GATE 2024
Exam Solutions

CS

COMPUTER SCIENCE & IT

Exam held on

10/02/2024
Forenoon Session

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SECTION - A GENERAL APTITUDE

Q.1 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 $\dfrac{p^4+q^4}{p^2q^2}$

(a) 9 (b) 79
(c) 81 (d) 83

Ans. (b)

$$\log(p^2 + q^2) = \log p + \log q + 2 \log 3$$
$$= \log p + \log q + \log 9$$
$$\log (p^2 + q^2) = \log(9pq)$$
$$p^2 + q^2 = 9pq$$
$$p^4 + q^4 + 2p^2q^2 = 81p^2q^2$$
$$p^4 + q^4 = 79p^2q^2$$

The value of $\dfrac{p^4+q^4}{p^2q^2} = \dfrac{79p^2q^2}{p^2q^2} = 79$

End of Solution

Q.2 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) $\dfrac{2}{\pi}$ (b) $\dfrac{1}{\pi}$
(c) $\dfrac{4}{\pi}$ (d) $\dfrac{3}{\pi}$

Ans. (b)

Area of rectangular sheet = $54 \times 4 = 216$ cm^2
Surface area of cube = 6 (side)^2
$216 = 6$ (side)^2
Side $= 6$
Volume of cube $= 6^3 = 216$

$$\text{Radius of cylinder} = \frac{4}{2\pi}$$

$$\text{Volume of cylinder} = \pi r^2 h = \pi\left(\frac{4}{2\pi}\right)^2 \times 54 = \frac{216}{\pi}$$

$$\frac{\text{Volume of cylinder}}{\text{Volume of cube}} = \frac{\frac{216}{\pi}}{216} = \frac{1}{\pi}$$

End of Solution

Q.3 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) on	(ii) down	(iii) for	(iv) on
(b)	(i) down	(ii) down	(iii) on	(iv) for
(c)	(i) down	(ii) out	(iii) for	(iv) on
(d)	(i) on	(ii) out	(iii) on	(iv) for

Ans. (c)

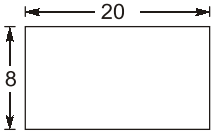
End of Solution

Q.4 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) 20
(c) 24 (d) 21

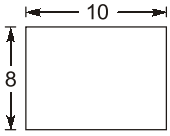
Ans. (a)

Given dimension 20 × 8 folded 3 times symmetrically along perpendicular to its longest edge.



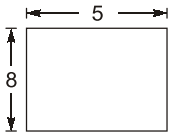
After folding first times

We get



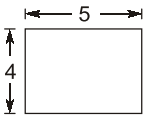
After folding second times

We get



After folding third times

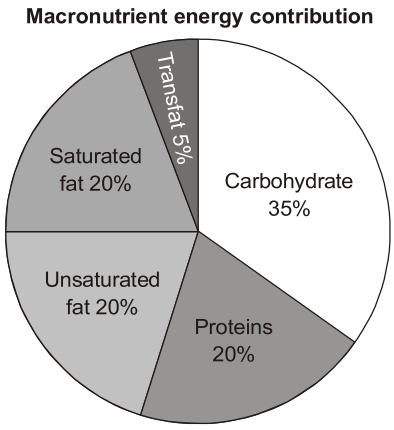
We get



So, the perimeter of final figure = 2(4 + 5) = 18 unit

End of Solution

Q.5 The pie chart present the percentage contribution of different macronutrients to a typical 2,000 kcal diet of a person.



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

Macronutrient	Energy density (kcal/g)
Carbohydrates	4
Proteins	4
Unsaturared fat	9
Saturared fat	9
Trans fat	9

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

(a) 3,600 (b) 100

(c) 44.4 (d) 77.8

Ans. (b)

$$\text{Total Fat} = \text{Saturated fat} + \text{unsaturated fat}$$
$$= 20 + 20 + 5$$
$$= 45\%$$

$$\text{Total fat in Kcal} = 2000 \times \frac{45}{100} = 900 \text{ Kcal}$$

Given all fat energy density = 9 Kcal/g

$$\text{There of total fat in gram} = \frac{900}{9} = 100 \text{ g}$$

End of Solution

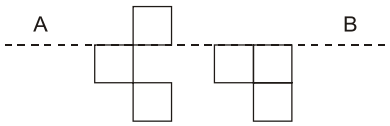
Q.6 If '→' denotes increasing order of intensity, then the meaning of the words [dry → arid → parched] is analogous to [diet → fast → _____]. Which one of the given options is appropriate to fill the blank?

(a) reject
(b) feast
(c) deny
(d) starve

Ans. (d)

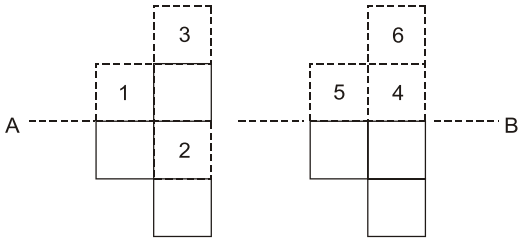
End of Solution

Q.7 The least number of squares to be added in the figure to make AB a line of symmetry is



(a) 4
(b) 5
(c) 7
(d) 6

Ans. (d)



End of Solution

Q.8 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) $14\frac{2}{7}\%$
(b) 10%
(c) 21%
(d) 30%

Ans. (b)

$$\text{Percentage of ₹5} = \frac{5\times 3}{1\times 5+5\times 3+10\times 13}\times 100$$

$$= \frac{15}{150}\times 100 = 10\%$$

End of Solution

Q.9 If two distinct non-zero real variables x and y are such that $(x + y)$ is proportional to $(x - y)$ then the value of $\frac{x}{y}$

(a) is a constant
(b) depends on xy
(c) depends only on x and not on y
(d) depends only on y and not on x

Ans. **(a)**

Given $(x + y) \propto (x - y)$

$\therefore$ $(x + y) = k(x - y)$

$x + y = kx - ky$

$(k - 1)x = (k + 1)y$

$$\frac{x}{y} = \frac{k+1}{k-1} = k' \text{ (constant)}$$

End of Solution

Q.10 Consider the following sample of numbers:

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

The median of the sample is

(a) 14
(b) 18.7
(c) 13.5
(d) 11

Ans. **(c)**

Arrange given series in ascending order

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

Median of the given data $= \frac{11+13}{2} = 12$

End of Solution

■■■■

SECTION - B TECHNICAL

Q.1 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) Only the leftmost leaf node
(c) All leaf nodes
(d) All internal nodes

Ans. (a)

- In B+ tree every node must occupy at least 50% except root node.
- Root node can be min 2 block pointers with one key allowed.

