GATE 2024 Computer Science and Information Technology (CS) Question Paper

Graduate Aptitude Test in Engineering (GATE)

Paper	Page No.
GATE 2024 Computer Science and Information Technology (CS) Question Paper- Set 1	2 - 37
GATE 2024 Computer Science and Information Technology (CS) Question Paper- Set 2	38 - 77

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General Aptitude (GA)

Q.1 – Q.5 Carry ONE mark Each

Q.1   If '→' denotes increasing order of intensity, then the meaning of the words

[dry → arid → parched] is analogous to [diet → fast → _____].

Which one of the given options is appropriate to fill the blank?

(A)   starve

(B)   reject

(C)   feast

(D)   deny

Q.2   If two distinct non-zero real variables x and y are such that $(x + y)$ is proportional to $(x - y)$ then the value of $\dfrac{x}{y}$

(A)   depends on xy

(B)   depends only on x and not on y

(C)   depends only on y and not on x

(D)   is a constant

2

Q.3   Consider the following sample of numbers:

9, 18, 11, 14, 15, 17, 10, 69, 11, 13

The median of the sample is

(A)   13.5

(B)   14

(C)   11

(D)   18.7

Q.4   The number of coins of ₹1, ₹5, and ₹10 denominations that a person has are in the ratio 5:3:13. Of the total amount, the percentage of money in ₹5 coins is

(A)   21%

(B) $14\frac{2}{7}\%$

(C)   10%

(D)   30%

Q.5   For positive non-zero real variables p and q, if

$$\log\,(p^2 + q^2) = \log p + \log q + 2\log 3\,,$$

then, the value of $\dfrac{p^4+q^4}{p^2 q^2}$ is

(A)   79

(B)   81

(C)   9

(D)   83

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4

Q.6 – Q.10 Carry TWO marks Each

Q.6   In the given text, the blanks are numbered (i)−(iv). Select the best match for all the blanks.

Steve was advised to keep his head ____(i)____ before heading ____(ii)____ to bat; for, while he had a head ____(iii)____ batting, he could only do so with a cool head ____(iv)____ his shoulders.

(A)   (i) down   (ii) down   (iii) on   (iv) for

(B)   (i) on   (ii) down   (iii) for   (iv) on

(C)   (i) down   (ii) out   (iii) for   (iv) on

(D)   (i) on   (ii) out   (iii) on   (iv) for

5

Q.7 A rectangular paper sheet of dimensions 54 cm × 4 cm is taken. The two longer edges of the sheet are joined together to create a cylindrical tube. A cube whose surface area is equal to the area of the sheet is also taken.

Then, the ratio of the volume of the cylindrical tube to the volume of the cube is

(A) $1/\pi$

(B) $2/\pi$

(C) $3/\pi$

(D) $4/\pi$

Q.8   The pie chart presents the percentage contribution of different macronutrients to a typical 2,000 kcal diet of a person.

Macronutrient energy contribution
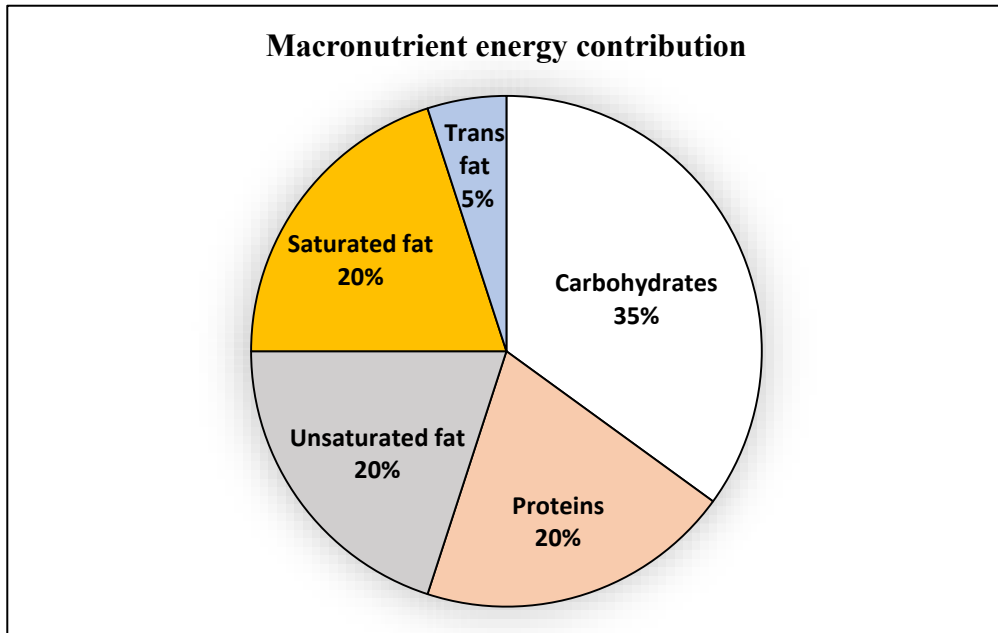
The typical energy density (kcal/g) of these macronutrients is given in the table.

| Macronutrient	Energy density (kcal/g)
Carbohydrates	4
Proteins	4
Unsaturated fat	9
Saturated fat	9
Trans fat	9

The total fat (all three types), in grams, this person consumes is

(A)   44.4

(B)   77.8

(C)   100

(D)   3,600

7

Q.9 A rectangular paper of 20 cm × 8 cm is folded 3 times. Each fold is made along the line of symmetry, which is perpendicular to its long edge. The perimeter of the final folded sheet (in cm) is

(A) 18

(B) 24

(C) 20

(D) 21

Q.10 The least number of squares to be added in the figure to make AB a line of symmetry is
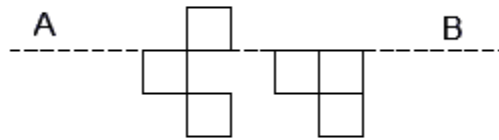
(A) 6

(B) 4

(C) 5

(D) 7

Q.11 – Q.35 Carry ONE mark Each

Q.11 Let $f: \mathbb{R} \rightarrow \mathbb{R}$ be a function such that $f(x) = \max\{x, x^3\}$, $x \in \mathbb{R}$, where $\mathbb{R}$ is the set of all real numbers. The set of all points where $f(x)$ is NOT differentiable is

(A) $\{-1, 1, 2\}$

(B) $\{-2, -1, 1\}$

(C) $\{0, 1\}$

(D) $\{-1, 0, 1\}$

Q.12 The product of all eigenvalues of the matrix $\begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \end{bmatrix}$ is

(A) -1

(B) 0

(C) 1

(D) 2

Q.13 Consider a system that uses 5 bits for representing signed integers in 2's complement format. In this system, two integers A and B are represented as $A=01010$ and $B=11010$. Which one of the following operations will result in either an arithmetic overflow or an arithmetic underflow?

(A) $A + B$

(B) $A - B$

(C) $B - A$

(D) $2 * B$

Q.14 Consider a permutation sampled uniformly at random from the set of all permutations of $\{1, 2, 3, \cdots, n\}$ for some $n \geq 4$. Let X be the event that 1 occurs before 2 in the permutation, and Y the event that 3 occurs before 4. Which one of the following statements is TRUE?

(A)   The events X and Y are mutually exclusive

(B)   The events X and Y are independent

(C)   Either event X or Y must occur

(D)   Event X is more likely than event Y

Q.15   Which one of the following statements is FALSE?

(A)   In the cycle stealing mode of DMA, one word of data is transferred between an I/O device and main memory in a stolen cycle

(B)   For bulk data transfer, the burst mode of DMA has a higher throughput than the cycle stealing mode

(C)   Programmed I/O mechanism has a better CPU utilization than the interrupt driven I/O mechanism

(D)   The CPU can start executing an interrupt service routine faster with vectored interrupts than with non-vectored interrupts

Q.16 A user starts browsing a webpage hosted at a remote server. The browser opens a single TCP connection to fetch the entire webpage from the server. The webpage consists of a top-level index page with multiple embedded image objects. Assume that all caches (e.g., DNS cache, browser cache) are all initially empty. The following packets leave the user's computer in some order.

(i) HTTP GET request for the index page
(ii) DNS request to resolve the web server's name to its IP address
(iii) HTTP GET request for an image object
(iv) TCP SYN to open a connection to the web server

Which one of the following is the CORRECT chronological order (earliest in time to latest) of the packets leaving the computer ?

