Algorithm, Data Structure & Programming
Description Sheet

Chapter 1 : Asymptotic Analysis of Algorithms

- Need for Performance Analysis
- Worst, Average and Best Cases
- Asymptotic Notations
- Analysis Of Loops
- Comparisons of Functions
- Asymptotic Behaviour of Polynomials

Chapter 2 : Recurrence Relations

- Substitution Method
- Master Theorem

Chapter 3 : Divide and Conquer

- Quick Sort
- Strassen's Matrix Multiplication
- Merge Sort
- Insertion Sort
- Counting Inversions
- Binary Search
- Bubble Sort
- Finding Min and Max

Chapter 4 : Greedy Techniques

- Knapsack (Fractional) Problem
- Minimum Cost Spanning Tree Problem
- Single Source Shortest Path Problem
- Huffman Coding

Chapter 5 : Dynamic Programing

- Fibonacci Numbers
- All-Pairs Shortest Paths Problem
- Matrix Chain Multiplication
- Longest Common Subsequence Problem
- The 0/1 Knapsack Problem
- Multistage Graph

Chapter 6 : Graph Based Algorithms

- Representations of Graphs
- Graph Searching

1 Divide and Conquer

Multiple Choice Questions

Q.1 Using which algorithm an array of n-elements in the range [1... n^3] will be sorted using O(n) time?
(a) Merge sort (b) Quick sort
(c) Radix sort (d) Insertion sort

Q.2 Consider the following C code:

```
int f(int x)
{   if (x < 1) return 1;
    else return f(x – 1) + g(x);
}
int g (int x)
{   if (x < 2) return 1;
    else return f(x – 1) + g(x/2);
}
```

Of the following, which best describes the growth of f(x) as a function of x?
(a) logarithmic (b) quadratic
(c) linear (d) exponential
[JNUEE-2004]

Q.3 Consider the polynominal $p(x) = a_0 + a_1x + a_2x^2 + a_2x^3$, where $a_i \neq 0$, $\forall i$. The minimum number of multiplcations needed to evaluate p on an input x is
(a) 3 (b) 4
(c) 6 (d) 9
[GATE-2006]

Q.4 Absence of terminating condition in a recursing program cause the following with time error:
(a) Array out of bounds (b) Stack overflow
(c) Null Pointer access (d) Division by zero
[DRDO-2008]

Q.5 Assume an array A [1, ..., n] has n-elements, and every element of an array is less than or equal to n. An element is said to be "majority element", if it is occurred in more than $\frac{n}{2}$ positions of an array. What is the time complexity to check whether the majority element exist or not in the given array? [Best answer]
(a) O(log n) (b) O(n)
(c) O(n log n) (d) $O(n^2)$

Q.6 For merging two sorted lists of sizes m and n into a sorted list of size m + n, we required comparisons of
(a) O(m) (b) O(n)
(c) O(m + n) (d) O(log m + log n)
[GATE-1995]

Q.7 Which of the following is divide and conquer application?
(a) Heapsort (b) Insertion sort
(c) Bubble sort (d) Merge sort
[DRDO-2008]

Q.8 Consider a sequence A of length n which is sorted except for one item that appears out of order. Which of the following can sort the sequence in O(n) time?
(a) Heapsort (b) Quicksort
(c) Merge sort (d) Insertion sort
[DRDO-2008]

Q.9 Binary search can be carried out on a set of ordered data items stored in a
(a) Array (b) Stack
(c) Queue (d) List
[DRDO-2008]

Q.10 The minimum number of comparisons required to sort 5 elements is
(a) 4 (b) 5
(c) 6 (d) 7
[DRDO-2008]

Q.11 The worst case time complexity of Quicksort for n elements when the median is selected as the pivot is:
(a) $O(n^2)$ (b) $O(n^2)$
(c) $O(n \log n)$ (d) $O(n \log n)$
[DRDO-2008]

Q.12 The most appropriate matching for the following pairs:
X : Depth first search 1 : Heap
Y : Breadth-first search 2 : Queue
Z : Sorting 3 : Stack
(a) X-1, Y-2, Z-3 (b) X-3, Y-1, Z-2
(c) X-3, Y-2, Z-1 (d) X-2, Y-3, Z-1
[GATE-2000]

Q.13 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 uniformly at random from 1..n
2. If A[i] = x then Stop else Goto 1;
Assuming that x is present A, what is the expected number of comparisons made by the algorithm before it terminates?
(a) n (b) n – 1
(c) 2n (d) n/2
[GATE-2002]

Q.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!)
[GATE-2001]

Q.15 Consider any array representation of an n element binary heap where the elements are sorted from index 1 to index n of the array. For the element sorted at index i of the array ($i \le n$), the index of the parent is
(a) $i - 1$ (b) $\left\lfloor \frac{i}{2} \right\rfloor$
(c) $\left\lceil \frac{i}{2} \right\rceil$ (d) $\frac{(i+1)}{2}$
[GATE-2001]

Q.16 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 $\Theta(n)$
[GATE-2003]

Q.17 Let A be a sequence of 8 distinct integers sorted in ascending order. How many distinct pairs of sequences, B and C are there such that (i) each is sorted in ascending order, (ii) B has 5 and C has 3 elements, and (iii) the result of merging B and C gives A?
(a) 2 (b) 30
(c) 56 (d) 256
[GATE-2003]

Q.18 A sort method is said to be stable if the relative order of keys is the same after the sort as it was before the sort. In which of the following pairs both sorting algorithms are stable?
(a) Quick-sort and Insertion-sort
(b) Insertion-sort and Bubble-sort
(c) Quick-sort and Heap-sort
(d) Quick-sort and Bubble-sort
[DRDO-2009]

Q.19 In a heap with n elements with the smallest element at the root, the 7th smallest element can be found in time
(a) $\Theta(n \log n)$ (b) $\Theta(n)$
(c) $\Theta(\log n)$ (d) $\Theta(1)$
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(a) 4 (b) 5

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(c) X-3, Y-2, Z-1 (d) X-2, Y-3, Z-1

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(c) become $\Theta(n \log n)$

(d) become $\Theta(n)$

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(b) Insertion-sort and Bubble-sort

(c) Quick-sort and Heap-sort

(d) Quick-sort and Bubble-sort

[DRDO-2009]

Q.19 In a heap with n elements with the smallest element at the root, the 7th smallest element can be found in time

(a) $\Theta(n \log n)$ (b) $\Theta(n)$

(c) $\Theta(\log n)$ (d) $\Theta(1)$

[GATE-2003]

Q.20 The minimum element in a max-heap represented by an array can be computed in time

(a) $\Theta(n \log n)$ (b) $O(n)$

(c) $\Theta(n^2)$ (d) $O(1)$

[DRDO-2009]

Q.21 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) $\log_{4/3} n$

(c) $\log_3 n$ (d) $\log_{3/2} n$

[GATE-2002]

Q.22 A binary search tree is used to locate the number 43. Which of the following probe sequences are possible and which are not?

(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

[GATE-1996]

Q.23 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

[GATE-2003]

Q.24 Maximum number of edges in a n-node undirected graph without self loops is

(a) n^2 (b) $\frac{n(n-1)}{2}$

(c) n – 1 (d) $\frac{(n+1)(n)}{2}$

[GATE-2002]

Q.25 Which one of the following arrays satisfied max-heap property?

(a) 16, 10, 12, 8, 3, 5

(b) 16, 8, 5, 10, 12, 3

(c) 16, 12, 8, 3, 5, 10

(d) 10, 16, 12, 8, 5, 3

[DRDO-2008]

Q.26 What is the upper bound on the number of edge disjoint spanning trees in a complete graph of n vertices?

(a) n (b) n – 1

(c) $\left[\frac{n}{2}\right]$ (d) $\left[\frac{n}{3}\right]$

[DRDO-2009]

Q.27 Given 2-sorted arrays each of n-elements and distinct. How much time it will take to find middle element of the union array?

(a) O(1) (b) O(log n)

(c) O(n) (d) None of these

Common Data for Q.28 & Q.29

A 3-ary max heap is like a binary max heap, but instead of 2 children, nodes have 3 childern. 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.

Q.28 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

[GATE-2006]

Q.29 Suppose the elements 7, 2, 10, and 4 are insetrted, in that order, into the valid 3-ary max heap found in the question, Q. 30. Which one of the following is the sequence of items in the arrary 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

[GATE-2006]

Q.30 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}

[GATE-2007]

Q.31 The maximum number of binary trees that can be formed with three unlabeled nodes is

(a) 1 (b) 5
(c) 4 (d) 3

[GATE-2007]

Q.32 Consider the following three claim

1. $(n+k)^m = \Theta(n^m)$ where k and m are constants
2. $2^{n+1} = O(2^n)$
3. $2^{2n+1} = O(2^n)$

Which of these claim are correct?

(a) 1 and 2 (b) 1 and 3
(c) 2 and 3 (d) 1, 2 and 3

[GATE-2003]

Q.33 Find the running time of the following algorithm.

procedure A(n)
If n < = 2 return (1);
else return $\left(A\left(\lceil \sqrt{n} \rceil\right)\right)$;

(a) O(n) (b) O(log n)
(c) O(log log n) (d) O(1)

[GATE-2002]

Q.34 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) $f(n) = O(g(n)$ and $g(n) \neq O(f(n))$
(b) $g(n) = O(f(n)$ and $f(n) \neq O(g(n))$
(c) $f(n) \neq O(g(n))$ and $g(n) \neq O(f(n))$
(d) $f(n) = O(g(n))$ and $g(n) = O(f(n))$

[GATE-2001]

Q.35 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))

[GATE-2000]

Q.36 Let F_k denote the k^{th} Fibonacci number with $F_k = F_{k-1} + F_{k-2}$ for $k \geq 2$, $F_0 = F_1 = 1$.

