SOLVED GATE (COMPUTER SCIENCE AND INFORMATION TECHNOLOGY) 2022

Engineering Mathematics and Technical Section

Q. No. 1–12 Multiple Choice Question (MCQ) Carry One Mark Each

1. Which one of the following statements is **true** for all positive functions $f(n)$?

(A) $f(n^2) = \theta(f(n)^2)$, when $f(n)$ is a polynomial

(B) $f(n^2) = o(f(n)^2)$

(C) $f(n^2) = O(f(n)^2)$, when $f(n)$ is an exponential function

(D) $f(n^2) = \Omega(f(n)^2)$

Solution: Taking option (A), we have $f(n^2) = \theta(f(n)^2)$ when $f(n)$ is a polynomial, here θ represents asymptotic tight bounds of function from above and below.

Taking option (B), we have $f(n^2) = O(f(n)^2)$ here small O notation represents upper bounds of the function.

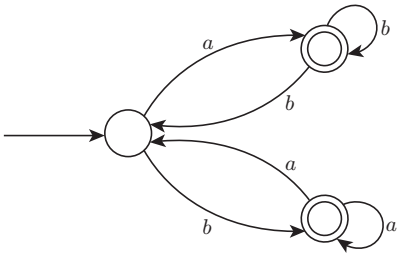
Taking option (C), we have $f(n^2) = O(f(n)^2)$ when $f(n)$ is an exponential function here by O notation represents upper bound of function only.

Taking option (D), we have $f(n^2) = \Omega(f(n)^2)$ here Ω notation represents asymptotic lower bound of the function only.

Among the given statements, option (A) is correct.

Ans. (A)

2. Which one of the following regular expressions correctly represents the language of the finite automaton given below?



(A) $ab^*bab^* + ba^*aba^*$

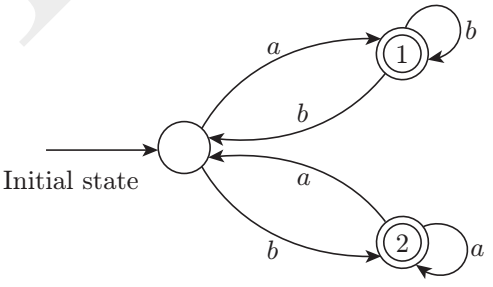
(B) $(ab^*b)^*ab^* + (ba^*a)^*ba^*$

(C) $(ab^*b + ba^*a)^*(a^* + b^*)$

(D) $(ba^*a + ab^*b)^*(ab^* + ba^*)$

Solution: Finding regular expression for all the strings that end up at the initial state.

$$\text{Initial state} = ab^*b + ba^*a$$



Now finding regular expression for all strings that end up at final state 1

$$\text{State 1} = (ab^*b + ba^*a)\ ab^*$$

Similarly, finding regular expression for all strings that end up at final state 2

$$\text{State 2} = (ab^*b + ba^*a)ba^*$$

Therefore, regular expression representing the language is

$$\text{State 1} + \text{State 2}$$

$$(ab^*b + ba^*a)ab^* + (ab^*b + ba^*a)ba^*$$

$$= (ab^*b + ba^*a)(ab^* + ba^*)$$

Ans. (D)

3. Which one of the following statements is **true**?

(A) The $LALR(1)$ parser for a grammar G cannot have reduce-reduce conflict if the $LR(1)$ parser for G does not have reduce-reduce conflict.

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(B) Symbol table is accessed only during the lexical analysis phase.
(C) Data flow analysis is necessary for run-time memory management.
(D) $LR(1)$ parsing is sufficient for deterministic context-free languages.

Solution: Among the given statements only statement (D) is correct, that is, $LR(1)$ parsing is sufficient for deterministic context free languages.

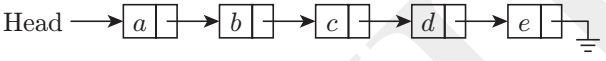
Ans. (D)

4. In a relational data model, which one of the following statements is **true**?
(A) A relation with only two attributes is always in BCNF.
(B) If all attributes of a relation are prime attributes, then the relation is in BCNF.
(C) Every relation has at least one non-prime attribute.
(D) BCNF decompositions preserve functional dependencies.

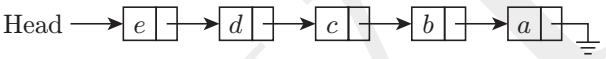
Solution: In a relational model a relation with only two attributes is always in BCNF. So, option (A) is correct.

Ans. (A)

5. Consider the problem of reversing a singly linked list. To take an example, given the linked list below,



the reversed linked list should look like



Which one of the following statements is **true** about the time complexity of algorithms that solve the above problem in $O(1)$ space?
(A) The best algorithm for the problem takes $\theta(n)$ time in the worst case.
(B) The best algorithm for the problem takes $\theta(n \log n)$ time in the worst case.
(C) The best algorithm for the problem takes $\theta(n^2)$ time in the worst case.
(D) It is not possible to reverse a singly linked list in $O(1)$ space.

Solution: In a singly linked list, three pointers are required to reverse the linked list. So, in the worst case, the best algorithm for the problem takes $\theta(n)$ time.

Ans. (A)

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

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

Solution: Given that, keys $= n$, hash table slots $= m$ and simple uniform hash functions $= h_1$ and h_2, where odd keys $= h_1$

$$\text{Number of keys in a slot } = \frac{n}{m}$$

Ans. (B)

7. Which one of the following facilitates transfer of bulk data from hard disk to main memory with the highest throughput?
(A) DMA based I/O transfer
(B) Interrupt driven I/O transfer
(C) Polling based I/O transfer
(D) Programmed I/O transfer

Solution: DMA based I/O transfer bulk data from hard disk to main memory with the highest throughput.

Ans. (A)

8. Let R1 and R2 be two 4-bit registers that store numbers in 2's complement form. For the operation R1 + R2, which one of the following values of R1 and R2 gives an arithmetic overflow?
(A) R1 = 1011 and R2 = 1110
(B) R1 = 1100 and R2 = 1010
(C) R1 = 0011 and R2 = 0100
(D) R1 = 1001 and R2 = 1111

Solution: When an arithmetic calculation exceeds the memory range assigned to hold it then it results to an arithmetic overflow.
Consider option (A), we have R1 = 1011 and R2 = 1110. So,

$$\text{R1} + \text{R2} = 1001$$

No overflow as sign bit is same.
Consider option (B), we have R1 = 1100 and R2 = 1010. So,

$$\text{R1} + \text{R2} = 0110$$

Overflow as sign bit is different.
Consider option (C), we have R1 = 0011 and R2 = 0100. So,

$$\text{R1} + \text{R2} = 0111$$

No overflow as sign bit is same.
Consider option (D), we have R1 = 1001 and R2 = 1111. So,

$$\text{R1} + \text{R2} = 1000$$

No overflow as sign bit is same.

Ans. (B)

9. Consider the following threads, T_1, T_2, and T_3 executing on a single processor, synchronized using three binary semaphore variables, S_1, S_2, and S_3, operated upon using standard `wait()` and `signal()`. The threads can be context switched in any order and at any time.

T_1	T_2	T_3

`while(true){`
`wait(S3);`
`print("C");`
`signal(S2); }`
	`while(true){`
	`wait(S1);`
	`print("B");`
	`signal(S3); }`
		`while(true){`
		`wait(S2);`
		`print("A");`
		`signal(S1); }`

Which initialization of the semaphores would print the sequence BCABCABCA....?

(A) $S_1 = 1; S_2 = 1; S_3 = 1$
(B) $S_1 = 1; S_2 = 1; S_3 = 0$
(C) $S_1 = 1; S_2 = 0; S_3 = 0$
(D) $S_1 = 0; S_2 = 1; S_3 = 1$

Solution: When $S_1 = 1$, $S_2 = 0$ and $S_3 = 0$. T_2 is executed first to print "B" then signal S_3 executes T_1 to prints "C" followed by signal S_2 which executes T_3 to print "A".
Thus, the output is BCABCABCA....

Ans. (C)

10. Consider the following two statements with respect to the matrices $A_{m\times n}$, $B_{n\times m}$, $C_{n\times n}$ and $D_{n\times n}$.

Statement 1: $tr(AB) = tr(BA)$
Statement 2: $tr(CD) = tr(DC)$
where $tr()$ represents the trace of a matrix. Which one of the following holds?

(A) Statement 1 is correct and Statement 2 is wrong.
(B) Statement 1 is wrong and Statement 2 is correct.
(C) Both Statement 1 and Statement 2 are correct.
(D) Both Statement 1 and Statement 2 are wrong.