(A) (iv), (ii), (iii), (i)

(B) (ii), (iv), (iii), (i)

(C) (ii), (iv), (i), (iii)

(D) (iv), (ii), (i), (iii)

Q.17 Given an integer array of size N, we want to check if the array is sorted (in either ascending or descending order). An algorithm solves this problem by making a single pass through the array and comparing each element of the array only with its adjacent elements. The worst-case time complexity of this algorithm is

(A) both $O(N)$ and $\Omega(N)$

(B) $O(N)$ but not $\Omega(N)$

(C) $\Omega(N)$ but not $O(N)$

(D) neither $O(N)$ nor $\Omega(N)$

Q.18   Consider the following C program:

```
#include <stdio.h>
int main(){
    int a = 6;
    int b = 0;
    while(a < 10) {
        a = a / 12 + 1;
        a += b;}
    printf("%d", a);
    return 0;}
```

Which one of the following statements is CORRECT?

(A)   The program prints 9 as output

(B)   The program prints 10 as output

(C)   The program gets stuck in an infinite loop

(D)   The program prints 6 as output

Q.19   Consider the following C program:

```
#include <stdio.h>        void fX(){
void fX();                 char a;
int main(){                if((a=getchar()) != '\n')
   fX();                       fX();
   return 0;}               if(a != '\n')
                               putchar(a);}
```

Assume that the input to the program from the command line is 1234 followed by a newline character. Which one of the following statements is CORRECT?

(A)   The program will not terminate

(B)   The program will terminate with no output

(C)   The program will terminate with 4321 as output

(D)   The program will terminate with 1234 as output

Q.20 Let S be the specification: "Instructors teach courses. Students register for courses. Courses are allocated classrooms. Instructors guide students." Which one of the following ER diagrams CORRECTLY represents S?
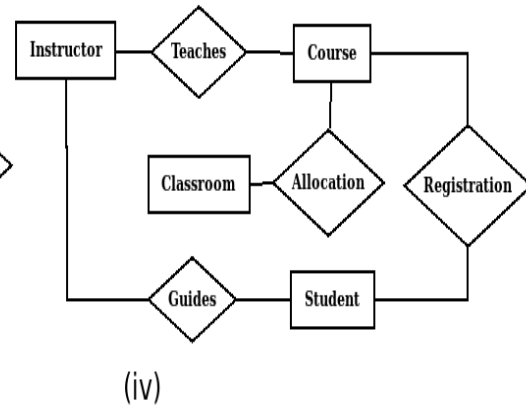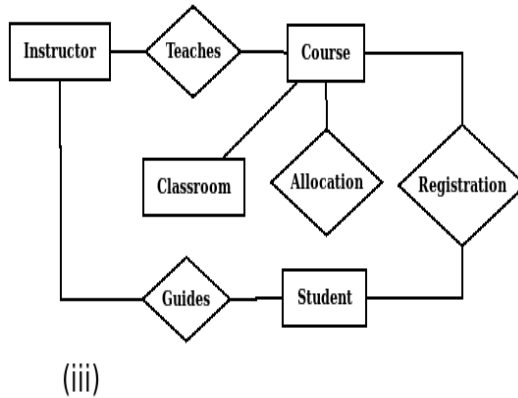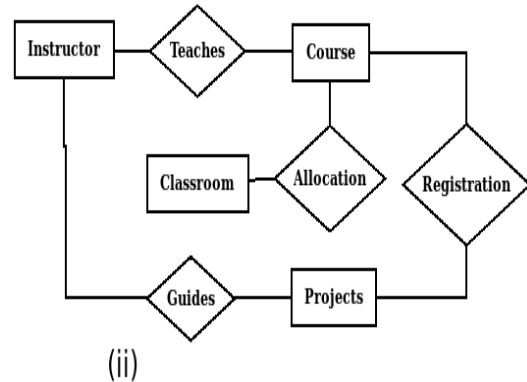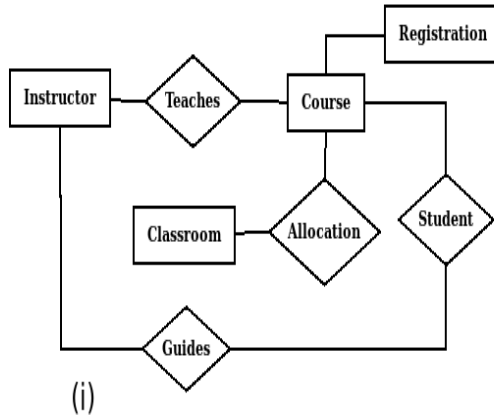
(A)   (i)

(B)   (ii)

(C)   (iii)

(D)   (iv)

Q.21 In a B+ tree, the requirement of at least half-full (50%) node occupancy is relaxed for which one of the following cases?

(A) Only the root node

(B) All leaf nodes

(C) All internal nodes

(D) Only the leftmost leaf node

Q.22 Which of the following statements about a relation **R** in first normal form (1NF) is/are TRUE ?

(A) **R** can have a multi-attribute key

(B) **R** cannot have a foreign key

(C) **R** cannot have a composite attribute

(D) **R** cannot have more than one candidate key

Q.23 Let L_1, L_2 be two regular languages and L_3 a language which is not regular. Which of the following statements is/are *always* TRUE?

(A) $L_1 = L_2$ if and only if $L_1 \cap \overline{L_2} = \phi$

(B) $L_1 \cup L_3$ is not regular

(C) $\overline{L_3}$ is not regular

(D) $\overline{L_1} \cup \overline{L_2}$ is regular

Q.24 Which of the following statements about threads is/are TRUE?

(A) Threads can only be implemented in kernel space

(B) Each thread has its own file descriptor table for open files

(C) All the threads belonging to a process share a common stack

(D) Threads belonging to a process are by default not protected from each other

17

Q.25 Which of the following process state transitions is/are NOT possible?

(A) Running to Ready

(B) Waiting to Running

(C) Ready to Waiting

(D) Running to Terminated

Q.26 Which of the following is/are Bottom-Up Parser(s)?

(A) Shift-reduce Parser

(B) Predictive Parser

(C) LL(1) Parser

(D) LR Parser

Q.27 Let A and B be two events in a probability space with $P(A) = 0.3$, $P(B) = 0.5$, and $P(A \cap B) = 0.1$. Which of the following statements is/are TRUE?

(A) The two events A and B are independent

(B) $P(A \cup B) = 0.7$

(C) $P(A \cap B^c) = 0.2$, where B^c is the complement of the event B

(D) $P(A^c \cap B^c) = 0.4$, where A^c and B^c are the complements of the events A and B, respectively

Q.28 Consider the circuit shown below where the gates may have propagation delays. Assume that all signal transitions occur instantaneously and that wires have no delays. Which of the following statements about the circuit is/are CORRECT?
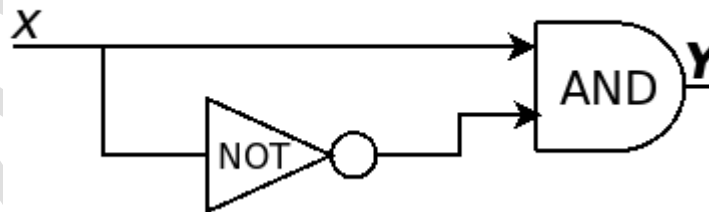
(A) With no propagation delays, the output Y is always logic Zero

(B) With no propagation delays, the output Y is always logic One

(C) With propagation delays, the output Y can have a transient logic One after X transitions from logic Zero to logic One

(D) With propagation delays, the output Y can have a transient logic Zero after X transitions from logic One to logic Zero

Q.29 TCP client P successfully establishes a connection to TCP server Q. Let N_P denote the sequence number in the SYN sent from P to Q. Let N_Q denote the acknowledgement number in the SYN ACK from Q to P. Which of the following statements is/are CORRECT?

(A) The sequence number N_P is chosen randomly by P

(B) The sequence number N_P is always 0 for a new connection

(C) The acknowledgement number N_Q is equal to N_P

(D) The acknowledgement number N_Q is equal to $N_P + 1$

Q.30 Consider a 5-stage pipelined processor with Instruction Fetch (IF), Instruction Decode (ID), Execute (EX), Memory Access (MEM), and Register Writeback (WB) stages. Which of the following statements about *forwarding* is/are CORRECT?

