Q. 1 – Q. 25 carry one mark each.

Q.1 If $g(x) = 1 - x$ and $h(x) = \frac{x}{x-1}$, then $\frac{g(h(x))}{h(g(x))}$ is:

(A) $\frac{h(x)}{g(x)}$ (B) $\frac{-1}{x}$ (C) $\frac{g(x)}{h(x)}$ (D) $\frac{x}{(1-x)^2}$

Q.2 $\lim_{x\to\infty} x^{1/x}$ is

(A) ∞ (B) 0 (C) 1 (D) Not defined

Q.3 Match the following:

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

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

Q.4 Which one of the following is the recurrence equation for the worst case time complexity of the Quicksort algorithm for sorting n (≥ 2) numbers? In the recurrence equations given in the options below, c is a constant.

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

Q.5 The height of a tree is the length of the longest root-to-leaf path in it. The maximum and minimum number of nodes in a binary tree of height 5 are

(A) 63 and 6, respectively (B) 64 and 5, respectively
(C) 32 and 6, respectively (D) 31 and 5, respectively

Q.6 Match the following:

(P) Condition coverage	(i) Black-box testing
(Q) Equivalence class partitioning	(ii) System testing
(R) Volume testing	(iii) White-box testing
(S) Alpha testing	(iv) Performance testing

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

Q.7 Which of the following is/are correct inorder traversal sequence(s) of binary search tree(s)?

I. 3, 5, 7, 8, 15, 19, 25
II. 5, 8, 9, 12, 10, 15, 25
III. 2, 7, 10, 8, 14, 16, 20
IV. 4, 6, 7, 9 18, 20, 25

(A) I and IV only (B) II and III only (C) II and IV only (D) II only

Q.8 Which one of the following is TRUE at any valid state in shift-reduce parsing?

(A) Viable prefixes appear only at the bottom of the stack and not inside
(B) Viable prefixes appear only at the top of the stack and not inside
(C) The stack contains only a set of viable prefixes
(D) The stack never contains viable prefixes

Q.9 Which one of the following is NOT equivalent to $p \leftrightarrow q$?

(A) $(\neg p \vee q) \wedge (p \vee \neg q)$ (B) $(\neg p \vee q) \wedge (q \rightarrow p)$
(C) $(\neg p \wedge q) \vee (p \wedge \neg q)$ (D) $(\neg p \wedge \neg q) \vee (p \wedge q)$

Q.10 For a set A, the power set of A is denoted by 2^A. If $A = \{5, \{6\}, \{7\}\}$, which of the following options are TRUE?

I. $\emptyset \in 2^A$ II. $\emptyset \subseteq 2^A$ III. $\{5, \{6\}\} \in 2^A$ IV. $\{5, \{6\}\} \subseteq 2^A$

(A) I and III only (B) II and III only
(C) I, II and III only (D) I, II and IV only

Q.11 Consider a 4-bit Johnson counter with an initial value of 0000. The counting sequence of this counter is

(A) 0, 1, 3, 7, 15, 14, 12, 8, 0 (B) 0, 1, 3, 5, 7, 9, 11, 13, 15, 0
(C) 0, 2, 4, 6, 8, 10, 12, 14, 0 (D) 0, 8, 12, 14, 15, 7, 3, 1, 0

Q.12 For computers based on three-address instruction formats, each address field can be used to specify which of the following:

(S1) A memory operand
(S2) A processor register
(S3) An implied accumulator register

(A) Either S1 or S2
(B) Either S2 or S3
(C) Only S2 and S3
(D) All of S1, S2 and S3

Q.13 Suppose two hosts use a TCP connection to transfer a large file. Which of the following statements is/are FALSE with respect to the TCP connection?

I. If the sequence number of a segment is m, then the sequence number of the subsequent segment is always $m+1$.
II. If the estimated round trip time at any given point of time is t sec, the value of the retransmission timeout is always set to greater than or equal to t sec.
III. The size of the advertised window never changes during the course of the TCP connection.
IV. The number of unacknowledged bytes at the sender is always less than or equal to the advertised window.

(A) III only (B) I and III only (C) I and IV only (D) II and IV only

Q.14 Suppose that everyone in a group of N people wants to communicate secretly with the N-1 others using symmetric key cryptographic system. The communication between any two persons should not be decodable by the others in the group. The number of keys required in the system as a whole to satisfy the confidentiality requirement is

(A) $2N$ (B) $N(N-1)$ (C) $N(N-1)/2$ (D) $(N-1)^2$

Q.15 Which of the following statements is/are FALSE?

I. XML overcomes the limitations in HTML to support a structured way of organizing content.
II. XML specification is not case sensitive while HTML specification is case sensitive.
III. XML supports user defined tags while HTML uses pre-defined tags.
IV. XML tags need not be closed while HTML tags must be closed.

(A) II only (B) I only (C) II and IV only (D) III and IV only

Q.16 Which one of the following fields of an IP header is NOT modified by a typical IP router?

(A) Checksum (B) Source address
(C) Time to Live (TTL) (D) Length

Q.17 In one of the pairs of protocols given below, both the protocols can use multiple TCP connections between the same client and the server. Which one is that?

(A) HTTP, FTP (B) HTTP, TELNET (C) FTP, SMTP (D) HTTP, SMTP

Q.18 For any two languages L_1 and L_2 such that L_1 is context-free and L_2 is recursively enumerable but not recursive, which of the following is/are necessarily true?

I. $\bar{L}_1$ (complement of L_1) is recursive
II. $\bar{L}_2$ (complement of L_2) is recursive
III. $\bar{L}_1$ is context-free
IV. $\bar{L}_1 \cup L_2$ is recursively enumerable

(A) I only (B) III only (C) III and IV only (D) I and IV only

Q.19 Consider a system with byte-addressable memory, 32-bit logical addresses, 4 kilobyte page size and page table entries of 4 bytes each. The size of the page table in the system in megabytes is _____ .

Q.20 The following two functions `P1` and `P2` that share a variable `B` with an initial value of 2 execute concurrently.

```
P1( ) {                          P2( ) {
       C = B – 1;                       D = 2 * B;
       B = 2 * C;                       B = D - 1;
}                                }
```

The number of distinct values that `B` can possibly take after the execution is_____.

Q.21 SELECT operation in SQL is equivalent to

(A) the selection operation in relational algebra
(B) the selection operation in relational algebra, except that SELECT in SQL retains duplicates
(C) the projection operation in relational algebra
(D) the projection operation in relational algebra, except that SELECT in SQL retains duplicates

Q.22 A file is organized so that the ordering of data records is the same as or close to the ordering of data entries in some index. Then that index is called

(A) Dense (B) Sparse (C) Clustered (D) Unclustered

Q.23 In the LU decomposition of the matrix $\begin{bmatrix} 2 & 2 \\ 4 & 9 \end{bmatrix}$, if the diagonal elements of U are both 1, then the lower diagonal entry l_{22} of L is_____.

Q.24 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.25 What are the worst-case complexities of insertion and deletion of a key in a binary search tree?

(A) $\theta(\log n)$ for both insertion and deletion
(B) $\theta(n)$ for both insertion and deletion
(C) $\theta(n)$ for insertion and $\theta(\log n)$ for deletion
(D) $\theta(\log n)$ for insertion and $\theta(n)$ for deletion

Q. 26 – Q. 55 carry two marks each.

Q.26 Suppose that the stop-and-wait protocol is used on a link with a bit rate of 64 kilobits per second and 20 milliseconds propagation delay. Assume that the transmission time for the acknowledgement and the processing time at nodes are negligible. Then the minimum frame size in bytes to achieve a link utilization of at least 50% is_____.

Q.27 Consider a max heap, represented by the array: 40, 30, 20, 10, 15, 16, 17, 8, 4.

Array Index	1	2	3	4	5	6	7	8	9
Value	40	30	20	10	15	16	17	8	4

Now consider that a value 35 is inserted into this heap. After insertion, the new heap is

(A) 40, 30, 20, 10, 15, 16, 17, 8, 4, 35
(B) 40, 35, 20, 10, 30, 16, 17, 8, 4, 15
(C) 40, 30, 20, 10, 35, 16, 17, 8, 4, 15
(D) 40, 35, 20, 10, 15, 16, 17, 8, 4, 30

Q.28 Consider the following C program segment.

```
while(first <= last)
{
      if (array[middle] < search)
         first = middle + 1;
      else if (array[middle] == search)
                found = TRUE;
           else last = middle - 1;
      middle = (first + last)/2;
}
if (first > last)  notPresent = TRUE;
```

The cyclomatic complexity of the program segment is _____.