End of Solution

Q.2 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) Threads belonging to a process are by default not protected from each other
(d) All the threads belonging to a process share a common stack

Ans. (c)

End of Solution

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

(a) 0
(b) 1
(c) –1
(d) 2

Ans. (a)

$$A = \begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \end{bmatrix}$$

$$|A| = 1(45 - 48) - 2(36 - 42) + 3(32 - 35)$$
$$= -3 + 12 - 9 = 0$$

Since the determinant of matrix is zero, so the product of eigen value = 0

End of Solution

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Q.4 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) $P(A \cap B^c) = 0.2$, where B^c is the complement of the event B

(b) The two events A and B are independent

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

(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

Ans. (a, c)

End of Solution

Q.5 Let $f : \mathbb{R} \to \mathbb{R}$ 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

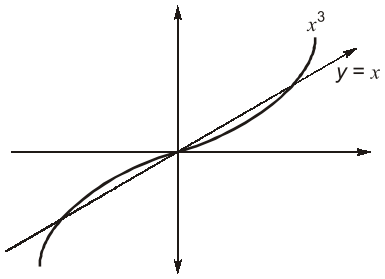
(a) {0, 1}
(b) {–1, 1, 2}
(c) {–2, –1, 1}
(d) {–1, 0, 1}

Ans. (d)

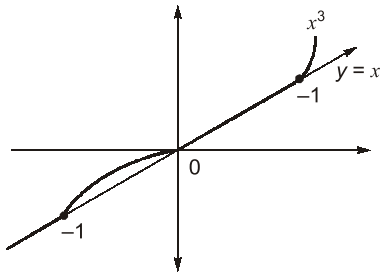
Putting $x^3 = x$

$$x(x^2 - 1) = 0$$

$$x = 0, -1, 1$$



$f(x) = \max(x, x^3)$



So, we have three sharp points at $x = -1, 0, 1$

So, these are non differentiable prints

Method II:

$$f(x) = \max\{x, x^3\} = \begin{cases} x & ; \quad x < -1 \\ x^3 & ; \quad -1 < x < 0 \\ x & ; \quad 0 < x < 1 \\ x^3 & ; \quad x > 1 \end{cases}$$

$$f'(x) = \begin{cases} 1 & ; \quad x < -1 \\ 3x^3 & ; \quad -1 < x < 0 \\ 1 & ; \quad 0 < x < 1 \\ x^3 & ; \quad x > 1 \end{cases}$$

$\because$ At $x = -1$, 0 and 1, LHD $\neq$ RHD so all three points are non differentiable points.

End of Solution

Q.6 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) $L_1 \cup L_3$ is not regular

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

(c) $L_1 = L_2$ if and only if $L_1 \cap \overline{L_3} = \phi$

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

Ans. **(b, d)**

(a) False

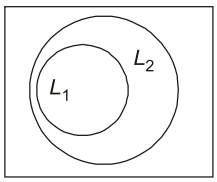
Let, $L_1 = \Sigma^*$

$L_1 \cup L_3 = \Sigma^* \cup L_3$

$= \Sigma^*$ which is regular

(b) True: If a language is not regular then its complement is also not regular.

(c) False: Consider the given Venn diagram



Here, $L_1 \cap \overline{L_3} = \phi$ but L_1 is not equal to L_2.

(d) True:

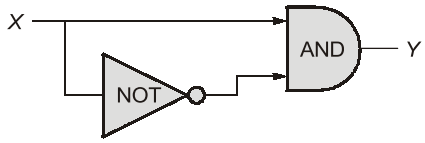
If L_1 and L_2 are regular

$\Rightarrow$ $\overline{L_1}$ and $\overline{L_2}$ are also regular.

$\Rightarrow$ $\overline{L_1} \cup \overline{L_2}$ are also regular.

End of Solution

Q.7 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?

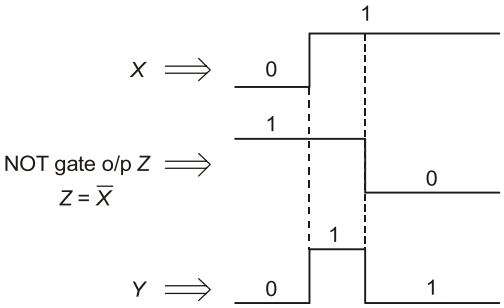


(a) With no propagation delays, the output Y is always logic Zero
(b) With no propagation delays, the output Y is always logic One
(c) With propagation delays, the output Y can have a transient logic Zero after X transitions from logic One to logic Zero
(d) With propagation delays, the output Y can have a transient logic One after X transitions from logic Zero to logic One

Ans. (a, d)

(a) If no propagation delay for AND and NOT gates, always one of the input of AND gate is '0', so output is always '0'.

(b)



Output Y is logic 1 for small time interval whenever X changes from logic '0' to logic '1', assuming gates are having some delay.
Answer is option (a), (d).