(A) In a pipelined execution, forwarding means the result from a source stage of an earlier instruction is passed on to the destination stage of a later instruction

(B) In forwarding, data from the output of the MEM stage can be passed on to the input of the EX stage of the next instruction

(C) Forwarding cannot prevent all pipeline stalls

(D) Forwarding does not require any extra hardware to retrieve the data from the pipeline stages

Q.31   Which of the following fields is/are modified in the IP header of a packet going out of a network address translation (NAT) device from an internal network to an external network?

(A)   Source IP

(B)   Destination IP

(C)   Header Checksum

(D)   Total Length

Q.32   Let A and B be non-empty finite sets such that there exist one-to-one and onto functions (i) from A to B and (ii) from $A \times A$ to $A \cup B$. The number of possible values of $|A|$ is _____

Q.33   Consider the operator precedence and associativity rules for the *integer* arithmetic operators given in the table below.

Operator	Precedence	Associativity
$+$	Highest	Left
$-$	High	Right
$*$	Medium	Right
$/$	Low	Right

The value of the expression $3 + 1 + 5 * 2 / 7 + 2 - 4 - 7 - 6 / 2$ as per the above rules is _____

Q.34 The number of spanning trees in a *complete* graph of 4 vertices labelled A, B, C, and D is _____

Q.35 Consider the following two relations, *R(A,B)* and *S(A,C)*:

R	
A	*B*
10	20
20	30
30	40
30	50
50	95

S	
A	*C*
10	90
30	45
40	80

The total number of tuples obtained by evaluating the following expression

$$\sigma_{B<C}(R \bowtie_{R.A=S.A} S)$$

is _____

Q.36 – Q.65 Carry TWO marks Each

Q.36 Consider a network path P—Q—R between nodes P and R via router Q. Node P sends a file of size 10^6 bytes to R via this path by splitting the file into chunks of 10^3 bytes each. Node P sends these chunks one after the other without any wait time between the successive chunk transmissions. Assume that the size of extra headers added to these chunks is negligible, and that the chunk size is less than the MTU.

Each of the links P—Q and Q—R has a bandwidth of 10^6 bits/sec, and negligible propagation latency. Router Q immediately transmits every packet it receives from P to R, with negligible processing and queueing delays. Router Q can simultaneously receive on link P—Q and transmit on link Q—R.

Assume P starts transmitting the chunks at time $t = 0$.
Which one of the following options gives the time (*in seconds, rounded off to 3 decimal places*) at which R receives all the chunks of the file?

(A) 8.000

(B) 8.008

(C) 15.992

(D) 16.000

Q.37 Consider the following syntax-directed definition (SDD).

$S \to DHTU$	$\{\ S.val\ =\ D.val\ +\ H.val\ +\ T.val\ +\ U.val;\ \}$
$D \to \text{"M"}D_1$	$\{\ D.val\ =\ 5\ +\ D_1.val;\ \}$
$D \to \epsilon$	$\{\ D.val\ =\ -5;\ \}$
$H \to \text{"L"}H_1$	$\{\ H.val\ =\ 5*10\ +\ H_1.val;\ \}$
$H \to \epsilon$	$\{\ H.val\ =\ -10;\ \}$
$T \to \text{"C"}T_1$	$\{\ T.val\ =\ 5*100\ +\ T_1.val;\ \}$
$T \to \epsilon$	$\{\ T.val\ =\ -5;\ \}$
$U \to \text{"K"}$	$\{\ U.val\ =\ 5;\ \}$

Given "MMLK" as the input, which one of the following options is the CORRECT value computed by the SDD (in the attribute $S.val$)?

(A) 45

(B) 50

(C) 55

(D) 65

Q.38 Consider the following grammar G, with S as the start symbol. The grammar G has three incomplete productions denoted by (1), (2), and (3).

$$S \rightarrow daT \mid \underline{\quad (1) \quad}$$
$$T \rightarrow aS \mid bT \mid \underline{\quad (2) \quad}$$
$$R \rightarrow \underline{\quad (3) \quad} \mid \epsilon$$

The set of terminals is $\{a, b, c, d, f\}$. The FIRST and FOLLOW sets of the different non-terminals are as follows.

$$\mathrm{FIRST}(S) = \{c, d, f\}, \ \mathrm{FIRST}(T) = \{a, b, \epsilon\}, \ \mathrm{FIRST}(R) = \{c, \epsilon\}$$

$$\mathrm{FOLLOW}(S) = \mathrm{FOLLOW}(T) = \{c, f, \$\}, \ \mathrm{FOLLOW}(R) = \{f\}$$

Which one of the following options CORRECTLY fills in the incomplete productions?

(A) (1) $S \rightarrow Rf$ (2) $T \rightarrow \epsilon$ (3) $R \rightarrow cTR$

(B) (1) $S \rightarrow fR$ (2) $T \rightarrow \epsilon$ (3) $R \rightarrow cTR$

(C) (1) $S \rightarrow fR$ (2) $T \rightarrow cT$ (3) $R \rightarrow cR$

(D) (1) $S \rightarrow Rf$ (2) $T \rightarrow cT$ (3) $R \rightarrow cR$

Q.39 Consider the following pseudo-code.

$L1$: $t1 = -1$

$L2$: $t2 = 0$

$L3$: $t3 = 0$

$L4$: $t4 = 4 * t3$

$L5$: $t5 = 4 * t2$

$L6$: $t6 = t5 * M$

$L7$: $t7 = t4 + t6$

$L8$: $t8 = a[t7]$

$L9$: **if** $t8 <= max$ **goto** $L11$

$L10$: $t1 = t8$

$L11$: $t3 = t3 + 1$

$L12$: **if** $t3 < M$ **goto** $L4$

$L13$: $t2 = t2 + 1$

$L14$: **if** $t2 < N$ **goto** $L3$

$L15$: $max = t1$

Which one of the following options CORRECTLY specifies the number of basic blocks and the number of instructions in the largest basic block, respectively ?

(A) 6 and 6

(B) 6 and 7

(C) 7 and 7

(D) 7 and 6

Q.40 Consider the following two threads T1 and T2 that update two shared variables a and b. Assume that initially a = b = 1. Though context switching between threads can happen at any time, each statement of T1 or T2 is executed atomically without interruption.

T1	T2
a = a + 1;	b = 2 * b;
b = b + 1;	a = 2 * a;

Which one of the following options lists all the possible combinations of values of a and b after both T1 and T2 finish execution?

(A) (a = 4, b = 4); (a = 3, b = 3); (a = 4, b = 3)

(B) (a = 3, b = 4); (a = 4, b = 3); (a = 3, b = 3)

(C) (a = 4, b = 4); (a = 4, b = 3); (a = 3, b = 4)

(D) (a = 2, b = 2); (a = 2, b = 3); (a = 3, b = 4)

Q.41 An array [82, 101, 90, 11, 111, 75, 33, 131, 44, 93] is heapified. Which one of the following options represents the first three elements in the heapified array?

(A) 82, 90, 101

(B) 82, 11, 93

(C) 131, 11, 93

(D) 131, 111, 90

Q.42   Consider the following recurrence relation:

$$T(n) = \begin{cases} \sqrt{n}\, T(\sqrt{n}) + n & \text{for } n \geq 1, \\ 1 & \text{for } n = 1. \end{cases}$$

Which one of the following options is CORRECT?

(A) $T(n) = \Theta(n \log\log n)$

(B) $T(n) = \Theta(n \log n)$

(C) $T(n) = \Theta(n^2 \log n)$

(D) $T(n) = \Theta(n^2 \log\log n)$

Q.43   Consider a binary min-heap containing 105 distinct elements. Let k be the index (in the underlying array) of the maximum element stored in the heap. The number of possible values of k is

(A)   53

(B)   52

(C)   27

(D)   1

28

Q.44   The symbol $\rightarrow$ indicates functional dependency in the context of a relational database. Which of the following options is/are TRUE?

(A) $(X, Y) \rightarrow (Z, W)$ implies $X \rightarrow (Z, W)$

(B) $(X, Y) \rightarrow (Z, W)$ implies $(X, Y) \rightarrow Z$

(C) $\big((X, Y) \rightarrow Z$ and $W \rightarrow Y\big)$ implies $(X, W) \rightarrow Z$

(D) $(X \rightarrow Y$ and $Y \rightarrow Z)$ implies $X \rightarrow Z$

Q.45   Let G be a directed graph and T a depth first search (DFS) spanning tree in G that is rooted at a vertex v. Suppose T is also a breadth first search (BFS) tree in G, rooted at v. Which of the following statements is/are TRUE for *every* such graph G and tree T ?