Q.29 Consider a LAN with four nodes S_1, S_2, S_3 and S_4. Time is divided into fixed-size slots, and a node can begin its transmission only at the beginning of a slot. A collision is said to have occurred if more than one node transmit in the same slot. The probabilities of generation of a frame in a time slot by S_1, S_2, S_3 and S_4 are 0.1, 0.2, 0.3 and 0.4, respectively. The probability of sending a frame in the first slot without any collision by any of these four stations is _____.

Q.30 The binary operator $\neq$ is defined by the following truth table.

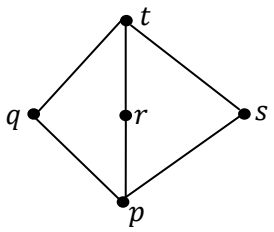
p	q	$p \neq q$
0	0	0
0	1	1
1	0	1
1	1	0

Which one of the following is true about the binary operator $\neq$?

(A) Both commutative and associative
(B) Commutative but not associative
(C) Not commutative but associative
(D) Neither commutative nor associative

Q.31 $\sum_{x=1}^{99} \frac{1}{x(x+1)}$ = _____.

Q.32 Suppose $\mathcal{L} = \{p, q, r, s, t\}$ is a lattice represented by the following Hasse diagram:



For any $x, y \in \mathcal{L}$, not necessarily distinct, $x \vee y$ and $x \wedge y$ are join and meet of x, y, respectively. Let $\mathcal{L}^3 = \{(x, y, z): x, y, z \in \mathcal{L}\}$ be the set of all ordered triplets of the elements of $\mathcal{L}$. Let p_r be the probability that an element $(x, y, z) \in \mathcal{L}^3$ chosen equiprobably satisfies $x \vee (y \wedge z) = (x \vee y) \wedge (x \vee z)$. Then

(A) $p_r = 0$
(B) $p_r = 1$
(C) $0 < p_r \leq \frac{1}{5}$
(D) $\frac{1}{5} < p_r < 1$

Q.33 Consider the operations

$f(X, Y, Z) = X'YZ + XY' + Y'Z'$ and $g(X, Y, Z) = X'YZ + X'YZ' + XY$.

Which one of the following is correct?

(A) Both $\{f\}$ and $\{g\}$ are functionally complete
(B) Only $\{f\}$ is functionally complete
(C) Only $\{g\}$ is functionally complete
(D) Neither $\{f\}$ nor $\{g\}$ is functionally complete

Q.34 Let *G* be a connected planar graph with 10 vertices. If the number of edges on each face is three, then the number of edges in *G* is _____.

Q.35 Let a_n represent the number of bit strings of length *n* containing two consecutive 1s. What is the recurrence relation for a_n?

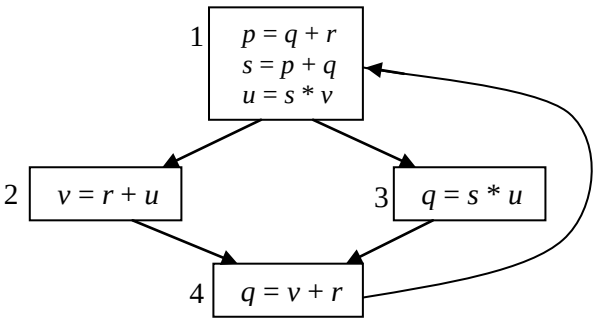
(A) $a_{n-2} + a_{n-1} + 2^{n-2}$
(B) $a_{n-2} + 2a_{n-1} + 2^{n-2}$
(C) $2a_{n-2} + a_{n-1} + 2^{n-2}$
(D) $2a_{n-2} + 2a_{n-1} + 2^{n-2}$

Q.36 A variable x is said to be live at a statement S_i in a program if the following three conditions hold simultaneously:

i. There exists a statement S_j that uses x

ii. There is a path from S_i to S_j in the flow graph corresponding to the program

iii. The path has no intervening assignment to x including at S_i and S_j



The variables which are live both at the statement in basic block 2 and at the statement in basic block 3 of the above control flow graph are

(A) p, s, u (B) r, s, u (C) r, u (D) q, v

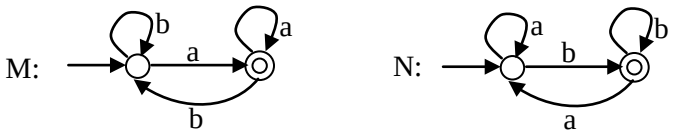
Q.37 The least number of temporary variables required to create a three-address code in static single assignment form for the expression $q + r / 3 + s – t * 5 + u * v / w$ is _____.

Q.38 Consider an Entity-Relationship (ER) model in which entity sets E_1 and E_2 are connected by an $m : n$ relationship R_{12}. E_1 and E_3 are connected by a $1 : n$ (1 on the side of E_1 and n on the side of E_3) relationship R_{13}.

E_1 has two single-valued attributes a_{11} and a_{12} of which a_{11} is the key attribute. E_2 has two single-valued attributes a_{21} and a_{22} of which a_{21} is the key attribute. E_3 has two single-valued attributes a_{31} and a_{32} of which a_{31} is the key attribute. The relationships do not have any attributes.

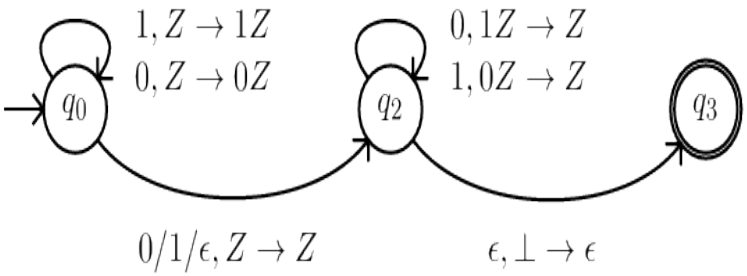
If a relational model is derived from the above ER model, then the minimum number of relations that would be generated if all the relations are in 3NF is _____.

Q.39



Consider the DFAs M and N given above. The number of states in a minimal DFA that accepts the language L(M) ∩ L(N) is_____

Q.40 Consider the NPDA $\langle Q = \{q_o, q_1, q_2\},\ \sum = \{0,1\},\ \Gamma = \{0,1,\perp\},\ \delta,\ q_0,\ \perp,\ F = \{q_2\}\rangle$, where (as per usual convention) Q is the set of states, $\sum$ is the input alphabet, Γ is the stack alphabet, δ is the state transition function, q_0 is the initial state, $\perp$ is the initial stack symbol, and F is the set of accepting states. The state transition is as follows:



Which one of the following sequences must follow the string 101100 so that the overall string is accepted by the automaton?

(A) 10110 (B) 10010 (C) 01010 (D) 01001

Q.41 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

Q.42 Consider a uniprocessor system executing three tasks T_1, T_2 and T_3, each of which is composed of an infinite sequence of jobs (or instances) which arrive periodically at intervals of 3, 7 and 20 milliseconds, respectively. The priority of each task is the inverse of its period, and the available tasks are scheduled in order of priority, with the highest priority task scheduled first. Each instance of T_1, T_2 and T_3 requires an execution time of 1, 2 and 4 milliseconds, respectively. Given that all tasks initially arrive at the beginning of the 1st millisecond and task preemptions are allowed, the first instance of T_3 completes its execution at the end of _____ milliseconds.

Q.43 A positive edge-triggered D flip-flop is connected to a positive edge-triggered JK flip-flop as follows. The *Q* output of the D flip-flop is connected to both the J and K inputs of the JK flip-flop, while the *Q* output of the JK flip-flop is connected to the input of the D flip-flop. Initially, the output of the D flip-flop is set to logic one and the output of the JK flip-flop is cleared. Which one of the following is the bit sequence (including the initial state) generated at the *Q* output of the JK flip-flop when the flip-flops are connected to a free-running common clock? Assume that J = K = 1 is the toggle mode and J = K = 0 is the state-holding mode of the JK flip-flop. Both the flip-flops have non-zero propagation delays.

(A) 0110110… (B) 0100100…
(C) 011101110… (D) 011001100…

Q.44 Consider a disk pack with a seek time of 4 milliseconds and rotational speed of 10000 rotations per minute (RPM). It has 600 sectors per track and each sector can store 512 bytes of data. Consider a file stored in the disk. The file contains 2000 sectors. Assume that every sector access necessitates a seek, and the average rotational latency for accessing each sector is half of the time for one complete rotation. The total time (in milliseconds) needed to read the entire file is _____.

