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GATE 2020
COMPUTER SCIENCE & IT

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Questions and Solutions

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SECTION A : GENERAL APTITUDE

Q.1 Goods and Services Tax (GST) is an indirect tax introduced in India in 2017 that is imposed on the supply of goods and services, and it subsumes all indirect taxes except few. It is a destination-based tax imposed on goods and services used, and it is not imposed at the point of origin from where goods come. GST also has a few components specific to state governments, central government and Union Territories (UTs).
Which one of the following statements can be inferred from the given passage?
(a) GST is imposed on the production of goods and services.
(b) GST does not have a component specific to UT.
(c) GST is imposed at the point of usage of goods and services.
(d) GST includes all indirect taxes.

Ans. **(c)**
According to passage GST is imposed on the supply of goods and services hence option (a) is incorrect which states that GST is imposed on production of goods and services.
In the passage it is mentioned that GST has a two components specific to UTs. So option (b) is incorrect.
Passage states that GST is a destination based tax which means it is imposed at the point of usage of goods and services. Hence (c) is correct.
Option (d) says GST includes all indirect taxes but as per passage it subsumes all indirect taxes **except few**.

End of Solution

Q.2 Raman is confident of speaking English _____ six months as he has been practising regularlythe last three weeks.
(a) for, since
(b) within, for
(c) during, for
(d) for, in

Ans. **(b)**
- 'within' is a preposition that is used to express something that occurs inside a particular period of time.
- 'for' is used here because
  (i) Sentence is in 'present perfect continuous tense'.
  (ii) For is used when we talk about a period of time.

End of Solution

Q.3 If P = 3, R = 27, T = 243, then Q + S = _____.

(a) 110 (b) 80

(c) 90 (d) 40

Ans. **(c)**

P = 3 R = 27 T = 243

P	Q	R	S	T
3^1	3^2	3^3	3^4	3^5

Hence Q + S = 90

End of Solution

Q.4 Two straight lines are drawn perpendicular to each other in X-Y plane. If α and β are the acute angles the straight lines make with the X-axis, then $\alpha + \beta$ is _____.

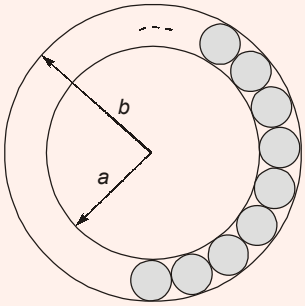
(a) 180° (b) 120°

(c) 90° (d) 60°

Ans. **(c)**

End of Solution

Q.5 The figure below shows an annular ring with outer and inner radii as *b* and *a*, respectively. The annular space has been painted in the form of blue colour circles touching the outer and inner periphery of annular space. If maximum *n* number of circles can be painted, then the unpainted are available in annular space is _____.



(a) $\pi[(b^2 - a^2) + n(b - a)^2]$ (b) $\pi\left[(b^2 - a^2) + \frac{\pi}{4}(b - a)^2\right]$

(c) $\pi[(b^2 - a^2) - n(b - a)^2]$ (d) $\pi\left[(b^2 - a^2) - \frac{\pi}{4}(b - a)^2\right]$

Ans. **(d)**

Unpainted area = Area of annular ring – Area of n blue color circles

Area of annular ring = $\pi b^2 - \pi a^2$

i.e. $\pi(b^2 - a^2)$

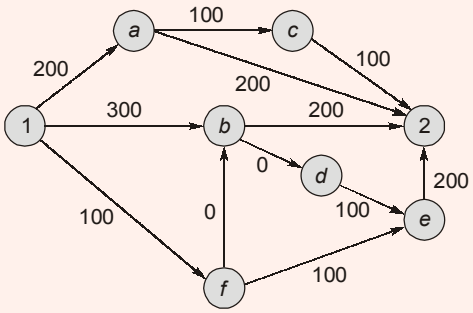
$$\text{Area of 1 blue circle} = \pi\left(\frac{b-a}{2}\right)^2$$

$$\text{Hence, area of } n \text{ blue circles} = n\pi\left(\frac{b-a}{2}\right)^2$$

$$\Rightarrow \quad \text{Unpainted area} = \pi\left[(b^2 - a^2) - \frac{\pi}{4}(b-a)^2\right]$$

End of Solution

Q.6 There are multiple routes to reach from node 1 to node 2, as shown in the network.



The cost of travel on an edge between two nodes is given in rupees. Nodes 'a' 'b', 'c', 'd', 'e' and 'f' are toll booths. The toll price at toll booths marked 'a' and 'c' is Rs. 200. and is Rs. 100 for the other toll booths. Which is the cheapest route from node 1 to node 2?

(a) 1-a-C-2 (b) 1-b-2

(c) 1-f-b-2 (d) 1-f-e-2

Ans. **(c)**

- Cost of 1-a-C-2 : 200 + 200 + 100 + 100 + 100 = 700
- Cost of 1-b-2 : 300 + 100 + 200 = 600
- Cost of 1-f-b-2 : 100 + 100 + 100 + 200 = 500
- Cost of 1-f-e-2 :100 + 100 + 100 + 200 + 200 = 700

Hence, 1-f-b-2 is having minimum cost.

End of Solution

Q.7 His knowledge of the subject was excellent but his classroom performance was _____.

(a) extremely poor
(b) praiseworthy
(c) desirable
(d) good

Ans. **(a)**

'But' is used for introducing an idea which contrasts with the statement that has been already said.

End of Solution

Q.8 Select the word that fits the analogy:

Cook : Cook :: Fly : _____

(a) Flying
(b) Flyer
(c) Flew
(d) Flighter

Ans. **(b)**

(i) Relation is verb : noun

(ii) One who cooks is a cook, similarly one who flies any aircraft is a flyer.

End of Solution

Q.9 The dawn of the 21st century witnessed the melting glaciers oscillating between giving too much and too little to billions of people who depend on their for fresh water. The UN climate report estimates that without deep cuts to man-made emissions, at least 30% of the northern hemisphere's surface permafrost could melt by the end of the century. Given this situation of imminent global exodus of billions of people displaced by rising seas, nation-states need to rethink their carbon footprint for political concerns, if not for environmental ones.

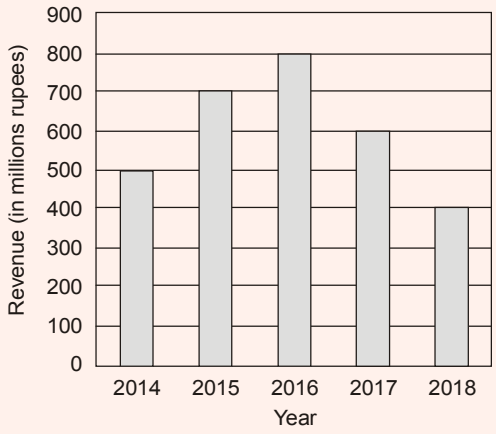
Which one of the following statements can be inferred from the given passage?

(a) Billions of people are affected by melting glaciers.
(b) Billions of people are responsible for man-made emissions.
(c) Nation-states do not have environmental concerns.
(d) Nation-states are responsible for providing fresh water to billions of people.

Ans. **(a)**

End of Solution

Q.10 The total revenue of a company during 2014-2018 is shown in the bar graph. If the total expenditure of the company in each year is 500 million rupees, then the aggregate profit loss (in percentage) on the total expenditure of the company during 2014-2018 is _____.



(a) 16.67% profit
(b) 20% loss
(c) 16.67% loss
(d) 20% profit

Ans. (d)

Total expenditure = 2500 million
Total revenue = 3000 million

So, $\text{profit } \% = \frac{500}{2500} \times 100 = 20\%$

End of Solution

■■■■

SECTION B : COMPUTER SCIENCE & IT

Q.1 Let R be the set of all binary relations on the set {1, 2, 3}. Suppose a relation is chosen from R at random. The probability that the chosen relation is reflexive (round off to 3 decimal places) is _____.