(A)   There are no back-edges in G with respect to the tree T

(B)   There are no cross-edges in G with respect to the tree T

(C)   There are no forward-edges in G with respect to the tree T

(D)   The only edges in G are the edges in T

Q.46 Consider the following read-write schedule S over three transactions T_1, T_2, and T_3, where the subscripts in the schedule indicate transaction IDs:

$$S: r_1(z); \; w_1(z); \; r_2(x); \; r_3(y); \; w_3(y); \; r_2(y); \; w_2(x); \; w_2(y);$$

Which of the following transaction schedules is/are conflict equivalent to S ?

(A) $T_1 T_2 T_3$

(B) $T_1 T_3 T_2$

(C) $T_3 T_2 T_1$

(D) $T_3 T_1 T_2$

Q.47 Consider a Boolean expression given by $F(X, Y, Z) = \sum(3,5,6,7)$.

Which of the following statements is/are CORRECT?

(A) $F(X, Y, Z) = \Pi(0,1,2,4)$

(B) $F(X, Y, Z) = XY + YZ + XZ$

(C) $F(X, Y, Z)$ is independent of input Y

(D) $F(X, Y, Z)$ is independent of input X

Q.48   Consider the following C function definition.

```
int f(int x, int y) {
  for (int i=0; i<y; i++) {
    x=x+x+y;
  }
  return x;
}
```
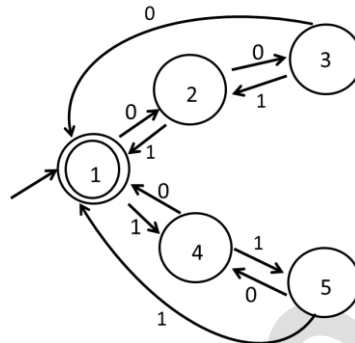
Which of the following statements is/are TRUE about the above function?

(A)   If the inputs are x=20, y=10, then the return value is greater than 2^{20}

(B)   If the inputs are x=20, y=20, then the return value is greater than 2^{20}

(C)   If the inputs are x=20, y=10, then the return value is less than 2^{10}

(D)   If the inputs are x=10, y=20, then the return value is greater than 2^{20}

Q.49   Let A be any $n \times m$ matrix, where $m > n$. Which of the following statements is/are TRUE about the system of linear equations $Ax = 0$?

(A)   There exist at least $m - n$ linearly independent solutions to this system

(B)   There exist $m - n$ linearly independent vectors such that every solution is a linear combination of these vectors

(C)   There exists a non-zero solution in which at least $m - n$ variables are 0

(D)   There exists a solution in which at least n variables are non-zero

Q.50 Consider the 5-state DFA M accepting the language $L(M) \subset (0 + 1)^*$ shown below. For any string $w \in (0 + 1)^*$ let $n_0(w)$ be the number of $0's$ in w and $n_1(w)$ be the number of $1's$ in w.

Which of the following statements is/are FALSE?

(A) States 2 and 4 are distinguishable in M

(B) States 3 and 4 are distinguishable in M

(C) States 2 and 5 are distinguishable in M

(D) Any string w with $n_0(w) = n_1(w)$ is in $L(M)$

Q.51   The chromatic number of a graph is the minimum number of colours used in a *proper* colouring of the graph. Let G be any graph with n vertices and chromatic number k. Which of the following statements is/are always TRUE?

(A) G contains a complete subgraph with k vertices

(B) G contains an independent set of size at least n/k

(C) G contains at least $k(k-1)/2$ edges

(D) G contains a vertex of degree at least k

Q.52   Consider the operators $\lozenge$ and $\square$ defined by $a \lozenge b = a + 2b$, $a \square b = ab$, for positive integers. Which of the following statements is/are TRUE?

(A)   Operator $\lozenge$ obeys the associative law

(B)   Operator $\square$ obeys the associative law

(C)   Operator $\lozenge$ over the operator $\square$ obeys the distributive law

(D)   Operator $\square$ over the operator $\lozenge$ obeys the distributive law

Q.53 Consider two set-associative cache memory architectures: **WBC**, which uses the write back policy, and **WTC**, which uses the write through policy. Both of them use the LRU (*Least Recently Used*) block replacement policy. The cache memory is connected to the main memory. Which of the following statements is/are TRUE?

(A) A read miss in **WBC** never evicts a dirty block

(B) A read miss in **WTC** never triggers a write back operation of a cache block to main memory

(C) A write hit in **WBC** can modify the value of the dirty bit of a cache block

(D) A write miss in **WTC** always writes the victim cache block to main memory before loading the missed block to the cache

Q.54 Consider a 512 GB hard disk with 32 storage surfaces. There are 4096 sectors per track and each sector holds 1024 bytes of data. The number of cylinders in the hard disk is _____

Q.55 The baseline execution time of a program on a 2 GHz single core machine is 100 nanoseconds (*ns*). The code corresponding to 90% of the execution time can be fully parallelized. The overhead for using an additional core is 10 *ns* when running on a multicore system. Assume that all cores in the multicore system run their share of the parallelized code for an equal amount of time.

The number of cores that minimize the execution time of the program is _____

Q.56 A given program has 25% load/store instructions. Suppose the ideal CPI (cycles per instruction) without any memory stalls is 2. The program exhibits 2% miss rate on instruction cache and 8% miss rate on data cache. The miss penalty is 100 cycles. The speedup (*rounded off to two decimal places*) achieved with a perfect cache (i.e., with NO data or instruction cache misses) is _____

Q.57 Consider the following code snippet using the `fork()` and `wait()` system calls. Assume that the code compiles and runs correctly, and that the system calls run successfully without any errors.

```
int x = 3;
while(x > 0) {
  fork();
  printf("hello");
  wait(NULL);
  x--;
}
```

The total number of times the `printf` statement is executed is _____

Q.58 Consider the entries shown below in the forwarding table of an IP router. Each entry consists of an IP prefix and the corresponding next hop router for packets whose destination IP address matches the prefix. The notation "/N" in a prefix indicates a subnet mask with the most significant N bits set to 1.

Prefix	Next hop router
10.1.1.0/24	R1
10.1.1.128/25	R2
10.1.1.64/26	R3
10.1.1.192/26	R4

This router forwards 20 packets each to 5 hosts. The IP addresses of the hosts are 10.1.1.16, 10.1.1.72, 10.1.1.132, 10.1.1.191, and 10.1.1.205 . The number of packets forwarded via the next hop router R2 is _____

Q.59 Let $G = (V, \Sigma, S, P)$ be a context-free grammar in Chomsky Normal Form with $\Sigma = \{a, b, c\}$ and V containing 10 variable symbols including the start symbol S. The string $w = a^{30}b^{30}c^{30}$ is derivable from S. The number of steps (application of rules) in the derivation $S \rightarrow^* w$ is _____

Q.60 The number of edges present in the forest generated by the DFS traversal of an undirected graph G with 100 vertices is 40. The number of connected components in G is _____

Q.61 Consider the following two regular expressions over the alphabet {0,1}:

$$r = 0^* + 1^*$$

$$s = 01^* + 10^*$$

The total number of strings of length less than or equal to 5, which are neither in r nor in s, is _____

Q.62 Consider a memory management system that uses a page size of 2 KB. Assume that both the physical and virtual addresses start from 0. Assume that the pages 0, 1, 2, and 3 are stored in the page frames 1, 3, 2, and 0, respectively. The physical address (*in decimal format*) corresponding to the virtual address 2500 (*in decimal format*) is _____

Q.63 A bag contains 10 red balls and 15 blue balls. Two balls are drawn randomly without replacement. Given that the first ball drawn is red, the probability (*rounded off to 3 decimal places*) that both balls drawn are red is _____