Q.45 Consider a non-pipelined processor with a clock rate of 2.5 gigahertz and average cycles per instruction of four. The same processor is upgraded to a pipelined processor with five stages; but due to the internal pipeline delay, the clock speed is reduced to 2 gigahertz. Assume that there are no stalls in the pipeline. The speed up achieved in this pipelined processor is_____.

Q.46 Suppose the following disk request sequence (track numbers) for a disk with 100 tracks is given: 45, 20, 90, 10, 50, 60, 80, 25, 70. Assume that the initial position of the R/W head is on track 50. The additional distance that will be traversed by the R/W head when the Shortest Seek Time First (SSTF) algorithm is used compared to the SCAN (Elevator) algorithm (assuming that SCAN algorithm moves towards 100 when it starts execution) is_____ tracks.

Q.47 Consider a main memory with five page frames and the following sequence of page references: 3, 8, 2, 3, 9, 1, 6, 3, 8, 9, 3, 6, 2, 1, 3. Which one of the following is true with respect to page replacement policies First In First Out (FIFO) and Least Recently Used (LRU)?

(A) Both incur the same number of page faults
(B) FIFO incurs 2 more page faults than LRU
(C) LRU incurs 2 more page faults than FIFO
(D) FIFO incurs 1 more page faults than LRU

Q.48 $\int_{1/\pi}^{2/\pi} \frac{\cos(1/x)}{x^2}\,dx =$_____.

Q.49 Consider the following 2×2 matrix A where two elements are unknown and are marked by a and b. The eigenvalues of this matrix are -1 and 7. What are the values of a and b?

$$A = \begin{pmatrix} 1 & 4 \\ b & a \end{pmatrix}.$$

(A) $a = 6, b = 4$
(B) $a = 4, b = 6$
(C) $a = 3, b = 5$
(D) $a = 5, b = 3$

Q.50 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.51 Consider the following relations:

Student

Roll_No	Student_Name
1	Raj
2	Rohit
3	Raj

Performance

Roll_No	Course	Marks
1	Math	80
1	English	70
2	Math	75
3	English	80
2	Physics	65
3	Math	80

Consider the following SQL query.

```
SELECT S.Student_Name, sum(P.Marks)
FROM Student S, Performance P
WHERE S.Roll_No = P.Roll_No
GROUP BY S.Student_Name
```

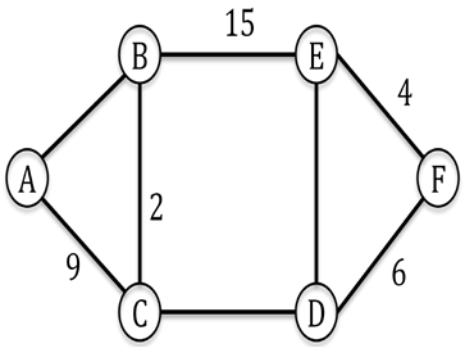
The number of rows that will be returned by the SQL query is _____.

Q.52 What is the output of the following C code? Assume that the address of *x* is 2000 (in decimal) and an integer requires four bytes of memory.

```
int main () {
        unsigned int x[4][3] =
         {{1,2,3},{4,5,6},{7,8,9},{10,11,12}};
        printf("%u, %u, %u", x+3, *(x+3), *(x+2)+3);
}
```

(A) 2036, 2036, 2036 (B) 2012, 4, 2204 (C) 2036, 10, 10 (D) 2012, 4, 6

Q.53 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.54 Consider the following C function.

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

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

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

Q.55 Consider the following pseudo code, where x and y are positive integers.

```
begin
  q := 0
  r := x
  while r ≥ y do
    begin
       r := r – y
       q := q + 1
    end
end
```

The post condition that needs to be satisfied after the program terminates is

(A) $\{r = qx + y \wedge r < y\}$ (B) $\{x = qy + r \wedge r < y\}$
(C) $\{y = qx + r \wedge 0 < r < y\}$ (D) $\{q + 1 < r - y \wedge y > 0\}$

END OF THE QUESTION PAPER

Q. 1 – Q. 25 carry one mark each.

Q.1 Consider the following two statements.

$S1$: If a candidate is known to be corrupt, then he will not be elected
$S2$: If a candidate is kind, he will be elected

Which one of the following statements follows from $S1$ and $S2$ as per sound inference rules of logic?

(A) If a person is known to be corrupt, he is kind
(B) If a person is not known to be corrupt, he is not kind
(C) If a person is kind, he is not known to be corrupt
(D) If a person is not kind, he is not known to be corrupt

Q.2 The cardinality of the power set of { 0, 1, 2, …, 10 } is _____.

Q.3 Let R be the relation on the set of positive integers such that aRb if and only if a and b are distinct and have a common divisor other than 1. Which one of the following statements about R is true?

(A) R is symmetric and reflexive but not transitive
(B) R is reflexive but not symmetric and not transitive
(C) R is transitive but not reflexive and not symmetric
(D) R is symmetric but not reflexive and not transitive

Q.4 The number of divisors of 2100 is _____ .

Q.5 The larger of the two eigenvalues of the matrix $\begin{bmatrix} 4 & 5 \\ 2 & 1 \end{bmatrix}$ is _____.

Q.6 An unordered list contains n distinct elements. The number of comparisons to find an element in this list that is neither maximum nor minimum is

(A) $\Theta(n \log n)$ (B) $\Theta(n)$ (C) $\Theta(\log n)$ (D) $\Theta(1)$

Q.7 The minimum number of JK flip-flops required to construct a synchronous counter with the count sequence (0,0,1,1,2,2,3,3,0,0,…) is _____ .

Q.8 Assume that for a certain processor, a read request takes 50 nanoseconds on a cache miss and 5 nanoseconds on a cache hit. Suppose while running a program, it was observed that 80% of the processor's read requests result in a cache hit. The average read access time in nanoseconds is _____.

Q.9 A computer system implements a 40-bit virtual address, page size of 8 kilobytes, and a 128-entry translation look-aside buffer (TLB) organized into 32 sets each having four ways. Assume that the TLB tag does not store any process id. The minimum length of the TLB tag in bits is _____.

Q.10 Consider the following statements.

I. The complement of every Turing decidable language is Turing decidable
II. There exists some language which is in NP but is not Turing decidable
III. If L is a language in NP, L is Turing decidable

Which of the above statements is/are true?

(A) Only II (B) Only III (C) Only I and II (D) Only I and III

Q.11 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

Q.12 Consider a complete binary tree where the left and the right subtrees of the root are max-heaps. The lower bound for the number of operations to convert the tree to a heap is

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

Q.13 A binary tree T has 20 leaves. The number of nodes in T having two children is _____.

Q.14 Consider the following C function.

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

The return value of `fun(5)` is _____.

Q.15 A software requirements specification (SRS) document should avoid discussing which one of the following?

(A) User interface issues
(B) Non-functional requirements
(C) Design specification
(D) Interfaces with third party software

Q.16 Consider two decision problems Q_1, Q_2 such that Q_1 reduces in polynomial time to 3-SAT and 3-SAT reduces in polynomial time to Q_2. Then which one of the following is consistent with the above statement?

(A) Q_1 is in NP, Q_2 is NP hard.
(B) Q_2 is in NP, Q_1 is NP hard.
(C) Both Q_1 and Q_2 are in NP .
(D) Both Q_1 and Q_2 are NP hard.

Q.17 Match the following:

P. Lexical analysis	1. Graph coloring
Q. Parsing	2. DFA minimization
R. Register allocation	3. Post-order traversal
S. Expression evaluation	4. Production tree

(A) P-2, Q-3, R-1, S-4
(B) P-2, Q-1, R-4, S-3
(C) P-2, Q-4, R-1, S-3
(D) P-2, Q-3, R-4, S-1

Q.18 In the context of abstract-syntax-tree (AST) and control-flow-graph (CFG), which one of the following is TRUE?

(A) In both AST and CFG, let node N_2 be the successor of node N_1. In the input program, the code corresponding to N_2 is present after the code corresponding to N_1
(B) For any input program, neither AST nor CFG will contain a cycle
(C) The maximum number of successors of a node in an AST and a CFG depends on the input program
(D) Each node in AST and CFG corresponds to at most one statement in the input program

Q.19 Consider the basic COCOMO model where *E* is the effort applied in person-months, *D* is the development time in chronological months, *KLOC* is the estimated number of delivered lines of code (in thousands) and a_b, b_b, c_b, d_b have their usual meanings. The basic COCOMO equations are of the form

(A) $E = a_b(KLOC)\exp(b_b), D = c_b(E)\exp(d_b)$
(B) $D = a_b(KLOC)\exp(b_b), E = c_b(D)\exp(d_b)$
(C) $E = a_b\exp(b_b), D = c_b(KLOC)\exp(d_b)$
(D) $E = a_b\exp(d_b), D = c_b(KLOC)\exp(b_b)$

Q.20 A system has 6 identical resources and *N* processes competing for them. Each process can request atmost 2 resources. Which one of the following values of *N* could lead to a deadlock?