Consider the following variation of an merge sort, which assumes that the number of elements in its list argument L is a Fibonacci number F_k.

Algorithm FibMergeSort(L)
L is a list of items from a totally ordered set, whose length is a Fibonacci number F_k.
{
If L contains only 1 element, then return L;
else
{
divide L into L_1 (the first F_{k-1} items) and L_2 (the remaining F_{k-2} items)
sorted L_1 := FibMergeSorte(L_1)
sorted L_2 := FibMergeSort (L_2)
sorted L := Merge(sortedL$_1$, sortedL$_2$)
return sortedL;
}
}

Assuming that the "divide" step in FibMergeSort takes constant time (no comparisons) and Merge behaves similar to the merge in the normal merge sort. Identify which of the following exp[ressions most closely matches the total number of comparisons performed by FibMergeSort when initially given a list of F_k elements?

(a) O(k log k) (b) $O(K^2)$
(c) $O(k F_k)$ (d) $O(F_k \log k)$

Q.37 If $T_1 = O(1)$, match **List-I** with **List-II** select the correct answer using the codes given below the Lists:

List-I	List-II
A. $T_n = T_{n-1} + n$	1. $T_n = O(n)$
B. $T_n = T_{n/2} + n$	2. $T_n = O(n^2)$
C. $T_n = T_{n/2} + n \log n$	3. $T_n = O(n \log n)$
D. $T_n = T_{n-1} + \log n$	4. $T_n = O(n^3)$

Codes:

	A	B	C	D
(a)	2	1	3	3
(b)	3	1	4	2
(c)	2	3	4	1
(d)	3	1	2	4

[GATE-1999]

Q.38 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 statements is true?

(a) t(n) is 0(1)

(b) $n \le t(n) \le n \log_2 n$

(c) $n \log_2 n \le t(n) < \left(\frac{n}{2}\right)$

(d) $t(n) = \left(\frac{n}{2}\right)$

[GATE-2000]

Q.39 Match **List-I** with **List-II** select the correct answer using the codes given below the Lists:

List-I

A. All pairs shortest paths

B. Quick sort

C. Minimum weight spanning tree

D. Connected components

List-II

1. Greedy
2. Depth-first search
3. Dynamic programming
4. Divide and conquer

Codes:

	A	B	C	D
(a)	2	4	1	3
(b)	3	4	1	2
(c)	3	4	2	1
(d)	4	1	2	3

[GATE-1997]

Q.40 The cube root of a natural number n is defined as the larger natural number m such that $m^3 \le n$. The complexity of computing the cube root of n(n is represented in 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 $O((\log\log n)^{0.5})$

[GATE-2003]

Q.41 Let T(n) be the function defined by

$$T(n) = \begin{cases} T(1) \text{ for } n = 1 \\ 7T(n/2) + 18n^2 \text{ for } n \ge 2 \end{cases}$$

Now which of the following statement is true?

(a) $T(n) = \Theta(\log_2 n)$ (b) $T(n) \Theta\left(n^{\log_2 7}\right)$

(c) $T(n) = O\left(n^{\log_2 n}\right)$ (d) None of these

Q.42 An algorithm runs a given input of size n. If n is 4096, the run time is 512 milliseconds. If n is 16384 the run time is 2048 milliseconds. What is the complexity of the algorithm in big-O notation?

(a) $O(n^{1/2})$ (b) O(n)

(c) O(n log n) (d) $O(n^2)$

[JNUEE-2003]

Q.43 What does the following algorithm approximate? (Assume $m > 1, \epsilon > 0$).

```
x = m ;
y = 1;
while (x – y > ∈)
{
    x = (x + y) / 2;
    y = m / x;
}
print (x);
```

(a) log m (b) m^2

(c) $m^{1/2}$ (d) $m^{1/3}$

[GATE-2004]

Q.44 Consider these two functions and two statements S1 and S2 about them.

```
int work1 (int* a, int i, int j)
{
    int x=a[i+ 2];
    a[j]=x+1;
    returna[i+2] – 3;}
}
```

```
intwork2 (int* a, int i, int j)
{
    int t1=i+2;
    int t2=a[t1];
    a[j] = t2 + 1;
    return t2 – 3;
}
```

S1: The transformation from work 1 to work 2 is valid, i.e., for any program state and input arguments, work 2 will compute the same output and have the same effect on program state as work 1

S2: All the transformations applied to work 1 to get work 2 will always improve the performance (i.e. reduce CPU time) of work 2 compared to work 1

(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

[GATE-2006]

Q.45 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 successfully for any n > 0 is

(a) $\lceil \log_2 n \rceil + 1$ (b) n
(c) log n (d) $\lfloor \log_2 n \rfloor + 1$

[GATE-2007]

Q.46 If T(n) = 3T(n/2) + n, if n >1. T(1) = 1. Then T(n) =?

(a) $\Theta(n)$ (b) $\Theta(n^{\log_2 3})$
(c) $\Theta(n^{3/2})$ (d) $\Theta(n^{\log_2 3} \log_2 n)$

[DRDO-2008]

Q.47 Let $S_1 = \sum_{r=0}^{\log n-1} \frac{nr}{2^r}$, and $S_2 = \sum_{r=0}^{\log n-1} r2^r$. Which of the following is true?

(a) $S_1 = \Theta(n \log n)$, $S_2 = \Theta(n \log n)$
(b) $S_1 = \Theta(n)$, $S_2 = \Theta(n \log n)$
(c) $S_1 = \Theta(n \log n)$, $S_2 = \Theta(n)$
(d) $S_1 = \Theta(n)$, $S_2 = \Theta(n)$

[DRDO-2008]

Q.48 Which one of the following statements are correct regarding Bellman-Ford shortest path algorithm?

P: Always finds a negative edge weight cycle if one exists.

Q: Find whether any negative edge weight cycle reachable from the source.

(a) P only (b) Q only
(c) Both P and Q (d) Neither P nor Q

Q.49 We have the following recurrence relation:

$$T(n) = \begin{cases} 1 & n \le 5 \\ T(n/5) + T(3n/4) + n & n > 5 \end{cases}$$

Then which of the following statement is TRUE?

(a) $T(n) \in \Theta(n^2)$ (b) $T(n) \in \Omega(\sqrt{n})$
(c) $T(n) \in \Theta(n)$ (d) $T(n) \in \Theta(n \log n)$

[DRDO-2009]

Q.50 We have the following recurrence relation:

$$T(n) = \begin{cases} 1 & n = 1 \\ 7T(n/2) + n^2 & n > 1 \end{cases}$$

Then which of the following statements is TRUE?

(a) $T(n) \in O(n)$ (b) $T(n) \in \Theta(n^{\log_2 7})$
(c) $T(n) \in \Theta(n^2)$ (d) $T(n) \in \Theta(n^3)$

[DRDO-2009]

Q.51 We are given a sequence of n-numbers a_1, a_2, a_3... a_n, we will assume that all the number are distinct. We say two indices i < j form an inversion if $a_i > a_j$.

How much time it will take to find total number of inversions in the given array?

(a) $O(n^2)$ (b) $O(n \log n)$
(c) $O(n)$ (d) None of these

Q.52 An array A[1 .... n] contains all the integers from 0 to n, except one element. How much time it will take to determine the missing integer?
(a) $O(n)$ (b) $O(\log n)$
(c) $O(n^2)$ (d) None of these

Q.53 You are given an infinite array A in which the first n-cells contains integers in sorted order and the rest of the cells are filled with ∞. If you are not given the value of n, find time complexity of an algorithm that takes an integer X as input and find the position of element X in the given array A.
(a) $O(n)$ (b) $O(\log n)$
(c) $O(n^2)$ (d) None of these

Q.54 The tightest lower bound on the number of comparisons, in the worst case, for comparison-based sorting is
(a) $O(n)$ (b) $O(n^2)$
(c) $\Omega(n \log n)$ (d) $\Omega(n \log^2 n)$

Q.55 Let A [1,..., 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) $O(n)$
[GATE-2004]

Q.56 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) $2^n + n$
[GATE-2004]

Q.57 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 (number of leaf-nodes in leaf-subtree of x, number of leaf-nodes in right-subtree of x) then the worst case time complexity of the program is
(a) $\Theta(n)$ (b) $O(n \log n)$
(c) $O(n)^2$ (d) $O(n^2 \log n)$
[GATE-2004]

Q.58 Let G (V, E) an undirected graph with positive edge weights. Dijkstra's single source -shortes path algorithm can be implemented using the binary heap data structure with time complexity?
(a) $O(|V|^2)$
(b) $O(|E|) + |V| \log |V|)$
(c) $O(|V| \log |V|)$
(d) $O((|E| + |V|) \log |V|)$
[GATE-2005]

Q.59 In a complete k-ary, every internal node has exactly k childern. The number of leaves in such a tree with n internal nodes is
(a) n k (b) $(n-1)k+1$
(c) $n(k-1)+1$ (d) $n(k-1)$
[GATE-2005]

Q.60 Suppose there are log n sorted lists of n/log n elements each. The time complexity of producing a sorted list of all these elements is:
(Hint : Use a heap data structure)
(a) $\Theta(n \log \log n)$ (b) $\Theta(n \log n)$
(c) $\Omega(n \log n)$ (d) $\Omega(n^{3/2})$
[GATE-2005]

Common Data For Q.61 & Q.62

Consider the following C - function:

```
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;
}
}
```

Q.61 The space complexity of the above function is

(a) O(1) (b) O(n)
(c) O(n!) (d) $O(n^n)$

[GATE-2005]

Q.62 Suppose we modify the above function foo() and store the values of foo(i), 0 < = 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) O(n!)