Q.64   Consider a digital logic circuit consisting of three 2-to-1 multiplexers M1, M2, and M3 as shown below. X1 and X2 are inputs of M1. X3 and X4 are inputs of M2. A, B, and C are select lines of M1, M2, and M3, respectively.
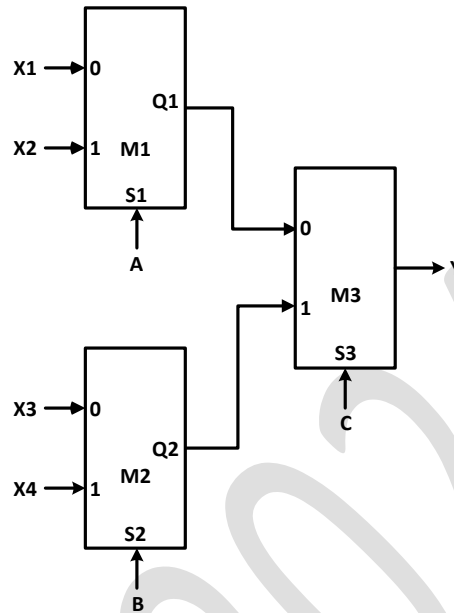
For an instance of inputs **X1=1, X2=1, X3=0**, and **X4=0**, the number of combinations of A, B, C that give the output **Y=1** is _____

Q.65   Consider sending an IP datagram of size 1420 bytes (including 20 bytes of IP header) from a sender to a receiver over a path of two links with a router between them. The first link (sender to router) has an MTU (Maximum Transmission Unit) size of 542 bytes, while the second link (router to receiver) has an MTU size of 360 bytes. The number of fragments that would be delivered at the receiver is _____

General Aptitude (GA)

Q.1 – Q.5 Carry ONE mark Each

Q.1   If '→' denotes increasing order of intensity, then the meaning of the words

[walk → jog → sprint] is analogous to [bothered → _____ → daunted].

Which one of the given options is appropriate to fill the blank?

(A)   phased

(B)   phrased

(C)   fazed

(D)   fused

Q.2   Two wizards try to create a spell using all the four elements, *water*, *air*, *fire*, and *earth*. For this, they decide to mix all these elements in all possible orders. They also decide to work independently. After trying all possible combination of elements, they conclude that the spell does not work.

How many attempts does each wizard make before coming to this conclusion, independently?

(A)   24

(B)   48

(C)   16

(D)   12

Q.3   In an engineering college of 10,000 students, 1,500 like neither their core branches nor other branches. The number of students who like their core branches is $1/4^{th}$ of the number of students who like other branches. The number of students who like both their core and other branches is 500.

The number of students who like their core branches is

(A)   1,800

(B)   3,500

(C)   1,600

(D)   1,500

Q.4   For positive non-zero real variables x and y, if

$$\ln\left(\frac{x+y}{2}\right) = \frac{1}{2}\left[\ln(x) + \ln(y)\right]$$

then, the value of $\frac{x}{y} + \frac{y}{x}$ is

(A)   1

(B)   1/2

(C)   2

(D)   4

Q.5   In the sequence 6, 9, 14, x, 30, 41, a possible value of x is

(A)   25

(B)   21

(C)   18

(D)   20

Q.6 – Q.10 Carry TWO marks Each

Q.6   Sequence the following sentences in a coherent passage.

P: This fortuitous geological event generated a colossal amount of energy and heat that resulted in the rocks rising to an average height of 4 km across the contact zone.

Q: Thus, the geophysicists tend to think of the Himalayas as an active geological event rather than as a static geological feature.

R: The natural process of the cooling of this massive edifice absorbed large quantities of atmospheric carbon dioxide, altering the earth's atmosphere and making it better suited for life.

S: Many millennia ago, a breakaway chunk of bedrock from the Antarctic Plate collided with the massive Eurasian Plate.

(A)   QPSR

(B)   QSPR

(C)   SPRQ

(D)   SRPQ

41

Q.7   A person sold two different items at the same price. He made 10% profit in one item, and 10% loss in the other item. In selling these two items, the person made a total of

(A)   1% profit

(B)   2% profit

(C)   1% loss

(D)   2% loss

Q.8   The pie charts depict the shares of various power generation technologies in the total electricity generation of a country for the years 2007 and 2023.
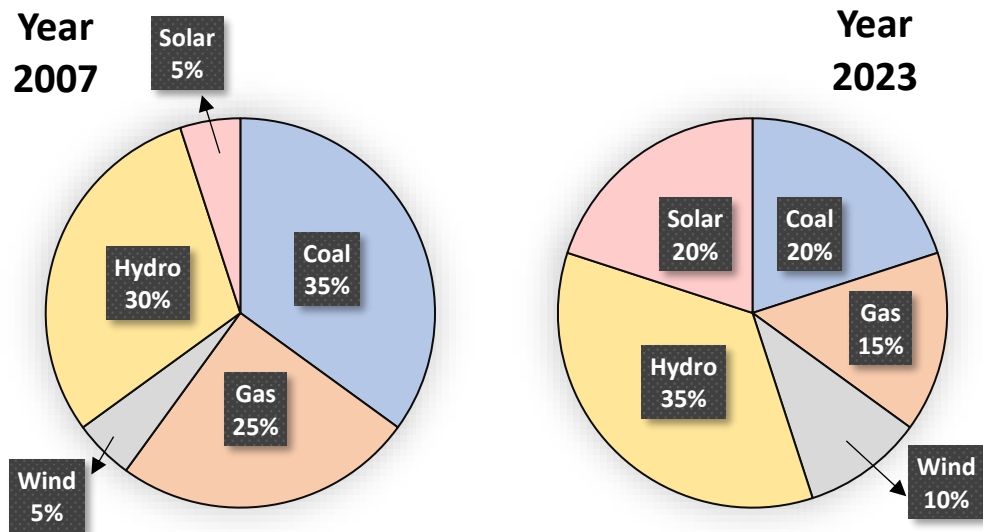
The renewable sources of electricity generation consist of Hydro, Solar and Wind. Assuming that the total electricity generated remains the same from 2007 to 2023, what is the percentage increase in the share of the renewable sources of electricity generation over this period?

(A)   25%

(B)   50%

(C)   77.5%

(D)   62.5%

Q.9 A cube is to be cut into 8 pieces of equal size and shape. Here, each cut should be straight and it should not stop till it reaches the other end of the cube.

The minimum number of such cuts required is

(A) 3

(B) 4

(C) 7

(D) 8

Q.10   In the 4 × 4 array shown below, each cell of the first three rows has either a cross (X) or a number.

1	X	4	3
X	5	5	4
3	X	6	X

The number in a cell represents the count of the immediate neighboring cells (left, right, top, bottom, diagonals) NOT having a cross (X). Given that the last row has no crosses (X), the sum of the four numbers to be filled in the last row is

(A)   11

(B)   10

(C)   12

(D)   9

45

Q.11 – Q.35 Carry ONE mark Each

Q.11 Consider a computer with a 4 MHz processor. Its DMA controller can transfer 8 bytes in 1 cycle from a device to main memory through cycle stealing at regular intervals. Which one of the following is the data transfer rate (*in bits per second*) of the DMA controller if 1% of the processor cycles are used for DMA?

(A) 2,56,000

(B) 3,200

(C) 25,60,000

(D) 32,000

Q.12 Let p and q be the following propositions:

  p: Fail grade can be given.

  q: Student scores more than 50% marks.

Consider the statement: "*Fail grade cannot be given when student scores more than 50% marks.*"

Which one of the following is the CORRECT representation of the above statement in propositional logic?

(A) $q \rightarrow \neg p$

(B) $q \rightarrow p$

(C) $p \rightarrow q$

(D) $\neg p \rightarrow q$

Q.13 Consider the following C program. Assume parameters to a function are evaluated from *right to left*.

```
#include <stdio.h>

int g(int p) { printf("%d", p); return p; }
int h(int q) { printf("%d", q); return q; }

void f(int x, int y) {
  g(x);
  h(y);
}

int main() {
  f(g(10),h(20));
}
```

Which one of the following options is the CORRECT output of the above C program?

(A)   20101020

(B)   10202010

(C)   20102010

(D)   10201020

Q.14 The format of a single-precision floating-point number as per the **IEEE 754** standard is:

Sign (1bit)	Exponent (8 bits)	Mantissa (23 bits)

Choose the largest floating-point number among the following options.

(A)

Sign	Exponent	Mantissa
0	0111 1111	1111 1111 1111 1111 1111 111

(B)

Sign	Exponent	Mantissa
0	1111 1110	1111 1111 1111 1111 1111 111

(C)

Sign	Exponent	Mantissa
0	1111 1111	1111 1111 1111 1111 1111 111

(D)

Sign	Exponent	Mantissa
0	0111 1111	0000 0000 0000 0000 0000 000

Q.15 Let $T(n)$ be the recurrence relation defined as follows:

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

Which one of the following statements is TRUE?