Ans. (0.125)

$$A = \{1, 2, 3\}$$
$$n = |A| = 3$$

$$\text{Number of relations on A} = 2^{n^2} = 2^{3^2} = 2^9$$

$$\text{Number of reflexive relations on A} = 2^{n^2-n} = 2^{3^2-3} = 2^6$$

$$\text{P(reflexive relation)} = \frac{2^6}{2^9} = \frac{1}{8} = 0.125$$

End of Solution

Q.2 Consider a relational database containing the following schemas.

Catalog		
sno	**pno**	**cost**
S1	P1	150
S1	P2	50
S1	P3	100
S2	P4	200
S2	P5	250
S3	P1	250
S3	P2	150
S3	P5	300
S3	P4	250

Supplies		
sno	**sname**	**location**
S1	M/s Royal furniture	Delhi
S1	M/s Balaji furniture	Bangalore
S3	M/s Premium furniture	Chennai

Parts		
pno	**sname**	**part_spec**
P1	Table	Wood
P2	Chair	Wood
P3	Table	Steel
P4	Almirah	Steel
P5	Almirah	Wood

The primary key of each table is indicated by underlining the constituent fields.

```
SELECT  s.sno, s.name
FROM    Suppliers s, Catalogue c
WHERE   s.no = c.sno AND
        cost > (SELECT AVG (cost)
                FROM Catalogue
                WHERE pno = 'P4'
                GROUP BY pno);
```

The number of rows returned by the above SQL query is

(a) 2 (b) 5

(c) 4 (d) 0

Ans. (c)

```
SELECT S.sno, S.sname
   FROM Supplier S, catalog C
   WHERE S.sno = C.sno AND
         cost > (SELECT AVG (cost)
                 FROM Catalog
                 WHERE pno = 'P4' GroupBy pno);
```

Catalog		
sno	**pno**	**cost**
S1	P1	150
S1	P2	50
S1	P3	100
S2	P4	200
S2	P5	250
S3	P1	250
S3	P2	150
S3	P5	300
S3	P4	250

AVG
225

sno	pno	cost
S2	P4	200
S4	P4	250

Results

sno	sname
S1	RF
S2	BF
S3	PF
S3	PF

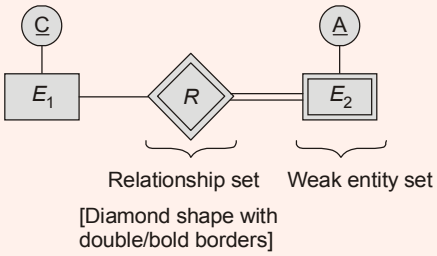
$\therefore$ 4 rows in table.

End of Solution

Q.3 Which one of the following is used to represent the supporting many-ore relationships of a weak entity set in an entity-relationship diagram?

(a) Rectangles with double/bold border
(b) Ovals with double/bold border
(c) Ovals that contain underlined identifiers
(d) Diamonds with double/bold border

Ans. **(d)**



End of Solution

Q.4 Consider allocation of memory to a new process. Assume that none of the existing holes in the memory will exactly fit the process's memory requirement. Hence, a new hole of smaller size will be created if allocation is made in any of the existing holes. Which one of the following statements is TRUE?

(a) The hole created by next fit is never larger than the hole created by best fit.
(b) The hole created by first fit is always larger than the hole created by next fit.
(c) The hole created by best fit is never larger than the hole created by first fit.
(d) The hole created by worst fit is always larger than the hole created by first fit.

Ans. **(c)**

The hole created by best fit is never larger than the hole created by first fit. This is correct option.

End of Solution

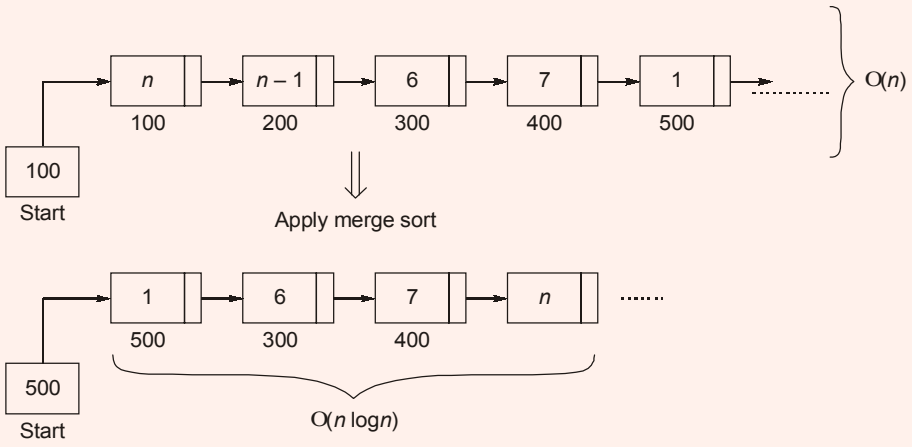
Q.5 What is the worst case time complexity of inserting n elements into an empty linked list, if the linked list needs to be maintained in sorted order?

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

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

Ans. **(a)**

Insert element at the beginning of linked list, take $O(1)$



End of Solution

Q.6 Consider the following C program:

```
#include <stdio.h>
int main( ) {
      int a[4][5] = {{1, 2, 3, 4, 5},
                     {6, 7, 8, 9, 10},
                     {11, 12, 13, 14, 15},
                     {16, 17, 18, 19, 20});
      printf("%d"\n,*(*(a+**a+2)+3));
      return(0);
}
```

The output of the program is _____.

Ans. **(19)**

End of Solution

Q.7 Consider the functions:

I. e^{-x}

II. $x^2 - \sin x$

III. $\sqrt{x^3 - 1}$

Which of the above functions is/are increasing everywhere in [0,1]?

(a) I and III only
(b) II and III only
(c) III only
(d) II only

Ans. **(c)**

$$f(x) = \sqrt{x^3 + 1}$$

$$f'(x) = \frac{1}{\sqrt{x^3 + 1}} \cdot 3x^2 > 0 \text{ in } [0, 1]$$

$\therefore$ Hence it is increasing function.

End of Solution

Q.8 Consider the following statements about process state transitions for a system using preemptive scheduling.

I. A running process can move to ready state.
II. A ready process can move to running state.
III. A blocked process can move to running state.
IV. A blocked process can move to ready state.

Which of the above statements arc TRUE?

(a) I, II, III and IV
(b) II and III only
(c) I, II and III only
(d) I, II and IV only

Ans. **(d)**

Statement I, II and IV are correct.

End of Solution

Q.9 Consider the following statements:

I. If $L_1 \cup L_2$ is regular, then both L_1 and L_2 must be regular.

II. The class of regular languages is closed under infinite union.

Which of the above statements is/are TRUE?

(a) Neither I nor II (b) II only

(c) I only (d) Both I and II

Ans. **(a)**

- If $L_1 \cup L_2$ is regular, then neither needs to be regular.
  Example: $\{a^n b^n\} \cup \{a^n b^n\}^c = (a + b)^*$ is regular but $\{a^n b^n\}$ and its complement both are non-regular.
  So statement I is false.
- The class of regular language is not closed under infinite union.
  Proof: It is was closed under infinite union then
  $a^n b^n = \{\in\} \cup \{ab\} \cup \{aabb\} \cup$ ..... will be infinite union of finite languages (which are regular) and hence will become regular. But we know that $\{a^n b^n \mid n \geq 0\}$ is non-regular.
  So II is false

So option (a), neither I nor II is the correct answer.

End of Solution

Q.10 The preorder traversal of a binary search tree is 15, 10. 12, 11, 20, 18, 16, 19. Which one of the following is the postorder traversal of the tree?