Solution: We know that,

$$tr\,(AB) = tr\,(BA)$$

where tr is trace of matrix, that is, sum of diagonal matrix.
Thus, both statements are correct and hence option (C) is correct.

Ans. (C)

11. What is printed by the following ANSI C program?

```
#include<stdio.h>
int main(int argc, char *argv[])
{
int x = 1, z[2] = {10, 11};
int *p = NULL;
p = &x;
*p = 10;
p = &z[1];
*(&z[0] + 1) += 3;
printf("%d, %d, %d\n", x, z[0], z[1]);
return 0;
}
```

(A) 1, 10, 11 (B) 1, 10, 14
(C) 10, 14, 11 (D) 10, 10, 14

Solution: Given that,
`p = &x;` $\Rightarrow$ p = address of x
`*p = 10;` $\Rightarrow$ p points to 10, that is, $x = 10$
`p = &z[1];` $\Rightarrow$ p = address of $z[1]$
`*(&z[0]+1)+=3;` $\Rightarrow$ * (address of $z[0] + 1$)+ = 3 $\Rightarrow$ *(address of $z[1]$)+ = 3

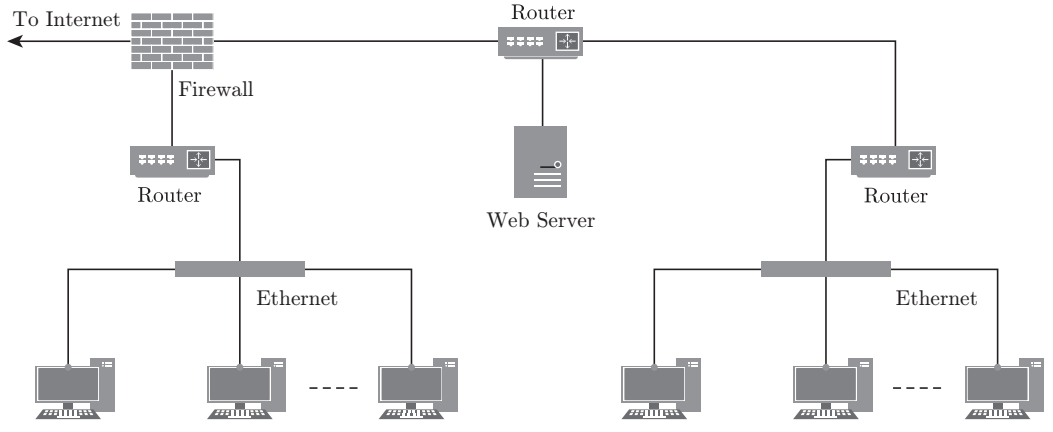
$\Rightarrow$ $z[1] = z[1] = 3 = 11 + 3 = 14$

So, $x = 10$
$z[0] = 10$
$z[1] = 14$

Therefore, output is 10, 10, 14.

Ans. (D)

12. Consider an enterprise network with two Ethernet segments, a web server and a firewall, connected via three routers as shown below.



What is the number of subnets inside the enterprise network?

(A) 3 (B) 12
(C) 6 (D) 8

Solution: From the diagram, each interface of router = 1 subnet
The left router has 2 interfaces, middle router has 3 interfaces and right router has 2 interfaces which sums to total 7 interfaces. Therefore, total of 7 subnets. However, there is a common interface between middle and right router, which leads to 7 – 1 = 6 subnets.
Therefore, total subnets = 7 – 1 = 6

Ans. (C)

Q. No. 13–17 Multiple Select Question (MSQ) Carry One Mark Each

13. Which of the following statements is/are **true**?

(A) Every subset of a recursively enumerable language is recursive.
(B) If a language L and its complement $\bar{L}$ are both recursively enumerable, then L must be recursive.
(C) Complement of a context-free language must be recursive.
(D) If L_1 and L_2 are regular, then $L_1 \cap L_2$ must be deterministic context-free.

Solution: Option A is incorrect – Every subset of a recursively enumerable language may or may not be recursive.
Option B is correct – If a language L and its complement $\bar{L}$ are both recursively enumerable, then L must be recursive.
Option C is correct – complement of a context – free language must be recursive.
Option D is correct – If L_1 and L_2 are regular, then $L_1 \cap L_2$ must be deterministic context free.

Ans. (B, C, D)

14. Let WB and WT be two set associative cache organizations that use LRU algorithm for cache block replacement. WB is a write back cache and WT is a write through cache. Which of the following statements is/are **false**?

(A) Each cache block in WB and WT has a dirty bit.
(B) Every write hit in WB leads to a data transfer from cache to main memory.
(C) Eviction of a block from WT will not lead to data transfer from cache to main memory.
(D) A read miss in WB will never lead to eviction of a dirty block from WB.

Solution: Option A – each cache block in WB and WT has a dirty bit. This statement is false.
Option B – every write hit in WB leads to a data transfer from cache to main memory. This statement is false.
Option C – eviction of a block from WT will not lead to data transfer from cache to main memory. This statement is true.
Option D – A read miss in WB will never lead to eviction of a dirty block from WB. This statement is false.

Ans. (A, B, D)

15. Consider the following three relations in a relational database.

$$Employee(\underline{eId}, Name),\ \text{Brand}(\underline{bId}, bName),\ \text{Own}(\underline{eId}, \underline{bId})$$

Which of the following relational algebra expressions return the set of *eIds* who own all the brands?

(A) $\prod_{eId}(\prod_{eId,bId}(Own) / \prod_{bId}(Brand))$

(B) $\prod_{eId}(Own) - \prod_{eId}((\prod_{eId}(Own) \times \prod_{bId}(Brand)) - \prod_{eId,bId}(Own))$

(C) $\prod_{eId}(\prod_{eId,bId}(Own) / \prod_{bId}(Own))$

(D) $\prod_{eId}((\prod_{eId}(Own) \times \prod_{bId}(Own)) / \prod_{bId}(Brand))$

Solution: Given that, relations in a relational database.

$$Employee(\underline{eId}, Name),\ \text{Brand}(\underline{bId}, bName),\ \text{Own}(\underline{eId}, \underline{bId})$$

In order to obtain set of *eId*s who own all the brands following relational algebra expressions can be used.

(A) $\prod_{eId}(\prod_{eId,bId}(Own) / \prod_{bId}(Brand))$

(B) $\prod_{eId}(Own) - \prod_{eId}((\prod_{eId}(Own) \times \prod_{bId}(Brand)) - \prod_{eId,bId}(Own))$

Ans. (A, B)

16. Which of the following statements is/are TRUE with respect to deadlocks?

(A) Circular wait is a necessary condition for the formation of deadlock.
(B) In a system where each resource has more than one instance, a cycle in its wait-for graph indicates the presence of a deadlock.
(C) If the current allocation of resources to processes leads the system to unsafe state, then deadlock will necessarily occur.
(D) In the resource-allocation graph of a system, if every edge is an assignment edge, then the system is not in deadlock state.

Solution: Option (A): Circular wait is a necessary condition for the formation of deadlock. This is correct statement.
Option (B): In a system where each resource has more than one instance, a cycle in its wait-for graph indicates the presence of a deadlock. This statement is false.
Option (C): If the current allocation of resources to processes leads the system to unsafe state, then deadlock will necessarily occur. This statement is false.
Option (D): In the resource – allocation graph of a system, if every edge is an assignment edge, then the system is not in deadlock state. This statement is true.

Ans. (A, D)

17. Which of the following statements is/are **true** for a group G?
(A) If for all $x, y \in G, (xy)^2 = x^2y^2$, then G is commutative.
(B) If for all $x \in G, x^2 = 1$, then G is commutative. Here, 1 is the identity element of G.
(C) If the order of G is 2, then G is commutative.
(D) If G is commutative, then a subgroup of G need not be commutative.

Solution:
Statement A: If for all $x, y \in G, (xy)^2 = x^2y^2$ then G is commutative,

$$(xy)^2 = x^2y^2$$

$$\Rightarrow \quad xyxy = xxyy$$

Now, using cancellation laws

$$yx = xy$$

Therefore, G is commutative. So, statement (A) is correct.

Statement B: If for all $x \in G$, $x^2 = 1$, then G is commutative. Here, 1 is identity of G.

$$x^2 = 1 \Rightarrow xx = 1$$

Now, multiply by x^{-1} on left side

$$x^{-1}xx = x^{-1}$$

$$ex = x^{-1} \qquad (\text{Since, } x^{-1}x = e)$$

$$x = x^{-1} \qquad (\text{Since, } ex = x)$$

If in a group every element has its own inverse then group is commutative. So, statement B is correct.

Statement C: If the order of G is 2, then G is commutative.
By definition, every group of prime order is commutative. So, statement C is correct.