[GATE-2005]

Q.63 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) = $\Theta(n \log n)$

[GATE-2006]

Q.64 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) $\Theta(\log_2 \log_2 n)$

[GATE-2007]

Q.65 Consider the following C code segment:

```
int IsPrime (n)
{
    int i, n;
    for (i = 2; i < = sqrt (n); i ++)
    {   if (n mod i == 0)
        printf ("Not Prime")
        return 0
    }
    return 1;
}
```

Let T(n) denote the 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

[GATE-2007]

Q.66 Suppose you have k-sorted arrays, each with n-elements and you want to combine those k-sorted arrays into a single sorted array of kn elements. How much time it will take?

(a) O(kn) (b) O(kn logk)
(c) $O(k^2)$ (d) None of these

Q.67 The number of comparisions required to find maximum and minimum in the given array of n-elements using divide and conquer is _____

(a) $\left\lfloor \frac{3n}{2} \right\rfloor$ (b) $\left\lceil \frac{3n}{2} \right\rceil$

(c) $\left\lfloor \frac{3n}{2} \right\rfloor + 2$ (d) $\left\lceil \frac{3n}{2} \right\rceil - 2$

Q.68 An algorithm performs $(\log N)^{1/2}$ find operations, N insert operations, $(\log N)^{1/2}$ delete operations, and $(\log N)^{1/2}$ 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

Q.69 An unordered list contains n distinct elements. The number of comparisons to find an element in this list that is neither 2nd maximum nor 2nd minimum is

(a) $\Theta(n \log n)$ (b) $\Theta(n)$
(c) $\Theta(\log n)$ (d) $\Theta(1)$

Q.70 Write the following statements True or False

(a) if f(n) = O(g(n)) then g(n) = O(f(n))
(b) f(n) + g(n) = Θ (min (f(n), g(n)))
(c) ~~f(n) + O(g(n)) = Θ~~(f(n))
(d) (logn)! and (loglogn)! are polynomially bounded

Q.71 If g = O(f) then find true statement from the following.

(a) f = O(g) (b) g = Θ(f)
(c) f+g = Θ(g) (d) f+g = Θ(f)

Q.72 Given a sorted array of n-elements where other than one element x every other element repeat two times. Then how much time will it take to find position of x.

Numerical Data Type Questions

Q.73 Suppose there are 4 sorted lists of n/4 elements each. If we merge these lists into a single sorted list of n elements, for the n = 400 number of key comparisons in the worst case using an efficient algorithm is _____.

Q.74 Construct the Max Heap assuming the following set of integers were inserted into it in given order

20, 32, 1, 3, 4, 5, 6, 7, 10, 23, 45 →

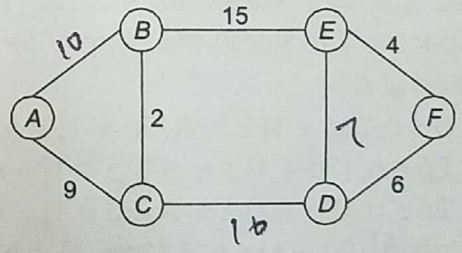
Postorder traversal of the resultant max heap was stored in a array A with an index variable i inorder (Starting from 0). Similarly level order traversal was stored in the array B using index variable j in order (Starting from 0). For particular element, respective i and j location values from A and B were obtained and $|i-j|$ is calculated. What could be the maximum possible value for $|i-j|$?

Q.75 Consider an array consisting of the following elements in unsorted order (placed randomly), but 60 as first element.

60, 80, 15, 95, 7, 12, 35, 90, 55

Quick sort partition algorithm is applied by choosing first element as pivot element. How many total number of arrangements of array integers is possible preserving the effect of first pass of partition algorithm.

Q.76 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 _____.



Q.77 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?

Try Yourself

T1. Let f (n) = Ω (n), g (n) = O (n) and h (n) = Θ (n). Then [f (n) . g (n)] + h (n) is _____

(a) Ω (n) (b) O (n)
(c) Θ (n) (d) None of these

[Ans: (a)]

T2. Consider the following "Max-heapify" algorithm. Array has size atleast n and $1 \le i \le n$. After applying the Max-heapify rooted at A [i], the result will be the subtree of A [1, ...n] rooted at A [i] is max heap. [Assume that except root A[i], all its children satisfies heap property]

```
Max-heapify (int A [ ], int n, int i)
{
    int p, m;
    p = i;
    while (X)
    {
        if (Y && Z)
        m = 2p + 1;
        else m = 2p;
        if (A [p] < A [m])
        {
            Swap (A [p], A [m]);
            p = m;
        }
    else
return;
    }
}
```

Find missing statements at X, Y and Z respectively to apply the heapify for subtree rooted at A [i].

(a) $p \le n, (2p + 1) \ge n, A [2p + 1] > A [2p]$
(b) $2p \le n, (2p + 1) \le n, A [2p + 1] > A [2p]$
(c) $2p \le n, (2p + 1) \ge n, A [2p + 1] < A [2p]$
(d) $p \le n, (2p + 1) \le n, A [2p + 1] < A [2p]$

[Ans: (b)]

T3. Consider the following function

```
find (int n)
{
    if (n < 2) then return;
    else
    {
        sum = 0;
        for (i = 1; i ≤ 4; i++) find(n/2);
        for (i = 1; i ≤ n*n; i++)
        sum = sum +1;
    }
}
```

Assume that the division operation takes constant time and "sum" is global variable. What is the time complexity of "find (n)"?

(a) $\Theta(n^2)$ (b) $\Theta(n^2 \log n)$
(c) $\Theta(n^3)$ (d) None of these

[Ans: (b)]

T4. Given n linearly ordered distinct elements. What is the worst case running time to find i^{th} smallest element $(1 \le i \le n)$ from those n elements? (Select the best answer by assuming n is larger than 50)

(a) O(logn) (b) O(n)
(c) O(nlogn) (d) $O(n^2)$

using median of 5 algo [Ans: (b)]

T5. Consider the following sorting algorithm.

```
Sorting (A, low, high)
{
    if (low = high) return;
    if (low+1 = high)
    {
        if (A[low] > A[high])
        Swap (A[low], A[high]);
        return;
    }
    t1 = low + ((high − low + 1)/3);
    t2 = low + 2·((high − low + 1)/3);
    Sorting (A, low, t2);
    Sorting (A, t1, high);
    Sorting (A, low, t2);
}
```

What is the running time of Sorting(A, 1, n) function.

(a) $\Theta(n^{1.7})$ (b) $\Theta(n^{2.7})$
(c) $\Theta(n^{3.7})$ (d) $\Theta(n^{0.7})$

[Ans: (b)]

T6. Merging K-sorted lists each of size n/k into one sorted list of n-elements using heap sort will take how much time?

[Ans: O(n log k)]

T7. Consider a modification to merge sort in which m/k sublists each of length k are sorted using insertion sort and then merged using standard merge procedure. Then find total time complexity of modified merge sort.

[Ans: O(nk)]

T8. $f_1 = 10^n$, $f_2 = n^{1/3}$, $f_3 = n^n$, $f_4 = \log n$, $f_5 = 2^{\log n}$. Arrange all these five functions in increasing order.

[Ans: $f_4 < f_2 < f_5 < f_1 < f_3$]

T9. Given n integers in the range of 0 to K we want to preprocess the input in such a way that to any query about how many of the n-integers fall in the range a...b is O(1). Then what will the preprocess time?

T10. The pseudo code for insertion sort is presented as a procedure called **Insertion-sort**, which takes array A[1...*n*] as parameter containing sequence of n elements to be sorted. Find the missing statements at X and Y respectively.

```
Insertion-sort (A)
{
    for j ← 2 to length [A]
    {
        key ← A[j]
        i = [ X ]
        While (i > 0 && A[i] > key)
        {
            A[i + 1] ← A [i]
            i = [ Y ]
        }
        A [i + 1] ← key
    }
}
```

(a) X: j − 1, Y: i + 1 (b) X: j + 1, Y: i + 1

(c) X: j − 1, Y: i − 1 (d) X: i − 1, Y: j − 1

[Ans: (c)]

T11. Consider the following C function. Find the time complexity and what is the value of 'q'?

```
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;
}
```

[Ans: O(n log n)]

■■■■

2 Gready Technique and Dynamic Programming

Multiple Choice Questions

Q.1 Adjacency list is preferred over adjacency matrix when the graph is

(a) Planar (b) Dense

(c) Clique (d) None of these

[DRDO-2008]

Sparse Graph

Common Data for Q.2 & Q.3

We are given 9 tasks T_1, T_2 ... T_9. The execution of each task requires one unit of time. We can execute one task at a time. 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

Q.2 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

[GATE-2005]

Q.3 What is the maximum profit earned?

(a) 147 (b) 165

(c) 167 (d) 175

[GATE-2005]

Q.4 Let G be an undirected connected graph with distinct edge weight. Let e_{max} be the edge with maximum weight and e_{min} with minimum weight. Which of the following statements is false?

(a) every minimum spanning tree of G must contain e_{min}

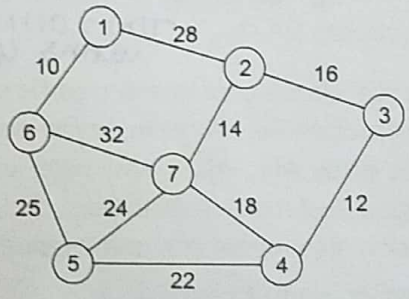
(b) If e_{max} is in a minimum spanning tree, then its removal must disconnect G

(c) no minimum spanning tree contains e_{max}

(d) G has a unique minimum spanning tree

[GATE-2000]

Q.5 Consider the following graph where the numbers denotes the weight of the particular edge



Now, calculate the minimum cost spanning tree of the above graph using either prim's or Kruskal's algorithm.