(a) 20, 19, 18, 16, 15, 12, 11, 10 (b) 10, 11, 12, 15, 16, 18, 19, 20

(c) 19, 16, 18, 20, 11, 12, 10, 15 (d) 11, 12, 10, 16, 19, 18, 20, 15

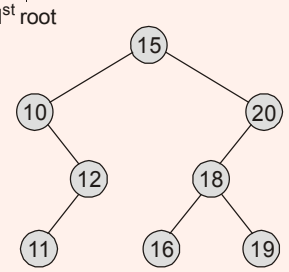
Ans. **(d)**

BST inorder: 10, 11, 12, (15), 16, 18, 19, 20

LST RST

Preorder: (15), 10, 12, 11, 20, 18, 16, 19

I^{st} root



Postorder: 11, 12, 10, 16, 19, 18, 20, 15

End of Solution

Q.11 Consider the following grammar:

$S \rightarrow aSB \mid d$
$B \rightarrow b$

The number of reduction steps taken by a bottom-up parser while accepting the string aaadbbb is _____.

Ans. **(7)**

$S \rightarrow aSB$
$\rightarrow aaSBB$ [$S \rightarrow aSB$]
$\rightarrow aaaSBBB$ [$S \rightarrow aSB$]
$\rightarrow aaadBBB$ [$S \rightarrow d$]
$\rightarrow aaadbBB$ [$B \rightarrow b$]
$\rightarrow aaadbbB$ [$B \rightarrow b$]
$\rightarrow aaadbbb$ [$B \rightarrow b$]
Total 7 steps required.

End of Solution

Q.12 Which one of the following regular expressions represents the set of all binary strings with an odd number of 1's?

(a) (0*10*10*)*0*1
(b) 10* (0*10*10*)*
(c) ((0 + 1)* 1(0 + 1)*1)*10*
(d) (0*10*10*)*10*

Ans. **(*)**

- Regular expression in option (a) is incorrect because it will force the strings to end with 1 and a string of odd number of 1's need not to end with 1.
- Regular expression in option (b) will force it to start with 1 and hence it is incorrect.
- Regular expression in option (c) can create odd number of 1's as well as even number of 1's and hence it is incorrect.
- Regular expression in option (d) is incorrect as it does not generate strings '01' or 1 or more 0 followed by 1 which is having an odd number of 1's.
  Note: Option (d) would be correct only when if the expression were **(0*10*10*)*10* + (0*10*)** means **(0*10*)** missing from the option. Hence option (d) is also incorrect.

End of Solution

Q.13 What is the worst case time complexity of inserting n^2 elements into an AVL-tree with n elements initially?

(a) $\theta(n^4)$ (b) $\theta(n^2 \log n)$

(c) $\theta(n^3)$ (d) $\theta(n^2)$

Ans. **(b)**

AVL with n element: [height balanced [–1, 0, +1] BST]

log$n$ level due to balanced BST.

(i) Every insertion of element:

log$n$: Find place to insert.

log$n$: If property not satisfied do rotation.

$\therefore$ n^2 element insertion:

For 1 element $\equiv$ 2 log$n$

So, for n^2 element $\equiv \theta(n^2 \log n)$

End of Solution

Q.14 Consider the language $L = \{a^n \mid n > 0\} \cup \{a^n b^n \mid n \geq 0\}$ and the following statements.

I. L is deterministic context-free.

II. L is context-free but not deterministic context-free.

III. L is not LL(k) for any k.

Which of the above statements is/are TRUE?

(a) I and III only (b) III only

(c) I only (d) II only

Ans. **(a)**

- Statement I: L in DCFL is true, since $\{a^n\} \cup \{a^n b^n\}$ = regular $\cup$ DCFL = DCFL, by closure property. So II is false and I is true.
- Statement III is true because we cannot write LL(k) grammar, for any value of k, since no matter how many a's are shown to compiler it will be impossible to distinguish between whether the string presented is in the form of $\{a^n\}$ or $\{a^n b^n\}$ and hence the production cannot be chosen uniquely for any value of k.

  So option (a) is correct, I and III only are true.

End of Solution

Q.15 A multiplexer is placed between a group of 32 registers and an accumulator to regulate data movement such that at any given point in time the content of only one register will move to the accumulator, The minimum number of select lines needed for the multiplexer is _____.

Ans. **(5)**

Number of registers = n = 32

Required multiplexer size is n : 1 i.e. 32 : 1

No of select lines required to the multiplexer = m

$\therefore$ $m = \log_2 n$

$m = \log_2 32$

$m = 5$

End of Solution

Q.16 If there are m input lines and n output lines for a decoder that is used to uniquely address a byte addressable 1 KB RAM, then the minimum value of $m + n$ is _____.

Ans. **(1034)**

We need 2^{10} outputs to map 1 KB RAM.

For this we need 10×2^{10} decoder.

Here $m = 10$ and $n = 2^{10}$

$m + n = 1034$

End of Solution

Q.17 A direct mapped cache memory of 1 MB has a block size of 256 bytes. The cache has an access time of 3 ns and a hit rate of 94%. During a cache miss, it takes 20 ns to bring the first word of a block from the main memory, while each subsequent word takes 5 ns. The word size is 64 bits. The average memory access time in ns (round off to 1 decimal place) is _____.

Ans. **(13.5)**

Word size = 64 bit = 8B

Block size = 256B

$\therefore$ $\dfrac{\text{Number of words}}{\text{Block}} = \dfrac{256}{8} = 2^5 (32)$

$T_{avg} = (0.94 \times 3) + (1 - 0.94)\,[3 + 20 + (31 \times 5)]$

$= 13.5$ ns

End of Solution

Q.18 Consider a double hashing scheme in which the primary hash function is $h_1(k) = k \bmod 23$ and the secondary hash function is $h_2(k) = 1 + (k \bmod 19)$. Assume that the table size is 23. Then the address returned by probe 1 in the probe sequence (assume that the probe sequence begins at probe 0) for key value $k = 90$ is _____.

Ans. **(13)**

For double hashing we use the formula as $(h_1(k) + i\, h_2(k))\%$ table size where i denotes probe value.

$$h_1(k) = 90\%\ 23 = 21$$
$$h_2(k) = 1 + k\ \%\ 19$$
$$= 1 + 90\ \%\ 19 = 15$$

For probe 1 the value of i is 1 thus, $(21 + 13)\ \%\ 23 = 13$

End of Solution

Q.19 Consider the following statements about the functionality of an IP based router.

I. A router does not modify the IP packets during forwarding.

II. It is not necessary for a router to implement any routing protocol.

III. A router should reassemble IP fragments if the MTU of the outgoing link is larger than the size of the incoming IP packet.

Which of the above statements is/are TRUE?

(a) I only
(b) I and II only
(c) II and III only
(d) II only

Ans. **(d)**

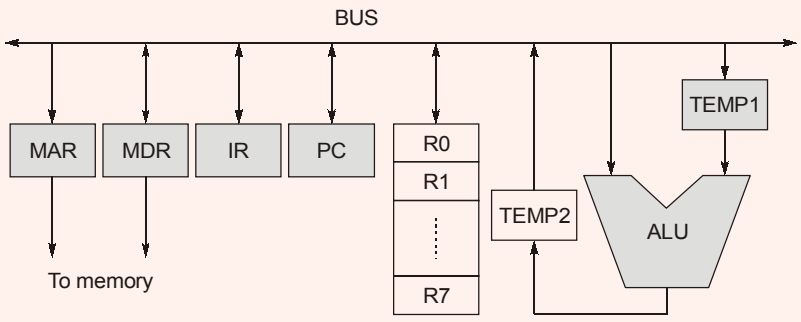
I. A router modifies the IP packets during forwarding because TTL is changing.

II. A router can also be used in LAN network it does not require routing protocol at that time.

III. Packet fragmentation is done if packet size is more than MTU.

End of Solution

Q.20 Consider the following data path diagram.