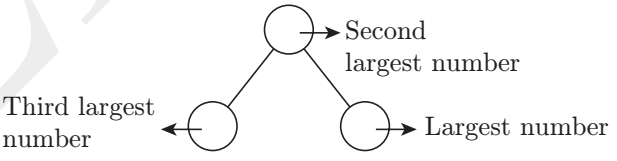
Statement D: If G is commutative, then a subgroup of G need not be commutative. This statement is false. If G is commutative, then a subgroup of G may also be commutative.
Let $x, y \in H$ which implies $x, y \in G$ and since G is a commutative group, $xy = yx$
Therefore, H is also a commutative group. So, statement (D) is incorrect.

Ans. (A, B, C)

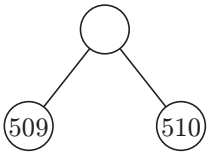
Q. No. 18–25 Multiple Select Question (MSQ) Carry One Mark Each

18. Suppose a binary search tree with 1000 distinct elements is also a complete binary tree. The tree is stored using the array representation of binary heap trees. Assuming that the array indices start with 0, the 3rd largest element of the tree is stored at index _____.

Solution: From given data, we have index number of first node $= 2^m - 1$
where m = height of tree
And number of nodes at each level $= 2^{(n-1)}$
where n = level number
In binary tree numbers are arranged as follow



For given binary tree with 1000 elements number of nodes at 10^{th} level $= 2^{10-1} = 2^9 = 512$
Index of first node at height $m = 9$ is $2^9 - 1 = 511$
Number of nodes at 9^{th} level $= 2^{9-1} = 2^8 = 256$
Index of first node at height $m = 8$ is $2^8 - 1 = 255$
So, index of last node in 9^{th} level $= 255 \times 2 = 510$
and index largest number = 510



Therefore, index of 3^{rd} largest number is 509.

Ans. (509)

19. Consider the augmented grammar with $\{+, *, (,), id\}$ as the set of terminals.

$$S' \rightarrow S$$
$$S \rightarrow S + R \mid R$$
$$R \rightarrow R * P \mid P$$
$$P \Rightarrow (S) \mid id$$

If I_0 is the set of two $LR(0)$ items $\{[S' \to S_{\bullet}], [S \to S_{\bullet} + R]\}$, then goto(closure($I_0$), +) contains exactly _____ items.

Solution: Applying augmented grammar on the set we have

$S' \to {}_{\bullet}S$	$\to$	$S' \to S_{\bullet}$	$\to$	$S \to S + {}_{\bullet}R$
$S \to {}_{\bullet}S + R$		$S \to S_{\bullet} + R$		$R \to {}_{\bullet}R * P$
$S \to {}_{\bullet}R$				$R \to {}_{\bullet}P$
$R \to {}_{\bullet}R * P$				$P \to {}_{\bullet}(S)$
$R \to {}_{\bullet}P$				$P \to {}_{\bullet}id$
$P \to {}_{\bullet}id$				
$P \to {}_{\bullet}(S)$				

Thus gets (closure (I_0), +) contains exactly 5 items.

Ans. (5)

20. Consider a simple undirected graph of 10 vertices. If the graph is disconnected, then the maximum number of edges it can have is _____.

Solution: An undirected graph contains set of nodes called vertex connected through set of links called edge.
Given that, simple undirected graph of 10 vertices.
Then, maximum number of edges

$$\frac{(10-1)(10)}{2} = \frac{9\times 10}{2} = 45$$

When the graph is disconnected, one of the vertex is not connected then maximum number of edges

$$\frac{(10-2)(10-2+1)}{2} = \frac{8\times 9}{2} = 36$$

Ans. (36)

21. Consider a relation $R(A, B, C, D, E)$ with the following three functional dependencies.

$$AB \to C; \qquad D; \qquad C \to E;$$

The number of superkeys in the relation R is _____.

Solution: Given that, relation $R(A, B, C, D, E)$

$$AB \to C; \qquad D; \qquad C \to E;$$

Candidate key in the relation is $\{A, B\}$. The number of super keys in relation, that is, set of attributes that uniquely identifies each type of relation can be obtained as: $\{C, D, E\}$ with $\{A, B\}$

$$2^3 = 8 \text{ Superkeys}$$

Ans. (8)

22. The number of arrangements of six identical balls in three identical bins is _____.

Solution: Possible arrangements of six identical balls in three identical bins are

(6, 0, 0), (5, 1, 0), (4, 2, 0), (3, 3, 0), (4, 1, 1), (3, 2, 1), (2, 2, 2)

That is, these are 7 possible arrangements.

Ans. (7)

23. A cache memory that has a hit rate of 0.8 has an access latency 10 ns and miss penalty 100 ns. An optimization is done on the cache to reduce the miss rate. However, the optimization results in an increase of cache access latency to 15 ns, whereas the miss penalty is not affected. The minimum hit rate (rounded off to two decimal places) needed after the optimization such that it should not increase the average memory access time is _____.

Solution: Given that,

$$\text{Hit rate} = 0.8$$

$$\text{Access latency} = 10 \text{ ns}$$

$$\text{Miss penalty} = 100 \text{ ns}$$

$$\text{Average memory access time} = (\text{Hit rate} \times \text{Access latency}) + (1 - \text{Hit rate})(\text{Miss penalty})$$

So,

$$\text{Average memory access time} = 0.8 \times 10 + (1 - 0.8)(100)$$
$$= 8 + 20 = 28 \text{ ns}$$

$$\text{New access latency} = 15 \text{ ns}$$

Miss penalty is not affected

$$\text{Let, hit rate} = r$$

Then new average memory access time

$$r \times 15 + (1 - r)\ 100$$
$$= 15r + 100 - 100r$$
$$= (-85r + 100) \text{ ns}$$

Now, new access memory access time should not excess earlier access memory time.

$$28 \text{ ns} = (-85r + 100) \text{ ns}$$
$$\Rightarrow \quad 85r = 100 - 28$$
$$\Rightarrow \quad r = \frac{72}{85} = 0.85$$

Therefore, minimum hit rate = 0.85

Ans. (0.85)

24. The value of the following limit is _____.

$$\lim_{x \to 0^+} \frac{\sqrt{x}}{1 - e^{2\sqrt{x}}}.$$

Solution: Given that,

$$\lim_{x\to 0^+}\frac{\sqrt{x}}{1-e^{2\sqrt{x}}}$$

Using L'Hospital's rule, we have

$$\lim_{x\to 0^+}\frac{f(x)}{g(x)}=\lim_{x\to 0^+}\frac{f'(x)}{g'(x)}$$

So,
$$\lim_{x\to 0^+}\frac{\sqrt{x}}{1-e^{2\sqrt{x}}}=\lim_{x\to 0^+}\frac{\frac{1}{2\sqrt{x}}}{-2\frac{e^{2\sqrt{x}}}{2\sqrt{x}}}$$

$$=\lim_{x\to 0^+}\frac{-1}{2e^{-2\sqrt{x}}}=\frac{-1}{2}=-0.5$$

Ans. (-0.5)

25. Consider the resolution of the domain name www.gate.org.in by a DNS resolver. Assume that no resource records are cached anywhere across the DNS servers and that iterative query mechanism is used in the resolution. The number of DNS query-response pairs involved in completely resolving the domain name is _____.

Solution: DNS resolver goes to
1. root server
2. top level domain
3. secondary level domain
4. authoritative DNS server

Therefore, number of DNS query – response pairs involved = 4

Ans. (4)

Q. No. 26–35 Multiple Choice Question (MCQ) Carry Two Marks Each

26. Which one of the following is the closed form for the generating function of the sequence $\{a_n\}_{n\geq 0}$ defined below?

$$a_n=\begin{cases}n+1, & n \text{ is odd}\\ 1, & \text{otherwise}\end{cases}$$

(A) $\frac{x(1+x^2)}{(1-x^2)^2}+\frac{1}{1-x}$ (B) $\frac{x(3-x^2)}{(1-x^2)^2}+\frac{1}{1-x}$

(C) $\frac{2x}{(1-x^2)^2}+\frac{1}{1-x}$ (D) $\frac{x}{(1-x^2)^2}+\frac{1}{1-x}$

Solution: We have,

$$a_n=\begin{cases}n+1, & n \text{ is odd}\\ 1, & \text{otherwise}\end{cases}$$

Generating function is

$$\sum_{\text{odd, } n} nx^n+\sum_{\text{odd } n}x^n+\sum_{\text{others}}x^n$$

$$=(x^2+3x^3+5x^5+\cdots)+(x^1+x^3+x^5+\cdots)+(x^0+x^2+x^4+\cdots)$$

$$=(x^2+3x^3+5x^5+\cdots)+(x^0+x^1+x^2+x^3+\cdots)$$

$$=\frac{x(1+x^2)}{(1-x^2)^2}+\frac{1}{1-x}$$

Ans. (A)

27. Consider a simple undirected unweighted graph with at least three vertices. If A is the adjacency matrix of the graph, then the number of 3-cycles in the graph is given by the trace of

(A) A^3 (B) A^3 divided by 2
(C) A^3 divided by 3 (D) A^3 divided by 6

Solution: Let adjacency matrix of the graph be $A[\,][\,]$ then, $A^n[i][j]$ represents number of distinct walks between i and j vertices of the graph.