(a) 92 (b) 99

(c) 102 (d) 123

Q.6 In a simple connected undirected graph with n nodes (where $n \geq 2$) the maximum number of nodes with distinct degrees is

(a) $n - 1$ (b) $n - 2$

(c) $n - 3$ (d) 2

[DRDO-2008]

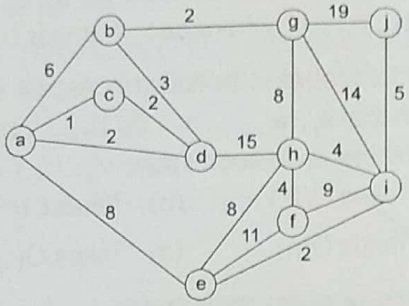
Q.7 A file contains characters a, e, i, o, u, s and t with frequencies 10, 15, 12, 3, 4, 13 and 1 respectively. If we use Huffman Coding for data compression then the average code length will be:

(a) $\frac{140}{58}$ (b) $\frac{146}{58}$

(c) $\frac{150}{58}$ (d) $\frac{174}{58}$

[DRDO-2009]

Q.8 What is the weight of a minimum spanning tree of the following graph?



(a) 29 (b) 31

(c) 38 (d) 41

[GATE-2003]

Q.9 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"

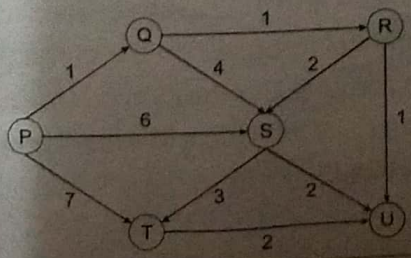
Here, x_s denotes the starting time and x_e denotes the ending time of activity X. We need to schedule the activities in a set of rooms available to us. An activity can be scheduled in a room only if the room is reserved for the activity for its entire duration. What is the minimum number of rooms required?

(a) 3 (b) 4

(c) 5 (d) 6

[GATE-2003]

Q.10 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

[GATE-2004]

Q.11 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

[GATE-2007]

Q.12 Let G (V, E) an undirected graph with positive edge weights. Dijkstra's single source -shortes path algorithm can be implemented using the sorted linked list data structure.

What will the time complexity?

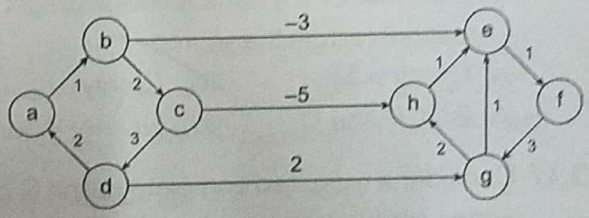
(a) O|V|^2)

(b) O(|V|^3)

(c) O(|V| log |V|)

(d) O((|E| + |V|) log |V|)

Q.13



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

[GATE-2008]

Common Data for Q.14 & Q.15

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}.

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

Q.14 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

[GATE-2010]

Q.15 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

[GATE-2010]

Q.16 Which one of the following statements are correct regarding Bellman-Ford shortest path algorithm?

P : Always finds a negative edge weight cycle if one exists.

Q : Find whether any negative edge weight cycle reachable from the source.

(a) P only (b) Q only

(c) Both P and Q (d) Neither P nor Q

Q.17 Consider a weighted complete garph G on the vertex set $\{v_1, v_2, \ldots, v_n\}$ 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) (n/2) (d) n^2

[GATE-2006]

Q.18 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

[GATE-2007]

Q.19 Given 2-arrays of numbers $a_1, a_2, a_3 \ldots a_n$ and $b_1, b_2, b_3 \ldots b_n$ where each number is 0 or 1.

The fastest algo to find the largest span (i, j) such that $a_i, a_{i+1} \ldots a_j = b_i, b_{i+1}, \ldots b_j$ or report that there is no such span.

(a) Takes $O(2^n)$ (b) Takes $O(n^2)$

(c) Takes O(n) (d) Takes $O(\sqrt{n})$ times

Common Data for Q.20 & Q.21

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.

Q.20 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 $l(i, j)$ to compute the length of the LCS of X[m] and Y[n] is given below:

$l(i, j)$ = 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) expr1 ≡ $l(i–1, j) + 1$

(b) expr1 ≡ $l(i, j –1)$

(c) expr2 ≡ max ($l(i–1, j)$, $l(i, j–1)$)

(d) expr2 ≡ max ($l(i–1, j–1)$, $l(i, j)$)

[GATE-2009]

Q.21 The values 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 $q<s$

[GATE-2009]

Q.22 The weight of a sequence $a_0, a_1, \ldots, a_{n-1}$ of real numbers is defined as $a_0 + a_1/2 + \ldots a_{n-1}/2^{n-1}$. 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 $a_0, a_1, \ldots, a_{n-1}$ and Y the maximum possible weight of a subsequence of $a_1, a_2, \ldots, a_{n-1}$.

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) $a_0 + Y/2$

[GATE-2010]

Q.23 Consider the following statements

I. For every weighted graph and any two vertices s and t, Bellman-ford algorithm starting at s will always return a shortest path to t.

II. At the termination of the Bellman-ford algorithm, even if graph has negative weight cycle, a correct shortest path is found for a vertex for which shortest path is well-defined.

Which of the above statements are true?

(a) only I (b) only II

(c) both I and II (d) None of these

Q.24 If graph contains negative weight edges then which of the following is correct when we run dijkstra's algorithm?

(a) It may not terminate

(b) It terminates but may produce incorrect results

(c) It never terminates due to cycles in graph

(d) None of these

Q.25 Consider the knapsack instance:

- Capacity of knapsack is 15 and 7 objects
- Profits: $(P_1, P_2, \ldots, P_7) = (10,5,15,7,6,18,3)$
- Weights: $(w_1, w_2, \ldots, w_7) = (2,3,5,7,1,4,1)$
- Objects: $(x_1, x_2, \ldots, x_7)$

If knapsack problem is solved using maximum profit per unit weight then find the object which is partially placed in the knapsack.

(a) x_1 (b) x_2

(c) x_3 (d) x_4

Q.26 Consider the following statements

I. Let *T* be a minimum spanning tree of a graph G. Then for any two vertices *u* and *v* the path from *u* to *v* in T is the shortest path from *u* to *v* in the graph G.

II. Suppose that average edge weight for a graph G is A_{avg}. Then the minimum spanning tree of G will have weight at most $(n-1)A_{avg}$. Where *n* is number of vertices in graph G.

Which of the above statements are true?

(a) Only I (b) Only II

(c) both I and II (d) None of these

Linked Answer for Q.27 & Q.28

Consider the following message:

aabbbbabccdddccccbbdd

Q.27 Find the number of bits required for huffman encoding of the above message.

(a) 30 (b) 38

(c) 42 (d) 46

Q.28 If huffman tree coded as left child with '0' and right child with '1' from every node then what is the decoded message for 110100

(a) abc (b) bcd

(c) acb (d) bda

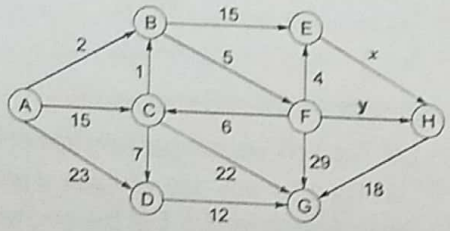
Q.29 Let $P_0 = 5, P_1 = 6, P_2 = 7, P_3 = 1, P_4 = 10, P_5 = 2$ and for $1 \le i \le 5$. Let X_i be a matrix with P_{i-1} rows and P_i columns, and $X = X_1.X_2.X_3.X_4.X_5$. Which of the following is optimum parenthesization for computing X?

(a) $((X_1(X_2.X_3))X_4)X_5$ (b) $(X_1(X_2.X_3))(X_4.X_5)$

(c) $(X_1X_2)((X_3X_4).X_5)$ (d) $((X_1.X_2)(X_3.X_4))X_5$

Numerical Data Type Questions

Q.30 Suppose that you are running Dijkstra's algorithm on the edge-weighted digraph below, starting from vertex A.

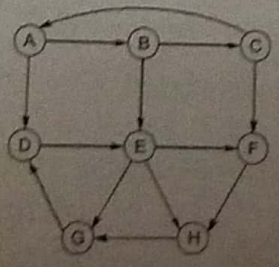


The table gives 'Distance' and 'Parent' entry of each vertex after vertex E has been deleted from the priority queue and relaxed.

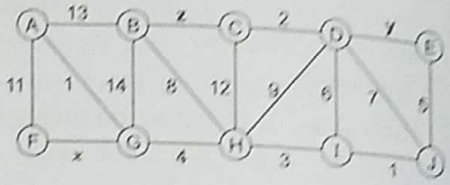
Vertex	Distance	Parent
A	0	NULL
B	2	A
C	13	F
D	23	A
E	11	F
F	7	B
G	36	F
H	19	E

What could be the possible value of expression $x+y$?

Q.31 Find the number of strong components in the following graph.

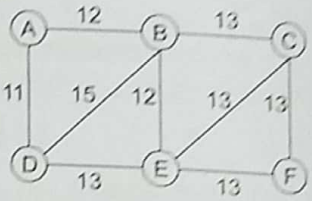


Q.32 Suppose that minimum spanning tree of the following edge weighted graph contains the edges with weights x, y and z



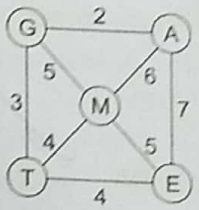
What is the maximum value of $x + y + z$?

Q.33 Consider the following graph G.



Find the number of minimum cost spanning trees using kruskal's algorithm or prim's algorithm.

Q.34 Assume Dijkstra's algorithm is used to find the shortest paths from node 'G' in the following graph.