Consider an instruction: R0 ← R1 + R2. The following steps are used to execute it over the given data path. Assume that PC is incremented appropriately. The subscripts r and w indicate read and write operations, respectively.

1. $R2_r$, $TEMP1_r$, ALU_{add}, $TEMP2_w$
2. $R1_r$, $TEMP1_w$
3. PC_r, MAR_w, MEM_r
4. $TEMP2_r$, $R0_w$
5. MDR_r, IR_w

Which one of the following is the correct order of execution of the above steps?

(a) 3, 5, 1, 2, 4 (b) 2, 1, 4, 5, 3

(c) 1, 2, 4, 3, 5 (d) 3, 5, 2, 1, 4

Ans. **(d)**

1. Send the address to memory via MAR.
2. Read the opcode into IR from the memory via MBR.
3. Send the first operand to Temp1(ALU).
4. Read the second operand directly from the R2 and process the data in ALU and store the result into TEMP2.
5. Store the result into R0.

End of Solution

Q.21 Assume that you have made a request for a web page through your web browser to a web server. Initially the browser cache is empty. Further, the browser is configured to send HTTP requests in non-persistent mode. The web page contains text and five very small images. The minimum number of TCP connections required to display the web page completely in your browser is _____.

Ans. **(6)**

In non persistent HTTP for every objects there is a TCP connection required.
Hence 1 TCP connection for text and 5 TCP connections for images required.
So total 6 connections are required.

End of Solution

Q.22 Let G be a group of 35 elements. Then the largest possible size of a subgroup of G other than G itself is _____.

Ans. **(7)**

Size of group = $O(G) = 35$

Lagranges theorem says if H is subgroup of G then $O(H) \mid O(G)$.

So $O(H)$ can be 1, 5, 7 or 35.

So largest subgroup size other than G itself is 7.

End of Solution

Q.23 Consider the following statements:

I. Daisy chaining is used to assign priorities in attending interrupts.

II. When a device raises a vectored interrupt, the CPU does polling to identify the source of interrupt.

III. In polling, the CPU periodically checks the status bits to know if any device needs its attention.

IV. During DMA, both the CPU and DMA controller can be bus masters at the same time.

Which of the above statements is/are TRUE?

(a) I and III only
(b) I and II only
(c) III only
(d) I and IV only

Ans. **(a)**

End of Solution

Q.24 For parameters a and b, both of which are $\omega(1)$, $T(n) = T(n^{1/a}) + 1$, and $T(b) = 1$. Then $T(n)$ is

(a) $\Theta(\log_2 \log_2 n)$
(b) $\Theta(\log_a \log_b n)$
(c) $\Theta(\log_b \log_a n)$
(d) $\Theta(\log_{ab} n)$

Ans. **(b)**

End of Solution

Q.25 Consider the following statements:

I. Symbol table is accessed only during lexical analysis and syntax analysis.

II. Compilers for programming languages that support recursion necessarily need heap storage for memory allocation in the run-time environment.

III. Errors violating the condition '*any variable must be declared before its use*' are detected during syntax analysis.

Which of the above statements is/are TRUE?

(a) I only
(b) I and III only
(c) I only
(d) None of I, II and III

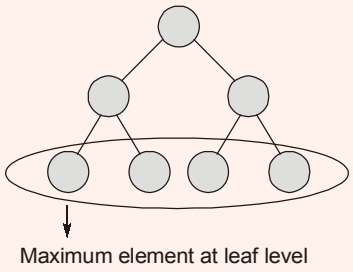
Ans. **(d)**

None of the given statements are correct.

End of Solution

Q.26 Consider the array representation of a binary min-heap containing 1023 elements. The minimum number of comparisons required to find the maximum in the heap _____.

Ans. **(511)**



$$\text{Number of element} = \left\lceil \frac{1023}{2} \right\rceil = 512$$

Now apply bubble sort requires 511 comparisons.

End of Solution

Q.27 Consider a paging system that uses 1-level page table residing in main memory and a TLB for address translation. Each main memory access takes 100 ns and TLB lookup takes 20 ns. Each page transfer to/from the disk takes 5000 ns. Assume that the TLB hit ratio is 95%, page fault rate is 10%. Assume that for 20% of the total page faults, a dirty page has to be written back to disk before the required page is read in from disk. TLB update time is negligible. The average memory access time in ns (round off to 1 decimal places) is _____.

Ans. **(154.5)**

$$\text{EMAT} = 0.95 \times (20 + 100) + 0.05 \times (0.9 \times (20 + 100 + 100) + 0.1 \times [0.2 \times (20 + 100 + 5000 + 5000) + 0.8 \times (20 + 100 + 5000)] = 154.5 \text{ ns}$$

End of Solution

Q.28 Each of a set of n processes executes the following code using two semaphores a and b initialized to 1 and 0, respectively. Assume that count is a shared variable initialized to 0 and not used in CODE SECTION P.

CODE SECTION P

```
wait(a);  count=count+1;
if  (count==n)  signal(b);
signal(a);  wait(b);  signal(b);
```

CODE SECTION Q

What does the code achieve?

(a) It ensures that at most two processes are in CODE SECTION Q at any time.
(b) It ensures that all processes execute CODE SECTION P mutually exclusively.
(c) It ensures that no process executes CODE SECTION Q before every process has finished CODE SECTION P.
(d) It ensures that at most $n - 1$ processes are in CODE SECTION P at any time.

Ans. **(c)**

All the processes running the given code will remain block due to wait(b) until the value of count becomes n.

When the value of count will become equals to n, value of b changes to 1 which will subsequently allow a process to go into section Q.

Hence, no process can go to section Q until all the process executes code section P.

End of Solution

Q.29 Let $G = (V, E)$ be a weighted undirected graph and let T be a Minimum Spanning Tree (MST) of G maintained using adjacency lists. Suppose a new weighted edge $(u, v) \in V \times V$ is added to G. The worst case time complexity of determining if T is still an MST of the resultant graph is

(a) $\Theta(|E||V|)$
(b) $\Theta(|V|)$
(c) $\Theta(|E| + |V|)$
(d) $\Theta(|E| \log |V|)$

Ans. **(b)**

End of Solution

Q.30 Consider the following five disk access requests of the form (request id, cylinder number) that are present in the disk scheduler queue at a given time.

(P, 155), (Q, 85), (R, 110), (S, 30), (T, 115)

Assume the head is positioned at cylinder 100. The scheduler follows Shortest Seek Time First scheduling to service the requests,

Which one of the following statements is FALSE?

(a) R is serviced before P.

(b) T is serviced before P.

(c) Q is serviced after S but before T.

(d) The head reverses its direction of movement between servicing of Q and P.

Ans. **(c)**

End of Solution

Q.31 Consider the following language:

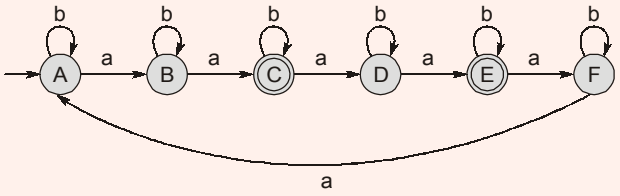
$L = \{x \in \{a, b\}^* \mid$ number of a's in x is divisible by 2 but not divisible by 3$\}$

The minimum number of states in a DFA that accepts L is _____.

