8.5.28 Binary Tree: GATE CSE 2007 | Question: 13

The maximum number of binary trees that can be formed with three unlabeled nodes is:

A. 1 B. 5 C. 4 D. 3

gatecse-2007 data-structures binary-tree normal

Answer key

8.5.29 Binary Tree: GATE CSE 2007 | Question: 39, UGCNET-June2015-II: 22

The inorder and preorder traversal of a binary tree are

d b e a f c g and a b d e c f g, respectively

The postorder traversal of the binary tree is:

A. d e b f g c a
B. e d b g f c a
C. e d b f g c a
D. d e f g b c a

gatecse-2007 data-structures binary-tree normal ugcnetcse-june2015-paper2

Answer key

8.5.30 Binary Tree: GATE CSE 2007 | Question: 46

Consider the following C program segment where $CellNode$ represents a node in a binary tree:

```
struct CellNode {
   struct CellNode *leftChild;
   int element;
   struct CellNode *rightChild;
};

int Getvalue (struct CellNode *ptr) {
   int value = 0;
   if (ptr != NULL) {
      if ((ptr->leftChild == NULL) &&
         (ptr->rightChild == NULL))
         value = 1;
      else
         value = value + GetValue(ptr->leftChild)
               + GetValue(ptr->rightChild);
   }
   return(value);
}
```

The value returned by $GetValue$ when a pointer to the root of a binary tree is passed as its argument is:

A. the number of nodes in the tree
B. the number of internal nodes in the tree
C. the number of leaf nodes in the tree
D. the height of the tree

gatecse-2007 data-structures binary-tree normal

Answer key

8.5.31 Binary Tree: GATE CSE 2010 | Question: 10

In a binary tree with n nodes, every node has an odd number of descendants. Every node is considered to be its own descendant. What is the number of nodes in the tree that have exactly one child?

A. 0 B. 1 C. $\frac{(n-1)}{2}$ D. $n-1$

gatecse-2010 data-structures binary-tree normal

Answer key

8.5.32 Binary Tree: GATE CSE 2011 | Question: 29

We are given a set of n distinct elements and an unlabeled binary tree with n nodes. In how many ways can we populate the tree with the given set so that it becomes a binary search tree?

A. 0 B. 1 C. $n!$ D. $\frac{1}{n+1}.^{2n}C_n$

gatecse-2011 binary-tree normal

Answer key

8.5.33 Binary Tree: GATE CSE 2012 | Question: 47

The height of a tree is defined as the number of edges on the longest path in the tree. The function shown in the pseudo-code below is invoked as height (root) to compute the height of a binary tree rooted at the tree pointer root.

```
int height(treeptr n)
{ if(n == NULL) return -1;
  if(n -> left == NULL)
    if(n -> right == NULL) return 0;
    else return B1; // Box 1

  else{h1 = height(n -> left);
      if(n -> right == NULL) return (1+h1);
      else{h2 = height(n -> right);
          return B2; // Box 2
          }
      }
}
```

The appropriate expressions for the two boxes **B1** and **B2** are:

A. **B1**: $(1+\text{height}(n \rightarrow \text{ right}))$; **B2**: $(1+\max(h1, h2))$
B. **B1**: $(\text{height}(n \rightarrow \text{ right}))$; **B2**: $(1+\max(h1, h2))$
C. **B1**: $\text{height}(n \rightarrow \text{ right})$; **B2**: $\max(h1, h2)$
D. **B1**: $(1+\text{height}(n \rightarrow \text{ right}))$; **B2**: $\max(h1, h2)$

gatecse-2012 data-structures binary-tree normal

Answer key

8.5.34 Binary Tree: GATE CSE 2014 Set 1 | Question: 12

Consider a rooted n node binary tree represented using pointers. The best upper bound on the time required to determine the number of subtrees having exactly 4 nodes is $O(n^a \log^b n)$. Then the value of $a+10b$ is __________.

gatecse-2014-set1 data-structures binary-tree numerical-answers normal

Answer key

8.5.35 Binary Tree: GATE CSE 2015 Set 1 | Question: 25

The height of a tree is the length of the longest root-to-leaf path in it. The maximum and minimum number of nodes in a binary tree of height 5 are

A. 63 and 6, respectively
B. 64 and 5, respectively
C. 32 and 6, respectively
D. 31 and 5, respectively

gatecse-2015-set1 data-structures binary-tree easy

Answer key

8.5.36 Binary Tree: GATE CSE 2015 Set 2 | Question: 10

A binary tree T has 20 leaves. The number of nodes in T having two children is _______.

gatecse-2015-set2 data-structures binary-tree normal numerical-answers

Answer key

8.5.37 Binary Tree: GATE CSE 2015 Set 3 | Question: 25

Consider a binary tree T that has 200 leaf nodes. Then the number of nodes in T that have exactly two children are _______.

gatecse-2015-set3 data-structures binary-tree normal numerical-answers

Answer key

8.5.38 Binary Tree: GATE CSE 2016 Set 2 | Question: 36

Consider the following New-order strategy for traversing a binary tree:

- Visit the root;
- Visit the right subtree using New-order;
- Visit the left subtree using New-order;

The New-order traversal of the expression tree corresponding to the reverse polish expression

```
3 4 * 5 - 2 ^ 6 7 * 1 + -
```

is given by:

A. $+-167*2\wedge 5-34*$
B. $-+1*67\wedge 2-5*34$
C. $-+1*76\wedge 2-5*43$
D. $176*+2543*-\wedge-$

gatecse-2016-set2 data-structures binary-tree normal

Answer key

8.5.39 Binary Tree: GATE CSE 2018 | Question: 20

The postorder traversal of a binary tree is $8, 9, 6, 7, 4, 5, 2, 3, 1$. The inorder traversal of the same tree is $8, 6, 9, 4, 7, 2, 5, 1, 3$. The height of a tree is the length of the longest path from the root to any leaf. The height of the binary tree above is _____

gatecse-2018 data-structures binary-tree numerical-answers one-mark

Answer key

8.5.40 Binary Tree: GATE CSE 2019 | Question: 46

Let T be a full binary tree with 8 leaves. (A full binary tree has every level full.) Suppose two leaves a and b of T are chosen uniformly and independently at random. The expected value of the distance between a and b in T (ie., the number of edges in the unique path between a and b) is (rounded off to 2 decimal places) _________.

gatecse-2019 numerical-answers data-structures binary-tree two-marks

Answer key

8.5.41 Binary Tree: GATE CSE 2021 Set 2 | Question: 16

Consider a complete binary tree with 7 nodes. Let A denote the set of first 3 elements obtained by performing Breadth-First Search (BFS) starting from the root. Let B denote the set of first 3 elements obtained by performing Depth-First Search (DFS) starting from the root.

The value of $|A-B|$ is _____________

gatecse-2021-set2 numerical-answers data-structures binary-tree one-mark

Answer key

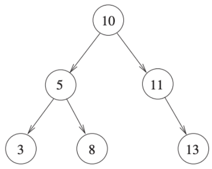
8.5.42 Binary Tree: GATE CSE 2023 | Question: 37

Consider the C function foo and the binary tree shown.

```
typedef struct node {
    int val;
    struct node *left, *right;
} node;

int foo(node *p) {
    int retval;
    if (p == NULL)
        return 0;
    else {
```

```
        retval = p->val + foo(p->left) + foo(p->right);
        printf("%d ", retval);
        return retval;
    }
}
```



When foo is called with a pointer to the root node of the given binary tree, what will it print?

A. $3\ 8\ 5\ 13\ 11\ 10$
B. $3\ 5\ 8\ 10\ 11\ 13$
C. $3\ 8\ 16\ 13\ 24\ 50$
D. $3\ 16\ 8\ 50\ 24\ 13$

gatecse-2023 data-structures binary-tree two-marks

Answer key☟

8.5.43 Binary Tree: GATE CSE 2025 | Set 2 | Question: 3

Consider a binary tree T in which every node has either zero or two children. Let $n > 0$ be the number of nodes in T.

Which ONE of the following is the number of nodes in T that have exactly two children?

A. $\frac{n-2}{2}$
B. $\frac{n-1}{2}$
C. $\frac{n}{2}$
D. $\frac{n+1}{2}$

gatecse2025-set2 data-structures binary-tree one-mark

Answer key☟

8.5.44 Binary Tree: GATE DS&AI 2024 | Question: 18

Consider the following tree traversals on a full binary tree:

i. Preorder
ii. Inorder
iii. Postorder

Which of the following traversal options is/are sufficient to uniquely reconstruct the full binary tree?

A. (i) and (ii)
B. (ii) and (iii)
C. (i) and (iii)
D. (ii) only

gate-ds-ai-2024 data-structures binary-tree multiple-selects one-mark

Answer key☟

8.5.45 Binary Tree: GATE DS&AI 2024 | Question: 42

Let H, I, L, and N represent height, number of internal nodes, number of leaf nodes, and the total number of nodes respectively in a rooted binary tree.

Which of the following statements is/are always TRUE?

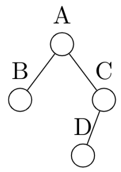
A. $L \leq I + 1$
B. $H + 1 \leq N \leq 2^{H+1} - 1$
C. $H \leq I \leq 2^H - 1$
D. $H \leq L \leq 2^{H-1}$

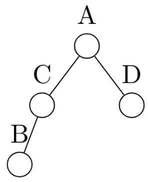
gate-ds-ai-2024 data-structures binary-tree multiple-selects two-marks

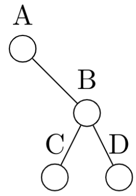
Answer key☟

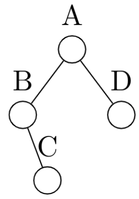
8.5.46 Binary Tree: GATE IT 2004 | Question: 54

Which one of the following binary trees has its inorder and preorder traversals as $BCAD$ and $ABCD$, respectively?

A. 

B. 

C. 

D. 

gateit-2004 binary-tree easy data-structures

Answer key

8.5.47 Binary Tree: GATE IT 2005 | Question: 50

In a binary tree, for every node the difference between the number of nodes in the left and right subtrees is at most 2. If the height of the tree is $h > 0$, then the minimum number of nodes in the tree is

A. 2^{h-1}
B. $2^{h-1} + 1$
C. $2^h - 1$
D. 2^h

gateit-2005 data-structures binary-tree normal

Answer key

8.5.48 Binary Tree: GATE IT 2006 | Question: 71

An array X of n distinct integers is interpreted as a complete binary tree. The index of the first element of the array is 0. The index of the parent of element $X[i], i \neq 0$, is?

A. $\left\lfloor \frac{i}{2} \right\rfloor$
B. $\left\lceil \frac{i-1}{2} \right\rceil$
C. $\left\lceil \frac{i}{2} \right\rceil$
D. $\left\lceil \frac{i}{2} \right\rceil - 1$

gateit-2006 data-structures binary-tree normal

Answer key

8.5.49 Binary Tree: GATE IT 2006 | Question: 73

An array X of n distinct integers is interpreted as a complete binary tree. The index of the first element of the array is 0. If the root node is at level 0, the level of element $X[i], i \neq 0$, is

A. $\lfloor \log_2 i \rfloor$
B. $\lceil \log_2 (i+1) \rceil$
C. $\lfloor \log_2 (i+1) \rfloor$
D. $\lceil \log_2 i \rceil$

gateit-2006 data-structures binary-tree normal

Answer key

8.5.50 Binary Tree: GATE IT 2006 | Question: 9

In a binary tree, the number of internal nodes of degree 1 is 5, and the number of internal nodes of degree 2 is 10. The number of leaf nodes in the binary tree is

A. 10
B. 11
C. 12
D. 15

gateit-2006 data-structures binary-tree normal

Answer key

8.5.51 Binary Tree: GATE IT 2008 | Question: 46

The following three are known to be the preorder, inorder and postorder sequences of a binary tree. But it is not known which is which.

I. $MBCAFHPYK$
II. $KAMCBYPFH$
III. $MABCKYFPH$

Pick the true statement from the following.

A. I and II are preorder and inorder sequences, respectively
B. I and III are preorder and postorder sequences, respectively
C. II is the inorder sequence, but nothing more can be said about the other two sequences
D. II and III are the preorder and inorder sequences, respectively

gateit-2008 data-structures normal binary-tree

Answer key

8.5.52 Binary Tree: GATE IT 2008 | Question: 76

A binary tree with $n > 1$ nodes has n_1, n_2 and n_3 nodes of degree one, two and three respectively. The degree of a node is defined as the number of its neighbours.

n_3 can be expressed as

A. $n_1 + n_2 - 1$
B. $n_1 - 2$
C. $[((n_1 + n_2)/2)]$
D. $n_2 - 1$

gateit-2008 data-structures binary-tree normal

Answer key

8.5.53 Binary Tree: GATE IT 2008 | Question: 77

A binary tree with $n > 1$ nodes has n_1, n_2 and n_3 nodes of degree one, two and three respectively. The degree of a node is defined as the number of its neighbours.

Starting with the above tree, while there remains a node v of degree two in the tree, add an edge between the two neighbours of v and then remove v from the tree. How many edges will remain at the end of the process?

A. $2 * n_1 - 3$
B. $n_2 + 2 * n_1 - 2$
C. $n_3 - n_2$
D. $n_2 + n_1 - 2$

gateit-2008 data-structures binary-tree normal

Answer key

8.6 Data Structures (5)

8.6.1 Data Structures: GATE CSE 1997 | Question: 6.2

Let G be the graph with 100 vertices numbered 1 to 100. Two vertices i and j are adjacent if $|i - j| = 8$ or $|i - j| = 12$. The number of connected components in G is

A. 8
B. 4
C. 12
D. 25

gate1997 data-structures normal graph-theory

Answer key

8.6.2 Data Structures: GATE CSE 2005 | Question: 2

An Abstract Data Type (ADT) is:

A. same as an abstract class
B. a data type that cannot be instantiated
C. a data type for which only the operations defined on it can be used, but none else
D. all of the above

gatecse-2005 data-structures normal abstract-data-type

Answer key

8.6.3 Data Structures: GATE CSE 2014 Set 1 | Question: 3

Let $G = (V, E)$ be a directed graph where V is the set of vertices and E the set of edges. Then which one of the following graphs has the same strongly connected components as G ?

A. $G_1 = (V, E_1)$ where $E_1 = \{(u, v) \mid (u, v) \notin E\}$
B. $G_2 = (V, E_2)$ where $E_2 = \{(u, v) \mid (v, u) \in E\}$
C. $G_3 = (V, E_3)$ where $E_3 = \{(u, v) \mid$ there is a path of length ≤ 2 from u to v in $E\}$
D. $G_4 = (V_4, E)$ where V_4 is the set of vertices in G which are not isolated

gatecse-2014-set1 data-structures graph-theory ambiguous

Answer key☟

8.6.4 Data Structures: GATE CSE 2016 Set 1 | Question: 38

Consider the weighted undirected graph with 4 vertices, where the weight of edge $\{i, j\}$ is given by the entry W_{ij} in the matrix W.

$$W = \begin{bmatrix} 0 & 2 & 8 & 5 \\ 2 & 0 & 5 & 8 \\ 8 & 5 & 0 & x \\ 5 & 8 & x & 0 \end{bmatrix}$$

The largest possible integer value of x, for which at least one shortest path between some pair of vertices will contain the edge with weight x is ___________.

gatecse-2016-set1 data-structures graph-theory normal numerical-answers

Answer key☟

8.6.5 Data Structures: GATE DS&AI 2024 | Question: 6

Match the items in **Column** 1 with the items in **Column** 2 in the following table:

	Column 1		Column 2
(p)	First In First Out	(i)	Stacks
(q)	Lookup Operation	(ii)	Queues
(r)	Last In First Out	(iii)	Hash Tables

A. $\text{(p)} - \text{(ii)}, \text{(q)} - \text{(iii)}, \text{(r)} - \text{(i)}$
B. $\text{(p)} - \text{(ii)}, \text{(q)} - \text{(i)}, \text{(r)} - \text{(iii)}$
C. $\text{(p)} - \text{(i)}, \text{(q)} - \text{(ii)}, \text{(r)} - \text{(iii)}$
D. $\text{(p)} - \text{(i)}, \text{(q)} - \text{(iii)}, \text{(r)} - \text{(ii)}$

gate-ds-ai-2024 data-structures match-the-following one-mark

Answer key☟

8.7 Hashing (16)

8.7.1 Hashing: GATE CSE 1996 | Question: 1.13

An advantage of chained hash table (external hashing) over the open addressing scheme is

A. Worst case complexity of search operations is less
B. Space used is less
C. Deletion is easier
D. None of the above

gate1996 data-structures hashing normal

Answer key☟

8.7.2 Hashing: GATE CSE 1996 | Question: 15

Insert the characters of the string $K\ R\ P\ C\ S\ N\ Y\ T\ J\ M$ into a hash table of size 10.

Use the hash function

$$h(x) = (ord(x) – ord(\text{“}a\text{”}) + 1) \mod 10$$

and linear probing to resolve collisions.

A. Which insertions cause collisions?
B. Display the final hash table.

gate1996 data-structures hashing normal descriptive

Answer key

8.7.3 Hashing: GATE CSE 1997 | Question: 12

Consider a hash table with n buckets, where external (overflow) chaining is used to resolve collisions. The hash function is such that the probability that a key value is hashed to a particular bucket is $\frac{1}{n}$. The hash table is initially empty and K distinct values are inserted in the table.

A. What is the probability that bucket number 1 is empty after the K^{th} insertion?
B. What is the probability that no collision has occurred in any of the K insertions?
C. What is the probability that the first collision occurs at the K^{th} insertion?

gate1997 data-structures hashing probability normal descriptive

Answer key

8.7.4 Hashing: GATE CSE 2004 | Question: 7

Given the following input $(4322, 1334, 1471, 9679, 1989, 6171, 6173, 4199)$ and the hash function x mod 10, which of the following statements are true?

I. $9679, 1989, 4199$ hash to the same value
II. $1471, 6171$ hash to the same value
III. All elements hash to the same value
IV. Each element hashes to a different value

A. I only
B. II only
C. I and II only
D. III or IV

gatecse-2004 data-structures hashing easy

Answer key

8.7.5 Hashing: GATE CSE 2007 | Question: 40

Consider a hash table of size seven, with starting index zero, and a hash function $(3x + 4) \mod 7$. Assuming the hash table is initially empty, which of the following is the contents of the table when the sequence $1, 3, 8, 10$ is inserted into the table using closed hashing? Note that – denotes an empty location in the table.

A. 8, –, –, –, –, –, 10
B. $1, 8, 10$, –, –, –, 3
C. 1, –, –, –, –, –, 3
D. $1, 10, 8$, –, –, –, 3

gatecse-2007 data-structures hashing easy

Answer key

8.7.6 Hashing: GATE CSE 2009 | Question: 36

The keys $12, 18, 13, 2, 3, 23, 5$ and 15 are inserted into an initially empty hash table of length 10 using open addressing with hash function $h(k) = k \mod 10$ and linear probing. What is the resultant hash table?

A.

0	
1	
2	2
3	23
4	
5	15
6	
7	
8	18
9	

B.

0	
1	
2	12
3	13
4	
5	5
6	
7	
8	18
9	

C.

0	
1	
2	12
3	13
4	2
5	3
6	23
7	5
8	18
9	15

D.

0	
1	
2	2, 12
3	13, 3, 23
4	
5	5, 15
6	
7	
8	18
9	

gatecse-2009 data-structures hashing normal

Answer key☟

8.7.7 Hashing: GATE CSE 2010 | Question: 52

A hash table of length 10 uses open addressing with hash function $h(k) = k \mod 10$, and linear probing. After inserting 6 values into an empty hash table, the table is shown as below

0	
1	
2	42
3	23
4	34
5	52
6	46
7	33
8	
9	

Which one of the following choices gives a possible order in which the key values could have been inserted in the table?

A. $46, 42, 34, 52, 23, 33$
B. $34, 42, 23, 52, 33, 46$
C. $46, 34, 42, 23, 52, 33$
D. $42, 46, 33, 23, 34, 52$

gatecse-2010 data-structures hashing normal

Answer key☟

8.7.8 Hashing: GATE CSE 2010 | Question: 53

A hash table of length 10 uses open addressing with hash function $h(k) = k \mod 10$, and linear probing. After inserting 6 values into an empty hash table, the table is shown as below

0	
1	
2	42
3	23
4	34
5	52
6	46
7	33
8	
9	

How many different insertion sequences of the key values using the same hash function and linear probing will result in the hash table shown above?

A. 10 B. 20 C. 30 D. 40

data-structures hashing normal gatecse-2010

Answer key☟

8.7.9 Hashing: GATE CSE 2014 Set 1 | Question: 40

Consider a hash table with 9 slots. The hash function is $h(k) = k \mod 9$. The collisions are resolved by chaining. The following 9 keys are inserted in the order: $5, 28, 19, 15, 20, 33, 12, 17, 10$. The maximum, minimum, and average chain lengths in the hash table, respectively, are

A. $3, 0$, and 1 B. $3, 3$, and 3 C. $4, 0$, and 1 D. $3, 0$, and 2

gatecse-2014-set1 data-structures hashing normal

Answer key☟

8.7.10 Hashing: GATE CSE 2014 Set 3 | Question: 40

Consider a hash table with 100 slots. Collisions are resolved using chaining. Assuming simple uniform hashing, what is the probability that the first 3 slots are unfilled after the first 3 insertions?

A. $(97 \times 97 \times 97)/100^3$
B. $(99 \times 98 \times 97)/100^3$
C. $(97 \times 96 \times 95)/100^3$
D. $(97 \times 96 \times 95/(3! \times 100^3)$

gatecse-2014-set3 data-structures hashing probability normal

Answer key☟

8.7.11 Hashing: GATE CSE 2015 Set 2 | Question: 33

Which one of the following hash functions on integers will distribute keys most uniformly over 10 buckets numbered 0 to 9 for i ranging from 0 to 2020?

A. $h(i) = i^2 \text{mod } 10$
B. $h(i) = i^3 \text{mod } 10$
C. $h(i) = (11 * i^2) \text{mod } 10$
D. $h(i) = (12 * i^2) \text{mod } 10$

gatecse-2015-set2 data-structures hashing normal

Answer key☟

8.7.12 Hashing: GATE CSE 2015 Set 3 | Question: 17

Given that hash table T with 25 slots that stores 2000 elements, the load factor a for T is _________.

gatecse-2015-set3 data-structures hashing easy numerical-answers

Answer key☟

8.7.13 Hashing: GATE DS&AI 2024 | Question: 11

Consider performing uniform hashing on an open address hash table with load factor $\alpha = \frac{n}{m} < 1$, where n elements are stored in the table with m slots. The expected number of probes in an unsuccessful search is at most $\frac{1}{1-\alpha}$.

Inserting an element in this hash table requires at most probes,_______ on average.

A. $\ln\left(\frac{1}{1-\alpha}\right)$ B. $\frac{1}{1-\alpha}$ C. $1 + \frac{\alpha}{2}$ D. $\frac{1}{1+\alpha}$

gate-ds-ai-2024 data-structures hashing uniform-hashing one-mark

Answer key☟

8.7.14 Hashing: GATE IT 2006 | Question: 20

Which of the following statement(s) is TRUE?

I. A hash function takes a message of arbitrary length and generates a fixed length code.
II. A hash function takes a message of fixed length and generates a code of variable length.

III. A hash function may give the same hash value for distinct messages.

A. I only
B. II and III only
C. I and III only
D. II only

gateit-2006 data-structures hashing normal

Answer key

8.7.15 Hashing: GATE IT 2007 | Question: 28

Consider a hash function that distributes keys uniformly. The hash table size is 20. After hashing of how many keys will the probability that any new key hashed collides with an existing one exceed 0.5.

A. 5
B. 6
C. 7
D. 10

gateit-2007 data-structures hashing probability normal

Answer key

8.7.16 Hashing: GATE IT 2008 | Question: 48

Consider a hash table of size 11 that uses open addressing with linear probing. Let $h(k) = k \mod 11$ be the hash function used. A sequence of records with keys

$43 \; 36 \; 92 \; 87 \; 11 \; 4 \; 71 \; 13 \; 14$

is inserted into an initially empty hash table, the bins of which are indexed from zero to ten. What is the index of the bin into which the last record is inserted?

A. 3
B. 4
C. 6
D. 7

gateit-2008 data-structures hashing normal

Answer key

8.8 Infix Prefix (5)

8.8.1 Infix Prefix: GATE CSE 1989 | Question: 4-ii

Compute the postfix equivalent of the following infix arithmetic expression

$a + b * c + d * e \uparrow f$

where $\uparrow$ represents exponentiation. Assume normal operator precedences.

gate1989 descriptive data-structures stack infix-prefix

Answer key

8.8.2 Infix Prefix: GATE CSE 1997 | Question: 1.7

Which of the following is essential for converting an infix expression to the postfix form efficiently?

A. An operator stack
B. An operand stack
C. An operand stack and an operator stack
D. A parse tree

gate1997 normal infix-prefix stack data-structures

Answer key

8.8.3 Infix Prefix: GATE CSE 1998 | Question: 19b

Compute the post fix equivalent of the following expression $3^* \log(x+1) - \frac{a}{2}$

gate1998 stack infix-prefix descriptive

Answer key

8.8.4 Infix Prefix: GATE CSE 2004 | Question: 38, ISRO2009-27

Assume that the operators $+, -, \times$ are left associative and $\hat{}$ is right associative. The order of precedence (from highest to lowest) is $\hat{}, \times, +, -$. The postfix expression corresponding to the infix expression

$a + b \times c - d$ ^ e ^ f is

A. $abc \times +def$ ^ ^$-$
B. $abc \times +de$ ^ f ^ $-$
C. $ab + c \times d - e$ ^ f ^
D. $- + a \times bc$ ^ ^ def

gatecse-2004 stack isro2009 infix-prefix

Answer key

8.8.5 Infix Prefix: GATE CSE 2007 | Question: 38, ISRO2016-27

The following postfix expression with single digit operands is evaluated using a stack:

$$8\ 2\ 3\ \hat{}\ /\ 2\ 3 * + 5\ 1 * -$$

Note that ^ is the exponentiation operator. The top two elements of the stack after the first $*$ is evaluated are

A. $6,1$
B. $5,7$
C. $3,2$
D. $1,5$

gatecse-2007 data-structures stack normal infix-prefix isro2016

Answer key

8.9 Linked List (23)

8.9.1 Linked List: GATE CSE 1987 | Question: 1-xv

In a circular linked list organization, insertion of a record involves modification of

A. One pointer.
B. Two pointers.
C. Multiple pointers.
D. No pointer.

gate1987 data-structures linked-list

Answer key

8.9.2 Linked List: GATE CSE 1987 | Question: 6a

A list of n elements is commonly written as a sequence of n elements enclosed in a pair of square brackets. For example. $[10, 20, 30]$ is a list of three elements and $[]$ is a nil list. Five functions are defined below:

- $car(l)$ returns the first element of its argument list l;
- $cdr(l)$ returns the list obtained by removing the first element of the argument list l;
- $glue(a, l)$ returns a list m such that $car(m) = a$ and $cdr(m) = l$.
- $f(x, y) \equiv$ if $x = []$ then y
  else $glue(car(x), f(cdr(x), y))$;
- $g(x) \equiv$ if $x = []$ then $[]$
  else $f(g(cdr(x)), glue(car(x), []))$

What do the following compute?

a. $f([32, 16, 8], [9, 11, 12])$
b. $g([5, 1, 8, 9])$

gate1987 data-structures linked-list descriptive

Answer key

8.9.3 Linked List: GATE CSE 1993 | Question: 13

Consider a singly linked list having n nodes. The data items $d_1, d_2, \dots d_n$ are stored in these n nodes. Let X be a pointer to the j^{th} node $(1 \leq j \leq n)$ in which d_j is stored. A new data item d stored in node with address Y is to be inserted. Give an algorithm to insert d into the list to obtain a list having items

$d_1, d_2, \ldots, d_j, d, \ldots, d_n$ in order without using the header.

gate1993 data-structures linked-list normal descriptive

Answer key

8.9.4 Linked List: GATE CSE 1994 | Question: 1.17, UGCNET-Sep2013-II: 32

Linked lists are not suitable data structures for which one of the following problems?

A. Insertion sort
B. Binary search
C. Radix sort
D. Polynomial manipulation

gate1994 data-structures linked-list normal ugcnetsep2013ii

Answer key

8.9.5 Linked List: GATE CSE 1995 | Question: 2.22

Which of the following statements is true?

I. As the number of entries in a hash table increases, the number of collisions increases.
II. Recursive programs are efficient
III. The worst case complexity for Quicksort is $O(n^2)$
IV. Binary search using a linear linked list is efficient

A. I and II
B. II and III
C. I and IV
D. I and III

gate1995 data-structures linked-list hashing

Answer key

8.9.6 Linked List: GATE CSE 1997 | Question: 1.4

The concatenation of two lists is to be performed on $O(1)$ time. Which of the following implementations of a list should be used?

A. Singly linked list
B. Doubly linked list
C. Circular doubly linked list
D. Array implementation of list

gate1997 data-structures linked-list easy

Answer key

8.9.7 Linked List: GATE CSE 1997 | Question: 18

Consider the following piece of 'C' code fragment that removes duplicates from an ordered list of integers.

```
Node *remove-duplicates (Node* head, int *j)
{
  Node *t1, *t2; *j=0;
  t1 = head;
  if (t1! = NULL)
    t2 = t1 ->next;
  else return head;
  *j = 1;
  if(t2 == NULL) return head;
  while (t2 != NULL)
  {
    if (t1.val != t2.val) ----------------> (S1)
    {
      (*j)++;
      t1 -> next = t2;
      t1 = t2; -----> (S2)
    }
      t2 = t2 ->next;
  }
  t1 -> next = NULL;
  return head;
}
```

Assume the list contains n elements ($n \geq 2$) in the following questions.

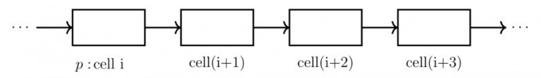
a. How many times is the comparison in statement $S1$ made?
b. What is the minimum and the maximum number of times statements marked $S2$ get executed?
c. What is the significance of the value in the integer pointed to by j when the function completes?

gate1997 data-structures linked-list normal descriptive

Answer key

8.9.8 Linked List: GATE CSE 1998 | Question: 19a

Let p be a pointer as shown in the figure in a single linked list.



What do the following assignment statements achieve?

```
q:= p -> next
p -> next:= q -> next
q -> next:=(q -> next) -> next
(p -> next) -> next:= q
```

gate1998 data-structures linked-list normal descriptive

Answer key

8.9.9 Linked List: GATE CSE 1999 | Question: 11b

Write a constant time algorithm to insert a node with data D just before the node with address p of a singly linked list.

gate1999 data-structures linked-list descriptive

Answer key

8.9.10 Linked List: GATE CSE 2002 | Question: 1.5

In the worst case, the number of comparisons needed to search a single linked list of length n for a given element is

A. $\log n$ B. $\frac{n}{2}$ C. $\log_2 n - 1$ D. n

gatecse-2002 easy data-structures linked-list

Answer key

8.9.11 Linked List: GATE CSE 2003 | Question: 90

Consider the function f defined below.

```
struct item {
       int data;
       struct item * next;
};
int f(struct item *p) {
    return ((p == NULL) || (p->next == NULL)||
       ((p->data <= p ->next -> data) &&
       f(p->next)));
}
```

For a given linked list p, the function f returns 1 if and only if

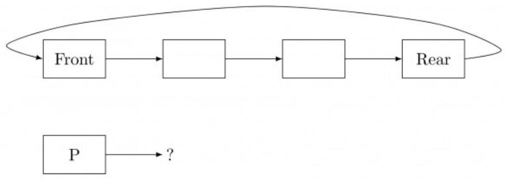
A. the list is empty or has exactly one element
B. the elements in the list are sorted in non-decreasing order of data value
C. the elements in the list are sorted in non-increasing order of data value
D. not all elements in the list have the same data value

gatecse-2003 data-structures linked-list normal

Answer key

8.9.12 Linked List: GATE CSE 2004 | Question: 36

A circularly linked list is used to represent a Queue. A single variable p is used to access the Queue. To which node should p point such that both the operations enQueue and deQueue can be performed in constant time?



A. rear node
B. front node
C. not possible with a single pointer
D. node next to front

gatecse-2004 data-structures linked-list normal

Answer key

8.9.13 Linked List: GATE CSE 2004 | Question: 40

Suppose each set is represented as a linked list with elements in arbitrary order. Which of the operations among $\text{union, intersection, membership, cardinality}$ will be the slowest?

A. union only
B. $\text{intersection, membership}$
C. $\text{membership, cardinality}$
D. $\text{union, intersection}$

gatecse-2004 data-structures linked-list normal

Answer key

8.9.14 Linked List: GATE CSE 2008 | Question: 62

The following C function takes a single-linked list of integers as a parameter and rearranges the elements of the list. The function is called with the list containing the integers $1, 2, 3, 4, 5, 6, 7$ in the given order. What will be the contents of the list after function completes execution?

```
struct node {
   int value;
   struct node *next;
};

void rearrange(struct node *list) {
   struct node *p, *q;
   int temp;
   if (!list || !list -> next) return;
   p = list; q = list -> next;
   while(q) {
      temp = p -> value; p->value =  q -> value;
      q->value = temp; p = q ->next;
      q = p? p ->next : 0;
   }
}
```

A. $1,2,3,4,5,6,7$
B. $2,1,4,3,6,5,7$
C. $1,3,2,5,4,7,6$
D. $2,3,4,5,6,7,1$

gatecse-2008 data-structures linked-list normal

Answer key

8.9.15 Linked List: GATE CSE 2010 | Question: 36

The following C function takes a singly-linked list as input argument. It modifies the list by moving the last element to the front of the list and returns the modified list. Some part of the code is left blank.

```
typedef struct node
{
   int value;
   struct node *next;
} Node;
Node *move_to-front(Node *head)
```

```
{
  Node *p, *q;
  if ((head == NULL) || (head -> next == NULL))
     return head;
  q = NULL;
  p = head;
  while (p->next != NULL)
  {
     q=p;
     p=p->next;
  }
  _______________

  return head;

}
```

Choose the correct alternative to replace the blank line.

A. $q = NULL; p \rightarrow next = head; head = p;$
B. $q \rightarrow next = NULL; head = p; p \rightarrow next = head;$
C. $head = p; p \rightarrow next = q; q \rightarrow next = NULL;$
D. $q \rightarrow next = NULL; p \rightarrow next = head; head = p;$

gatecse-2010 data-structures linked-list normal

Answer key

8.9.16 Linked List: GATE CSE 2016 Set 2 | Question: 15

N items are stored in a sorted doubly linked list. For a *delete* operation, a pointer is provided to the record to be deleted. For a *decrease-key* operation, a pointer is provided to the record on which the operation is to be performed.

An algorithm performs the following operations on the list in this order: $\Theta(N)$ *delete*, $O(\log N)$ *insert*, $O(\log N)$ *find*, and $\Theta(N)$ *decrease-key*. What is the time complexity of all these operations put together?

A. $O(\log^2 N)$ B. $O(N)$ C. $O(N^2)$ D. $\Theta(N^2 \log N)$

gatecse-2016-set2 data-structures linked-list time-complexity normal algorithms

Answer key

8.9.17 Linked List: GATE CSE 2017 Set 1 | Question: 08

Consider the C code fragment given below.

```
typedef struct node {
   int data;
   node* next;
} node;

void join(node* m, node* n) {
   node* p = n;
   while(p->next != NULL) {
      p = p->next;
   }
   p->next = m;
}
```

Assuming that m and n point to valid NULL-terminated linked lists, invocation of join will

A. append list m to the end of list n for all inputs.
B. either cause a null pointer dereference or append list m to the end of list n.
C. cause a null pointer dereference for all inputs.
D. append list n to the end of list m for all inputs.

gatecse-2017-set1 data-structures linked-list normal

Answer key

8.9.18 Linked List: GATE CSE 2020 | Question: 16

What is the worst case time complexity of inserting n elements into an empty linked list, if the linked list needs to be maintained in sorted order?

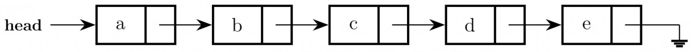
A. $\Theta(n)$ B. $\Theta(n \log n)$ C. $\Theta(n)^2$ D. $\Theta(1)$

gatecse-2020 linked-list one-mark

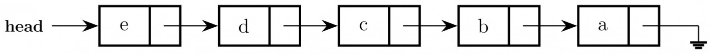
Answer key

8.9.19 Linked List: GATE CSE 2022 | Question: 5

Consider the problem of reversing a singly linked list. To take an example, given the linked list below,



the reversed linked list should look like



Which one of the following statements is TRUE about the time complexity of algorithms that solve the above problem in $O(1)$ space?

A. The best algorithm for the problem takes $\theta(n)$ time in the worst case.
B. The best algorithm for the problem takes $\theta(n \log n)$ time in the worst case.
C. The best algorithm for the problem takes $\theta(n^2)$ time in the worst case.
D. It is not possible to reverse a singly linked list in $O(1)$ space.

gatecse-2022 data-structures linked-list one-mark

Answer key

8.9.20 Linked List: GATE CSE 2023 | Question: 3

Let SLLdel be a function that deletes a node in a singly-linked list given a pointer to the node and a pointer to the head of the list. Similarly, let DLLdel be another function that deletes a node in a doubly-linked list given a pointer to the node and a pointer to the head of the list.
Let n denote the number of nodes in each of the linked lists. Which one of the following choices is TRUE about the worst-case time complexity of SLLdel and DLLdel?

A. SLLdel is $O(1)$ and DLLdel is $O(n)$
B. Both SLLdel and DLLdel are $O(\log(n))$
C. Both SLLdel and DLLdel are $O(1)$
D. SLLdel is $O(n)$ and DLLdel is $O(1)$

gatecse-2023 data-structures linked-list one-mark

Answer key

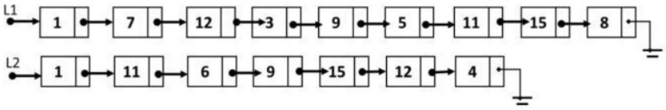
8.9.21 Linked List: GATE CSE 2025 | Set 1 | Question: 52

Let LIST be a datatype for an implementation of linked list defined as follows:

```
typedef struct list {
int data;
struct list *next;
} LIST;
```

Suppose a program has created two linked lists, $L1$ and $L2$, whose contents are given in the figure below (code for creating $L1$ and $L2$ is not provided here). $L1$ contains 9 nodes, and $L2$ contains 7 nodes.

Consider the following C program segment that modifies the list $L1$. The number of nodes that will be there in $L1$ after the execution of the code segment is __________. (Answer in integer)




```
int find (int query, LIST *list) {
while (list != NULL) {
if(list->data == query) return 1 ;
list = list->next;
}
return 0 ;
}
int main (){
... ... ...
ptr1=L1; ptr2=L2;
while (ptrl->next != NULL){
query = ptr1->next->data;
if (find (query, L2))
ptr1->next = ptr1->next->next;
else ptr1 = ptr1->next;
}
... .... ...
return 0;
}
```

gatecse2025-set1 data-structures linked-list numerical-answers two-marks

Answer key

8.9.22 Linked List: GATE IT 2004 | Question: 13

Let P be a singly linked list. Let Q be the pointer to an intermediate node x in the list. What is the worst-case time complexity of the best-known algorithm to delete the node x from the list ?

A. $O(n)$ B. $O(\log^2 n)$ C. $O(\log n)$ D. $O(1)$

gateit-2004 data-structures linked-list normal ambiguous

Answer key

8.9.23 Linked List: GATE IT 2005 | Question: 54

The following C function takes a singly-linked list of integers as a parameter and rearranges the elements of the list. The list is represented as pointer to a structure. The function is called with the list containing the integers $1, 2, 3, 4, 5, 6, 7$ in the given order. What will be the contents of the list after the function completes execution?

```
struct node {int value; struct node *next;);
void rearrange (struct node *list) {
   struct node *p, *q;
   int temp;
   if (!list || !list -> next) return;
   p = list; q = list -> next;
   while (q) {
      temp = p -> value;
      p -> value = q -> value;
      q -> value = temp;
      p = q -> next;
      q = p ? p -> next : 0;
    }
}
```

A. $1,2,3,4,5,6,7$ B. $2,1,4,3,6,5,7$
C. $1,3,2,5,4,7,6$ D. $2,3,4,5,6,7,1$

gateit-2005 data-structures linked-list normal

Answer key

8.10 Number of Swap (1)

8.10.1 Number of Swap: GATE CSE 2025 | Set 1 | Question: 23

The pseudocode of a function fun () is given below:

```
fun(int A[0,....,n-1]) {
for i=0 to n-2
for j=0 to n-i-2
if (A[j]>A[j+1])
then swap A[j] and A[j+1]
}
```

Let $A[0, \ldots, 29]$ be an array storing 30 distinct integers in descending order. The number of swap operations that will be performed, if the function fun () is called with $A[0, \ldots, 29]$ as argument, is _________. (Answer in integer)

gatecse2025-set1 data-structures array number-of-swap numerical-answers one-mark

Answer key

8.11 Priority Queue (2)

8.11.1 Priority Queue: GATE CSE 1997 | Question: 4.7

A priority queue Q is used to implement a stack that stores characters. PUSH (C) is implemented as INSERT (Q, C, K) where K is an appropriate integer key chosen by the implementation. POP is implemented as DELETEMIN(Q). For a sequence of operations, the keys chosen are in

A. non-increasing order
B. non-decreasing order
C. strictly increasing order
D. strictly decreasing order

gate1997 data-structures stack normal priority-queue

Answer key

8.11.2 Priority Queue: GATE CSE 2023 | Question: 36

Let A be a priority queue for maintaining a set of elements. Suppose A is implemented using a max-heap data structure. The operation $\text{EXTRACT-MAX}(A)$ extracts and deletes the maximum element from A. The operation $\text{INSERT}(A, key)$ inserts a new element key in A. The properties of a max-heap are preserved at the end of each of these operations.