Therefore, $A^3[i][j]$ represents triangle that begins and ends at i vertex in graph, that is, 3-cycle in the graph.

$$A^3=A^3_{11}+A^2_{22}+\cdots A^3_{nn}$$

Since each vertex is distinct and counted separately, then number of 3-cycles $=\frac{A^3}{3}$

Moreover since the graph is undirected eliminating double counting we get number of 3-cycles

$$\frac{1}{2}\times\frac{A^3}{3}=\frac{A^3}{6}$$

Ans. (D)

28. Which one of the following statements is FALSE?

(A) The TLB performs an associative search in parallel on all its valid entries using page number of incoming virtual address.
(B) If the virtual address of a word given by CPU has a TLB hit, but the subsequent search for the word results in a cache miss, then the word will always be present in the main memory.
(C) The memory access time using a given inverted page table is always same for all incoming virtual addresses.
(D) In a system that uses hashed page tables, if two distinct virtual addresses V1 and V2 map to the same value while hashing, then the memory access time of these addresses will not be the same.

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Solution: Among given statements, statement (C) is false. The memory access time using a given inverted page table is not same for all incoming virtual addresses.

Ans. (C)

29. Let $R_i(z)$ and $W_i(z)$ denote read and write operations on a data element z by a transaction T_i, respectively. Consider the schedule S with four transactions.

$$S : R_4(x)R_2(x)R_3(x)R_1(y)W_1(x)W_3(y)R_4(y)$$

Which one of the following serial schedules is conflict equivalent to S?

(A) $T_1 \rightarrow T_3 \rightarrow T_4 \rightarrow T_2$ (B) $T_1 \rightarrow T_4 \rightarrow T_3 \rightarrow T_2$

(C) $T_4 \rightarrow T_1 \rightarrow T_3 \rightarrow T_2$ (D) $T_3 \rightarrow T_1 \rightarrow T_4 \rightarrow T_2$

Solution: Given that,

$R_i(z) \rightarrow$ read operation on data element z

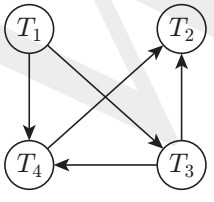
$W_i(z) \rightarrow$ write operation on data element z

and schedule is

$$S : R_4(x)R_2(x)R_3(x)R_1(y)W_1(x)W_3(y)R_4(y)$$

T_1	T_2	T_3	T_4
	$R_2(x)$		$R_4(x)$
		$R_3(x)$	
$R_1(y)$			
$W_1(y)$			
	$W_2(y)$		
		$W_3(y)$	
			$R_4(y)$

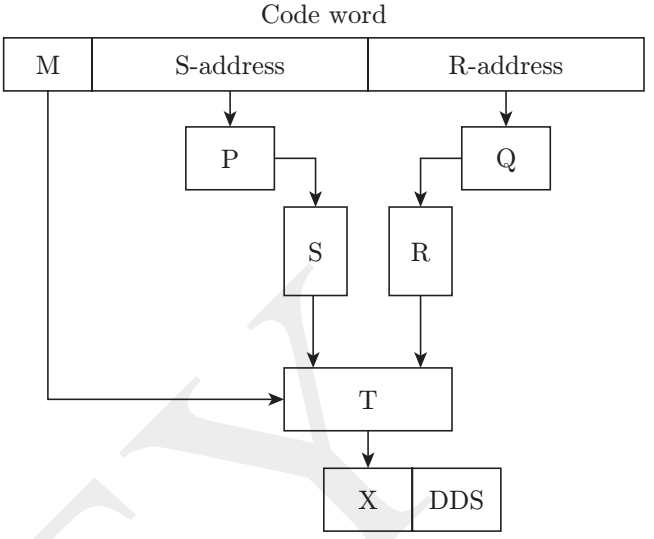
Thus, the schedule graph is as follows



So, schedule that is conflict equivalent to S is $T_1 \rightarrow T_3 \rightarrow T_4 \rightarrow T_2$.

Ans. (A)

30. Consider a digital display system (DDS) shown in the figure that displays the contents of register X. A 16-bit code word is used to load a word in X, either from S or from R. S is a 1024-word memory segment and R is a 32-word register file. Based on the value of mode bit M, T selects an input word to load in X. P and Q interface with the corresponding bits in the code word to choose the addressed word. Which one of the following represents the functionality of P, Q, and T?



(A) P is 10:1 multiplexer; Q is 5:1 multiplexer; T is 2:1 multiplexer

(B) P is 10:2^{10} decoder; Q is 5:2^5 decoder; T is 2:1 encoder

(C) P is 10:2^{10} decoder; Q is 5:2^5 decoder; T is 2:1 multiplexer

(D) P is 1:10 de-multiplexer; Q is 1:5 de-multiplexer; T is 2:1 multiplexer

Solution: In the given DDS system, based on address provided to P, memory unit S is selected. The decoder handles this function.

Unit P: We need a decoder that is able to get address of 1024 words, that is, 10 bits and select one out of 2^{10} addresses. Therefore, unit P is a 10:2^{10} decoder.

Similarly, unit Q: we need a decoder that is able to get address of 32 words, that is, is 5 bits and select one out of 2^5 addresses. So, Q is a $5 : 2^5$ decoder.

Now unit T choses one of the two inputs and loads it to X. This is performed using a multiplexer. So, T is a 2×1 multiplexer.

Ans. (C)

31. Consider three floating point numbers A, B and C stored in registers R_A, R_B and R_C, respectively as per IEEE-754 single precision floating point format. The 32-bit content stored in these registers (in hexadecimal form) are as follows.

R_A = 0xC1400000	R_B = 0x42100000	R_C = 0x41400000

Which one of the following is **false**?

(A) $A + C = 0$ (B) $C = A + B$

(C) $B = 3C$ (D) $(B - C) > 0$

Solution: Given that, $R_A = 0 \times 01400000$; $R_B = 0 \times 42100000$; and $R_C = 0 \times 41400000$
Converting to decimal format we get

$$R_A = 0 \times 01400000 = (-1)^1 \times 1.1 \times 2^{(130-127)}$$
$$= -1.1 \times 2^3 = -1100 = -12$$
$$R_B = 0 \times 42100000 = (-1)^0 \times 1.001 \times 2^{(132-137)}$$
$$= 1.001 \times 2^5 = 100100 = 36$$
$$R_C = 0 \times 4140000$$
$$= (-1)^0 \times 1.1 \times 2^{(120-127)}$$
$$= 1.1 \times 2^3 = 1100 = 12$$

Taking Option (A), we have

$$A + C = R_A + R_C = -12 + 12 = 0 \text{ (TRUE)}$$

Taking Option (B), we have

$$A + B = R_A + R_B = -12 + 36 = 24 \neq R_C$$

Therefore, $A + B \neq C$ (FALSE)

Taking Option (C), we have

$$B = 3C \text{ (TRUE) as } 3C = 3 \times R_C$$
$$= 3 \times 12 = 36 = R_B$$

Taking Option (D), we have

$$(B - C) > 0 \qquad \text{(TRUE)}$$
$$B - C = R_B - R_C = 36 - 12 = 24 > 0$$

Ans. (B)

32. Consider four processes P, Q, R, and S scheduled on a CPU as per round robin algorithm with a time quantum of 4 units. The processes arrive in the order P, Q, R, S, all at time $t = 0$. There is exactly one context switch from S to Q, exactly one context switch from R to Q, and exactly two context switches from Q to R. There is no context switch from S to P. Switching to a ready process after the termination of another process is also considered a context switch. Which one of the following is NOT possible as CPU burst time (in time units) of these processes?
(A) P = 4, Q = 10, R = 6, S = 2
(B) P = 2, Q = 9, R = 5, S = 1
(C) P = 4, Q = 12, R = 5, S = 4
(D) P = 3, Q = 7, R = 7, S = 3

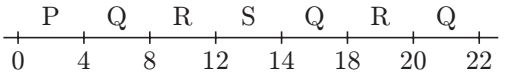
Solution: In round robin scheduling each process gets turn for a fixed time in a cyclic queue. Given, processes P, Q, R and S

Time quantum = 4 units

There is exactly one context suited from S to Q and R to Q.