Ans. **(6)**

The minimum number of states in a DFA that accepts:

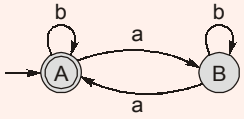
$L = \{x \in \{a, b\}^* \mid$ number of a's is divisible by 2 but not divisible by 3$\}$ is 6 states as shown below:



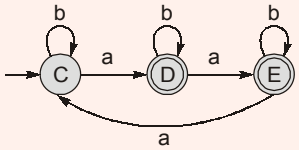
(or) alternatively it can be designed by taking a product automata of

$L_1 = \{x \in \{a, b\}^* \mid$ number of a's divisible by 2$\}$ and $L_2 = \{x \in \{a, b\}^* \mid$ number of a's not divisible by 3$\}$ as shown below:

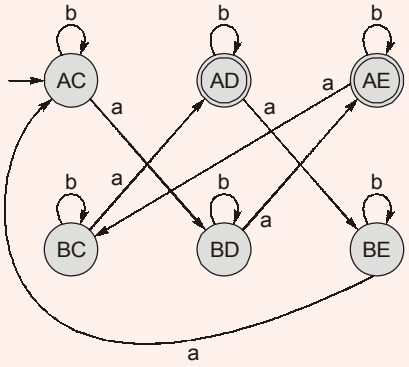
Minimum DFA for L_1:



Minimum DFA for L_2:



Product automata $L_1 \cap L_2$ having six states, shown below:



Which is same as our directly designed machine with 6 states.

End of Solution

Q.32 Consider the following C functions:

```
int tob(int b, int* arr) {
   int i;
   for(i=0, b>0; i++) {
      if(b%2)  arr[i]=1;
      else     arr[i]=0;
      b=b/2;
   }
   return(i);

}
```

```
int pp(int a, int b) {
   int arr[20];
   int i, tot=1, ex, len;
   ex=a;
   len=tob(b,arr);
   for(i=0; i<len; i++) {
      if(arr[i]==1)
         tot=tot * ex;
      ex = ex * ex;
   }
   return(tot);
}
```

The value returned by `pp(3,4)` is _____.

Ans. **(81)**

After executing the given C program integer 81 is returned.

End of Solution

Q.33 Consider a non-pipelined processor operating at 2.5 GHz. It takes 5 clock cycles to complete an instruction. You are going to make a 5-stage pipeline out of this processor. Overheads associated with pipelining force you to operate the pipelined processor at 2 GHz. In a given program, assume that 30% are memory instructions. 60% are ALU instructions and the rest are branch instructions. 5% of the memory instructions cause stalls of 50 clock cycles each due to cache misses and 50% of the branch instructions cause stalls of 2 cycles each. Assume that there are no stalls associated with the execution of ALL) instructions. For this program, the speedup achieved by the pipelined processor over the non-pipelined processor (round off to 2 decimal places) is _____.

Ans. (2.16)

Non-pipeline:

Clock frequency = 2.5 GHz

$$\text{Cycle time} = \frac{1}{2.5\ \text{GHz}} = 0.4\ \text{ns}$$

CPI = 5

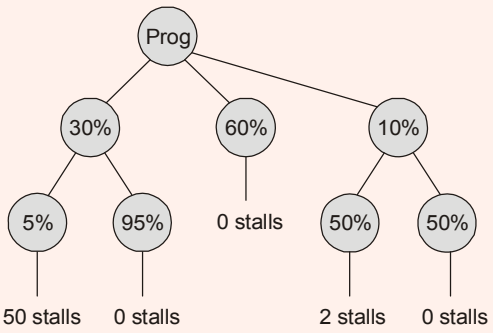
So, $ET_{\text{non-pipe}} = \text{CPI} \times \text{Cycle time}$

$= 5 \times 0.4\ \text{ns} = 2\ \text{ns}$

Pipeline:

Clock frequency = 2.5 GHz

$$\text{Cycle time} = \frac{1}{2\ \text{GHz}} = 0.5\ \text{ns}$$



Number of stalls/instruction = 0.85

Average instruction ET_{pipe} = (1 + Number of stalls/instruction) × Cycle time

$= (1 + 0.85) \times 0.5\ \text{ns} = 0.925\ \text{ns}$

$$S = \frac{ET_{\text{non-pipe}}}{ET_{\text{pipe}}} = \frac{2}{0.925} = 2.16$$

End of Solution

Q.34 Which of the following languages are undecidable? Note that ⟨M⟩ indicates encoding of the Turing machine M.

$L_1 = \{\langle M\rangle \mid L(M) = \phi\}$

$L_2 = \{\langle M, w, q\rangle \mid M \text{ on input } w \text{ reaches state } q \text{ in exactly 100 steps}\}$

$L_3 = \{\langle M\rangle \mid L(M) \text{ is not recursive}\}$

$L_4 = \{\langle M\rangle \mid L(M) \text{ contains at least 21 members}\}$

(a) L_2, L_3 and L_4 only (b) L_1, L_3 and L_4 only

(c) L_1 and L_3 only (d) L_2 and L_3 only

Ans. **(b)**

Rice's theorem applies to L_1, L_3 and L_4 since then have condition based on L(M), which are non-trivial.

L_1 : L(M)= ϕ is non-trivial condition because some Turing machines accept ϕ and some don't.

L_3 : L(M)= non-recursive, is non-trivial because some Turing machines accept non-recursive and some accept recursive.

L_4 : $|L(M)| \geq 21$ is non-trivial since some Turing machines accept more than 21 strings, some accept less.

L_2 : We cannot apply Rice's theorem since condition is not on L(M) but on M reaching a state q in exactly 100 steps which can be checked on a UTM.
So L_2 is decidable.

So, option (b), L_1, L_3 and L_4 are undecidable is correct.

End of Solution

Q.35 Consider a schedule of transactions T_1 and T_2:

T_1	RA			RC		WD		WD	Commit	
T_2		RB	WB		RD		WC			Commit

Here, RX stands for "Read(X)" and WX stands for "Write(X)'". Which one of the following schedules is conflict equivalent to the above schedule?

(a)

T_1					RA	RC	WD	WB	Commit	
T_2	RB	WB	RD	WC						Commit

(b)

T_1				RA	RC	WD	WB		Commit	
T_2	RB	WB	RD					WC		Commit

(c)

T_1	RA	RC	WD	WB					Commit	
T_2					RB	WB	RD	WC		Commit

(d)

T_1	RA	RC	WD				WB		Commit	
T_2				RB	WB	RD		WC		Commit

Ans. **(b)**

T_1	T_2
$r_1(A)$	
	$r_2(B)$
	$w_2(B)$
$r_1(C)$	
	$r_2(D)$
$w_1(D)$	
	$w_2(c)$
$w_1(B)$	
Commit	
	Commit

Conflict equal

$\Longrightarrow$ Conflict equal

T_1	T_2
	$r_2(B)$
	$w_2(B)$
	$r_2(D)$
$r_1(A)$	
$r_1(C)$	
$w_1(D)$	
$w_1(B)$	
	$w_2(c)$
Commit	
	Commit

End of Solution

Q.36 Which one of the following predicate formulae is NOT logically valid?
Note that W is a predicate formula without any free occurrence of x.

(a) $\exists x(p(x) \wedge W) \equiv \exists x\ p(x) \wedge W$ (b) $\forall x(p(x) \rightarrow W) \equiv \forall x\ p(x) \rightarrow W$

(c) $\exists x(p(x) \rightarrow W) \equiv \forall x\ p(x) \rightarrow W$ (d) $\forall x(p(x) \vee W) \equiv \forall x\ p(x) \vee W$

Ans. **(b)**

$\forall x\ (p(x) \rightarrow W) \Rightarrow (\forall x\ p(x)) \rightarrow W$ is true.

But $(\forall x\ p(x)) \rightarrow W \Rightarrow \forall x\ (p(x) \rightarrow W)$ is false.

Since if LHS is true then $(P_1 \wedge P_2 \wedge P_3 \ldots \wedge P_n) \rightarrow W$ will be true and RHS will be false since $P_1 \rightarrow W$, itself will be false, since only P_1 true cannot make W true (we need all the P_1, P_2 ..., P_n to be true to make W true)

So LHS $\Rightarrow$ RHS true and RHS $\Rightarrow$ LHS is false so LHS $\neq$ RHS.

So option (b) is invalid.