End of Solution

Q.8 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) $B - A$
(b) $A - B$
(c) $A + B$
(d) $2 * B$

Ans. **(b)**

5 bit 2's complement Range
$\{-(2^{5-1}) \text{ to } +(2^{5-1} - 1)\}$
$\{-16 \text{ to } +15\}$
A : 01010 $\Rightarrow$ +10
B : 11010 $\Rightarrow$ –6
$(B - A) \Rightarrow -6 - (+10) \Rightarrow -16$
$(A - B) \Rightarrow 10 - (-6) \Rightarrow +16$
$(A - B) \Rightarrow 10 + (-6) \Rightarrow +4$
$2B \Rightarrow 2 * -6 \Rightarrow -12$

End of Solution

Q.9 A user starts browsing a webpage hosted at a remote server. The browser opens a single 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) (iv), (ii), (i), (iii)
(c) (ii), (iv), (i), (iii)
(d) (ii), (iv), (iii), (i)

Ans. **(c)**

DNS related Key:
(ii), (iv), (i), (iii)
TCP sync, ack related
$N_q = N_p + 1$
Random selection of sequence no
IP fragmentation related (NAT device)
TTL, SIP
IP fragmentation related 6 fragments
Packet switching related 8.008,
IPv4 CIDR (Routing Table) 40.

End of Solution

Q.10 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) $\Omega(N)$ but not $O(N)$
(b) $O(N)$ but not $\Omega(N)$
(c) Both $O(N)$ and $\Omega(N)$
(d) Neither $O(N)$ nor $\Omega(N)$

Ans. (c)

```
                                    ASc = 0; desc = 0;
for (i = 1; i ≤ n − 1; i++)
{
    if (A[i] > A[i + j])// not Asc order
        Asc = 1;
    if (A[i] < A[i + j])// not desc order
        desc = 1;
}
If (Asc == 0)
    print("Given array ascending order")
else if (desc == 0)
    print("Given array is descending order")
else
    print("Given array unsorted")
```

End of Solution

Q.11 Consider the following C program:

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

Which one of the following statements is CORRECT?

(a) The program prints 6 as output
(b) The program prints 10 as output
(c) The program prints 9 as output
(d) The program gets stuck in an infinite loop

Ans. (d)

End of Solution

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Q.12 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) Forwarding does not require any extra hardware to retrieve the data from the pipeline stages

(b) 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

(c) 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

(d) Forwarding cannot prevent all pipeline stalls

Ans. **(b, c, d)**

- Buffer is used to hold the intermediate result to performed the Data.
- Forwarding can't prevent all the pipeline stalls. This mechanism minimizes only Data stall.
- For the load instructions memory data is forwarded to execute state with stall.

End of Solution

Q.13 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 acknowledgement number N_Q is equal to N_P

(b) The sequence number N_Q is always 0 for a new connection

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

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

Ans. **(c, d)**

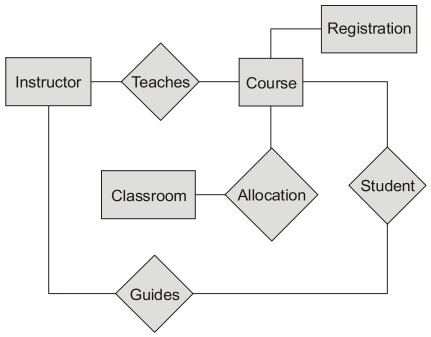
The acknowledgment number will always be sequence number of the next expected data.

The initial sequence number will always be random number within range of 0 to $2^{32} - 1$.

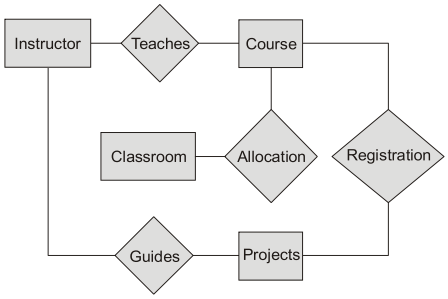
End of Solution

Q.14 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?

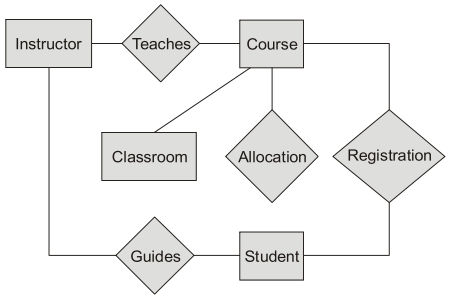
(i)



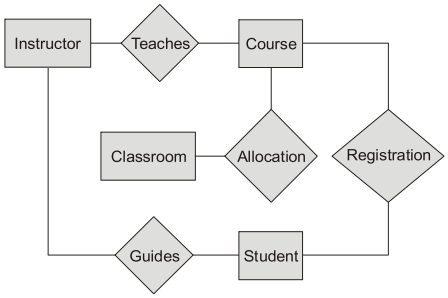
(ii)



(iii)



(iv)



(a) (iii)
(b) (ii)
(c) (iv)
(d) (i)

Ans. **(c)**

"Instructor", "Course", "Student", "Classroom" are entity sets.
"Teach" relationship set between Instructor & Course "Register" relationship set between Student & Course.
"Allocation" relationship set between course and Classroom.
"Guide" relationship set between Instructor && Student.

End of Solution

Q.15 Which of the following statements about a relation R in first normal form (1NF) is/are TRUE?

(a) R cannot have a composite attribute
(b) R cannot have a foreign key
(c) R can have a multi-attribute key
(d) R cannot have more than one candidate key

Ans. (a, c)

1NF relation:

- Every attribute of R must be atomic.
- Not allowed multivalued attributes.
- Not allowed composite attributes.
- Must have atleast one candidate key.
- May consist foreign keys.
- Can have composite key [multi-attribute key].

End of Solution

Q.16 Which of the following process state transitions is/are NOT possible?

(a) Waiting to Running
(b) Ready to Waiting
(c) Running to Terminated
(d) Running to Ready

Ans. (a, b)

End of Solution

Q.17 Consider the following program:

```
#include <stdio.h>
void fX( );
int main( ) f
    fX( );
return 0; }
```

```
void fX( ) {
char a;
if ((a=getchar?( )) != '\n')
    fX( );
if (a != '\n')
    putchar (a); }
```

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

(a) The program will terminate with 1234 as output
(b) The program will not terminate
(c) The program will terminate with no output
(d) The program will terminate with 4321 as output

Ans. (d)

End of Solution

Q.18 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 _____.

