BYJU'S EXAM PREP

GATE 2019

Computer Science & Information Technology

Questions & Solutions

SECTION: GENERAL APTITUDE

1. The expenditure on the project _____ as follows: equipment Rs.20 lakhs, salaries Rs.12 lakhs, and contingency Rs.3 lakhs.

A. break down B. break

C. breaks down D. breaks

Ans. C

Sol.

Break down means to separate something into smaller parts. The subject-word agreement states that Singular nouns go with singular verbs while plural nouns go with plural verbs. Expenditure is singular noun, and its plural form is expenditures. The expenditure (**singular noun**) in the project breaks (**singular verb used in the phrase**) down as follows. The above statement satisfies the subject verb agreement and hence, the correct option is C.

2. The search engine's business model _____ around the fulcrum of trust.

A. revolves B. plays

C. sinks D. bursts

Ans. A

Sol.

The search engine business model revolves around the fulcrum of trust.

Fulcrum is anything that plays a central or essential role in an activity, event, or situation.

3. Two cars start at the same time from the same location and go in the same direction. The speed of the first car is 50 km/h and the speed of the second car is 60 km/h. The number of hours it takes for the distance between the two cars to be 20 km is _____.

A. 1 B. 2

C. 3 D. 6

Ans. B

Sol.

Speed of car A = 50 km/hr

Speed of car B = 60 km/hr

Since, both cars A and B are moving in same direction, the relative speed = 60 – 50 = 10 km/hr

Distance required between them = 20 km

$$\therefore \text{Time} = \frac{\text{distance}}{\text{speed}} = \frac{20}{10} = 2\text{hrs}$$

4. Ten friends planned to share equally the cost of buying a gift for their teacher. When two of them decided not to contribute, each of the other friends had to pay Rs 150 more. The cost of the gift was Rs. _____.

A. 666 B. 3000

C. 6000 D. 12000

Ans. C

Sol.

Let share of each student = x

Total cost of gift = 10 * x

10x = 8(x + 150)

10x = 8x + 1200

2x = 1200

x = 600

Thus, Total cost of gift = 10 × 600 = 6000.

5. A court is to a judge as _____ is to a teacher.

A. a student B. a punishment

C. a syllabus D. a school

Ans. D

Sol.

A 'court' is for a 'judge' as a 'school' is for a 'teacher'.

Court is a place where a judge works.

Similarly, school is a place where a teacher works.

6. The police arrested four criminals – P, Q, R and S. The criminals knew each other. They made the following statements:

P says, "Q committed the crime."

Q says, "S committed the crime."

R says, "I did not do it."

S says, "What Q said about me is false."

Assume only one of the arrested four committed the crime and only one of the statements made above is true. Who committed the crime?

A. P B. R

C. S D. Q

Ans. B

Sol.

Case I:

Criminals	P	Q	R	S
Assumption	F	T	F	F
Result	Q_{NC}	S_C	R_C	S_C

S and R are criminal in the result is impossible because only one person committed the crime.

Case II:

Criminals	P	Q	R	S
Assumption	T	F	F	F
Result	Q_C	S_{NC}	R_C	S_C

Q and R are criminal in the result is impossible because only one person committed the crime.

Case III:

Criminals	P	Q	R	S
Assumption	F	F	T	F
Result	Q_{NC}	S_{NC}	R_{NC}	S_C

S_{NC} and S_C in the result which is contradiction. [S committed crime and same time not committed crime which is contradiction]

Case IV:

Criminals	P	Q	R	S
Assumption	F	F	F	T
Result	Q_{NC}	S_{NC}	R_C	S_{NC}

R is criminal in the result.

Alternative way-

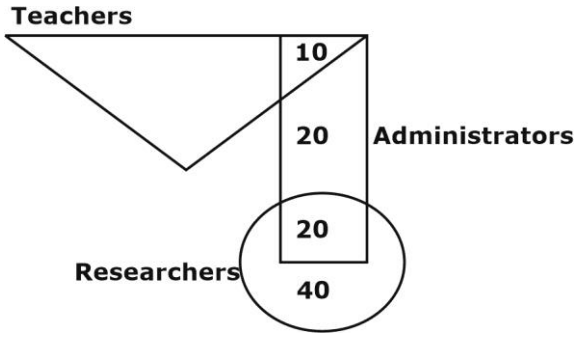
Assuming S is saying the truth.