When A contains n elements, which one of the following statements about the worst case running time of these two operations is TRUE?

A. Both $\text{EXTRACT-MAX}(A)$ and $\text{INSERT}(A, key)$ run in $O(1)$.
B. Both $\text{EXTRACT-MAX}(A)$ and $\text{INSERT}(A, key)$ run in $O(\log(n))$.
C. $\text{EXTRACT-MAX}(A)$ runs in $O(1)$ whereas $\text{INSERT}(A, key)$ runs in $O(n)$.
D. $\text{EXTRACT-MAX}(A)$ runs in $O(1)$ whereas $\text{INSERT}(A, key)$ runs in $O(\log(n))$.

gatecse-2023 data-structures priority-queue time-complexity binary-heap two-marks

Answer key

8.12 Queue (14)

8.12.1 Queue: GATE CSE 1992 | Question: 09

Suggest a data structure for representing a subset S of integers from 1 to n. Following operations on the set S are to be performed in constant time (independent of cardinality of S).

i.	MEMBER (X) :	Check whether X is in the set S or not
ii.	FIND-ONE (S) :	If S is not empty, return one element of the set S (any arbitrary element will do)
iii.	ADD (X) :	Add integer X to set S
ii.	DELETE (X) :	Delete integer X from S

Give pictorial examples of your data structure. Give routines for these operations in an English like language. You may assume that the data structure has been suitable initialized. Clearly state your assumptions regarding initialization.

gate1992 data-structures normal descriptive queue

Answer key

8.12.2 Queue: GATE CSE 1994 | Question: 26

A queue Q containing n items and an empty stack S are given. It is required to transfer all the items from the queue to the stack, so that the item at the front of queue is on the TOP of the stack, and the order of all other items are preserved. Show how this can be done in $O(n)$ time using only a constant amount of additional storage. Note that the only operations which can be performed on the queue and stack are Delete, Insert, Push and Pop. Do not assume any implementation of the queue or stack.

gate1994 data-structures queue stack normal descriptive

Answer key

8.12.3 Queue: GATE CSE 1996 | Question: 1.12

Consider the following statements:

i. First-in-first out types of computations are efficiently supported by STACKS.
ii. Implementing LISTS on linked lists is more efficient than implementing LISTS on an array for almost all the basic LIST operations.
iii. Implementing QUEUES on a circular array is more efficient than implementing QUEUES on a linear array with two indices.
iv. Last-in-first-out type of computations are efficiently supported by QUEUES.

A. (ii) and (iii) are true
B. (i) and (ii) are true
C. (iii) and (iv) are true
D. (ii) and (iv) are true

gate1996 data-structures easy queue stack linked-list

Answer key

8.12.4 Queue: GATE CSE 2001 | Question: 2.16

What is the minimum number of stacks of size n required to implement a queue of size n?

A. One
B. Two
C. Three
D. Four

gatecse-2001 data-structures easy stack queue

Answer key

8.12.5 Queue: GATE CSE 2006 | Question: 49

An implementation of a queue Q, using two stacks $S1$ and $S2$, is given below:

```
void insert (Q, x) {
   push (S1, x);
}
void delete (Q) {
   if (stack-empty(S2)) then
      if (stack-empty(S1)) then {
         print("Q is empty");
         return;
      }
      else while (!(stack-empty(S1))){
         x=pop(S1);
```

```
        push(S2,x);
    }
  x=pop(S2);
}
```

Let n *insert* and $m(\leq n)$ *delete* operations be performed in an arbitrary order on an empty queue Q. Let x and y be the number of *push* and *pop* operations performed respectively in the process. Which one of the following is true for all m and n?

A. $n+m \leq x < 2n$ and $2m \leq y \leq n+m$
B. $n+m \leq x < 2n$ and $2m \leq y \leq 2n$
C. $2m \leq x < 2n$ and $2m \leq y \leq n+m$
D. $2m \leq x < 2n$ and $2m \leq y \leq 2n$

gatecse-2006 data-structures queue stack normal

Answer key

8.12.6 Queue: GATE CSE 2012 | Question: 35

Suppose a circular queue of capacity $(n-1)$ elements is implemented with an array of n elements. Assume that the insertion and deletion operations are carried out using REAR and FRONT as array index variables, respectively. Initially, REAR $=$ FRONT $= 0$. The conditions to detect queue full and queue empty are:

A. $\text{full} : (\text{REAR}+1) \mod n == \text{FRONT}$
$\text{empty} : \text{REAR} == \text{FRONT}$
B. $\text{full} : (\text{REAR}+1) \mod n == \text{FRONT}$
$\text{empty} : (\text{FRONT}+1) \mod n == \text{REAR}$
C. $\text{full} : \text{REAR} == \text{FRONT}$
$\text{empty} : (\text{REAR}+1) \mod n == \text{FRONT}$
D. $\text{full} : (\text{FRONT}+1) \mod n == \text{REAR}$
$\text{empty} : \text{REAR} == \text{FRONT}$

gatecse-2012 data-structures queue normal

Answer key

8.12.7 Queue: GATE CSE 2013 | Question: 44

Consider the following operation along with Enqueue and Dequeue operations on queues, where k is a global parameter.

```
MultiDequeue(Q){
  m = k
  while (Q is not empty) and (m > 0) {
    Dequeue(Q)
    m = m - 1
  }
}
```

What is the worst case time complexity of a sequence of n queue operations on an initially empty queue?

A. $\Theta(n)$ B. $\Theta(n+k)$ C. $\Theta(nk)$ D. $\Theta(n^2)$

gatecse-2013 data-structures algorithms normal queue

Answer key

8.12.8 Queue: GATE CSE 2016 Set 1 | Question: 10

A queue is implemented using an array such that ENQUEUE and DEQUEUE operations are performed efficiently. Which one of the following statements is **CORRECT** (n refers to the number of items in the queue) ?

A. Both operations can be performed in $O(1)$ time.
B. At most one operation can be performed in $O(1)$ time but the worst case time for the operation will be $\Omega(n)$.
C. The worst case time complexity for both operations will be $\Omega(n)$.

D. Worst case time complexity for both operations will be $\Omega(\log n)$

gatecse-2016-set1 data-structures queue normal

Answer key

8.12.9 Queue: GATE CSE 2016 Set 1 | Question: 41

Let Q denote a queue containing sixteen numbers and S be an empty stack. $Head(Q)$ returns the element at the head of the queue Q without removing it from Q. Similarly $Top(S)$ returns the element at the top of S without removing it from S. Consider the algorithm given below.

```
while Q is not Empty do
 if S is Empty OR Top(S) ≤ Head (Q) then
   x:= Dequeue (Q);
   Push (S, x);
 else
   x:= Pop(S);
   Enqueue (Q, x);
 end
end
```

The maximum possible number of iterations of the **while** loop in the algorithm is _______.

gatecse-2016-set1 data-structures queue difficult numerical-answers

Answer key

8.12.10 Queue: GATE CSE 2017 Set 2 | Question: 13

A circular queue has been implemented using a singly linked list where each node consists of a value and a single pointer pointing to the next node. We maintain exactly two external pointers FRONT and REAR pointing to the front node and the rear node of the queue, respectively. Which of the following statements is/are CORRECT for such a circular queue, so that insertion and deletion operations can be performed in $O(1)$ time?

I. Next pointer of front node points to the rear node.
II. Next pointer of rear node points to the front node.

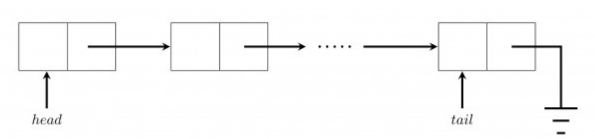
A. (I) only.
B. (II) only.
C. Both (I) and (II).
D. Neither (I) nor (II).

gatecse-2017-set2 data-structures queue

Answer key

8.12.11 Queue: GATE CSE 2018 | Question: 3

A queue is implemented using a non-circular singly linked list. The queue has a head pointer and a tail pointer, as shown in the figure. Let n denote the number of nodes in the queue. Let 'enqueue' be implemented by inserting a new node at the head, and 'dequeue' be implemented by deletion of a node from the tail.



Which one of the following is the time complexity of the most time-efficient implementation of 'enqueue' and 'dequeue, respectively, for this data structure?

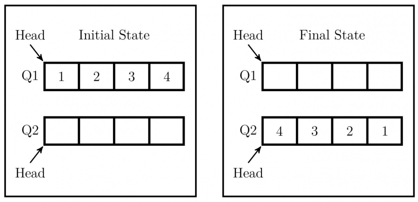
A. $\Theta(1), \Theta(1)$
B. $\Theta(1), \Theta(n)$
C. $\Theta(n), \Theta(1)$
D. $\Theta(n), \Theta(n)$

gatecse-2018 algorithms data-structures queue normal linked-list one-mark

Answer key

8.12.12 Queue: GATE CSE 2022 | Question: 52

Consider the queues Q_1 containing four elements and Q_2 containing none (shown as the **Initial State** in the figure). The only operations allowed on these two queues are **Enqueue (Q, element)** and **Dequeue (Q)**. The minimum number of **Enqueue** operations on Q_1 required to place the elements of Q_1 in Q_2 in reverse order (shown as the **Final State** in the figure) without using any additional storage is_______________.



gatecse-2022 numerical-answers data-structures queue two-marks

Answer key☟

8.12.13 Queue: GATE DS&AI 2024 | Question: 22

The fundamental operations in a double-ended queue D are:

insertFirst (e) - Insert a new element e at the beginning of D.

insertLast (e) - Insert a new element e at the end of D.

removeFirst () - Remove and return the first element of D.

removeLast () - Remove and return the last element of D.

In an empty double-ended queue, the following operations are performed:

insertFirst (10)
insertLast (32)
a $\leftarrow$ removeFirst ()
insertLast (28)
insertLast (17)
a $\leftarrow$ removeFirst ()
a $\leftarrow$ removeLast ()

The value of $\mathbf{a}$ is _________.

gate-ds-ai-2024 numerical-answers data-structures queue one-mark

Answer key☟

8.12.14 Queue: GATE IT 2007 | Question: 30

Suppose you are given an implementation of a queue of integers. The operations that can be performed on the queue are:

i. $isEmpty(Q)$ — returns true if the queue is empty, false otherwise.
ii. $delete(Q)$ — deletes the element at the front of the queue and returns its value.
iii. $insert(Q, i)$ — inserts the integer i at the rear of the queue.

Consider the following function:

```
void f (queue Q) {
int i ;
if (!isEmpty(Q)) {
   i = delete(Q);
   f(Q);
   insert(Q, i);
  }
}
```

What operation is performed by the above function f ?

A. Leaves the queue Q unchanged
B. Reverses the order of the elements in the queue Q
C. Deletes the element at the front of the queue Q and inserts it at the rear keeping the other elements in the same order
D. Empties the queue Q

gateit-2007 data-structures queue normal

Answer key

8.13 Stack (18)

8.13.1 Stack: GATE CSE 1991 | Question: 03,vii

The following sequence of operations is performed on a stack:

$$PUSH(10), PUSH(20), POP, PUSH(10), PUSH(20), POP, POP, POP, PUSH(20), POP$$

The sequence of values popped out is

A. $20, 10, 20, 10, 20$
B. $20, 20, 10, 10, 20$
C. $10, 20, 20, 10, 20$
D. $20, 20, 10, 20, 10$

gate1991 data-structures stack easy

Answer key

8.13.2 Stack: GATE CSE 1994 | Question: 1.14

Which of the following permutations can be obtained in the output (in the same order) using a stack assuming that the input is the sequence $1, 2, 3, 4, 5$ in that order?

A. $3, 4, 5, 1, 2$
B. $3, 4, 5, 2, 1$
C. $1, 5, 2, 3, 4$
D. $5, 4, 3, 1, 2$

gate1994 data-structures stack normal

Answer key

8.13.3 Stack: GATE CSE 1995 | Question: 2.21

The postfix expression for the infix expression $A + B * (C + D)/F + D * E$ is:

A. $AB + CD + *F/D + E*$
B. $ABCD + *F/DE * ++$
C. $A * B + CD/F * DE ++$
D. $A + *BCD/F * DE ++$

gate1995 data-structures stack easy

Answer key

8.13.4 Stack: GATE CSE 2000 | Question: 13

Suppose a stack implementation supports, in addition to PUSH and POP, an operation REVERSE, which reverses the order of the elements on the stack.

A. To implement a queue using the above stack implementation, show how to implement ENQUEUE using a single operation and DEQUEUE using a sequence of 3 operations.
B. The following post fix expression, containing single digit operands and arithmetic operators $+$ and $*$, is evaluated using a stack.
   $5\ 2 * 3\ 4 + 5\ 2 * * +$
   Show the contents of the stack
   i. After evaluating $5\ 2 * 3\ 4 +$
   ii. After evaluating $5\ 2 * 3\ 4 + 5\ 2$
   iii. At the end of evaluation

gatecse-2000 data-structures stack normal descriptive

Answer key

8.13.5 Stack: GATE CSE 2003 | Question: 64

Let **S** be a stack of size $n \geq 1$. Starting with the empty stack, suppose we push the first n natural numbers in sequence, and then perform n pop operations. Assume that Push and Pop operations take X seconds each, and Y seconds elapse between the end of one such stack operation and the start of the next operation. For $m \geq 1$, define the stack-life of m as the time elapsed from the end of $Push(m)$ to the start of the pop operation that removes m from **S**. The average stack-life of an element of this stack is

A. $n(X+Y)$ B. $3Y+2X$ C. $n(X+Y)-X$ D. $Y+2X$

gatecse-2003 data-structures stack normal

Answer key

8.13.6 Stack: GATE CSE 2004 | Question: 3

A single array $A[1 \dots \text{MAXSIZE}]$ is used to implement two stacks. The two stacks grow from opposite ends of the array. Variables $top1$ and $top2$ $(top1 < top2)$ point to the location of the topmost element in each of the stacks. If the space is to be used efficiently, the condition for "**stack full**" is

A. $(top1 = \text{MAXSIZE}/2)$ and $(top2 = \text{MAXSIZE}/2 + 1)$
B. $top1 + top2 = \text{MAXSIZE}$
C. $(top1 = \text{MAXSIZE}/2)$ or $(top2 = \text{MAXSIZE})$
D. $top1 = top2 - 1$

gatecse-2004 data-structures stack easy

Answer key

8.13.7 Stack: GATE CSE 2004 | Question: 5

The best data structure to check whether an arithmetic expression has balanced parentheses is a

A. queue B. stack C. tree D. list

gatecse-2004 data-structures easy stack

Answer key

8.13.8 Stack: GATE CSE 2014 Set 2 | Question: 41

Suppose a stack implementation supports an instruction REVERSE, which reverses the order of elements on the stack, in addition to the PUSH and POP instructions. Which one of the following statements is TRUE (*with respect to this modified stack*)?

A. A queue cannot be implemented using this stack.
B. A queue can be implemented where ENQUEUE takes a single instruction and DEQUEUE takes a sequence of two instructions.
C. A queue can be implemented where ENQUEUE takes a sequence of three instructions and DEQUEUE takes a single instruction.
D. A queue can be implemented where both ENQUEUE and DEQUEUE take a single instruction each.

gatecse-2014-set2 data-structures stack easy

Answer key

8.13.9 Stack: GATE CSE 2015 Set 2 | Question: 38

Consider the C program below

```
#include <stdio.h>
int *A, stkTop;
int stkFunc (int opcode, int val)
{
   static int size=0, stkTop=0;
   switch (opcode) {
      case -1: size = val; break;
      case 0: if (stkTop < size ) A[stkTop++]=val; break;
      default: if (stkTop) return A[--stkTop];
   }
   return -1;
```

```
}
int main()
{
   int B[20]; A=B; stkTop = -1;
   stkFunc (-1, 10);
   stkFunc (0, 5);
   stkFunc (0, 10);
   printf ("%d\n", stkFunc(1, 0)+ stkFunc(1, 0));
}
```

The value printed by the above program is ________.

gatecse-2015-set2 data-structures stack easy numerical-answers

Answer key

8.13.10 Stack: GATE CSE 2015 Set 3 | Question: 12

The result evaluating the postfix expression $10\ 5 + 60\ 6 / * 8 -$ is

A. 284 B. 213 C. 142 D. 71

gatecse-2015-set3 data-structures stack easy

Answer key

8.13.11 Stack: GATE CSE 2021 Set 1 | Question: 21

Consider the following sequence of operations on an empty stack.

$$\textsf{push}(54); \textsf{push}(52); \textsf{pop}(); \textsf{push}(55); \textsf{push}(62); \textsf{s} = \textsf{pop}();$$

Consider the following sequence of operations on an empty queue.

$$\textsf{enqueue}(21); \textsf{enqueue}(24); \textsf{dequeue}(); \textsf{enqueue}(28); \textsf{enqueue}(32); \textsf{q} = \textsf{dequeue}();$$

The value of $\textsf{s}+\textsf{q}$ is ___________.

gatecse-2021-set1 data-structures stack easy numerical-answers one-mark

Answer key

8.13.12 Stack: GATE CSE 2023 | Question: 49

Consider a sequence a of elements $a_0 = 1, a_1 = 5, a_2 = 7, a_3 = 8, a_4 = 9,$ and $a_5 = 2$. The following operations are performed on a stack S and a queue Q, both of which are initially empty.

I. **push** the elements of a from a_0 to a_5 in that order into S.
II. **enqueue** the elements of a from a_0 to a_5 in that order into Q.
III. **pop** an element from S.
IV. **dequeue** an element from Q.
V. **pop** an element from S.
VI. **dequeue** an element from Q.
VII. **dequeue** an element from Q and push the same element into S.
VIII. Repeat operation VII three times.
IX. **pop** an element from S.
X. **pop** an element from S.

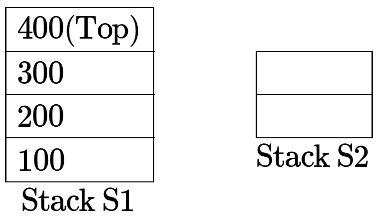
The top element of S after executing the above operations is _____________.

gatecse-2023 data-structures stack numerical-answers two-marks easy

Answer key

8.13.13 Stack: GATE CSE 2024 | Set 2 | Question: 38

Let S1 and S2 be two stacks. S1 has capacity of 4 elements. S2 has capacity of 2 elements. S1 already has 4 elements: $100, 200, 300,$ and 400, whereas S2 is empty, as shown below.



Only the following three operations are available:

- PushToS2: Pop the top element from S1 and push it on S2.
- PushToS1: Pop the top element from S2 and push it on S1.
- GenerateOutput: Pop the top element from S1 and output it to the user.

Note that the pop operation is not allowed on an empty stack and the push operation is not allowed on a full stack.

Which of the following output sequences can be generated by using the above operations?

A. $100, 200, 400, 300$
B. $200, 300, 400, 100$
C. $400, 200, 100, 300$
D. $300, 200, 400, 100$

gatecse2024-set2 data-structures stack multiple-selects two-marks

Answer key

8.13.14 Stack: GATE CSE 2025 | Set 2 | Question: 35

Consider a stack data structure into which we can PUSH and POP records. Assume that each record pushed in the stack has a positive integer key and that all keys are distinct.

We wish to augment the stack data structure with an $O(1)$ time MIN operation that returns a pointer to the record with smallest key present in the stack

1. without deleting the corresponding record, and
2. without increasing the complexities of the standard stack operations.

Which one or more of the following approach(es) can achieve it?

A. Keep with every record in the stack, a pointer to the record with the smallest key below it.
B. Keep a pointer to the record with the smallest key in the stack.
C. Keep an auxiliary array in which the key values of the records in the stack are maintained in sorted order.
D. Keep a Min-Heap in which the key values of the records in the stack are maintained.

gatecse2025-set2 data-structures stack multiple-selects two-marks

Answer key

8.13.15 Stack: GATE DA 2025 | Question: 54

Consider the following pseudocode.

```
Create empty stack S
Set x=0, flag=0, sum=0
Push x onto S
while (S is not empty){
  if (flag equals 0){
    Set x = x+1
    Push x onto S}
  if (x equals 8):
    Set flag=1
  if (flag equals 1){
    x = Pop(S)
    if (x is odd):
      Pop (S)
    Set sum = sum + x}
}
Output sum
```

The value of sum output by a program executing the above pseudocode is ________ (Answer in integer)

gateda-2025 data-structures stack output numerical-answers two-marks

Answer key

8.13.16 Stack: GATE IT 2004 | Question: 52

A program attempts to generate as many permutations as possible of the string, '$abcd$' by pushing the characters a, b, c, d in the same order onto a stack, but it may pop off the top character at any time. Which one of the following strings CANNOT be generated using this program?

A. $abcd$ B. $dcba$ C. $cbad$ D. $cabd$

gateit-2004 data-structures normal stack

Answer key

8.13.17 Stack: GATE IT 2005 | Question: 13

A function f defined on stacks of integers satisfies the following properties. $f(\emptyset) = 0$ and $f(push(S, i)) = max(f(S), 0) + i$ for all stacks S and integers i.

If a stack S contains the integers $2, -3, 2, -1, 2$ in order from bottom to top, what is $f(S)$?

A. 6 B. 4 C. 3 D. 2

gateit-2005 data-structures stack normal

Answer key

8.13.18 Stack: GATE IT 2007 | Question: 32

Consider the following C program:

```c
#include <stdio.h>
        #define EOF -1
        void push (int); /* push the argument on the stack */
        int pop  (void); /* pop the top of the stack */
        void flagError ();
        int main ()
       {        int c, m, n, r;
                 while ((c = getchar ()) != EOF)
                { if  (isdigit (c) )
                          push (c);
                 else if ((c == '+') || (c == '*'))
                {          m = pop ();
                           n = pop ();
                           r = (c == '+') ? n + m : n*m;
                           push (r);
                  }
                  else if (c != ' ')
                          flagError ();
          }
           printf("% c", pop ());
}
```

What is the output of the program for the following input?

$5\,2 * 3\,3\,2 + * +$

A. 15 B. 25 C. 30 D. 150

gateit-2007 stack normal

Answer key

8.14 Time Complexity (1)

8.14.1 Time Complexity: GATE CSE 2025 | Set 2 | Question: 28

A meld operation on two instances of a data structure combines them into one single instance of the same data structure. Consider the following data structures:

P. Unsorted doubly linked list with pointers to the head node and tail node of the list.

Q. Min-heap implemented using an array.

R. Binary Search Tree.

Which ONE of the following options gives the worst-case time complexities for meld operation on instances of size n of these data structures?

A. $\mathrm{P}: \Theta(1), \mathrm{Q}: \Theta(n), \mathrm{R}: \Theta(n)$
B. $\mathrm{P}: \Theta(1), \mathrm{Q}: \Theta(n \log n), \mathrm{R}: \Theta(n)$
C. $\mathrm{P}: \Theta(n), \mathrm{Q}: \Theta(n \log n), \mathrm{R}: \Theta\left(n^2\right)$
D. $\mathrm{P}: \Theta(1), \mathrm{Q}: \Theta(n), \mathrm{R}: \Theta(n \log n)$

gatecse2025-set2 data-structures time-complexity two-marks

Answer key

8.15 Tree (14)

8.15.1 Tree: GATE CSE 1990 | Question: 13a

Consider the height-balanced tree T_t with values stored at only the leaf nodes, shown in Fig.4.

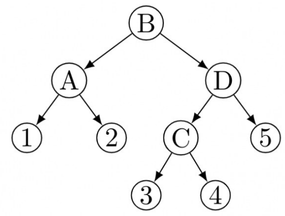


Fig.4

(i) Show how to merge to the tree, T_1 elements from tree T_2 shown in Fig.5 using node D of tree T_1.

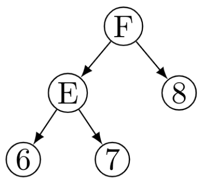


Fig.5

(ii) What is the time complexity of a merge operation of balanced trees T_1 and T_2 where T_1 and T_2 are of height h_1 and h_2 respectively, assuming that rotation schemes are given. Give reasons.

gate1990 data-structures tree descriptive

Answer key

8.15.2 Tree: GATE CSE 1992 | Question: 02,vii

A $2-3$ tree is such that

a. All internal nodes have either 2 or 3 children
b. All paths from root to the leaves have the same length

The number of internal nodes of a $2-3$ tree having 9 leaves could be

A. 4
B. 5
C. 6
D. 7

gate1992 tree data-structures normal multiple-selects

Answer key

8.15.3 Tree: GATE CSE 1994 | Question: 5

A $3-\text{ary}$ tree is a tree in which every internal node has exactly three children. Use induction to prove that the number of leaves in a $3-\text{ary}$ tree with n internal nodes is $2(n+1)$.

gate1994 data-structures tree proof descriptive

Answer key

8.15.4 Tree: GATE CSE 1998 | Question: 1.24

Which of the following statements is false?

A. A tree with a n nodes has $(n–1)$ edges
B. A labeled rooted binary tree can be uniquely constructed given its postorder and preorder traversal results.
C. A complete binary tree with n internal nodes has $(n+1)$ leaves.
D. The maximum number of nodes in a binary tree of height h is $2^{h+1}-1$

gate1998 data-structures tree multiple-selects normal

Answer key

8.15.5 Tree: GATE CSE 1998 | Question: 2.11

A complete n-ary tree is one in which every node has 0 or n sons. If x is the number of internal nodes of a complete n-ary tree, the number of leaves in it is given by

A. $x(n-1)+1$
B. $xn-1$
C. $xn+1$
D. $x(n+1)$

gate1998 data-structures tree normal

Answer key

8.15.6 Tree: GATE CSE 2002 | Question: 2.9

The number of leaf nodes in a rooted tree of n nodes, with each node having 0 or 3 children is:

A. $\frac{n}{2}$
B. $\frac{(n-1)}{3}$
C. $\frac{(n-1)}{2}$
D. $\frac{(2n+1)}{3}$

gatecse-2002 data-structures tree normal

Answer key

8.15.7 Tree: GATE CSE 2004 | Question: 6

Level order traversal of a rooted tree can be done by starting from the root and performing

A. preorder traversal
B. in-order traversal
C. depth first search
D. breadth first search

gatecse-2004 data-structures tree easy

Answer key

8.15.8 Tree: GATE CSE 2005 | Question: 36

In a complete k-ary tree, every internal node has exactly k children. The number of leaves in such a tree with n internal node is:

A. nk
B. $(n-1)k+1$
C. $n(k-1)+1$
D. $n(k-1)$

gatecse-2005 data-structures tree normal

Answer key

8.15.9 Tree: GATE CSE 2007 | Question: 43

A complete $n-ary$ tree is a tree in which each node has n children or no children. Let I be the number of internal nodes and L be the number of leaves in a complete $n-ary$ tree. If $L=41$ and $I=10$, what is the value of n?

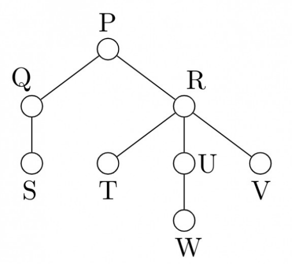
A. 3　B. 4　C. 5　D. 6

gatecse-2007　data-structures　tree　normal

Answer key

8.15.10 Tree: GATE CSE 2014 Set 3 | Question: 12

Consider the following rooted tree with the vertex labeled P as the root:



The order in which the nodes are visited during an in-order traversal of the tree is

A. SQPTRWUV　B. SQPTUWRV　C. SQPTWUVR　D. SQPTRUWV

gatecse-2014-set3　data-structures　tree　easy

Answer key

8.15.11 Tree: GATE CSE 2014 Set 3 | Question: 41

Consider the pseudocode given below. The function $DoSomething()$ takes as argument a pointer to the root of an arbitrary tree represented by the $leftMostChild-rightSibling$ representation. Each node of the tree is of type $treeNode$.

```
typedef struct treeNode* treeptr;

struct treeNode
{
   treeptr leftMostChild, rightSibling;
};

int DoSomething (treeptr tree)
{
   int value=0;
   if (tree != NULL) {
      if (tree->leftMostChild == NULL)
         value = 1;
      else
      value = DoSomething(tree->leftMostChild);
      value = value + DoSomething(tree->rightSibling);
   }
   return(value);
}
```

When the pointer to the root of a tree is passed as the argument to $DoSomething$, the value returned by the function corresponds to the

A. number of internal nodes in the tree.

B. height of the tree.

C. number of nodes without a right sibling in the tree.

D. number of leaf nodes in the tree

gatecse-2014-set3　data-structures　tree　normal

Answer key

8.15.12 Tree: GATE CSE 2017 Set 1 | Question: 20

Let T be a tree with 10 vertices. The sum of the degrees of all the vertices in T is ________

gatecse-2017-set1 data-structures tree easy numerical-answers

Answer key☟

8.15.13 Tree: GATE CSE 2021 Set 1 | Question: 41

An $articulation\ point$ in a connected graph is a vertex such that removing the vertex and its incident edges disconnects the graph into two or more connected components.

Let T be a DFS tree obtained by doing DFS in a connected undirected graph G.

Which of the following options is/are correct?

A. Root of T can never be an articulation point in G.
B. Root of T is an articulation point in G if and only if it has 2 or more children.
C. A leaf of T can be an articulation point in G.
D. If u is an articulation point in G such that x is an ancestor of u in T and y is a descendent of u in T, then all paths from x to y in G must pass through u.

gatecse-2021-set1 multiple-selects data-structures tree two-marks

Answer key☟

8.15.14 Tree: GATE CSE 2025 | Set 1 | Question: 25

The height of any rooted tree is defined as the maximum number of edges in the path from the root node to any leaf node.

Suppose a Min-Heap T stores 32 keys. The height of T is ___________. (Answer in integer)

gatecse2025-set1 data-structures tree binary-heap numerical-answers easy one-mark

Answer key☟

Answer Keys

8.1.1	N/A	8.1.2	B	8.1.3	N/A	8.1.4	B	8.1.5	C
8.1.6	A	8.2.1	N/A	8.2.2	C	8.2.3	N/A	8.2.4	N/A
8.2.5	A	8.2.6	A	8.2.7	N/A	8.2.8	A	8.2.9	B
8.2.10	C	8.2.11	B	8.2.12	5	8.2.13	C	8.3.1	N/A
8.3.2	C	8.3.3	N/A	8.3.4	B	8.3.5	D	8.3.6	A
8.3.7	D	8.3.8	A	8.3.9	D	8.3.10	A	8.3.11	B
8.3.12	C	8.3.13	D	8.3.14	B	8.3.15	A	8.3.16	B
8.3.17	A	8.3.18	D	8.3.19	B	8.3.20	8	8.3.21	80
8.3.22	A	8.3.23	511	8.3.24	C	8.3.25	B	8.3.26	A
8.3.27	B	8.3.28	C	8.3.29	B	8.4.1	B	8.4.2	N/A
8.4.3	D	8.4.4	N/A	8.4.5	C	8.4.6	B	8.4.7	B
8.4.8	B	8.4.9	B	8.4.10	A	8.4.11	B	8.4.12	B
8.4.13	C	8.4.14	D	8.4.15	C	8.4.16	110	8.4.17	A
8.4.18	B	8.4.19	B	8.4.20	64	8.4.21	B	8.4.22	B
8.4.23	B	8.4.24	B	8.4.25	D	8.4.26	509	8.4.27	A
8.4.28	A;B	8.4.29	4:4	8.4.30	C	8.4.31	D	8.4.32	C

8.4.33	A	8.4.34	D	8.4.35	C	8.4.36	B	8.5.1	False
8.5.2	False	8.5.3	N/A	8.5.4	N/A	8.5.5	N/A	8.5.6	A;C;D
8.5.7	B	8.5.8	144	8.5.9	N/A	8.5.10	N/A	8.5.11	N/A
8.5.12	N/A	8.5.13	N/A	8.5.14	N/A	8.5.15	B	8.5.16	N/A
8.5.17	C	8.5.18	N/A	8.5.19	N/A	8.5.20	C	8.5.21	D
8.5.22	D	8.5.23	N/A	8.5.24	B	8.5.25	D	8.5.26	D
8.5.27	C	8.5.28	B	8.5.29	A	8.5.30	C	8.5.31	A
8.5.32	B	8.5.33	A	8.5.34	1	8.5.35	A	8.5.36	19
8.5.37	199	8.5.38	C	8.5.39	4	8.5.40	4.25	8.5.41	1 : 1
8.5.42	C	8.5.43	B	8.5.44	A;B;C	8.5.45	A;B;C	8.5.46	D
8.5.47	B	8.5.48	D	8.5.49	C	8.5.50	B	8.5.51	D
8.5.52	B	8.5.53	A	8.6.1	B	8.6.2	C	8.6.3	B
8.6.4	12	8.6.5	A	8.7.1	C	8.7.2	N/A	8.7.3	N/A
8.7.4	C	8.7.5	B	8.7.6	C	8.7.7	C	8.7.8	C
8.7.9	A	8.7.10	A	8.7.11	B	8.7.12	80	8.7.13	B
8.7.14	C	8.7.15	B	8.7.16	D	8.8.1	N/A	8.8.2	A
8.8.3	N/A	8.8.4	A	8.8.5	A	8.9.1	B	8.9.2	N/A
8.9.3	N/A	8.9.4	B	8.9.5	D	8.9.6	C	8.9.7	N/A
8.9.8	N/A	8.9.9	N/A	8.9.10	D	8.9.11	B	8.9.12	A
8.9.13	D	8.9.14	B	8.9.15	D	8.9.16	C	8.9.17	B
8.9.18	C	8.9.19	A	8.9.20	D	8.9.21	5:5	8.9.22	A
8.9.23	B	8.10.1	435:435	8.11.1	D	8.11.2	B	8.12.1	N/A
8.12.2	N/A	8.12.3	A	8.12.4	B	8.12.5	A	8.12.6	A
8.12.7	A	8.12.8	A	8.12.9	256	8.12.10	B	8.12.11	B
8.12.12	0	8.12.13	17	8.12.14	B	8.13.1	B	8.13.2	B
8.13.3	B	8.13.4	N/A	8.13.5	C	8.13.6	D	8.13.7	B
8.13.8	C	8.13.9	15	8.13.10	C	8.13.11	86 : 86	8.13.12	8
8.13.13	B;C;D	8.13.14	A	8.13.15	24:24	8.13.16	D	8.13.17	C
8.13.18	B	8.14.1	A	8.15.1	N/A	8.15.2	A;D	8.15.3	N/A
8.15.4	B;C	8.15.5	A	8.15.6	D	8.15.7	D	8.15.8	C
8.15.9	C	8.15.10	A	8.15.11	D	8.15.12	18	8.15.13	B
8.15.14	5:5								

9 Programming: Programming in C (127)

9.1 Aliasing (1)

9.1.1 Aliasing: GATE CSE 2000 | Question: 1.16

Aliasing in the context of programming languages refers to

A. multiple variables having the same memory location
B. multiple variables having the same value
C. multiple variables having the same identifier
D. multiple uses of the same variable

gatecse-2000 programming easy aliasing

Answer key

9.2 Array (10)

9.2.1 Array: GATE CSE 2011 | Question: 22

What does the following fragment of C program print?

```
char c[] = "GATE2011";
char *p = c;
printf("%s", p + p[3] - p[1]);
```

A. GATE2011 B. E2011 C. 2011 D. 011

gatecse-2011 programming programming-in-c normal array

Answer key

9.2.2 Array: GATE CSE 2015 Set 1 | Question: 35

What is the output of the following C code? Assume that the address of x is 2000 (in decimal) and an integer requires four bytes of memory.

```
int main () {
        unsigned int x [4] [3] =
        {{1, 2, 3}, {4, 5, 6}, {7, 8, 9}, {10, 11, 12}};
        printf ("%u, %u, %u", x + 3, *(x + 3), *(x + 2) + 3);
}
```

A. $2036, 2036, 2036$
B. $2012, 4, 2204$
C. $2036, 10, 10$
D. $2012, 4, 6$

gatecse-2015-set1 programming programming-in-c array normal

Answer key

9.2.3 Array: GATE CSE 2015 Set 3 | Question: 30

Consider the following two C code segments. Y and X are one and two dimensional arrays of size n and $n \times n$ respectively, where $2 \leq n \leq 10$. Assume that in both code segments, elements of Y are initialized to 0 and each element $X[i][j]$ of array X is initialized to $i+j$. Further assume that when stored in main memory all elements of X are in same main memory page frame.

Code segment 1 :

```
// initialize elements of Y to 0
// initialize elements of X[i][j] of X to i+j
for (i=0; i<n; i++)
   Y[i] += X[0][i];
```

Code segment 2 :

```
// initialize elements of Y to 0
// initialize elements of X[i][j] of X to i+j
for (i=0; i<n; i++)
   Y[i] += X[i][0];
```

Which of the following statements is/are correct?

S1: Final contents of array Y will be same in both code segments

S2: Elements of array X accessed inside the for loop shown in code segment 1 are contiguous in main memory

S3: Elements of array X accessed inside the for loop shown in code segment 2 are contiguous in main memory

A. Only S2 is correct
B. Only S3 is correct
C. Only S1 and S2 are correct
D. Only S1 and S3 are correct

gatecse-2015-set3 programming-in-c normal array

Answer key

9.2.4 Array: GATE CSE 2015 Set 3 | Question: 7

Consider the following C program segment.

```
# include <stdio.h>
int main()
{
   char s1[7] = "1234", *p;
   p = s1 + 2;
   *p = '0';
   printf("%s", s1);
}
```

What will be printed by the program?

A. 12
B. 120400
C. 1204
D. 1034

gatecse-2015-set3 programming programming-in-c normal array

Answer key

9.2.5 Array: GATE CSE 2019 | Question: 24

Consider the following C program:

```
#include <stdio.h>
int main() {
      int arr[]={1, 2, 3, 4, 5, 6, 7, 8, 9, 0, 1, 2, 5}, *ip=arr+4;
      printf(“%d\n”, ip[1]);
      return 0;
}
```

The number that will be displayed on execution of the program is _______

gatecse-2019 numerical-answers programming-in-c programming array easy one-mark

Answer key

9.2.6 Array: GATE CSE 2020 | Question: 22

Consider the following C program.

```
#include <stdio.h>
int main () {
   int  a[4] [5] = {{1, 2, 3, 4, 5},
                 {6, 7,8, 9, 10},
                 {11, 12, 13, 14, 15},
                 {16, 17,18, 19, 20}};
   printf(“%d\n”, *(*(a+**a+2)+3));
   return(0);
}
```

The output of the program is _______.

gatecse-2020 numerical-answers programming-in-c array one-mark

Answer key

9.2.7 Array: GATE IT 2004 | Question: 58

Consider the following C program which is supposed to compute the transpose of a given 4×4 matrix M. Note that, there is an X in the program which indicates some missing statements. Choose the correct option to replace X in the program.

```
#include<stdio.h>
#define ROW 4
#define COL 4
int M[ROW][COL] = {1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16};
main()
{
   int i, j, t;
   for (i = 0; i < 4; ++i)
   {
      X
   }
   for (i = 0; i < 4; ++i)
      for (j = 0; j < 4; ++j)
         printf ("%d", M[i][j]);
}
```

A.
```
for(j = 0; j < 4; ++j){
    t = M[i][j];
    M[i][j] = M[j][i];
    M[j][i] = t;
}
```

B.
```
for(j = 0; j < 4; ++j){
    M[i][j] = t;
    t = M[j][i];
    M[j][i] = M[i][j];
}
```

C.
```
for(j = i; j < 4; ++j){
    t = M[i][j];
    M[i][j] = M[j][i];
    M[j][i] = t;
}
```

D.
```
for(j = i; j < 4; ++j){
    M[i][j] = t;
    t = M[j][i];
    M[j][i] = M[i][j];
}
```

gateit-2004 programming easy programming-in-c array

Answer key ☟

9.2.8 Array: GATE IT 2008 | Question: 49

What is the output printed by the following C code?

```
# include <stdio.h>
int main ()
{
   char a [6] = "world";
   int i, j;
   for (i = 0, j = 5; i < j; a [i++] = a [j--]);
   printf ("%s\n", a);
}
```

A. dlrow B. Null string C. dlrld D. worow

gateit-2008 programming programming-in-c normal array

Answer key ☟

9.2.9 Array: GATE IT 2008 | Question: 51

Consider the C program given below. What does it print?

```
#include <stdio.h>
int main ()
{
      int i, j;
      int a [8] = {1, 2, 3, 4, 5, 6, 7, 8};
      for(i = 0; i < 3; i++) {
          a[i] = a[i] + 1;
          i++;
      }
      i--;
      for (j = 7; j > 4; j--) {
           int i = j/2;
           a[i] = a[i] - 1;
      }
      printf ("%d, %d", i, a[i]);
}
```

A. $2,3$ B. $2,4$ C. $3,2$ D. $3,3$

gateit-2008 programming programming-in-c normal array

Answer key

9.2.10 Array: GATE IT 2008 | Question: 52

C program is given below:

```
# include <stdio.h>
int main ()
{
    int i, j;
    char a [2] [3] = {{'a', 'b', 'c'}, {'d', 'e', 'f'}};
    char b [3] [2];
    char *p = *b;
    for (i = 0; i < 2; i++) {
        for (j = 0; j < 3; j++) {
        *(p + 2*j + i) = a [i] [j];
        }
    }
}
```

What should be the contents of the array b at the end of the program?