(A) 1 (B) 2 (C) 3 (D) 4

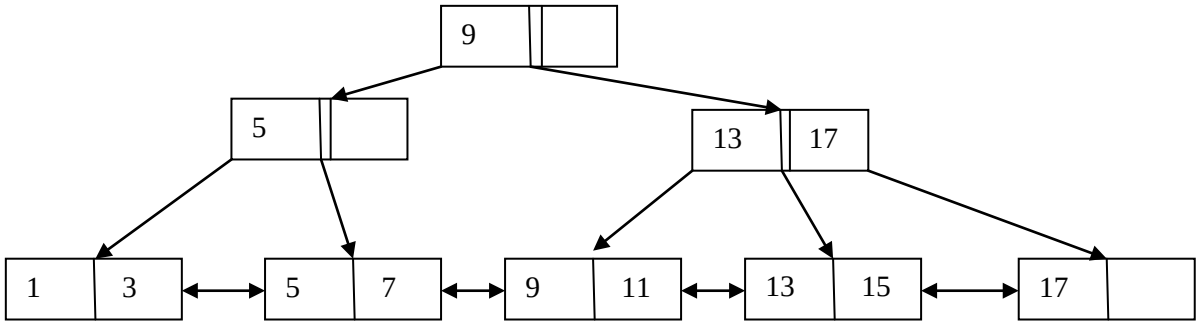
Q.21 Consider the following transaction involving two bank accounts `x` and `y`.

```
read(x); x := x - 50; write(x); read(y); y:= y + 50; write(y)
```

The constraint that the sum of the accounts *x* and *y* should remain constant is that of

(A) Atomicity
(B) Consistency
(C) Isolation
(D) Durability

Q.22 With reference to the B+ tree index of order 1 shown below, the minimum number of nodes (including the Root node) that must be fetched in order to satisfy the following query: "Get all records with a search key greater than or equal to 7 and less than 15" is _____.



Q.23 Identify the correct order in which a server process must invoke the function calls `accept`, `bind`, `listen`, and `recv` according to UNIX socket API.

(A) listen, accept, bind, recv
(B) bind, listen, accept, recv
(C) bind, accept, listen, recv
(D) accept, listen, bind, recv

Q.24 A link has a transmission speed of 10^6 bits/sec. It uses data packets of size 1000 bytes each. Assume that the acknowledgment has negligible transmission delay, and that its propagation delay is the same as the data propagation delay. Also assume that the processing delays at nodes are negligible. The efficiency of the stop-and-wait protocol in this setup is exactly 25%. The value of the one-way propagation delay (in milliseconds) is _____.

Q.25 Which one of the following statements is NOT correct about HTTP cookies?

(A) A cookie is a piece of code that has the potential to compromise the security of an Internet user
(B) A cookie gains entry to the user's work area through an HTTP header
(C) A cookie has an expiry date and time
(D) Cookies can be used to track the browsing pattern of a user at a particular site

Q. 26 – Q. 55 carry two marks each.

Q.26 Consider the following routing table at an IP router:

Network No.	Net Mask	Next Hop
128.96.170.0	255.255.254.0	Interface 0
128.96.168.0	255.255.254.0	Interface 1
128.96.166.0	255.255.254.0	R2
128.96.164.0	255.255.252.0	R3
0.0.0.0	Default	R4

For each IP address in Group I identify the correct choice of the next hop from Group II using the entries from the routing table above.

Group I
i) 128.96.171.92
ii) 128.96.167.151
iii) 128.96.163.151
iv) 128.96.165.121

Group II
a) Interface 0
b) Interface 1
c) R2
d) R3
e) R4

(A) i-a, ii-c, iii-e, iv-d
(B) i-a, ii-d, iii-b, iv-e
(C) i-b, ii-c, iii-d, iv-e
(D) i-b, ii-c, iii-e, iv-d

Q.27 Host A sends a UDP datagram containing 8880 bytes of user data to host B over an Ethernet LAN. Ethernet frames may carry data up to 1500 bytes (i.e. MTU=1500 bytes). Size of UDP header is 8 bytes and size of IP header is 20 bytes. There is no option field in IP header. How many total number of IP fragments will be transmitted and what will be the contents of offset field in the last fragment?

(A) 6 and 925
(B) 6 and 7400
(C) 7 and 1110
(D) 7 and 8880

Q.28 Assume that the bandwidth for a TCP connection is 1048560 bits /sec. Let α be the value of RTT in milliseconds (rounded off to the nearest integer) after which the TCP window scale option is needed. Let β be the maximum possible window size with window scale option. Then the values of α and β are

(A) 63 milliseconds, 65535×2^{14}
(B) 63 milliseconds, 65535×2^{16}
(C) 500 milliseconds, 65535×2^{14}
(D) 500 milliseconds, 65535×2^{16}

Q.29 Consider a simple checkpointing protocol and the following set of operations in the log.

(start, T4); (write, T4, *y*, 2, 3); (start, T1); (commit, T4); (write, T1, *z*, 5, 7);
(checkpoint);
(start, T2); (write, T2, *x*, 1, 9); (commit, T2); (start, T3), (write, T3, *z*, 7, 2);

If a crash happens now and the system tries to recover using both undo and redo operations, what are the contents of the undo list and the redo list?

(A) Undo: T3, T1; Redo: T2
(B) Undo: T3, T1; Redo: T2, T4
(C) Undo: none; Redo: T2, T4, T3, T1
(D) Undo: T3, T1, T4; Redo: T2

Q.30 Consider two relations R_1(A,B) with the tuples (1,5), (3,7) and R_2(A,C) = (1,7), (4,9). Assume that R(A,B,C) is the full natural outer join of R_1 and R_2. Consider the following tuples of the form (A,B,C): *a* = (1,5,*null*), *b* = (1,*null*,7), *c* = (3, *null*, 9), *d* = (4,7,*null*), *e* = (1,5,7), *f* = (3,7,*null*), *g* = (4,*null*,9). Which one of the following statements is correct?

(A) R contains *a, b, e, f, g* but not *c, d.*
(B) R contains all of *a, b, c, d, e, f, g.*
(C) R contains *e, f, g* but not *a, b.*
(D) R contains *e* but not *f, g.*

Q.31 Consider six memory partitions of sizes 200 KB, 400 KB, 600 KB, 500 KB, 300 KB and 250 KB, where KB refers to kilobyte. These partitions need to be allotted to four processes of sizes 357 KB, 210 KB, 468 KB and 491 KB in that order. If the best fit algorithm is used, which partitions are NOT allotted to any process?

(A) 200 KB and 300 KB
(B) 200 KB and 250 KB
(C) 250 KB and 300 KB
(D) 300 KB and 400 KB

Q.32 Consider a typical disk that rotates at 15000 rotations per minute (RPM) and has a transfer rate of 50×10^6 bytes/sec. If the average seek time of the disk is twice the average rotational delay and the controller's transfer time is 10 times the disk transfer time, the average time (in milliseconds) to read or write a 512-byte sector of the disk is _____.

Q.33 A computer system implements 8 kilobyte pages and a 32-bit physical address space. Each page table entry contains a valid bit, a dirty bit, three permission bits, and the translation. If the maximum size of the page table of a process is 24 megabytes, the length of the virtual address supported by the system is _____ bits.

Q.34 Consider the intermediate code given below.

```
(1)   i = 1
(2)   j = 1
(3)   t1 = 5 * i
(4)   t2 = t1 + j
(5)   t3 = 4 * t2
(6)   t4 = t3
(7)   a[t4] = -1
(8)   j = j + 1
(9)   if j<=5 goto (3)
(10)  i=i+1
(11)  if i<5 goto (2)
```

The number of nodes and edges in the control-flow-graph constructed for the above code, respectively, are

(A) 5 and 7 (B) 6 and 7 (C) 5 and 5 (D) 7 and 8

Q.35 The number of states in the minimal deterministic finite automaton corresponding to the regular expression $(0 + 1)^*(10)$ is _____.

Q.36 Which of the following languages is/are regular?