P says Q committed the crime (FALSE) means Q has not.

Q says S committed the crime (FALSE) means S has not.

R says I did not (FALSE) means R has committed the crime.

7. In the given diagram, teachers are represented in the triangle, researchers in the circle and administrators in the rectangle. Out of the total number of the people, the percentage of administrators shall be in the range of _____.



A. 0 to 15 B. 16 to 30

C. 31 to 45 D. 46 to 60

Ans. C

Sol.

Total number of administrators = 10+20+20 = 50

Now the total number of persons

= 80+20+20+40 = 160

Hence the percentage of administrators required = (50/160) * 100 = 31.25%

∴ **The answer is option C** as 31 to 45 is the correct answer.

8. ."A recent High Court judgement has sought to dispel the idea of begging as a disease — which leads to its stigmatization and criminalization — and to regard it as a symptom. The underlying disease is the failure of the state to protect citizens who fall through the social security net."

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

A. Beggars are lazy people who beg because they are unwilling to work

B. Beggars are created because of the lack of social welfare schemes

C. Begging is an offence that has to be dealt with firmly

D. Begging has to be banned because it adversely affects the welfare of the state

Ans. B

Sol.

The passage states that the underlying disease behind begging is the failure of the state to protect citizens who fall through the social security net.

Thus, Option B can be concluded from the above.

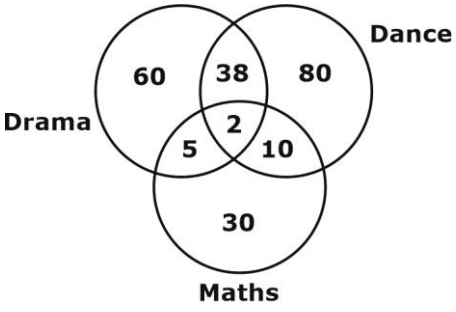
9. In a college, there are three student clubs. Sixty students are only in the Drama club, 80 students are only in the Dance club, 30 students are only in the Maths club, 40 students are in both Drama and Dance clubs, 12 students are in both Dance and Maths clubs, 7 students are in both Drama and Maths clubs, and 2 students are in all the clubs. If 75% of the students in the college are not in any of these clubs, then the total number of students in the college is _____.

A. 1000 B. 975

C. 900 D. 225

Ans. C

Sol.



Total number of students in all three clubs = 60 + 38 + 80 + 5 + 2 + 10 + 30 = 225

Total number of students in the college = X

Given that 75% of students are not of any of these three clubs.

Remaining 25% of X = 225

0.25X = 225 ⇒ X = 225/0.25

= 900

10. Three of the five students allocated to a hostel put in special requests to the warden. Given the floor plan of the vacant rooms, select the allocation plan that will accommodate all their requests.

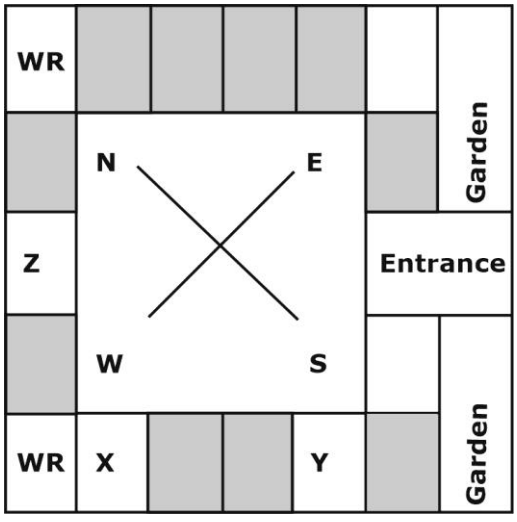
Request by X: Due to pollen allergy, I want to avoid a wing next to the garden.

Request by Y: I want to live as far from the washrooms as possible, since I am very sensitive to smell.