Ans. (2)

$\because$ $f : A \to B$ is one-one and onto

$\Rightarrow$ $|A| = |B| = n$

We check: $f : A \times A \to A \cup B$

$n^2 \begin{cases} n, \text{ if } (A = B) \\ 2n, \text{ if } (A \neq B, A \cap B = \phi) \end{cases}$

$\because$ f is one-one

$|A \times B| = |A \cup B|$

So either $n^2 = n$ (or) $n^2 = 2n$

$\Downarrow$ $\Downarrow$

$n = 0, 1$ $n = 0, 2$

$\therefore$ $n = 1$ or 2

$\therefore$ Number of possible values of cardinality of $A = 2$.

End of Solution

Q.19 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) Total Length
(b) Source IP
(c) Destination IP
(d) Header Checksum

Ans. (b, d)

End of Solution

Q.20 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 _____.

Ans. (6)

Given expression is 3 + 1 + 5 * 2 / 7 + 2 – 4 – 7 – 6 / 2

+ is highest and left associative

((3 + 1) + 5) * 2 / (7 + 2) – 4 – 7 – 6 / 2

= 9 * 2 / 9 – 4 – 7 – 6 / 2

– is high and right associative

$\Rightarrow$ 9 * 2 / (9 – (4 – (7 – 6))) / 2 = 9 * 2 / 6 / 2

* is high precedence

$\Rightarrow$ (9 * 2) / 6 / 2 = 18 / 6 / 2

/ is right associative

$\Rightarrow$ (18 / (6 / 2)) = $\frac{18}{3}$ = 6

End of Solution

Q.21 The number of spanning trees in a complete graph of 4 vertices labelled *A*, *B*, *C*, and *D* is _____.

Ans. (16)

Complete connected graph of *n* vertices number of spanning trees : n^{n-2}

For 4 vertices complete graph number of spanning trees : $4^{4-2} = 16$

End of Solution

Q.22 Which of the following is/are Bottom-Up Parser(s)?

(a) LR Parser
(b) Predictive Parser
(c) Shift-reduce Parser
(d) LL(1) Parser

Ans. (a, c)

LR parser and Shift-Reduce parsers are bottom up parsers.

Answer is (a) and (c).

End of Solution

Q.23 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) The CPU can start executing an interrupt service routine faster with vectored interrupts than with non-vectored interrupts
(c) Programmed I/O mechanism has a better CPU utilization than the interrupt driven I/O mechanism
(d) For bulk data transfer, the burst mode of DMA has a higher throughput than the cycle stealing mode

Ans. (c)

In programmed I/O mode processor utilization is very poor because, I/O operations are programmed in the CPU.

End of Solution

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Q.24 Consider a permutation sampled uniformly at random from the set of all permutations of {1, 2, 3, ... , 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) Event X is more likely than event Y
(b) The events X and Y are independent
(c) Either event X or Y must occur
(d) The events X and Y are mutually exclusive

Ans. (b)

$$n(s) = n! = 4! = 24$$

X = 1 occurs before '2'

1				Can be done in 3! ways
3	1			Can be done in 2! ways
4	1			Can be done in 2! ways
3	4	1	2	2 ways
4	3	1	2	

$$n(X) = 6 + 2 + 2 + 2 = 12 \text{ ways}$$

Y = 3 occurs before 4

3				Can be filled in 3! ways
1	3			Can be filled in 2! ways
2	3			Can be filled in 2! ways
		3	4	Can be filled in 2! ways

$\therefore$ $$n(Y) = 6 + 2 + 2 + 2 = 12 \text{ ways}$$

$(X \cap Y)$ = Both X and Y occurs

1	3			→ 2! ways
1	2	3	4	→ 1 way
3	1	4	2	→ 1 way
3	1	2	4	→ 1 way

$$n(X \cap Y) = 6 \text{ ways}$$

$$P(X \cap Y) = \frac{6}{24},\ P(X) = \frac{12}{24},\ P(Y) = \frac{12}{24}$$

$\because$ $$P(X)\,P(Y) = \frac{12}{24} \times \frac{12}{24} = \frac{6}{24} = P(X \cap Y)$$

$\therefore$ X and Y are independent.

End of Solution

Q.25 Consider the following two relations, $R(A, B)$ and $S(A, C)$:

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

S	
A	**B**
10	90
30	45
40	80

The total number of tuples obtained by evaluating the following expression

$$\sigma_{B<C}(R \bowtie_{RA=SA} S)$$

is _____.

Ans. (2)

$R \bowtie_{R.A=S.A} S$ result $\Rightarrow$

A	B	A	C
10	20	10	90
20	40	30	45
30	50	30	45

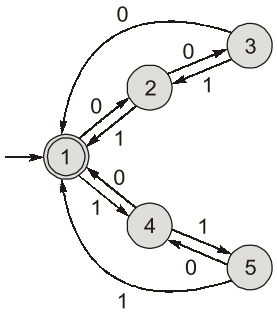
$\sigma_{B<C}(R \bowtie_{R.A=S.A} S)$ result $\Rightarrow$

A	B	A	C
10	20	10	90
20	40	30	45

} Results 2 tuples

End of Solution

Q.26 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 5 are distinguishable in M

(b) States 2 and 4 are distinguishable in M

(c) States 3 and 4 are distinguishable in M

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

Ans. (a, c)

Minimize the given DFA:

Step 1: Separate the final and non final states.

$$S_1 = \{1\}, \{2, 3, 4, 5\}$$

Step 2: States 2, 5 are 0-closure and also 1-closure.

States 3, 4 are 0-closure and also 1-closure.

$$\therefore \quad S_2 = \{1\}, \{2, 5\}, \{3, 4\}$$

Step 3:

$$S_3 = \{1\}, \{2, 5\}, \{3, 4\}$$

$\therefore$ The states 2 & 5 and 3 & 4 are not distinguishable but the states 2 and 4 distinguishable we can't construct a FA for $n_0(w) = n_1(w)$ but the given machine accepts all the strings having equal number of 0's and 1's.

$\therefore$ (a), (c) are false (b), (d) are true.

End of Solution

Q.27 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 _____.