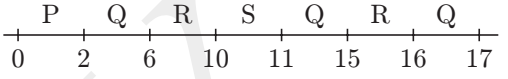
These are exactly two context switches from Q to R no context switch from S to P.
Consider option (A), we have

P = 4, Q = 10, R = 6, S = 2



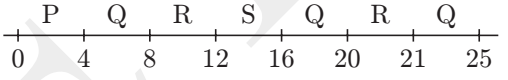
Since this is possible
Consider option (B)

P = 2, Q = 9, R = 5, S = 1



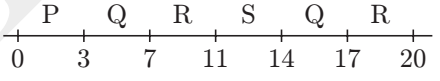
Since this is possible.
Consider option (C)

P = 4, Q = 12, R = 5, S = 4



Since this is possible.
Consider option (D)

P = 3, Q = 7, R = 7, S = 3



Since this is not possible as there is no context switching from R to Q.

Ans. (D)

33. What is printed by the following ANSI C program?

```
#include<stdio.h>
int main(int argc, char *argv[])
{
int a[3][3][3] =
{{1, 2, 3, 4, 5, 6, 7, 8, 9},
{10, 11, 12, 13, 14, 15, 16, 17, 18},
{19, 20, 21, 22, 23, 24, 25, 26, 27}};
int i = 0, j = 0, k = 0;
for( i = 0; i < 3; i++ ){
for(k = 0; k < 3; k++ )
printf("%d ", a[i][j][k]);
printf("\n");
}
return 0;
}
```

(A)
```
1   2   3
10  11  12
19  20  21
```

(B)
```
1   4   7
10  13  16
19  22  25
```

(C)
```
1  2  3
4  5  6
7  8  9
```

(D)
```
1   2   3
13  14  15
25  26  27
```

Solution: Executing the given program, we get

For $i = 0$, $j = 0$, $k = 0, 1, 2$

$i = 0, k = 0$ $a[0][0][0] = 1$

$k = 1$ $a[0][0][1] = 2$

$k = 2$ $a[0][0][2] = 3$

For $i = 1$, $j = 0$, $k = 0, 1, 2$

$i = 1, k = 0$ $a[1][0][0] = 10$

$k = 1$ $a[1][0][1] = 11$

$k = 2$ $a[1][0][2] = 12$

For $i = 2$, $j = 0$, $k = 0, 1, 2$

$i = 2, k = 0$ $a[2][0][0] = 19$

$k = 1$ $a[2][0][1] = 20$

$k = 2$ $a[2][0][2] = 21$

Therefore, output is

```
 1   2   3
10  11  12
19  20  21
```

Ans. (A)

34. What is printed by the following ANSI C program?

```
#include<stdio.h>
int main(int argc, char *argv[]){
      char a = 'P';
      char b = 'x';
      char c = (a & b) + '*';
      char d = (a | b) - '-';
      char e = (a ^ b) + '+';
      printf("%c %c %c\n", c, d, e);
      return 0;
}
```

ASCII encoding for relevant characters is given below

A	B	C	…	Z
65	66	67	…	90

a	b	c	…	z
97	98	99	…	122

*	+	—
42	43	45

(A) `z K S` (B) `122 75 83`

(C) `* - +` (D) `P x +`

Solution: Executing the given program, we get

char a = 'P';

char b = 'x';

char c = (a & b) + 'x';

a = 80

b = 120

converting to binary representation

a = 1010000

b = 1111000

a & b = 101000

* = 42 = 0101010

Therefore, (a & b) + '*' = 1111010 = 122

(a & b) + '*' = z

char c = 'z'

Now, char d = (a|b) – '–';

a = 1010000

b = 1111000

a|b = 1111000

– = 45 = 0101101

Therefore, (a|b) – '–' = 1001011 = 75

(a|b) – '–' = k

char d = 'k'

Now, char e = (a^b) + '+'

a = 1010000

b = 1111000

a^b = 0101000

+ = 43 = 0101011

Therefore, (a^b) + '+' = 1010011 = 83

(a^b) + '+' = S

char e = 'S'

So, output is `z k S`

Ans. (A)

35. Consider solving the following system of simultaneous equations using LU decomposition.

$$x_1 + x_2 - 2x_3 = 4$$
$$x_1 + 3x_2 - x_3 = 7$$
$$2x_1 + x_2 - 5x_3 = 7$$

where L and U are denoted as

$$L = \begin{pmatrix} L_{11} & 0 & 0 \\ L_{21} & L_{22} & 0 \\ L_{31} & L_{32} & L_{33} \end{pmatrix}, U = \begin{pmatrix} U_{11} & U_{12} & U_{13} \\ 0 & U_{22} & U_{23} \\ 0 & 0 & U_{33} \end{pmatrix}$$

Which one of the following is the correct combination of values for L_{32}, U_{33}, and x_1?

(A) $L_{32} = 2, U_{33} = -\frac{1}{2}, x_1 = -1$

(B) $L_{32} = 2, U_{33} = 2, x_1 = -1$

(C) $L_{32} = -\frac{1}{2}, U_{33} = 2, x_1 = 0$

(D) $L_{32} = -\frac{1}{2}, U_{33} = -\frac{1}{2}, x_1 = 0$

Solution: Writing the given equations in matrix form $AX = B$

$$\begin{bmatrix} 1 & 1 & -2 \\ 1 & 3 & -1 \\ 2 & 1 & -5 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} 4 \\ 7 \\ 7 \end{bmatrix}$$

Here $$A = \begin{bmatrix} 1 & 1 & -2 \\ 1 & 3 & -1 \\ 2 & 1 & -5 \end{bmatrix}$$

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Now using elementary row transformation $R_2 \rightarrow R_2 \rightarrow R_1$, we get

$$A = \begin{bmatrix} 1 & 1 & -2 \\ 0 & 2 & 1 \\ 2 & 1 & -5 \end{bmatrix}$$

Now $R_3 \rightarrow R_3 - 2R_1$, we get

$$A = \begin{bmatrix} 1 & 1 & -2 \\ 0 & 2 & 1 \\ 0 & -1 & -1 \end{bmatrix}$$

Now $R_3 \rightarrow R_3 - \left(\frac{-R_2}{2}\right)$, we get

$$A = U = \begin{bmatrix} 1 & 1 & -2 \\ 0 & 2 & 1 \\ 0 & 0 & -1/2 \end{bmatrix}$$

Similarly, $I = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$

Now $R_2 \rightarrow R_2 - R_1$, we get

$$I = \begin{bmatrix} 1 & 0 & 0 \\ -1 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Now $R_3 \rightarrow R_3 - 2R_1$, we get

$$I = \begin{bmatrix} 1 & 0 & 0 \\ -1 & 1 & 0 \\ -2 & 0 & 1 \end{bmatrix}$$

Now $R_3 \rightarrow R_3 - \left(\frac{+R_2}{2}\right)$, we get

$$I = L = \begin{bmatrix} 1 & 0 & 0 \\ -1 & 1 & 0 \\ -3/2 & -1/2 & 1 \end{bmatrix}$$

Therefore, $L_{32} = -1/2$, $U_{33} = -1/2$ and $x_1 = 0$.

Ans. (D)

Q. No. 36–45 Multiple Select Question (MSQ) Carry Two Marks Each

36. Which of the following is/are undecidable?

(A) Given two Turing machines M_1 and M_2, decide if $L(M_1) = L(M_2)$.

(B) Given a Turing machine M, decide if $L(M)$ is regular.

(C) Given a Turing machine M, decide if M accepts all strings.

(D) Given a Turing machine M, decide if M takes more than 1073 steps on every string.

Solution: A language is undecidable if the turing machines that accept the language is not able to make a decision for every input string. Among the given options, situation (A), (B) and (C) are undecidable.

Ans. (A, B, C)

37. Consider the following languages:

$$L_1 = \{a^n w a^n \mid w \in \{a,b\}^*\}$$

$$L_2 = \{wxw^R \mid w,x \in \{a,b\}^*, \mid w \mid, \mid x \mid > 0\}$$

Note that w^R is the reversal of the string w. Which of the following is/are **true**?

(A) L_1 and L_2 are regular.

(B) L_1 and L_2 are context-free.

(C) L_1 is regular and L_2 is context-free.

(D) L_1 and L_2 are context-free but not regular.

Solution: Given that,

$$L_1 = \{a^n \omega a^n \mid \omega \in \{a,b\}^*\}$$

$$L_2 = \{\omega x \omega^R \mid \omega, x \in \{a,b\}^*, |\omega|, |x| > 0\}$$

Here L_1 and L_2 both are regular.