Find the number of edges which are not included in any of the shortest paths from node G.

Common Data for Q.35 & Q.36

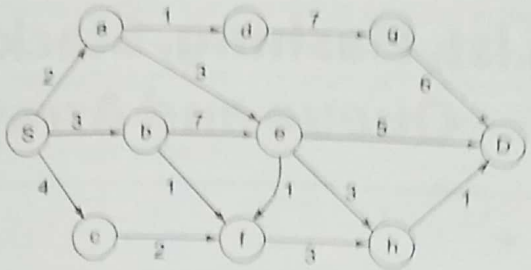
Matrix multiplication is associative and matrix chain multiplication uses following matrices:

A_1 is 10×100,
A_2 is 100×5,
A_3 is 5×50, and
A_4 is 50×1

Q.35 Find the number of orderings that are possible to compute $A_1 A_2 A_3 A_4$.

Q.36 Find the maximum number of multiplications required to compute $A_1 A_2 A_3 A_4$.

Q.37 Consider the following graph G



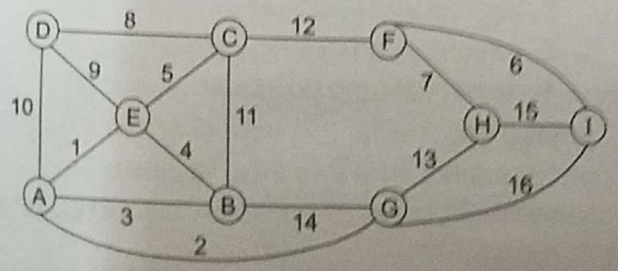
What is minimum distance from S to D?

Q.38 Let G be 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 _____.

Q.39 Suppose P, Q, R, S, T are sorted sequences having lengths 20, 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 _____.

Try Yourself

T1. Consider the weighted undirected graph below



Assume prim's algorithm and kruskal's algorithm are executed on the above graph to find the minimum spanning tree. For a particular edge (e_i) which is included in minimum spanning tree and the position of an edge in minimum spanning tree is denoted by (e_{p_i}). Where $1 \le e_{p_i} \le 8$ (where position defines the order in which edges are included in the MST). Then what is the maximum value of $(e_{p_i})_{prim's} - (e_{p_i})_{kruskal's}$?

T2. Complexity of kruskal algorithm for finding the minimum cost spanning tree of an undirected graph contain n-vertices and m-edges, if the edges are already sorted

T3. Given a sequence of n-real numbers $a_1, a_2, a_3, \ldots, a_n$ then to find contigious subsequences $a_i, a_{i+1}, \ldots, a_j$ such that its sum is maximum.

How much time the above problem will take if you use dynamic program?

[Ans: O(n)]

T4. Let T be a minimum cost spanning tree of G. Suppose that we decreased the weight of one of the edge in T. Then to check modified T is MST are not how much time will take?

[Ans: O(1)]

T5. Let T be a MST of G. Suppose that we decreased the weight of one of the edge present in G but not in T. Then how much time will take to construct MST for the modified graph G?

[Ans: O(V)]

T6. Let G be a undirected graph on n-nodes. Any two of the following statements implies the 3rd. Is it True / False?

1. G is connected
2. G dont have cycle
3. G contain n–1 edges

[Ans: True]

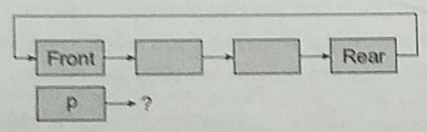
T7. Let A_1, A_2, A_3 and A_4 be four matrices of dimensions 10×5, 5×20, 20×10, and 10×5, respectively. The minimum number of scalar multiplications required to find the product $A_1 A_2 A_3 A_4$ using the basic matrix multiplication method is ___

[GATE-2016, Ans: (1500)]

3 Linked List, Hashing, Stack, Queue and Array

Multiple Choice Questions

Q.1 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

[GATE-2004]

Q.2 The following C function takes a singly-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 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

[GATE-2008]

Q.3 Consider the label sequences obtained by the following pairs of traversals on a labeled binary tree. Which of these pairs identify a tree uniquely?

1. preorder and postorder
2. inorder and postorder
3. preorder and inorder
4. level order and postorder

(a) 1 only (b) 2 and 3
(c) 3 only (d) 4 only

[GATE-2004]

Q.4 Suppose each set is represented as a linked list with elements in arbitrary order. Which of the operations among union, intersection, membership, cardinality will be the solwest?

(a) union only
(b) intersection, membership
(c) membership, cardinality
(d) union, intersection

[GATE-2004]

Q.5 Consider
in the figu
first elem
last eleme
operation
the lengt

(a) Add
list
(b) Dele
(c) Add
(d) Inte

Q.6 A data
which
with no
is to b
access
field a

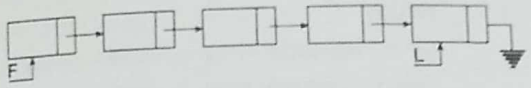
There

```
struct
int no
{
    if
    re
    (a
}
```

Selec
make
(a) A
(b) A
(c) A
(d) A

Q.7 A do
of th
the
a do
(a)
(b)
(c)
(d)

Q.5 Consider a singly linked list of the form as given in the figure below, where F is a pointer to the first element in the list and L is a pointer to the last element in the list. For which of the following operations, the corresponding time depends on the length of the list?



(a) Add an element after the last element of the list
(b) Delete the last element of the list
(c) Add an element before the first element
(d) Interchange the first two elements of the list

[JNUEE-2007]

Q.6 A data structure is comprised of nodes each of which has exactly two pointers to other nodes with no null pointers. The following C program is to be used to count the number of nodes accessible from a given node. It uses a mark field assumed to be initially zero for all nodes.

There is a statement missing from this code.

```
struct test {int info, mark; struct test * p, *q}
int nodecount (struct test *a)
{
    if (a → mark) return 0;
    return nodecount (a → p) + nodecount
    (a → q) + 1;
}
```

Select from the following the change that should make the program work property

(a) Add a → mark = 1; as the first statement
(b) Add a → mark = 0; after the if-statement
(c) Add a → mark = 1; after the if-statement
(d) Add a → mark = 0; as the last statement

[JNUEE-2005]

Q.7 A doubly-linked list facilitates the determination of the predecessor of a given item. Which of the following operations utilizes this property of a doubly-linked list to its greatest advantage?

(a) accessing an item
(b) recovering a lost pointer
(c) copying a list
(d) merging two lists [JNUEE-2004]

Q.8 The following C function takes a singly-linked list as input argument. It modified 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->next = head; head = p;
(b) q->next = NULL; head = p; p->next = head;
(c) head = p; p->next = q; q->next = NULL;
(d) q->next = NULL; p-next = head; head = p;

[GATE-2010]

Q.9 Let LASTPOST, LASTIN and LASTPRE denote the last vertex visited in a postorder, inorder an preorder traversal. Respectively, of a complete binary tree. Which of the following is always tree?

(a) LASTIN = LASTPOST
(b) LASTIN = LASTPRE
(c) LASTPRE = LASTPOST
(d) none of the above

[GATE-2000]

Q.10 The number of !eaf 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) $\frac{(2n+1)}{3}$

[GATE-2002]

Q.11 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

[ISRO-2009]

Q.12 Binary search can be carried out on a set of ordered data items stored in a

(a) Array (b) Stack

(c) Queue (d) List

[DRDO-2008]

Q.13 A binary tree can be uniquely reconstructed from the following traversal(s):

(a) Preorder

(b) Postorder

(c) Preorder and Postorder

(d) Inorder and Preorder [DRDO-2008]

Q.14 Insert keys 4, 12, 8, 16, 6, 18, 24, 7 inot an initially empty binary search tree. Delete the node having the key 6. The preorder traversal after deletion is

(a) 4, 12, 7, 8, 24, 18, 16

(b) 4, 12, 8, 7, 16, 18, 24

(c) 4, 12, 8, 7, 24, 18, 16

(b) 4, 12, 7, 8, 16, 18, 24 [DRDO-2009]

Q.15 The concatenation of 2-lists is to be performed in O(1) time. Which one of the following implements?

(a) Single linked list

(b) Doubly linked list

(c) Circular doubly linked list

(d) None of these

Q.16 Consider the following C program.

```
struct listnode
{   int data;
    struct listnode *next;
};
void fun (struct listnode *head)
{   if (head == NULL || head → next == NULL)
    return;
    struct listnode *tmp = head → next;
    head → next = tmp → next;
    free (tmp);
    fun (head → next);
}
```

What is the functionality of the above function?

(a) It reverses the linked list

(b) It deletes the linked list

(c) Alternate nodes will be deleted

(d) It reverses the linked list and delete alternate nodes

Q.17 Consider the following code.

```
int f(Struct Node *A, Struct Node *B)
{
    if (A == NULL && B == NULL) return 0;
    else if (A == NULL || B == NULL) return 1;
    else if (A → data != B → data) return 1;
    if (f(A → left, B → left) || f(A → right, B → right)) return 1;
    else return 0;
}
```

Assume Node is a structure type with 3 members as follows:

```
Struct Node
{   int data;
    Struct Node *left;
    Struct Node *right;
};
```

If two binary tree root pointers are passed to the function f( ), then which of the following statement is correct?

(a) It compares two given binary trees and returns 1 if two trees are different and it returns 0 otherwise.

(b) It compares two given binary trees and returns 0 if two trees are different and it returns 0 otherwise.