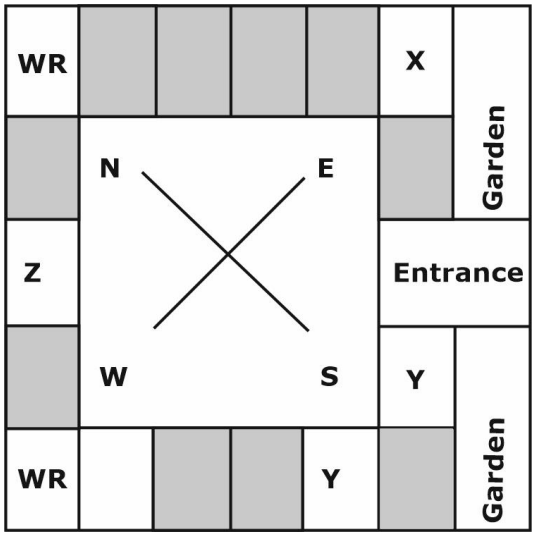
Request by Z: I believe in Vaastu and so want to stay in the South-west wing.

The shaded rooms are already occupied. WR is washroom.

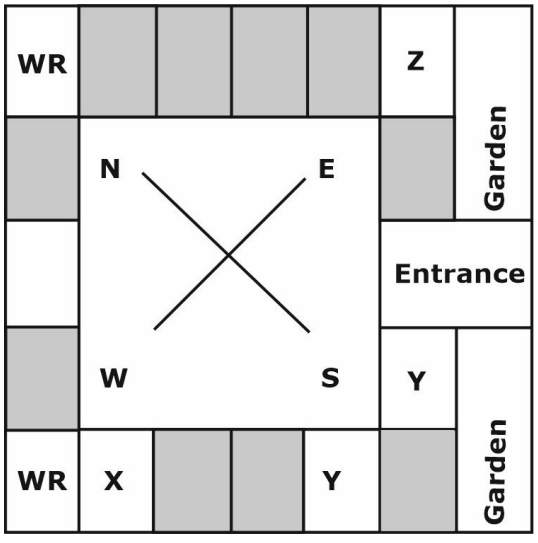
A.



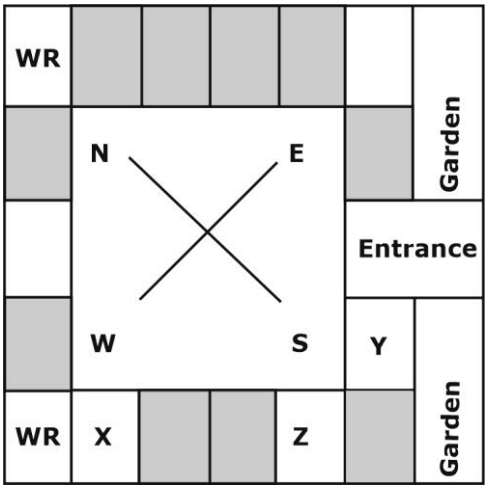
B.



C.



D.



Ans. D

Sol.

In such type of question use the **Option elimination method**

Because of Request from X : Option B is eliminated as it cannot be satisfied in that option.

Because of Request from Y : None of the option can be eliminated as it can is satisfied in all options.

Because of Request from Z : We can select D as an answer because none of the other option satisfy it. So according to conditions mentioned in the question 'D' is the best suited option.

TECHNICAL

1. A particular processor uses a fully associative cache of size 16 kB. The cache block size is 16 bytes. Assume that the main memory is byte-addressable and uses a 32-bit address. How many bits are required for the Tag and the Index fields, respectively, in the addresses generated by the processor?

A. 24 bits and 0 bits B. 28 bits and 4 bits

C. 24 bits and 4 bits D. 28 bits and 0 bits

Ans. D

Sol.

Given that cache is Fully Associative.

There are no index bits in fully associative cache because every main memory block can go to any location in the cache ⟹ Index bits = 0.

Given that memory is byte addressable and uses 32-bit address.

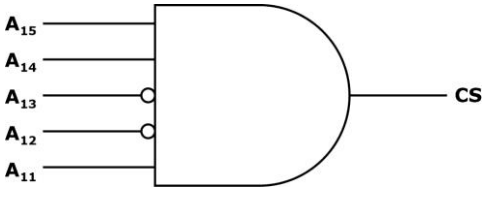
Cache Block size is 16 Bytes ⟹ Number of bits required for Block Offset $=\lceil \log_2 16 \rceil = 4$ bits

∴ Number of Tag bits $=32-4=28$.