A. $\begin{matrix} a & b \\ c & d \\ e & f \end{matrix}$

B. $\begin{matrix} a & d \\ b & e \\ c & f \end{matrix}$

C. $\begin{matrix} a & c \\ e & b \\ d & f \end{matrix}$

D. $\begin{matrix} a & e \\ d & c \\ b & f \end{matrix}$

gateit-2008 programming programming-in-c normal array

Answer key

9.3 Functions (1)

9.3.1 Functions: GATE CSE 2024 | Set 2 | Question: 3

Consider the following C program. Assume parameters to a function are evaluated from *right to left.*

```
#include <stdio.h>

int g(int p) { printf("%d", p); return p; }

int h(int q) { printf("%d", q); return q; }

void f(int x, int y) {

g(x);

h(y);

}

int main() {

f(g(10), h(20));

}
```

Which one of the following options is the CORRECT output of the above C program?

A. 20101020 B. 10202010 C. 20102010 D. 10201020

gatecse2024-set2 programming programming-in-c functions one-mark

Answer key

9.4 Goto (2)

9.4.1 Goto: GATE CSE 1989 | Question: 3-i

An unrestricted use of the "go to" statement is harmful because of which of the following reason (s):

A. It makes it more difficult to verify programs.
B. It makes programs more inefficient.
C. It makes it more difficult to modify existing programs.
D. It results in the compiler generating longer machine code.

gate1989 normal programming goto

Answer key

9.4.2 Goto: GATE CSE 1994 | Question: 1.5

An unrestricted use of the "*goto*" statement is harmful because

A. it makes it more difficult to verify programs
B. it increases the running time of the programs
C. it increases the memory required for the programs
D. it results in the compiler generating longer machine code

gate1994 programming easy goto

Answer key

9.5 Identify Function (6)

9.5.1 Identify Function: GATE CSE 1995 | Question: 3

Consider the following high level programming segment. Give the contents of the memory locations for variables W, X, Y and Z after the execution of the program segment. The values of the variables A and B are $5CH$ and $92H$, respectively. Also indicate error conditions if any.

```
var
   A, B, W, X, Y   :unsigned byte;
   Z               :unsigned integer, (each integer is represented by two bytes)
begin
   X               :=A+B
   Y               :=abs(A-B);
   W                :=A-B
   Z               :=A*B
end;
```

gate1995 programming identify-function descriptive

Answer key

9.5.2 Identify Function: GATE CSE 1998 | Question: 2.13

What is the result of the following program?

```
   program side-effect (input, output);
   var x, result: integer;
   function f (var x:integer):integer;
   begin
      x:x+1;f:=x;
   end
begin
   x:=5;
   result:=f(x)*f(x);
   writeln(result);
   end
```

A. 5 B. 25 C. 36 D. 42

gate1998 programming normal identify-function

Answer key

9.5.3 Identify Function: GATE CSE 2017 Set 2 | Question: 14

Consider the following function implemented in C:

```
void printxy(int x, int y) {
    int *ptr;
    x=0;
    ptr=&x;
    y=*ptr;
    *ptr=1;
    printf("%d, %d", x, y);
}
```

The output of invoking $printxy(1, 1)$ is:

A. $0,0$ B. $0,1$ C. $1,0$ D. $1,1$

gatecse-2017-set2 programming-in-c identify-function pointers

Answer key

9.5.4 Identify Function: GATE CSE 2017 Set 2 | Question: 43

Consider the following snippet of a C program. Assume that swap $(\&x, \&y)$ exchanges the content of x and y:

```
int main () {
    int array[] = {3, 5, 1, 4, 6, 2};
    int done =0;
    int i;
    while (done==0) {
        done =1;
        for (i=0; i<=4; i++) {
            if (array[i] < array[i+1]) {
                swap(&array[i], &array[i+1]);
                done=0;
            }
        }
        for (i=5; i>=1; i--) {
            if (array[i] > array[i-1]) {
                swap(&array[i], &array[i-1]);
                done =0;
            }
        }
    }
    printf("%d", array[3]);
}
```

The output of the program is _______

gatecse-2017-set2 programming algorithms numerical-answers identify-function

Answer key

9.5.5 Identify Function: GATE CSE 2019 | Question: 18

Consider the following C program :

```
#include<stdio.h>
int jumble(int x, int y){
    x = 2*x+y;
    return x;
}
int main(){
    int x=2, y=5;
    y=jumble(y,x);
    x=jumble(y,x);
    printf("%d \n",x);
    return 0;
}
```

The value printed by the program is ______________.

gatecse-2019 programming-in-c numerical-answers identify-function one-mark

Answer key

9.5.6 Identify Function: GATE IT 2004 | Question: 15

Let x be an integer which can take a value of 0 or 1. The statement

```
if (x == 0) x = 1; else x = 0;
```

is equivalent to which one of the following ?

A. $x = 1 + x;$ B. $x = 1 - x;$ C. $x = x - 1;$ D. $x = 1\% x;$

gateit-2004 programming easy identify-function

Answer key

9.6 Loop Invariants (8)

9.6.1 Loop Invariants: GATE CSE 1987 | Question: 7a

List the invariant assertions at points A, B, C, D and E in program given below:

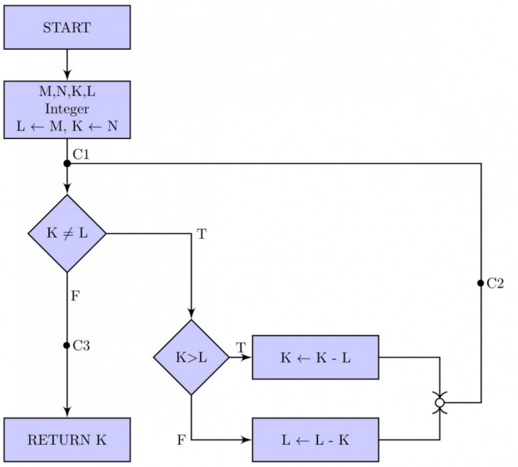
```
Program division (input, output)
Const
   dividend = 81;
   divisor = 9;
Var  remainder, quotient:interger
begin
   (*(dividend >= 0) AND (divisor > 0)*)
   remainder := dividend;
   quotient := 0;
   (*A*)
While (remainder >= 0) do
begin (*B*)
   quotient := quotient + 1;
   remainder := remainder - divisor;
   (*C*)
end;
   (*D*)
   quotient := quotient - 1;
   remainder := remainder + divisor;
   (*E*)
end
```

gate1987 programming loop-invariants descriptive

Answer key

9.6.2 Loop Invariants: GATE CSE 1988 | Question: 6ii

Below figure is the flow-chart corresponding to a program to calculate the $\gcd$ of two integers, M and N respectively, $(M, N > 0)$. Use assertions at the cut point C_1, C_2 and C_3 to prove that the flow-chart is correct.



gate1988 normal descriptive loop-invariants

Answer key

9.6.3 Loop Invariants: GATE CSE 1988 | Question: 8ii

Consider the two program segments below:

a.
```
for
   i:=1 to f(x) by 1 do
   S
end
```

b.
```
i:=1;
While   i<=f(x) do
      S
      i:=i+1
end
```

Under what conditions are these two programs equivalent? Treat S as any sequence of statements and f as a function.

gate1988 programming descriptive loop-invariants

Answer key

9.6.4 Loop Invariants: GATE CSE 1991 | Question: 1,vi

Consider the following PASCAL program segment:

```
if i mod 2 = 0 then
   while i >= 0 do
   begin
      i := i div 2;
      if i mod 2 < > 0  then i := i - 1;
      else i := i – 2;
   end;
```

An appropriate loop-invariant for the while-loop is ________

gate1991 programming loop-invariants normal fill-in-the-blanks

Answer key

9.6.5 Loop Invariants: GATE CSE 2004 | Question: 32

Consider the following program fragment for reversing the digits in a given integer to obtain a new integer. Let $n = d_1\, d_2\, \dots\, d_m$.

```
int n, rev;
rev = 0;
while(n > 0) {
   rev = rev * 10 + n%10;
```

```
    n = n/10;
}
```

The loop invariant condition at the end of the i^{th} iteration is:

A. $n = d_1\, d_2\, \dots\, d_{m-i} \qquad \textbf{and} \qquad \text{rev} = d_m\, d_{m-1}\, \dots\, d_{m-i+1}$
B. $n = d_{m-i+1}\, \dots\, d_{m-1}\, d_m \qquad \textbf{or} \qquad \text{rev} = d_{m-i}\, \dots\, d_2\, d_1$
C. $n \neq \text{rev}$
D. $n = d_1\, d_2\, \dots\, d_m \qquad \textbf{or} \qquad \text{rev} = d_m\, \dots\, d_2\, d_1$

gatecse-2004 programming loop-invariants normal

Answer key ☟

9.6.6 Loop Invariants: GATE CSE 2015 Set 1 | Question: 33

Consider the following pseudo code, where x and y are positive integers.

```
begin
    q := 0
    r := x
  while r ≥ y do
     begin
     r := r - y
     q := q + 1
    end
end
```

The post condition that needs to be satisfied after the program terminates is

A. $\{r = qx + y \wedge r < y\}$
B. $\{x = qy + r \wedge r < y\}$
C. $\{y = qx + r \wedge 0 < r < y\}$
D. $\{q + 1 < r - y \wedge y > 0\}$

gatecse-2015-set1 programming loop-invariants normal

Answer key ☟

9.6.7 Loop Invariants: GATE CSE 2016 Set 2 | Question: 35

The following function computes X^Y for positive integers X and Y.

```
int exp (int X, int Y) {
     int res =1, a = X, b = Y;

     while (b != 0) {
        if (b % 2 == 0) {a = a * a; b = b/2; }
        else        {res = res * a; b = b - 1; }
     }
     return res;
}
```

Which one of the following conditions is TRUE before every iteration of the loop?

A. $X^Y = a^b$
B. $(res * a)^Y = (res * X)^b$
C. $X^Y = res * a^b$
D. $X^Y = (res * a)^b$

gatecse-2016-set2 programming loop-invariants normal

Answer key ☟

9.6.8 Loop Invariants: GATE CSE 2017 Set 2 | Question: 37

Consider the C program fragment below which is meant to divide x by y using repeated subtractions. The variables x, y, q and r are all unsigned int.

```
while (r >= y) {
    r=r-y;
    q=q+1;
}
```

Which of the following conditions on the variables x, y, q and r before the execution of the fragment will ensure that the loop terminated in a state satisfying the condition $x == (y * q + r)$?

A. $(q == r)$ && $(r == 0)$
B. $(x > 0)$ && $(r == x)$ && $(y > 0)$
C. $(q == 0)$ && $(r == x)$ && $(y > 0)$
D. $(q == 0)$ && $(y > 0)$

gatecse-2017-set2 programming loop-invariants

Answer key☟

9.7 Output (10)

9.7.1 Output: GATE CSE 2021 Set 2 | Question: 10

Consider the following $\mathrm{ANSI\ C}$ program.

```
#include <stdio.h>
int main()
{
   int arr[4][5];
   int  i, j;
   for (i=0; i<4; i++)
   {
      for (j=0; j<5; j++)
      {
         arr[i][j] = 10 * i + j;
      }
   }
   printf("%d", *(arr[1]+9));
   return 0;
}
```

What is the output of the above program?

A. 14 B. 20 C. 24 D. 30

gatecse-2021-set2 programming-in-c array output one-mark

Answer key☟

9.7.2 Output: GATE CSE 2022 | Question: 33

What is printed by the following $\mathrm{ANSI\ C}$ program?

```
#include<stdio.h>

int main (int argc, char *argv[])

{

      int a[3][3][3] =

      {{1, 2, 3, 4, 5, 6, 7, 8, 9},
       {10, 11, 12, 13, 14, 15, 16, 17, 18},
       {19, 20, 21, 22, 23, 24, 25, 26, 27}};

   int i = 0, j = 0, k = 0;

   for ( i = 0; i < 3; i ++) {

      for ( k = 0; k < 3; k++)

         printf("%d", a[i][j][k]);

      printf ("\n");

   }

   return 0;

}
```

A. $\begin{matrix} 1 & 2 & 3 \\ 10 & 11 & 12 \\ 19 & 20 & 21 \end{matrix}$

B. $\begin{matrix} 1 & 4 & 7 \\ 10 & 13 & 16 \\ 19 & 22 & 25 \end{matrix}$

C. $\begin{matrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \end{matrix}$

D. $\begin{matrix} 1 & 2 & 3 \\ 13 & 14 & 15 \\ 25 & 26 & 27 \end{matrix}$

gatecse-2022 programming programming-in-c array output two-marks

Answer key☟

9.7.3 Output: GATE CSE 2022 | Question: 34

What is printed by the following ANSI C program?

```
#include<stdio.h>

int main(int argc, char *argv[]) {

    char a = ‘P’;

    char b = ‘x’;

    char c = (a&b) + ‘*’;

    char d = (a|b) – ‘-’;

    char e = (a^b) + ‘+’;

    printf(“%c %c %c\n”, c, d, e);

    return 0;

}
```

ASCII encoding for relevant characters is given below

A	B	C	...	Z
65	66	67	...	90

a	b	c	...	z
97	98	99	...	122

$*$	$+$	$-$
42	43	45

A. z K S

B. $122\ 75\ 83$

C. $* - +$

D. $\text{P x} +$

gatecse-2022 programming programming-in-c output two-marks

Answer key☟

9.7.4 Output: GATE CSE 2023 | Question: 25

The integer value printed by the ANSI-C program given below is _______________

```
#include<stdio.h>

int funcp(){
    static int x = 1;
    x++;
    return x;
}
```

```
int main(){
    int x,y;
    x = funcp();
    y = funcp()+x;
    printf("%d\n", (x+y));
    return 0;
}
```

gatecse-2023 programming programming-in-c output numerical-answers one-mark

Answer key

9.7.5 Output: GATE CSE 2024 | Set 1 | Question: 8

Consider the following C program:

```
#include <stdio.h>

int main() {

int a=6;

int b = 0;

while (a<10)   {

a = a / 12+1 ;

a += b ;}

printf ("%d", a);

return 0 ; }
```

Which one of the following statements is CORRECT?

A. The program prints 9 as output
B. The program prints 10 as output
C. The program gets stuck in an infinite loop
D. The program prints 6 as output

gatecse2024-set1 programming programming-in-c output one-mark

Answer key

9.7.6 Output: GATE CSE 2024 | Set 1 | Question: 9

Consider the following C program:

```
#include <stdio.h>
void fX ();
int main(){
fX();
return 0 };
```

```
void fX () {
char a;
if ((a=g e t c h a r())  ! = '\n')
fX();
if (a ! = '\n')
putchar (a); }
```

Assume that the input to the program from the command line is 1234 followed by a newline character. Which one of the following statements is CORRECT?

A. The program will not terminate
B. The program will terminate with no output
C. The program will terminate with 4321 as output
D. The program will terminate with 1234 as output

gatecse2024-set1 programming programming-in-c output one-mark

Answer key

9.7.7 Output: GATE CSE 2024 | Set 2 | Question: 23

Consider the following C function definition.

```
int fX(char *a) {

char *b = a;

while (*b)

b++;

return b - a; }
```

Which of the following statements is/are TRUE?

A. The function call $\mathrm{fX}(\text{"a b c d"})$ will always return a value
B. Assuming a character array c is declared as char $c[] =$ "abcd" in main ( ), the function call fX (c) will always return a value
C. The code of the function will not compile
D. Assuming a character pointer c is declared as char $^*\mathrm{c} =$ "abcd" in main (), the function call $\mathrm{fX}(\mathrm{c})$ will always return a value

gatecse2024-set2 programming programming-in-c multiple-selects output one-mark

Answer key

9.7.8 Output: GATE CSE 2025 | Set 1 | Question: 53

Consider the following C program:

```
#include <stdio.h>
int gate (int n) {
int d, t, newnum, turn;
newnum = turn = 0; t=1;
while (n>=t) t *= 10;
t /=10;
while (t>0) {
d = n/t;
n = n%t;
t /= 10;
if (turn) newnum = 10*newnum + d;
turn = (turn + 1) % 2;
}
return newnum;
}
int main () {
printf ("%d", gate(14362));
return 0;
}
```

The value printed by the given C program is _________. (Answer in integer)

gatecse2025-set1 programming-in-c output numerical-answers two-marks

Answer key

9.7.9 Output: GATE CSE 2025 | Set 2 | Question: 23

```
int x=126,y=105;
do {
if(x>y) x=x-y;
else y=y-x;
} while(x!=y);
printf("%d",x);
```

The output of the given C code segment is __________. (Answer in integer) gatecse2025-set2 programming-in-c output numerical-answers one-mark

Answer key

9.7.10 Output: GATE CSE 2025 | Set 2 | Question: 53

Consider the following C program:

```
#include <stdio.h>

int g(int n) {
   return (n+10);
}

int f(int n) {
   return g(n*2);
}

int main() {
   int sum, n;
   sum=0;
   for (n=1; n<3; n++)
       sum += g(f(n));
   printf ("%d", sum);
   return 0;
}
```

The output of the given C program is ___________. (Answer in integer)

gatecse2025-set2 programming-in-c output numerical-answers two-marks

Answer key

9.8 Parameter Passing (12)

9.8.1 Parameter Passing: GATE CSE 1992 | Question: 10b

Show the activation records and the display structure just after the procedures called at lines marked x and y have started their execution. Be sure to indicate which of the two procedures named A you are referring to.

```
Program Test;
   Procedure A;
      Procedure B;
         Procedure A;
         begin
         ......
         end A;
      begin
         y: A;
      end B;
   begin
      B;
   end A;

begin
   x: A;
end Test
```

gate1992 parameter-passing programming runtime-environment normal descriptive

Answer key

9.8.2 Parameter Passing: GATE CSE 1994 | Question: 1.20

In which of the following cases is it possible to obtain different results for call-by-reference and call-by-name parameter passing methods?

A. Passing a constant value as a parameter
B. Passing the address of an array as a parameter
C. Passing an array element as a parameter
D. Passing an array

gate1994 programming parameter-passing easy

Answer key

9.8.3 Parameter Passing: GATE CSE 2001 | Question: 2.17 | UGCNET-AUG2016-III: 21

What is printed by the print statements in the program $P1$ assuming call by reference parameter passing?

```
Program P1()
{
   x = 10;
   y = 3;
   func1(y,x,x);
   print x;
   print y;
}

func1(x,y,z)
{
   y = y + 4;
   z = x + y + z
}
```

A. $10, 3$ B. $31, 3$ C. $27, 7$ D. None of the above

gatecse-2001 programming-in-c parameter-passing normal ugcnetcse-aug2016-paper3

Answer key

9.8.4 Parameter Passing: GATE CSE 2003 | Question: 73

The following program fragment is written in a programming language that allows global variables and does not allow nested declarations of functions.

```
global int i=100, j=5;
void P(x) {
 int i=10;
   print(x+10);
   i=200;
   j=20;
   print (x);
}
main() {P(i+j);}
```

If the programming language uses static scoping and call by need parameter passing mechanism, the values printed by the above program are:

A. $115, 220$ B. $25, 220$ C. $25, 15$ D. $115, 105$

gatecse-2003 compiler-design normal runtime-environment parameter-passing

Answer key

9.8.5 Parameter Passing: GATE CSE 2008 | Question: 60

What is printed by the following C program?

```
int f(int x, int *py, int **ppz)
{
   int y, z;
   **ppz += 1; z = **ppz;   // corrected z = *ppz; to z = **ppz;
   *py += 2; y = *py;
   x += 3;
   return x+y+z;
}

void main()
{
   int c, *b, **a;
   c = 4; b = &c; a = &b;
   printf("%d", f(c, b, a));

}
```

A. 18 B. 19 C. 21 D. 22

gatecse-2008 programming programming-in-c normal parameter-passing

Answer key

9.8.6 Parameter Passing: GATE CSE 2010 | Question: 11

What does the following program print?

```
#include<stdio.h>

void f(int *p, int *q) {
   p=q;
   *p=2;
}

int i=0, j=1;

int main() {
   f(&i, &j);
   printf("%d %d\n", i,j);
   return 0;
}
```

A. $2\ 2$ B. $2\ 1$ C. $0\ 1$ D. $0\ 2$

gatecse-2010 programming programming-in-c easy parameter-passing

Answer key

9.8.7 Parameter Passing: GATE CSE 2013 | Question: 42

What is the return value of $f(p,p)$, if the value of p is initialized to 5 before the call? Note that the first parameter is passed by reference, whereas the second parameter is passed by value.

```
int f (int &x, int c) {
     c = c - 1;
     if (c==0) return 1;
     x = x + 1;
     return f(x,c) * x;
}
```

gatecse-2013 compiler-design normal marks-to-all numerical-answers parameter-passing runtime-environment

Answer key

9.8.8 Parameter Passing: GATE CSE 2016 Set 1 | Question: 15

Consider the following C program.

```
# include <stdio.h>
void mystery (int *ptra, int *ptrb) {
    int *temp;
    temp = ptrb;
    ptrb =ptra;
    ptra = temp;
}
int main () {
   int a = 2016, b=0, c= 4, d = 42;
   mystery (&a, &b);
   if (a < c)
        mystery (&c, &a);
   mystery (&a, &d);
   printf("%d\n", a);
}
```

The output of the program is _________.

gatecse-2016-set1 programming-in-c easy numerical-answers parameter-passing

Answer key

9.8.9 Parameter Passing: GATE CSE 2016 Set 2 | Question: 12

The value printed by the following program is _______.

```
    void f (int * p, int m) {
```

```
        m = m + 5;
       *p = *p + m;
        return;
    }
    void main () {
     int i=5, j=10;

     f (&i, j);
     printf ("%d", i+j);
    }
```

gatecse-2016-set2 programming-in-c normal numerical-answers parameter-passing

Answer key☟

9.8.10 Parameter Passing: GATE CSE 2018 | Question: 29

```
#include<stdio.h>
void fun1(char* s1, char* s2){
   char* temp;
   temp = s1;
   s1 = s2;
   s2 = temp;
}
void fun2(char** s1, char** s2){
   char* temp;
   temp = *s1;
   *s1 = *s2;
   *s2 = temp;
}
int main(){
   char *str1="Hi", *str2 = "Bye";
   fun1(str1, str2); printf("%s %s", str1, str2);
   fun2(&str1, &str2); printf("%s %s", str1, str2);
   return 0;
}
```

The output of the program above is:

A. Hi Bye Bye Hi
B. Hi Bye Hi Bye
C. Bye Hi Hi Bye
D. Bye Hi Bye Hi

gatecse-2018 programming-in-c pointers parameter-passing normal programming two-marks

Answer key☟

9.8.11 Parameter Passing: GATE IT 2006 | Question: 50

Which one of the choices given below would be printed when the following program is executed?

```
#include <stdio.h>
void swap (int *x, int *y)
{
   static int *temp;
   temp = x;
   x = y;
   y = temp;
}
void printab ()
{
   static int i, a = -3, b = -6;
   i = 0;
   while (i <= 4)
   {
      if ((i++)%2 == 1) continue;
      a = a + i;
      b = b + i;
   }
   swap (&a, &b);
   printf("a =  %d, b = %d\n", a, b);
}
main()
{
   printab();
   printab();
}
```

A. $a = 0, b = 3$
$a = 0, b = 3$

B. $a = 3, b = 0$
$a = 12, b = 9$

C. $a = 3, b = 6$
$a = 3, b = 6$

D. $a = 6, b = 3$
$a = 15, b = 12$

gateit-2006 programming programming-in-c normal parameter-passing

Answer key

9.8.12 Parameter Passing: GATE IT 2008 | Question: 50

Consider the C program below. What does it print?

```
# include <stdio.h>
# define swapl (a, b) tmp = a; a = b; b = tmp
void swap2 ( int a, int b)
{
      int tmp;
      tmp = a; a = b; b = tmp;
 }
void swap3 (int*a, int*b)
{
      int tmp;
      tmp = *a; *a = *b; *b = tmp;
}
int main ()
{
      int num1 = 5, num2 = 4, tmp;
      if (num1 < num2) {swap1 (num1, num2);}
      if (num1 < num2) {swap2 (num1 + 1, num2);}
      if (num1 > = num2) {swap3 (&num1, &num2);}
      printf ("%d, %d", num1, num2);
}
```

A. $5, 5$

B. $5, 4$

C. $4, 5$

D. $4, 4$

gateit-2008 programming programming-in-c easy parameter-passing

Answer key

9.9 Pointers (14)

9.9.1 Pointers: GATE CSE 2000 | Question: 1.12

The most appropriate matching for the following pairs

$X:\quad$ m = malloc(5); m = NULL;	$1:\quad$ using dangling pointers
$Y:\quad$ free(n); n -> value = 5;	$2:\quad$ using uninitialized pointers
$Z:\quad$ char *p , *p = 'a' ;	$3:\quad$ lost memory

is:

A. $X - 1 \;\; Y - 3 \;\; Z - 2$

B. $X - 2 \;\; Y - 1 \;\; Z - 3$

C. $X - 3 \;\; Y - 2 \;\; Z - 1$

D. $X - 3 \;\; Y - 1 \;\; Z - 2$

gatecse-2000 programming programming-in-c easy match-the-following pointers

Answer key

9.9.2 Pointers: GATE CSE 2001 | Question: 2.18

Consider the following three C functions:

$[P1]$

```
int *g(void)
{
   int x = 10;
   return (&x);
}
```

$[P2]$

```
int *g(void)
{
```

```
    int *px;
    *px = 10;
    return px;
}
```

$[P3]$

```
int *g(void)
{
    int *px;
    px = (int*) malloc (sizeof(int));
    *px = 10;
    return px;
}
```

Which of the above three functions are likely to cause problems with pointers?

A. Only $P3$ B. Only $P1$ and $P3$ C. Only $P1$ and $P2$ D. $P1, P2$ and $P3$

gatecse-2001 programming programming-in-c normal pointers

Answer key

9.9.3 Pointers: GATE CSE 2003 | Question: 2

Assume the following C variable declaration:

```
int *A[10], B[10][10];
```

Of the following expressions:

I. $A[2]$
II. $A[2][3]$
III. $B[1]$
IV. $B[2][3]$

which will not give compile-time errors if used as left hand sides of assignment statements in a C program?

A. I, II, and IV only B. II, III, and IV only C. II and IV only D. IV only

gatecse-2003 programming programming-in-c easy pointers

Answer key

9.9.4 Pointers: GATE CSE 2003 | Question: 89

Consider the C program shown below:

```
#include<stdio.h>
#define print(x) printf("%d", x)

int x;
void Q(int z)
{
      z+=x;
      print(z);
}

void P(int *y)
{
      int x = *y + 2;
      Q(x);
      *y = x - 1;
      print(x);
}
main(void) {
      x = 5;
      P(&x);
      print(x);
}
```

The output of this program is:

A. 12 7 6 B. 22 12 11 C. 14 6 6 D. 7 6 6 gatecse-2003 programming programming-in-c normal pointers

Answer key

9.9.5 Pointers: GATE CSE 2005 | Question: 1, ISRO2017-55

What does the following C-statement declare?

int (*f) (int *);

A. A function that takes an integer pointer as argument and returns an integer
B. A function that takes an integer as argument and returns an integer pointer
C. A pointer to a function that takes an integer pointer as argument and returns an integer
D. A function that takes an integer pointer as argument and returns a function pointer

gatecse-2005 programming programming-in-c pointers easy isro2017

Answer key

9.9.6 Pointers: GATE CSE 2006 | Question: 57

Consider this C code to swap two integers and these five statements: the code

```
void swap (int *px, int *py)
{
        *px = *px - *py;
        *py = *px + *py;
        *px = *py - *px;
}
```

S1: will generate a compilation error

S2: may generate a segmentation fault at runtime depending on the arguments passed

S3: correctly implements the swap procedure for all input pointers referring to integers stored in memory locations accessible to the process

S4: implements the swap procedure correctly for some but not all valid input pointers

S5: may add or subtract integers and pointers

A. S1 B. S2 and S3 C. S2 and S4 D. S2 and S5

gatecse-2006 programming programming-in-c normal pointers

Answer key

9.9.7 Pointers: GATE CSE 2014 Set 1 | Question: 10

Consider the following program in C language:

```
#include <stdio.h>

main()
{
   int i;
   int*pi = &i;

   scanf("%d",pi);
   printf("%d\n", i+5);
}
```

Which one of the following statements is **TRUE?**

A. Compilation fails.
B. Execution results in a run-time error.
C. On execution, the value printed is 5 more than the address of variable i.
D. On execution, the value printed is 5 more than the integer value entered.

gatecse-2014-set1 programming programming-in-c easy pointers

Answer key

9.9.8 Pointers: GATE CSE 2015 Set 3 | Question: 26

Consider the following C program

```
#include<stdio.h>
int main()  {
    static int a[] = {10, 20, 30, 40, 50};
    static int *p[] = {a, a+3, a+4, a+1, a+2};
    int **ptr = p;
    ptr++;
    printf("%d%d", ptr-p, **ptr);

}
```

The output of the program is _______.

gatecse-2015-set3 programming programming-in-c normal numerical-answers pointers

Answer key

9.9.9 Pointers: GATE CSE 2017 Set 1 | Question: 13

Consider the following C code:

```
#include<stdio.h>
int *assignval (int *x, int val) {
    *x = val;
    return x;
}

void main () {
    int *x = malloc(sizeof(int));
    if (NULL == x) return;
    x = assignval (x,0);
    if (x) {
        x = (int *)malloc(sizeof(int));
        if (NULL == x) return;
        x = assignval (x,10);
    }
    printf("%d\n", *x);
    free(x);
}
```

The code suffers from which one of the following problems:

A. compiler error as the return of $malloc$ is not typecast appropriately.
B. compiler error because the comparison should be made as $x == \text{NULL}$ and not as shown.
C. compiles successfully but execution may result in dangling pointer.
D. compiles successfully but execution may result in memory leak.

gatecse-2017-set1 programming-in-c programming pointers

Answer key

9.9.10 Pointers: GATE CSE 2017 Set 2 | Question: 55

Consider the following C program.

```
#include<stdio.h>
#include<string.h>
int main() {
    char* c="GATECSIT2017";
    char* p=c;
    printf("%d", (int)strlen(c+2[p]-6[p]-1));
    return 0;
}
```

The output of the program is _______

gatecse-2017-set2 programming-in-c numerical-answers array pointers

Answer key

9.9.11 Pointers: GATE CSE 2022 | Question: 11

What is printed by the following ANSI C program?

```
#include<stdio.h>

int main(int argc, char *argv[])

{

    int x = 1, z[2] = {10, 11};

    int *p = NULL;

    p = &x;

    *p = 10;

    p = &z[1];

    *(&z[0] + 1) += 3;

    printf("%d, %d, %d\n", x, z[0], z[1]);

    return 0;

}
```

A. $1, 10, 11$ B. $1, 10, 14$ C. $10, 14, 11$ D. $10, 10, 14$

gatecse-2022 programming programming-in-c pointers output one-mark

Answer key

9.9.12 Pointers: GATE CSE 2024 | Set 2 | Question: 26

What is the output of the following C program?

```
#include <stdio.h>
int main()  {
double a[2]={20.0,25.0},* p,* q;
p=a ;
q=p+1 ;
printf("%d,%d", (int) (q-p),( int)(* q- * p));
return 0;}
```

A. $4, 8$ B. $1, 5$ C. $8, 5$ D. $1, 8$

gatecse2024-set2 programming programming-in-c pointers two-marks

Answer key

9.9.13 Pointers: GATE CSE 2025 | Set 1 | Question: 24

```
#include <stdio.h>
void foo(int *p, int x) {
*p=x;
}
int main(){
int *z;
int a = 20, b = 25;
z = &a;
foo(z,b);
printf("%d",a);
return 0;
}
```

The output of the given C program is ___________. (Answer in integer)

gatecse2025-set1 programming-in-c pointers output numerical-answers easy one-mark

Answer key

9.9.14 Pointers: GATE CSE 2025 | Set 2 | Question: 52

Consider the following C program:

```
#include<stdio.h>
int main(){
    int a;
    int arr[5] = {30,50,10};
    int *ptr;
    ptr = &arr[0] + 1;
    a = *ptr;
    (*ptr)++;
    ptr++;
    printf("%d", a + (*ptr) + arr[1]);
    return 0;
}
```

The output of the above program is _________. (Answer in integer)

gatecse2025-set2 programming-in-c pointers output numerical-answers two-marks

Answer key

9.10 Programming Constructs (1)

9.10.1 Programming Constructs: GATE CSE 1999 | Question: 2.5

Given the programming constructs

i. assignment
ii. for loops where the loop parameter cannot be changed within the loop
iii. if-then-else
iv. forward go to
v. arbitrary go to
vi. non-recursive procedure call
vii. recursive procedure/function call
viii. repeat loop,

which constructs will you not include in a programming language such that it should be possible to program the terminates (i.e., halting) function in the same programming language

A. (ii), (iii), (iv)
B. (v), (vii), (viii)
C. (vi), (vii), (viii)
D. (iii), (vii), (viii)

gate1999 programming normal programming-constructs

Answer key

9.11 Programming In C (31)

9.11.1 Programming In C: GATE CSE 2000 | Question: 2.20

The value of j at the end of the execution of the following C program:

```
int incr (int i)
{
   static int count = 0;
   count = count + i;
   return (count);
}
main () {
   int i, j;
   for (i = 0; i <= 4; i++)
     j = incr (i);
}
```

is:

A. 10
B. 4
C. 6
D. 7

gatecse-2000 programming programming-in-c easy

Answer key

9.11.2 Programming In C: GATE CSE 2002 | Question: 1.17

In the C language:

A. At most one activation record exists between the current activation record and the activation record for the main
B. The number of activation records between the current activation record and the activation records from the main depends on the actual function calling sequence.
C. The visibility of global variables depends on the actual function calling sequence
D. Recursion requires the activation record for the recursive function to be saved in a different stack before the recursive function can be called.

gatecse-2002 programming programming-in-c easy descriptive

Answer key

9.11.3 Programming In C: GATE CSE 2002 | Question: 2.18

The C language is:

A. A context free language
B. A context sensitive language
C. A regular language
D. Parsable fully only by a Turing machine

gatecse-2002 programming programming-in-c normal

Answer key

9.11.4 Programming In C: GATE CSE 2002 | Question: 2.8

Consider the following declaration of a two-dimensional array in C:

char $a[100][100]$;

Assuming that the main memory is byte-addressable and that the array is stored starting from memory address 0, the address of $a[40][50]$ is:

A. 4040
B. 4050
C. 5040
D. 5050

gatecse-2002 programming-in-c programming easy

Answer key

9.11.5 Programming In C: GATE CSE 2004 | Question: 33

Consider the following C program segment:

```
char p[20]; int i;
char* s = "string";
int length = strlen(s);
for(i = 0; i < length; i++)
    p[i] = s[length-i];
printf("%s", p);
```

The output of the program is:

A. gnirts
B. string
C. gnirt
D. no output is printed

gatecse-2004 programming programming-in-c easy

Answer key

9.11.6 Programming In C: GATE CSE 2005 | Question: 32

Consider the following C program:

```
double foo (double); /* Line 1 */
int main() {
    double da, db;
    //input da
    db = foo(da);
}
```

```
double foo (double a) {
    return a;
}
```

The above code compiled without any error or warning. If Line 1 is deleted, the above code will show:

A. no compile warning or error
B. some compiler-warnings not leading to unintended results
C. some compiler-warnings due to type-mismatch eventually leading to unintended results
D. compiler errors

gatecse-2005 programming programming-in-c compiler-design easy

Answer key ☟

9.11.7 Programming In C: GATE CSE 2008 | Question: 18

Which combination of the integer variables $x, y,$ and z makes the variable a get the value 4 in the following expression?

$$a = (x > y)?((x > z)?x : z) : ((y > z)?y : z)$$

A. $x = 3, y = 4, z = 2$
B. $x = 6, y = 5, z = 3$
C. $x = 6, y = 3, z = 5$
D. $x = 5, y = 4, z = 5$

gatecse-2008 programming programming-in-c easy

Answer key ☟

9.11.8 Programming In C: GATE CSE 2008 | Question: 61

Choose the correct option to fill $?1$ and $?2$ so that the program below prints an input string in reverse order. Assume that the input string is terminated by a new line character.

```
void reverse(void)
{
    int c;
    if(?1) reverse();
    ?2
}
main()
{
    printf("Enter text");
    printf("\n");
    reverse();
    printf("\n");
}
```

A. $?1$ is $(getchar()! =' \backslash n')$
   $?2$ is $getchar(c);$
B. $?1$ is $((c = getchar())! =' \backslash n')$
   $?2$ is $getchar(c);$
C. $?1$ is $(c! =' \backslash n')$
   $?2$ is $putchar(c);$
D. $?1$ is $((c = getchar())! =' \backslash n')$
   $?2$ is $putchar(c);$

gatecse-2008 programming normal programming-in-c

Answer key ☟

9.11.9 Programming In C: GATE CSE 2012 | Question: 48

Consider the following C code segment.

```
int a, b, c = 0;
void prtFun(void);
```

```
main()
{
   static int a = 1;       /* Line 1 */
   prtFun();
   a += 1;
   prtFun();
   printf(" \n %d %d ", a, b);
}

void prtFun(void)
{
   static int a = 2;       /* Line 2 */
   int b = 1;
   a += ++b;
   printf(" \n %d %d ", a, b);
}
```

What output will be generated by the given code segment?

A. $\begin{matrix} 3 & 1 \\ 4 & 1 \\ 4 & 2 \end{matrix}$
B. $\begin{matrix} 4 & 2 \\ 6 & 1 \\ 6 & 1 \end{matrix}$
C. $\begin{matrix} 4 & 2 \\ 6 & 2 \\ 2 & 0 \end{matrix}$
D. $\begin{matrix} 3 & 1 \\ 5 & 2 \\ 5 & 2 \end{matrix}$

gatecse-2012 programming programming-in-c normal

Answer key

9.11.10 Programming In C: GATE CSE 2012 | Question: 49

Consider the following C code segment.

```
int a, b, c = 0;
void prtFun(void);
main()
{
   static int a = 1;       /* Line 1 */
   prtFun();
   a += 1;
   prtFun();
   printf(" \n %d %d ", a, b);
}

void prtFun(void)
{
   static int a = 2;       /* Line 2 */
   int b = 1;
   a += ++b;
   printf(" \n %d %d ", a, b);
}
```

What output will be generated by the given code segment if:

Line 1 is replaced by **auto int** $a = 1;$

Line 2 is replaced by **register int** $a = 2;$

A. $\begin{matrix} 3 & 1 \\ 4 & 1 \\ 4 & 2 \end{matrix}$
B. $\begin{matrix} 4 & 2 \\ 6 & 1 \\ 6 & 1 \end{matrix}$
C. $\begin{matrix} 4 & 2 \\ 6 & 2 \\ 2 & 0 \end{matrix}$
D. $\begin{matrix} 4 & 2 \\ 4 & 2 \\ 2 & 0 \end{matrix}$

normal gatecse-2012 programming-in-c programming

Answer key

9.11.11 Programming In C: GATE CSE 2014 Set 2 | Question: 11

Suppose n and p are unsigned int variables in a C program. We wish to set p to ${}^nC_3$. If n is large, which one of the following statements is most likely to set p correctly?

A. $p = n * (n-1) * (n-2)/6;$
B. $p = n * (n-1)/2 * (n-2)/3;$
C. $p = n * (n-1)/3 * (n-2)/2;$
D. $p = n * (n-1) * (n-2)/6.0;$

gatecse-2014-set2 programming programming-in-c normal

Answer key

9.11.12 Programming In C: GATE CSE 2014 Set 2 | Question: 42

Consider the C function given below.

```
int f(int j)
{
    static int i = 50;
    int k;
    if (i == j)
    {
        printf("something");
        k = f(i);
        return 0;
    }
    else return 0;
}
```

Which one of the following is **TRUE**?

A. The function returns 0 for all values of j.
B. The function prints the string **something** for all values of j.
C. The function returns 0 when $j = 50$.
D. The function will exhaust the runtime stack or run into an infinite loop when $j = 50$.

gatecse-2014-set2 programming programming-in-c

Answer key

9.11.13 Programming In C: GATE CSE 2015 Set 1 | Question: 11

The output of the following C program is_____________.

```
void f1 ( int a, int b)  {
                int c;
                c = a; a = b;
                 b = c;
}
void f2 ( int * a, int * b) {
               int c;
               c = * a; *a = *b; *b = c;
}
int main () {
       int a = 4, b = 5, c = 6;
       f1 ( a, b);
       f2 (&b, &c);
       printf ("%d", c - a - b);
 }
```

gatecse-2015-set1 programming programming-in-c easy numerical-answers

Answer key

9.11.14 Programming In C: GATE CSE 2015 Set 3 | Question: 54

Consider the following C program:

```
#include<stdio.h>
int f1(void);
int f2(void);
int f3(void);
int x=10;
int main()
{
    int x=1;
    x += f1() + f2 () + f3() + f2();
    printf("%d", x);
    return 0;
}
int f1() { int x = 25; x++; return x;}
int f2() { static int x = 50; x++; return x;}
int f3() { x *= 10; return x;}
```

The output of the program is ______.

gatecse-2015-set3 programming programming-in-c normal numerical-answers

Answer key

9.11.15 Programming In C: GATE CSE 2016 Set 1 | Question: 12

Consider the following "C" program.

```
void f(int, short);
void main()
{
    int i = 100;
    short s = 12;
    short *p = &s;
    ____________; // call to f()
}
```

Which one of the following expressions , when placed in the blank above, will NOT result in a type checking error?