L_1: $\{wxw^R \mid w, x \in \{a, b\}^*$ and $|w|, |x| > 0\}$, w^R is the reverse of string w
L_2: $\{a^n b^m \mid m \neq n$ and $m, n \geq 0\}$
L_3: $\{a^p b^q c^r \mid p, q, r \geq 0\}$

(A) L_1 and L_3 only (B) L_2 only (C) L_2 and L_3 only (D) L_3 only

Q.37 Given below are some algorithms, and some algorithm design paradigms.

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

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

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

Q.38 A Young tableau is a 2D array of integers increasing from left to right and from top to bottom. Any unfilled entries are marked with ∞, and hence there cannot be any entry to the right of, or below a ∞. The following Young tableau consists of unique entries.

1	2	5	14
3	4	6	23
10	12	18	25
31	∞	∞	∞

When an element is removed from a Young tableau, other elements should be moved into its place so that the resulting table is still a Young tableau (unfilled entries may be filled in with a ∞). The minimum number of entries (other than 1) to be shifted, to remove 1 from the given Young tableau is _____.

Q.39 Suppose you are provided with the following function declaration in the C programming language.

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

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

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

```
int kth_smallest(int a[], int n, int k)
{
   int left_end = partition(a,n);

   if ( left_end+1 == k ){
       return a[left_end];
   }

   if ( left_end+1 > k ){
       return kth_smallest( _____ );
   } else {
       return kth_smallest( _____ );
   }
}
```

The missing argument lists are respectively

(A) `(a, left_end, k)` and `(a+left_end+1, n-left_end-1, k-left_end-1)`
(B) `(a, left_end, k)` and `(a, n-left_end-1, k-left_end-1)`
(C) `(a+left_end+1, n-left_end-1, k-left_end-1)` and `(a, left_end, k)`
(D) `(a, n-left_end-1, k-left_end-1)` and `(a, left_end, k)`

Q.40 Which one of the following hash functions on integers will distribute keys most uniformly over 10 buckets numbered 0 to 9 for i ranging from 0 to 2020?

(A) $h(i) = i^2 \bmod 10$
(B) $h(i) = i^3 \bmod 10$
(C) $h(i) = (11 * i^2) \bmod 10$
(D) $h(i) = (12 * i) \bmod 10$

Q.41 The secant method is used to find the root of an equation f(x) = 0. It is started from two distinct estimates x_a and x_b for the root. It is an iterative procedure involving linear interpolation to a root. The iteration stops if $f(x_b)$ is very small and then x_b is the solution. The procedure is given below. Observe that there is an expression which is missing and is marked by **?**. Which is the suitable expression that is to be put in place of **?** so that it follows all steps of the secant method?

Secant

```
Initialize: xa, xb, ε, N        // ε = convergence indicator
                                 // N = maximum no. of iterations
    fb = f(xb)
    i = 0
    while (i < N and  |fb| >  ε) do
        i = i + 1                // update counter
        xt = ?                   // missing expression for
                                 // intermediate value
        xa = xb                  // reset xa
        xb = xt                  //  reset xb
        fb = f(xb)               // function value at new xb
    end while
    if  |fb| >  ε then           // loop is terminated with i=N
        write "Non-convergence"
    else
         write "return xb"
    end if
```

(A) $x_b - (f_b - f(x_a))f_b / (x_b - x_a)$

(B) $x_a - (f_a - f(x_a))f_a / (x_b - x_a)$

(C) $x_b - (x_b - x_a)f_b / (f_b - f(x_a))$

(D) $x_a - (x_b - x_a)\ f_a / (f_b - f(x_a))$

Q.42 Consider the C program below.

```
#include <stdio.h>
int *A, stkTop;

int stkFunc(int opcode, int val)
{
     static int size=0, stkTop=0;

     switch (opcode) {
          case -1: size = val; break;
          case  0: if (stkTop < size) A[stkTop++] = val; break;
          default: if (stkTop) return A[--stkTop];
     }
     return -1;
}

int main()
{
     int B[20]; A = B; stkTop = -1;

     stkFunc (-1, 10);
     stkFunc ( 0, 5);
     stkFunc ( 0, 10);
     printf ("%d\n", stkFunc(1, 0) + stkFunc(1, 0));
}
```

The value printed by the above program is _____.

Q.43 Consider the sequence of machine instructions given below:

MUL	R5, R0, R1
DIV	R6, R2, R3
ADD	R7, R5, R6
SUB	R8, R7, R4

In the above sequence, R0 to R8 are general purpose registers. In the instructions shown, the first register stores the result of the operation performed on the second and the third registers. This sequence of instructions is to be executed in a pipelined instruction processor with the following 4 stages: (1) Instruction Fetch and Decode (IF), (2) Operand Fetch (OF), (3) Perform Operation (PO) and (4) Write back the result (WB). The IF, OF and WB stages take 1 clock cycle each for any instruction. The PO stage takes 1 clock cycle for ADD or SUB instruction, 3 clock cycles for MUL instruction and 5 clock cycles for DIV instruction. The pipelined processor uses operand forwarding from the PO stage to the OF stage. The number of clock cycles taken for the execution of the above sequence of instructions is _____.

Q.44 Consider a processor with byte-addressable memory. Assume that all registers, including Program Counter (PC) and Program Status Word (PSW), are of size 2 bytes. A stack in the main memory is implemented from memory location $(0100)_{16}$ and it grows upward. The stack pointer (SP) points to the top element of the stack. The current value of SP is $(016E)_{16}$. The CALL instruction is of two words, the first word is the op-code and the second word is the starting address of the subroutine (one word = 2 bytes). The CALL instruction is implemented as follows:

- Store the current value of PC in the stack
- Store the value of PSW register in the stack
- Load the starting address of the subroutine in PC

The content of PC just before the fetch of a CALL instruction is $(5FA0)_{16}$. After execution of the CALL instruction, the value of the stack pointer is

(A) $(016A)_{16}$ (B) $(016C)_{16}$ (C) $(0170)_{16}$ (D) $(0172)_{16}$

Q.45 The number of min-terms after minimizing the following Boolean expression is _____.

$$[D' + AB' + A'C + AC'D + A'C'D]'$$

Q.46 Let $f(x) = x^{-(1/3)}$ and A denote the area of the region bounded by $f(x)$ and the X-axis, when x varies from -1 to 1. Which of the following statements is/are TRUE?

I) f is continuous in $[-1, 1]$
II) f is not bounded in $[-1, 1]$
III) A is nonzero and finite

(A) II only (B) III only
(C) II and III only (D) I, II and III

Q.47 Perform the following operations on the matrix $\begin{bmatrix} 3 & 4 & 45 \\ 7 & 9 & 105 \\ 13 & 2 & 195 \end{bmatrix}$.

(i) Add the third row to the second row
(ii) Subtract the third column from the first column.

The determinant of the resultant matrix is_____.

Q.48 The number of onto functions (surjective functions) from set $X = \{1, 2, 3, 4\}$ to set $Y = \{a, b, c\}$ is _____.

Q.49 Let X and Y denote the sets containing 2 and 20 distinct objects respectively and F denote the set of all possible functions defined from X to Y. Let f be randomly chosen from F. The probability of f being one-to-one is _____.

Q.50 Consider the alphabet $\sum = \{0, 1\}$, the null/empty string λ and the sets of strings X_0, X_1, and X_2 generated by the corresponding non-terminals of a regular grammar. X_0, X_1, and X_2 are related as follows.

$$X_0 = 1\ X_1$$
$$X_1 = 0\ X_1 + 1\ X_2$$
$$X_2 = 0\ X_1 + \{\lambda\}$$

Which one of the following choices precisely represents the strings in X_0?

(A) 10(0* + (10)*)1
(B) 10(0* + (10)*)*1
(C) 1(0 + 10)*1
(D) 10(0 + 10)*1 + 110(0 + 10)*1

Q.51 A graph is self-complementary if it is isomorphic to its complement. For all self-complementary graphs on n vertices, n is

(A) A multiple of 4
(B) Even
(C) Odd
(D) Congruent to 0 mod 4, or, 1 mod 4.

Q.52 In a connected graph, a bridge is an edge whose removal disconnects a graph. Which one of the following statements is true?

(A) A tree has no bridges
(B) A bridge cannot be part of a simple cycle
(C) Every edge of a clique with size ≥ 3 is a bridge (A clique is any complete subgraph of a graph)
(D) A graph with bridges cannot have a cycle

Q.53 Which one of the following well formed formulae is a tautology?