Note that option (c) is true because by Boolean algebra,

$$\text{LHS} = \exists x\ (p(x) \rightarrow W) \equiv \exists x\ (\sim p(x) \vee W)$$
$$\equiv \exists x\ (\sim p(x)) \vee W$$
$$\text{RHS} = \forall x\ p(x) \rightarrow W \equiv \sim(\forall x\ p(x)) \vee W$$
$$\equiv \exists x\ \sim p(x) \vee W$$

So LHS = RHS.

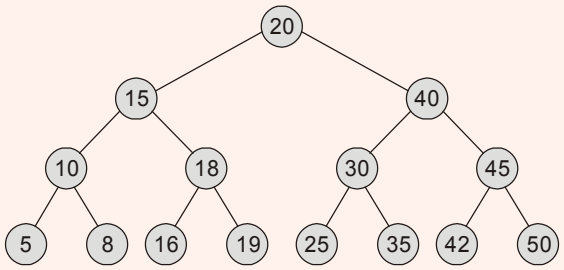
End of Solution

Q.37 In a balanced binary search tree with n elements, what is the worst case time complexity of reporting all elements in range $[a, b]$? Assume that the number of reported elements is k.

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

(c) $\Theta(\log n + k)$ (d) $\Theta(k \log n)$

Ans. **(c)**



Let $a = 16$, $b = 42$

16: Find the '16' element in the BST = $O(\log n)$

42: Find the '42' element in the BST = $O(\log n)$

[16, 42]: Inorder sorted element between 16 to 42

{16, 18, 19, 20, 25, 30, 35, 40, 42} $\Rightarrow$ requires $O(k)$ time for k element

So total time: $O(2 \log n + k) \equiv O(\log n + k)$

End of Solution

Q.38 Consider the following C functions:

```
int fun1(int n) {
   static int i = 0;
   if (n > 0) {
      ++i;
      fun1(n - 1);
   }
   return(i);
}
```

```
int fun2(int n) {
   static int i = 0;
   if (n > 0) {
      i = i + fun1(n);
      fun2(n - 1);
   }
   return(i);
}
```

The return value of fun2 (5) is _____.

Ans. **(55)**

- Variable i is static in both the functions thus its value will persist throughout the program.
- When fun2 (5) gets called, it will first call fun1 with value of n as 5 and then fun2 will gets called with $n = 4$.
- Similarly, same steps are taken for all the upcoming values of n.

End of Solution

Q.39 Consider the productions A → PQ and A → XY. Each of the five non-terminals A, P, Q, X and Y has two attributes: s is a synthesized attribute, and i is an inherited attribute. Consider the following rules.

Rule 1: P.i = A.i + 2, Q.i = P.i + A.i and A.s = P.s + Q.s
Rule 2: X.i = A.i + Y.s and Y.i = X.s + A.i

Which one of the following is TRUE?
(a) Neither Rule 1 nor Rule 2 is L-attributed.
(b) Both Rule 1 and Rule 2 are L-attributed.
(c) Only Rule 1 is L-attributed.
(d) Only Rule 2 is L-attributed.

Ans. **(c)**
Rule 1: It is L-attributed by definition.
Rule 2: It is not L-attributed because this expression (X.i = A.i + Y.s) fails to satisfy the definition of L-attributed.

End of Solution

Q.40 For $n > 2$, let $a \in \{0,1\}^n$ be a non-zero vector. Suppose that x is chosen uniformly at random from $\{0, 1\}^n$. Then, the probability that $\sum_{i=1}^{n} a_i x_i$ is an odd number is _____.

Ans. **(0.5)**

$$a = \begin{bmatrix} a_1 \\ a_2 \\ \vdots \\ a_n \end{bmatrix}, \quad x = \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_n \end{bmatrix}$$

Fixed non-zero

$a_i = 0$ or 1
$x_i = 0$ or 1

$\sum_{i=1}^{n} a_i x_i$ value lies between 0 to n.

Total number cases = 2^n

$a_i x_i$	0	1	2	.....	n
fav	${}^nC_0$	${}^nC_1$	${}^nC_2$	.....	${}^nC_n$

$$P\left[\sum_{i=1}^{n} a_i x_i \text{ is odd}\right] = \frac{{}^nC_1 + {}^nC_3 + \ldots}{2^n} = \frac{2^{n-1}}{2^n} = \frac{1}{2} = 0.5$$

End of Solution

Q.41 Consider a database implemented using B+ tree for file indexing and installed on a disk drive with block size of 4 KB. The size of search key is 12 bytes and the size of tree/ disk pointer is 8 bytes. Assume that the database has one million records. Also assume that no node of the B+ tree and no records are present initially in main memory. Consider that each record fits into one disk block. The minimum number of disk accesses required to retrieve any record in the database is _____.

Ans. **(4)**

Block size = 4 KB

Search key = 12 bytes

Tree pointer = 8 bytes

DB records 1 million = 1000000

B+ tree index each record fits into one block

$\Rightarrow$ Keys given to find levels of B+ tree : Bulk loading B+ tree design we can use

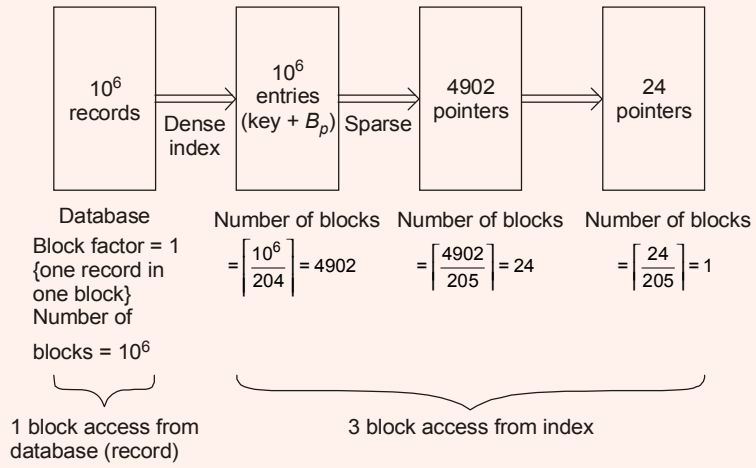
$\Rightarrow$ Order of B tree nodes $P \times B_p + (P - 1)$ Keys $\leq$ Block size

$$P \times 8 + (P - 1)12 \leq 4096$$

$$20P \leq 4108$$

$$P = \left\lfloor \frac{4108}{20} \right\rfloor = 205$$

$\Rightarrow$ Minimum levels and index: Max fill factor of each node.



$\Rightarrow$ Minimum 4 block access required to access record.

End of Solution

Q.42 The number of permutations of the characters in LILAC so that no character appears in its original position, if the two L's are indistinguishable, is _____.

Ans. **(12)**

Since both L's are indistinguishable.

First L's can be arranged in 3 positions 2, 3, or 5 in ${}^3C_2 = 3$ ways as follows:

_ L _ L _

or _ L _ _ L

or _ _ _ L L

Now the letters I, A, C can be deranged in $2 \times 2!$ ways. Example in _ L _ L _. C cannot occupy 5^{th} position, so only 2 ways.

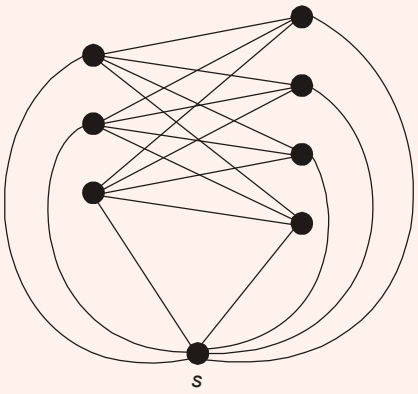
Remaining I and A can be arranged in remaining 2 position in 2! ways = 2 ways.

So answer is $3 \times 2 \times 2! = 12$.