A. $f(s, *s)$ B. $i = f(i, s)$ C. $f(i, *s)$ D. $f(i, *p)$

gatecse-2016-set1 programming-in-c easy

Answer key

9.11.16 Programming In C: GATE CSE 2016 Set 1 | Question: 34

The following function computes the maximum value contained in an integer array $P[\,]$ of size n $(n >= 1)$.

```
int max (int *p,int n) {
    int a = 0, b=n-1;

    while (__________) {
        if (p[a]<= p[b]) {a = a+1;}
        else            {b = b-1;}
    }
    return p[a];
}
```

The missing loop condition is:

A. $a\ != n$
B. $b\ != 0$
C. $b > (a + 1)$
D. $b\ != a$

gatecse-2016-set1 programming-in-c normal

Answer key

9.11.17 Programming In C: GATE CSE 2017 Set 1 | Question: 53

Consider the following C program.

```
#include<stdio.h>
#include<string.h>

void printlength(char *s, char *t) {
    unsigned int c=0;
    int len = ((strlen(s) - strlen(t)) > c) ? strlen(s) : strlen(t);
    printf("%d\n", len);
}

void main() {
    char *x = "abc";
    char *y = "defgh";
    printlength(x,y);
}
```

Recall that $strlen$ is defined in $string.h$ as returning a value of type $size\_t$, which is an unsigned int. The output of the program is __________ .

gatecse-2017-set1 programming programming-in-c normal numerical-answers

Answer key

9.11.18 Programming In C: GATE CSE 2017 Set 1 | Question: 55

The output of executing the following C program is ________________ .

```
#include<stdio.h>

int total(int v) {
   static int count = 0;
   while(v) {
      count += v&1;
      v >>= 1;
   }
   return count;
}

void main() {
   static int x=0;
   int i=5;
   for(; i>0; i--) {
      x = x + total(i);
   }
   printf("%d\n", x);
}
```

gatecse-2017-set1 programming programming-in-c normal numerical-answers

Answer key

9.11.19 Programming In C: GATE CSE 2017 Set 2 | Question: 2

Match the following:

$P.$	static char var ;	i.	Sequence of memory locations to store addresses
$Q.$	m = malloc(10); m =NULL ;	ii.	A variable located in data section of memory
$R.$	char *ptr[10] ;	iii.	Request to allocate a CPU register to store data
$S.$	register int varl;	iv.	A lost memory which cannot be freed

A. P-ii; Q-iv; R-i; S-iii
B. P-ii; Q-i; R-iv; S-iii
C. P-ii; Q-iv; R-iii; S-i
D. P-iii; Q-iv; R-i; S-ii

gatecse-2017-set2 programming programming-in-c match-the-following

Answer key

9.11.20 Programming In C: GATE CSE 2017 Set 2 | Question: 54

Consider the following C program.

```
#include<stdio.h>
int main () {
   int m=10;
   int n, n1;
   n=++m;
   n1=m++;
   n--;
   --n1;
   n-=n1;
   printf("%d", n);
   return 0;
}
```

The output of the program is ______

gatecse-2017-set2 programming-in-c numerical-answers easy

Answer key

9.11.21 Programming In C: GATE CSE 2018 | Question: 32

Consider the following C code. Assume that unsigned long int type length is 64 bits.

```
unsigned long int fun(unsigned long int n) {
      unsigned long int i, j=0, sum = 0;
```

```
    for( i=n; i>1; i=i/2) j++;
    for( ; j>1; j=j/2) sum++;
    return sum;
}
```

The value returned when we call fun with the input 2^{40} is:

A. 4 B. 5 C. 6 D. 40

gatecse-2018 programming-in-c normal programming two-marks

Answer key

9.11.22 Programming In C: GATE CSE 2019 | Question: 27

Consider the following C program:

```
#include <stdio.h>
int r() {
      static int num=7;
      return num--;
}
int main() {
      for (r();r();r())
            printf("%d",r());
      return 0;
}
```

Which one of the following values will be displayed on execution of the programs?

A. 41 B. 52 C. 63 D. 630

gatecse-2019 programming-in-c programming two-marks

Answer key

9.11.23 Programming In C: GATE CSE 2019 | Question: 52

Consider the following C program:

```
#include <stdio.h>
int main() {
   float sum = 0.0, j=1.0, i=2.0;
   while (i/j > 0.0625) {
      j=j+j;
      sum=sum+i/j;
      printf("%f\n", sum);
   }
   return 0;
}
```

The number of times the variable sum will be printed, when the above program is executed, is __________

gatecse-2019 numerical-answers programming-in-c programming two-marks

Answer key

9.11.24 Programming In C: GATE CSE 2019 | Question: 53

Consider the following C program:

```
#include <stdio.h>
int main()
{
   int a[] = {2, 4, 6, 8, 10};
   int i, sum=0, *b=a+4;
   for (i=0; i<5; i++)
      sum=sum+(*b-i)-*(b-i);
   printf("%d\n", sum);
   return 0;
}
```

The output of the above C program is ________

gatecse-2019 numerical-answers programming-in-c programming two-marks

Answer key

9.11.25 Programming In C: GATE CSE 2021 Set 1 | Question: 37

Consider the following $\mathrm{ANSI\ C}$ program.

```
#include <stdio.h>
int main()
{
    int i, j, count;
    count=0;
    i=0;
    for (j=-3; j<=3; j++)
    {
        if (( j >= 0) && (i++))
            count = count + j;
    }
    count = count +i;
    printf("%d", count);
    return 0;
}
```

Which one of the following options is correct?

A. The program will not compile successfully
B. The program will compile successfully and output 10 when executed
C. The program will compile successfully and output 8 when executed
D. The program will compile successfully and output 13 when executed

gatecse-2021-set1 programming-in-c two-marks

Answer key

9.11.26 Programming In C: GATE CSE 2024 | Set 1 | Question: 38

Consider the following C function definition.

```
int f (int x, int y){
for (int i=0 ; i<y ; i++ ) {
x= x + x + y;
}
return x;
}
```

Which of the following statements is/are TRUE about the above function?

A. If the inputs are $x = 20, y = 10$, then the return value is greater than 2^{20}
B. If the inputs are $x = 20, y = 20$, then the return value is greater than 2^{20}
C. If the inputs are $x = 20, y = 10$, then the return value is less than 2^{10}
D. If the inputs are $x = 10, y = 20$, then the return value is greater than 2^{20}

gatecse2024-set1 multiple-selects programming programming-in-c two-marks

Answer key

9.11.27 Programming In C: GATE IT 2004 | Question: 59

What is the output of the following program?

```
#include<stdio.h>
int funcf (int x);
int funcg (int y);
main ()
{
    int x = 5, y = 10, count;
    for (count = 1; count <= 2; ++count) {
        y += funcf(x) + funcg(x);
        printf ("%d", y);
    }
}
funcf (int x) {
    int y;
```

```
    y = funcg(x);
    return (y);
}
funcg (int x) {
    static int y = 10;
    y += 1;
    return (y + x);
}
```

A. $43\ 80$ B. $42\ 74$ C. $33\ 37$ D. $32\ 32$

gateit-2004 programming programming-in-c normal

Answer key

9.11.28 Programming In C: GATE IT 2004 | Question: 60

Choose the correct option to fill the $?1$ and $?2$ so that the program prints an input string in reverse order. Assume that the input string is terminated by a new line character.

```
#include <stdio.h>
void wrt_it (void);
int main (void)
{
    printf("Enter Text");
    printf ("\n");
    wrt_it();
    printf ("\n");
    return 0;
}
void wrt_it (void)
{
    int c;
    if (?1)
        wrt_it();
    ?2
}
```

A. $?1$ is $getchar()! =$ '\n'
$?2$ is $getchar(c);$
B. $?1$ is $(c = getchar()); ! =$ '\n'
$?2$ is $getchar(c);$
C. $?1$ is $c! =$ '\n'
$?2$ is $putchar(c);$
D. $?1$ is $(c = getchar())! =$ '\n'
$?2$ is $putchar(c);$

gateit-2004 programming programming-in-c normal

Answer key

9.11.29 Programming In C: GATE IT 2005 | Question: 58

Let a be an array containing n integers in increasing order. The following algorithm determines whether there are two distinct numbers in the array whose difference is a specified number $S > 0$.

```
i = 0; j = 1;
while (j < n ){
        if (E) j++;
        else if (a[j] - a[i] == S) break;
        else i++;
}
if (j < n) printf("yes") else printf ("no");
```

Choose the correct expression for E.

A. $a[j] - a[i] > S$ B. $a[j] - a[i] < S$
C. $a[i] - a[j] < S$ D. $a[i] - a[j] > S$

gateit-2005 programming normal programming-in-c

Answer key

9.11.30 Programming In C: GATE IT 2006 | Question: 51

Which one of the choices given below would be printed when the following program is executed?

```
#include <stdio.h>
int a1[] = {6, 7, 8, 18, 34, 67};
int a2[] = {23, 56, 28, 29};
int a3[] = {-12, 27, -31};
int *x[] = {a1, a2, a3};
void print(int *a[])
{
        printf("%d,", a[0][2]);
        printf("%d,", *a[2]);
        printf("%d,", *++a[0]);
        printf("%d,", *(++a)[0]);
        printf("%d\n", a[-1][+1]);
}
main()
{
        print(x);
}
```

A. $8, -12, 7, 23, 8$
B. $8, 8, 7, 23, 7$
C. $-12, -12, 27, -31, 23$
D. $-12, -12, 27, -31, 56$

gateit-2006 programming programming-in-c normal

Answer key

9.11.31 Programming In C: GATE IT 2007 | Question: 31

Consider the C program given below :

```
#include <stdio.h>
int main ()   {
   int sum = 0, maxsum = 0,  i,  n = 6;
   int a [] = {2, -2, -1, 3, 4, 2};
   for (i = 0; i < n; i++)    {
         if (i == 0 || a [i]  < 0  || a [i] < a [i - 1])  {
               if (sum > maxsum) maxsum = sum;
               sum = (a [i] > 0) ? a [i] : 0;
         }
         else sum += a [i];
   }
   if (sum > maxsum) maxsum = sum ;
   printf ("%d\n", maxsum);

}
```

What is the value printed out when this program is executed?

A. 9
B. 8
C. 7
D. 6

gateit-2007 programming programming-in-c normal

Answer key

9.12 Programming Paradigms (2)

9.12.1 Programming Paradigms: GATE CSE 2004 | Question: 1

The goal of structured programming is to:

A. have well indented programs
B. be able to infer the flow of control from the compiled code
C. be able to infer the flow of control from the program text
D. avoid the use of GOTO statements

gatecse-2004 programming easy programming-paradigms

Answer key

9.12.2 Programming Paradigms: GATE CSE 2004 | Question: 90

Choose the best matching between the programming styles in Group 1 and their characteristics in Group 2.

Group 1	Group 2
$P.$ Functional	1. Common-based, procedural
$Q.$ Logic	2. Imperative, abstract data types
$R.$ Object-oriented	3. Side-effect free, declarative, expression evaluations
$S.$ Imperative	4. Declarative, clausal representation, theorem proving

A. $P-2 \quad Q-3 \quad R-4 \quad S-1$
B. $P-4 \quad Q-3 \quad R-2 \quad S-1$
C. $P-3 \quad Q-4 \quad R-1 \quad S-2$
D. $P-3 \quad Q-4 \quad R-2 \quad S-1$

gatecse-2004 programming normal programming-paradigms match-the-following

Answer key☟

9.13 Recursion (18)

9.13.1 Recursion: GATE CSE 1991 | Question: 01,x

Consider the following recursive definition of fib:

```
fib(n) :=  if n = 0 then 1
        else if n = 1 then 1
        else fib(n-1) + fib(n-2)
```

The number of times fib is called (including the first call) for evaluation of $fib(7)$ is___________.

gate1991 programming recursion normal numerical-answers

Answer key☟

9.13.2 Recursion: GATE CSE 1994 | Question: 21

Consider the following recursive function:

```
function fib (n:integer);integer;
begin
if (n=0) or (n=1) then fib := 1
else fib := fib(n-1) + fib(n-2)
end;
```

The above function is run on a computer with a stack of 64 bytes. Assuming that only return address and parameter are passed on the stack, and that an integer value and an address takes 2 bytes each, estimate the maximum value of n for which the stack will not overflow. Give reasons for your answer.

gate1994 programming recursion normal descriptive

Answer key☟

9.13.3 Recursion: GATE CSE 2000 | Question: 16

A recursive program to compute Fibonacci numbers is shown below. Assume you are also given an array $f[0\dots m]$ with all elements initialized to 0.

```
fib(n) {
   if (n > M) error ();
   if (n == 0) return 1;
   if (n == 1)return 1;
   if (▭)________________________(1)
      return ▭__________________(2)
   t = fib(n - 1) + fib(n - 2);
   ▭______________________________(3)
   return t;
}
```

A. Fill in the boxes with expressions/statement to make $fib()$ store and reuse computed Fibonacci values. Write the box number and the corresponding contents in your answer book.
B. What is the time complexity of the resulting program when computing $fib(n)$?

gatecse-2000 algorithms normal descriptive recursion

Answer key

9.13.4 Recursion: GATE CSE 2001 | Question: 13

Consider the following C program:

```
void abc(char*s)
{
    if(s[0]=='\0')return;
    abc(s+1);
    abc(s+1);
    printf("%c",s[0]);
}

main()
{
    abc("123");
}
```

A. What will be the output of the program?
B. If $abc(s)$ is called with a null-terminated string s of length n characters (not counting the null ('\0') character), how many characters will be printed by $abc(s)$?

gatecse-2001 programming recursion normal descriptive

Answer key

9.13.5 Recursion: GATE CSE 2002 | Question: 11

The following recursive function in C is a solution to the Towers of Hanoi problem.

```
void move(int n, char A, char B, char C)  {
    if (......................) {
        move (.............................);
        printf("Move disk %d from pole %c to pole %c\n", n, A, C);
        move (.....................);
    }
}
```

Fill in the dotted parts of the solution.

gatecse-2002 programming recursion descriptive

Answer key

9.13.6 Recursion: GATE CSE 2004 | Question: 31, ISRO2008-40

Consider the following C function:

```
int f(int n)
{
    static int i = 1;
    if(n >= 5) return n;
    n = n+i;
    i++;
    return f(n);
}
```

The value returned by $f(1)$ is:

A. 5 B. 6 C. 7 D. 8

gatecse-2004 programming programming-in-c recursion easy isro2008

Answer key

9.13.7 Recursion: GATE CSE 2005 | Question: 81b

```
double foo(int n)
{
```

```
    int i;
    double sum;
    if(n == 0)
    {
        return 1.0;
    }
    else
    {
        sum = 0.0;
        for(i = 0; i < n; i++)
        {
            sum += foo(i);
        }
        return sum;
    }

}
```

Suppose we modify the above function $foo()$ and stores the value of $foo(i)$ $0 \leq i < n$, as and when they are computed. With this modification the time complexity for function $foo()$ is significantly reduced. The space complexity of the modified function would be:

A. $O(1)$ B. $O(n)$ C. $O(n^2)$ D. $n!$

gatecse-2005 programming recursion normal

Answer key

9.13.8 Recursion: GATE CSE 2007 | Question: 42

Consider the following C function:

```
int f(int n)
{
    static int r = 0;
    if (n <= 0) return 1;
    if (n > 3)
    {   r = n;
        return f(n-2) + 2;
    }
    return f(n-1) + r;
}
```

What is the value of $f(5)$?

A. 5 B. 7 C. 9 D. 18

gatecse-2007 programming recursion normal

Answer key

9.13.9 Recursion: GATE CSE 2014 Set 2 | Question: 40

Consider the following function.

```
double f(double x){
    if( abs(x*x - 3) < 0.01)
        return x;
    else
        return f(x/2 + 1.5/x);
}
```

Give a value q (to 2 decimals) such that $f(q)$ will return q:_____.

gatecse-2014-set2 programming recursion numerical-answers normal

Answer key

9.13.10 Recursion: GATE CSE 2015 Set 2 | Question: 15

Consider the following function written in the C programming langauge :

```
void foo(char *a)
 {
    if (*a && *a != ' ')
     {
```

```
        foo(a+1);
        putchar(*a);
    }
}
```

The output of the above function on input "$ABCD\ EFGH$" is

A. $ABCD\ EFGH$ B. $ABCD$ C. $HGFE\ DCBA$ D. $DCBA$

gatecse-2015-set2 programming programming-in-c normal recursion

Answer key

9.13.11 Recursion: GATE CSE 2016 Set 1 | Question: 35

What will be the output of the following C program?

```
void count (int n) {
    static int d=1;

    printf ("%d",n);
    printf ("%d",d);
    d++;
    if (n>1) count (n-1);
    printf ("%d",d);



}

void main(){
    count (3);
}
```

A. $3\ 1\ 2\ 2\ 1\ 3\ 4\ 4\ 4$
B. $3\ 1\ 2\ 1\ 1\ 1\ 2\ 2\ 2$
C. $3\ 1\ 2\ 2\ 1\ 3\ 4$
D. $3\ 1\ 2\ 1\ 1\ 1\ 2$

gatecse-2016-set1 programming-in-c recursion normal

Answer key

9.13.12 Recursion: GATE CSE 2016 Set 2 | Question: 37

Consider the following program:

```
int f (int * p, int n)
{
    if (n <= 1) return 0;
    else return max (f (p+1, n-1), p[0] - p[1]);
}
 int main ()
{
    int a[] = {3, 5, 2, 6, 4};
    printf(" %d", f(a, 5));
}
```

Note: $\max(x, y)$ returns the maximum of x and y.
The value printed by this program is ________.

gatecse-2016-set2 programming-in-c normal numerical-answers recursion

Answer key

9.13.13 Recursion: GATE CSE 2017 Set 1 | Question: 35

Consider the following two functions.

```
void fun1(int n) {
    if(n == 0) return;
    printf("%d", n);
    fun2(n - 2);
    printf("%d", n);
}
```

```
void fun2(int n) {
    if(n == 0) return;
    printf("%d", n);
    fun1(++n);
    printf("%d", n);
}
```

The output printed when $\text{fun1}(5)$ is called is

A. 53423122233445
B. 53423120112233
C. 53423122132435
D. 53423120213243

gatecse-2017-set1 programming normal tricky recursion

Answer key

9.13.14 Recursion: GATE CSE 2017 Set 1 | Question: 36

Consider the C functions foo and bar given below:

```
int foo(int val) {
    int x=0;
    while(val > 0) {
        x = x + foo(val--);
    }
    return val;
}
```

```
int bar(int val) {
    int x = 0;
    while(val > 0) {
        x= x + bar(val-1);
    }
    return val;
}
```

Invocations of $foo(3)$ and $bar(3)$ will result in:

A. Return of 6 and 6 respectively.
B. Infinite loop and abnormal termination respectively.
C. Abnormal termination and infinite loop respectively.
D. Both terminating abnormally.

gatecse-2017-set1 programming-in-c programming normal recursion

Answer key

9.13.15 Recursion: GATE CSE 2018 | Question: 21

Consider the following C program:

```
#include<stdio.h>

int counter=0;

int calc (int a, int b) {
        int c;
        counter++;
        if(b==3) return (a*a*a);
        else {
                c = calc(a, b/3);
                return (c*c*c);
        }
}

int main() {
        calc(4, 81);
        printf("%d", counter);
}
```

The output of this program is ______.

gatecse-2018 programming-in-c numerical-answers recursion programming one-mark

Answer key

9.13.16 Recursion: GATE CSE 2020 | Question: 46

Consider the following C functions.

```
int fun1(int n) {
   static int i= 0;
   if (n > 0) {
     ++i;
    fun1(n-1);
  }
  return (i);
}
```

```
int fun2(int n) {
   static int i= 0;
   if (n>0) {
     i = i+ fun1 (n) ;
     fun2(n-1) ;
  }
return (i);
}
```

The return value of $\text{fun2}(5)$ is _________

gatecse-2020 numerical-answers programming-in-c recursion two-marks

Answer key

9.13.17 Recursion: GATE CSE 2025 | Set 1 | Question: 51

```
#include <stdio.h>
int foo(int S[],int size) {
    if(size == 0) return 0;
    if(size == 1) return 1;
    if(S[0] != S[1]) return 1+foo(S+1,size-1);
    return foo(S+1,size-1);
}
int main() {
    int A[]={0,1,2,2,2,0,0,1,1};
    printf("%d",foo(A,9));
    return 0;
}
```

The value printed by the given C program is ___________. (Answer in integer)

gatecse2025-set1 programming-in-c recursion output numerical-answers two-marks

Answer key

9.13.18 Recursion: GATE IT 2007 | Question: 27

The function f is defined as follows:

```
int f (int n) {
   if (n <= 1) return 1;
   else if (n % 2  == 0) return f(n/2);
   else return f(3n - 1);
}
```

Assuming that arbitrarily large integers can be passed as a parameter to the function, consider the following statements.

i. The function f terminates for finitely many different values of $n \geq 1$.
ii. The function f terminates for infinitely many different values of $n \geq 1$.
iii. The function f does not terminate for finitely many different values of $n \geq 1$.
iv. The function f does not terminate for infinitely many different values of $n \geq 1$.

Which one of the following options is true of the above?

A. i and iii
B. i and iv
C. ii and iii
D. ii and iv

gateit-2007 programming recursion normal

Answer key

9.14 Strings (1)

9.14.1 Strings: GATE CSE 2025 | Set 2 | Question: 9

Consider the following C program:

```
#include <stdio.h>
void stringcopy (char *, char *);
int () {
    char a[30] "@Hello World";
    stringcopy(, a+2);
    printf("%s\n",a);
    return 0;
}
void stringcopy(char *s, char *t) {
while (*t)
    *s++=*t++;
}
```

Which one of the following will be the output of the program?

A. @#Hello World!
B. Hello World!
C. ello World!
D. @#Hello World!d!

gatecse2025-set2 programming-in-c strings output one-mark

Answer key

9.15 Structure (5)

9.15.1 Structure: GATE CSE 2000 | Question: 1.11

The following C declarations:

```
struct node {
    int i:
    float j;
};
struct node *s[10];
```

define s to be:

A. An array, each element of which is a pointer to a structure of type node
B. A structure of 2 fields, each field being a pointer to an array of 10 elements
C. A structure of 3 fields: an integer, a float, and an array of 10 elements
D. An array, each element of which is a structure of type node

gatecse-2000 programming programming-in-c easy structure

Answer key

9.15.2 Structure: GATE CSE 2018 | Question: 2

Consider the following C program:

```
#include<stdio.h>
struct Ournode{
    char x, y, z;
};
int main() {
    struct Ournode p={'1', '0', 'a'+2};
    struct Ournode *q=&p;
    printf("%c, %c", *((char*)q+1), *((char*)q+2));
    return 0;
}
```

The output of this program is:

A. 0, c
B. 0, a+2
C. '0', 'a+2'
D. '0', 'c'

gatecse-2018 programming-in-c programming structure normal one-mark

Answer key

9.15.3 Structure: GATE CSE 2021 Set 2 | Question: 35

Consider the following ANSI C program:

```
#include <stdio.h>
#include <stdlib.h>
struct Node{
    int value;
    struct Node *next;};
int main( ) {
  struct Node *boxE, *head, *boxN; int index=0;
  boxE=head= (struct Node *) malloc(sizeof(struct Node));
  head → value = index;
  for (index =1; index<=3; index++){
    boxN = (struct Node *) malloc (sizeof(struct Node));
    boxE → next = boxN;
    boxN → value = index;
    boxE = boxN; }
for (index=0; index<=3; index++) {
  printf("Value at index %d is %d\n", index, head → value);
  head = head → next;
  printf("Value at index %d is %d\n", index+1, head → value); } }
```

Which one of the following statements below is correct about the program?

A. Upon execution, the program creates a linked-list of five nodes
B. Upon execution, the program goes into an infinite loop
C. It has a missing **return** which will be reported as an error by the compiler
D. It dereferences an uninitialized pointer that may result in a run-time error

gatecse-2021-set2 programming-in-c normal pointers structure two-marks

Answer key☟

9.15.4 Structure: GATE IT 2004 | Question: 61

Consider the following C program:

```
#include <stdio.h>
typedef struct {
  char *a;
  char *b;
  } t;
void f1 (t s);
void f2 (t *p);
main()
{
  static t s = {"A", "B"};
  printf ("%s %s\n", s.a, s.b);
  f1(s);
  printf ("%s %s\n", s.a, s.b);
  f2(&s);
}
void f1 (t s)
{
  s.a = "U";
  s.b = "V";
  printf ("%s %s\n", s.a, s.b);
  return;
}
void f2(t *p)
{
  p -> a  = "V";
  p -> b = "W";
  printf("%s %s\n", p -> a, p -> b);
  return;
}
```

What is the output generated by the program ?

A. $A\ B$
$U\ V$
$V\ W$
$V\ W$

B. $A\ B$
$U\ V$
$A\ B$
$V\ W$

C. $A\ B$

D. $A\ B$

$U\ V$
$U\ V$
$V\ W$

$U\ V$
$V\ W$
$U\ V$

gateit-2004 programming programming-in-c normal structure

Answer key

9.15.5 Structure: GATE IT 2006 | Question: 49

Which one of the choices given below would be printed when the following program is executed ?

```
#include <stdio.h>
struct test {
            int i;
            char *c;
}st[] = {5, "become", 4, "better", 6, "jungle", 8, "ancestor", 7, "brother"};
main ()
{
   struct test *p = st;
   p += 1;
   ++p -> c;
   printf("%s,", p++ -> c);
   printf("%c,", *++p -> c);
   printf("%d,", p[0].i);
   printf("%s \n", p -> c);
}
```

A. jungle, n, 8, nclastor
B. etter, u, 6, ungle
C. cetter, k, 6, jungle
D. etter, u, 8, ncestor

gateit-2006 programming programming-in-c normal structure

Answer key

9.16 Switch Case (2)

9.16.1 Switch Case: GATE CSE 2012 | Question: 3

What will be the output of the following C program segment?

```
char inChar = 'A';
  switch ( inChar ) {
    case 'A' : printf ("Choice A \ n");
    case 'B' :
    case 'C' : printf ("Choice B");
    case 'D' :
    case 'E' :
    default : printf ("No Choice");
  }
```

A. No Choice
B. Choice A
C. Choice A
Choice B No Choice
D. Program gives no output as it is erroneous

gatecse-2012 programming easy programming-in-c switch-case

Answer key

9.16.2 Switch Case: GATE CSE 2015 Set 3 | Question: 48

Consider the following C program:

```
#include<stdio.h>
int main()
{
   int i, j, k = 0;
   j=2 * 3 / 4 + 2.0 / 5 + 8 / 5;
   k-=--j;
   for (i=0; i<5; i++)
   {
      switch(i+k)
      {
         case 1:
         case 2: printf("\n%d", i+k);
         case 3: printf("\n%d", i+k);
         default: printf("\n%d", i+k);
      }
   }
```

```
    return 0;
}
```

The number of times printf statement is executed is _______.

gatecse-2015-set3 programming programming-in-c switch-case normal numerical-answers

Answer key

9.17 Type Checking (1)

9.17.1 Type Checking: GATE CSE 2003 | Question: 24

Which of the following statements is FALSE?

A. In statically typed languages, each variable in a program has a fixed type
B. In un-typed languages, values do not have any types
C. In dynamically typed languages, variables have no types
D. In all statically typed languages, each variable in a program is associated with values of only a single type during the execution of the program

gatecse-2003 programming normal type-checking

Answer key

9.18 Union (1)

9.18.1 Union: GATE CSE 2000 | Question: 1.17, ISRO2015-79

Consider the following C declaration:

```
    struct {
       short x[5];
       union {
           float y;
           long z;
       } u;
     )t;
```

Assume that the objects of the type short, float and long occupy 2 bytes, 4 bytes and 8 bytes, respectively. The memory requirement for variable t, ignoring alignment consideration, is:

A. 22 bytes B. 14 bytes C. 18 bytes D. 10 bytes

gatecse-2000 programming programming-in-c easy isro2015 union

Answer key

9.19 Variable Binding (1)

9.19.1 Variable Binding: GATE IT 2007 | Question: 34, UGCNET-Dec2012-III: 52

Consider the program below in a hypothetical programming language which allows global variables and a choice of static or dynamic scoping.

```
int i;
program main()
{
    i = 10;
    call f();
}

procedure f()
{
    int i = 20;
    call g ();
}
procedure g()
{
    print i;
}
```

Let x be the value printed under static scoping and y be the value printed under dynamic scoping. Then, x and y are:

A. $x = 10, y = 20$ B. $x = 20, y = 10$ C. $x = 10, y = 10$ D. $x = 20, y = 20$

gateit-2007 programming variable-binding easy ugcnetcse-dec2012-paper3

Answer key☟

Answer Keys

9.1.1	A	9.2.1	C	9.2.2	A	9.2.3	C	9.2.4	C
9.2.5	6	9.2.6	19	9.2.7	C	9.2.8	B	9.2.9	C
9.2.10	B	9.3.1	A	9.4.1	A	9.4.2	A	9.5.1	N/A
9.5.2	C	9.5.3	C	9.5.4	3	9.5.5	26	9.5.6	B
9.6.1	N/A	9.6.2	N/A	9.6.3	N/A	9.6.4	N/A	9.6.5	A
9.6.6	B	9.6.7	C	9.6.8	C	9.7.1	C	9.7.2	A
9.7.3	A	9.7.4	7	9.7.5	C	9.7.6	C	9.7.7	A;B;D
9.7.8	46:46	9.7.9	21:21	9.7.10	46:46	9.8.1	N/A	9.8.2	C
9.8.3	B	9.8.4	D	9.8.5	B	9.8.6	D	9.8.7	6561
9.8.8	2016	9.8.9	30	9.8.10	A	9.8.11	D	9.8.12	C
9.9.1	D	9.9.2	C	9.9.3	A	9.9.4	A	9.9.5	C
9.9.6	C	9.9.7	D	9.9.8	140	9.9.9	D	9.9.10	2
9.9.11	D	9.9.12	B	9.9.13	25:25	9.9.14	111:111	9.10.1	B
9.11.1	A	9.11.2	B	9.11.3	B	9.11.4	B	9.11.5	D
9.11.6	D	9.11.7	A	9.11.8	D	9.11.9	C	9.11.10	D
9.11.11	B	9.11.12	D	9.11.13	-5	9.11.14	230	9.11.15	D
9.11.16	D	9.11.17	3	9.11.18	23	9.11.19	A	9.11.20	0
9.11.21	B	9.11.22	B	9.11.23	5	9.11.24	10	9.11.25	B
9.11.26	B;D	9.11.27	A	9.11.28	D	9.11.29	B	9.11.30	A
9.11.31	C	9.12.1	C	9.12.2	D	9.13.1	41	9.13.2	16
9.13.3	N/A	9.13.4	N/A	9.13.5	N/A	9.13.6	C	9.13.7	B
9.13.8	D	9.13.9	1.72 : 1.74	9.13.10	D	9.13.11	A	9.13.12	3
9.13.13	A	9.13.14	C	9.13.15	4	9.13.16	55	9.13.17	5:5
9.13.18	D	9.14.1	D	9.15.1	A	9.15.2	A	9.15.3	D
9.15.4	B	9.15.5	B	9.16.1	X	9.16.2	10	9.17.1	C
9.18.1	C	9.19.1	A						

10 Theory of Computation (286)

Regular expressions and finite automata, Context-free grammars and push-down automata, Regular and context-free languages, Pumping lemma, Turing machines and undecidability.

Mark Distribution in Previous GATE

Year	2025 - 1	2025 - 2	2024 - 1	2024 - 2	2023	2022	2021 - 1	2021 - 2	Minimum	Average	Maximu
1 Mark Count	2	3	1	1	3	2	2	3	1	2.13	3
2 Marks Count	4	2	2	3	3	3	3	4	2	3	4
Total Marks	10	7	5	7	9	8	8	11	**5**	**8.13**	**11**

10.1 Closure Property (9)

10.1.1 Closure Property: GATE CSE 1989 | Question: 3-ii

Context-free languages and regular languages are both closed under the operation (s) of :

A. Union
B. Intersection
C. Concatenation
D. Complementation

gate1989 easy theory-of-computation closure-property multiple-selects

Answer key

10.1.2 Closure Property: GATE CSE 1992 | Question: 16

Which of the following three statements are true? Prove your answer.

i. The union of two recursive languages is recursive.
ii. The language $\{O^n \mid n \text{ is a prime}\}$ is not regular.
iii. Regular languages are closed under infinite union.

gate1992 theory-of-computation normal closure-property proof descriptive

Answer key

10.1.3 Closure Property: GATE CSE 2002 | Question: 2.14

Which of the following is true?

A. The complement of a recursive language is recursive
B. The complement of a recursively enumerable language is recursively enumerable
C. The complement of a recursive language is either recursive or recursively enumerable
D. The complement of a context-free language is context-free

gatecse-2002 theory-of-computation easy closure-property

Answer key

10.1.4 Closure Property: GATE CSE 2013 | Question: 17

Which of the following statements is/are **FALSE**?

1. For every non-deterministic Turing machine, there exists an equivalent deterministic Turing machine.
2. Turing recognizable languages are closed under union and complementation.
3. Turing decidable languages are closed under intersection and complementation.
4. Turing recognizable languages are closed under union and intersection.

A. 1 and 4 only
B. 1 and 3 only
C. 2 only
D. 3 only

gatecse-2013 theory-of-computation normal closure-property

Answer key

10.1.5 Closure Property: GATE CSE 2016 Set 2 | Question: 18

Consider the following types of languages: L_1: Regular, L_2: Context-free, L_3: Recursive, L_4: Recursively enumerable. Which of the following is/are **TRUE ?**

I. $\overline{L_3} \cup L_4$ is recursively enumerable.
II. $\overline{L_2} \cup L_3$ is recursive.
III. $L_1^* \cap L_2$ is context-free.
IV. $L_1 \cup \overline{L_2}$ is context-free.

A. I only.
B. I and III only.
C. I and IV only.
D. I, II and III only.

gatecse-2016-set2 theory-of-computation regular-language context-free-language closure-property normal

Answer key

10.1.6 Closure Property: GATE CSE 2017 Set 2 | Question: 04

Let L_1, L_2 be any two context-free languages and R be any regular language. Then which of the following is/are CORRECT?

I. $L_1 \cup L_2$ is context-free
II. $\overline{L_1}$ is context-free
III. $L_1 - R$ is context-free
IV. $L_1 \cap L_2$ is context-free

A. I, II and IV only
B. I and III only
C. II and IV only
D. I only

gatecse-2017-set2 theory-of-computation closure-property

Answer key

10.1.7 Closure Property: GATE CSE 2018 | Question: 7

The set of all recursively enumerable languages is:

A. closed under complementation
B. closed under intersection
C. a subset of the set of all recursive languages
D. an uncountable set

gatecse-2018 theory-of-computation closure-property easy one-mark

Answer key

10.1.8 Closure Property: GATE CSE 2025 | Set 2 | Question: 20

Consider the two lists List I and List II given below:

List I	**List II**
Context-free languages	Closed under union
Recursive languages	Not closed under complementation
Regular languages	Closed under intersection

For matching of items in List I with those in List II, which of the following option(s) is/are CORRECT?

A. (i) - (a), (ii) - (b), and (iii) - (c)
B. (i) - (b), (ii) - (a), and (iii) - (c)
C. (i) - (b), (ii) - (c), and (iii) - (a)
D. (i) - (a), (ii) - (c), and (iii) - (b)

gatecse2025-set2 theory-of-computation closure-property match-the-following multiple-selects easy one-mark

Answer key

10.1.9 Closure Property: GATE IT 2006 | Question: 32

Let L be a context-free language and M a regular language. Then the language $L \cap M$ is

A. always regular
B. never regular
C. always a deterministic context-free language
D. always a context-free language

gateit-2006 theory-of-computation closure-property easy

Answer key

10.2 Context Free Grammar (2)

10.2.1 Context Free Grammar: GATE CSE 2025 | Set 1 | Question: 9

Consider the following context-free grammar G, where S, A, and B are the variables (non-terminals), a and b are the terminal symbols, S is the start variable, and the rules of G are described as:

$$S \rightarrow aaB \mid Abb$$
$$A \rightarrow a \mid aA$$
$$B \rightarrow b \mid bB$$

Which ONE of the languages $L(G)$ is accepted by G ?

A. $L(G) = \{a^2b^n \mid n \geq 1\} \cup \{a^nb^2 \mid n \geq 1\}$
B. $L(G) = \{a^nb^{2n} \mid n \geq 1\} \cup \{a^{2n}b^n \mid n \geq 1\}$
C. $L(G) = \{a^nb^n \mid n \geq 1\}$
D. $L(G) = \{a^{2n}b^{2n} \mid n \geq 1\}$

gatecse2025-set1 theory-of-computation context-free-grammar easy one-mark

Answer key

10.2.2 Context Free Grammar: GATE CSE 2025 | Set 2 | Question: 15

Let G_1, G_2 be Context Free Grammars (CFGs) and R be a regular expression. For a grammar G, let $L(G)$ denote the language generated by G.

Which ONE among the following questions is decidable?

A. Is $L(G_1) = L(G_2)$?
B. Is $L(G_1) \cap L(G_2) = \emptyset$?
C. Is $L(G_1) = L(R)$?
D. Is $L(G_1) = \emptyset$?

gatecse2025-set2 theory-of-computation context-free-grammar decidability easy one-mark

Answer key

10.3 Context Free Language (33)

10.3.1 Context Free Language: GATE CSE 1987 | Question: 2k

State whether the following statements are TRUE or FALSE:

The intersection of two CFL's is also a CFL.

gate1987 theory-of-computation context-free-language true-false

Answer key

10.3.2 Context Free Language: GATE CSE 1992 | Question: 02,xix

Context-free languages are:

A. closed under union
B. closed under complementation
C. closed under intersection
D. closed under Kleene closure

gate1992 context-free-language theory-of-computation normal multiple-selects

Answer key

10.3.3 Context Free Language: GATE CSE 1995 | Question: 2.20

Which of the following definitions below generate the same language as L, where $L = \{x^n y^n \text{ such that } n \geq 1\}$?

I. $E \rightarrow xEy \mid xy$

II. $xy \mid (x^+ xyy^+)$

III. $x^+ y^+$

A. I only
B. I and II
C. II and III
D. II only

gate1995 theory-of-computation easy context-free-language

Answer key

10.3.4 Context Free Language: GATE CSE 1996 | Question: 2.8

If L_1 and L_2 are context free languages and R a regular set, one of the languages below is not necessarily a context free language. Which one?

A. $L_1 . L_2$
B. $L_1 \cap L_2$
C. $L_1 \cap R$
D. $L_1 \cup L_2$

gate1996 theory-of-computation context-free-language easy

Answer key

10.3.5 Context Free Language: GATE CSE 1996 | Question: 2.9

Define a context free languages $L \in \{0,1\}^*$, $\text{init}(L) = \{u \mid uv \in L$ for some v in $\{0,1\}^*\}$ (in other words, $\text{init}(L)$ is the set of prefixes of L)

Let $L = \{w \mid w \text{ is nonempty and has an equal number of 0's and 1's}\}$

Then $\text{init}(L)$ is:

A. the set of all binary strings with unequal number of 0's and 1's
B. the set of all binary strings including null string
C. the set of all binary strings with exactly one more 0 than the number of 1's or one more 1 than the number of 0's
D. None of the above

gate1996 theory-of-computation context-free-language normal

Answer key

10.3.6 Context Free Language: GATE CSE 1999 | Question: 1.5

Context-free languages are closed under:

A. Union, intersection
B. Union, Kleene closure
C. Intersection, complement
D. Complement, Kleene closure

gate1999 theory-of-computation context-free-language easy

Answer key

10.3.7 Context Free Language: GATE CSE 1999 | Question: 7

Show that the language

$$L = \{xcx \mid x \in \{0,1\}^* \text{ and } c \text{ is a terminal symbol}\}$$

is not context free. c is not 0 or 1.

gate1999 theory-of-computation context-free-language normal proof

Answer key

10.3.8 Context Free Language: GATE CSE 2000 | Question: 7

A. Construct as minimal finite state machine that accepts the language, over $\{0, 1\}$, of all strings that contain neither the substring 00 nor the substring 11.
B. Consider the grammar
   - $S \to aSAb$
   - $S \to \epsilon$
   - $A \to bA$
   - $A \to \epsilon$

   where S, A are non-terminal symbols with S being the start symbol; a, b are terminal symbols and ϵ is the empty string. This grammar generates strings of the form $a^i b^j$ for some $i, j \geq 0$, where i and j satisfy some condition. What is the condition on the values of i and j?

gatecse-2000 theory-of-computation descriptive regular-language context-free-language

Answer key☟

10.3.9 Context Free Language: GATE CSE 2001 | Question: 1.5

Which of the following statements is true?

A. If a language is context free it can always be accepted by a deterministic push-down automaton
B. The union of two context free languages is context free
C. The intersection of two context free languages is a context free
D. The complement of a context free language is a context free

gatecse-2001 theory-of-computation context-free-language easy

Answer key☟

10.3.10 Context Free Language: GATE CSE 2003 | Question: 51

Let $G = (\{S\}, \{a, b\}, R, S)$ be a context free grammar where the rule set R is $S \to aSb \mid SS \mid \epsilon$
Which of the following statements is true?

A. G is not ambiguous
B. There exist $x, y \in L(G)$ such that $xy \notin L(G)$
C. There is a deterministic pushdown automaton that accepts $L(G)$
D. We can find a deterministic finite state automaton that accepts $L(G)$

gatecse-2003 theory-of-computation context-free-language normal

Answer key☟

10.3.11 Context Free Language: GATE CSE 2005 | Question: 57

Consider the languages:

- $L_1 = \left\{ww^R \mid w \in \{0, 1\}^*\right\}$
- $L_2 = \left\{w\#w^R \mid w \in \{0, 1\}^*\right\}$, where $\#$ is a special symbol
- $L_3 = \{ww \mid w \in \{0, 1\}^*\}$

Which one of the following is TRUE?