(A) $\forall x\ \exists y\ R(x,y) \leftrightarrow\ \exists y\ \forall x\ R(x,y)$
(B) $(\forall x\ [\exists y\ R(x,y) \rightarrow S(x,y)]) \rightarrow\ \forall x \exists y\ S(x,y)$
(C) $[\forall x\ \exists y\ (P(x,y) \rightarrow R(x,y)] \leftrightarrow [\forall x\ \exists y\ (\neg P(x,y) \vee R(x,y)]$
(D) $\forall x\ \forall y\ P(x,y) \rightarrow\ \forall x\ \forall y\ P(y,x)$

Q.54 Which one of the following assertions concerning code inspection and code walkthrough is true?

(A) Code inspection is carried out once the code has been unit tested
(B) Code inspection and code walkthrough are synonyms
(C) Adherence to coding standards is checked during code inspection
(D) Code walkthrough is usually carried out by an independent test team

Q.55 A half adder is implemented with XOR and AND gates. A full adder is implemented with two half adders and one OR gate. The propagation delay of an XOR gate is twice that of an AND/OR gate. The propagation delay of an AND/OR gate is 1.2 microseconds. A 4-bit ripple-carry binary adder is implemented by using four full adders. The total propagation time of this 4-bit binary adder in microseconds is_____.

END OF THE QUESTION PAPER

Q. 1 – Q. 25 carry one mark each.

Q.1 Consider the following C program segment.

```
#include <stdio.h>

int main()
{
      char s1[7] = "1234", *p;
      p = s1 + 2;
      *p = '0';
      printf("%s", s1);
}
```

What will be printed by the program?

(A) 12 (B) 120400 (C) 1204 (D) 1034

Q.2 Suppose U is the power set of the set $S = \{1,2,3,4,5,6\}$. For any $T \in U$, let $|T|$ denote the number of elements in T and T' denote the complement of T. For any $T, R \in U$, let $T \setminus R$ be the set of all elements in T which are not in R. Which one of the following is true?

(A) $\forall X \in U\ (|X| = |X'|)$
(B) $\exists X \in U\ \exists Y \in U\ (|X| = 5, |Y| = 5 \text{ and } X \cap Y = \emptyset)$
(C) $\forall X \in U\ \forall Y \in U\ (|X| = 2, |Y| = 3 \text{ and } X \setminus Y = \emptyset)$
(D) $\forall X \in U\ \forall Y \in U\ (X \setminus Y = Y' \setminus X')$

Q.3 Consider the relation $X(P, Q, R, S, T, U)$ with the following set of functional dependencies

$$F = \{ \{P, R\} \rightarrow \{S, T\}, \{P, S, U\} \rightarrow \{Q, R\} \}$$

Which of the following is the trivial functional dependency in F^+, where F^+ is closure of F **?**

(A) $\{P, R\} \rightarrow \{S, T\}$ (B) $\{P, R\} \rightarrow \{R, T\}$ (C) $\{P, S\} \rightarrow \{S\}$ (D) $\{P, S, U\} \rightarrow \{Q\}$

Q.4 The maximum number of processes that can be in *Ready* state for a computer system with n CPUs is

(A) n (B) n^2 (C) 2^n (D) Independent of n

Q.5 Among simple LR (SLR) , canonical LR, and look-ahead LR (LALR), which of the following pairs identify the method that is very easy to implement and the method that is the most powerful , in that order?

(A) SLR, LALR
(B) Canonical LR, LALR
(C) SLR, canonical LR
(D) LALR, canonical LR

Q.6 Let # be a binary operator defined as

$X \# Y = X' + Y'$ where X and Y are Boolean variables.

Consider the following two statements.

(S1) $(P \# Q)\#R = P\#(Q \# R)$
(S2) $Q\#R = R\#Q$

Which of the following is/are true for the Boolean variables P, Q and R?

(A) Only S1 is true
(B) Only S2 is true
(C) Both S1 and S2 are true
(D) Neither S1 nor S2 are true

Q.7 Consider a software project with the following information domain characteristics for calculation of function point metric.

Number of external inputs (I) = 30
Number of external outputs (O) = 60
Number of external inquiries (E) = 23
Number of files (F) = 08
Number of external interfaces (N) = 02

It is given that the complexity weighting factors for I, O, E, F and N are 4, 5, 4, 10 and 7, respectively. It is also given that, out of fourteen value adjustment factors that influence the development effort, four factors are not applicable, each of the other four factors have value 3, and each of the remaining factors have value 4. The computed value of function point metric is _____.

Q.8 In a web server, ten WebPages are stored with the URLs of the form http://www.yourname.com/var.html; where, var is a different number from 1 to 10 for each Webpage. Suppose, the client stores the Webpage with $var = 1$ (say W1) in local machine, edits and then tests. Rest of the WebPages remains on the web server. W1 contains several relative URLs of the form "var.html" referring to the other WebPages. Which one of the following statements needs to be added in W1, so that all the relative URLs in W1 refer to the appropriate WebPages on the web server?

(A) <a href: "http://www.yourname.com/", href: "...var.html">
(B) <base href: "http://www.yourname.com/">
(C) <a href: "http://www.yourname.com/">
(D) <base href: "http://www.yourname.com/", range:"…var.html">

Q.9 Consider the following statements.

I. TCP connections are full duplex
II. TCP has no option for selective acknowledgement
III. TCP connections are message streams

(A) Only I is correct
(B) Only I and III are correct
(C) Only II and III are correct
(D) All of I, II and III are correct

Q.10 Consider the equality $\sum_{i=0}^{n} i^3 = X$ and the following choices for X

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

The equality above remains correct if X is replaced by

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

Q.11 Consider a binary tree T that has 200 leaf nodes. Then, the number of nodes in T that have exactly two children are _____.

Q.12 Given a hash table T with 25 slots that stores 2000 elements, the load factor α for T is _____.

Q.13 In the given matrix $\begin{bmatrix} 1 & -1 & 2 \\ 0 & 1 & 0 \\ 1 & 2 & 1 \end{bmatrix}$, one of the eigenvalues is 1. The eigenvectors corresponding to the eigenvalue 1 are

(A) $\{\alpha(4,2,1) | \alpha \neq 0, \alpha \in \mathbb{R}\}$
(B) $\{\alpha(-4,2,1) | \alpha \neq 0, \alpha \in \mathbb{R}\}$
(C) $\{\alpha(\sqrt{2}, 0,1) | \alpha \neq 0, \alpha \in \mathbb{R}\}$
(D) $\{\alpha(-\sqrt{2}, 0,1) | \alpha \neq 0, \alpha \in \mathbb{R}\}$

Q.14 The value of $\lim_{x \to \infty} (1 + x^2)^{e^{-x}}$ is

(A) 0
(B) $\frac{1}{2}$
(C) 1
(D) ∞

Q.15 The number of 4 digit numbers having their digits in non-decreasing order (from left to right) constructed by using the digits belonging to the set {1, 2, 3} is_____.

Q.16 In a room there are only two types of people, namely Type 1 and Type 2. Type 1 people always tell the truth and Type 2 people always lie. You give a fair coin to a person in that room, without knowing which type he is from and tell him to toss it and hide the result from you till you ask for it. Upon asking, the person replies the following

"The result of the toss is head if and only if I am telling the truth."

Which of the following options is correct?

(A) The result is head
(B) The result is tail
(C) If the person is of Type 2, then the result is tail
(D) If the person is of Type 1, then the result is tail

Q.17 While inserting the elements 71, 65, 84, 69, 67, 83 in an empty binary search tree (BST) in the sequence shown, the element in the lowest level is

(A) 65 (B) 67 (C) 69 (D) 83

Q.18 The result evaluating the postfix expression 10 5 + 60 6 / * 8 − is

(A) 284 (B) 213 (C) 142 (D) 71

Q.19 Consider the following relation

Cinema(*theater*, *address*, *capacity*)

Which of the following options will be needed at the end of the SQL query

```
SELECT P1.address
FROM Cinema P1
```

such that it always finds the addresses of theaters with maximum capacity?

(A) WHERE P1.*capacity* >= All (select P2.*capacity* from Cinema P2)
(B) WHERE P1.*capacity* >= Any (select P2.*capacity* from Cinema P2)
(C) WHERE P1.*capacity* > All (select max(P2.*capacity*) from Cinema P2)
(D) WHERE P1.*capacity* > Any (select max(P2.*capacity*) from Cinema P2)

Q.20 Consider the following array of elements.

$$\langle 89, 19, 50, 17, 12, 15, 2, 5, 7, 11, 6, 9, 100 \rangle$$

The minimum number of interchanges needed to convert it into a max-heap is

(A) 4 (B) 5 (C) 2 (D) 3

Q.21 Two processes *X* and *Y* need to access a critical section. Consider the following synchronization construct used by both the processes

Process *X*	Process *Y*

`/* other code for process X */`
`while(true)`
`{`
`  varP = true;`
`  while(varQ == true)`
`  {`
`  /* Critical Section */`
`  varP = false;`
`  }`
`}`
`/* other code for process X */`
	`/* other code for process Y */`
	`while(true)`
	`{`
	`  varQ = true;`
	`  while(varP == true)`
	`  {`
	`  /* Critical Section */`
	`  varQ = false;`
	`  }`
	`}`
	`/* other code for process Y */`

Here, `varP` and `varQ` are shared variables and both are initialized to false. Which one of the following statements is true?