End of Solution

Q.43 Graph G is obtained by adding vertex s to $K_{3,4}$ and making s adjacent to every vertex of $K_{3,4}$. The minimum number of colours required to edge-colour G is _____.

Ans. **(7)**



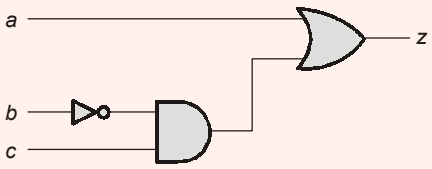
7 edges are touching at S each of which needs to be colors by different color.

So 7 colors minimum are required. All other vertices have less than 7 edges touching.

So 7 colors only are required for edge coloring.

End of Solution

Q.44 Consider the Boolean function $z(a, b, c)$.



Which one of the following minterm lists represents the circuit given above?

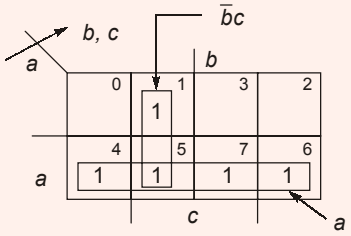
(a) $z = \sum(2, 4, 5, 6, 7)$ (b) $z = \sum(1, 4, 5, 6, 7)$

(c) $z = \sum(0, 1, 3, 7)$ (d) $z = \sum(2, 3, 5)$

Ans. **(b)**

$\therefore \quad z(a, b, c) = a + \bar{b}c$

K-map of the output z is



$\therefore \quad z(a, b, c) = \sum m(1, 4, 5, 6, 7)$

End of Solution

Q.45 A computer system with a word length of 32 bits has a 16 MB byte-addressable main memory and a 64 KB, 4-way set associative cache memory with a block size of 256 bytes. Consider the following tour physical addresses represented in hexadecimal notation.

A1 = 0x42C8A4, A2 = 0x546888, A3 = 0x6A289C, A4 = 0x5E4880

Which one of the following is TRUE?

(a) A1 and A3 are mapped to the same cache set.

(b) A2 and A3 are mapped to the same cache set.

(c) A3 and A4 are mapped to the same cache set.

(d) A1 and A4 are mapped to different cache sets.

Ans. **(b)**

Word length = 32 bit, MM size = 16 MB

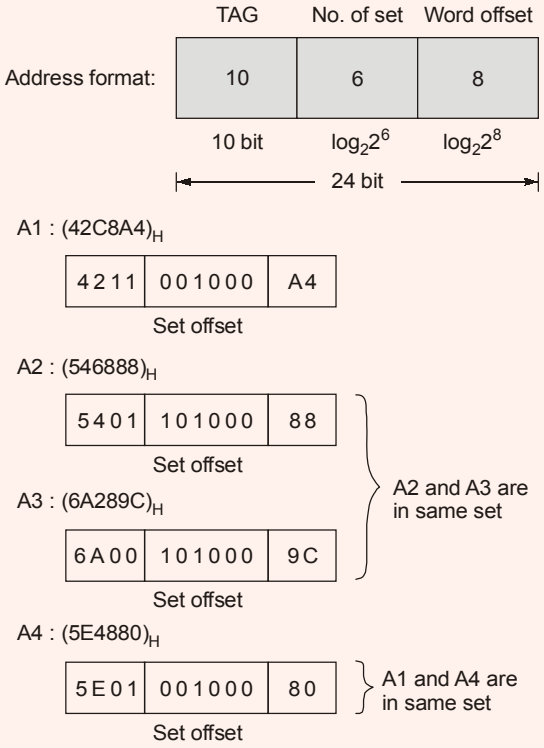
Physical address = 24 bit, CM size = 64 KB

4-way set associative

Block size = 256 B

$$\text{Number of lines (N)} = \frac{64\,\text{K}}{256} \Rightarrow \frac{2^{16}}{2^8} = 2^8$$

$$\text{Number of sets (S)} = \frac{\text{N}}{\text{P-way}} \Rightarrow \frac{2^8}{4} = 2^6$$



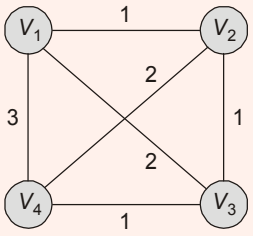
Hence, option (b) is correct choice.

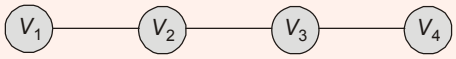
End of Solution

Q.46 Consider a graph $G = (V, E)$, where $V = \{v_2, v_2, ..., v_{100}\}$, $E = \{(v_i, v_j) \mid 1 \le i < j \le 100\}$ and weight of the edge (v_i, v_j) is $|i - j|$. The weight of minimum spanning tree of G is _____.

Ans. **(99)**

Consider small instance of 4-vertices



Clearly,  would be a MST with cost 3.

Hence for 100 vertices, 99 will the weight of minimum spanning tree.

End of Solution

Q.47 Let $G = (V, E)$ be a directed, weighted graph with weight function $w : E \to \mathbb{R}$. For some function $f : V \to \mathbb{R}$, for each edge $(u, v) \in E$, define $w'(u, v)$ as $w(u, v) + f(v)$. Which one of the options completes the following sentence so that it is TRUE?

"The shortest paths in G under w are shortest paths under w' too, _____".

(a) if and only if $f(u)$ is the distance from s to u in the graph obtained by adding a new vertex s to G and edges of zero weight from s to every vertex of G

(b) if and only if $\forall u \in V$, $f(u)$ is positive

(c) if and only if $\forall u \in V$, $f(u)$ is negative

(d) for every $f : V \to \mathbb{R}$

Ans. **(a)**

$$w(u, v) = (u, v) \text{ edge weight}$$

$$w'(u, v) = w(u, v) + \underbrace{f(u) - f(v)}_{0} = w(u, v)$$

So, option (a) correct.

End of Solution

Q.48 Let A and B be two $n \times n$ matrices over real numbers. Let rank(M) and det(M) denote the rank and determinant of a matrix M, respectively. Consider the following statements:

I. rank(AB) = rank(A) rank(B)

II. det(AB) = det(A) det(B)

III. rank(A + B) ≤ rank(A) + rank(B)

IV. det(A + B) ≤ det(A) + det(B)

Which of the above statements are TRUE?

(a) III and IV only (b) II and III only

(c) I and IV only (d) I and II only

Ans. **(b)**

Statement II and III are correct statements directly based on properties of matrices.

End of Solution

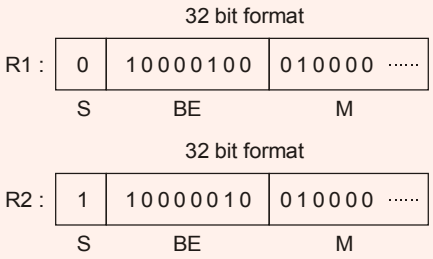
Q.49 Consider three registers R1, R2, and R3 that store numbers in IEEE-754 single precision floating point format. Assume that R1 and R2 contain the values (in hexadecimal notation) 0x42200000 and 0xC1200000, respectively.

If $R3 = \frac{R1}{R2}$, what is the value stored in R3?

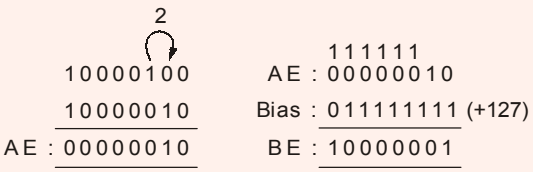
(a) 0xC0800000
(b) 0x40800000
(c) 0x83400000
(d) 0xC8500000

Ans. **(a)**

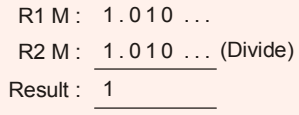
R1: 0x42200000
R2: 0xC1200000



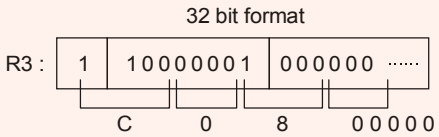
1. Subtract the exponents i.e. divisor exponent from the dividend exponent.