(c) It compares two given binary trees but return value can not be used to differentiate the trees
(d) None of these

Q.18 Let h(k) = k mod 7. Calculate the number of collisions with linear probing for insertion of the following keys:
29 36 16 30
(a) 2 (b) 3
(c) 4 (d) 5
[GATE-2000]

Q.19 Which of the following is the best choice as m in the hash function, h(k) = k mod m?
(a) 61 (b) 701
(c) 81 (d) 1031
[GATE-2000]

Q.20 Consider the following function:

```
void madeeasy (int n)
{
    enqueue (Q, 0);
    enqueue (Q, 1);
    for (i = 0; i < n; i++)
    {
        x = dequeue (Q);
        y = dequeue (Q);
        enqueue (Q, y);
        enqueue (Q, x + y);
        print (x);
    }
}
```

What is the functionality of above function madeeasy?
(a) Prints numbers from 0 to n – 1
(b) Prints numbers from n – 1 to 0
(c) Prints first n fibbonacci numbers
(d) Prints first n fibbonacci numbers in reverse order

Q.21 Choosing the hash function randomly from a class of hash functions such that it is independent of the keys to be stored, is termed as:
(a) perfect hashing
(b) simple uniform hashing
(c) universal hashing
(d) none of the above [GATE-2000]

Q.22 Given the hash function h(k, i) = (h'(k) + i + i²) mod 11 and h'(k) = k mod 11.
What is the number of collisions to store the following keys?
Following keys : 23 12 19 11 33 16 46 37
(a) 3 (b) 2
(c) 11 (d) None of these
[GATE-2000]

Common Data for Q.23 & Q.24

Q.23 Consider an open address hash table with a total of 10,000 slots, containing 9800 entries. What is the expected number of probes in a successful search?
(a) 2 (b) 3
(c) 4 (d) 4.5
[GATE-2000]

Q.24 In above problem, what is the expected number of probes in unsuccessful search?
(a) 4 (b) 10
(c) 20 (d) 50
[GATE-2000]

Q.25 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	12,2
3	13,3,23
4	
5	5,15
6	
7	
8	18
9	

[GATE-2009]

Q.26 Consider a hash table consisting of M = 11slots (numbering of slots start from 0), and suppose integer key values are hashed into the table using the hash function h1:

```
int h1 (int key)
{   int x;
    x = (key + 5) * (key + 5);
    x = x/16;
    x = x + key;
    x = x % 11;
    return x;
}
```

Suppose that collisions are resolved using linear probing. The probe sequence is given therefore by (h1(k) + i) (mod 11) (i starts from 0). The integer key values listed below are to be inserted, in the order given. What are the final contents of the hash table after the following key values have been inserted in the given order:

43, 23, 1, 0, 15, 31, 4, 7, 11, 3

(a)

43	0	31	1		23	15	7	11	3	4

(b)

43	0	1	31		7	15	23	11	4	3

(c)

43	0	31	1		7	23	15	11	4	3

(d) None of the above

Linked Answer for Q.27 & Q.28

A has 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 as shown below.

0	
1	
2	42
3	23
4	34
5	52
6	46
7	33
8	
9	

Q.27 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 [GATE-2010]

Q.28 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 [GATE-2010]

Q.29 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?

1. 9679, 1989, 4199 hash to the same value
2. 1471, 6171 hash to the same value
3. All elements hash to the same value
4. Each element hashes to a different value

(a) 1 only (b) 2 only
(c) 1 and 2 only (d) 3 and 4 only
[GATE-2003]

Q.30 Consider the hash table of size 7, with starting index 0, and a has 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 (Linear probing)?

(a) 8, -, -, -, -,-, 10 (b) 1, 8, 10, -, -, -, 3
(c) 1, -, -, -, -, -, 3 (d) 1, 10, 8, -, -, -, 3
[GATE-2007]

Q.31 A one dimensional array A has indices 1 .... 75. Each element is a string and takes up three memory words. The array is stored at location 1120 decimal. The starting address of A[49] is
(a) 1267 (b) 1164
(c) 1264 (d) 1169
[ISRO-2009]

Q.32 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
[GATE-2001]

Q.33 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
[GATE-2002]

Q.34 Suppose you are given an array s[1...n] and a procedure reverse (s, i, j) which reverse the order of elements between positions i and j (both inclusive). What does the following sequence do, where $1 \le k \le n$.
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 [GATE-2000]

Q.35 Assume that there are two lower triangular matrices A and B of size n × n. If matrix A and transpose of B are fit into a rectangular matrix C of size n × (n + 1), then
(a) B[i, j] = C[i, j + 1] (b) B[i, j] = C[j + 1, i]
(c) B[i, j] = C[j, i + 1] (d) None of these
[JNUEE-2009]

Q.36 Assume that a lower triangular matrix A[0.. n – 1, 0.. n – 1] is stored in a linear array $B\left[0..\frac{1}{2}n(n+1)-1\right]$ in row-by-row order. For n = 100, if A[0, 0] is stored in B[0], where is A[90, 80] stored in B array?
(a) 4175 (b) 0
(c) 4165 (d) 4160
[JNUEE-2009]

Q.37 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 turning machine is needed in the general case
[GATE-2002]

Q.38 Let S be a stack of size $n \le 1$. 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 $m \le 1$, 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
[GATE-2003]

Q.39 A single array A[1...MAXSIZE] is used to implement two stacks. The two stacks grow from opposite ends of the array. Variables top 1 and top 2 (top 1 < top 2) 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) (top 1 = MAXSIZE/2) and (top 2 = MAXSIZE/2 + 1)
(b) top 1 + top 2 = MAXSIZE
(c) (top 1 = MAXSIZE/2) or (top 2 = MAXSIZE)
(d) top 1 = top 2 – 1 [GATE-2004]

Q.40 To remove recursion from a program we have to use the following data structures
(a) Array (b) Stack
(c) Queue (d) List
[DRDO-2008]

Q.41 The expression 1 * 2 ^ 3 * 4 ^ 5 * 6 will be evaluated as
(a) 32^{30} (b) 162^{30}
(c) 49152 (d) 173458
[ISRO-2009]

Q.42 What is the maximum size of the operator stack during the conversion of the infix expression A + B*C – D/E to postfix?
(a) 1 (b) 2
(c) 3 (d) 4 [DRDO-2008]

Q.43 What is the maximum size of the operand stack while evaluating the postfix expression 6 2 3 + –3 8 2/+ *?
(a) 1 (b) 2
(c) 3 (d) 4 [DRDO-2008]

Q.44 Assume that the operators x, –, + are left associative and ^ is right associative. The order of precedence (from highest to lowest) is ^, x, +, –. the postfix expression corresponding to the infix expression a + b x c – d ^ e ^ f is
(a) abc x + def ^ ^ _
(b) abc x + de ^ f ^
(c) ab + c x d – e ^ f ^
(d) – + a x bc ^ ^ def [ISRO-2009]

Q.45 The best data structure to check whether an arithmetic expression has balanced parentheses is a
(a) queue (b) stack
(c) tree (d) list [GATE-2004]

Numerical Data Type Questions

Q.46 What is the maximum possible height of an AVL tree with 20 nodes?
[DRDO-2008]

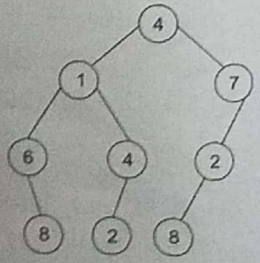
Q.47 A binary search tree was constructed by inserting following elements in to an initially empty binary tree.
50, 27, 16, 88, 34, 65, 52, 77, 93, 4, 12, 29, 44, 92
Preorder and postorder traversals of the resultant binary search tree were stored in arrays A and B respectively. How many elements have same index location in both the arrays? [Assume arrays A and B start from the same index]

Q.48 Consider the following elements which are inserted into initially empty AVL tree in the given order.
11, 7, 12, 13, 2, 9, 1, 3, 4
What is the last element in preorder traversal of left subtree of resultant AVL tree?

Q.49 Consider the following C program

```
struct treenode
{
    int data;
    struct treenode *left;
    struct treenode *right;
}
int gate2015 (struct treenode *root)
{
    int gate;
    if (root ==NULL) return 0;
    if (root → data % 2==1)
    {
        root → data –=1;
        gate ++;
    }
    else
        root → data +=1;
return (root → data + gate2015 (root → left) +
gate2015 (root → right);
}
```

If the above code is executed on the following tree then what is the output?



Q.50 Consider the tree T in which left subtree contains half of the maximum number of nodes possible in the AVL tree of height 6 and right subtree consists of one 3rd of the minimum number of nodes possible in AVL tree of height '6'. Then what will be the total number of nodes in T.

Q.51 The key 14, 4, 6, 16, 32, 50 in the order are inserted into an initially empty AVL tree. Find total number of rotations to make AVL with the given keys. Assume "single rotation = 1 rotation" and "double rotation = 1 rotation".

Common Data for Q.52 & Q.53

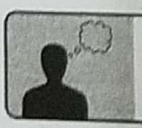
Consider the following keys that are hashed into the hash table in the order given using the hash function h(i) = (2i + 5) mod 11.

12, 44, 13, 88, 23, 94, 11, 39, 20, 16, 5.

Assume hash table has locations from 0 to 10.

Q.52 Find the location of an element 39, if hash table uses linear probing to hash the given elements.

Q.53 If hash table uses chaining to handle the collisions, how many locations are left without hashing any element into it?



Try Yourself

T1. If we implement stack using single linked list how much time push and pop operations will take?

[Ans: Push-O(1), Pop-O(1)]

T2. If we implement queue using single linked list how much time enqueue and dequeue operations will take?

[Ans: enqueue-O(1), dequeue-O(n)]

T3. Consider the implementation of multiple stacks in single array S of size P from index 0 to P – 1. Number of stacks are Q. The following function PUSH ( ), used to push data x on to a particular stack i where T_i is used as top variable for stack i (i indicates stack number).

```
PUSH (S, P, Q, T_i, x)
{
    if (_____A_____)
    {
        printf ("stack overflow");
        exit (1);
    }
    else
        T_i++;
    S[T_i] = x;
}
```

Stack 0 stores elements from 0 to Q – 1, stack 1 stores from q to 2Q – 1, and similarly other stack will store elements. Which of the following is the correct expression to replace A in the above function?