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

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

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

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

Q.16 Let $f(x)$ be a continuous function from $\mathbb{R}$ to $\mathbb{R}$ such that

$$f(x) = 1 - f(2 - x)$$

Which one of the following options is the CORRECT value of $\int_0^2 f(x)dx$?

(A) 0

(B) 1

(C) 2

(D) -1

Q.17   Let A be the adjacency matrix of a simple undirected graph G. Suppose A is its own inverse. Which one of the following statements is *always* TRUE?

(A) G is a cycle

(B) G is a perfect matching

(C) G is a complete graph

(D)   There is no such graph G

Q.18   When six unbiased dice are rolled simultaneously, the probability of getting all distinct numbers (*i.e.*, 1, 2, 3, 4, 5, and 6) is

(A) $\dfrac{1}{324}$

(B) $\dfrac{5}{324}$

(C) $\dfrac{7}{324}$

(D) $\dfrac{11}{324}$

50

Q.19   Once the DBMS informs the user that a transaction has been successfully completed, its effect should persist even if the system crashes before all its changes are reflected on disk. This property is called

(A)   durability

(B)   atomicity

(C)   consistency

(D)   isolation

Q.20   In the context of owner and weak entity sets in the ER (Entity-Relationship) data model, which one of the following statements is TRUE?

(A)   The weak entity set MUST have total participation in the identifying relationship

(B)   The owner entity set MUST have total participation in the identifying relationship

(C)   Both weak and owner entity sets MUST have total participation in the identifying relationship

(D)   Neither weak entity set nor owner entity set MUST have total participation in the identifying relationship

Q.21   Consider the following two sets:

Set *X*	Set *Y*
P. Lexical Analyzer	1. Abstract Syntax Tree
Q. Syntax Analyzer	2. Token
R. Intermediate Code Generator	3. Parse Tree
S. Code Optimizer	4. Constant Folding

Which one of the following options is the CORRECT match from **Set *X*** to **Set *Y*** ?

(A)   P – 4; Q – 1; R – 3; S – 2

(B)   P – 2; Q – 3; R – 1; S – 4

(C)   P – 2; Q – 1; R – 3; S – 4

(D)   P – 4; Q – 3; R – 2; S – 1

52

Q.22 Which one of the following regular expressions is equivalent to the language accepted by the DFA given below?
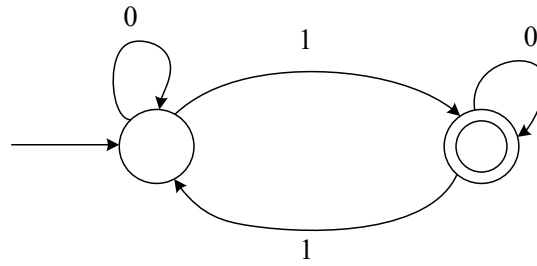
(A) $0^*1(0 + 10^*1)^*$

(B) $0^*(10^*11)^*0^*$

(C) $0^*1(010^*1)^*0^*$

(D) $0(1 + 0^*10^*1)^*0^*$

53

Q.23   Node X has a TCP connection open to node Y. The packets from X to Y go through an intermediate IP router R. Ethernet switch S is the first switch on the network path between X and R. Consider a packet sent from X to Y over this connection.

Which of the following statements is/are TRUE about the destination IP and MAC addresses on this packet at the time it leaves X?

(A)   The destination IP address is the IP address of R

(B)   The destination IP address is the IP address of Y

(C)   The destination MAC address is the MAC address of S

(D)   The destination MAC address is the MAC address of Y

Q.24   Which of the following tasks is/are the responsibility/responsibilities of the memory management unit (MMU) in a system with paging-based memory management?

(A)   Allocate a new page table for a newly created process

(B)   Translate a virtual address to a physical address using the page table

(C)   Raise a trap when a virtual address is not found in the page table

(D)   Raise a trap when a process tries to write to a page marked with read-only permission in the page table

Q.25 Consider a process P running on a CPU. Which one or more of the following events will *always* trigger a context switch by the OS that results in process P moving to a non-running state (e.g., ready, blocked)?

(A) P makes a blocking system call to read a block of data from the disk

(B) P tries to access a page that is in the swap space, triggering a page fault

(C) An interrupt is raised by the disk to deliver data requested by some other process

(D) A timer interrupt is raised by the hardware

Q.26 Which of the following file organizations is/are I/O efficient for the scan operation in DBMS?

(A) Sorted

(B) Heap

(C) Unclustered tree index

(D) Unclustered hash index

Q.27 Which of the following statements about the Two Phase Locking (2PL) protocol is/are TRUE?

(A) 2PL permits only serializable schedules

(B) With 2PL, a transaction always locks the data item being read or written just before every operation and always releases the lock just after the operation

(C) With 2PL, once a lock is released on any data item inside a transaction, no more locks on any data item can be obtained inside that transaction

(D) A deadlock is possible with 2PL

Q.28 Which of the following statements about IPv4 fragmentation is/are TRUE?

(A) The fragmentation of an IP datagram is performed *only* at the source of the datagram

(B) The fragmentation of an IP datagram is performed at any IP router which finds that the size of the datagram to be transmitted exceeds the MTU

(C) The reassembly of fragments is performed *only* at the destination of the datagram

(D) The reassembly of fragments is performed at all intermediate routers along the path from the source to the destination

Q.29   Which of the following statements is/are FALSE?

(A)   An attribute grammar is a syntax-directed definition (SDD) in which the functions in the semantic rules have no side effects

(B)   The attributes in a L-attributed definition cannot always be evaluated in a depth-first order

(C)   Synthesized attributes can be evaluated by a bottom-up parser as the input is parsed

(D)   All L-attributed definitions based on LR(1) grammar can be evaluated using a bottom-up parsing strategy

Q.30   For a Boolean variable x, which of the following statements is/are FALSE?

(A) $x.1 = x$

(B) $x + 1 = x$

(C) $x.x = 0$

(D) $x + \bar{x} = 1$

Q.31   An instruction format has the following structure:

Instruction Number: *Opcode destination reg, source reg-1, source reg-2*

Consider the following sequence of instructions to be executed in a pipelined processor:

I1: DIV R3, R1, R2

I2: SUB R5, R3, R4

I3: ADD R3, R5, R6

I4: MUL R7, R3, R8

Which of the following statements is/are TRUE?

(A)   There is a RAW dependency on R3 between I1 and I2

(B)   There is a WAR dependency on R3 between I1 and I3

(C)   There is a RAW dependency on R3 between I2 and I3

(D)   There is a WAW dependency on R3 between I3 and I4

Q.32   Which of the following fields of an IP header is/are *always* modified by any router before it forwards the IP packet?

(A)   Source IP Address

(B)   Protocol

(C)   Time to Live (TTL)

(D)   Header Checksum

Q.33   Consider the following C function definition.

```
int fX(char *a){
    char *b = a;
    while(*b)
        b++;
    return b - a;}
```

Which of the following statements is/are TRUE?

(A)   The function call `fX("abcd")` will always return a value

(B)   Assuming a character array `c` is declared as `char c[] = "abcd"` in `main()`, the function call `fX(c)` will always return a value

(C)   The code of the function will not compile

(D)   Assuming a character pointer `c` is declared as `char *c = "abcd"` in `main()`, the function call `fX(c)` will always return a value

Q.34   Let P be the partial order defined on the set {1,2,3,4} as follows

$$P = \{(x, x) \mid x \in \{1,2,3,4\}\} \cup \{(1,2), (3,2), (3,4)\}$$

The number of total orders on {1,2,3,4} that contain P is _____

Q.35   Let A be an array containing integer values. The distance of A is defined as the minimum number of elements in A that must be replaced with another integer so that the resulting array is sorted in non-decreasing order. The distance of the array $[2, 5, 3, 1, 4, 2, 6]$ is _____

60

Q.36 – Q.65 Carry TWO marks Each

Q.36   What is the output of the following C program?

```
#include <stdio.h>
int main() {
    double a[2]={20.0, 25.0}, *p, *q;
    p = a;
    q = p + 1;
    printf("%d,%d", (int)(q - p), (int)(*q - *p));
    return 0;}
```

(A)   4,8

(B)   1,5

(C)   8,5

(D)   1,8

Q.37 Consider a single processor system with four processes A, B, C, and D, represented as given below, where for each process the first value is its arrival time, and the second value is its CPU burst time.