So, TAG = 28 bits

Index = 0 bit (No address)

2. The chip select logic for a certain DRAM chip in a memory system design is shown below. Assume that the memory system has 16 address lines denoted by A_{15} to A_0. What is the range of addresses (in hexadecimal) of the memory system that can get enabled by the chip select (CS) signal0?

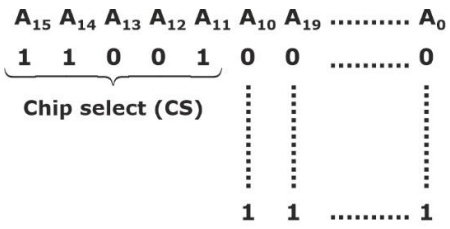


A. C800 to CFFF B. CA00 to CAFF

C. C800 to C8FF D. DA00 to DFFF

Ans. A

Sol.



[C800 to CFFF]

3. Which one of the following kinds of derivation is used by LR parsers?

A. Leftmost B. Leftmost in reverse

C. Rightmost D. Rightmost in reverse

Ans. D

Sol. LR parser is a bottom-up parser. Hence, it uses right most derivation in reverse order.

4. In 16-bit 2's complement representation, the decimal number −28 is:

A. 1111 1111 0001 1100

B. 0000 0000 1110 0100

C. 1111 1111 1110 0100

D. 1000 0000 1110 0100

Ans. C

Sol. +28 ⇒ 0000 0000 0001 1100

−28 ⇒ 1111 1111 1110 0100 (2's complement form)

5. Let U = {1,2,…,n}. Let $A=\{(x, X) \mid x \in X, X \subseteq U\}$. Consider the following two statements on $|A|$.

I. $|A| = n2^{n-1}$

II. $|A| = \sum_{k=1}^{n} k \binom{n}{k}$

Which of the above statements is/are TRUE?

A. Only I B. Only II

C. Both I and II D. Neither I nor II

Ans. C

Sol.

A = {(x, X), x ∈ X and X ⊆ U}

The number of k element subsets of a set U with n elements $= \binom{n}{k} = {}^{n}C_{k}$

The number of possible ordered pairs (x, X) where $x \in X$ is then 2^{n-1} sets. Now, for n elements total $n \cdot 2^{n-1}$ number of order pairs are possible.

Thus, statement I is true .

But since by the combinatoric identity

$$\sum_{k=1}^{n} k \cdot \binom{n}{k} = n.2^{n-41}$$

Statement II is identity similar to statement I, thus also true.

6. Which one of the following is NOT a valid identity?

A. $(x \oplus y) \oplus z = x \oplus (y \oplus z)$

B. $(x + y) \oplus z = x \oplus (y + z)$

C. $x \oplus y = x + y$, if $xy = 0$

D. $x \oplus y = (xy + x'y')'$

Ans. B

Sol.

A. XOR is associative so$(x \oplus y) \oplus z = x \oplus (y \oplus z)$

B. For 2 input, XOR and XNOR are complement to each other, i.e., $x \oplus y = (xy + x'y')'$

C. $x \oplus y = x + y$, if $xy = 0$

Only false statement is option B.

7. If L is a regular language over $\Sigma = \{a, b\}$, which one of the following languages is NOT regular?

A. $L \cdot L^R = \{xy \mid x \in L, y^R \in L\}$

B. $\{ww^R \mid w \in L\}$

C. Prefix $(L) = \{x \in \Sigma^* | \exists y \in \Sigma^*$ such that $xy \in L\}$

D. Suffix $(L) = \{y \in \Sigma^* | \exists x \in \Sigma^*$ such that $xy \in L\}$

Ans. B

Sol.

If L is regular, $L \cdot L^R$ is also regular by closure property.

Suffix (L) and Prefix (L) are also regular by closure property.

However option (b) $\{ww^R | w \in L\}$ need not be regular since if L is an infinite regular language, then $\{ww^R | w \in L\}$ will not only be infinite, but also non-regular. Since it involves string matching and we can increase in length indefinitely and then finite automata FA will run out of memory.