A. L_1 is a deterministic CFL
B. L_2 is a deterministic CFL
C. L_3 is a CFL, but not a deterministic CFL
D. L_3 is a deterministic CFL

gatecse-2005 theory-of-computation context-free-language easy

Answer key☟

10.3.12 Context Free Language: GATE CSE 2006 | Question: 19

Let

$L_1 = \{0^{n+m}1^n0^m \mid n, m \geq 0\}$,

$L_2 = \{0^{n+m}1^{n+m}0^m \mid n, m \geq 0\}$ and

$L_3 = \{0^{n+m}1^{n+m}0^{n+m} \mid n, m \geq 0\}$.

Which of these languages are NOT context free?

A. L_1 only
B. L_3 only
C. L_1 and L_2
D. L_2 and L_3

gatecse-2006 theory-of-computation context-free-language normal

Answer key

10.3.13 Context Free Language: GATE CSE 2009 | Question: 12, ISRO2016-37

$$S \to aSa \mid bSb \mid a \mid b$$

The language generated by the above grammar over the alphabet $\{a, b\}$ is the set of:

A. all palindromes
B. all odd length palindromes
C. strings that begin and end with the same symbol
D. all even length palindromes

gatecse-2009 theory-of-computation context-free-language easy isro2016

Answer key

10.3.14 Context Free Language: GATE CSE 2015 Set 3 | Question: 32

Which of the following languages are context-free?

$L_1 : \{a^m b^n a^n b^m \mid m, n \geq 1\}$

$L_2 : \{a^m b^n a^m b^n \mid m, n \geq 1\}$

$L_3 : \{a^m b^n \mid m = 2n + 1\}$

A. L_1 and L_2 only
B. L_1 and L_3 only
C. L_2 and L_3 only
D. L_3 only

gatecse-2015-set3 theory-of-computation context-free-language normal

Answer key

10.3.15 Context Free Language: GATE CSE 2016 Set 1 | Question: 16

Which of the following languages is generated by the given grammar?

$$S \to aS \mid bS \mid \varepsilon$$

A. $\{a^n b^m \mid n, m \geq 0\}$
B. $\{w \in \{a, b\}^* \mid w \text{ has equal number of a's and b's}\}$
C. $\{a^n \mid n \geq 0\} \cup \{b^n \mid n \geq 0\} \cup \{a^n b^n \mid n \geq 0\}$
D. $\{a, b\}^*$

gatecse-2016-set1 theory-of-computation context-free-language normal

Answer key

10.3.16 Context Free Language: GATE CSE 2016 Set 1 | Question: 42

Consider the following context-free grammars;

$G_1 : S \to aS \mid B, B \to b \mid bB$

$G_2 : S \to aA \mid bB, A \to aA \mid B \mid \varepsilon, B \to bB \mid \varepsilon$

Which one of the following pairs of languages is generated by G_1 and G_2 ,respectively?

A. $\{a^m b^n \mid m > 0 \text{ or } n > 0\}$ and $\{a^m b^n \mid m > 0 \text{ and } n > 0\}$
B. $\{a^m b^n \mid m > 0 \text{ and } n > 0\}$ and $\{a^m b^n \mid m > 0 \text{ or } n \geq 0\}$
C. $\{a^m b^n \mid m \geq 0 \text{ or } n > 0\}$ and $\{a^m b^n \mid m > 0 \text{ and } n > 0\}$
D. $\{a^m b^n \mid m \geq 0 \text{ and } n > 0\}$ and $\{a^m b^n \mid m > 0 \text{ or } n > 0\}$

gatecse-2016-set1 theory-of-computation context-free-language normal

Answer key

10.3.17 Context Free Language: GATE CSE 2016 Set 2 | Question: 43

Consider the following languages:

- $L_1 = \{a^n b^m c^{n+m} : m, n \geq 1\}$
- $L_2 = \{a^n b^n c^{2n} : n \geq 1\}$

Which one of the following is TRUE?

A. Both L_1 and L_2 are context-free.
B. L_1 is context-free while L_2 is not context-free.
C. L_2 is context-free while L_1 is not context-free.
D. Neither L_1 nor L_2 is context-free.

gatecse-2016-set2 theory-of-computation context-free-language normal

Answer key

10.3.18 Context Free Language: GATE CSE 2017 Set 1 | Question: 10

Consider the following context-free grammar over the alphabet $\Sigma = \{a, b, c\}$ with S as the start symbol:

$$S \rightarrow abScT \mid abcT$$

$$T \rightarrow bT \mid b$$

Which one of the following represents the language generated by the above grammar?

A. $\{(ab)^n (cb)^n \mid n \geq 1\}$
B. $\{(ab)^n cb^{m_1} cb^{m_2} \dots cb^{m_n} \mid n, m_1, m_2, \dots, m_n \geq 1\}$
C. $\{(ab)^n (cb^m)^n \mid m, n \geq 1\}$
D. $\{(ab)^n (cb^n)^m \mid m, n \geq 1\}$

gatecse-2017-set1 theory-of-computation context-free-language normal

Answer key

10.3.19 Context Free Language: GATE CSE 2017 Set 1 | Question: 34

If G is a grammar with productions

$S \rightarrow SaS \mid aSb \mid bSa \mid SS \mid \epsilon$

where S is the start variable, then which one of the following strings is not generated by G?

A. $abab$ B. $aaab$ C. $abbaa$ D. $babba$

gatecse-2017-set1 theory-of-computation context-free-language normal

Answer key

10.3.20 Context Free Language: GATE CSE 2017 Set 1 | Question: 38

Consider the following languages over the alphabet $\Sigma = \{a, b, c\}$. Let $L_1 = \{a^n b^n c^m \mid m, n \geq 0\}$ and $L_2 = \{a^m b^n c^n \mid m, n \geq 0\}$.

Which of the following are context-free languages?

I. $L_1 \cup L_2$
II. $L_1 \cap L_2$

A. I only
B. II only
C. I and II
D. Neither I nor II

gatecse-2017-set1 theory-of-computation context-free-language normal

Answer key

10.3.21 Context Free Language: GATE CSE 2017 Set 2 | Question: 16

Identify the language generated by the following grammar, where S is the start variable.

- $S \rightarrow XY$
- $X \rightarrow aX \mid a$
- $Y \rightarrow aYb \mid \epsilon$

A. $\{a^m b^n \mid m \geq n, n > 0\}$
B. $\{a^m b^n \mid m \geq n, n \geq 0\}$
C. $\{a^m b^n \mid m > n, n \geq 0\}$
D. $\{a^m b^n \mid m > n, n > 0\}$

gatecse-2017-set2 theory-of-computation context-free-language

Answer key

10.3.22 Context Free Language: GATE CSE 2019 | Question: 31

Which one of the following languages over $\Sigma = \{a, b\}$ is NOT context-free?

A. $\{ww^R \mid w \in \{a, b\}^*\}$
B. $\{wa^n b^n w^R \mid w \in \{a, b\}^*, n \geq 0\}$
C. $\{wa^n w^R b^n \mid w \in \{a, b\}^*, n \geq 0\}$
D. $\{a^n b^i \mid i \in \{n, 3n, 5n\}, n \geq 0\}$

gatecse-2019 theory-of-computation context-free-language two-marks

Answer key

10.3.23 Context Free Language: GATE CSE 2021 Set 1 | Question: 1

Suppose that L_1 is a regular language and L_2 is a context-free language. Which one of the following languages is NOT necessarily context-free?

A. $L_1 \cap L_2$
B. $L_1 \cdot L_2$
C. $L_1 - L_2$
D. $L_1 \cup L_2$

gatecse-2021-set1 context-free-language theory-of-computation one-mark

Answer key

10.3.24 Context Free Language: GATE CSE 2021 Set 2 | Question: 41

For a string w, we define w^R to be the reverse of w. For example, if $w = 01101$ then $w^R = 10110$.

Which of the following languages is/are context-free?

A. $\{wxw^R x^R \mid w, x \in \{0, 1\}^*\}$
B. $\{ww^R xx^R \mid w, x \in \{0, 1\}^*\}$
C. $\{wxw^R \mid w, x \in \{0, 1\}^*\}$
D. $\{wxx^R w^R \mid w, x \in \{0, 1\}^*\}$

gatecse-2021-set2 multiple-selects theory-of-computation context-free-language two-marks

Answer key

10.3.25 Context Free Language: GATE CSE 2022 | Question: 38

Consider the following languages:

- $L_1 = \{ww \mid w \in \{a, b\}^*\}$
- $L_2 = \{a^n b^n c^m \mid m, n \geq 0\}$

- $L_3 = \{a^m b^n c^n | m, n \geq 0\}$

Which of the following statements is/are FALSE?

A. L_1 is not context-free but L_2 and L_3 are deterministic context-free.
B. Neither L_1 nor L_2 is context-free.
C. L_2, L_3 and $L_2 \cap L_3$ all are context-free.
D. Neither L_1 nor its complement is context-free.

gatecse-2022 theory-of-computation context-free-language multiple-selects two-marks

Answer key

10.3.26 Context Free Language: GATE CSE 2023 | Question: 29

Consider the context-free grammar G below

$$S \rightarrow aSb \mid X$$
$$X \rightarrow aX \mid Xb \mid a \mid b,$$

where S and X are non-terminals, and a and b are terminal symbols. The starting non-terminal is S.

Which one of the following statements is CORRECT?

A. The language generated by G is $(a+b)^*$
B. The language generated by G is $a^*(a+b)b^*$
C. The language generated by G is $a^*b^*(a+b)$
D. The language generated by G is not a regular language

gatecse-2023 theory-of-computation context-free-language two-marks

Answer key

10.3.27 Context Free Language: GATE CSE 2025 | Set 1 | Question: 35

Consider the following two languages over the alphabet $\{a, b, c\}$, where m and n are natural numbers.

$$L_1 = \left\{a^m b^m c^{m+n} \mid m, n \geq 1\right\}$$
$$L_2 = \left\{a^m b^n c^{m+n} \mid m, n \geq 1\right\}$$

Which ONE of the following statements is CORRECT?

A. Both L_1 and L_2 are context-free languages.
B. L_1 is a context-free language but L_2 is not a context-free language.
C. L_1 is not a context-free language but L_2 is a context-free language.
D. Neither L_1 nor L_2 are context-free languages.

gatecse2025-set1 theory-of-computation context-free-language two-marks

Answer key

10.3.28 Context Free Language: GATE IT 2006 | Question: 34

In the context-free grammar below, S is the start symbol, a and b are terminals, and ϵ denotes the empty string.

- $S \rightarrow aSAb \mid \epsilon$
- $A \rightarrow bA \mid \epsilon$

The grammar generates the language

A. $((a+b)^*b)$
B. $\{a^m b^n \mid m \leq n\}$
C. $\{a^m b^n \mid m = n)$
D. a^*b^*

gateit-2006 theory-of-computation context-free-language normal

Answer key

10.3.29 Context Free Language: GATE IT 2006 | Question: 4

In the context-free grammar below, S is the start symbol, a and b are terminals, and ϵ denotes the empty string.

$S \to aSa \mid bSb \mid a \mid b \mid \epsilon$

Which of the following strings is NOT generated by the grammar?

A. $aaaa$
B. $baba$
C. $abba$
D. $babaaabab$

gateit-2006 theory-of-computation context-free-language easy

Answer key

10.3.30 Context Free Language: GATE IT 2007 | Question: 46

The two grammars given below generate a language over the alphabet $\{x, y, z\}$

- $G1 : S \to x \mid z \mid x\,S \mid z\,S \mid y\,B$
  $B \to y \mid z \mid y\,B \mid z\,B$
- $G2 : S \to y \mid z \mid y\,S \mid z\,S \mid x\,B$
  $B \to y \mid y\,S$

Which one of the following choices describes the properties satisfied by the strings in these languages?

A. $G1$: No y appears before any x
   $G2$: Every x is followed by at least one y
B. $G1$: No y appears before any x
   $G2$: No x appears before any y
C. $G1$: No y appears after any x
   $G2$: Every x is followed by at least one y
D. $G1$: No y appears after any x
   $G2$: Every y is followed by at least one x

gateit-2007 theory-of-computation normal context-free-language

Answer key

10.3.31 Context Free Language: GATE IT 2007 | Question: 48

Consider the grammar given below:

$S \to x\,B \mid y\,A$
$A \to x \mid x\,S \mid y\,A\,A$
$B \to y \mid y\,S \mid x\,B\,B$

Consider the following strings.

i. $xxyyx$
ii. $xxyyxy$
iii. $xyxy$
iv. $yxxy$
v. yxx
vi. xyx

Which of the above strings are generated by the grammar ?

A. i, ii and iii
B. ii, v and vi
C. ii, iii and iv
D. i, iii and iv

gateit-2007 theory-of-computation context-free-language normal

Answer key

10.3.32 Context Free Language: GATE IT 2007 | Question: 49

Consider the following grammars. Names representing terminals have been specified in capital letters.

\begin{array}{|llll|}\hline \text{$G1$:} & \text{stmnt} & \text{$\rightarrow$} & \text{WHILE (expr) stmnt} \\%\hline \text{} & \text{stmnt}

Which one of the following statements is true?

A. G_1 is context-free but not regular and G_2 is regular
B. G_2 is context-free but not regular and G_1 is regular
C. Both G_1 and G_2 are regular
D. Both G_1 and G_2 are context-free but neither of them is regular

gateit-2007 theory-of-computation context-free-language normal

Answer key

10.3.33 Context Free Language: GATE IT 2008 | Question: 34

Consider a CFG with the following productions.

$S \rightarrow AA \mid B$
$A \rightarrow 0A \mid A0 \mid 1$
$B \rightarrow 0B00 \mid 1$

S is the start symbol, A and B are non-terminals and 0 and 1 are the terminals. The language generated by this grammar is:

A. $\{0^n 10^{2n} \mid n \geq 1\}$
B. $\{0^i 10^j 10^k \mid i, j, k \geq 0\} \cup \{0^n 10^{2n} \mid n \geq 0\}$
C. $\{0^i 10^j \mid i, j \geq 0\} \cup \{0^n 10^{2n} \mid n \geq 0\}$
D. The set of all strings over $\{0, 1\}$ containing at least two 0's

gateit-2008 theory-of-computation context-free-language normal

Answer key

10.4 Countable Uncountable Set (3)

10.4.1 Countable Uncountable Set: GATE CSE 1997 | Question: 3.4

Given $\Sigma = \{a, b\}$, which one of the following sets is not countable?

A. Set of all strings over Σ
B. Set of all languages over Σ
C. Set of all regular languages over Σ
D. Set of all languages over Σ accepted by Turing machines

gate1997 theory-of-computation normal countable-uncountable-set

Answer key

10.4.2 Countable Uncountable Set: GATE CSE 2014 Set 3 | Question: 16

Let Σ be a finite non-empty alphabet and let 2^{Σ^*} be the power set of Σ^*. Which one of the following is **TRUE**?

A. Both 2^{Σ^*} and Σ^* are countable
B. 2^{Σ^*} is countable and Σ^* is uncountable
C. 2^{Σ^*} is uncountable and Σ^* is countable
D. Both 2^{Σ^*} and Σ^* are uncountable

gatecse-2014-set3 theory-of-computation normal countable-uncountable-set

Answer key☟

10.4.3 Countable Uncountable Set: GATE CSE 2019 | Question: 34

Consider the following sets:

S1: Set of all recursively enumerable languages over the alphabet $\{0, 1\}$

S2: Set of all syntactically valid C programs

S3: Set of all languages over the alphabet $\{0, 1\}$

S4: Set of all non-regular languages over the alphabet $\{0, 1\}$

Which of the above sets are uncountable?

A. S1 and S2 B. S3 and S4 C. S2 and S3 D. S1 and S4

gatecse-2019 theory-of-computation countable-uncountable-set two-marks

Answer key☟

10.5 Decidability (29)

10.5.1 Decidability: GATE CSE 1987 | Question: 2l

State whether the following statement are TRUE or FALSE.

A is recursive if both A and its complement are accepted by Turing machines.

gate1987 theory-of-computation turing-machine decidability true-false

Answer key☟

10.5.2 Decidability: GATE CSE 1987 | Question: 2m

State whether the following statements are TRUE or FALSE:

The problem as to whether a Turing machine M accepts input w is undecidable.

gate1987 theory-of-computation turing-machine decidability true-false

Answer key☟

10.5.3 Decidability: GATE CSE 1988 | Question: 2viii

State the halting problem of the Turing machine.

gate1988 theory-of-computation descriptive decidability turing-machine

Answer key☟

10.5.4 Decidability: GATE CSE 1989 | Question: 3-iii

Which of the following problems are undecidable?

A. Membership problem in context-free languages.
B. Whether a given context-free language is regular.
C. Whether a finite state automation halts on all inputs.
D. Membership problem for type 0 languages.

gate1989 normal theory-of-computation decidability multiple-selects

Answer key☟

10.5.5 Decidability: GATE CSE 1990 | Question: 3-vii

It is undecidable whether:

A. An arbitrary Turing machine halts after 100 steps.

B. A Turing machine prints a specific letter.
C. A Turing machine computes the products of two numbers
D. None of the above.

gate1990 normal theory-of-computation decidability multiple-selects

Answer key

10.5.6 Decidability: GATE CSE 1995 | Question: 11

Let L be a language over Σ i.e., $L \subseteq \Sigma^*$. Suppose L satisfies the two conditions given below.

i. L is in NP and
ii. For every n, there is exactly one string of length n that belongs to L.

Let L^c be the complement of L over Σ^*. Show that L^c is also in NP.

gate1995 theory-of-computation normal decidability proof descriptive

Answer key

10.5.7 Decidability: GATE CSE 1996 | Question: 1.9

Which of the following statements is false?

A. The Halting Problem of Turing machines is undecidable
B. Determining whether a context-free grammar is ambiguous is undecidable
C. Given two arbitrary context-free grammars G_1 and G_2 it is undecidable whether $L(G_1) = L(G_2)$
D. Given two regular grammars G_1 and G_2 it is undecidable whether $L(G_1) = L(G_2)$

gate1996 theory-of-computation decidability easy

Answer key

10.5.8 Decidability: GATE CSE 1997 | Question: 6.5

Which one of the following is not decidable?

A. Given a Turing machine M, a string s and an integer k, M accepts s within k steps
B. Equivalence of two given Turing machines
C. Language accepted by a given finite state machine is not empty
D. Language generated by a context free grammar is non-empty

gate1997 theory-of-computation decidability easy

Answer key

10.5.9 Decidability: GATE CSE 1999 | Question: 10

Suppose we have a function HALTS which when applied to any arbitrary function f and its arguments will say TRUE if function f terminates for those arguments and FALSE otherwise. Example: Given the following function definition.

FACTORIAL (N) = IF (N=0) THEN 1 ELSE N*FACTORIAL (N-1)

Then HALTS (FACTORIAL, 4) = TRUE and HALTS (FACTORIAL, -5) = FALSE

Let us define the function FUNNY (f) = IF HALTS (f) THEN not (f) ELSE TRUE

a. Show that FUNNY terminates for all functions f.
b. use (a) to prove (by contradiction) that it is not possible to have a function like HALTS which for arbitrary functions and inputs says whether it will terminate on that input or not.

gate1999 theory-of-computation descriptive decidability

Answer key

10.5.10 Decidability: GATE CSE 2000 | Question: 2.9

Consider the following decision problems:

$(P1)$: Does a given finite state machine accept a given string?

$(P2)$: Does a given context free grammar generate an infinite number of strings?

Which of the following statements is true?

A. Both $(P1)$ and $(P2)$ are decidable
B. Neither $(P1)$ nor $(P2)$ is decidable
C. Only $(P1)$ is decidable
D. Only $(P2)$ is decidable

gatecse-2000 theory-of-computation decidability normal

Answer key

10.5.11 Decidability: GATE CSE 2001 | Question: 2.7

Consider the following problem X.

Given a Turing machine M over the input alphabet Σ, any state q of M and a word $w \in \Sigma^*$, does the computation of M on w visit the state of q?

Which of the following statements about X is correct?

A. X is decidable
B. X is undecidable but partially decidable
C. X is undecidable and not even partially decidable
D. X is not a decision problem

gatecse-2001 theory-of-computation decidability normal

Answer key

10.5.12 Decidability: GATE CSE 2001 | Question: 7

Let a decision problem X be defined as follows:

X: Given a Turing machine M over Σ and any word $w \in \Sigma$, does M loop forever on w?

You may assume that the halting problem of Turing machine is undecidable but partially decidable.

A. Show that X is undecidable
B. Show that X is not even partially decidable

gatecse-2001 theory-of-computation decidability turing-machine easy descriptive

Answer key

10.5.13 Decidability: GATE CSE 2002 | Question: 14

The aim of the following question is to prove that the language $\{M \mid M \text{ is the code of the Turing Machine which, irrespective of the input, halts and outputs a } 1\}$, is undecidable. This is to be done by reducing from the language $\{M', x \mid M' \text{ halts on } x\}$, which is known to be undecidable. In parts (a) and (b) describe the 2 main steps in the construction of M. In part (c) describe the key property which relates the behaviour of M on its input w to the behaviour of M' on x.

A. On input w, what is the first step that M must make?
B. On input w, based on the outcome of the first step, what is the second step M must make?
C. What key property relates the behaviour of M on w to the behaviour of M' on x?

gatecse-2002 theory-of-computation decidability normal turing-machine descriptive difficult

Answer key

10.5.14 Decidability: GATE CSE 2003 | Question: 52

Consider two languages L_1 and L_2 each on the alphabet Σ. Let $f : \Sigma^* \rightarrow \Sigma^*$ be a polynomial time computable bijection such that $(\forall x)[x \in L_1$ iff $f(x) \in L_2]$. Further, let f^{-1} be also polynomial time computable.

Which of the following **CANNOT** be true?

A. $L_1 \in P$ and L_2 is finite
B. $L_1 \in NP$ and $L_2 \in P$
C. L_1 is undecidable and L_2 is decidable
D. L_1 is recursively enumerable and L_2 is recursive

gatecse-2003 theory-of-computation normal decidability

Answer key

10.5.15 Decidability: GATE CSE 2003 | Question: 53

A single tape Turing Machine M has two states $q0$ and $q1$, of which $q0$ is the starting state. The tape alphabet of M is $\{0, 1, B\}$ and its input alphabet is $\{0, 1\}$. The symbol B is the blank symbol used to indicate end of an input string. The transition function of M is described in the following table.

	0	1	B
$q0$	$q1, 1, R$	$q1, 1, R$	$Halt$
$q1$	$q1, 1, R$	$q0, 1, L$	$q0, B, L$

The table is interpreted as illustrated below.

The entry $(q1, 1, R)$ in row $q0$ and column 1 signifies that if M is in state $q0$ and reads 1 on the current page square, then it writes 1 on the same tape square, moves its tape head one position to the right and transitions to state $q1$.

Which of the following statements is true about M?

A. M does not halt on any string in $(0+1)^+$
B. M does not halt on any string in $(00+1)^*$
C. M halts on all strings ending in a 0
D. M halts on all strings ending in a 1

gatecse-2003 theory-of-computation decidability normal

Answer key

10.5.16 Decidability: GATE CSE 2007 | Question: 6

Which of the following problems is undecidable?

A. Membership problem for CFGs
B. Ambiguity problem for CFGs
C. Finiteness problem for FSAs
D. Equivalence problem for FSAs

gatecse-2007 theory-of-computation decidability normal

Answer key

10.5.17 Decidability: GATE CSE 2008 | Question: 10

Which of the following are decidable?

I. Whether the intersection of two regular languages is infinite
II. Whether a given context-free language is regular
III. Whether two push-down automata accept the same language
IV. Whether a given grammar is context-free

A. I and II
B. I and IV
C. II and III
D. II and IV

gatecse-2008 theory-of-computation decidability easy

Answer key

10.5.18 Decidability: GATE CSE 2012 | Question: 24

Which of the following problems are decidable?

1. Does a given program ever produce an output?
2. If L is a context-free language, then, is $\bar{L}$ also context-free?
3. If L is a regular language, then, is $\bar{L}$ also regular?
4. If L is a recursive language, then, is $\bar{L}$ also recursive?

A. $1,2,3,4$ B. $1,2$ C. $2,3,4$ D. $3,4$

gatecse-2012 theory-of-computation decidability normal

Answer key

10.5.19 Decidability: GATE CSE 2013 | Question: 41

Which of the following is/are undecidable?

1. G is a CFG. Is $L(G) = \phi$?
2. G is a CFG. Is $L(G) = \Sigma^*$?
3. M is a Turing machine. Is $L(M)$ regular?
4. A is a DFA and N is an NFA. Is $L(A) = L(N)$?

A. 3 only
B. 3 and 4 only
C. $1,2$ and 3 only
D. 2 and 3 only

gatecse-2013 theory-of-computation decidability normal

Answer key

10.5.20 Decidability: GATE CSE 2014 Set 3 | Question: 35

Which one of the following problems is undecidable?

A. Deciding if a given context-free grammar is ambiguous.
B. Deciding if a given string is generated by a given context-free grammar.
C. Deciding if the language generated by a given context-free grammar is empty.
D. Deciding if the language generated by a given context-free grammar is finite.

gatecse-2014-set3 theory-of-computation context-free-language decidability normal

Answer key

10.5.21 Decidability: GATE CSE 2015 Set 2 | Question: 21

Consider the following statements.

I. The complement of every Turing decidable language is Turing decidable
II. There exists some language which is in NP but is not Turing decidable
III. If L is a language in NP, L is Turing decidable

Which of the above statements is/are true?

A. Only II B. Only III C. Only I and II D. Only I and III

gatecse-2015-set2 theory-of-computation decidability easy

Answer key

10.5.22 Decidability: GATE CSE 2015 Set 3 | Question: 53

Language L_1 is polynomial time reducible to language L_2. Language L_3 is polynomial time reducible to language L_2, which in turn polynomial time reducible to language L_4. Which of the following is/are true?

I. $\text{if } L_4 \in P, \text{ then } L_2 \in P$
II. $\text{if } L_1 \in P \text{ or } L_3 \in P, \text{ then } L_2 \in P$
III. $L_1 \in P, \text{ if and only if } L_3 \in P$
IV. $\text{if } L_4 \in P, \text{ then } L_3 \in P$

A. II only B. III only C. I and IV only D. I only gatecse-2015-set3 theory-of-computation decidability normal

Answer key☟

10.5.23 Decidability: GATE CSE 2016 Set 1 | Question: 17

Which of the following decision problems are undecidable?

I. Given NFAs N_1 and N_2 , is $L(N_1) \cap L(N_2) = \Phi$
II. Given a CFG $G = (N, \Sigma, P, S)$ and a string $x \in \Sigma^*$, does $x \in L(G)$} ?
III. Given CFGs G_1 and G_2, is $L(G_1) = L(G_2)$?
IV. Given a TM M, is $L(M) = \Phi$?

A. I and IV only
B. II and III only
C. III and IV only
D. II and IV only

gatecse-2016-set1 theory-of-computation decidability easy

Answer key☟

10.5.24 Decidability: GATE CSE 2017 Set 1 | Question: 39

Let A and B be finite alphabets and let $\#$ be a symbol outside both A and B. Let f be a total function from A^* to B^*. We say f is *computable* if there exists a Turing machine M which given an input $x \in A^*$, always halts with $f(x)$ on its tape. Let L_f denote the language $\left\{x\#f(x) \mid x \in A^*\right\}$. Which of the following statements is true:

A. f is computable if and only if L_f is recursive.
B. f is computable if and only if L_f is recursively enumerable.
C. If f is computable then L_f is recursive, but not conversely.
D. If f is computable then L_f is recursively enumerable, but not conversely.

gatecse-2017-set1 theory-of-computation decidability difficult

Answer key☟

10.5.25 Decidability: GATE CSE 2017 Set 2 | Question: 41

Let $L(R)$ be the language represented by regular expression R. Let $L(G)$ be the language generated by a context free grammar G. Let $L(M)$ be the language accepted by a Turing machine M. Which of the following decision problems are undecidable?

I. Given a regular expression R and a string w, is $w \in L(R)$?
II. Given a context-free grammar G, is $L(G) = \emptyset$
III. Given a context-free grammar G, is $L(G) = \Sigma^*$ for some alphabet Σ?
IV. Given a Turing machine M and a string w, is $w \in L(M)$?

A. I and IV only
B. II and III only
C. II, III and IV only
D. III and IV only

gatecse-2017-set2 theory-of-computation decidability

Answer key☟

10.5.26 Decidability: GATE CSE 2018 | Question: 36

Consider the following problems. $L(G)$ denotes the language generated by a grammar G. L(M) denotes the language accepted by a machine M.

I. For an unrestricted grammar G and a string w, whether $w \in L(G)$
II. Given a Turing machine M, whether $L(M)$ is regular
III. Given two grammarG_1 and G_2, whether $L(G_1) = L(G_2)$
IV. Given an NFA N, whether there is a deterministic PDA P such that N and P accept the same language

Which one of the following statement is correct?

A. Only I and II are undecidable
B. Only II is undecidable

C. Only II and IV are undecidable

D. Only I, II and III are undecidable

gatecse-2018 theory-of-computation decidability easy two-marks

Answer key

10.5.27 Decidability: GATE CSE 2020 | Question: 26

Which of the following languages are undecidable? Note that $\langle M \rangle$ indicates encoding of the Turing machine M.

- $L_1 = \{\langle M \rangle \mid L(M) = \varnothing\}$
- $L_2 = \{\langle M, w, q \rangle \mid M \text{ on input } w \text{ reaches state } q \text{ in exactly } 100 \text{ steps}\}$
- $L_3 = \{\langle M \rangle \mid L(M) \text{ is not recursive}\}$
- $L_4 = \{\langle M \rangle \mid L(M) \text{contains at least } 21 \text{ members}\}$

A. L_1, L_3, and L_4 only

B. L_1 and L_3 only

C. L_2 and L_3 only

D. L_2, L_3, and L_4 only

gatecse-2020 theory-of-computation decidability two-marks

Answer key

10.5.28 Decidability: GATE CSE 2021 Set 2 | Question: 36

Consider the following two statements about regular languages:

- S_1: Every infinite regular language contains an undecidable language as a subset.
- S_2: Every finite language is regular.

Which one of the following choices is correct?

A. Only S_1 is true

B. Only S_2 is true

C. Both S_1 and S_2 are true

D. Neither S_1 nor S_2 is true

gatecse-2021-set2 theory-of-computation regular-language decidability two-marks

Answer key

10.5.29 Decidability: GATE CSE 2022 | Question: 36

Which of the following is/are undecidable?

A. Given two Turing machines M_1 and M_2, decide if $L(M_1) = L(M_2)$.

B. Given a Turing machine M, decide if $L(M)$ is regular.

C. Given a Turing machine M, decide if M accepts all strings.

D. Given a Turing machine M, decide if M takes more than 1073 steps on every string.

gatecse-2022 theory-of-computation turing-machine decidability multiple-selects two-marks

Answer key

10.6 Dpda (1)

10.6.1 Dpda: GATE CSE 2025 | Set 2 | Question: 14

Which ONE of the following languages is accepted by a deteministic pushdown automaton?

A. Any regular language

B. Any context-free language

C. Any language accepted by a non-deterministic pushdown automaton

D. Any decidable language

gatecse2025-set2 theory-of-computation dpda one-mark

Answer key

10.7 Finite Automata (42)

10.7.1 Finite Automata: GATE CSE 1988 | Question: 15

Consider the DFA M and NFA M_2 as defined below. Let the language accepted by machine M be L. What language machine M_2 accepts, if

i. $F2 = A$?
ii. $F2 = B$?
iii. $F2 = C$?
iv. $F2 = D$?

- $M = (Q, \Sigma, \delta, q_0, F)$
- $M_2 = (Q2, \Sigma, \delta_2, q_{00}, F2)$

Where,

$Q2 = (Q \times Q \times Q) \cup \{q_{00}\}$

$\delta_2(q_{00}, \epsilon) = \{\langle q_0, q, q\rangle \mid q \in Q\}$

$\delta_2(\langle p, q, r\rangle, \sigma) = \langle \delta(p, \sigma), \delta(q, \sigma), r\rangle$

for all $p, q, r \in Q$ and $\sigma \in \Sigma$

$A = \{\langle p, q, r\rangle \mid p \in F; q, r \in Q\}$

$B = \{\langle p, q, r\rangle \mid q \in F; p, r \in Q\}$

$C = \{\langle p, q, r\rangle \mid p, q, r \in Q; \exists s \in \Sigma^*, \delta(p, s) \in F\}$

$D = \{\langle p, q, r\rangle \mid p, q \in Q; r \in F\}$

gatе1988 descriptive theory-of-computation finite-automata difficult

Answer key☟

10.7.2 Finite Automata: GATE CSE 1991 | Question: 17,b

Let L be the language of all binary strings in which the third symbol from the right is a 1. Give a non-deterministic finite automaton that recognizes L. How many states does the minimized equivalent deterministic finite automaton have? Justify your answer briefly?

gate1991 theory-of-computation finite-automata normal descriptive

Answer key☟

10.7.3 Finite Automata: GATE CSE 1993 | Question: 27

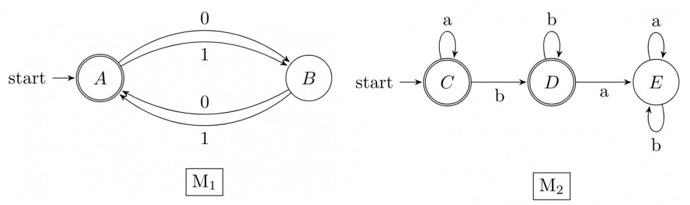
Draw the state transition of a deterministic finite state automaton which accepts all strings from the alphabet $\{a, b\}$, such that no string has 3 consecutive occurrences of the letter b.

gate1993 theory-of-computation finite-automata easy descriptive

Answer key☟

10.7.4 Finite Automata: GATE CSE 1996 | Question: 12

Given below are the transition diagrams for two finite state machines M_1 and M_2 recognizing languages L_1 and L_2 respectively.



A. Display the transition diagram for a machine that recognizes $L_1 . L_2$, obtained from transition diagrams for M_1 and M_2 by adding only ε transitions and no new states.
B. Modify the transition diagram obtained in part (a) obtain a transition diagram for a machine that recognizes

$(L_1 . L_2)^*$ by adding only ε transitions and no new states.
(Final states are enclosed in double circles).

gate1996 theory-of-computation finite-automata normal descriptive

Answer key

10.7.5 Finite Automata: GATE CSE 1997 | Question: 21

Given that L is a language accepted by a finite state machine, show that L^P and L^R are also accepted by some finite state machines, where

$$L^P = \{s \mid ss' \in L \text{ some string } s'\}$$

$$L^R = \{s \mid s \text{ obtained by reversing some string in } L\}$$

gate1997 theory-of-computation finite-automata proof

Answer key

10.7.6 Finite Automata: GATE CSE 1998 | Question: 1.10

Which of the following set can be recognized by a Deterministic Finite state Automaton?

A. The numbers $1, 2, 4, 8, \dots 2^n, \dots$ written in binary
B. The numbers $1, 2, 4, 8, \dots 2^n, \dots$ written in unary
C. The set of binary string in which the number of zeros is the same as the number of ones.
D. The set $\{1, 101, 11011, 1110111, \dots\}$

gate1998 theory-of-computation finite-automata normal

Answer key

10.7.7 Finite Automata: GATE CSE 2001 | Question: 5

Construct DFA's for the following languages:

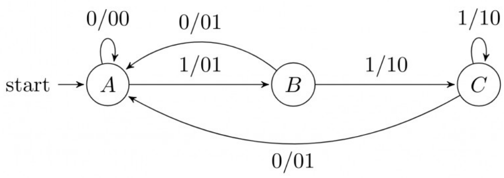
A. $L = \{w \mid w \in \{a, b\}^*, \text{ w has baab as a substring }\}$
B. $L = \{w \mid w \in \{a, b\}^*, \text{ w has an odd number of a's and an odd number of b's }\}$

gatecse-2001 theory-of-computation easy descriptive finite-automata normal

Answer key

10.7.8 Finite Automata: GATE CSE 2002 | Question: 2.5

The finite state machine described by the following state diagram with A as starting state, where an arc label is x/y, and x stands for 1-bit input and y stands for 2-bit output



A. outputs the sum of the present and the previous bits of the input
B. outputs 01 whenever the input sequence contains 11
C. outputs 00 whenever the input sequence contains 10
D. none of the above

gatecse-2002 theory-of-computation normal finite-automata

Answer key☟

10.7.9 Finite Automata: GATE CSE 2002 | Question: 21

We require a four state automaton to recognize the regular expression $(a \mid b)^*abb$

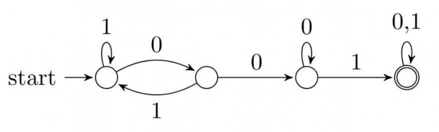
A. Give an NFA for this purpose
B. Give a DFA for this purpose

gatecse-2002 theory-of-computation finite-automata normal descriptive

Answer key☟

10.7.10 Finite Automata: GATE CSE 2003 | Question: 50

Consider the following deterministic finite state automaton M.



Let S denote the set of seven bit binary strings in which the first, the fourth, and the last bits are 1. The number of strings in S that are accepted by M is

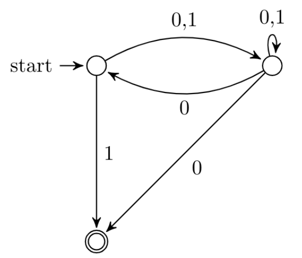
A. 1 B. 5 C. 7 D. 8

gatecse-2003 theory-of-computation finite-automata normal

Answer key☟

10.7.11 Finite Automata: GATE CSE 2003 | Question: 55

Consider the NFA M shown below.



Let the language accepted by M be L. Let L_1 be the language accepted by the NFA M_1 obtained by changing the accepting state of M to a non-accepting state and by changing the non-accepting states of M to accepting states. Which of the following statements is true?

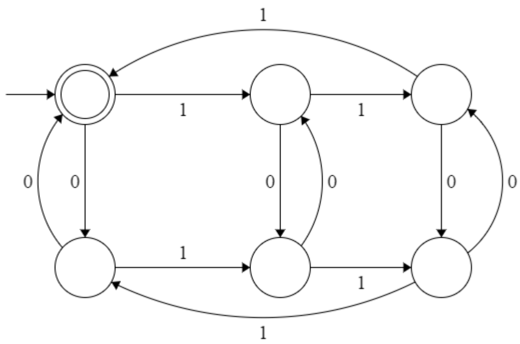
A. $L_1 = \{0,1\}^* - L$ B. $L_1 = \{0,1\}^*$ C. $L_1 \subseteq L$ D. $L_1 = L$

gatecse-2003 theory-of-computation finite-automata normal

Answer key☟

10.7.12 Finite Automata: GATE CSE 2004 | Question: 86

The following finite state machine accepts all those binary strings in which the number of 1's and 0's are respectively:



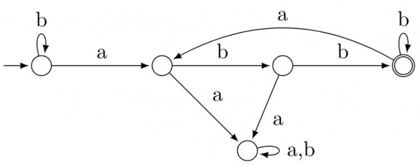
A. divisible by 3 and 2 B. odd and even C. even and odd D. divisible by 2 and 3

gatecse-2004 theory-of-computation finite-automata easy

Answer key

10.7.13 Finite Automata: GATE CSE 2005 | Question: 53

Consider the machine M:



The language recognized by M is:

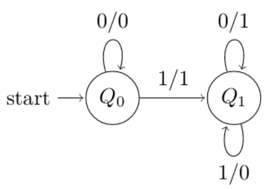
A. $\{w \in \{a, b\}^* \mid \text{every a in } w \text{ is followed by exactly two } b\text{'s}\}$
B. $\{w \in \{a, b\}^* \mid \text{every a in } w \text{ is followed by at least two } b\text{'s}\}$
C. $\{w \in \{a, b\}^* \mid w \text{ contains the substring '}abb\text{'}\}$
D. $\{w \in \{a, b\}^* \mid w \text{ does not contain '}aa\text{' as a substring}\}$

gatecse-2005 theory-of-computation finite-automata normal

Answer key

10.7.14 Finite Automata: GATE CSE 2005 | Question: 63

The following diagram represents a finite state machine which takes as input a binary number from the least significant bit.



Which of the following is TRUE?

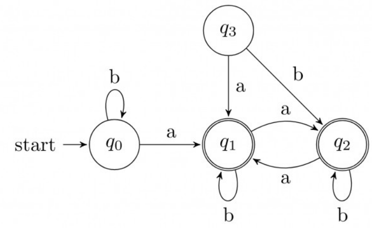
A. It computes 1's complement of the input number
B. It computes 2's complement of the input number
C. It increments the input number
D. it decrements the input number

gatecse-2005 theory-of-computation finite-automata easy

Answer key

10.7.15 Finite Automata: GATE CSE 2007 | Question: 74

Consider the following Finite State Automaton:



The language accepted by this automaton is given by the regular expression

A. $b^*ab^*ab^*ab^*$ B. $(a+b)^*$ C. $b^*a(a+b)^*$ D. $b^*ab^*ab^*$

gatecse-2007 theory-of-computation finite-automata normal

Answer key

10.7.16 Finite Automata: GATE CSE 2008 | Question: 49

Given below are two finite state automata ($\rightarrow$ indicates the start state and F indicates a final state)

Y

	a	b
$\rightarrow 1$	1	2
$2(F)$	2	1

Z

	a	b
$\rightarrow 1$	2	2
$2(F)$	1	1

Which of the following represents the product automaton $Z \times Y$?