A (0, 10), B (2, 6), C (4, 3), and D (6, 7).

Which one of the following options gives the average waiting times when preemptive Shortest Remaining Time First (SRTF) and Non-Preemptive Shortest Job First (NP-SJF) CPU scheduling algorithms are applied to the processes?

(A)   SRTF = 6, NP-SJF = 7

(B)   SRTF = 6, NP-SJF = 7.5

(C)   SRTF = 7, NP-SJF = 7.5

(D)   SRTF = 7, NP-SJF = 8.5

Q.38 Which one of the following CIDR prefixes exactly represents the range of IP addresses 10.12.2.0 to 10.12.3.255?

(A)   10.12.2.0/23

(B)   10.12.2.0/24

(C)   10.12.0.0/22

(D)   10.12.2.0/22

Q.39 You are given a set V of distinct integers. A binary search tree T is created by inserting all elements of V one by one, starting with an empty tree. The tree T follows the convention that, at each node, all values stored in the left subtree of the node are smaller than the value stored at the node. You are not aware of the sequence in which these values were inserted into T, and you do not have access to T.

Which one of the following statements is TRUE?

(A) Inorder traversal of T can be determined from V

(B) Root node of T can be determined from V

(C) Preorder traversal of T can be determined from V

(D) Postorder traversal of T can be determined from V

Q.40 Consider the following context-free grammar where the start symbol is S and the set of terminals is $\{a,b,c,d\}$.

$$S \rightarrow AaAb \mid BbBa$$
$$A \rightarrow cS \mid \epsilon$$
$$B \rightarrow dS \mid \epsilon$$

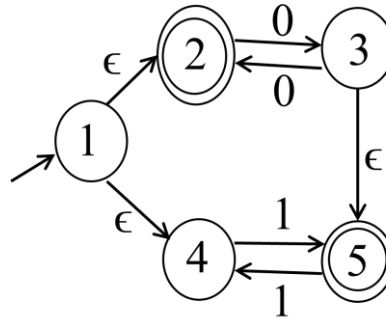The following is a partially-filled LL(1) parsing table.

	a	b	c	d	$\$$
S	$S \rightarrow AaAb$	$S \rightarrow BbBa$	(1)	(2)	
A	$A \rightarrow \epsilon$	(3)	$A \rightarrow cS$		
B	(4)	$B \rightarrow \epsilon$		$B \rightarrow dS$	

Which one of the following options represents the CORRECT combination for the numbered cells in the parsing table?

Note: In the options, "blank" denotes that the corresponding cell is empty.

(A) (1) $S \rightarrow AaAb$ (2) $S \rightarrow BbBa$ (3) $A \rightarrow \epsilon$ (4) $B \rightarrow \epsilon$

(B) (1) $S \rightarrow BbBa$ (2) $S \rightarrow AaAb$ (3) $A \rightarrow \epsilon$ (4) $B \rightarrow \epsilon$

(C) (1) $S \rightarrow AaAb$ (2) $S \rightarrow BbBa$ (3) blank (4) blank

(D) (1) $S \rightarrow BbBa$ (2) $S \rightarrow AaAb$ (3) blank (4) blank

64

Q.41   Let M be the 5-state NFA with ϵ-transitions shown in the diagram below.

Which one of the following regular expressions represents the language accepted by M ?

(A) $(00)^* + 1(11)^*$

(B) $0^* + (1 + 0(00)^*)(11)^*$

(C) $(00)^* + (1 + (00)^*)(11)^*$

(D) $0^+ + 1(11)^* + 0(11)^*$

Q.42 Consider an array X that contains n positive integers. A subarray of X is defined to be a sequence of array locations with consecutive indices.

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

```
int first=0, second=0, len1=0, len2=0, maxlen=0;
for (int i=0; i < n; i++) {
  if (X[i] == first) {
    len2++; len1++;
  } else if (X[i] == second) {
    len2++;
    len1 =    (P)   ;
    second = first;
  } else {
    len2 =    (Q)   ;
    len1 = 1; second = first;
  }
  if (len2 > maxlen) {
    maxlen = len2;
  }
  first = X[i];
}
```

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

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

(A) (P) len1+1 (Q) len2+1

(B) (P) 1 (Q) len1+1

(C) (P) 1 (Q) len2+1

(D) (P) len2+1 (Q) len1+1

Q.43 Consider the following expression: $x[i] = (p + r) * -s[i] + u/w$. The following sequence shows the list of triples representing the given expression, with entries missing for triples (1), (3), and (6).

(0)	+	p	r
(1)			
(2)	uminus	(1)	
(3)			
(4)	/	u	w
(5)	+	(3)	(4)
(6)			
(7)	=	(6)	(5)

Which one of the following options fills in the missing entries CORRECTLY?

(A)   (1) =[] s i (3) * (0) (2)   (6) []= x i

(B)   (1) []= s i (3) – (0) (2)   (6) =[] x (5)

(C)   (1) =[] s i (3) * (0) (2)   (6) []= x (5)

(D)   (1) []= s i (3) – (0) (2)   (6) =[] x i

67

Q.44 Let x and y be random variables, not necessarily independent, that take real values in the interval $[0,1]$. Let $z = xy$ and let the mean values of x, y, z be $\bar{x}, \bar{y}, \bar{z}$, respectively. Which one of the following statements is TRUE?

(A) $\bar{z} = \bar{x}\bar{y}$

(B) $\bar{z} \leq \bar{x}\bar{y}$

(C) $\bar{z} \geq \bar{x}\,\bar{y}$

(D) $\bar{z} \leq \bar{x}$

Q.45 The relation schema, `Person(pid,city)`, describes the city of residence for every person uniquely identified by `pid`. The following relational algebra operators are available: `selection`, `projection`, `cross product`, and `rename`.

To find the list of cities where at least 3 persons reside, using the above operators, the minimum number of `cross product` operations that must be used is

(A) 1

(B) 2

(C) 3

(D) 4

Q.46 Consider a multi-threaded program with two threads `T1` and `T2`. The threads share two semaphores: `s1` (initialized to 1) and `s2` (initialized to 0). The threads also share a global variable `x` (initialized to 0). The threads execute the code shown below.

```
// code of T1        // code of T2
wait(s1);            wait(s1);
x = x+1;             x = x+1;
print(x);            print(x);
wait(s2);            signal(s2);
signal(s1);          signal(s1);
```

Which of the following outcomes is/are possible when threads `T1` and `T2` execute concurrently?

(A)   `T1` runs first and prints 1, `T2` runs next and prints 2

(B)   `T2` runs first and prints 1, `T1` runs next and prints 2

(C)   `T1` runs first and prints 1, `T2` does not print anything (deadlock)

(D)   `T2` runs first and prints 1, `T1` does not print anything (deadlock)

Q.47 Let A be an $n \times n$ matrix over the set of all real numbers $\mathbb{R}$. Let B be a matrix obtained from A by swapping two rows. Which of the following statements is/are TRUE?

(A)   The determinant of B is the negative of the determinant of A

(B)   If A is invertible, then B is also invertible

(C)   If A is symmetric, then B is also symmetric

(D)   If the trace of A is zero, then the trace of B is also zero

Q.48 Let S1 and S2 be two stacks. S1 has capacity of 4 elements. S2 has capacity of 2 elements. S1 already has 4 elements: 100, 200, 300, and 400, whereas S2 is empty, as shown below.

| 400 (Top) |
| 300 |
| 200 |
| 100 |
Stack S1

| |
| |
Stack S2

Only the following three operations are available:
PushToS2: Pop the top element from S1 and push it on S2.
PushToS1: Pop the top element from S2 and push it on S1.
GenerateOutput: Pop the top element from S1 and output it to the user.

Note that the pop operation is not allowed on an empty stack and the push operation is not allowed on a full stack.

Which of the following output sequences can be generated by using the above operations?

(A) 100, 200, 400, 300

(B) 200, 300, 400, 100

(C) 400, 200, 100, 300

(D) 300, 200, 400, 100

Q.49   Which of the following is/are EQUAL to 224 in radix-5 (*i.e.*, base-5) notation?