(a) $T_i == \left(\frac{P}{Q} \times i - 1\right)$

(b) $T_i = = \left(\frac{P}{Q} \times i + 1\right)$

(c) $T_i = = \left(\frac{P}{Q} \times (i-1) - 1\right)$

(d) $T_i == \left(\frac{P}{Q} \times (i+1) - 1\right)$ **[Ans: (d)]**

T4. 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, x)
    {
        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 (≤ 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 processes. Which one of the following is true for all m and n?

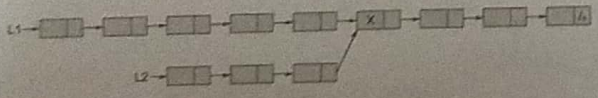
(a) $n + m \le x \le 2n$ and $2m \le n + m$
(b) $n + m \le x < 2n$ and $2m \le y \le 2n$
(c) $2m \le x < 2n$ and $2m \le y \le n + m$
(d) $2m \le x < 2n$ and $2m \le y \le 2n$ **[Ans: (a)]**

T5. Consider 3 dimensional Array A[90] [30] [40] stored in linear array in column major order. If the base address starts at 10, what is the location of A [20] [20] [30]?
Assume the first element is stored at A[1][1][1].
[Ans: (22079)]

T6. Consider the following infix expression which is to be converted to postfix expression using stack.
(((P + Q) * (R + S)) / T) + (A * (B + C))
What is the size of stack? **[Ans: (15)]**

T7. Consider the hashing table with 'm' slots and 'n' keys. If the expected number of probes in unsuccessful search is 3, then find the expected number of probes in a successful search.
[Ans: (0.7324)]

T8. Consider the two linked list L1 and L2 given below each of length m and n



What will be the worst case time complexity to find address of node 'X', where both linked list will intersect with each other?

(a) O(m log n) (b) O(m + n)
(c) O(n log m) (d) O(n^2 log m)
[Ans: (b)]

T9. 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 listof 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) $\Theta(n^2)$ (b) $\Theta(n + m)$
(c) $\Theta(nm^2)$ (d) $\Theta(n^4)$
[GATE-2016, Ans: (b)]

T10. 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 _____.
[GATE-2016, Ans: (256)]

■■■■

4 Tree and Graph

Multiple Choice Questions

Q.1 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 these

[GATE-2001]

Q.2 How many undirected graphs (not necessarily connected) can be constructed out of a given set $V = \{v_1, v_2, \ldots, v_n\}$ of n vertices?

(a) $\frac{n(n-1)}{2}$ (b) 2^n

(c) n! (d) $2^{\frac{n(n-1)}{2}}$

[GATE-2001]

Q.3 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 statements 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

[GATE-2000]

Q.4 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

[GATE-2003]

Q.5 Among the following statements, identify the false statement.

(a) We must balance a left-of-left unbalanced AVL tree by rotating the out-of-balance node to the right.

(b) The inorder traversal of a binary search tree produces an ordered list.

(c) When a module calls a subroutine recursively, in each call, all of the information is popped in the same order when subroutines are terminated one after another and finally the control is returned to the calling module.

(d) A recursion algorithm has two elements : Each call either solves only part of the problem or it reduces the size of the problem.

[JNUEE-2003]

Q.6 A data structure is required for storing a set of integers such that each of the following operations can be done in (log n) time, where n is the number of elements in the set.

1. Deletion of the smallest element.
2. 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 binary search tree nor heap can be used

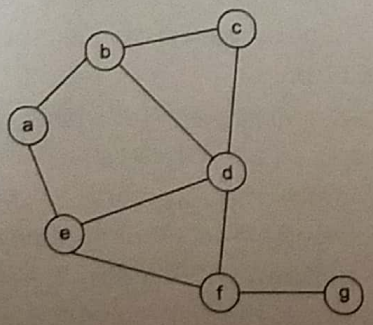
[ISRO-2009]

Q.7 Postorder traversal of a binary search tree is given as follows 35, 40, 55, 60, 50, 100. Then the given tree is:

(a) Minheap tree (b) Maxheap true

(c) Strict binary tree (d) None of these

Q.8 Consider te following graph:



A possible Depth First Search (DFS) sequence for the above graph is

(a) d, e, b, a, c, f, g (b) b, a, e, c, d, f, g

(c) d, b, a, e, f, c, g (d) b, c, d, e, f, g, a

[DRDO-2009]

Q.9 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 inorder 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, 0, 15, 29

[GATE-2004]

Q.10 Suppose a binary tree has only three nodes A, B, and C and you are given that the post-order traversal for the tree is B-A-C. The exact pre-order traversal for the tree is.

(a) C-A-B

(b) A-B-C

(c) C-B-A

(d) a definite pre-order traversal cannot be determined from the information given

Q.11 Level order traversal of a rooted tree can be done by starting from the root and performing

(a) preorder traversal

(b) inorder traversal

(c) depth first search

(d) breadth first search

[GATE-2004]

Q.12 Consider the label sequences obtained by the following pairs of traversals on a labeled binary tree.

Which of these pairs identify a tree uniquely?

1. preorder and postorder
2. inorder and postorder
3. preorder and inorder
4. level order and postorder

(a) 1 only (b) 2 and 3

(c) 3 only (d) 4 only

[GATE-2004]

Q.13 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

[GATE-2007]

Q.14 Which one 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

[GATE-1994]

Q.15 Match **List-I** with **List-II** select the correct answer using the codes given below the Lists:

List-I

A. Strassen's matrix multiplication

B. Kruskal's minimum spanning tree

C. Bi-connected components algorithm

D. Floyd's shortest path

List-II

1. Greedy method
2. Dynamic programming
3. Divide and Conquer
4. Depth first search

Codes:

	A	B	C	D
(a)	3	1	4	2
(b)	3	4	1	2
(c)	2	4	1	3
(d)	2	1	4	3

Q.16 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) $\Theta(mn)$

[GATE-2007]

Q.17 Which of the following statement is false?

(a) The depth of any DFS (Depth First Search) tree rooted at a vertex is at least as much as the depth of any BFS tree rooted at the same vertex.

(b) if all edges in a graph have distinct weight then the shortest path between two vertices is unique

(c) For a directed graph, the absence of back edges in a DFS tree means graph has no cycle

(d) BFS takes $O(V^2)$ time in a graph $G(V, E)$ if graph is represented with an adjacency matrix.

Q.18 Consider the tree arcs of a BFS traversal from a source node w in an weighted, connected, undirected graph with equal edge weights. The tree T formed by the tree arcs is a data structure for computing.

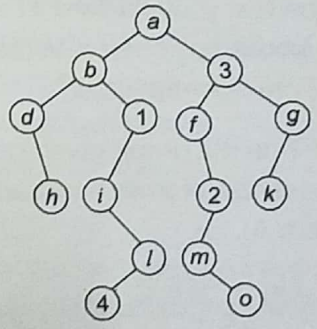
(a) the shortest path between every pair of vertices

(b) The shortest path from w to every vertex in the graph

(c) the shortest path from w to only those nodes that are leaves of T

(d) the longest path in the graph

Q.19 Consider the following tree



If the inorder traversal of the above tree is dhbinleafmojckg then fill the numbers 1, 2, 3 and 4 in the above tree.

(a) n, e, j and c (b) e, j, c and n

(c) j, c, n and e (d) All of these

Q.20 A binary search tree contains the values 11, 22, 33, 44, 55, 66, 77 and 88. Which of the following is a valid preorder traversal?

(a) 55, 33, 11, 22, 44, 77, 66, 88

(b) 55, 33, 22, 44, 11, 66, 77, 88

(c) 55, 33, 11, 22, 66, 44, 88, 77

(d) 55, 33, 11, 44, 22, 66, 77, 88

Q.21 In delete operation of binary search tree, we need inorder successor (or predecessor) of a node when a node to be deleted where it has both left and right child. Which of the following is true about inorder successor needed in delete operation?

(a) Inorder successor is always either leaf node or a node with empty right child.
(b) Inorder successor maybe a an ancestor of the node.
(c) Inorder successor is always a leaf node.
(d) Inorder successor is always either a leaf node or a node with empty left child.

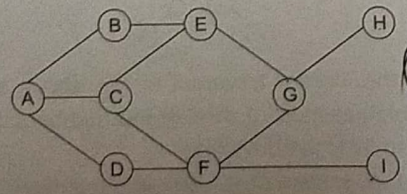
Q.22 The worst case running time complexity to search for an element in a balanced binary search tree with $(2n)!$ elements?

(a) $O(n^n)$ (b) $O(n \log n)$
(c) $O(n)$ (d) $O(n^2)$

Numerical Data Type Questions

Q.23 Assume the preorder traversal of binary tree is "abc". How many total different binary trees are possible whose postorder traversal is "cba" with the given preorder traversal?

Q.24 Apply DFT on the graph given below and find minimum number of times backtracking required (starts from A).



Try Yourself

T1. 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 [Ans: (d)]

T2. Given two inputs BST and Min heap tree with n-nodes. To get the sorted order which is better and how much time? [Ans: BST and ...]

T3. Given an adjacency-list representation of directed graph G(V, E). Then how much time does it take to compute the out-degree of each vertex. [Ans: ...]

T4. If the graph G(V, E) is represented using adjacency matrix then to find universal sink (in-degree is V–1 and out-degree is 0). [Ans: ...]

T5. 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) $O(d2^d)$ but not $O(2d)$

[GATE-2016, Ans: (b)]

T6. 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).