8. Consider Z = X – Y, where X, Y and Z are all in sign-magnitude form. X and Y are each represented in n bits. To avoid overflow, the representation of Z would require a minimum of:

A. n bits

B. n - 1 bits

C. n + 1 bits

D. n + 2 bits

Ans. C

Sol. For example:

Let,

$$\left.\begin{matrix} X = +6, n = 4 \\ Y = -5, n = 4 \end{matrix}\right\} \Rightarrow (X - Y) = +11$$

Hence,

Z = 11 which required 5 bits which is (n + 1) bits

9. Let X be a square matrix. Consider the following two statements on X.

I. X is invertible.

II. Determinant of X is non-zero.

Which one of the following is TRUE?

A. I implies II; II does not imply I.

B. II implies I; I does not imply II.

C. I does not imply II; II does not imply I.

D. I and II are equivalent statements.

Ans. D

Sol. Matrix is invertible if and only if it has nonzero determinant.

And if the matrix has nonzero determinant, we can find the inverse as well.

So, both I and II are equivalent statements.

10. Let G be an arbitrary group. Consider the following relations on G:

R_1: $\forall a, b \in G$, $a\ R_1\ b$ if and only if $\exists g \in G$ such that $a = g^{-1} bg$

R_2: $\forall a, b \in G$, $a\ R_2 b$ if and only if $a = b^{-1}$

Which of the above is/are equivalence relation/relations?

A. R_1 and R_2

B. R_1 only

C. R_2 only

D. Neither R_1 nor R_2

Ans. B

Sol. R_1: $\forall a, b \in G$, $a\ R_1\ b$ if and only if $\exists g \in G$ such that $a = g^{-1} bg$

Reflexive: $a = g^{-1} ag$ can be satisfied by putting g = e, identity "e" always exists in a group.

So, reflexive.

Symmetric: aRb ⇒ a = $g^{-1}bg$ for some g

⇒ b = gag^{-1} = $(g^{-1})^{-1}$ ag^{-1}

g^{-1} always exists for every g ∈ G.

So, symmetric.

Transitive: aRb and bRc ⇒ a = $g1^{-1}bg_1$ and b = g_2^{-1} cg_2 for some g_1g_2∈ G.

Now a = g_1^{-1} $g_2^{-1}cg_2g_1$ = $(g_2g_1)^{-1}cg_2g_1$

g_1∈ G and g_2∈ G ⇒ g_2g_1∈ G since group is closed so aRb and aRb ⇒ aRc hence transitive

Clearly R_1 is equivalence relation.

R_2 is not equivalence it need not even be reflexive, since aR_2 a ⇒ a = a^{-1}∀a which not be true in a group.

R_1 is equivalence relation and thus B is the correct answer.

11. Consider the following two statements about database transaction schedules:

I. Strict two-phase locking protocol generates conflict serializable schedules that are also recoverable.

II. Timestamp-ordering concurrency control protocol with Thomas' Write Rule can generate view serializable schedules that are not conflict serializable.

Which of the above statements is/are TRUE?

A. I only B. II only

C. Both I and II D. Neither I nor II

Ans. C

Sol. I. Strict 2PL guaranteed conflict serializable because of 2PL condition and also strict recoverable.

II. Thomas Write timestamp ordering ensures serializable. Thomas write rule timestamp ordering allowed to execute schedule which is view equal serial schedule based on timestamp ordering.

12. Let G be an undirected complete graph on n vertices, where n > 2. Then, the number of different Hamiltonian cycles in G is equal to

A. n! B. (n – 1)!

C. 1 D. $\frac{(n-1)!}{2}$

Ans. C or D

Sol. In a complete graph we can traverse the n vertices in any order and return to the starting vertex and form a Hamiltonian cycle. The number of such cycles will be n!

However, since circular rotations will have to ignored. Since for example K_4 with vertices {1, 2, 3, 4}, the cycle 1-2-3-4 is same as 2-3-4-1 is same as 3-4-1-2 etc. we now get only (n – 1)! distinct Hamiltonian cycles. Further, the cycle 1-2-3-4 and 1-4-3-2 are also same (clockwise and anticlockwise).

So, ignoring this orientation also we finally get $\frac{(n-1)!}{2}$ distinct Hamiltonian cycles.

However, in gate answer key, the answer key was given as C or D.

13. Compute $\lim_{x\to 3}\frac{x^4-81}{2x^2-5x-3}$

A. 1 B. 53/12

C. 108/7 D. Limit does not exist

Ans. C

Sol. $\lim_{x\to 3}\frac{x^4-81}{2x^2-5x-3}=\frac{0}{0}$ form.