2. Divide the mantissa i.e.



3. Sign (opposite sign division result sign is –ve)



Hence, option (a) is correct answer.

End of Solution

Q.50 Consider the following languages.

$L_1 = \{wxyx \mid w, x, y \in (0 + 1)^+\}$
$L_2 = \{xy \mid x, y \in (a + b)^*, |x| = |y|, x \neq y\}$

Which one of the following is TRUE?

(a) L_1 is regular and L_2 is context-free.
(b) L_1 is context-free hut L_2 is not context-free.
(c) Neither L_1 nor L_2 is context-free.
(d) L_1 is context-free but not regular and L_1 is context-free.

Ans. **(a)**

$L_1 = \{wxyz \mid w, x, y \in (0 + 1)^+\}$ is regular because by putting x as "0" and then "1" we can create a subset $w0y0 + w1y1$

$$r = (0 + 1)^+ 0 (0 + 1)^+ 0 + (0 + 1)^+ 1(0 + 1)^+ 1$$

Which can be shown to cover all other strings obtained by putting x as "00", "01", "10" and "11" etc.

Hence we can write regular expression r to represent given language "L_1" and hence it is regular.

L_2 has strings which can be broken into two parts x and y with not only equal length but also $x \neq y$. The $x \neq y$ involves, string matching which FA cannot do and hence L_2 is not regular.

It is however, context free because even length strings always have $|x| = |y|$. So only one strings matching required and hence CFL.

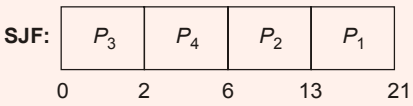
End of Solution

Q.51 Consider the following set of processes, assumed to have arrived at time 0. Consider the CPU scheduling algorithms Shortest Job First (SJF) and Round Robin (RR). For RR, assume that the processes are scheduled in the order P_1, P_2, P_3, P_4.

Processes	P_1	P_2	P_3	P_4
Burst time (in ms)	8	7	2	4

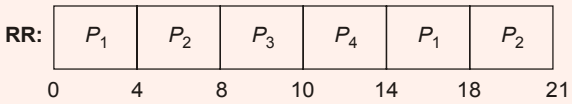
If the time quantum for RR is 4 ms, then the absolute value of the difference between the average turnaround times (in ms) of SJF and RR (round off to 2 decimal places) is _____.

Ans. **(5.25)**



Turn Around Time (TAT) = (21 – 0) + (13 – 0) + (2 – 0) + (6 – 0)

$$\text{Average TAT} = \frac{42}{4} = 10.5$$



Turn Around Time (TAT) = (18 – 0) + (21 – 0) + (10 – 0) + (14 – 0)
= 18 + 21 + 10 + 14

$$\text{Average TAT} = \frac{63}{4} = 15.75$$

Hence, $|\text{SJF (TAT)} - \text{RR(TAT)}|$
$= |10.5 - 15.75| = 5.25$

End of Solution

Q.52 Consider a TCP connection between a client and a server with the following specifications: the round trip time is 6 ns, the size of the receiver advertised window is 50 KB, slow-start threshold at the client is 32 KB, and the maximum segment size is 2 KB. The connection is established at time $t = 0$. Assume that there are no timeouts and errors during transmission. Then the size of the congestion window (in KB) at time $t + 60$ ms after all acknowledgments are processed is _____.

Ans. **(44)**

At time $t = 0$ there are not timeouts
Threshold = 32 KB
MSS = 2 KB
At time $t + 60$, window size = 44

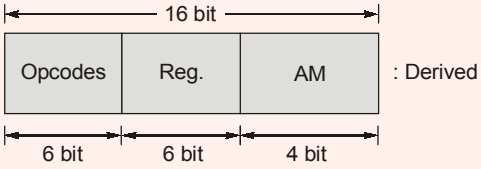
End of Solution

Q.53 A processor has 64 registers and uses 16-bit instruction format. It has two types of instructions: I-type and R-type. Each I-type instruction contains an opcode, a register name, and a 4-bit immediate value. Each R-type instruction contains an opcode and two register names. If there are 8 distinct I-type opcodes, then the maximum number of distinct R-type opcodes is _____.

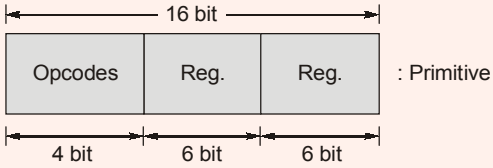
Ans. **(14)**

Given, 16 bit instruction and 64 registers

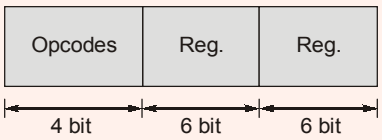
I-type:



R-type:



1. Primitive instruction
   R-type:



2. Number of operation possible = $2^4 = 16$
3. Number of tree opcodes = $(16 - x)$
   Assume x is number of R-type instruction existed.
4. Number of I-type instruction possible = $(16 - x) \times 2^2$

$$8 = 64 - 4x$$

$$4x = 64 - 8 = 56$$

$$x = \frac{56}{4} \Rightarrow 14$$

End of Solution

Q.54 An organization requires a range of IP addresses to assign one to each of its 1500 computers. The organization has approached an Internet Service Provider (ISP) for this task. The ISP uses CIDR and serves the requests from the available IP address space 202.61.0.0/17. The ISP wants to assign an address space to the organization which will minimize the number of routing entries in the ISP's router using route aggregation. Which of the following address spaces are potential candidates from which the ISP can allot any one to the organization?

I. 202.61.84.0/21
II. 202.61.104.0/21
III. 202.61.64.0/21
IV. 202.61.144.0/21

(a) I and IV only
(b) III and IV only
(c) I and II only
(d) II and III only

Ans. **(d)**

$$/17 \Rightarrow 11111111\ 11111111\ 10000000\ 00000000$$
$$\Rightarrow 255.255.128.0$$
$$1500 \simeq 2048 = 2^{11} = 2^3 \times 2^8$$
$$= 2^{32-21} = 2^{11} = /21$$
$$/17 \Rightarrow 202.61.0.0/17$$

$$0.0 \Rightarrow \underline{00000000}.\underline{00000000} \text{ to } \underline{00000111}.\underline{11111111} \quad (0.0 - 7.255)$$
$$\underline{00001000}.\underline{00000000} \text{ to } \underline{00001111}.\underline{11111111} \quad (8.0 - 15.255)$$
$$\underline{00010000}.\underline{00000000} \text{ to } \underline{00010111}.\underline{11111111} \quad (16.0 - 23.255)$$

Sequence is 0, 8, 16, 24, 32, 40, 48, 56, 64, 72, 80, 96, 104, 112, 120.
Hence 64 and 104 is present in sequence so it is the possible IP addresses.
So option (d) is correct.

End of Solution

Q.55 Consider a relational table R that is in 3NF, but not in BCNF. Which one of the following statements is TRUE?

(a) R has a non-trivial functional dependency X $\rightarrow$ A, where X is not a superkey and A is a prime attribute.

(b) R has a non-trivial functional dependency X $\rightarrow$ A, where X is not a superkey and A is a non-prime attribute and X is not a proper subset of any key.

(c) R has a non-trivial functional dependency X $\rightarrow$ A, where X is not a superkey and A is a non-prime attribute and X is a proper subset of some key.

(d) A cell in R holds a set instead of an atomic value.

Ans. **(a)**

R(A, B, C, D, E)

Key: ABC, BCD

FD: $\underbrace{BC}_{x} \rightarrow \underbrace{D}_{A}$: 'x' is not super key and 'A' is prime attribute.

End of Solution

■■■■