Also, we know that every regular language is context free.

Therefore, option (A): L_1 and L_2 are regular. This is TRUE

Option (B): L_1 and L_2 are context free. This is TRUE

Option (C): L_1 is regular and L_2 is context free. This is TRUE

Option (D): L_1 and L_2 are context free but not regular. This is FALSE.

Ans. (A, B, C)

38. Consider the following languages:

$$L_1 = \{ww \mid w \in \{a,b\}^*\}$$

$$L_2 = \{a^n b^n c^m \mid m,n \geq 0\}$$

$$L_3 = \{a^m b^n c^n \mid m,n \geq 0\}$$

Which of the following statements is/are **false**?

(A) L_1 is not context-free but L_2 and L_3 are deterministic context-free.

(B) Neither L_1 nor L_2 is context-free.

(C) L_2, L_3 and $L_2 \cap L_3$ all are context-free.

(D) Neither L_1 nor its complement is context-free.

Solution: Given that,

$$L_1 = \{ww / w \in \{a,b\}^*\}$$

$$L_2 = \{a^n b^n c^m \mid m,n \geq 0\}$$

$$L_3 = \{a^m b^n c^n \mid m,n \geq 0\}$$

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Here, L_1 is not a context free language as it is not accepted by Pushdown Automata (PDA).
L_2 is a context free language as it is accepted by PDA.
L_3 is a context free language as it is accepted by PDA.

So, $L_2 \cap L_3 = \{a^n b^n c^m \text{ or } a^m b^n c^n \mid m,n \geq 0\}$

This is not context free language it is context sensitive language.
Also complement of L is context free as L_1 is not context free language.
Thus option (A) is TRUE: L_1 is not context free but L_2 and L_3 are deterministic context free
Option (B) is FALSE: neither L_1 or L_2 is context flow.
Option (C) is FALSE: L_2, L_3 and $L_2 \cap L_3$ are all context free
Option (D) is FALSE: neither L_1 nor its complement is context free

Ans. (B, C, D)

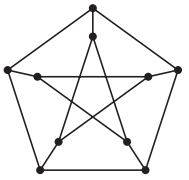
39. Consider a simple undirected weighted graph G, all of whose edge weights are distinct. Which of the following statements about the minimum spanning trees of G is/are **true**?

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

Solution: Option (A): The edge with the second smallest weight is always part of any minimum spanning tree of G. This statement is correct.
Option (B): One or both of the edges with the third smallest and the fourth smallest weights are part of any minimum spanning tree of G. This statement is correct.
Option (C): Suppose $S \subseteq V$ be such that $S \neq \phi$ and $S \neq V$. Consider the edge with the minimum weight such that one of its vertices is in S and the other in V/s. Such an edge will always be part of any minimum spanning tree of G. This statement is TRUE.
Option (D): G can have multiple minimum spanning tree. This statement is incorrect. Since G has all edge weights distinct, so, it cannot have multiple minimum spanning tree.

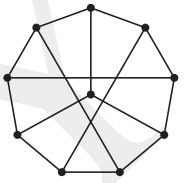
Ans. (A, B, C)

40. The following simple undirected graph is referred to as the Peterson graph.



Which of the following statements is/are **true**?

(A) The chromatic number of the graph is 3.
(B) The graph has a Hamiltonian path.
(C) The following graph is isomorphic to the Peterson graph.



(D) The size of the largest independent set of the given graph is 3. (A subset of vertices of a graph form an independent set if no two vertices of the subset are adjacent.)

Solution: Option (A): The chromatic number of the graph is 3. This statement is correct.
Option (B): The graph has a Hamiltonian path. This statement is correct.
Option (C): The graph is isomorphic to the Peterson graph. This statement is correct.
Option (D): The size of the largest independent set of the given graph is 3. This statement is incorrect. The size of the largest independent set of the graph is 4.

Ans. (A, B, C)

41. Consider the following recurrence:

$$\begin{aligned} f(1) &= 1; \\ f(2n) &= 2f(n)-1, && \text{for } n \geq 1; \\ f(2n+1) &= 2f(n)+1, && \text{for } n \geq 1. \end{aligned}$$

Then, which of the following statements is/are **true**?

(A) $f(2^n - 1) = 2^n - 1$ (B) $f(2^n) = 1$
(C) $f(5 \cdot 2^n) = 2^{n+1} + 1$ (D) $f(2^n + 1) = 2^n + 1$

Solution: We have

$$f(1) = 1; \quad f(2n) = 2f(n) - 1,$$

and $f(2n+1) = 2f(n) + 1$

For $n = 2$, $f(2) = 2f(1) - 1 = 2 - 1 = 1$

For $n = 3$, $f(3) = f(2 \times 1 + 1) = 2f(1) + 1 = 2 + 1 = 3$

For $n = 4$, $f(4) = f(2 \times 2) = 2f(2) - 1 = 2 \times 1 - 1 = 1$

For $n = 5$,
$f(5) = f(2\times2+1) = 2f(2)+1 = 2\times1+1 = 3$
For $n=6$, $f(6) = f(2\times3) = 2f(3)-1 = 2\times3-1 = 5$
For $n = 7$,
$f(7) = f(2\times3+1) = 2f(3)+1 = 2\times3+1 = 7$
For $n=8$, $f(8) = f(2\times4) = 2f(4)-1 = 2\times1-1 = 1$
For $n = 9$,
$f(9) = f(2\times4+1) = 2f(4)+1 = 2\times1+1 = 3$
For $n = 10$,
$f(10) = f(2\times5) = 2f(5)-1 = 2\times3-1 = 5$
Using the analysis we conclude that

$$f(2^n) = 1\,,\ f(2^n+1) = 3\,,\ f(2^n-1) = 2^n-1\,,$$
$$f(5\cdot2^n) = (2^{n+1}+1)$$

Therefore, $f(2^n+1) \neq 2^n+1$

So, option (A), (B) and (C) are correct and option (D) is false.

Ans. (A, B, C)

42. Which of the properties hold for the adjacency matrix A of a simple undirected unweighted graph having n vertices?
(A) The diagonal entries of A^2 are the degrees of the vertices of the graph.
(B) If the graph is connected, then none of the entries of $A^{n-1}+I_n$ can be zero.
(C) If the sum of all the elements of A is at most $2(n-1)$, then the graph must be acyclic.
(D) If there is at least a 1 in each of A's rows and columns, then the graph must be connected.

Solution: For an adjacency matrix A of a simple undirected unweighted graph having n vertices, the diagonal entries of A^2 are the degrees of the vertices of the graph.

Ans. (A)

43. Which of the following is/are the eigenvector(s) for the matrix given below?

$$\begin{pmatrix}-9 & -6 & -2 & -4\\ -8 & -6 & -3 & -1\\ 20 & 15 & 8 & 5\\ 32 & 21 & 7 & 12\end{pmatrix}$$

(A) $\begin{pmatrix}-1\\1\\0\\1\end{pmatrix}$ (B) $\begin{pmatrix}1\\0\\-1\\0\end{pmatrix}$

(C) $\begin{pmatrix}-1\\0\\2\\2\end{pmatrix}$ (D) $\begin{pmatrix}0\\1\\-3\\0\end{pmatrix}$

Solution: We know that,

$$AX = \lambda X$$

where λ is eigen values of matrix A.
Consider option (A), we have

$$X = \begin{bmatrix}-1\\1\\0\\1\end{bmatrix}$$

Then, $$AX = \begin{bmatrix}-9 & -6 & -2 & -4\\ -8 & -6 & -3 & -1\\ 20 & 15 & 8 & 5\\ 32 & 21 & 7 & 12\end{bmatrix}\begin{bmatrix}-1\\1\\0\\1\end{bmatrix}$$

$$= \begin{bmatrix}9-6-4\\ +8-6-1\\ -20+15+5\\ -32+21+12\end{bmatrix} = \begin{bmatrix}-1\\1\\0\\1\end{bmatrix}$$

So, $AX = 1X$ with $\lambda = 1$. Therefore, $\begin{bmatrix}-1\\0\\0\\1\end{bmatrix}$ is an eigen vector.
Consider option (B), we have

$$X = \begin{bmatrix}1\\0\\-1\\0\end{bmatrix}$$

Then, $$AX = \begin{bmatrix}-9 & -6 & -2 & -4\\ -8 & -6 & -3 & -1\\ 20 & 15 & 8 & 5\\ 32 & 21 & 7 & 12\end{bmatrix}\begin{bmatrix}1\\0\\-1\\0\end{bmatrix}$$

$$= \begin{bmatrix}-9+2\\-8+3\\20-8\\32-7\end{bmatrix} = \begin{bmatrix}-7\\-5\\12\\25\end{bmatrix}$$

Therefore, $AX \neq \lambda X$ so $\begin{bmatrix}1\\0\\-1\\0\end{bmatrix}$ is not an eigen vector.
Consider option (C), we have

$$X = \begin{bmatrix}-1\\0\\2\\2\end{bmatrix}$$

Then, $$AX = \begin{bmatrix}-9 & -6 & -2 & -4\\ -8 & -6 & -3 & -1\\ 20 & 15 & 8 & 5\\ 32 & 21 & 7 & 12\end{bmatrix}\begin{bmatrix}-1\\0\\2\\2\end{bmatrix}$$

$$= \begin{bmatrix} 9-4-8 \\ 8-6-2 \\ -20+16+10 \\ -32+14+24 \end{bmatrix} = \begin{bmatrix} -3 \\ 0 \\ 6 \\ 6 \end{bmatrix} = 3\begin{bmatrix} -1 \\ 0 \\ 2 \\ 2 \end{bmatrix}$$

Therefore, $AX = 3X$ with $\lambda = 3$ so $\begin{bmatrix} -1 \\ 0 \\ 2 \\ 2 \end{bmatrix}$ is an eigen vector.