Ans. (60)

Number of vertices (V) = 100

{Number of edges present in forest of DFS traversal} = 40

[DFS spanning tee edges]

Number of connected components of graph (G) = {Number of vertices of graph (G)} – {Number of spanning tree edges of DFS traversal of graph G}

$$= 100 - 40 = 60$$

End of Solution

Q.28 Consider the following syntax-directed definition (SDD).

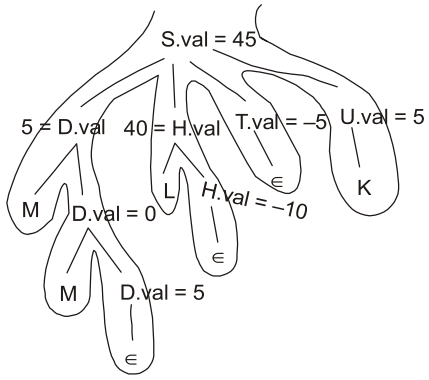
$S \rightarrow DHTU$	{S.val = D.val + H.val + T.val + U.val; }
$S \rightarrow$ "M" D_1	{D.val = 5 + D_1.val; }
$D \rightarrow \in$	{D.val = –5; }
$H \rightarrow$ "L" H_1	{H.val = 5 * 10 + H_1.val; }
$H \rightarrow \in$	{H.val = –10; }
$T \rightarrow$ "C" T_1	{T.val = 5 * 100 + T_1.val; }
$T \rightarrow \in$	{T.val = –5; }
$U \rightarrow$ "K"	{U.val = 5; }

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

(a) 50 (b) 45

(c) 55 (d) 65

Ans. (45)



Answer is 45.

End of Solution

Q.29 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 _____.

Ans. (4096)

$$\text{Disk capacity} = \text{Number of surfaces} \times \text{Number of tracks per surface} \times \text{Number sectors per track} \times \text{Number of bytes per sector}$$

$$512\ \text{GB} = 32 \times x \times 4096 \times 1024\ \text{B}$$

$$2^{39}\ \text{B} = 2^5 \times x \times 2^{12} \times 2^{10}\ \text{B}$$

$$2^{39}\ \text{B} = 2^{27}x\ \text{B}$$

$$x = \frac{2^{39}\text{B}}{2^{27}\text{B}} = 2^{12}$$

$$x = 4096$$

End of Solution

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Q.30 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) 16.000
(b) 8.000
(c) 8.008
(d) 15.992

Ans. (c)

End of Solution

Q.31 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 write hit in **WBC** can modify the value of the dirty bit of a cache block
(b) A read miss in **WTC** never triggers a write back operation of a cache block to main memory
(c) A write miss in **WTC** always writes the victim cache block to main memory before loading the missed block to the cache
(d) A read miss in **WBC** never evicts a dirty block

Ans. (a, b)

In write Back Protocol, CPO updates only the cache Blocks. So, for every update, dirty bit will be affected. Before replace the cache Block due to a miss operation main memory before copy back to main memory before bring the new Block.
In write Through protocol, CPU updates cache and main memory simultaneously. So, No need to copy back the cache blocks into a main memory before brine the new blocks due bring the new blacks due to a miss operations.

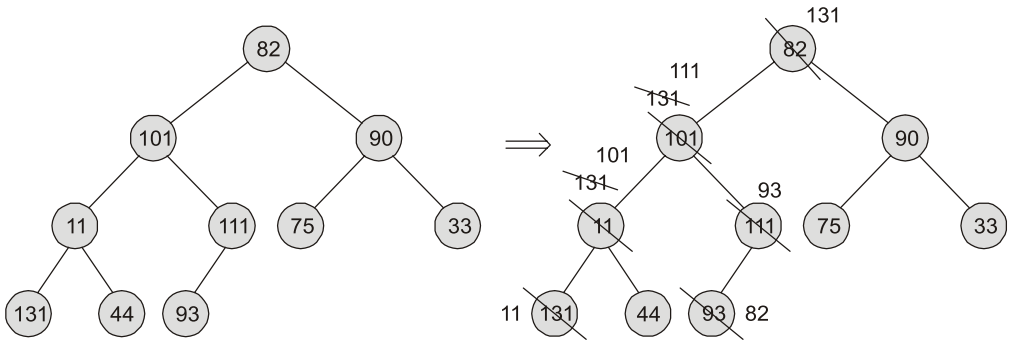
End of Solution

Q.32 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) 131, 111, 90
(b) 131, 11, 93
(c) 82, 11, 93
(d) 82, 90, 101

Ans. **(a)**

Heapify: bottom-up construction
(Adjust internal nodes into max heap).
CBT of given 10 elements.



End of Solution

Q.33 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 _____.

Ans. **(6)**

End of Solution

Q.34 The symbol $\rightarrow$ indicates functional dependency in the context of a relational database. Which of the following options is/are TRUE?

(a) $(X \rightarrow Y$ and $Y \rightarrow Z)$ implies $X \rightarrow Z$
(b) $(X, Y) \rightarrow (Z, W)$ implies $X \rightarrow (Z, W)$
(c) $((X, Y) \rightarrow Z$ and $W \rightarrow Y)$ implies $(X, W) \rightarrow Z$
(d) $(X, Y) \rightarrow (Z, W)$ implies $(X, Y) \rightarrow Z$

Ans. **(a, c, d)**

- $X \rightarrow Y,\ Y \rightarrow Z \Rightarrow X \rightarrow Z$
- $XY \rightarrow ZW \not\Rightarrow X \rightarrow ZW$
- $XY \rightarrow Z,\ W \rightarrow Y \Rightarrow XW \rightarrow Z$
- $XY \rightarrow ZW \Rightarrow XY \rightarrow Z$

End of Solution

Q.35 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:

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

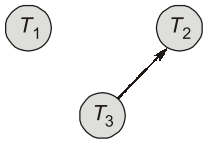
Which of the following transaction schedules is/are conflict equivalent to S?