A.

	a	b
$\rightarrow P$	S	R
Q	R	S
R(F)	Q	P
S	Q	P

B.

	a	b
$\rightarrow P$	S	Q
Q	R	S
R(F)	Q	P
S	P	Q

C.

	a	b
$\rightarrow P$	Q	S
Q	R	S
R(F)	Q	P
S	Q	P

D.

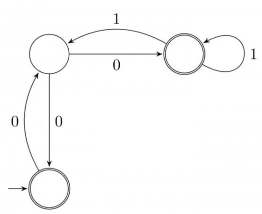
	a	b
$\rightarrow P$	S	Q
Q	S	R
R(F)	Q	P
S	Q	P

gatecse-2008 normal theory-of-computation finite-automata

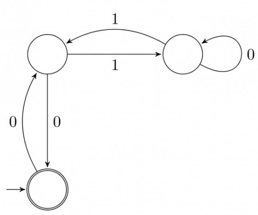
Answer key

10.7.17 Finite Automata: GATE CSE 2008 | Question: 52

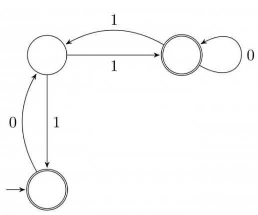
Match the following NFAs with the regular expressions they correspond to:

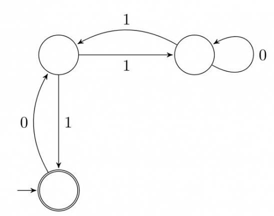


P



Q





S

R

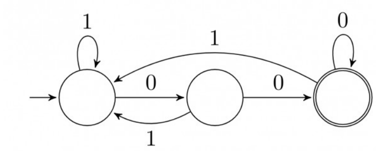
1. $\epsilon + 0(01^*1 + 00)^*01^*$
2. $\epsilon + 0(10^*1 + 00)^*0$
3. $\epsilon + 0(10^*1 + 10)^*1$
4. $\epsilon + 0(10^*1 + 10)^*10^*$

A. $P-2, Q-1, R-3, S-4$
B. $P-1, Q-3, R-2, S-4$
C. $P-1, Q-2, R-3, S-4$
D. $P-3, Q-2, R-1, S-4$

gatecse-2008 theory-of-computation finite-automata normal

Answer key

10.7.18 Finite Automata: GATE CSE 2009 | Question: 41



The above DFA accepts the set of all strings over $\{0, 1\}$ that

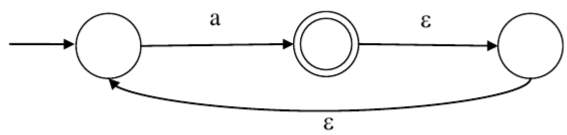
A. begin either with 0 or 1.
B. end with 0.
C. end with 00.
D. contain the substring 00.

gatecse-2009 theory-of-computation finite-automata easy

Answer key

10.7.19 Finite Automata: GATE CSE 2012 | Question: 12

What is the complement of the language accepted by the NFA shown below?
Assume $\Sigma = \{a\}$ and ϵ is the empty string.



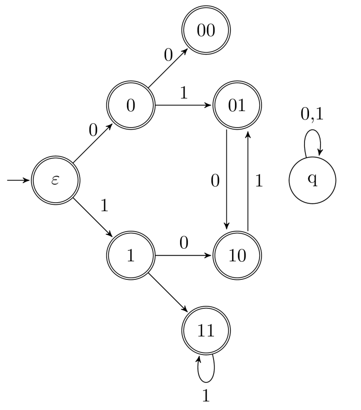
A. ϕ
B. $\{\epsilon\}$
C. a^*
D. $\{a, \epsilon\}$

gatecse-2012 finite-automata easy theory-of-computation

Answer key

10.7.20 Finite Automata: GATE CSE 2012 | Question: 46

Consider the set of strings on $\{0, 1\}$ in which, *every substring of* 3 *symbols* has at most *two* zeros. For example, 001110 and 011001 are in the language, but 100010 is not. All strings of length less than 3 are also in the language. A partially completed DFA that accepts this language is shown below.



The missing arcs in the DFA are:

A.

	00	01	10	11	q
00	1	0			
01				1	
10	0				
11			0		

B.

	00	01	10	11	q
00		0			1
01		1			
10				0	
11		0			

C.

	00	01	10	11	q
00		1			0
01		1			
10			0		
11		0			

D.

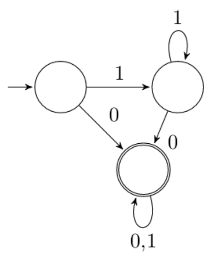
	00	01	10	11	q
00		1			0
01				1	
10	0				
11			0		

gatecse-2012 theory-of-computation finite-automata normal

Answer key

10.7.21 Finite Automata: GATE CSE 2013 | Question: 33

Consider the DFA A given below.



Which of the following are **FALSE**?

1. Complement of $L(A)$ is context-free.
2. $L(A) = L((11^*0+0)(0+1)^*0^*1^*)$
3. For the language accepted by A, A is the minimal DFA.
4. A accepts all strings over $\{0,1\}$ of length at least 2.

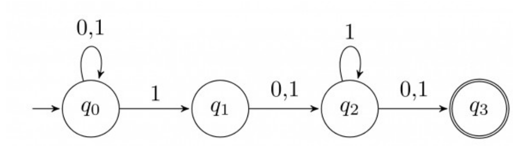
A. 1 and 3 only B. 2 and 4 only C. 2 and 3 only D. 3 and 4 only

gatecse-2013 theory-of-computation finite-automata normal

Answer key

10.7.22 Finite Automata: GATE CSE 2014 Set 1 | Question: 16

Consider the finite automaton in the following figure:



What is the set of reachable states for the input string 0011?

A. $\{q_0, q_1, q_2\}$ B. $\{q_0, q_1\}$ C. $\{q_0, q_1, q_2, q_3\}$ D. $\{q_3\}$

gatecse-2014-set1 theory-of-computation finite-automata easy

Answer key☟

10.7.23 Finite Automata: GATE CSE 2016 Set 2 | Question: 42

Consider the following two statements:

I. If all states of an **NFA** are accepting states then the language accepted by the **NFA** is Σ^*.
II. There exists a regular language A such that for all languages B, $A \cap B$ is regular.

Which one of the following is **CORRECT**?

A. Only **I** is true
B. Only **II** is true
C. Both **I** and **II** are true
D. Both **I** and **II** are false

gatecse-2016-set2 theory-of-computation finite-automata normal

Answer key☟

10.7.24 Finite Automata: GATE CSE 2017 Set 2 | Question: 39

Let δ denote the transition function and $\hat{\delta}$ denote the extended transition function of the ϵ-NFA whose transition table is given below:

δ	ϵ	a	b
$\rightarrow q_0$	$\{q_2\}$	$\{q_1\}$	$\{q_0\}$
q_1	$\{q_2\}$	$\{q_2\}$	$\{q_3\}$
q_2	$\{q_0\}$	$\emptyset$	$\emptyset$
q_3	$\emptyset$	$\emptyset$	$\{q_2\}$

Then $\hat{\delta}(q_2, aba)$ is

A. $\emptyset$
B. $\{q_0, q_1, q_3\}$
C. $\{q_0, q_1, q_2\}$
D. $\{q_0, q_2, q_3\}$

gatecse-2017-set2 theory-of-computation finite-automata

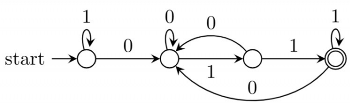
Answer key☟

10.7.25 Finite Automata: GATE CSE 2021 Set 1 | Question: 38

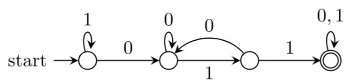
Consider the following language:

$$L = \{w \in \{0,1\}^* \mid w \text{ ends with the substring } 011\}$$

Which one of the following deterministic finite automata accepts L?

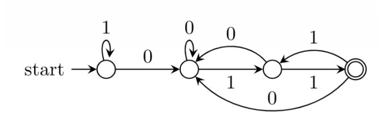


A.

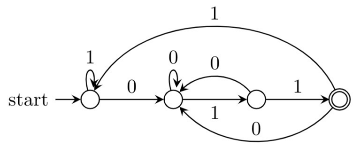


B.

C.



D.

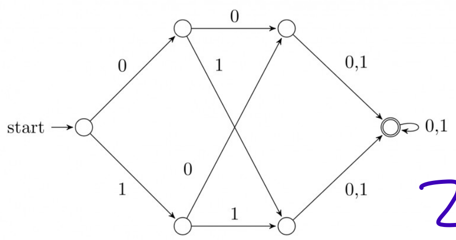


gatecse-2021-set1 theory-of-computation finite-automata two-marks

Answer key

10.7.26 Finite Automata: GATE CSE 2021 Set 2 | Question: 17

Consider the following deterministic finite automaton (DFA)



256

The number of strings of length 8 accepted by the above automaton is ___________

gatecse-2021-set2 numerical-answers theory-of-computation finite-automata one-mark

Answer key

10.7.27 Finite Automata: GATE CSE 2021 Set 2 | Question: 28

Suppose we want to design a synchronous circuit that processes a string of 0's and 1's. Given a string, it produces another string by replacing the first 1 in any subsequence of consecutive 1's by a 0. Consider the following example.

$$\begin{array}{ll} \text{Input sequence:} & 00100011000011100 \\ \text{Output sequence:} & 00000001000001100 \end{array}$$

A *Mealy Machine* is a state machine where both the next state and the output are functions of the present state and the current input.

The above mentioned circuit can be designed as a two-state Mealy machine. The states in the Mealy machine can be represented using Boolean values 0 and 1. We denote the current state, the next state, the next incoming bit, and the output bit of the Mealy machine by the variables s, t, b and y respectively.

Assume the initial state of the Mealy machine is 0.

What are the Boolean expressions corresponding to t and y in terms of s and b?

A.
$t = s + b$
$y = sb$

B.
$t = b$
$y = sb$

C.
$t = b$
$y = s\bar{b}$

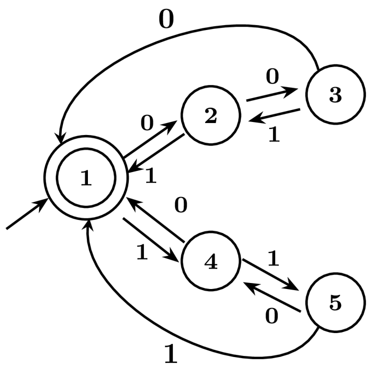
D.
$t = s + b$
$y = s\bar{b}$

gatecse-2021-set2 theory-of-computation finite-automata two-marks

Answer key

10.7.28 Finite Automata: GATE CSE 2024 | Set 1 | Question: 40

Consider the 5 -state DFA. M accepting the language $L(M) \subset (0+1)^*$ shown below. For any string $w \in (0+1)^*$ let $n_0(w)$ be the number of $0's$ in w and $n_1(w)$ be the number of 1 's in w.



Which of the following statements is/are FALSE?

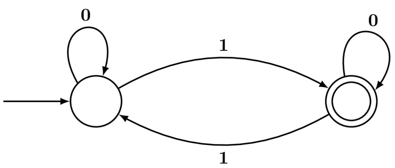
A. States 2 and 4 are distinguishable in M
B. States 3 and 4 are distinguishable in M
C. States 2 and 5 are distinguishable in M
D. Any string w with $n_0(w) = n_1(w)$ is in $L(M)$

gatecse2024-set1 multiple-selects theory-of-computation finite-automata two-marks

Answer key☟

10.7.29 Finite Automata: GATE CSE 2024 | Set 2 | Question: 12

Which one of the following regular expressions is equivalent to the language accepted by the DFA given below?



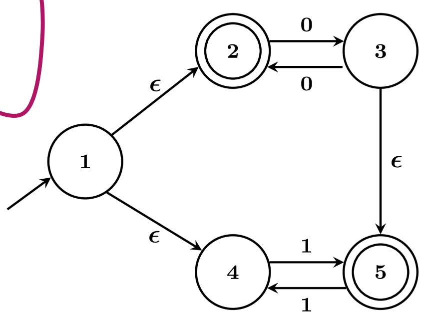
A. $0^*1(0+10^*1)^*$
B. $0^*(10^*11)^*0^*$
C. $0^*1(010^*1)^*0^*$
D. $0(1+0^*10^*1)^*0^*$

gatecse2024-set2 theory-of-computation finite-automata one-mark

Answer key☟

10.7.30 Finite Automata: GATE CSE 2024 | Set 2 | Question: 31

Let M be the 5-state NFA with ϵ-transitions shown in the diagram below.



Which one of the following regular expressions represents the language accepted by M?

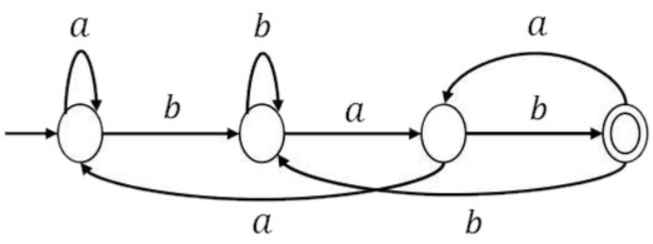
A. $(00)^* + 1(11)^*$
B. $0^* + (1 + 0(00)^*)(11)^*$
C. $(00)^* + (1 + (00)^*)(11)^*$
D. $0^+ + 1(11)^* + 0(11)^*$

gatecse2024-set2 theory-of-computation finite-automata two-marks

Answer key

10.7.31 Finite Automata: GATE CSE 2025 | Set 1 | Question: 40

Consider the following deterministic finite automaton (DFA) defined over the alphabet, $\Sigma = \{a, b\}$. Identify which of the following language(s) is/are accepted by the given DFA.



A. The set of all strings containing an even number of b 's.
B. The set of all strings containing the pattern bab.
C. The set of all strings ending with the pattern bab.
D. The set of all strings not containing the pattern aba.

gatecse2025-set1 theory-of-computation finite-automata multiple-selects easy two-marks

Answer key

10.7.32 Finite Automata: GATE IT 2004 | Question: 41

Let $M = (K, \Sigma, \sigma, s, F)$ be a finite state automaton, where

$K = \{A, B\}, \Sigma = \{a, b\}, s = A, F = \{B\},$
$\sigma(A, a) = A, \sigma(A, b) = B, \sigma(B, a) = B$ and $\sigma(B, b) = A$

A grammar to generate the language accepted by M can be specified as $G = (V, \Sigma, R, S)$, where $V = K \cup \Sigma$, and $S = A$.

Which one of the following set of rules will make $L(G) = L(M)$?

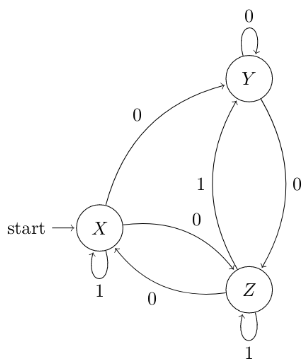
A. $\{A \to aB, A \to bA, B \to bA, B \to aA, B \to \epsilon)$
B. $\{A \to aA, A \to bB, B \to aB, B \to bA, B \to \epsilon)$
C. $\{A \to bB, A \to aB, B \to aA, B \to bA, B \to \epsilon)$
D. $\{A \to aA, A \to bA, B \to aB, B \to bA, A \to \epsilon)$

gateit-2004 theory-of-computation finite-automata normal

Answer key

10.7.33 Finite Automata: GATE IT 2005 | Question: 37

Consider the non-deterministic finite automaton (NFA) shown in the figure.



State X is the starting state of the automaton. Let the language accepted by the NFA with Y as the only accepting state be $L1$. Similarly, let the language accepted by the NFA with Z as the only accepting state be $L2$. Which of the following statements about $L1$ and $L2$ is TRUE?

A. $L1 = L2$
B. $L1 \subset L2$
C. $L2 \subset L1$
D. None of the above

gateit-2005 theory-of-computation finite-automata normal

Answer key

10.7.34 Finite Automata: GATE IT 2005 | Question: 39

Consider the regular grammar:

- $S \rightarrow Xa \mid Ya$
- $X \rightarrow Za$
- $Z \rightarrow Sa \mid \epsilon$
- $Y \rightarrow Wa$
- $W \rightarrow Sa$

where S is the starting symbol, the set of terminals is $\{a\}$ and the set of non-terminals is $\{S, W, X, Y, Z\}$.
We wish to construct a deterministic finite automaton (DFA) to recognize the same language. What is the minimum number of states required for the DFA?

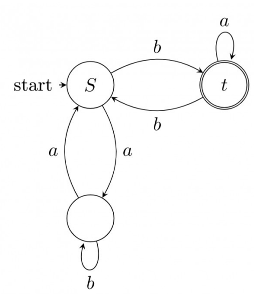
A. 2
B. 3
C. 4
D. 5

gateit-2005 theory-of-computation finite-automata normal

Answer key

10.7.35 Finite Automata: GATE IT 2006 | Question: 3

In the automaton below, s is the start state and t is the only final state.



Consider the strings $u = abbaba, v = bab, \text{and} w = aabb$. Which of the following statements is true?

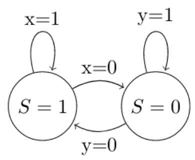
A. The automaton accepts u and v but not w
B. The automaton accepts each of $u, v,$ and w
C. The automaton rejects each of $u, v,$ and w
D. The automaton accepts u but rejects v and w

gateit-2006 theory-of-computation finite-automata easy

Answer key

10.7.36 Finite Automata: GATE IT 2006 | Question: 37

For a state machine with the following state diagram the expression for the next state S^+ in terms of the current state S and the input variables x and y is



A. $S^+ = S'.y' + S.x$
B. $S^+ = S.x.y' + S'.y.x'$

C. $S^+ = x.y'$

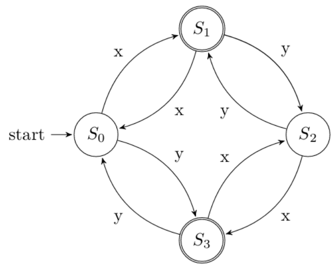
D. $S^+ = S'.y + S.x'$

gateit-2006 theory-of-computation finite-automata normal

Answer key

10.7.37 Finite Automata: GATE IT 2007 | Question: 47

Consider the following DFA in which S_0 is the start state and S_1, S_3 are the final states.



What language does this DFA recognize?

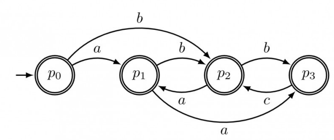
A. All strings of x and y
B. All strings of x and y which have either even number of x and even number of y or odd number of x and odd number of y
C. All strings of x and y which have equal number of x and y
D. All strings of x and y with either even number of x and odd number of y or odd number of x and even number of y

gateit-2007 theory-of-computation finite-automata normal

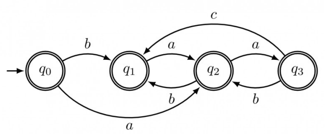
Answer key

10.7.38 Finite Automata: GATE IT 2007 | Question: 50

Consider the following finite automata P and Q over the alphabet $\{a, b, c\}$. The start states are indicated by a double arrow and final states are indicated by a double circle. Let the languages recognized by them be denoted by $L(P)$ and $L(Q)$ respectively.

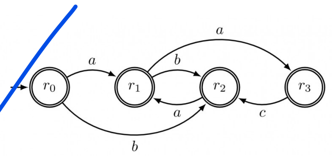


(P)

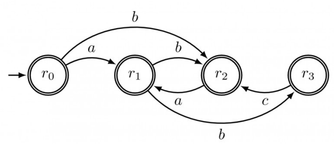


(Q)

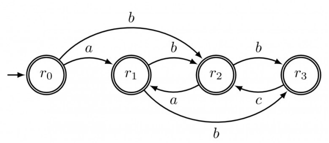
The automation which recognizes the language $L(P) \cap L(Q)$ is :



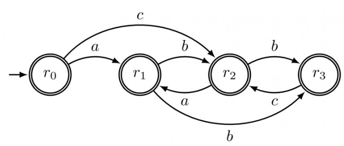
A.



B.



C.



D.

gateit-2007 theory-of-computation finite-automata normal

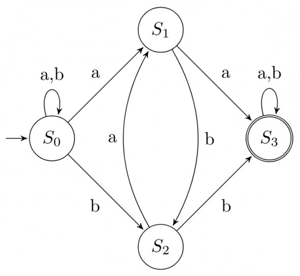
Answer key

10.7.39 Finite Automata: GATE IT 2007 | Question: 71

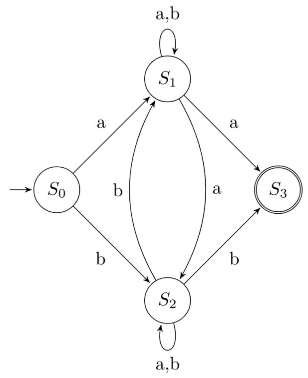
Consider the regular expression $R = (a + b)^*(aa + bb)(a + b)^*$

Which of the following non-deterministic finite automata recognizes the language defined by the regular expression R? Edges labeled λ denote transitions on the empty string.

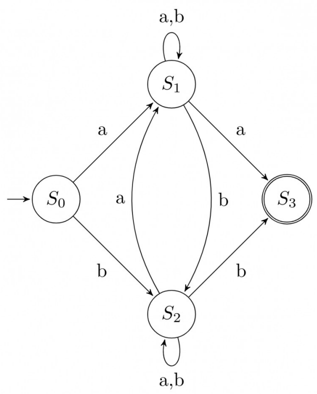
A.



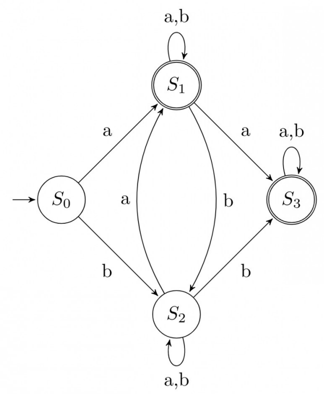
B.



C.



D.



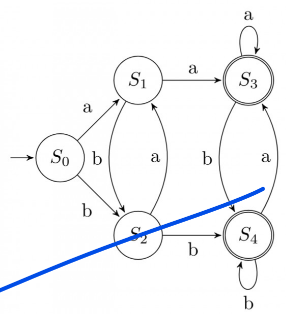
gateit-2007 theory-of-computation finite-automata normal

Answer key

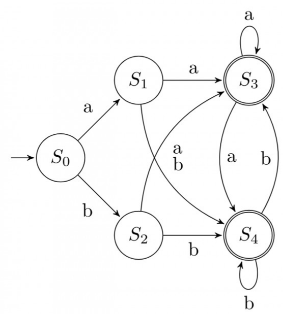
10.7.40 Finite Automata: GATE IT 2007 | Question: 72

Consider the regular expression $R = (a+b)^*(aa+bb)(a+b)^*$

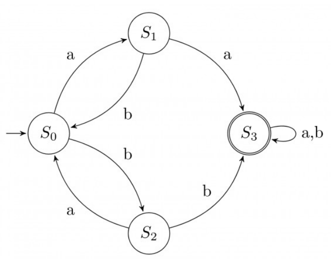
Which deterministic finite automaton accepts the language represented by the regular expression R?



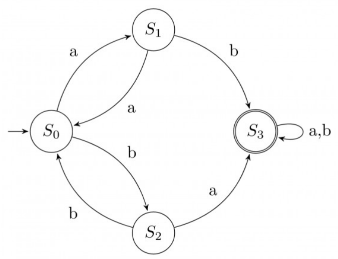
A.



B.



C.



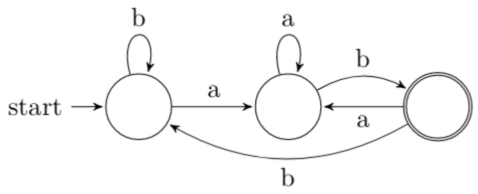
D.

gateit-2007 theory-of-computation finite-automata normal

Answer key

10.7.41 Finite Automata: GATE IT 2008 | Question: 32

If the final states and non-final states in the DFA below are interchanged, then which of the following languages over the alphabet $\{a, b\}$ will be accepted by the new DFA?



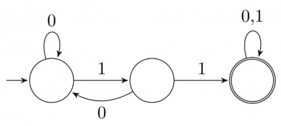
A. Set of all strings that do not end with ab
B. Set of all strings that begin with either an a or a b
C. Set of all strings that do not contain the substring ab,
D. The set described by the regular expression $b^*aa^*(ba)^*b^*$

gateit-2008 theory-of-computation finite-automata normal

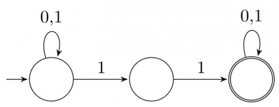
Answer key

10.7.42 Finite Automata: GATE IT 2008 | Question: 36

Consider the following two finite automata. M_1 accepts L_1 and M_2 accepts L_2.



M_1



M_2

Which one of the following is/are TRUE?

A. $L_1 = L_2$
B. $L_1 \subset L_2$
C. $L_1 \cap L_2^C = \varnothing$
D. $L_1 \cup L_2 \neq L_1$

gateit-2008 theory-of-computation finite-automata normal

Answer key

10.8 Finite State Machines (1)

10.8.1 Finite State Machines: GATE CSE 2025 | Set 1 | Question: 49

Consider a finite state machine (FSM) with one input X and one output f, represented by the given state transition table. The minimum number of states required to realize this FSM is ________. (Answer in integer).

Present state	Next state		Output f	
	X=0	X=1	X=0	X=1
A	F	B	0	0
B	D	C	0	0
C	F	E	0	0
D	G	A	1	0
E	D	C	0	0
F	F	B	1	1
G	G	H	0	1
H	G	A	1	0

gatecse2025-set1 theory-of-computation finite-state-machines numerical-answers two-marks

Answer key

10.9 Identify Class Language (31)

10.9.1 Identify Class Language: GATE CSE 1987 | Question: 1-xiii

FORTRAN is a:

A. Regular language.
B. Context-free language.
C. Context-sensitive language.
D. None of the above.

gate1987 theory-of-computation identify-class-language

Answer key

10.9.2 Identify Class Language: GATE CSE 1988 | Question: 2ix

What is the type of the language L, where $L = \{a^n b^n \mid 0 < n < 327\text{-th prime number}\}$

gate1988 normal descriptive theory-of-computation identify-class-language

Answer key

10.9.3 Identify Class Language: GATE CSE 1991 | Question: 17,a

Show that the Turing machines, which have a read only input tape and constant size work tape, recognize precisely the class of regular languages.

gate1991 theory-of-computation descriptive identify-class-language proof

Answer key

10.9.4 Identify Class Language: GATE CSE 1994 | Question: 19

A. Given a set:

$$S = \{x \mid \text{ there is an x-block of 5's in the decimal expansion of } \pi\}$$

(Note: x-*block* is a maximal block of x successive 5's)
Which of the following statements is true with respect to S? No reason to be given for the answer.

i. S is regular
ii. S is recursively enumerable
iii. S is not recursively enumerable
iv. S is recursive

B. Given that a language L_1 is regular and that the language $L_1 \cup L_2$ is regular, is the language L_2 always regular? Prove your answer.

gate1994 theory-of-computation identify-class-language normal descriptive

Answer key

10.9.5 Identify Class Language: GATE CSE 1999 | Question: 2.4

If $L1$ is context free language and $L2$ is a regular language which of the following is/are false?

A. $L1 - L2$ is not context free
B. $L1 \cap L2$ is context free
C. $\sim L1$ is context free
D. $\sim L2$ is regular

gate1999 theory-of-computation identify-class-language normal multiple-selects

Answer key

10.9.6 Identify Class Language: GATE CSE 2000 | Question: 1.5

Let L denote the languages generated by the grammar $S \to 0S0 \mid 00.$
Which of the following is TRUE?

A. $L = 0^+$
B. L is regular but not 0^+
C. L is context free but not regular
D. L is not context free

gatecse-2000 theory-of-computation easy identify-class-language

Answer key

10.9.7 Identify Class Language: GATE CSE 2002 | Question: 1.7

The language accepted by a Pushdown Automaton in which the stack is limited to 10 items is best described as

A. Context free
B. Regular
C. Deterministic Context free
D. Recursive

gatecse-2002 theory-of-computation easy identify-class-language

Answer key

10.9.8 Identify Class Language: GATE CSE 2004 | Question: 87

The language $\{a^m b^n c^{m+n} \mid m, n \geq 1\}$ is

A. regular
B. context-free but not regular
C. context-sensitive but not context free
D. type-0 but not context sensitive

gatecse-2004 theory-of-computation normal identify-class-language

Answer key

10.9.9 Identify Class Language: GATE CSE 2005 | Question: 55

Consider the languages:
$L_1 = \{a^n b^n c^m \mid n, m > 0\}$ and $L_2 = \{a^n b^m c^m \mid n, m > 0\}$
Which one of the following statements is FALSE?

A. $L_1 \cap L_2$ is a context-free language
B. $L_1 \cup L_2$ is a context-free language
C. $L_1 \text{ and } L_2$ are context-free languages
D. $L_1 \cap L_2$ is a context sensitive language

gatecse-2005 theory-of-computation identify-class-language normal

Answer key

10.9.10 Identify Class Language: GATE CSE 2006 | Question: 30

For $s \in (0+1)^*$ let $d(s)$ denote the decimal value of s(e.g. $d(101) = 5$). Let

$$L = \{s \in (0+1)^* \mid d(s) \bmod 5 = 2 \text{ and } d(s) \bmod 7 \neq 4\}$$

Which one of the following statements is true?

A. L is recursively enumerable, but not recursive
B. L is recursive, but not context-free
C. L is context-free, but not regular
D. L is regular

gatecse-2006 theory-of-computation normal identify-class-language

Answer key☟

10.9.11 Identify Class Language: GATE CSE 2006 | Question: 33

Let L_1 be a regular language, L_2 be a deterministic context-free language and L_3 a recursively enumerable, but not recursive, language. Which one of the following statements is false?

A. $L_1 \cap L_2$ is a deterministic CFL
B. $L_3 \cap L_1$ is recursive
C. $L_1 \cup L_2$ is context free
D. $L_1 \cap L_2 \cap L_3$ is recursively enumerable

gatecse-2006 theory-of-computation normal identify-class-language

Answer key☟

10.9.12 Identify Class Language: GATE CSE 2007 | Question: 30

The language $L = \left\{0^i 2 1^i \mid i \geq 0\right\}$ over the alphabet $\{0, 1, 2\}$ is:

A. not recursive
B. is recursive and is a deterministic CFL
C. is a regular language
D. is not a deterministic CFL but a CFL

gatecse-2007 theory-of-computation normal identify-class-language

Answer key☟

10.9.13 Identify Class Language: GATE CSE 2008 | Question: 51

Match the following:

E.	Checking that identifiers are declared before their use	P.	$L = \{a^n b^m c^n d^m \mid n \geq 1, m \geq 1\}$
F.	Number of formal parameters in the declaration of a function agrees with the number of actual parameters in a use of that function	Q.	$X \rightarrow XbX \mid XcX \mid dXf \mid g$
G.	Arithmetic expressions with matched pairs of parentheses	R.	$L = \{wcw \mid w \in (a \mid b)^*\}$
H.	Palindromes	S.	$X \rightarrow bXb \mid cXc \mid \epsilon$

A. E-P, F-R, G-Q, H-S
B. E-R, F-P, G-S, H-Q
C. E-R, F-P, G-Q, H-S
D. E-P, F-R, G-S, H-Q

gatecse-2008 normal theory-of-computation identify-class-language match-the-following

Answer key☟

10.9.14 Identify Class Language: GATE CSE 2008 | Question: 9

Which of the following is true for the language

$$\{a^p \mid p \text{ is a prime }\}?$$

A. It is not accepted by a Turing Machine
B. It is regular but not context-free
C. It is context-free but not regular
D. It is neither regular nor context-free, but accepted by a Turing machine

gatecse-2008 theory-of-computation easy identify-class-language

Answer key

10.9.15 Identify Class Language: GATE CSE 2009 | Question: 40

Let $L = L_1 \cap L_2$, where L_1 and L_2 are languages as defined below:

$L_1 = \{a^m b^m c a^n b^n \mid m, n \geq 0\}$

$L_2 = \{a^i b^j c^k \mid i, j, k \geq 0\}$

Then L is

A. Not recursive
B. Regular
C. Context free but not regular
D. Recursively enumerable but not context free.

gatecse-2009 theory-of-computation easy identify-class-language

Answer key

10.9.16 Identify Class Language: GATE CSE 2010 | Question: 40

Consider the languages

$L1 = \{0^i 1^j \mid i \neq j\}$,

$L2 = \{0^i 1^j \mid i = j\}$,

$L3 = \{0^i 1^j \mid i = 2j + 1\}$,

$L4 = \{0^i 1^j \mid i \neq 2j\}$

A. Only $L2$ is context free.
B. Only $L2$ and $L3$ are context free.
C. Only $L1$ and $L2$ are context free.
D. All are context free

gatecse-2010 theory-of-computation context-free-language identify-class-language normal

Answer key

10.9.17 Identify Class Language: GATE CSE 2011 | Question: 26

Consider the languages $L1,\ L2\, and\, L3$ as given below.

$L1 = \{0^p 1^q \mid p, q \in N\}$,

$L2 = \{0^p 1^q \mid p, q \in N\, and\, p = q\}\, and,$

$L3 = \{0^p 1^q 0^r \mid p, q, r \in N\, and\, p = q = r\}.$

Which of the following statements is **NOT TRUE**?

A. Push Down Automata (PDA) can be used to recognize $L1$ and $L2$
B. $L1$ is a regular language
C. All the three languages are context free
D. Turing machines can be used to recognize all the languages

gatecse-2011 theory-of-computation identify-class-language normal

Answer key

10.9.18 Identify Class Language: GATE CSE 2013 | Question: 32

Consider the following languages.

$L_1 = \{0^p 1^q 0^r \mid p, q, r \geq 0\}$

$L_2 = \{0^p 1^q 0^r \mid p, q, r \geq 0, p \neq r\}$

Which one of the following statements is **FALSE**?

A. L_2 is context-free.
B. $L_1 \cap L_2$ is context-free.
C. Complement of L_2 is recursive.
D. Complement of L_1 is context-free but not regular.

gatecse-2013 theory-of-computation identify-class-language normal

Answer key

10.9.19 Identify Class Language: GATE CSE 2014 Set 3 | Question: 36

Consider the following languages over the alphabet $\sum = \{0, 1, c\}$

$L_1 = \{0^n 1^n \mid n \geq 0\}$

$L_2 = \{wcw^r \mid w \in \{0, 1\}^*\}$

$L_3 = \{ww^r \mid w \in \{0, 1\}^*\}$

Here, w^r is the reverse of the string w. Which of these languages are deterministic Context-free languages?

A. None of the languages
B. Only L_1
C. Only L_1 and L_2
D. All the three languages

gatecse-2014-set3 theory-of-computation identify-class-language context-free-language normal

Answer key

10.9.20 Identify Class Language: GATE CSE 2017 Set 1 | Question: 37

Consider the context-free grammars over the alphabet $\{a, b, c\}$ given below. S and T are non-terminals.

$G_1 : S \rightarrow aSb \mid T, T \rightarrow cT \mid \epsilon$

$G_2 : S \rightarrow bSa \mid T, T \rightarrow cT \mid \epsilon$

The language $L\left(G_1\right) \cap L(G_2)$ is

A. Finite
B. Not finite but regular
C. Context-Free but not regular
D. Recursive but not context-free

gatecse-2017-set1 theory-of-computation context-free-language identify-class-language normal

Answer key

10.9.21 Identify Class Language: GATE CSE 2017 Set 2 | Question: 40

Consider the following languages.

- $L_1 = \{a^p \mid p \text{ is a prime number}\}$
- $L_2 = \{a^n b^m c^{2m} \mid n \geq 0, m \geq 0\}$
- $L_3 = \{a^n b^n c^{2n} \mid n \geq 0\}$
- $L_4 = \{a^n b^n \mid n \geq 1\}$

Which of the following are CORRECT?

I. L_1 is context free but not regular
II. L_2 is not context free
III. L_3 is not context free but recursive
IV. L_4 is deterministic context free

A. I, II and IV only
B. II and III only
C. I and IV only
D. III and IV only

gatecse-2017-set2 theory-of-computation identify-class-language

Answer key

10.9.22 Identify Class Language: GATE CSE 2018 | Question: 35

Consider the following languages:

I. $\{a^m b^n c^p d^q \mid m + p = n + q, \text{ where } m, n, p, q \geq 0\}$
II. $\{a^m b^n c^p d^q \mid m = n \text{ and } p = q, \text{ where } m, n, p, q \geq 0\}$
III. $\{a^m b^n c^p d^q \mid m = n = p \text{ and } p \neq q, \text{ where } m, n, p, q \geq 0\}$
IV. $\{a^m b^n c^p d^q \mid mn = p + q, \text{ where } m, n, p, q \geq 0\}$

Which of the above languages are context-free?

A. I and IV only B. I and II only C. II and III only D. II and IV only

gatecse-2018 theory-of-computation identify-class-language context-free-language normal two-marks

Answer key

10.9.23 Identify Class Language: GATE CSE 2020 | Question: 10

Consider the language $L = \{a^n \mid n \geq 0\} \cup \{a^n b^n \mid n \geq 0\}$ and the following statements.

I. L is deterministic context-free.
II. L is context-free but not deterministic context-free.
III. L is not $LL(k)$ for any k.

Which of the above statements is/are TRUE?

A. I only
B. II only
C. I and III only
D. III only

gatecse-2020 theory-of-computation identify-class-language one-mark

Answer key

10.9.24 Identify Class Language: GATE CSE 2020 | Question: 32

Consider the following languages.

$$L_1 = \{wxyx \mid w, x, y \in (0+1)^+\}$$
$$L_2 = \{xy \mid x, y \in (a+b)^*, \mid x \mid = \mid y \mid, x \neq y\}$$

Which one of the following is TRUE?

A. L_1 is regular and L_2 is context- free.
B. L_1 context- free but not regular and L_2 is context-free.
C. Neither L_1 nor L_2 is context- free.
D. L_1 context- free but L_2 is not context-free.

gatecse-2020 theory-of-computation identify-class-language two-marks

Answer key

10.9.25 Identify Class Language: GATE CSE 2021 Set 2 | Question: 12

Let L_1 be a regular language and L_2 be a context-free language. Which of the following languages is/are context-free?

A. $L_1 \cap \overline{L_2}$

B. $\overline{\overline{L_1} \cup \overline{L_2}}$

C. $L_1 \cup (L_2 \cup \overline{L_2})$

D. $(L_1 \cap L_2) \cup (\overline{L_1} \cap L_2)$

gatecse-2021-set2 multiple-selects theory-of-computation identify-class-language one-mark

Answer key

10.9.26 Identify Class Language: GATE CSE 2022 | Question: 13

Which of the following statements is/are TRUE?

A. Every subset of a recursively enumerable language is recursive.
B. If a language L and its complement $\overline{L}$ are both recursively enumerable, then L must be recursive.
C. Complement of a context-free language must be recursive.
D. If L_1 and L_2 are regular, then $L_1 \cap L_2$ must be deterministic context-free.

gatecse-2022 theory-of-computation identify-class-language recursive-and-recursively-enumerable-languages multiple-selects one-mark

Answer key

10.9.27 Identify Class Language: GATE CSE 2022 | Question: 37

Consider the following languages:

$L_1 = \{a^n w a^n | w \in \{a,b\}^*\}$

$L_2 = \{wxw^R | w,x \in \{a,b\}^*, |w|,|x| > 0\}$

Note that w^R is the reversal of the string w. Which of the following is/are TRUE?

A. L_1 and L_2 are regular.
B. L_1 and L_2 are context-free.
C. L_1 is regular and L_2 is context-free.
D. L_1 and L_2 are context-free but not regular.

gatecse-2022 theory-of-computation identify-class-language context-free-language multiple-selects two-marks

Answer key

10.9.28 Identify Class Language: GATE CSE 2023 | Question: 14

Which of the following statements is/are CORRECT?

A. The intersection of two regular languages is regular.
B. The intersection of two context-free languages is context-free.
C. The intersection of two recursive languages is recursive.
D. The intersection of two recursively enumerable languages is recursively enumerable.

gatecse-2023 theory-of-computation identify-class-language multiple-selects one-mark

Answer key

10.9.29 Identify Class Language: GATE IT 2005 | Question: 4

Let L be a regular language and M be a context-free language, both over the alphabet Σ. Let L^c and M^c denote the complements of L and M respectively. Which of the following statements about the language $L^c \cup M^c$ is TRUE?

A. It is necessarily regular but not necessarily context-free.
B. It is necessarily context-free.
C. It is necessarily non-regular.
D. None of the above

gateit-2005 theory-of-computation normal identify-class-language

Answer key

10.9.30 Identify Class Language: GATE IT 2005 | Question: 6

The language $\{0^n 1^n 2^n \mid 1 \leq n \leq 10^6\}$ is

A. regular
B. context-free but not regular
C. context-free but its complement is not context-free
D. not context-free

gateit-2005 theory-of-computation easy identify-class-language

Answer key

10.9.31 Identify Class Language: GATE IT 2008 | Question: 33

Consider the following languages.

- $L_1 = \{a^i b^j c^k \mid i = j, k \geq 1\}$
- $L_2 = \{a^i b^j \mid j = 2i, i \geq 0\}$

Which of the following is true?