Consider option D, we have

$$X = \begin{bmatrix} 0 \\ 1 \\ -3 \\ 0 \end{bmatrix}$$

Then, $$AX = \begin{bmatrix} -9 & -6 & -2 & -4 \\ -8 & -6 & -3 & -1 \\ 20 & 15 & 8 & 5 \\ 32 & 21 & 7 & 12 \end{bmatrix}\begin{bmatrix} 0 \\ 1 \\ -3 \\ 0 \end{bmatrix}$$

$$= \begin{bmatrix} -6+6 \\ -6+9 \\ 15-24 \\ 21-21 \end{bmatrix} = \begin{bmatrix} 0 \\ 3 \\ -9 \\ 0 \end{bmatrix} = 3\begin{bmatrix} 0 \\ 1 \\ -3 \\ 0 \end{bmatrix}$$

Therefore, $AX = 3X$ with $\lambda = 3$ so $\begin{bmatrix} 0 \\ 1 \\ -3 \\ 0 \end{bmatrix}$ is an eigen vector.

Ans. (A, C, D)

44. Consider a system with 2 KB direct mapped data cache with a block size of 64 bytes. The system has a physical address space of 64 KB and a word length of 16 bits. During the execution of a program, four data words P, Q, R, and S are accessed in that order 10 times (i.e., PQRSPQRS…). Hence, there are 40 accesses to data cache altogether. Assume that the data cache is initially empty and no other data words are accessed by the program. The addresses of the first bytes of P, Q, R, and S are 0xA248, 0xC28A, 0xCA8A, and 0xA262, respectively. For the execution of the above program, which of the following statements is/are TRUE with respect to the data cache?

(A) Every access to S is a hit.
(B) Once P is brought to the cache it is never evicted.
(C) At the end of the execution only R and S reside in the cache.
(D) Every access to R evicts Q from the cache.

Solution: Given that,

Cache size = 2 kB

Block size = 64 bytes

Physical address space = 64 kB

Word length = 16 bits

Address of P = 0xA248 = 1010 0010 0100 1000
Address of Q = 0xC28A = 1100 0010 1000 1010
Address of R = 0xCA8A = 1100 1010 1000 1010
Address of S = 0xA262 = 1010 0010 0110 0010
Reference to S leads to cache hit
So, every access to S is a hit.
Therefore, option (A) is TRUE.
Blocks P and S are mapped to same line in cache and block R and Q are also mapped to same line in cache. Thus, S is replaced by P, and Q is replaced by R every time it is loaded.
So once P is brought to cache it is never evicted. Thus, option (B) is TRUE.
Every access to R evicts Q from the cache. Thus option (D) is TRUE.
At the end of execution R and P reside in the cache. So option (C) is FALSE.

Ans. (A, B, D)

45. Consider routing table of an organization's router shown below:

Subnet Number	**Subnet Mask**	**Next Hop**
12.20.164.0	255.255.252.0	R1
12.20.170.0	255.255.254.0	R2
12.20.168.0	255.255.254.0	Interface 0
12.20.166.0	255.255.254.0	Interface 1
Default		R3

Which of the following prefixes in CIDR notation can be collectively used to correctly aggregate all of the subnets in the routing table?

(A) 12.20.164.0/20 (B) 12.20.164.0/22
(C) 12.20.164.0/21 (D) 12.20.168.0/22

Solution: 12.20.164.0/22 and 12.20.168.0/22 can be used to aggregate all of the subnets in the routing table.

Ans. (B, D)

Q. No. 46–55 Multiple Select Question (MSQ) Carry Two Marks Each

46. Consider the relational database with the following four schemas and their respective instances.

`Student(sNo, sName, dNo)` `Dept(dNo, dName)`
`Course(cNo, cName, dNo)` `Register(sNo, cNo)`

Student		
sNo	**sName**	**dNo**
S01	James	D01
S02	Rocky	D01
S03	Jackson	D02
S04	Jane	D01
S05	Milli	D02

Dept	
dNo	**dName**
D01	CSE
D02	EEE

Course		
cNo	**cName**	**dNo**
C11	DS	D01
C12	OS	D01
C21	DE	D02
C22	PT	D02
C23	CV	D03

Register	
sNo	**cNo**
S01	C11
S01	C12
S02	C11
S03	C21
S03	C22
S03	C23
S04	C11
S04	C12
S05	C11
S05	C21

SQL Query:

```
SELECT * FROM Student AS S WHERE NOT EXIST
(SELECT cNo FROM Course WHERE dNo = "D01"
     EXCEPT
SELECT cNo FROM Register WHERE sNo = S.sNo)
```

The number of rows returned by the above SQL query is _____.

Solution: The given SQL query will return all tuples that are enrolled in department D01 for both courses C11 and C12 that are offered by department D01.

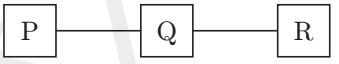
So, row returned by SQL query is

S01	James	D01
S04	Jane	D01

Therefore, two rows are returned.

Ans. (2)

47. Consider a network with three routers P, Q, R shown in the figure below. All the links have cost of unity.



The routers exchange distance vector routing information and have converged on the routing tables, after which the link Q−R fails. Assume that P and Q send out routing updates at random times, each at the same average rate. The probability of a routing loop formation (rounded off to one decimal place) between P and Q, leading to count-to-infinity problem, is _____.

Solution: Here we have two possibilities

1. node Q receives update from node P first. Count infinity problem occurs in this case
2. node P receives update from node Q first. No count-to-infinity problem occurs in this case

Therefore, probability of count-to-infinity

$$\text{Problem} = \frac{1}{2} = 0.5$$

Ans. (0.5)

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

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

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

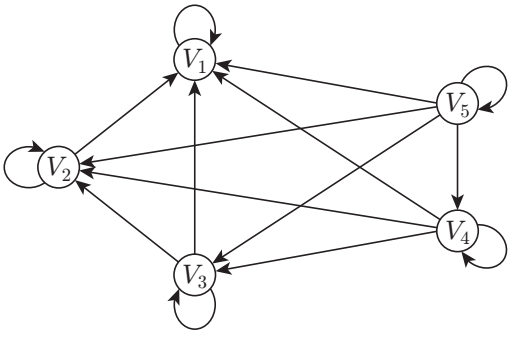
Solution: Given that, $V = \{1, 2, 3, 4, 5\}$ and

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

So, the adjacency matrix is

$$A = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 & 0 \\ 1 & 1 & 1 & 0 & 0 \\ 1 & 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 & 1 \end{bmatrix}$$

Graph of this matrix is



Therefore, number of direct spanning trees rooted at vertex $5 = 4 \times 3 \times 2 \times 1 = 24$

Ans. (24)

49. Consider a 100 Mbps link between an earth station (sender) and a satellite (receiver) at an altitude of 2100 km. The signal propagates at a speed of 3×10^8 m/s. The time taken (in milliseconds, rounded off to two decimal places) for the receiver to completely receive a packet of 1000 bytes transmitted by the sender is _____.