[GATE-2016, Ans: (64)]

5 Programming

Multiple Choice Questions

Q.1 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

[GATE-2000]

Q.2 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 use of same variable

[JNUEE-2008]

Q.3 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

[GATE-2004]

Q.4 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

[GATE-2005]

Q.5 A common property of logic programming languages and functional languages is
(a) both are procedural language
(b) both are based on λ-calculus
(c) both are declarative
(d) all of the above

[GATE-2005]

Q.6 Which of the following are essential features of an object-oriented programming languages?
1. Abstraction and encapsulation
2. Strictly-typedness
3. Type-safe property coupled with sub-type rule
4. Polymorphism in the presence of inheritance

(a) 1 and 2 only (b) 1 and 4 only
(c) 1, 2 and 4 only (d) 1, 3 and 4 only

[GATE-2005]

Q.7 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

[GATE-2005]

Q.8 Consider the following C function.

```
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;
}
```

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

(a) X^y (b) e^x
(c) $\ln(1 + x)$ (d) X^x

[GATE-2003]

Q.9 Assume the following C variable declaration

```
int * A[10], B[10] [10];
```

Of the following expressions

1. A[2] 2. A[2][3]
3. B[1] 4. B[2] [3]

Which will not give compile-time errors if used as left hand sides of assignment statements in a C program?

(a) 1, 2 and 4 only (b) 2, 3 and 4 only
(c) 2 and 4 only (d) 4 only

[GATE-2003]

Q.10 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

[GATE-2002]

Q.11 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 these

[GATE-2001]

Q.12 Consider the following program

Program P2

```
var n:int;
procedure W(var x:int)
begin
    x = x + 1;
    print x;
end
Procedure D
begin
    var n:int;
    n = 3;
    W(n);
End
begin      \\beginP2
    n = 10;
    D;
end
```

If the language has dynamic scoping and parameters are passed by reference. What will be printed by the program?

(a) 10 (b) 11
(c) 3 (d) None of these

[GATE-2001]

Q.13 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 record for 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 on a different stack before the recursive fraction can be called

[GATE-2002]

Q.14 Consider the following C declaration

```
struct
{   short s [5]
    union
    {   float y;
        long z;
    } u;
} t;
```

Assume that 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 considerations, is

(a) 22 bytes (b) 14 bytes
(c) 18 bytes (d) 10 bytes

[GATE-2000]

Q.15 An unrestricted use of the "goto" statement is harmful because
(a) it makes it more difficult to varify 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

[GATE-1994]

Q.16 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

[GATE-2007]

Q.17 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

[GATE-2005]

Q.18 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

[GATE-2004]

Q.19 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

[GATE-2004]

Q.20 Consider the following C-function:

```
int f (int a, int b)
{
    if (b > a) return (f (b, a) );
    else if (b==0) return (a);
         else return (f (b, a%b) );
}
```

Which of the following will be returned by the function call f(18, 30)?
(a) 2 (b) 3
(c) 6 (d) 8

[DRDO-2009]

Q.21 In a C program how many bytes are required to store the string "john" in a charater array"
(a) 2 (b) 3
(c) 4 (d) 5

[DRDO-2009]

Q.22 Consider a declaration

```
int a = 5, *b = & a;
printf ("%d", a*b);
```

The output is
(a) 25 (b) garbage
(c) 5 * address of b (d) error message

[JNUEE-2009]

Q.23

```
main ()
{
    void *vp;
    char ch = 'g'
    char *cp = "goofy";
    int j = 20;
    vp = &ch;
    printf("%c", * (char *) vp);
    vp = &j;
    printf("%d", *(int *) vp);
    vp = cp;
    printf("%s", (char *) vp + 3);
}
```

(a) g20fy (b) goofy
(c) go2fy (d) none of these

Q.24 For the following program

```
main( ) {
    inc( ); inc( ); inc( );
}
inc( ) {
    static int x;
    printf("%d", ++x);
}
```

the output
(a) prints 0, 1, 2
(b) prints 1, 2, 3
(c) prints 3 consecutive but unpredictable numbers
(d) prints 111

[JNUEE-2009]

Q.25

```
main () {
    int i = 258;
    int * iptr = &i;
    printf("%d%d",*((char *) iptr), *((char *) iptr + 1));
}
```

(a) 2,1 (b) 2, 5
(c) 1, 2 (d) 5, 2

Q.26

```
main () {
    int i = 300
    char *ptr = (char*)&i;
    *++ptr = 2;
    printf("%d", i);
}
```

(a) 556 (b) 300
(c) 655 (d) 003

Q.27 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

[GATE-2010]

Q.28 The following program is to be tested for statement coverage:

```
begin
    if (a = = b) {S1; exit;}
    else if (c = = d) {S2;}
    else {S3; exit;}
S4;
end
```

The test cases T1, T2, T3 and T4 given below are expressed in terms of the properties satisfied by the values of variables a, b, c and d. The exact values are not given.

T1 : a, b, c and d are all equal
T2 : a, b, c and d are all distinct
T3 : a = b and c != d
T4 : a !=b and c = d

Which of the test suites given below ensures coverage of statements S1, S2, S3 and S4?

(a) T1, T2, T3 (b) T2, T4
(c) T3, T4 (d) T1, T2, T4

[GATE-2010]

Q.29 Consider the following code.

```
int x = 0, i;
for (i = 0; i < 10; i ++)
    if (i % 2 && x ++)
        x + = 2;
```

What will be the value of x?

(a) 11 (b) 13
(c) 15 (d) 17

Q.30 What is the output of the following program?

```
int main ( )
{
    char *str = "Gate2015"
    printf ("%d", madeeasy (str)) ;
    return 0;
}
int madeeasy (char *P1)
{
    char *P2 = P1 ;
    while (*++P1) ;
    return (P1 – P2);
}
```

Q.31 Consider the following code.

```
int a[10], *p, *q;
p = &a[5];
q = &a[7];
```

Which of the following statement is incorrect with respect to pointers?

(a) p+1 (b) q–3
(c) p+q (d) q–p

Q.32 Consider the following code.

```
int a = 32, b = 2, c = 3;
Switch (X)
{
    Case 2: printf("%d", a);
    Case 4: printf("%d", b);
    Case 6: break;
    Case 8: printf("%d", c);
    default: printf("%d", b);
}
```

Find the missing statement X, if the above 'C' code prints the output as 32.

(a) b * c (b) b * c – 2
(c) b + c * 2 (d) None of these

Q.33 What is the output of the following program?

```
int f(int a) {
    printf ("%d", a++);
    return (++a);
}
main( ) {
    int b = 1;
    b = f(b);
    b = f(b);
    b = f(1 + f(b));
}
```

Code:

(a)	1	3	3	5
(b)	1	3	5	8
(c)	2	3	3	5
(d)	2	4	6	8

Q.34 Consider the following C program

```
# include <stdio. h>
void f(int x, int * p) {
    *p  = x;
    x   = 10;
}
int main ( ) {
    int a = 5,  b = 6;
    int  *p = &a, **q;
    *p = 20; q = &p;
    f(a, &b);
    *q = &b;
    *p = 30;
    printf("%d, %d", a, b);
}
```

What is the output product by above C program

(a) 10, 20 (b) 20, 30

(c) 30, 10 (d) 20, 20

Q.35 Consider the following function written in the C programming language.

```
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

Numerical Data Type Questions

Q.36 What is printed by the following C program?

```
void main( )
{
    int c, *b, **a;
    c = 4;
    b = &c;
    a = & b;
    printf ("% d", f (c, b, a));
}
int f ( int x, int *py, int ** ppz)
{
    int y, z;
    **ppz + = 1;
    z = **ppz ;
    *py + = 2;
    y = *py;
    x + = 3;
    return (x + y + z);
}
```

Q.37 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);
}
```

Q.38 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};
    print f("%d", f(a, 6));
    return 0;
}
```

Q.39 Find the output of the following function call A(6)

```
A(n)
{   if (n < 1) return (1)
    else return A(n – 2) + B(n – 1)
}
B(n)
{   if (n ≤ 1) return (1)
    else return B(n – 1) + A(n – 2)
}
```

Try Yourself

T1. Find the time complexity of following function

```
A(n)
{   for (i = 1 to n)
    {   if (n mod i = = 0)
        {   for (j = 1 to n)
            printf(j)
        }
    }
}
```

[Ans: $O(n^2)$]

T2. What is the output of following program?

```
main( )
{   int i = 3;
    switch (i)
    {
        default : printf("zero")
        Case 1 : printf("one")
            break
        Case 2 : printf("two")
            break
        Case 3 : printf("three")
            break
    }
}
```

[Ans: O(1)]

T3. Write the meaning of following C declarations

1. const int *p;
2. int *const p;

T4. Write the meaning of following C declarations

1. char (*(*x())[])();
2. char (*(*x[3])())[5];
3. void (*b(int, void (*f) (int)))(int);
4. void (*ptr)(int (*)[2], int (*) (void));

T5.

```
int main( )
{
    int i;
    char a[ ] = "\0";
    if(printf(("%s", a))
    printf("string empty");
    else
    printf("string is not empty");
    return 0;
}
```

Output of the above program is

(a) string empty (b) string is not empty
(c) no output (d) 0

[Ans: (b)]

T6. 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

[GATE-2016, Ans: (a)]

T7. 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

[GATE-2016, Ans: (c)]

T8. 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 befor every iteration of the loop?

(a) $X^Y = a^b$ (b) $(res * a)^Y = (res * X)^b$
(c) $X^Y = res * a^b$ (d) $X^Y = (res * a)^b$

[GATE-2016, Ans: (c)]

T9. 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};
print f("%d", f(a, 5));
}
```

Note: max (x, y) returns the maximum of x and y.

The value printed by this program is ___.

[GATE-2016, Ans: (3)]

■■■■