A. L_1 is not a CFL but L_2 is
B. $L_1 \cap L_2 = \varnothing$ and L_1 is non-regular
C. $L_1 \cup L_2$ is not a CFL but L_2 is

D. There is a 4-state PDA that accepts L_1, but there is no DPDA that accepts L_2.

gateit-2008 theory-of-computation normal identify-class-language

Answer key

10.10 Minimal State Automata (25)

10.10.1 Minimal State Automata: GATE CSE 1987 | Question: 2j

State whether the following statements are TRUE or FALSE:

A minimal DFA that is equivalent to an NDFA with n nodes has always 2^n states.

gate1987 theory-of-computation finite-automata minimal-state-automata

Answer key

10.10.2 Minimal State Automata: GATE CSE 1997 | Question: 20

Construct a finite state machine with minimum number of states, accepting all strings over (a, b) such that the number of a's is divisible by two and the number of b's is divisible by three.

gate1997 theory-of-computation finite-automata normal minimal-state-automata descriptive

Answer key

10.10.3 Minimal State Automata: GATE CSE 1997 | Question: 70

Following is a state table for time finite state machine.

Present State	Next State Output	
	Input- 0	Input-1
A	B.1	H.1
B	F.1	D.1
C	D.0	E.1
D	C.0	F.1
E	D.1	C.1
F	C.1	C.1
G	C.1	D.1
H	C.0	A.1

A. Find the equivalence partition on the states of the machine.

B. Give the state table for the minimal machine. (Use appropriate names for the equivalent states. For example if states X and Y are equivalent then use XY as the name for the equivalent state in the minimal machine).

gate1997 theory-of-computation minimal-state-automata descriptive

Answer key

10.10.4 Minimal State Automata: GATE CSE 1998 | Question: 2.5

Let L be the set of all binary strings whose last two symbols are the same. The number of states in the minimal state deterministic finite state automaton accepting L is

A. 2 B. 5 C. 8 D. 3

gate1998 theory-of-computation finite-automata normal minimal-state-automata

Answer key

10.10.5 Minimal State Automata: GATE CSE 1998 | Question: 4

Design a deterministic finite state automaton (using minimum number of states) that recognizes the following language:

$L = \{w \in \{0,1\}^* \mid w$ interpreted as binary number (ignoring the leading zeros) is divisible by five$\}$.

gate1998 theory-of-computation finite-automata normal minimal-state-automata descriptive

Answer key

10.10.6 Minimal State Automata: GATE CSE 1999 | Question: 1.4

Consider the regular expression $(0+1)(0+1)\dots N$ times. The minimum state finite automaton that recognizes the language represented by this regular expression contains

A. n states
B. $n+1$ states
C. $n+2$ states
D. None of the above

gate1999 theory-of-computation finite-automata easy minimal-state-automata

Answer key

10.10.7 Minimal State Automata: GATE CSE 2001 | Question: 1.6

Given an arbitrary non-deterministic finite automaton (NFA) with N states, the maximum number of states in an equivalent minimized DFA at least

A. N^2
B. 2^N
C. $2N$
D. $N!$

gatecse-2001 finite-automata theory-of-computation easy minimal-state-automata

Answer key

10.10.8 Minimal State Automata: GATE CSE 2001 | Question: 2.5

Consider a DFA over $\Sigma = \{a, b\}$ accepting all strings which have number of a's divisible by 6 and number of b's divisible by 8. What is the minimum number of states that the DFA will have?

A. 8
B. 14
C. 15
D. 48

gatecse-2001 theory-of-computation finite-automata minimal-state-automata

Answer key

10.10.9 Minimal State Automata: GATE CSE 2002 | Question: 2.13

The smallest finite automaton which accepts the language $\{x|$ length of x is divisible by $3\}$ has

A. 2 states
B. 3 states
C. 4 states
D. 5 states

gatecse-2002 theory-of-computation normal finite-automata minimal-state-automata

Answer key

10.10.10 Minimal State Automata: GATE CSE 2006 | Question: 34

Consider the regular language $L = (111 + 11111)^*$. The minimum number of states in any DFA accepting this languages is:

A. 3
B. 5
C. 8
D. 9

gatecse-2006 theory-of-computation finite-automata normal minimal-state-automata

Answer key

10.10.11 Minimal State Automata: GATE CSE 2007 | Question: 29

A minimum state deterministic finite automaton accepting the language

$L = \{w \mid w \in \{0,1\}^*$, number of 0s and 1s in w are divisible by 3 and 5, respectively $\}$ has

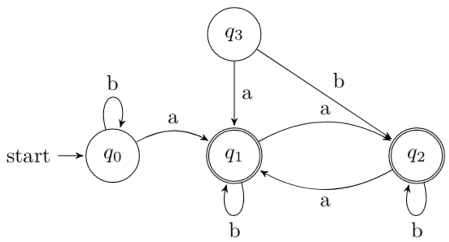
A. 15 states
B. 11 states
C. 10 states
D. 9 states

gatecse-2007 theory-of-computation finite-automata normal minimal-state-automata

Answer key

10.10.12 Minimal State Automata: GATE CSE 2007 | Question: 75

Consider the following Finite State Automaton:



The minimum state automaton equivalent to the above FSA has the following number of states:

A. 1 B. 2 C. 3 D. 4

normal gatecse-2007 theory-of-computation finite-automata minimal-state-automata

Answer key

10.10.13 Minimal State Automata: GATE CSE 2010 | Question: 41

Let w be any string of length n in $\{0,1\}^*$. Let L be the set of all substrings of w. What is the minimum number of states in non-deterministic finite automation that accepts L?

A. $n-1$ B. n C. $n+1$ D. 2^{n-1}

gatecse-2010 theory-of-computation finite-automata normal minimal-state-automata

Answer key

10.10.14 Minimal State Automata: GATE CSE 2011 | Question: 42

Definition of a language L with alphabet $\{a\}$ is given as following.

$$L = \{a^{nk} \mid k > 0, \ and \ n \text{ is a positive integer constant}\}$$

What is the minimum number of states needed in a DFA to recognize L?

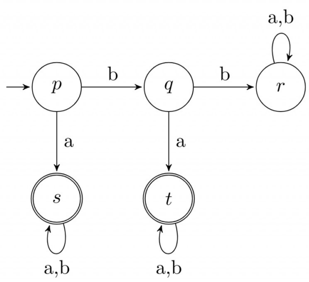
A. $k+1$ B. $n+1$ C. 2^{n+1} D. 2^{k+1}

gatecse-2011 theory-of-computation finite-automata normal minimal-state-automata

Answer key

10.10.15 Minimal State Automata: GATE CSE 2011 | Question: 45

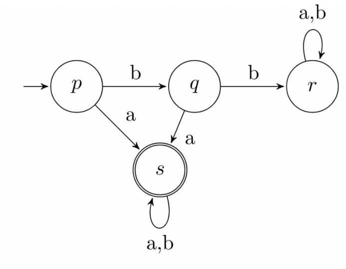
A deterministic finite automaton (DFA) D with alphabet $\Sigma = \{a, b\}$ is given below.

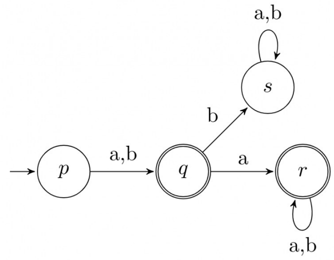


Which of the following finite state machines is a valid minimal DFA which accepts the same languages as D?

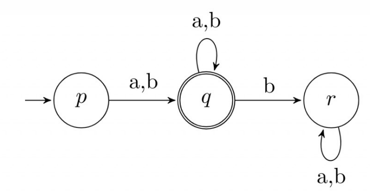
A.

B.

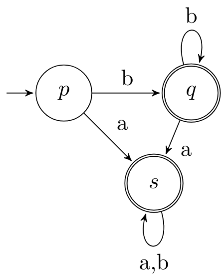




C.



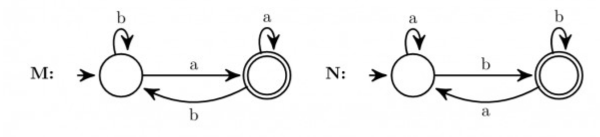
D.



gatecse-2011 theory-of-computation finite-automata easy minimal-state-automata

Answer key

10.10.16 Minimal State Automata: GATE CSE 2015 Set 1 | Question: 52



Consider the DFAs M and N given above. The number of states in a minimal DFA that accept the language $L(M) \cap L(N)$ is____________.

gatecse-2015-set1 theory-of-computation finite-automata easy numerical-answers minimal-state-automata

Answer key

10.10.17 Minimal State Automata: GATE CSE 2015 Set 2 | Question: 53

The number of states in the minimal deterministic finite automaton corresponding to the regular expression $(0+1)^*(10)$ is _____.

gatecse-2015-set2 theory-of-computation finite-automata normal numerical-answers minimal-state-automata

Answer key

10.10.18 Minimal State Automata: GATE CSE 2015 Set 3 | Question: 18

Let L be the language represented by the regular expression $\Sigma^*0011\Sigma^*$ where $\Sigma = \{0, 1\}$. What is the minimum number of states in a DFA that recognizes $\bar{L}$ (complement of L)?

A. 4 B. 5 C. 6 D. 8

gatecse-2015-set3 theory-of-computation finite-automata normal minimal-state-automata

Answer key

10.10.19 Minimal State Automata: GATE CSE 2016 Set 2 | Question: 16

The number of states in the minimum sized DFA that accepts the language defined by the regular expression.

$$(0+1)^*(0+1)(0+1)^*$$

is ________.

gatecse-2016-set2 theory-of-computation finite-automata normal numerical-answers minimal-state-automata

Answer key

10.10.20 Minimal State Automata: GATE CSE 2017 Set 1 | Question: 22

Consider the language L given by the regular expression $(a+b)^*b(a+b)$ over the alphabet $\{a,b\}$. The smallest number of states needed in a deterministic finite-state automaton (DFA) accepting L is ___________ .

gatecse-2017-set1 theory-of-computation finite-automata numerical-answers minimal-state-automata

Answer key

10.10.21 Minimal State Automata: GATE CSE 2017 Set 2 | Question: 25

The minimum possible number of states of a deterministic finite automaton that accepts the regular language L = $\{w_1aw_2$ | $w_1, w_2 \in \{a,b\}^*$, $|w_1| = 2, |w_2| \geq 3\}$ is ______________ .

theory-of-computation gatecse-2017-set2 finite-automata numerical-answers minimal-state-automata

Answer key

10.10.22 Minimal State Automata: GATE CSE 2018 | Question: 6

Let N be an NFA with n states. Let k be the number of states of a minimal DFA which is equivalent to N. Which one of the following is necessarily true?

A. $k \geq 2^n$
B. $k \geq n$
C. $k \leq n^2$
D. $k \leq 2^n$

gatecse-2018 theory-of-computation minimal-state-automata normal one-mark

Answer key

10.10.23 Minimal State Automata: GATE CSE 2019 | Question: 48

Let Σ be the set of all bijections from $\{1,\dots,5\}$ to $\{1,\dots,5\}$, where id denotes the identity function, i.e. $id(j) = j, \forall j$. Let $\circ$ denote composition on functions. For a string $x = x_1 x_2 \dots x_n \in \Sigma^n, n \geq 0$, let $\pi(x) = x_1 \circ x_2 \circ \dots \circ x_n$. Consider the language $L = \{x \in \Sigma^* \mid \pi(x) = id\}$. The minimum number of states in any DFA accepting L is _______

gatecse-2019 numerical-answers theory-of-computation finite-automata minimal-state-automata difficult two-marks

Answer key

10.10.24 Minimal State Automata: GATE CSE 2023 | Question: 53

Consider the language L over the alphabet $\{0,1\}$, given below:

$$L = \{w \in \{0,1\}^* \mid w \text{ does not contain three or more consecutive } 1\text{'s}\}.$$

The minimum number of states in a Deterministic Finite-State Automaton (DFA) for L is ____________.

gatecse-2023 theory-of-computation minimal-state-automata numerical-answers two-marks

Answer key

10.10.25 Minimal State Automata: GATE IT 2008 | Question: 6

Let N be an NFA with n states and let M be the minimized DFA with m states recognizing the same language. Which of the following in NECESSARILY true?

A. $m \leq 2^n$
B. $n \leq m$
C. M has one accept state
D. $m = 2^n$

gateit-2008 theory-of-computation finite-automata normal minimal-state-automata

Answer key

10.11 Non Determinism (6)

10.11.1 Non Determinism: GATE CSE 1992 | Question: 02,xx

In which of the cases stated below is the following statement true?
"For every non-deterministic machine M_1 there exists an equivalent deterministic machine M_2 recognizing the same language".

A. M_1 is non-deterministic finite automaton.
B. M_1 is non-deterministic PDA.
C. M_1 is a non-deterministic Turing machine.
D. For no machines M_1 and M_2, the above statement true.

gate1992 theory-of-computation easy non-determinism multiple-selects

Answer key

10.11.2 Non Determinism: GATE CSE 1994 | Question: 1.16

Which of the following conversions is not possible (algorithmically)?

A. Regular grammar to context free grammar
B. Non-deterministic FSA to deterministic FSA
C. Non-deterministic PDA to deterministic PDA
D. Non-deterministic Turing machine to deterministic Turing machine

gate1994 theory-of-computation easy non-determinism

Answer key

10.11.3 Non Determinism: GATE CSE 1998 | Question: 1.11

Regarding the power of recognition of languages, which of the following statements is false?

A. The non-deterministic finite-state automata are equivalent to deterministic finite-state automata.
B. Non-deterministic Push-down automata are equivalent to deterministic Push-down automata.
C. Non-deterministic Turing machines are equivalent to deterministic Turing machines.
D. Multi-tape Turing machines are available are equivalent to Single-tape Turing machines.

gate1998 theory-of-computation easy non-determinism

Answer key

10.11.4 Non Determinism: GATE CSE 2005 | Question: 54

Let N_f and N_p denote the classes of languages accepted by non-deterministic finite automata and non-deterministic push-down automata, respectively. Let D_f and D_p denote the classes of languages accepted by deterministic finite automata and deterministic push-down automata respectively. Which one of the following is TRUE?

A. $D_f \subset N_f \text{ and } D_p \subset N_p$
B. $D_f \subset N_f \text{ and } D_p = N_p$
C. $D_f = N_f \text{ and } D_p = N_p$
D. $D_f = N_f \text{ and } D_p \subset N_p$

gatecse-2005 theory-of-computation easy non-determinism

Answer key

10.11.5 Non Determinism: GATE CSE 2011 | Question: 8

Which of the following pairs have **DIFFERENT** expressive power?

A. Deterministic finite automata (DFA) and Non-deterministic finite automata (NFA)
B. Deterministic push down automata (DPDA) and Non-deterministic push down automata (NPDA)
C. Deterministic single tape Turing machine and Non-deterministic single tape Turing machine

D. Single tape Turing machine and multi-tape Turing machine

gatecse-2011 theory-of-computation easy non-determinism

Answer key☟

10.11.6 Non Determinism: GATE IT 2004 | Question: 9

Which one of the following statements is FALSE?

A. There exist context-free languages such that all the context-free grammars generating them are ambiguous
B. An unambiguous context-free grammar always has a unique parse tree for each string of the language generated by it
C. Both deterministic and non-deterministic pushdown automata always accept the same set of languages
D. A finite set of string from some alphabet is always a regular language

gateit-2004 theory-of-computation easy non-determinism

Answer key☟

10.12 Number of States (1)

10.12.1 Number of States: GATE CSE 2025 | Set 2 | Question: 50

Let $\Sigma = \{1, 2, 3, 4\}$. For $x \in \Sigma^*$, let $\text{prod}(x)$ be the product of symbols in x modulo 7. We take $\text{prod}(\epsilon) = 1$, where ϵ is the null string.

For example, $\text{prod}(124) = (1 \times 2 \times 4) \bmod 7 = 1$.

Define $L = \{x \in \Sigma^* \mid \text{prod}(x) = 2\}$.

The number of states in a minimum state DFA for L is __________ . (Answer in integer)

gatecse2025-set2 theory-of-computation finite-automata number-of-states numerical-answers two-marks

Answer key☟

10.13 Pumping Lemma (2)

10.13.1 Pumping Lemma: GATE CSE 2019 | Question: 15

For $\Sigma = \{a, b\}$, let us consider the regular language $L = \{x \mid x = a^{2+3k} \text{ or } x = b^{10+12k}, k \geq 0\}$. Which one of the following can be a pumping length (the constant guaranteed by the pumping lemma) for L ?

A. 3 B. 5 C. 9 D. 24

gatecse-2019 theory-of-computation pumping-lemma one-mark

Answer key☟

10.13.2 Pumping Lemma: GATE IT 2005 | Question: 40

A language L satisfies the Pumping Lemma for regular languages, and also the Pumping Lemma for context-free languages. Which of the following statements about L is TRUE?

A. L is necessarily a regular language.
B. L is necessarily a context-free language, but not necessarily a regular language.
C. L is necessarily a non-regular language.
D. None of the above

gateit-2005 theory-of-computation pumping-lemma easy

Answer key☟

10.14 Pushdown Automata (15)

10.14.1 Pushdown Automata: GATE CSE 1996 | Question: 13

Let $Q = (\{q_1, q_2\}, \{a, b\}, \{a, b, \perp\}, \delta, \perp, \phi)$ be a pushdown automaton accepting by empty stack for the language which is the set of all nonempty even palindromes over the set $\{a, b\}$. Below is an incomplete specification of the transitions δ. Complete the specification. The top of the stack is assumed to be at the right end of the string representing stack contents.

1. $\delta(q_1, a, \perp) = \{(q_1, \perp a)\}$
2. $\delta(q_1, b, \perp) = \{(q_1, \perp b)\}$
3. $\delta(q_1, a, a) = \{(q_1, aa)\}$
4. $\delta(q_1, b, a) = \{(q_1, ab)\}$
5. $\delta(q_1, a, b) = \{(q_1, ba)\}$
6. $\delta(q_1, b, b) = \{(q_1, bb)\}$
7. $\delta(q_1, a, a) = \{(\dots, \dots)\}$
8. $\delta(q_1, b, b) = \{(\dots, \dots)\}$
9. $\delta(q_2, a, a) = \{(q_2, \epsilon)\}$
10. $\delta(q_2, b, b) = \{(q_2, \epsilon)\}$
11. $\delta(q_2, \epsilon, \perp) = \{(q_2, \epsilon)\}$

gate1996 theory-of-computation pushdown-automata normal descriptive

Answer key

10.14.2 Pushdown Automata: GATE CSE 1997 | Question: 6.6

Which of the following languages over $\{a, b, c\}$ is accepted by a deterministic pushdown automata?

A. $\{wcw^R \mid w \in \{a,b\}^*\}$
B. $\{ww^R \mid w \in \{a,b,c\}^*\}$
C. $\{a^nb^nc^n \mid n \geq 0\}$
D. $\{w \mid w \text{ is a palindrome over } \{a,b,c\}\}$

Note: w^R is the string obtained by reversing $'w'$.

gate1997 theory-of-computation pushdown-automata easy

Answer key

10.14.3 Pushdown Automata: GATE CSE 1998 | Question: 13

Let $M = (\{q_0, q_1\}, \{0, 1\}, \{z_0, X\}, \delta, q_0, z_0, \phi)$ be a Pushdown automation where δ is given by

$\delta(q_0, 1, z_0) = \{(q_0, Xz_0)\}$

$\delta(q_0, \epsilon, z_0) = \{(q_0, \epsilon)\}$

$\delta(q_0, 1, X) = \{(q_0, XX)\}$

$\delta(q_1, 1, X) = \{(q_1, \epsilon)\}$

$\delta(q_0, 0, X) = \{(q_1, X)\}$

$\delta(q_0, 0, z_0) = \{(q_0, z_0)\}$

a. What is the language accepted by this PDA by empty stack?
b. Describe informally the working of the PDA

gate1998 theory-of-computation pushdown-automata descriptive

Answer key

10.14.4 Pushdown Automata: GATE CSE 1999 | Question: 1.6

Let L_1 be the set of all languages accepted by a PDA by final state and L_2 the set of all languages accepted by empty stack. Which of the following is true?

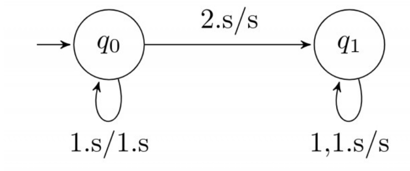
A. $L_1 = L_2$
B. $L_1 \supset L_2$
C. $L_1 \subset L_2$
D. None

normal theory-of-computation gate1999 pushdown-automata

Answer key

10.14.5 Pushdown Automata: GATE CSE 2000 | Question: 8

A push down automation (pda) is given in the following extended notation of finite state diagram:



The nodes denote the states while the edges denote the moves of the pda. The edge labels are of the form $d,\ s/s'$ where d is the input symbol read and s, s' are the stack contents before and after the move. For example the edge labeled $1, s/1.s$ denotes the move from state q_0 to q_0 in which the input symbol 1 is read and pushed to the stack.

A. Introduce two edges with appropriate labels in the above diagram so that the resulting pda accepts the language $\left\{x2x^R \mid x \in \{0,1\}^*, x^R \text{ denotes reverse of x}\right\}$, by empty stack.
B. Describe a non-deterministic pda with three states in the above notation that accept the language $\{0^n1^m \mid n \leq m \leq 2n\}$ by empty stack

gatecse-2000 theory-of-computation descriptive pushdown-automata

Answer key

10.14.6 Pushdown Automata: GATE CSE 2001 | Question: 6

Give a deterministic PDA for the language $L = \{a^ncb^{2n} \mid n \geq 1\}$ over the alphabet $\Sigma = \{a, b, c\}$. Specify the acceptance state.

gatecse-2001 theory-of-computation normal pushdown-automata descriptive

Answer key

10.14.7 Pushdown Automata: GATE CSE 2009 | Question: 16, ISRO2017-12

Which one of the following is FALSE?

A. There is a unique minimal DFA for every regular language
B. Every NFA can be converted to an equivalent PDA.
C. Complement of every context-free language is recursive.
D. Every nondeterministic PDA can be converted to an equivalent deterministic PDA.

gatecse-2009 theory-of-computation easy isro2017 pushdown-automata

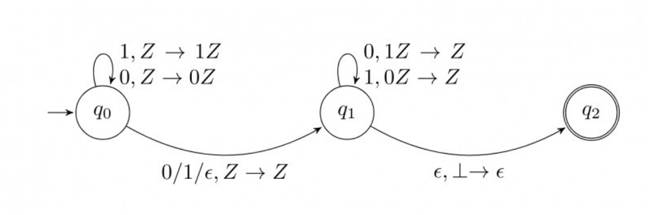
Answer key

10.14.8 Pushdown Automata: GATE CSE 2015 Set 1 | Question: 51

Consider the NPDA

$$\langle Q = \{q_0, q_1, q_2\}, \Sigma = \{0, 1\}, \Gamma = \{0, 1, \perp\}, \delta, q_0, \perp, F = \{q_2\}\rangle$$

, where (as per usual convention) Q is the set of states, Σ is the input alphabet, Γ is the stack alphabet, δ is the state transition function q_0 is the initial state, $\perp$ is the initial stack symbol, and F is the set of accepting states. The state transition is as follows:



Which one of the following sequences must follow the string 101100 so that the overall string is accepted by the automaton?

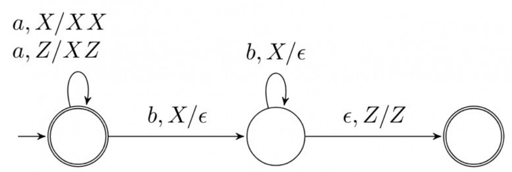
A. 10110 B. 10010 C. 01010 D. 01001

gatecse-2015-set1 theory-of-computation pushdown-automata normal

Answer key

10.14.9 Pushdown Automata: GATE CSE 2016 Set 1 | Question: 43

Consider the transition diagram of a PDA given below with input alphabet $\Sigma = \{a, b\}$ and stack alphabet $\Gamma = \{X, Z\}$. Z is the initial stack symbol. Let L denote the language accepted by the PDA



Which one of the following is **TRUE**?

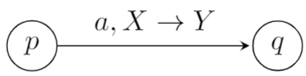
A. $L = \{a^n b^n \mid n \geq 0\}$ and is not accepted by any finite automata
B. $L = \{a^n \mid n \geq 0\} \cup \{a^n b^n \mid n \geq 0\}$ and is not accepted by any deterministic PDA
C. L is not accepted by any Turing machine that halts on every input
D. $L = \{a^n \mid n \geq 0\} \cup \{a^n b^n \mid n \geq 0\}$ and is deterministic context-free

gatecse-2016-set1 theory-of-computation pushdown-automata normal

Answer key

10.14.10 Pushdown Automata: GATE CSE 2021 Set 1 | Question: 51

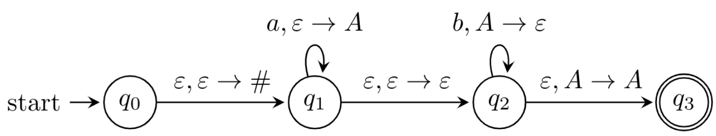
In a pushdown automaton $P = (Q, \Sigma, \Gamma, \delta, q_0, F)$, a transition of the form,



where $p, q \in Q$, $a \in \Sigma \cup \{\epsilon\}$, and $X, Y \in \Gamma \cup \{\epsilon\}$, represents

$$(q, Y) \in \delta(p, a, X).$$

Consider the following pushdown automaton over the input alphabet $\Sigma = \{a, b\}$ and stack alphabet $\Gamma = \{\#, A\}$.



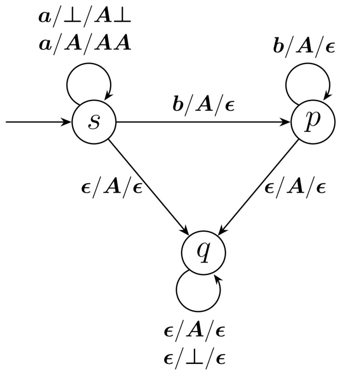
The number of strings of length 100 accepted by the above pushdown automaton is ___________

gatecse-2021-set1 theory-of-computation pushdown-automata numerical-answers two-marks

Answer key

10.14.11 Pushdown Automata: GATE CSE 2023 | Question: 30

Consider the pushdown automaton (PDA) P below, which runs on the input alphabet $\{a, b\}$, has stack alphabet $\{\perp, A\}$, and has three states $\{s, p, q\}$, with s being the start state. A transition from state u to state v, labelled $c/X/\gamma$, where c is an input symbol or ϵ, X is a stack symbol, and γ is a string of stack symbols, represents the fact that in state u, the (PDA) can read c from the input, with X on the top of its stack, pop X from the stack, push in the string γ on the stack, and go to state v. In the initial configuration, the stack has only the symbol $\perp$ in it. The (PDA) accepts by empty stack.



Which one of the following options correctly describes the language accepted by P?

A. $\{a^m b^n \mid 1 \leq m \text{ and } n < m\}$
B. $\{a^m b^n \mid 0 \leq n \leq m\}$
C. $\{a^m b^n \mid 0 \leq m \text{ and } 0 \leq n\}$
D. $\{a^m \mid 0 \leq m\} \cup \{b^n \mid 0 \leq n\}$

gatecse-2023 theory-of-computation pushdown-automata two-marks

Answer key☟

10.14.12 Pushdown Automata: GATE IT 2004 | Question: 40

Let $M = (K, \Sigma, \Gamma, \Delta, s, F)$ be a pushdown automaton, where

$K = (s, f), F = \{f\}, \Sigma = \{a, b\}, \Gamma = \{a\}$ and
$\Delta = \{((s, a, \epsilon), (s, a)), ((s, b, \epsilon), (s, a)), ((s, a, a), (f, \epsilon)), ((f, a, a), (f, \epsilon)), ((f, b, a), (f, \epsilon))\}$.

Which one of the following strings is not a member of $L(M)$?

A. aaa B. $aabab$ C. $baaba$ D. bab

gateit-2004 theory-of-computation pushdown-automata normal

Answer key☟

10.14.13 Pushdown Automata: GATE IT 2005 | Question: 38

Let P be a non-deterministic push-down automaton (NPDA) with exactly one state, q, and exactly one symbol, Z, in its stack alphabet. State q is both the starting as well as the accepting state of the PDA. The stack is initialized with one Z before the start of the operation of the PDA. Let the input alphabet of the PDA be Σ. Let $L(P)$ be the language accepted by the PDA by reading a string and reaching its accepting state. Let $N(P)$ be the language accepted by the PDA by reading a string and emptying its stack.
Which of the following statements is TRUE?

A. $L(P)$ is necessarily Σ^* but $N(P)$ is not necessarily Σ^*.
B. $N(P)$ is necessarily Σ^* but $L(P)$ is not necessarily Σ^*.
C. Both $L(P)$ and $N(P)$ are necessarily Σ^*.
D. Neither $L(P)$ nor $N(P)$ are necessarily Σ^*

gateit-2005 theory-of-computation pushdown-automata normal

Answer key

10.14.14 Pushdown Automata: GATE IT 2006 | Question: 31

Which of the following languages is accepted by a non-deterministic pushdown automaton (PDA) but NOT by a deterministic PDA?

A. $\{a^n b^n c^n \mid n \geq 0\}$
B. $\{a^l b^m c^n \mid l \neq m \text{ or } m \neq n\}$
C. $\{a^n b^n \mid n \geq 0\}$
D. $\{a^m b^n \mid m, n \geq 0\}$

gateit-2006 theory-of-computation pushdown-automata normal

Answer key

10.14.15 Pushdown Automata: GATE IT 2006 | Question: 33

Consider the pushdown automaton (PDA) below which runs over the input alphabet (a, b, c). It has the stack alphabet $\{Z_0, X\}$ where Z_0 is the bottom-of-stack marker. The set of states of the PDA is (s, t, u, f) where s is the start state and f is the final state. The PDA accepts by final state. The transitions of the PDA given below are depicted in a standard manner. For example, the transition $(s, b, X) \rightarrow (t, XZ_0)$ means that if the PDA is in state s and the symbol on the top of the stack is X, then it can read b from the input and move to state t after popping the top of stack and pushing the symbols Z_0 and X (in that order) on the stack.

$(s, a, Z_0) \rightarrow (s, XXZ_0)$
$(s, \epsilon, Z_0) \rightarrow (f, \epsilon)$
$(s, a, X) \rightarrow (s, XXX)$
$(s, b, X) \rightarrow (t, \epsilon)$
$(t, b, X) \rightarrow (t, \epsilon)$
$(t, c, X) \rightarrow (u, \epsilon)$
$(u, c, X) \rightarrow (u, \epsilon)$
$(u, \epsilon, Z_0) \rightarrow (f, \epsilon)$

The language accepted by the PDA is

A. $\{a^l b^m c^n \mid l = m = n\}$
B. $\{a^l b^m c^n \mid l = m\}$
C. $\{a^l b^m c^n \mid 2l = m + n\}$
D. $\{a^l b^m c^n \mid m = n\}$

gateit-2006 theory-of-computation pushdown-automata normal

Answer key

10.15 Recursive and Recursively Enumerable Languages (16)

10.15.1 Recursive and Recursively Enumerable Languages: GATE CSE 1990 | Question: 3-vi

Recursive languages are:

A. A proper superset of context free languages.
B. Always recognizable by pushdown automata.
C. Also called type 0 languages.
D. Recognizable by Turing machines.

gate1990 normal theory-of-computation turing-machine recursive-and-recursively-enumerable-languages multiple-selects

Answer key

10.15.2 Recursive and Recursively Enumerable Languages: GATE CSE 2003 | Question: 13

Nobody knows yet if $P = NP$. Consider the language L defined as follows.

$$L = \begin{cases} (0+1)^* & \text{if } P = NP \\ \phi & otherwise \end{cases}$$

Which of the following statements is true?

A. L is recursive
B. L is recursively enumerable but not recursive
C. L is not recursively enumerable
D. Whether L is recursively enumerable or not will be known after we find out if $P = NP$

gatecse-2003 theory-of-computation normal recursive-and-recursively-enumerable-languages

Answer key

10.15.3 Recursive and Recursively Enumerable Languages: GATE CSE 2003 | Question: 15

If the strings of a language L can be effectively enumerated in lexicographic (i.e., alphabetic) order, which of the following statements is true?

A. L is necessarily finite
B. L is regular but not necessarily finite
C. L is context free but not necessarily regular
D. L is recursive but not necessarily context-free

theory-of-computation gatecse-2003 normal recursive-and-recursively-enumerable-languages

Answer key

10.15.4 Recursive and Recursively Enumerable Languages: GATE CSE 2003 | Question: 54

Define languages L_0 and L_1 as follows :

- $L_0 = \{\langle M, w, 0 \rangle \mid M \text{ halts on } w\}$
- $L_1 = \{\langle M, w, 1 \rangle \mid M \text{ does not halts on } w\}$

Here $\langle M, w, i \rangle$ is a triplet, whose first component M is an encoding of a Turing Machine, second component w is a string, and third component i is a bit.

Let $L = L_0 \cup L_1$. Which of the following is true?

A. L is recursively enumerable, but L' is not
B. L' is recursively enumerable, but L is not
C. Both L and L' are recursive
D. Neither L nor L' is recursively enumerable

theory-of-computation recursive-and-recursively-enumerable-languages gatecse-2003 difficult

Answer key

10.15.5 Recursive and Recursively Enumerable Languages: GATE CSE 2004 | Question: 89

L_1 is a recursively enumerable language over Σ. An algorithm A effectively enumerates its words as $\omega_1, \omega_2, \omega_3, \ldots$. Define another language L_2 over $\Sigma \cup \{\#\}$ as $\{w_i \# w_j \mid w_i, w_j \in L_1, i < j\}$. Here # is new symbol. Consider the following assertions.

- S_1 : L_1 is recursive implies L_2 is recursive
- S_2 : L_2 is recursive implies L_1 is recursive

Which of the following statements is true?

A. Both S_1 and S_2 are true
B. S_1 is true but S_2 is not necessarily true
C. S_2 is true but S_1 is not necessarily true
D. Neither is necessarily true

gatecse-2004 theory-of-computation recursive-and-recursively-enumerable-languages difficult

Answer key

10.15.6 Recursive and Recursively Enumerable Languages: GATE CSE 2005 | Question: 56

Let L_1 be a recursive language, and let L_2 be a recursively enumerable but not a recursive language. Which one of the following is TRUE?

A. L_1' is recursive and L_2' is recursively enumerable
B. L_1' is recursive and L_2' is not recursively enumerable
C. L_1' and L_2' are recursively enumerable

D. L_1' is recursively enumerable and L_2' is recursive

gatecse-2005 theory-of-computation recursive-and-recursively-enumerable-languages easy

Answer key☟

10.15.7 Recursive and Recursively Enumerable Languages: GATE CSE 2008 | Question: 13, ISRO2016-36

If L and $\overline{L}$ are recursively enumerable then L is

A. regular
B. context-free
C. context-sensitive
D. recursive

gatecse-2008 theory-of-computation easy isro2016 recursive-and-recursively-enumerable-languages

Answer key☟

10.15.8 Recursive and Recursively Enumerable Languages: GATE CSE 2008 | Question: 48

Which of the following statements is false?

A. Every NFA can be converted to an equivalent DFA
B. Every non-deterministic Turing machine can be converted to an equivalent deterministic Turing machine
C. Every regular language is also a context-free language
D. Every subset of a recursively enumerable set is recursive

gatecse-2008 theory-of-computation easy recursive-and-recursively-enumerable-languages

Answer key☟

10.15.9 Recursive and Recursively Enumerable Languages: GATE CSE 2010 | Question: 17

Let L_1 be the recursive language. Let L_2 and L_3 be languages that are recursively enumerable but not recursive. Which of the following statements is not necessarily true?

A. $L_2 - L_1$ is recursively enumerable.
B. $L_1 - L_3$ is recursively enumerable.
C. $L_2 \cap L_3$ is recursively enumerable.
D. $L_2 \cup L_3$ is recursively enumerable.

gatecse-2010 theory-of-computation recursive-and-recursively-enumerable-languages decidability normal

Answer key☟

10.15.10 Recursive and Recursively Enumerable Languages: GATE CSE 2014 Set 1 | Question: 35

Let L be a language and $\bar{L}$ be its complement. Which one of the following is **NOT** a viable possibility?

A. Neither L nor $\bar{L}$ is recursively enumerable $(r.e.)$.
B. One of L and $\bar{L}$ is r.e. but not recursive; the other is not r.e.
C. Both L and $\bar{L}$ are r.e. but not recursive.
D. Both L and $\bar{L}$ are recursive.

gatecse-2014-set1 theory-of-computation easy recursive-and-recursively-enumerable-languages

Answer key☟

10.15.11 Recursive and Recursively Enumerable Languages: GATE CSE 2014 Set 2 | Question: 16

Let $A \leq_m B$ denotes that language A is mapping reducible (also known as many-to-one reducible) to language B. Which one of the following is FALSE?

A. If $A \leq_m B$ and B is recursive then A is recursive.
B. If $A \leq_m B$ and A is undecidable then B is undecidable.

C. If $A \leq_m B$ and B is recursively enumerable then A is recursively enumerable.
D. If $A \leq_m B$ and B is not recursively enumerable then A is not recursively enumerable.

gatecse-2014-set2 theory-of-computation recursive-and-recursively-enumerable-languages normal

Answer key☟

10.15.12 Recursive and Recursively Enumerable Languages: GATE CSE 2014 Set 2 | Question: 35

Let $\langle M \rangle$ be the encoding of a Turing machine as a string over $\Sigma = \{0, 1\}$. Let

$$L = \{\langle M \rangle \mid M \text{ is a Turing machine} \\ \text{that accepts a string of length } 2014\}.$$

Then L is:

A. decidable and recursively enumerable
B. undecidable but recursively enumerable
C. undecidable and not recursively enumerable
D. decidable but not recursively enumerable

gatecse-2014-set2 theory-of-computation recursive-and-recursively-enumerable-languages normal

Answer key☟

10.15.13 Recursive and Recursively Enumerable Languages: GATE CSE 2015 Set 1 | Question: 3

For any two languages L_1 and L_2 such that L_1 is context-free and L_2 is recursively enumerable but not recursive, which of the following is/are necessarily true?

I. $\bar{L}_1$ (Complement of L_1) is recursive
II. $\bar{L}_2$ (Complement of L_2) is recursive
III. $\bar{L}_1$ is context-free
IV. $\bar{L}_1 \cup L_2$ is recursively enumerable

A. I only
B. III only
C. III and IV only
D. I and IV only

gatecse-2015-set1 theory-of-computation recursive-and-recursively-enumerable-languages normal

Answer key☟

10.15.14 Recursive and Recursively Enumerable Languages: GATE CSE 2016 Set 2 | Question: 44

Consider the following languages.

- $L_1 = \{\langle M \rangle \mid M \text{ takes at least 2016 steps on some input}\}$,
- $L_2 = \{\langle M \rangle \mid M \text{ takes at least 2016 steps on all inputs}\}$ and
- $L_3 = \{\langle M \rangle \mid M \text{ accepts } \epsilon\}$,

where for each Turing machine M, $\langle M \rangle$ denotes a specific encoding of M. Which one of the following is TRUE?

A. L_1 is recursive and L_2, L_3 are not recursive
B. L_2 is recursive and L_1, L_3 are not recursive
C. L_1, L_2 are recursive and L_3 is not recursive
D. L_1, L_2, L_3 are recursive

gatecse-2016-set2 theory-of-computation recursive-and-recursively-enumerable-languages

Answer key☟

10.15.15 Recursive and Recursively Enumerable Languages: GATE CSE 2021 Set 1 | Question: 12

Let $\langle M \rangle$ denote an encoding of an automaton M. Suppose that $\Sigma = \{0, 1\}$. Which of the following languages is/are NOT recursive?

A. $L = \{\langle M \rangle \mid M \text{ is a DFA such that } L(M) = \emptyset\}$

B. $L = \{\langle M \rangle \mid M$ is a DFA such that $L(M) = \Sigma^*\}$
C. $L = \{\langle M \rangle \mid M$ is a PDA such that $L(M) = \emptyset\}$
D. $L = \{\langle M \rangle \mid M$ is a PDA such that $L(M) = \Sigma^*\}$

gatecse-2021-set1 multiple-selects theory-of-computation recursive-and-recursively-enumerable-languages one-mark

Answer key

10.15.16 Recursive and Recursively Enumerable Languages: GATE CSE 2021 Set 1 | Question: 39

For a Turing machine M, $\langle M \rangle$ denotes an encoding of M. Consider the following two languages.

$$L_1 = \{\langle M \rangle \mid M \text{ takes more than 2021 steps on all inputs}\}$$
$$L_2 = \{\langle M \rangle \mid M \text{ takes more than 2021 steps on some input}\}$$

Which one of the following options is correct?

A. Both L_1 and L_2 are decidable
B. L_1 is decidable and L_2 is undecidable
C. L_1 is undecidable and L_2 is decidable
D. Both L_1 and L_2 are undecidable

gatecse-2021-set1 theory-of-computation recursive-and-recursively-enumerable-languages decidability easy two-marks

Answer key

10.16 Reduction (2)

10.16.1 Reduction: GATE CSE 2005 | Question: 45

Consider three decision problems P_1, P_2 and P_3. It is known that P_1 is decidable and P_2 is undecidable. Which one of the following is TRUE?

A. P_3 is decidable if P_1 is reducible to P_3
B. P_3 is undecidable if P_3 is reducible to P_2
C. P_3 is undecidable if P_2 is reducible to P_3
D. P_3 is decidable if P_3 is reducible to P_2's complement

gatecse-2005 theory-of-computation decidability normal reduction

Answer key

10.16.2 Reduction: GATE CSE 2016 Set 1 | Question: 44

Let X be a recursive language and Y be a recursively enumerable but not recursive language. Let W and Z be two languages such that $\overline{Y}$ reduces to W, and Z reduces to $\overline{X}$ (reduction means the standard many-one reduction). Which one of the following statements is TRUE?