(A) The proposed solution prevents deadlock but fails to guarantee mutual exclusion
(B) The proposed solution guarantees mutual exclusion but fails to prevent deadlock
(C) The proposed solution guarantees mutual exclusion and prevents deadlock
(D) The proposed solution fails to prevent deadlock and fails to guarantee mutual exclusion

Q.22 Let L be the language represented by the regular expression $\Sigma^*0011\Sigma^*$ where $\Sigma = \{0, 1\}$. What is the minimum number of states in a DFA that recognizes $\bar{L}$ (complement of L)?

(A) 4 (B) 5 (C) 6 (D) 8

Q.23 Consider a software program that is artificially seeded with 100 faults. While testing this program, 159 faults are detected, out of which 75 faults are from those artificially seeded faults. Assuming that both real and seeded faults are of same nature and have same distribution, the estimated number of undetected real faults is _____.

Q.24 Consider a machine with a byte addressable main memory of 2^{20} bytes, block size of 16 bytes and a direct mapped cache having 2^{12} cache lines. Let the addresses of two consecutive bytes in main memory be $(E201F)_{16}$ and $(E2020)_{16}$. What are the tag and cache line address (in hex) for main memory address $(E201F)_{16}$?

(A) E, 201 (B) F, 201 (C) E, E20 (D) 2, 01F

Q.25 Consider a CSMA/CD network that transmits data at a rate of 100 Mbps (10^8 bits per second) over a 1 km (kilometer) cable with no repeaters. If the minimum frame size required for this network is 1250 bytes, what is the signal speed (km/sec) in the cable?

(A) 8000 (B) 10000 (C) 16000 (D) 20000

Q. 26 – Q. 55 carry two marks each.

Q.26 The velocity v (in kilometer/minute) of a motorbike which starts from rest, is given at fixed intervals of time t (in minutes) as follows:

t	2	4	6	8	10	12	14	16	18	20
v	10	18	25	29	32	20	11	5	2	0

The approximate distance (in kilometers) rounded to two places of decimals covered in 20 minutes using Simpson's 1/3rd rule is _____.

Q.27 Assume that a mergesort algorithm in the worst case takes 30 seconds for an input of size 64. Which of the following most closely approximates the maximum input size of a problem that can be solved in 6 minutes?

(A) 256 (B) 512 (C) 1024 (D) 2048

Q.28 Consider the following recursive C function.

```
void get(int n)
 {
      if (n<1) return;
      get(n-1);
      get(n-3);
      printf("%d", n);
 }
```

If `get(6)` function is being called in `main()` then how many times will the `get()` function be invoked before returning to the `main()`?

(A) 15 (B) 25 (C) 35 (D) 45

Q.29 Consider a B+ tree in which the search key is 12 bytes long, block size is 1024 bytes, record pointer is 10 bytes long and block pointer is 8 bytes long. The maximum number of keys that can be accommodated in each non-leaf node of the tree is _____.

Q.30 Given the function $F = P' + QR$, where F is a function in three Boolean variables P, Q and R and $P' = !P$, consider the following statements.

(S1) $F = \sum(4, 5, 6)$
(S2) $F = \sum(0, 1, 2, 3, 7)$
(S3) $F = \prod(4, 5, 6)$
(S4) $F = \prod(0, 1, 2, 3, 7)$

Which of the following is true?

(A) (S1)- False, (S2)- True, (S3)- True, (S4)- False
(B) (S1)- True, (S2)- False, (S3)- False, (S4)- True
(C) (S1)- False, (S2)- False, (S3)- True, (S4)- True
(D) (S1)- True, (S2)- True, (S3)- False, (S4)- False

Q.31 Language L_1 is polynomial time reducible to language L_2. Language L_3 is polynomial time reducible to L_2, which in turn is polynomial time reducible to language L_4. Which of the following is/are true?

I. if $L_4 \in P$, then $L_2 \in P$

II. if $L_1 \in P$ or $L_3 \in P$, then $L_2 \in P$

III. $L_1 \in P$, if and only if $L_3 \in P$

IV. if $L_4 \in P$, then $L_1 \in P$ and $L_3 \in P$

(A) II only
(B) III only
(C) I and IV only
(D) I only

Q.32 Consider the following C program.

```
#include<stdio.h>
int f1(void);
int f2(void);
int f3(void);
int x = 10;

int main( )
 {
   int x = 1;
   x += f1( ) + f2( ) + f3( ) + f2( );
   printf("%d", x);
   return 0;
 }

int f1() { int x = 25; x++; return x;}
int f2() { static int x = 50; x++; return x;}
int f3() { x *= 10; return x};
```

The output of the program is _____.

Q.33 Consider the following C program.

```
#include<stdio.h>
int main( )
{
   static int a[ ] = {10, 20, 30, 40, 50};
   static int *p[ ] = {a, a+3, a+4, a+1, a+2};
   int **ptr = p;
   ptr++;
   printf("%d%d", ptr-p,**ptr);
}
```

The output of the program is _____.

Q.34 Which of the following languages are context-free?

$L_1 = \{a^m b^n a^n b^m \mid m, n \geq 1\}$
$L_2 = \{a^m b^n a^m b^n \mid m, n \geq 1\}$
$L_3 = \{a^m b^n \mid m = 2n + 1\}$

(A) L_1 and L_2 only (B) L_1 and L_3 only (C) L_2 and L_3 only (D) L_3 only

Q.35 Consider the following policies for preventing deadlock in a system with mutually exclusive resources.

I. Processes should acquire all their resources at the beginning of execution. If any resource is not available, all resources acquired so far are released
II. The resources are numbered uniquely, and processes are allowed to request for resources only in increasing resource numbers
III. The resources are numbered uniquely, and processes are allowed to request for resources only in decreasing resource numbers
IV. The resources are numbered uniquely. A process is allowed to request only for a resource with resource number larger than its currently held resources

Which of the above policies can be used for preventing deadlock?

(A) Any one of I and III but not II or IV
(B) Any one of I, III, and IV but not II
(C) Any one of II and III but not I or IV
(D) Any one of I, II, III, and IV

Q.36 In the network 200.10.11.144/27, the fourth octet (in decimal) of the last IP address of the network which can be assigned to a host is _____.

Q.37 Consider a network connecting two systems located 8000 kilometers apart. The bandwidth of the network is 500×10^6 bits per second. The propagation speed of the media is 4×10^6 meters per second. It is needed to design a Go-Back-N sliding window protocol for this network. The average packet size is 10^7 bits. The network is to be used to its full capacity. Assume that processing delays at nodes are negligible. Then, the minimum size in bits of the sequence number field has to be _____.

Q.38 Consider the following reservation table for a pipeline having three stages S_1, S_2 and S_3.

	$Time \rightarrow$ 1	2	3	4	5
S_1	X				X
S_2		X		X	
S_3			X		

The minimum average latency (MAL) is _____.

Q.39 Consider the following code sequence having five instructions I_1 to I_5. Each of these instructions has the following format.

OP Ri, Rj, Rk

where operation OP is performed on contents of registers Rj and Rk and the result is stored in register Ri.

I_1: ADD R1, R2, R3
I_2: MUL R7, R1, R3
I_3: SUB R4, R1, R5
I_4: ADD R3, R2, R4
I_5: MUL R7, R8, R9

Consider the following three statements.

S1: There is an anti-dependence between instructions I_2 and I_5
S2: There is an anti-dependence between instructions I_2 and I_4
S3: Within an instruction pipeline an anti-dependence always creates one or more stalls

Which one of above statements is/are correct?

(A) Only S1 is true
(B) Only S2 is true
(C) Only S1 and S3 are true
(D) Only S2 and S3 are true

Q.40 Consider the following two C code segments. Y and X are one and two dimensional arrays of size n and $n \times n$ respectively, where $2 \leq n \leq 10$. Assume that in both code segments, elements of Y are initialized to 0 and each element X[i][j] of array X is initialized to i+j. Further assume that when stored in main memory all elements of X are in same main memory page frame.