(a) $T_3\ T_1\ T_2$ (b) $T_1\ T_2\ T_3$

(c) $T_3\ T_2\ T_1$ (d) $T_1\ T_3\ T_2$

Ans. **(a, c, d)**

Precedence graph of schedule(s):



Serial schedules conflict equal to S are

$T_1\ T_3\ T_2$

$T_3\ T_1\ T_2$

$T_3\ T_2\ T_1$

End of Solution

Q.36 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 _____.

Ans. **(0.375) [0.370 to 0.380]**

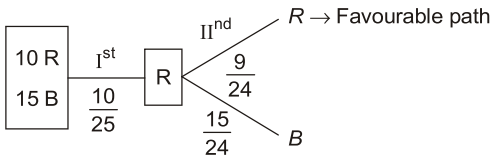
10R
15B

It is given that first ball drawn is red, then remaining balls are

9R
15B

P(both ball is red) $\Rightarrow \dfrac{9}{24}$

or



$$\text{Prop. (both red ball)} = \frac{\text{Favourable}}{\text{Total}}$$

$$= \frac{\frac{10}{25}\times\frac{9}{24}}{\frac{10}{25}\times\frac{9}{24}+\frac{10}{25}\times\frac{15}{24}} = \frac{10\times 9}{10\times 9+10\times 15} = \frac{9}{24}$$

End of Solution

Q.37 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}

Ans. (b, d)

End of Solution

Q.38 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 _____.

Ans. (179)

If the grammar is in CNF, then for any string of length 'n' it takes $2n - 1$ steps to derive that string.

Given string $w = a^{30}\, b^{30}\, c^{30}$

$\Rightarrow$ $|w| = 90$

$\therefore$ It takes $2 \times 90 - 1$ i.e. 179 steps.

End of Solution

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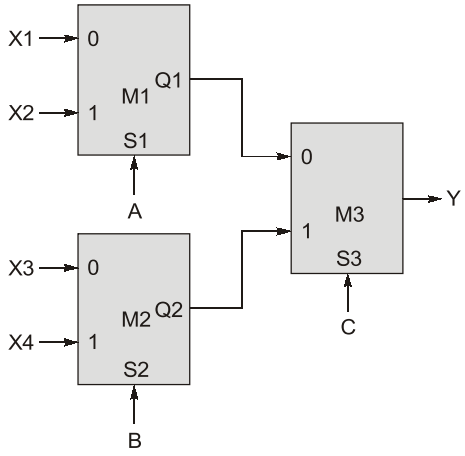
Q.39 Consider a digital logic circuit consisting of three 2-to-1 multiplexers M1, M2, and M3 as shown below. X1 and X2 are inputs of M1. X3 and X4 are inputs of M2. *A*, *B*, and *C* are select lines of M1, M2, and M3, respectively.



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 _____.

Ans. **(4)**

$$2:1 \text{ MUX o/p} = \bar{S}_0 I_0 + S_0 I_1$$

$$\text{MUX } M_1 \text{ o/p} = \bar{A}\cdot 1 + A\cdot 1 = 1$$

$$\text{MUX } M_2 \text{ o/p} = \bar{B}\cdot 0 + B\cdot 0 = 0$$

$$\text{MUX } M_3 \text{ o/p} = \bar{C}\cdot 1 + C\cdot 0 = \bar{C}$$

$$\therefore \quad Y = \bar{C}$$

Whenever $C = 0$, the output $Y = 1$

A and *B* variables may be with any values.

A	*B*	*C*	*Y*
0	0	0	1
0	1	0	1
1	0	0	1
1	1	0	1

For '4' combinations the output $Y = 1$.

Answer is 4.

End of Solution

Q.40 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 _____.

Ans. (6596)

$$\text{P.A.} \rightarrow (1100111000100)_2 \rightarrow (6596)_{10}$$

End of Solution

Q.41 Consider the following pseudo-code.

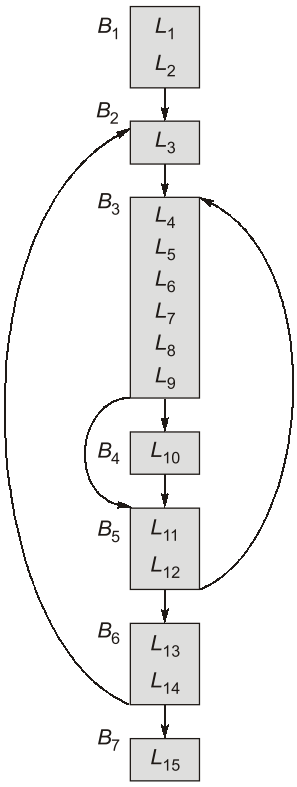
```
L1:   t1 = –1
L2:   t2 = 0
L3:   t3 = 0
L4:   t4 = 4 * t3
L5:   t5 = 4 * t2
L6:   t6 = t5 * M
L7:   t7 = t4 + t6
L8:   t8 = a[t7]
L9:   if t8 <= max goto L11
L10:  t1 = t8
L11:  t3 = t3 + 1
L12:  if t3 < M goto L4
L13:  t2 = t2 + 1
L14:  if t2 < N goto L3
L15:  max = t1
```

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) 7 and 6
(c) 6 and 7
(d) 7 and 7

Ans. (b)

L_1 , L_3 , L_4 , L_{10} , L_{11} , L_{13} and L_{15} are leader statements



7 basic blocks B_3 is the largest basic block and it contain 6 statements.

End of Solution

Q.42 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 exists a solution in which at least n variables are non-zero

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

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

Ans. (a)

End of Solution

Q.43 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 _____.

Ans. (14)

End of Solution

Q.44 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) 52
(b) 1
(c) 53
(d) 27

Ans. (c)

In binary min heap of n elements exactly $\left\lfloor \frac{n}{2} \right\rfloor$ internal nodes and $\left\lceil \frac{n}{2} \right\rceil$ leaf nodes.

Max element in min heap of n distinct elements must be one of the leaf node.

$\therefore$ $\left\lceil \frac{105}{2} \right\rceil$ are number of leaf nodes = 53

End of Solution

Q.45 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 _____.