Solution: We have,

Time taken = Transmission time + Propagation time

where, $$\text{Transmission time} = \frac{\text{Packet size}}{\text{Bandwidth}}$$

$$= \frac{1000 \text{ bytes}}{100 \text{ mbps}} = \frac{1000 \times 8}{100 \times 10^6}$$

$$= 0.08 \times 10^{-3} \text{ s} = 0.08 \text{ ms}$$

and $$\text{Propagation time} = \frac{\text{Distance}}{\text{Speed}}$$

$$= \frac{2100 \text{ km}}{3 \times 10^8 \text{ m/s}} = \frac{2100 \times 10^3}{3 \times 10^8}$$

$$= 7 \times 10^{-3} \text{ s} = 7 \text{ ms}$$

Therefore,

$$\text{Time taken} = 0.08 \text{ ms} + 7 \text{ ms} = 7.08 \text{ ms}$$

Ans. (7.08)

50. Consider the data transfer using TCP over a 1 Gbps link. Assuming that the maximum segment lifetime (MSL) is set to 60 seconds, the minimum number of bits required for the sequence number field of the TCP header, to prevent the sequence number space from wrapping around during the MSL is _____.

Solution: Given that,

$$\text{Bandwidth} = 1 \text{ Gbps} = \frac{2^{30}}{8} \text{ bps}$$

Number of bytes transferred in 60 seconds

$$= \frac{2^{30}}{8} \times 60 = 7.5 \times 2^{30}$$

Minimum number of bits required for sequence number field is

$$\text{ceil } (\log(7.5 \times 2^{30})) = \text{ceil } (32.9) = 33$$

Ans. (33)

51. A processor X_1 operating at 2 GHz has a standard 5-stage RISC instruction pipeline having a base CPI (cycles per instruction) of one without any pipeline hazards. For a given program P that has 30% branch instructions, control hazards incur 2 cycles stall for every branch. A new version of the processor X_2 operating at same clock frequency has an additional branch predictor unit (BPU) that completely eliminates stalls for correctly predicted branches. There is neither any savings nor any additional stalls for wrong predictions. There are no structural hazards and data hazards for X_1 and X_2. If the BPU has a prediction accuracy of 80%, the speed up (rounded off to two decimal places) obtained by X_2 over X_1 in executing P is _____.

Solution: We have,

$$\text{Speedp up} = \frac{\text{Execution time of } X_1}{\text{Execution time of } X_2}$$

$$\text{Execution time of } X_1 = \text{CPI} \times \text{cycle time}$$

where, CPI = 1 + number of stalls
So, execution time of $X_1 = (1 + 0.3 \times 2) \times 0.5 = 0.8$ ns
Similarly, execution time of $X_2 = (1 + 0.3\ (1 - 0.8)\ (2))\ 0.5$

$$= (1 + 0.3 \times 0.2 \times 2) \times 0.5 = 0.56 \text{ ns}$$

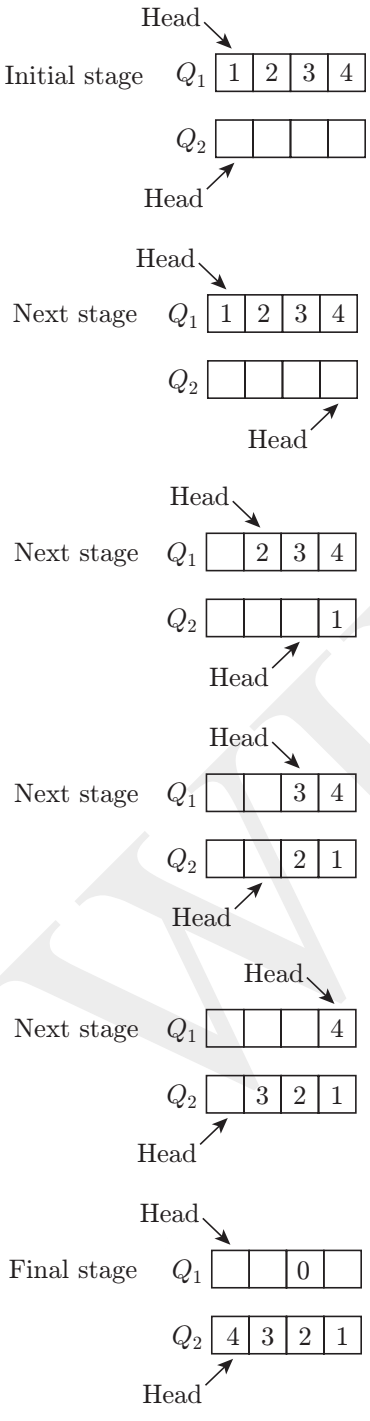
Therefore, $$\text{Speedup} = \frac{0.8}{0.56} = 1.4285 \sim 1.43$$

Ans. (1.43)

52. Consider the queues Q_1 containing four elements and Q_2 containing none (shown as the Initial State in the figure). The only operations allowed on these two queues are `Enqueue(Q,element)` and `Dequeue(Q)`. The minimum number of `Enqueue`

operations on Q_1 required to place the elements of Q_1 in Q_2 in reverse order (shown as the Final State in the figure) without using any additional storage is _____.

Solution: Following is the figure showing stages (initial to final) in the given operation:



No Enqueue operations were required.

Ans. (0)

53. Consider two files systems A and B, that use contiguous allocation and linked allocation, respectively. A file of size 100 blocks is already stored in A and also in B. Now, consider inserting a new block in the middle of the file (between 50^{th} and 51^{st} block), whose data is already available in the memory. Assume that there are enough free blocks at the end of the file and that the file control blocks are already in memory. Let the number of disk accesses required to insert a block in the middle of the file in A and B are n_A and, n_B respectively, then the value of $n_A + n_B$ is _____.

Solution: Consider case 1 of contiguous allocation:
In order to insert a new block in middle of the file we need 50 read operations, 50 write operations and one operation to write the newly inserted block, thus $n_A = 101$.
Consider cases 2 of linked allocation:
In order to insert a new block in operations, we need 50 read operations, one operation to shift the pointer of 50^{th} element and one operation to change pointer of the new element, thus $n_B = 52$

So, $\quad n_A + n_B = 101 + 52 \ = 153$

Ans. (153)

54. Consider a demand paging system with four page frames (initially empty) and LRU page replacement policy. For the following page reference string

7, 2, 7, 3, 2, 5, 3, 4, 6, 7, 7, 1, 5, 6, 1

the page fault rate, defined as the ratio of number of page faults to the number of memory accesses (rounded off to one decimal place) is _____.

Solution: Given page reference string

7, 2, 7, 3, 2, 5, 3, 4, 6, 7, 7, 1, 5, 6, 1

and Page fault rate $= \dfrac{\text{Number of page faults}}{\text{Number of memory access}}$

With four page frame and LRU page replacement policy there are 9 page faults

7	2	7	3	2	5	3	4
↑ page fault	↑ page fault		↑ page fault		↑ page fault		↑ page fault

6	7	7	1	5	6	1
↑ page fault	↑ page fault		↑ page fault	↑ page fault		

Number of memory access = 15

Therefore, $\quad$ Page fault rate $= \dfrac{9}{15} = 0.6$

Ans. (0.6)

55. Consider the following grammar along with translation rules.

$$\begin{aligned}
S &\rightarrow S_1 \# T && \{S_{\bullet val} = S_{1\bullet val} * T_{\bullet val}\} \\
S &\rightarrow T && \{S_{\bullet val} = T_{\bullet val}\} \\
T &\rightarrow T_1 \% R && \{T_{\bullet val} = T_{1\bullet val} \div R_{\bullet val}\} \\
T &\rightarrow R && \{T_{\bullet val} = R_{\bullet val}\} \\
R &\rightarrow id && \{R_{\bullet val} = id_{\bullet val}\}
\end{aligned}$$

Here # and % are operators and *id* is a token that represents an integer and $id_{\bullet val}$ represents the corresponding integer value. The set of non-terminals is $\{S, T, R, P\}$ and a subscripted non-terminal indicates an instance of the non-terminal. Using this translation scheme, the computed value of $S_{\bullet val}$ for root of the parse tree for the expression 20#10%5#8%2%2 is _____.

Solution: Given grammar along with translation rules.

$$\begin{aligned}
S &\rightarrow S_1 \# T && \{S_{\bullet val} = S_{1\bullet val} * T_{\bullet val}\} \\
S &\rightarrow T && \{S_{\bullet val} = T_{\bullet val}\} \\
T &\rightarrow T_1 \% R && \{T_{\bullet val} = T_{1\bullet val} \div R_{\bullet val}\} \\
T &\rightarrow R && \{T_{\bullet val} = R_{\bullet val}\} \\
R &\rightarrow id && \{R_{\bullet val} = id_{\bullet val}\}
\end{aligned}$$

and expression

$$\begin{aligned}
&20\#10\%5\#8\%2\%2 \\
&= 20 * (10 \div 5) * ((8 \div 2) \div 2)) \\
&= 20 * 2 * (4 \div 2) \ = 20 * 2 * 2 \ = 80
\end{aligned}$$

Ans. (80)

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