So, apply L'H rule:

$\lim_{x\to 3}\frac{4x^3}{4x-5}=\frac{108}{7}$

14. Which one of the following statements is NOT correct about the B^+ tree data structure used for creating an index of a relational database table?

A. B+ Tree is a height-balanced tree

B. Non-leaf nodes have pointers to data records

C. Key values in each node are kept in sorted order

D. Each leaf node has a pointer to the next leaf node

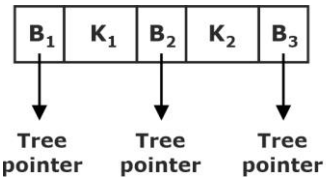
Ans. B

Sol.

B+ tree non leaf node have pointer to data records is false statement.

B+ tree non leaf node consists of only keys and tree pointers (node pointers).

Below is the structure of B+ tree non leaf node



K_1 and K_2 are keys

15. For Σ = {a, b}, let us consider the regular language L = {x |x = a^{2+3k} or x = $b^{10 + 12k}$, k ≥ 0}. Which one of the following can be a pumping length (the constant guaranteed by the pumping lemma) for L?

A. 3 B. 5

C. 9 D. 24

Ans. D

Sol.

L = {a^{2+3k} or $b^{10 + 12k}$} for k ≥ 0

= a^2 (a^3)* or b^{10} (b^{12})*

= {a^2 , a^5 , a^8 , ..., b^{10} , b^{22} , b^{34} .....}

The pumping length is p, then for any string w ∈ L with |w| ≥ p must have a repetition i.e. such a string must be breakable into w = xyz such that |y| ≥ 0 and y can be pumped indefinitely, which is same as saying xyz ∈ L ⇒ xy *z ∈ L.

The minimum pumping length in this language is clearly 11, since b10 is a string which has no repetition number, so upto 10 no number can serve as a pumping length. Minimum pumping length is 11. Any number at or above minimum pumping length can serve as a pumping length. The only number at or above 11, in the choice given is 24.

16. Which of the following protocol pairs can be used to send and retrieve e-mails (in that order)?

A. IMAP, POP3 B. SMTP, POP3

C. SMTP, MIME D. IMAP, SMTP

Ans. B

Sol.

SMTP is push protocol and is used to send email and POP3 is pull protocol i.e. to retrieve email.

17. The following C program is executed on a Unix/Linux system:

```
#include<unistd.h>
int main()
{
int i;
for (i=0; i<10; i++)
if (i%2 == 0) fork();
return 0;
}
```

The total number of child processes created is _____.

Ans. 31

Sol.

Since the if condition will be validated for 5 times as, i=0, 2, 4, 6, 8.

So the number of child processes created is: 2^n-1.

So total processes created are =2^5-1= 31.

18. Consider the following C program:

```
#include <stdio.h>
int jumble(int x, int y){
x=2*x+y;
return x;
}
int main(){
int x=2, y=5;
y=jumble(y,x);
x=jumble(y,x);
printf("%d \n", x);
return 0;
}
```

The value printed by the program is _____.

Ans. 26

Sol.

initially x=2, y=5

jumble (5,2) is called and y will be updated as 12

jumble(12,2) is called and x will updated as 26

So, final value of x=26.

19. Consider the grammar given below:

S → Aa

A → BD

B → b | ϵ

D → d | ϵ

Let a, b, d, and $ be indexed as follows:

a	b	d	$
3	2	1	0

Compute the FOLLOW set of the non-terminal B and write the index values for the symbols in the FOLLOW set in the descending order. (For example, if the FOLLOW set is {a, b, d, $}, then the answer should be 3210)

Ans. 31

Sol.

$S \rightarrow Aa$

$A \rightarrow BD$

$B \rightarrow b \mid \in$

$D \rightarrow d \mid \in$

Follow (B) = {d, a}

Hence their index in descending order is 31.

20. An array of 25 distinct elements is to be sorted using quicksort. Assume that the pivot element is chosen uniformly at random. The probability that the pivot element gets placed in the worst possible location in the first round of partitioning (rounded off to 2 decimal places) is _____.

Ans. 0.08

Sol.