Ans. (3)

$$= (100\,\text{ns} \times 10\%) + \left(\frac{100\,\text{ns} \times 90\%}{x}\right) + (x-1)10\,\text{ns}$$

$$= 10\,\text{ns} + \frac{90\,\text{ns}}{x} + (x-1)10\,\text{ns}$$

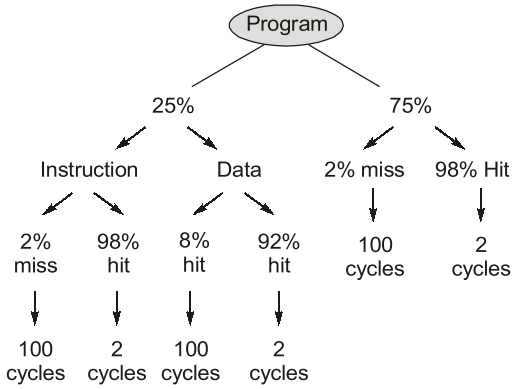
If $x = 1$ then ET = 100 ns
If $x = 2$ then ET = 65 ns
If $x = 3$ then ET = 60 ns
If $x = 4$ then ET = 62.5 ns
If $x = 5$ then ET = 68 ns
So, minimum execution time is possible with $x = 3$

End of Solution

Q.46 A given program has 25% load/store instructions. Suppose the ideal CPI (cycles per instruction) without any memory stalls is 2. The program exhibits 2% miss rate on instruction cache and 8% miss rate on data cache. The miss penalty is 100 cycles. The speedup (rounded off to two decimal places) achieved with a perfect cache (i.e., with NO data or instruction cache misses) is _____.

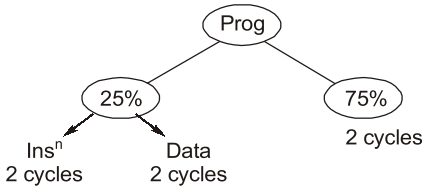
Ans. (2.56) (2.56 to 2.60)

Normal cache:



ET = (0.25 × 0.02 × 100) + (0.2 × 0.98 × 2) + (0.25 × 0.08 × 100)
+ (0.25 × 0.92 × 2) + (0.75 × 0.02 × 100) + (0.75 × 0.98 × 2)
ET = 0.5 + 0.49 + 2 + 0.46 + 1.5 + 1.47 = 6.42

Perfect cache:



ET = 0.25 × 2 + 0.25 × 2 + 0.75 × 2
= 0.5 + 0.5 + 1.5 = 2.5

$$S = \frac{ET_{\text{Normal cache}}}{ET_{\text{Perfect cache}}} = \frac{6.42}{2.5} = 2.56$$

End of Solution

Q.47 Consider the following recurrence relation:

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

Which one of the following options is CORRECT?

(a) $T(n) = \Theta(n \log \log n)$ (b) $T(n) = \Theta(n^2 \log n)$

(c) $T(n) = \Theta(n \log n)$ (d) $T(n) = \Theta(n^2 \log \log n)$

Ans. (a)

$$T(n) = n^{1/2} \cdot T\left(n^{1/2}\right) + n$$

$$= n^{1/2}\left[n^{\frac{1}{2^2}} T\left(n^{\frac{1}{2^2}}\right) + n^{1/2}\right] + n$$

$$= n^{\frac{3}{2^2}} \cdot T\left(n^{\frac{1}{2^2}}\right) + n + n$$

$$= n^{\frac{3}{2^2}}\left[n^{\frac{1}{2^3}} + T\left(n^{\frac{1}{2^3}}\right) + n^{\frac{1}{2^2}}\right] + 2n$$

$$= n^{\frac{7}{2^3}} \cdot T\left(n^{\frac{1}{2^3}}\right) + 3n$$

$\vdots$ k times

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

$$\left\{\therefore \; n^{\frac{1}{2^k}} = 2 \;\; 2^k = \log_2 n \;\; k = \log_2 \log_2 n\right.$$

$$= \frac{n}{n^{\frac{1}{2^k}}} \cdot T(2) + n \cdot \log_2 \log_2 n$$

$$T(n) = \frac{n}{2} + n \cdot \log_2 \log_2 n = \theta(n \log_2 \log_2 n)$$

End of Solution

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Q.48 Consider the entries shown below in the forwarding table of an IP router. Each entry consists of an IP prefix and the corresponding next hop router for packets whose destination IP address matches the prefix. The notation/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 _____.

Ans. (40)

End of Solution

Q.49 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 $\frac{n}{k}$.

(c) G contains a vertex of degree at least k.

(d) G contains at least $\frac{k(k-1)}{2}$ edges

Ans. (b, d)

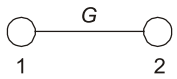
$\because$ We know that, the number of vertices in the largest independent set of a graph G.

$$\beta(G) \geq \frac{n}{k}$$

$\therefore$ Option (b) is true.

It we take a counter example.

Let,



its chromatic number $k = 2$

and edges $\frac{k(k-1)}{2} = \frac{2(2-1)}{2} = 1$

$\therefore$ Graph 'G' contains atleast $\frac{k(k-1)}{2}$ edges whose $k = 2$.

$\therefore$ Option (d) is also true.

End of Solution

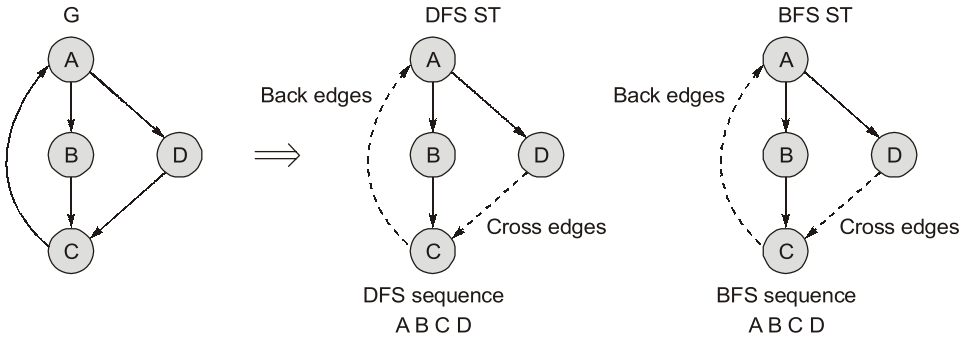
Q.50 Let G be a directed graph and T a depth first search (DFS) spanning tree in G that is rooted at a vertex v. Suppose T is also a breadth first search (BFS) tree in G, rooted at v. Which of the following statements is/are TRUE for every such graph G and tree T?