Code segment 1:

```
//initialize elements of Y to 0
//initialize elements X[i][j] of X to i+j

   for(i = 0; i < n; i++)
       Y[i] += X[0][i];
```

Code Segment 2:

```
//initialize elements of Y to 0
//initialize elements X[i][j] of X to i+j

     for(i = 0; i < n; i++)
       Y[i] += X[i][0];
```

Which of the following statements is/are correct?

S1: Final contents of array Y will be same in both code segments
S2: Elements of array X accessed inside the for loop shown in code segment 1 are contiguous in main memory
S3: Elements of array X accessed inside the for loop shown in code segment 2 are contiguous in main memory

(A) Only S2 is correct
(B) Only S3 is correct
(C) Only S1 and S2 are correct
(D) Only S1 and S3 are correct

Q.41 Consider the following partial Schedule *S* involving two transactions *T1* and *T2*. Only the *read* and the *write* operations have been shown. The *read* operation on data item *P* is denoted by *read(P)* and the *write* operation on data item *P* is denoted by *write(P)*.

Time instance	Transaction-id	
	T1	*T2*
1	*read(A)*	
2	*write(A)*	
3		*read(C)*
4		*write(C)*
5		*read(B)*
6		*write(B)*
7		*read(A)*
8		*commit*
9	*read(B)*	

Schedule *S*

Suppose that the transaction *T1* fails immediately after time instance 9. Which one of the following statements is correct?

(A) *T2* must be aborted and then both *T1* and *T2* must be re-started to ensure transaction atomicity
(B) Schedule *S* is non-recoverable and cannot ensure transaction atomicity
(C) Only *T2* must be aborted and then re-started to ensure transaction atomicity
(D) Schedule *S* is recoverable and can ensure atomicity and nothing else needs to be done

Q.42 If the following system has non-trivial solution,

$$px + qy + rz = 0$$
$$qx + ry + pz = 0$$
$$rx + py + qz = 0,$$

then which one of the following options is TRUE?

(A) $p - q + r = 0$ or $p = q = -r$
(B) $p + q - r = 0$ or $p = -q = r$
(C) $p + q + r = 0$ or $p = q = r$
(D) $p - q + r = 0$ or $p = -q = -r$

Q.43 Consider the following C program:

```
#include<stdio.h>
int main( )
{
    int i, j, k = 0;
    j = 2 * 3 / 4 + 2.0 / 5 + 8 / 5;
    k -= --j;
    for(i = 0; i < 5; i++)
      {
         switch(i + k)
         {
            case 1:
            case 2: printf("\n%d", i+k);
            case 3: printf("\n%d", i+k);
            default: printf("\n%d", i+k);
         }
      }
    return 0;
}
```

The number of times printf statement is executed is _____.

Q.44 If for non-zero x, $af(x) + bf\left(\frac{1}{x}\right) = \frac{1}{x} - 25$ where $a \neq b$ then $\int_1^2 f(x)dx$ is

(A) $\frac{1}{a^2 - b^2}\left[a(\ln 2 - 25) + \frac{47b}{2}\right]$
(B) $\frac{1}{a^2 - b^2}\left[a(2\ln 2 - 25) - \frac{47b}{2}\right]$
(C) $\frac{1}{a^2 - b^2}\left[a(2\ln 2 - 25) + \frac{47b}{2}\right]$
(D) $\frac{1}{a^2 - b^2}\left[a(\ln 2 - 25) - \frac{47b}{2}\right]$

Q.45 Let *G* be a connected undirected graph of 100 vertices and 300 edges. The weight of a minimum spanning tree of *G* is 500. When the weight of each edge of *G* is increased by five, the weight of a minimum spanning tree becomes _____.

Q.46 Two hosts are connected via a packet switch with 10^7 bits per second links. Each link has a propagation delay of 20 microseconds. The switch begins forwarding a packet 35 microseconds after it receives the same. If 10000 bits of data are to be transmitted between the two hosts using a packet size of 5000 bits, the time elapsed between the transmission of the first bit of data and the reception of the last bit of the data in microseconds is_____.

Q.47 For the processes listed in the following table, which of the following scheduling schemes will give the lowest average turnaround time?

Process	Arrival Time	Processing Time
A	0	3
B	1	6
C	4	4
D	6	2

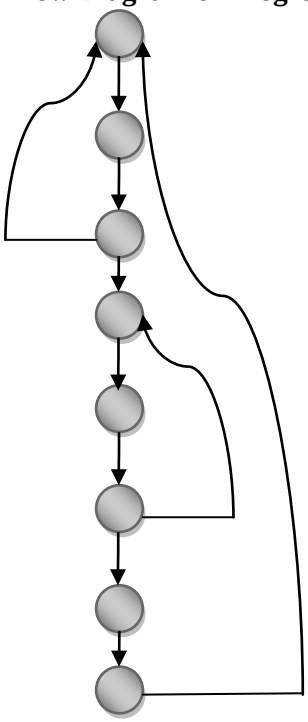
(A) First Come First Serve
(B) Non-preemptive Shortest Job First
(C) Shortest Remaining Time
(D) Round Robin with Quantum value two

Q.48 Consider three software items: Program-*X*, Control Flow Diagram of Program-*Y* and Control Flow Diagram of Program-*Z* as shown below

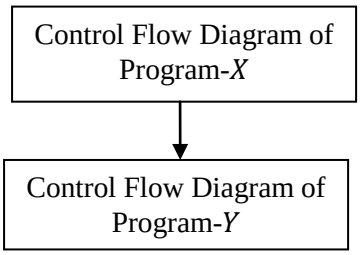
Program-*X*:

```
sumcal(int maxint, int value)
{
    int result=0, i=0;
    if (value <0)
    {
      value = –value;
    }
    while((i<value) AND (result
<= maxint))
    {
       i=i+1;
      result = result + 1;
    }
    if(result <= maxint)
    {
       printf(result);
    }
    else
    {
      printf("large");
    }
    printf("end of program");
}
```

Control Flow Diagram of Program-*Y*:



Control Flow Diagram of Program-*Z*:



The values of McCabe's Cyclomatic complexity of Program-*X*, Program-*Y*, and Program-*Z* respectively are

(A) 4, 4, 7 (B) 3, 4, 7 (C) 4, 4, 8 (D) 4, 3, 8

Q.49 Consider the equation $(43)_x = (y3)_8$ where x and y are unknown. The number of possible solutions is _____

Q.50 Let *R* be a relation on the set of ordered pairs of positive integers such that ((*p*,*q*),(*r*,*s*)) $\in$ *R* if and only if $p - s = q - r$. Which one of the following is true about *R*?

(A) Both reflexive and symmetric
(B) Reflexive but not symmetric
(C) Not reflexive but symmetric
(D) Neither reflexive nor symmetric

Q.51 Suppose X_i for $i = 1,2,3$ are independent and identically distributed random variables whose probability mass functions are $\Pr[X_i = 0] = \Pr[X_i = 1] = 1/2$ for $i = 1, 2, 3$. Define another random variable $Y = X_1X_2 \oplus X_3$, where $\oplus$ denotes XOR. Then

$\Pr[Y = 0|X_3 = 0] =$_____.

Q.52 The total number of prime implicants of the function $f(w, x, y, z) = \sum(0, 2, 4, 5, 6, 10)$ is _____.

Q.53 Suppose $c = \langle c[0], \ldots, c[k-1] \rangle$ is an array of length k, where all the entries are from the set $\{0, 1\}$. For any positive integers a and n, consider the following pseudocode.

```
DOSOMETHING(c, a, n)
z ← 1
for i ← 0 to k − 1
    do z ← z^2 mod n
     if c[i] = 1
          then z ← (z × a) mod n
return z
```

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

Q.54 Let $f(n) = n$ and $g(n) = n^{(1+\sin n)}$, where n is a positive integer. Which of the following statements is/are correct?

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

(A) Only I
(B) Only II
(C) Both I and II
(D) Neither I nor II

Q.55 Consider the following grammar G

$S \rightarrow F \mid H$
$F \rightarrow p \mid c$
$H \rightarrow d \mid c$

where S, F, and H are non-terminal symbols, p, d, and c are terminal symbols. Which of the following statement(s) is/are correct?

S1. LL(1) can parse all strings that are generated using grammar G
S2. LR(1) can parse all strings that are generated using grammar G

(A) Only S1 (B) Only S2 (C) Both S1 and S2 (D) Neither S1 nor S2

END OF THE QUESTION PAPER