Given an array of 25 distinct elements, and pivot element is chosen uniformly randomly. So, there are only 2 worst case position in the pivot element, that is, it is either first (or) last.

Therefore, required probability is,

= 2/25

= 0.08

21. The value of 3^{51} mod 5 is _____.

Ans. 2

Sol.

By Fermat's theorem

$3^{(5-1)}$ mod 5 = 1

3^4 mod 5 = 1

Now, 3^{51} mod 5 = $(3^4)^{12} \cdot 3^3$ mod 5

= 3^3 mod 5

= 2

22. Two numbers are chosen independently and uniformly at random from the set {1, 2,...,13}. The probability (rounded off to 3 decimal places) that their 4-bit (unsigned) binary representations have the same most significant bit is _____.

Ans. 0.502 to 0.504

Sol.

The binary representation of numbers (1,2,3.....13) in 4-bits:

0 - 0000

1 - 0001

2 - 0010

3 - 0011

4 - 0100

5 - 0101

6 - 0110

7 - 0111

8 - 1000

9 - 1001

10 - 1010

11 - 1011

12 - 1100

13 - 1101

As it can be seen that there are 6 numbers whose MSB is 1, and 7 numbers which start with 0.

So the probability that their 4-bit binary representation have the same MSB is :

= P(MSB is 0) + P(MSB is 1)

= (7*7)/(13*13) + (6*6)/(13*13)

= (49+36)/169

= 85/169

=0.5029

23. Consider three concurrent processes P1, P2 and P3 as shown below, which access a shared variable D that has been initialized to 100

P1	P2	P3
:	:	:
:	:	:
D = D + 20	D = D – 50	D = D + 10
:	:	:
:	:	:

The processes are executed on a uniprocessor system running a time-shared operating system. If

the minimum and maximum possible values of D after the three processes have completed execution are X and Y respectively, then the value of Y – X is _____.

Ans. 80

Sol.

Total possible sequences of execution are: P1 P2 P3, P1 P3 P2, P2 P1 P3, P2 P3 P1, P3 P1 P2 and P3 P2 P1.

Whatever the sequence we will use to execute, we will get 80 as answer.

So, X= 50 and Y= 130

Hence, Y-X = 80

24. Consider the following C program:

```
#include <stdio.h>
int main(){
int arr[]={1,2,3,4,5,6,7,8,9,0,1,2,5},
*ip=arr+4;
printf("%d\n", ip[1]);
return 0;
}
```

The number that will be displayed on execution of the program is _____ .

Ans. 6

Sol.

Here **answer** will be **6.**

ip is an integer pointer. The initial assignment sets it to the element at array index 4 i.e. 5.

Hence ip holds address of array index 4

The next statement refers to the next integer after it which is 6(ip[1]=∗(ip+1))

25. Consider a sequence of 14 elements: A = [−5, −10, 6, 3, −1, −2, 13, 4, −9, −1, 4, 12, −3, 0]. The subsequence sum $S(i,j) = \sum_{k=i}^{j} A[k]$. Determine the maximum of S(i, j), where 0 ≤ i ≤ j < 14. (Divide and conquer approach may be used.)

Ans. 29

Sol.

The maximum sum of the array {6, 3, -1, -2, 13, 4, -9, -1, 4, 12 } which sum up to 29.

26. Consider the following C function.

```
void convert(int n){
if(n<0)
printf("%d",n);
else {
convert(n/2);
printf("%d",n%2);
}
}
```

Which one of the following will happen when the function convert is called with any positive integer n as argument?

A. It will print the binary representation of n and terminate

B. It will print the binary representation of n in the reverse order and terminate

C. It will print the binary representation of n but will not terminate

D. It will not print anything and will not terminate

Ans. D

Sol.

Let n=5,

function calling goes as: convert(5) → convert(2) → convert(1) → convert(0) now when we go for convert(0) then in if condition its mentioned as if(n<0) but our n = 0 , so still the condition is false, it will go into else block and implement convert(0/2) which is convert(0) , so it will go on calling the same way again and again leading to stack overflow.

Hence, the program will not print anything (as after every function call, the value returned is greater than 0) and will not terminate.

27. Consider the following C program:

```
#include<stdio.h>
int r(){
static int num=7;
return num--;
```

}

int main(){

for (r();r();r())

printf("%d",r());

return 0;

}

Which one of the following values will be displayed on execution of the programs?