(A)   64 in radix-10

(B)   100 in radix-8
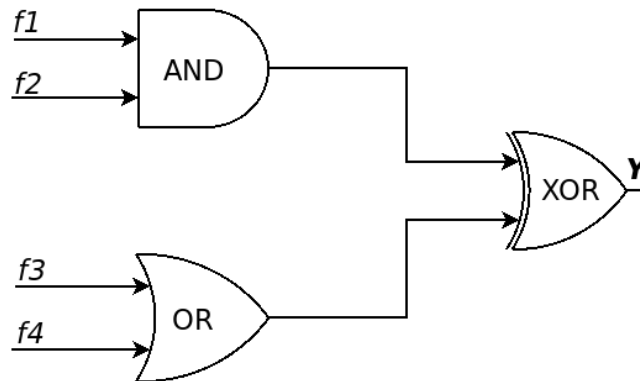
(C)   50 in radix-16

(D)   121 in radix-7

Q.50   Consider 4-variable functions *f1*, *f2*, *f3*, *f4* expressed in sum-of-minterms form as given below.

$$f1 = \sum(0,2,3,5,7,8,11,13)$$

$$f2 = \sum(1,3,5,7,11,13,15)$$

$$f3 = \sum(0,1,4,11)$$

$$f4 = \sum(0,2,6,13)$$

With respect to the circuit given above, which of the following options is/are CORRECT?

(A) $Y = \sum(0,1,2,11,13)$

(B) $Y = \Pi(3,4,5,6,7,8,9,10,12,14,15)$

(C) $Y = \sum(0,1,2,3,4,5,6,7)$

(D) $Y = \Pi(8,9,10,11,12,13,14,15)$

Q.51   Let G be an undirected connected graph in which every edge has a positive integer weight. Suppose that every spanning tree in G has *even* weight. Which of the following statements is/are TRUE for *every* such graph G ?

(A)   All edges in G have even weight

(B)   All edges in G have even weight **OR** all edges in G have odd weight

(C)   In each cycle C in G, all edges in C have even weight

(D)   In each cycle C in G, either all edges in C have even weight **OR** all edges in C have odd weight

Q.52   Consider a context-free grammar G with the following 3 rules.

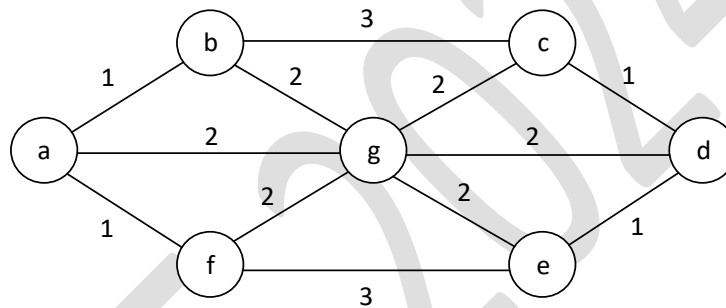$$S \rightarrow aS, \ S \rightarrow aSbS, \ S \rightarrow c$$

Let $w \in L(G)$. Let $n_a(w), \ n_b(w), \ n_c(w)$ denote the number of times a, b, c occur in w, respectively. Which of the following statements is/are TRUE?

(A) $n_a(w) > n_b(w)$

(B) $n_a(w) > n_c(w) - 2$

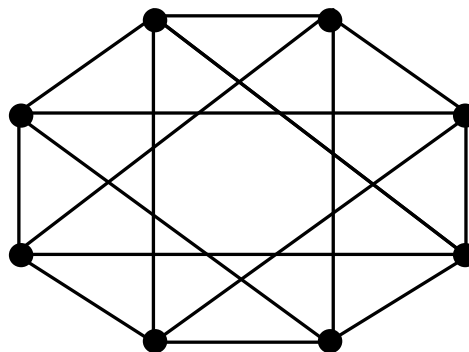(C) $n_c(w) = n_b(w) + 1$

(D) $n_c(w) = n_b(w) * 2$

Q.53   Consider a disk with the following specifications: rotation speed of 6000 RPM, average seek time of 5 milliseconds, 500 sectors/track, 512-byte sectors. A file has content stored in 3000 sectors located *randomly* on the disk. Assuming average rotational latency, the total time (*in seconds, rounded off to 2 decimal places*) to read the entire file from the disk is _____

Q.54   Consider a TCP connection operating at a point of time with the congestion window of size 12 MSS (Maximum Segment Size), when a timeout occurs due to packet loss. Assuming that all the segments transmitted in the next two RTTs (Round Trip Time) are acknowledged correctly, the congestion window size (*in MSS*) during the third RTT will be _____

Q.55   Consider an Ethernet segment with a transmission speed of 10^8 bits/sec and a maximum segment length of 500 meters. If the speed of propagation of the signal in the medium is 2×10^8 meters/sec, then the minimum frame size (*in bits*) required for collision detection is _____

Q.56   A functional dependency $F: X \rightarrow Y$ is termed as a *useful functional dependency* if and only if it satisfies all the following three conditions:
   - X is not the empty set.
   - Y is not the empty set.
   - Intersection of X and Y is the empty set.

   For a relation R with 4 attributes, the total number of possible useful functional dependencies is _____

Q.57   A processor with 16 general purpose registers uses a 32-bit instruction format. The instruction format consists of an opcode field, an addressing mode field, two register operand fields, and a 16-bit scalar field. If 8 addressing modes are to be supported, the maximum number of unique opcodes possible for every addressing mode is _____

Q.58   A non-pipelined instruction execution unit operating at 2 GHz takes an average of 6 cycles to execute an instruction of a program P. The unit is then redesigned to operate on a 5-stage pipeline at 2 GHz. Assume that the ideal throughput of the pipelined unit is 1 instruction per cycle. In the execution of program P, 20% instructions incur an average of 2 cycles stall due to data hazards and 20% instructions incur an average of 3 cycles stall due to control hazards. The speedup (*rounded off to one decimal place*) obtained by the pipelined design over the non-pipelined design is _____

Q.59   The number of distinct minimum-weight spanning trees of the following graph is _____

Q.60   The chromatic number of a graph is the minimum number of colours used in a *proper* colouring of the graph. The chromatic number of the following graph is _____

75

Q.61 A processor uses a 32-bit instruction format and supports byte-addressable memory access. The ISA of the processor has 150 distinct instructions. The instructions are equally divided into two types, namely R-type and I-type, whose formats are shown below.

R-type Instruction Format:

OPCODE	UNUSED	DST Register	SRC Register1	SRC Register 2

I-type Instruction Format:

OPCODE	DST Register	SRC Register	# Immediate value/address

In the OPCODE, 1 bit is used to distinguish between I-type and R-type instructions and the remaining bits indicate the operation. The processor has 50 architectural registers, and all register fields in the instructions are of equal size.

Let X be the number of bits used to encode the UNUSED field, Y be the number of bits used to encode the OPCODE field, and Z be the number of bits used to encode the immediate value/address field. The value of $X + 2Y + Z$ is _____

Q.62 Let L_1 be the language represented by the regular expression $b^*ab^*(ab^*ab^*)^*$ and $L_2 = \{ w \in (a + b)^* \mid |w| \le 4\}$, where $|w|$ denotes the length of string w. The number of strings in L_2 which are also in L_1 is _____

Q.63 Let Z_n be the group of integers $\{0, 1, 2, \dots , n - 1\}$ with addition modulo n as the group operation. The number of elements in the group $Z_2 \times Z_3 \times Z_4$ that are their own inverses is _____

Q.64 Consider a 32-bit system with 4 KB page size and page table entries of size 4 bytes each. Assume 1 KB = 2^{10} bytes. The OS uses a 2-level page table for memory management, with the page table containing an outer page directory and an inner page table. The OS allocates a page for the outer page directory upon process creation. The OS uses demand paging when allocating memory for the inner page table, i.e., a page of the inner page table is allocated only if it contains at least one valid page table entry.

An active process in this system accesses 2000 unique pages during its execution, and none of the pages are swapped out to disk. After it completes the page accesses, let X denote the minimum and Y denote the maximum number of pages across the two levels of the page table of the process.

The value of $X+Y$ is _____

Q.65 Consider the following augmented grammar, which is to be parsed with a SLR parser. The set of terminals is $\{a,b,c,d,\#,@\}$

$$S' \rightarrow S$$
$$S \rightarrow SS \mid Aa \mid bAc \mid Bc \mid bBa$$
$$A \rightarrow d\#$$
$$B \rightarrow @$$

Let $I_0 = CLOSURE(\{S' \rightarrow \bullet S\})$. The number of items in the set $GOTO(I_0, \ S)$ is _____