A. W can be recursively enumerable and Z is recursive.
B. W can be recursive and Z is recursively enumerable.
C. W is not recursively enumerable and Z is recursive.
D. W is not recursively enumerable and Z is not recursive.

gatecse-2016-set1 theory-of-computation easy recursive-and-recursively-enumerable-languages reduction

Answer key

10.17 Regular Expression (29)

10.17.1 Regular Expression: GATE CSE 1987 | Question: 10d

Give a regular expression over the alphabet $\{0, 1\}$ to denote the set of proper non-null substrings of the string 0110.

gate1987 theory-of-computation regular-expression descriptive

Answer key

10.17.2 Regular Expression: GATE CSE 1991 | Question: 03,xiii

Let $r = 1(1+0)^*$, $s = 11^*0$ and $t = 1^*0$ be three regular expressions. Which one of the following is true?

A. $L(s) \subseteq L(r)$ and $L(s) \subseteq L(t)$
B. $L(r) \subseteq L(s)$ and $L(s) \subseteq L(t)$
C. $L(s) \subseteq L(t)$ and $L(s) \subseteq L(r)$
D. $L(t) \subseteq L(s)$ and $L(s) \subseteq L(r)$
E. None of the above

gate1991 theory-of-computation regular-expression normal multiple-selects

Answer key

10.17.3 Regular Expression: GATE CSE 1992 | Question: 02,xvii

Which of the following regular expression identities is/are TRUE?

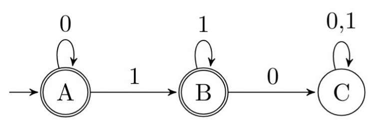
A. $r^{(*)} = r^*$
B. $(r^*s^*) = (r+s)^*$
C. $(r+s)^* = r^* + s^*$
D. $r^*s^* = r^* + s^*$

gate1992 theory-of-computation regular-expression easy multiple-selects

Answer key

10.17.4 Regular Expression: GATE CSE 1994 | Question: 2.10

The regular expression for the language recognized by the finite state automaton of figure is ________



gate1994 theory-of-computation finite-automata regular-expression easy fill-in-the-blanks

Answer key

10.17.5 Regular Expression: GATE CSE 1995 | Question: 1.9 , ISRO2017-13

In some programming language, an identifier is permitted to be a letter followed by any number of letters or digits. If L and D denote the sets of letters and digits respectively, which of the following expressions defines an identifier?

A. $(L+D)^+$
B. $(L.D)^*$
C. $L(L+D)^*$
D. $L(L.D)^*$

gate1995 theory-of-computation regular-expression easy isro2017

Answer key

10.17.6 Regular Expression: GATE CSE 1996 | Question: 1.8

Which two of the following four regular expressions are equivalent? (ε is the empty string).

i. $(00)^*(\varepsilon+0)$
ii. $(00)^*$
iii. 0^*
iv. $0(00)^*$

A. (i) and (ii)
B. (ii) and (iii)
C. (i) and (iii)
D. (iii) and (iv)

gate1996 theory-of-computation regular-expression easy

Answer key

10.17.7 Regular Expression: GATE CSE 1997 | Question: 6.4

Which one of the following regular expressions over $\{0,1\}$ denotes the set of all strings not containing 100 as substring?

A. $0^*(1+0)^*$ B. 0^*1010^* C. $0^*1^*01^*$ D. $0^*(10+1)^*$

gate1997 theory-of-computation regular-expression normal

Answer key

10.17.8 Regular Expression: GATE CSE 1998 | Question: 1.12

The string 1101 does not belong to the set represented by

A. $110^*(0+1)$
B. $1(0+1)^*101$
C. $(10)^*(01)^*(00+11)^*$
D. $(00+(11)^*0)^*$

gate1998 theory-of-computation regular-expression easy multiple-selects

Answer key

10.17.9 Regular Expression: GATE CSE 1998 | Question: 1.9

If the regular set A is represented by $A=(01+1)^*$ and the regular set B is represented by $B=((01)^*1^*)^*$, which of the following is true?

A. $A \subset B$
B. $B \subset A$
C. A and B are incomparable
D. $A=B$

gate1998 theory-of-computation regular-expression normal

Answer key

10.17.10 Regular Expression: GATE CSE 1998 | Question: 3b

Give a regular expression for the set of binary strings where every 0 is immediately followed by exactly k 1's and preceded by at least k 1's (k is a fixed integer)

gate1998 theory-of-computation regular-expression easy descriptive

Answer key

10.17.11 Regular Expression: GATE CSE 2000 | Question: 1.4

Let S and T be languages over $\Sigma=\{a,b\}$ represented by the regular expressions $(a+b^*)^*$ and $(a+b)^*$, respectively. Which of the following is true?

A. $S \subset T$ B. $T \subset S$ C. $S=T$ D. $S \cap T=\phi$

gatecse-2000 theory-of-computation regular-expression easy

Answer key

10.17.12 Regular Expression: GATE CSE 2003 | Question: 14

The regular expression $0^*(10^*)^*$ denotes the same set as

A. $(1^*0)^*1^*$
B. $0+(0+10)^*$
C. $(0+1)^*10(0+1)^*$
D. None of the above

gatecse-2003 theory-of-computation regular-expression easy

Answer key

10.17.13 Regular Expression: GATE CSE 2009 | Question: 15

Which one of the following languages over the alphabet $\{0,1\}$ is described by the regular expression: $(0+1)^*0(0+1)^*0(0+1)^*$?

A. The set of all strings containing the substring 00
B. The set of all strings containing at most two 0's
C. The set of all strings containing at least two 0's
D. The set of all strings that begin and end with either 0 or 1

gatecse-2009 theory-of-computation regular-expression easy

Answer key

10.17.14 Regular Expression: GATE CSE 2010 | Question: 39

Let $L = \{w \in (0+1)^* \mid w \text{ has even number of } 1s\}$. i.e., L is the set of all the bit strings with even numbers of 1s. Which one of the regular expressions below represents L?

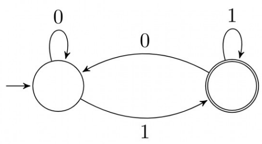
A. $(0^*10^*1)^*$
B. $0^*(10^*10^*)^*$
C. $0^*(10^*1)^*0^*$
D. $0^*1(10^*1)^*10^*$

gatecse-2010 theory-of-computation regular-expression normal

Answer key

10.17.15 Regular Expression: GATE CSE 2014 Set 1 | Question: 36

Which of the regular expressions given below represent the following DFA?



I. $0^*1(1+00^*1)^*$
II. $0^*1^*1+11^*0^*1$
III. $(0+1)^*1$

A. I and II only
B. I and III only
C. II and III only
D. I, II and III

gatecse-2014-set1 theory-of-computation regular-expression finite-automata easy

Answer key

10.17.16 Regular Expression: GATE CSE 2014 Set 3 | Question: 15

The length of the shortest string NOT in the language (over $\Sigma = \{a, b\}$) of the following regular expression is _______.

$$a^*b^*(ba)^*a^*$$

gatecse-2014-set3 theory-of-computation regular-expression numerical-answers easy

Answer key

10.17.17 Regular Expression: GATE CSE 2016 Set 1 | Question: 18

Which one of the following regular expressions represents the language: *the set of all binary strings having two consecutive* 0*'s and two consecutive* 1*'s*?

A. $(0+1)^*0011(0+1)^* + (0+1)^*1100(0+1)^*$
B. $(0+1)^*(00(0+1)^*11+11(0+1)^*00)(0+1)^*$
C. $(0+1)^*00(0+1)^* + (0+1)^*11(0+1)^*$
D. $00(0+1)^*11+11(0+1)^*00$

gatecse-2016-set1 theory-of-computation regular-expression normal

Answer key

10.17.18 Regular Expression: GATE CSE 2020 | Question: 7

Which one of the following regular expressions represents the set of all binary strings with an odd number of $1'$s?

A. $((0+1)^*1(0+1)^*1)^*10^*$
B. $(0^*10^*10^*)^*0^*1$
C. $10^*(0^*10^*10^*)^*$
D. $(0^*10^*10^*)^*10^*$

gatecse-2020 regular-expression normal theory-of-computation one-mark

Answer key

10.17.19 Regular Expression: GATE CSE 2021 Set 2 | Question: 47

Which of the following regular expressions represent(s) the set of all binary numbers that are divisible by three? Assume that the string ϵ is divisible by three.

A. $(0+1(01^*0)^*1)^*$

B. $(\cancel{0+11+10}(1+00)^*01)^*$

C. $(\cancel{0^*(1(01^*0)}^*1)^*)^*$

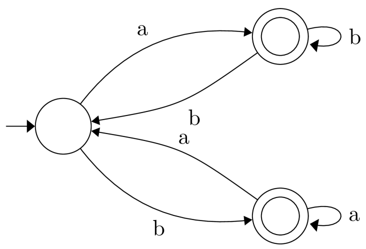
D. $(0+11+11(1+00)^*00)^*$

gatecse-2021-set2 multiple-selects theory-of-computation regular-expression two-marks

Answer key

10.17.20 Regular Expression: GATE CSE 2022 | Question: 2

Which one of the following regular expressions correctly represents the language of the finite automaton given below?



A. $ab^*bab^*+ba^*aba^*$

B. $(ab^*b)^*ab^*+(ba^*a)^*ba^*$

C. $(ab^*b+ba^*a)^*(a^*+b^*)$

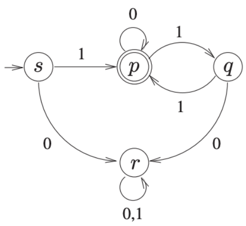
D. $(ba^*a+ab^*b)^*(ab^*+ba^*)$

gatecse-2022 theory-of-computation finite-automata regular-expression one-mark

Answer key

10.17.21 Regular Expression: GATE CSE 2023 | Question: 4

Consider the Deterministic Finite-state Automaton (DFA) $\mathcal{A}$ shown below. The DFA runs on the alphabet $\{0,1\}$, and has the set of states $\{s,p,q,r\}$, with s being the start state and p being the only final state.



Which one of the following regular expressions correctly describes the language accepted by $\mathcal{A}$?

A. $1(0^*11)^*$

B. $0(0+1)^*$

C. $1(0+11)^*$

D. $1(110^*)^*$

gatecse-2023 theory-of-computation regular-expression one-mark

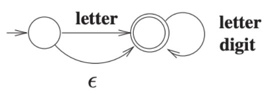
Answer key

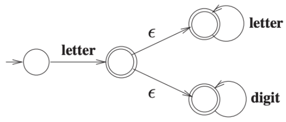
10.17.22 Regular Expression: GATE CSE 2023 | Question: 9

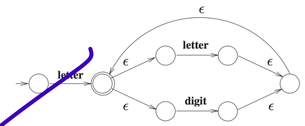
Consider the following definition of a lexical token **id** for an identifier in a programming language, using extended regular expressions:

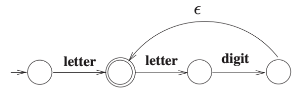
$$
\begin{aligned}
&\textbf{letter} && \rightarrow [\mathrm{A}-\mathrm{Za}-\mathrm{z}] \\
&\textbf{digit} && \rightarrow [0-9] \\
&\textbf{id} && \rightarrow \textbf{letter}\ (\ \textbf{letter}\ |\ \textbf{digit}\ )^*
\end{aligned}
$$

Which one of the following Non-deterministic Finite-state Automata with ϵ-transitions accepts the set of valid identifiers? (A double-circle denotes a final state)

A. 

B. 

C. 

D. 

gatecse-2023 theory-of-computation regular-expression one-mark

Answer key

10.17.23 Regular Expression: GATE CSE 2024 | Set 1 | Question: 51

Consider the following two regular expressions over the alphabet $\{0,1\}$:

$r = 0^* + 1^*$

44

$s = 01^* + 10^*$

The total number of strings of length less than or equal to 5, which are neither in r nor in s, is ________.

gatecse2024-set1 numerical-answers theory-of-computation regular-expression two-marks

Answer key

10.17.24 Regular Expression: GATE CSE 2024 | Set 2 | Question: 52

Let L_1 be the language represented by the regular expression $b^*ab^*(ab^*ab^*)^*$ and $L_2 = \{w \in (a+b)^* || w |\leq 4\}$, where $|w|$ denotes the length of string w. The number of strings in L_2 which are also in L_1 is __________.

5

gatecse2024-set2 numerical-answers theory-of-computation regular-expression two-marks

Answer key

10.17.25 Regular Expression: GATE IT 2004 | Question: 7

Which one of the following regular expressions is NOT equivalent to the regular expression $(a+b+c)^*$?

A. $(a^* + b^* + c^*)^*$
B. $(a^*b^*c^*)^*$
C. $((ab)^* + c^*)^*$
D. $(a^*b^* + c^*)^*$

gateit-2004 theory-of-computation regular-expression normal

Answer key

10.17.26 Regular Expression: GATE IT 2005 | Question: 5

Which of the following statements is TRUE about the regular expression 01^*0?

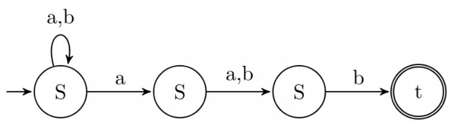
A. It represents a finite set of finite strings.
B. It represents an infinite set of finite strings.
C. It represents a finite set of infinite strings.
D. It represents an infinite set of infinite strings.

gateit-2005 theory-of-computation regular-expression easy

Answer key

10.17.27 Regular Expression: GATE IT 2006 | Question: 5

Which regular expression best describes the language accepted by the non-deterministic automaton below?



A. $(a+b)^*\ a(a+b)b$
B. $(abb)^*$
C. $(a+b)^*\ a(a+b)^*\ b(a+b)^*$
D. $(a+b)^*$

gateit-2006 theory-of-computation regular-expression normal

Answer key

10.17.28 Regular Expression: GATE IT 2007 | Question: 73

Consider the regular expression $R = (a+b)^*\ (aa+bb)\ (a+b)^*$

Which one of the regular expressions given below defines the same language as defined by the regular expression R ?

A. $(a(ba)^* + b(ab)^*)(a+b)^+$
B. $(a(ba)^* + b(ab)^*)^*(a+b)^*$
C. $(a(ba)^*(a+bb) + b(ab)^*(b+aa))(a+b)^*$
D. $(a(ba)^*(a+bb) + b(ab)^*(b+aa))(a+b)^+$

gateit-2007 theory-of-computation regular-expression normal

Answer key

10.17.29 Regular Expression: GATE IT 2008 | Question: 5

Which of the following regular expressions describes the language over $\{0,1\}$ consisting of strings that contain exactly two 1's?

A. $(0+1)^*\ 11(0+1)^*$
B. $0^*\ 110^*$
C. $0^*10^*10^*$
D. $(0+1)^*1(0+1)^*1(0+1)^*$

gateit-2008 theory-of-computation regular-expression easy

Answer key

10.18 Regular Grammar (3)

10.18.1 Regular Grammar: GATE CSE 1990 | Question: 15a

Is the language generated by the grammar G regular? If so, give a regular expression for it, else prove otherwise

- G:
  - $S \to aB$
  - $B \to bC$
  - $C \to xB$
  - $C \to c$

gate1990 descriptive theory-of-computation regular-language regular-grammar

Answer key

10.18.2 Regular Grammar: GATE CSE 2015 Set 2 | Question: 35

Consider the alphabet $\Sigma = \{0,1\}$, the null/empty string λ and the set of strings $X_0, X_1,$ and X_2 generated by the corresponding non-terminals of a regular grammar. $X_0, X_1,$ and X_2 are related as follows.

- $X_0 = 1X_1$
- $X_1 = 0X_1 + 1X_2$
- $X_2 = 0X_1 + \{\lambda\}$

Which one of the following choices precisely represents the strings in X_0?

A. $10(0^* + (10)^*)1$
B. $10(0^* + (10)^*)^*1$
C. $1(0 + 10)^*1$
D. $10(0 + 10)^*1 + 110(0 + 10)^*1$

gatecse-2015-set2 theory-of-computation regular-grammar normal

Answer key☟

10.18.3 Regular Grammar: GATE IT 2006 | Question: 29

Consider the regular grammar below

$S \to bS \mid aA \mid \epsilon$
$A \to aS \mid bA$

The Myhill-Nerode equivalence classes for the language generated by the grammar are

A. $\{w \in (a+b)^* \mid \#a(w) \text{ is even}) \text{ and} \{w \in (a+b)^* \mid \#a(w) \text{ is odd}\}$
B. $\{w \in (a+b)^* \mid \#a(w) \text{ is even}) \text{ and} \{w \in (a+b)^* \mid \#b(w) \text{ is odd}\}$
C. $\{w \in (a+b)^* \mid \#a(w) = \#b(w) \text{and } \{w \in (a+b)^* \mid \#a(w) \neq \#b(w)\}$
D. $\{\epsilon\}, \{wa \mid w \in (a+b)^* \text{and} \{wb \mid w \in (a+b)^*\}$

gateit-2006 theory-of-computation normal regular-grammar

Answer key☟

10.19 Regular Language (36)

10.19.1 Regular Language: GATE CSE 1987 | Question: 2h

State whether the following statements are TRUE or FALSE:

Regularity is preserved under the operation of string reversal.

gate1987 theory-of-computation regular-language true-false

Answer key☟

10.19.2 Regular Language: GATE CSE 1987 | Question: 2i

State whether the following statements are TRUE or FALSE:

All subsets of regular sets are regular.

gate1987 theory-of-computation regular-language true-false

Answer key☟

10.19.3 Regular Language: GATE CSE 1990 | Question: 3-viii

Let R_1 and R_2 be regular sets defined over the alphabet Σ Then:

A. $R_1 \cap R_2$ is not regular.
B. $R_1 \cup R_2$ is regular.
C. $\Sigma^* - R_1$ is regular.
D. R_1^* is not regular.

gate1990 normal theory-of-computation regular-language multiple-selects

Answer key☟

10.19.4 Regular Language: GATE CSE 1991 | Question: 03,xiv

Which of the following is the strongest correct statement about a finite language over some finite alphabet Σ?

A. It could be undecidable
B. It is Turing-machine recognizable
C. It is a context-sensitive language.
D. It is a regular language.
E. None of the above,

gate1991 theory-of-computation easy regular-language multiple-selects

Answer key☟

10.19.5 Regular Language: GATE CSE 1995 | Question: 2.24

Let $\Sigma=\{0,1\}$, $L=\Sigma^*$ and $R=\{0^n1^n \mid n>0\}$ then the languages $L\cup R$ and R are respectively

A. regular, regular
B. not regular, regular
C. regular, not regular
D. not regular, not regular

gate1995 theory-of-computation easy regular-language

Answer key

10.19.6 Regular Language: GATE CSE 1996 | Question: 1.10

Let $L\subseteq\Sigma^*$ where $\Sigma=\{a,b\}$. Which of the following is true?

a. $L=\{x \mid x \text{ has an equal number of } a\text{'s and } b\text{'s}\}$ is regular
b. $L=\{a^nb^n \mid n\geq 1\}$ is regular
c. $L=\{x \mid x \text{ has more number of } a\text{'s than } b\text{'s}\}$ is regular
d. $L=\{a^mb^n \mid m\geq 1, n\geq 1\}$ is regular

gate1996 theory-of-computation normal regular-language

Answer key

10.19.7 Regular Language: GATE CSE 1998 | Question: 2.6

Which of the following statements is false?

a. Every finite subset of a non-regular set is regular
b. Every subset of a regular set is regular
c. Every finite subset of a regular set is regular
d. The intersection of two regular sets is regular

gate1998 theory-of-computation easy regular-language

Answer key

10.19.8 Regular Language: GATE CSE 1999 | Question: 6

A. Given that A is regular and $(A\cup B)$ is regular, does it follow that B is necessarily regular? Justify your answer.
B. Given two finite automata $M1, M2$, outline an algorithm to decide if $L(M1)\subset L(M2)$. (note: strict subset)

gate1999 theory-of-computation normal regular-language descriptive

Answer key

10.19.9 Regular Language: GATE CSE 2000 | Question: 2.8

What can be said about a regular language L over $\{a\}$ whose minimal finite state automaton has two states?

A. L must be $\{a^n \mid n \text{ is odd}\}$
B. L must be $\{a^n \mid n \text{ is even}\}$
C. L must be $\{a^n \mid n\geq 0\}$
D. Either L must be $\{a^n \mid n \text{ is odd}\}$, or L must be $\{a^n \mid n \text{ is even}\}$

gatecse-2000 theory-of-computation easy regular-language

Answer key

10.19.10 Regular Language: GATE CSE 2001 | Question: 1.4

Consider the following two statements:

$S_1 : \left\{0^{2n} \mid n \geq 1\right\}$ is a regular language

$S_2 : \{0^m 1^n 0^{m+n} \mid m \geq 1 \text{ and } n \geq 1\}$ is a regular language

Which of the following statement is correct?

A. Only S_1 is correct
B. Only S_2 is correct
C. Both S_1 and S_2 are correct
D. None of S_1 and S_2 is correct

gatecse-2001 theory-of-computation easy regular-language

Answer key

10.19.11 Regular Language: GATE CSE 2001 | Question: 2.6

Consider the following languages:

- $L1 = \{ww \mid w \in \{a, b\}^*\}$
- $L2 = \left\{ww^R \mid w \in \{a, b\}^*, w^R \text{ is the reverse of w}\right\}$
- $L3 = \left\{0^{2i} \mid \text{ i is an integer}\right\}$
- $L4 = \left\{0^{i^2} \mid \text{ i is an integer}\right\}$

Which of the languages are regular?

A. Only $L1$ and $L2$
B. Only $L2, L3$ and $L4$
C. Only $L3$ and $L4$
D. Only $L3$

gatecse-2001 theory-of-computation normal regular-language

Answer key

10.19.12 Regular Language: GATE CSE 2006 | Question: 29

If s is a string over $(0 + 1)^*$ then let $n_0(s)$ denote the number of 0's in s and $n_1(s)$ the number of 1's in s. Which one of the following languages is not regular?

A. $L = \{s \in (0 + 1)^* \mid n_0(s) \text{ is a 3-digit prime }\}$
B. $L = \{s \in (0 + 1)^* \mid \text{ for every prefix s' of s, } \mid n_0(s') - n_1(s') \mid \leq 2\}$
C. $L = \{s \in (0 + 1)^* \mid n_0(s) - n_1(s) \mid \leq 4\}$
D. $L = \{s \in (0 + 1)^* \mid n_0(s) \mod 7 = n_1(s) \mod 5 = 0\}$

gatecse-2006 theory-of-computation normal regular-language

Answer key

10.19.13 Regular Language: GATE CSE 2007 | Question: 31

Which of the following languages is regular?

A. $\{ww^R \mid w \in \{0, 1\}^+\}$
B. $\{ww^Rx \mid x, w \in \{0, 1\}^+\}$
C. $\{wxw^R \mid x, w \in \{0, 1\}^+\}$
D. $\{xww^R \mid x, w \in \{0, 1\}^+\}$

gatecse-2007 theory-of-computation normal regular-language

Answer key

10.19.14 Regular Language: GATE CSE 2007 | Question: 7

Which of the following is TRUE?

A. Every subset of a regular set is regular
B. Every finite subset of a non-regular set is regular
C. The union of two non-regular sets is not regular
D. Infinite union of finite sets is regular

gatecse-2007 theory-of-computation easy regular-language

Answer key

10.19.15 Regular Language: GATE CSE 2008 | Question: 53

Which of the following are regular sets?

I. $\{a^n b^{2m} \mid n \geq 0, m \geq 0\}$
II. $\{a^n b^m \mid n = 2m\}$
III. $\{a^n b^m \mid n \neq m\}$
IV. $\{xcy \mid x, y, \in \{a, b\}^*\}$

A. I and IV only
B. I and III only
C. I only
D. IV only

gatecse-2008 theory-of-computation normal regular-language

Answer key

10.19.16 Regular Language: GATE CSE 2011 | Question: 24

Let P be a regular language and Q be a context-free language such that $Q \subseteq P$. (For example, let P be the language represented by the regular expression $p^* q^*$ and Q be $\{p^n q^n \mid n \in N\}$). Then which of the following is **ALWAYS** regular?

A. $P \cap Q$
B. $P - Q$
C. $\Sigma^* - P$
D. $\Sigma^* - Q$

gatecse-2011 theory-of-computation easy regular-language

Answer key

10.19.17 Regular Language: GATE CSE 2012 | Question: 25

Given the language $L = \{ab, aa, baa\}$, which of the following strings are in L^*?

1. $abaabaaabaa$
2. $aaaabaaaa$
3. $baaaaabaaaab$
4. $baaaaabaa$

A. $1, 2$ and 3
B. $2, 3$ and 4
C. $1, 2$ and 4
D. $1, 3$ and 4

gatecse-2012 theory-of-computation easy regular-language

Answer key

10.19.18 Regular Language: GATE CSE 2013 | Question: 8

Consider the languages $L_1 = \phi$ and $L_2 = \{a\}$. Which one of the following represents $L_1 {L_2}^* \cup {L_1}^*$?

A. $\{\epsilon\}$
B. ϕ
C. a^*
D. $\{\epsilon, a\}$

gatecse-2013 theory-of-computation normal regular-language

Answer key

10.19.19 Regular Language: GATE CSE 2014 Set 1 | Question: 15

Which one of the following is **TRUE**?

A. The language $L = \{a^n b^n \mid n \geq 0\}$ is regular.
B. The language $L = \{a^n \mid n \text{ is prime }\}$ is regular.
C. The language L= $\{w \mid w \text{ has } 3k + 1 \; b's \text{ for some } k \in N \text{ with } \Sigma = \{a, b\}\}$ is regular.
D. The language $L = \{ww \mid w \in \Sigma^* \text{ with } \Sigma = \{0, 1\}\}$ is regular.

gatecse-2014-set1 theory-of-computation regular-language normal

Answer key

10.19.20 Regular Language: GATE CSE 2014 Set 2 | Question: 15

If $L_1 = \{a^n \mid n \geq 0\}$ and $L_2 = \{b^n \mid n \geq 0\}$, consider

I. $L_1 . L_2$ is a regular language
II. $L_1 . L_2 = \{a^n b^n \mid n \geq 0\}$

Which one of the following is CORRECT?

A. Only I
B. Only II
C. Both I and II
D. Neither I nor II

gatecse-2014-set2 theory-of-computation normal regular-language

Answer key

10.19.21 Regular Language: GATE CSE 2014 Set 2 | Question: 36

Let $L_1 = \{w \in \{0,1\}^* \mid w \text{ has at least as many occurrences of } (110)'\text{s as } (011)'\text{s}\}$. Let $L_2 = \{w \in \{0,1\}^* \mid w \text{ has at least as many occurrences of } (000)'\text{s as } (111)'\text{s}\}$. Which one of the following is TRUE?

A. L_1 is regular but not L_2
B. L_2 is regular but not L_1
C. Both L_1 and L_2 are regular
D. Neither L_1 nor L_2 are regular

gatecse-2014-set2 theory-of-computation normal regular-language

Answer key

10.19.22 Regular Language: GATE CSE 2015 Set 2 | Question: 51

Which of the following is/are regular languages?

$L_1 : \left\{wxw^R \mid w, x \in \{a,b\}^* \text{ and } |w|, |x| > 0\right\}, w^R \text{ is the reverse of string } w$

$L_2 : \{a^n b^m \mid m \neq n \text{ and } m, n \geq 0\}$

$L_3 : \{a^p b^q c^r \mid p, q, r \geq 0\}$

A. L_1 and L_3 only
B. L_2 only
C. L_2 and L_3 only
D. L_3 only

gatecse-2015-set2 theory-of-computation normal regular-language

Answer key

10.19.23 Regular Language: GATE CSE 2016 Set 2 | Question: 17

Language L_1 is defined by the grammar: $S_1 \rightarrow aS_1b \mid \varepsilon$

Language L_2 is defined by the grammar: $S_2 \rightarrow abS_2 \mid \varepsilon$

Consider the following statements:

- P: L_1 is regular
- Q: L_2 is regular

Which one of the following is **TRUE**?

A. Both P and Q are true.
B. P is true and Q is false.
C. P is false and Q is true.
D. Both P and Q are false.

gatecse-2016-set2 theory-of-computation easy regular-language

Answer key

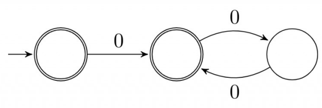
10.19.24 Regular Language: GATE CSE 2018 | Question: 52

Given a language L, define L^i as follows:

$$L^0 = \{\varepsilon\}$$

$$L^i = L^{i-1} \bullet L \text{ for all } I > 0$$

The order of a language L is defined as the smallest k such that $L^k = L^{k+1}$. Consider the language L_1(over alphabet 0) accepted by the following automaton.



The order of L_1 is ________.

gatecse-2018 theory-of-computation numerical-answers regular-language two-marks

Answer key

10.19.25 Regular Language: GATE CSE 2019 | Question: 7

If L is a regular language over $\Sigma = \{a, b\}$, which one of the following languages is NOT regular?

A. $L.L^R = \{xy \mid x \in L, y^R \in L\}$
B. $\{ww^R \mid w \in L\}$
C. $\text{Prefix }(L) = \{x \in \Sigma^* \mid \exists y \in \Sigma^* \text{such that } xy \in L\}$
D. $\text{Suffix }(L) = \{y \in \Sigma^* \mid \exists x \in \Sigma^* \text{such that } xy \in L\}$

gatecse-2019 theory-of-computation regular-language one-mark

Answer key

10.19.26 Regular Language: GATE CSE 2020 | Question: 51

Consider the following language.

$L = \{x \in \{a, b\}^* \mid \text{number of } a\text{'s in } x \text{ divisible by } 2 \text{ but not divisible by } 3\}$

The minimum number of states in DFA that accepts L is _________

gatecse-2020 numerical-answers theory-of-computation regular-language two-marks

Answer key

10.19.27 Regular Language: GATE CSE 2020 | Question: 8

Consider the following statements.

I. If $L_1 \cup L_2$ is regular, then both L_1 and L_2 must be regular.
II. The class of regular languages is closed under infinite union.

Which of the above statements is/are TRUE?

A. I only
B. II only
C. Both I and II
D. Neither I nor II

gatecse-2020 theory-of-computation regular-language one-mark

Answer key

10.19.28 Regular Language: GATE CSE 2021 Set 2 | Question: 9

Let $L \subseteq \{0, 1\}^*$ be an arbitrary regular language accepted by a minimal DFA with k states. Which one of the following languages must necessarily be accepted by a minimal DFA with k states?

A. $L - \{01\}$
B. $L \cup \{01\}$
C. $\{0,1\}^* - L$
D. $L \cdot L$

gatecse-2021-set2 theory-of-computation finite-automata regular-language one-mark

Answer key

10.19.29 Regular Language: GATE CSE 2024 | Set 1 | Question: 13

Let L_1, L_2 be two regular languages and L_3 a language which is not regular.
Which of the following statements is/are always TRUE?

A. $L_1 = L_2$ if and only if $L_1 \cap \overline{L_2} = \phi$

B. $L_1 \cup L_3$ is not regular

C. $\overline{L_3}$ is not regular

D. $\overline{L_1} \cup \overline{L_2}$ is regular

gatecse2024-set1 multiple-selects theory-of-computation regular-language one-mark

Answer key☟

10.19.30 Regular Language: GATE CSE 2025 | Set 1 | Question: 18

A regular language L is accepted by a non-deterministic finite automaton (NFA) with n states. Which of the following statement(s) is/are FALSE?

A. L may have an accepting NFA with $< n$ states.
B. L may have an accepting DFA with $< n$ states.
C. There exists a DFA with $\leq 2^n$ states that accepts L.
D. Every DFA that accepts L has $> 2^n$ states.

gatecse2025-set1 theory-of-computation finite-automata regular-language multiple-selects one-mark

Answer key☟

10.19.31 Regular Language: GATE CSE 2025 | Set 1 | Question: 34

Consider the following two languages over the alphabet $\{a, b\}$:

$$L_1 = \{\alpha\beta\alpha \mid \alpha \in \{a,b\}^+ \text{AND } \beta \in \{a,b\}^+\}$$
$$L_2 = \{\alpha\beta\alpha \mid \alpha \in \{a\}^+ \text{AND } \beta \in \{a,b\}^+\}$$

Which ONE of the following statements is CORRECT?

A. Both L_1 and L_2 are regular languages.
B. L_1 is a regular language but L_2 is not a regular language.
C. L_1 is not a regular language but L_2 is a regular language.
D. Neither L_1 nor L_2 is a regular language.

gatecse2025-set1 theory-of-computation regular-language two-marks

Answer key☟

10.19.32 Regular Language: GATE CSE 2025 | Set 2 | Question: 42

Let $\Sigma = \{a, b, c\}$. For $x \in \Sigma^*$, and $\alpha \in \Sigma$, let $\#_\alpha(x)$ denote the number of occurrences of α in x.
Which one or more of the following option(s) define(s) regular language(s)?

A. $\{a^m b^n \mid m, n \geq 0\}$
B. $\{a,b\}^* \cap \{a^m b^n c^{m-n} \mid m \geq n \geq 0\}$
C. $\{w \mid w \in \{a,b\}^*, \#_a(w) \equiv 2 (\bmod 7)$, and $\#_b(w) \equiv 3 (\bmod 9)\}$
D. $\{w \mid w \in \{a,b\}^*, \#_a(w) \equiv 2 (\bmod 7)$, and $\#_a(w) = \#_b(w)\}$

gatecse2025-set2 theory-of-computation regular-language multiple-selects two-marks

Answer key☟

10.19.33 Regular Language: GATE IT 2006 | Question: 30

Which of the following statements about regular languages is NOT true ?

A. Every language has a regular superset
B. Every language has a regular subset
C. Every subset of a regular language is regular
D. Every subset of a finite language is regular

gateit-2006 theory-of-computation easy regular-language

Answer key

10.19.34 Regular Language: GATE IT 2006 | Question: 80

Let L be a regular language. Consider the constructions on L below:

I. repeat $(L) = \{ww \mid w \in L\}$
II. prefix $(L) = \{u \mid \exists v : uv \in L\}$
III. suffix $(L) = \{v \mid \exists u : uv \in L\}$
IV. half $(L) = \{u \mid \exists v : |v| = |u| \text{ and } uv \in L\}$

Which of the constructions could lead to a non-regular language?

A. Both I and IV
B. Only I
C. Only IV
D. Both II and III

gateit-2006 theory-of-computation normal regular-language

Answer key

10.19.35 Regular Language: GATE IT 2006 | Question: 81

Let L be a regular language. Consider the constructions on L below:

I. $\text{repeat}(L) = \{ww \mid w \in L\}$
II. $\text{prefix}(L) = \{u \mid \exists v : uv \in L\}$
III. $\text{suffix}(L) = \{v \mid \exists u : uv \in L\}$
IV. $\text{half}(L) = \{u \mid \exists v : |v| = |u| \text{ and } uv \in L\}$

Which of the constructions could lead to a non-regular language?

a. Both I and IV
b. Only I
c. Only IV
d. Both II and III

Which choice of L is best suited to support your answer above?

A. $(a+b)^*$
B. $\{\epsilon, a, ab, bab\}$
C. $(ab)^*$
D. $\{a^n b^n \mid n \geq 0\}$

gateit-2006 theory-of-computation normal regular-language

Answer key

10.19.36 Regular Language: GATE IT 2008 | Question: 35

Which of the following languages is (are) non-regular?

- $L_1 = \{0^m 1^n \mid 0 \leq m \leq n \leq 10000\}$
- $L_2 = \{w \mid w \text{ reads the same forward and backward}\}$
- $L_3 = \{w \in \{0,1\}^* \mid w \text{ contains an even number of 0's and an even number of 1's}\}$

A. L_2 and L_3 only
B. L_1 and L_2 only
C. L_3 only
D. L_2 only

gateit-2008 theory-of-computation normal regular-language

Answer key

Answer Keys

10.1.1	A;C	10.1.2	A;B	10.1.3	A	10.1.4	C	10.1.5	D
10.1.6	B	10.1.7	B	10.1.8	B;C	10.1.9	D	10.2.1	A
10.2.2	D	10.3.1	False	10.3.2	A;D	10.3.3	A	10.3.4	B
10.3.5	B	10.3.6	B	10.3.7	N/A	10.3.8	N/A	10.3.9	B
10.3.10	C	10.3.11	B	10.3.12	D	10.3.13	B	10.3.14	B

10.3.15	D	10.3.16	D	10.3.17	B	10.3.18	B	10.3.19	D
10.3.20	A	10.3.21	C	10.3.22	C	10.3.23	C	10.3.24	B;C;D
10.3.25	B;C;D	10.3.26	B	10.3.27	C	10.3.28	B	10.3.29	B
10.3.30	A	10.3.31	C	10.3.32	D	10.3.33	B	10.4.1	B
10.4.2	C	10.4.3	B	10.5.1	True	10.5.2	True	10.5.3	N/A
10.5.4	B;D	10.5.5	B;C	10.5.6	N/A	10.5.7	D	10.5.8	B
10.5.9	N/A	10.5.10	A	10.5.11	B	10.5.12	N/A	10.5.13	N/A
10.5.14	C	10.5.15	A	10.5.16	B	10.5.17	B	10.5.18	D
10.5.19	D	10.5.20	A	10.5.21	D	10.5.22	C	10.5.23	C
10.5.24	A	10.5.25	D	10.5.26	D	10.5.27	A	10.5.28	C
10.5.29	A;B;C	10.6.1	A	10.7.1	N/A	10.7.2	N/A	10.7.3	N/A
10.7.4	N/A	10.7.5	N/A	10.7.6	A	10.7.7	N/A	10.7.8	A
10.7.9	N/A	10.7.10	C	10.7.11	B	10.7.12	A	10.7.13	X
10.7.14	B	10.7.15	C	10.7.16	A	10.7.17	C	10.7.18	C
10.7.19	B	10.7.20	D	10.7.21	D	10.7.22	A	10.7.23	B
10.7.24	C	10.7.25	D	10.7.26	256 : 256	10.7.27	B	10.7.28	B;C
10.7.29	A	10.7.30	B	10.7.31	C	10.7.32	B	10.7.33	A
10.7.34	B	10.7.35	D	10.7.36	A	10.7.37	D	10.7.38	A
10.7.39	A	10.7.40	A	10.7.41	A	10.7.42	A	10.8.1	5:5
10.9.1	C	10.9.2	N/A	10.9.3	N/A	10.9.4	N/A	10.9.5	A;C
10.9.6	B	10.9.7	B	10.9.8	B	10.9.9	A	10.9.10	D
10.9.11	B	10.9.12	B	10.9.13	C	10.9.14	D	10.9.15	C
10.9.16	D	10.9.17	C	10.9.18	D	10.9.19	C	10.9.20	B
10.9.21	D	10.9.22	B	10.9.23	C	10.9.24	A	10.9.25	B;C;D
10.9.26	B;C;D	10.9.27	A;B;C	10.9.28	A;C;D	10.9.29	D	10.9.30	A
10.9.31	B	10.10.1	0	10.10.2	N/A	10.10.3	N/A	10.10.4	B
10.10.5	N/A	10.10.6	B	10.10.7	B	10.10.8	D	10.10.9	B
10.10.10	D	10.10.11	A	10.10.12	B	10.10.13	C	10.10.14	B
10.10.15	A	10.10.16	1	10.10.17	3	10.10.18	B	10.10.19	2
10.10.20	4	10.10.21	8	10.10.22	D	10.10.23	120	10.10.24	4
10.10.25	A	10.11.1	A;C	10.11.2	C	10.11.3	B	10.11.4	D
10.11.5	B	10.11.6	C	10.12.1	6:6	10.13.1	D	10.13.2	D
10.14.1	N/A	10.14.2	A	10.14.3	N/A	10.14.4	A	10.14.5	N/A
10.14.6	N/A	10.14.7	D	10.14.8	B	10.14.9	D	10.14.10	50 : 50
10.14.11	A	10.14.12	B	10.14.13	D	10.14.14	B	10.14.15	C
10.15.1	A;D	10.15.2	A	10.15.3	D	10.15.4	D	10.15.5	A
10.15.6	B	10.15.7	D	10.15.8	D	10.15.9	B	10.15.10	C
10.15.11	D	10.15.12	B	10.15.13	D	10.15.14	C	10.15.15	D
10.15.16	A	10.16.1	C	10.16.2	C	10.17.1	N/A	10.17.2	A;C
10.17.3	A	10.17.4	N/A	10.17.5	C	10.17.6	C	10.17.7	D

10.17.8	C;D	10.17.9	D	10.17.10	N/A	10.17.11	C	10.17.12	A
10.17.13	C	10.17.14	B	10.17.15	B	10.17.16	3	10.17.17	B
10.17.18	X	10.17.19	A;B;C	10.17.20	D	10.17.21	C	10.17.22	C
10.17.23	44	10.17.24	15	10.17.25	C	10.17.26	B	10.17.27	A
10.17.28	C	10.17.29	C	10.18.1	N/A	10.18.2	C	10.18.3	A
10.19.1	True	10.19.2	False	10.19.3	B;C	10.19.4	D	10.19.5	C
10.19.6	D	10.19.7	B	10.19.8	N/A	10.19.9	X	10.19.10	A
10.19.11	D	10.19.12	C	10.19.13	C	10.19.14	B	10.19.15	A
10.19.16	C	10.19.17	C	10.19.18	A	10.19.19	C	10.19.20	A
10.19.21	A	10.19.22	A	10.19.23	C	10.19.24	2	10.19.25	B
10.19.26	6	10.19.27	D	10.19.28	C	10.19.29	C;D	10.19.30	D
10.19.31	C	10.19.32	A;C	10.19.33	C	10.19.34	B	10.19.35	A
10.19.36	D								