(a) The only edges in G are the edges in T.
(b) There are no cross-edges in G with respect to the tree T.
(c) There are no back-edges in G with respect to the tree T.
(d) There are no forward-edges in G with respect to the tree T.

Ans. (d)

G : Directed graph

T : DFS spanning tree of G rooted at V and BFS spanning tree of G rooted at V.



BFS spanning tree is also must be DFS spanning tree is given constraint so that no forward edges possible.

End of Solution

Q.51 Consider the following grammar G, with S as the start symbol. The grammar G has three incomplete productions denoted by (1), (2), and (3).

$$S \rightarrow daT \mid \underline{\quad (1) \quad}$$

$$T \rightarrow aS \mid bT \mid \underline{\quad (2) \quad}$$

$$R \rightarrow \underline{\quad (3) \quad} \mid \in$$

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

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

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

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

(a) (1) $S \rightarrow fR$, (2) $T \rightarrow cT$, (3) $R \rightarrow cR$
(b) (1) $S \rightarrow fR$, (2) $T \rightarrow \in$, (3) $R \rightarrow cTR$
(c) (1) $S \rightarrow Rf$, (2) $T \rightarrow cT$, (3) $R \rightarrow cR$
(d) (1) $S \rightarrow Rf$, (2) $T \rightarrow \in$, (3) $R \rightarrow cTR$

Ans. (d)

By verification process the production will be

$S \rightarrow daT \mid Rf$

$T \rightarrow aS \mid bT \mid \in$

$R \rightarrow cTR \mid \in$

$\text{First}(S) = \{d, c, f\}$

$\text{First}(T) = \{a, b, \in\}$

$\text{First}(R) = \{c, \in\}$

End of Solution

Q.52 Consider a Boolean expression given by $F(X, Y, Z) = \Sigma(3, 5, 6, 7)$
Which of the following statement is/are CORRECT?

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

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

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

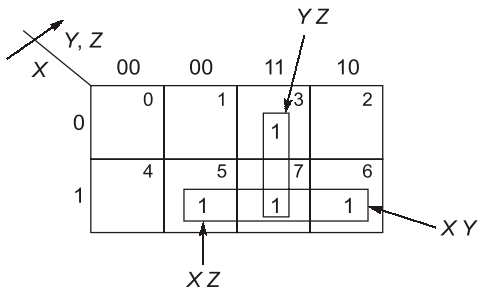
(d) $F(X, Y, Z)$ is independent of input X

Ans. (a, c)

Given function $F(X, Y, Z) = \Sigma m(3, 5, 6, 7)$

In terms of max terms function is

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



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

End of Solution

Q.53 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 is s, is _____.

Ans. **(44)**

The number of strings of length less than or equal to 5 over {0, 1} is

$2^0 + 2^1 + 2^2 + 2^3 + 2^4 + 25 = 63$

Given, $R = 0^* + 1^*$

The strings in R of length less than or equal to 5 are 11,

i.e. $\in$, 0, 00, 000, 0000, 00000

and 1, 11, 111, 1111, 11111

Given, $S = 01^* + 10^*$

The strings in S of length less than or equal to 5 are 10,

i.e., 0, 01, 011, 0111, 01111

and 1, 10, 100, 1000, 10000

The total number of strings in R and S of length less than or equal to 5 is

$= 11 + 10 - 2 = 19$

(The string 0 and 1 are common in R and S)

$\therefore$ The number of strings over {0, 1} of length less than or equal to 5 neither in R nor in S is $= 63 - 19 = 44$

End of Solution

Q.54 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) $(a = 3, b = 4); (a = 4, b = 3); (a = 3, b = 3)$

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

(c) $(a = 2, b = 2); (a = 2, b = 3); (a = 3, b = 4)$

(d) $(a = 4, b = 4); (a = 3, b = 3); (a = 4, b = 3)$

Ans. **(d)**

End of Solution

Q.55 Consider the operators ◊ and □ defined by $a \lozenge b = a + 2b$, $a \square b = ab$, for positive integers. Which of the following statements is/are TRUE?

(a) Operator ◊ obeys the associative law.

(b) Operator ◊ over the operator □ obeys the distributive law.

(c) Operator □ obeys the associative law.

(d) Operator □ over the operator ◊ obeys the distributive law.

Ans. **(c, d)**

Check with options:

(a) Consider $a \lozenge (b \lozenge c) = a \lozenge (b + 2c)$

$= a + 2(b + 2c)$

$= a + 2b + 4c$

Consider $(a \lozenge b) \lozenge c = (a + 2b) \lozenge c$

$= a + 2b + 2c$

$\therefore \quad (a \lozenge b) \lozenge c \neq a \lozenge (b \lozenge c)$

Option (a) is false.

(b) Distributive

$$a \lozenge (b \square c) = (a \lozenge b) \square (a \lozenge c)$$
$$a \Delta (bc) \neq (a + 2b) \square (a + 2c)$$
$$a + 2bc \neq (a + 2b)(a + 2c)$$
$$a(b + 2c) = ab + 2ac$$

(c) Distributive law

$$a \square (b \lozenge c) = (a \square b) \lozenge (a \square c)$$
$$a \square (b \lozenge c) = (ab) \lozenge (ac)$$
$$a \square (b + 2c) = ab + 2ac$$
$$a(b + 2c) = ab + 2ac$$

$\therefore$ Option (c) is true.

(d) Associativity

Consider $a \square (b \square c) = a \square (bc) = abc$

and consider $(a \square b) \square c) = (ab) \square c$

$= abc$

$\therefore$ □ is associative.

End of Solution

■■■■