A. 41 B. 52

C. 63 D. 630

Ans. B

Sol.

for (r();r();r())

printf("%d",r());

before main starts the execution **num** initialized with 7 (note that it is stored under static memory due to it is static number.)

So first r() will return 7 and then 6 will go to second r() which is a condition (why 6 then notice its num-- so first it will return value then decrement , Now second r() which is a condition will return 6 and decrement to 5 ,further as this condition satisfies 5 will go for print :

printf("%d", r());

Now again here there is r() so it will print 5 and decrement again to 4

Which will go to increment/decrement condition of for that is third r() and as we see its a decrement num--

so it will return 4 and decrement to 3 which will again go to second r() and will return 3 with decrementing to 2 and that 2 will go to print r() which will print 2 .

so final print is 52.

28. Consider three machines M, N, and P with IP addresses 100.10.5.2, 100.10.5.5, and 100.10.5.6 respectively. The subnet mask is set to 255.255.255.252 for all the three machines. Which one of the following is true?

A. M, N, and P all belong to the same subnet

B. Only M and N belong to the same subnet

C. Only N and P belong to the same subnet

D. M, N, and P belong to three different subnets

Ans. C

Sol.

Take each IP address and do bitwise AND with given Subnet Mask. If we find the same network ID for the given IP addresses, then it will belong to the same subnet.

Therefore, P and N belong to the same subnet.

Hence, C is correct answer.

29. Suppose that in an IP-over-Ethernet network, a machine X wishes to find the MAC address of another machine Y in its subnet. Which one of the following techniques can be used for this?

A. X sends an ARP request packet to the local gateway's IP address which then finds the MAC address of Y and sends to X.

B. X sends an ARP request packet to the local gateway's MAC address which then finds the MAC address of Y and sends to X

C. X sends an ARP request packet with broadcast MAC address in its local subnet.

D. X sends an ARP request packet with broadcast IP address in its local subnet.

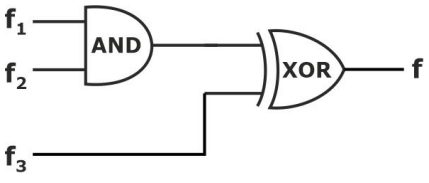
Ans. C

Sol. X sends an ARP request packet with broadcast MAC address in its local subnet

30. Consider three 4-variable functions f_1, f_2, and f_3, which are expressed in sum-of-minterms as:

$f_1 = \Sigma(0, 2, 5, 8, 14)$, $f_2 = \Sigma(2, 3, 6, 8, 14, 15)$, $f_3 = \Sigma (2, 7, 11, 14)$

For the following circuit with one AND gate and one XOR gate, the output function f can be expressed as:



A. Σ (7, 8, 11)

B. Σ (2, 7, 8, 11, 14)

C. Σ (2, 14)

D. Σ (0, 2, 3, 5, 6, 7, 8, 11, 14, 15)

Ans. A

Sol.

$f_1 . f_2 = \Sigma(2, 8, 14)$

$f = f_3 \oplus (f_1 . f_2)$

$= \Sigma(7, 8, 11)$

31. Which one of the following languages over Σ = {a, b}is NOT context-free?

A. $\{ww^R \mid w \in \{a,b\}^*\}$

B. $\{wa^n b^n w^R \mid w \in \{a, b\}^*, n \geq 0\}$

C. $\{wa^n w^R b^n \mid w \in \{a,b\}^*, n \geq 0\}$

D. $\{a^n b^i \mid i \in \{n, 3n, 5n\}, n \geq 0\}$

Ans. C

Sol.

(a) $\{ww^R \mid w \in \{a, b\}^* \}$ is a CFL

(b) $\{wa^n b^n w^R \mid w \in \{a, b\}^*, n \geq 0\}$ is a CFL, since we can first push w, then a's, b's pop with a's and w^R pops with the w. So PDA can accept the language.

(c) $\{wa^n w^R b^n \mid w \in \{a, b\}^*, n \geq 0\}$ is a not CFL because after pushing w, we need to push a's into stack which will stop the w from being matched with w^R. If we don't push a's after w, than later we cannot match with bn. So this language is not acceptable by a PDA and hence not a CFL.

(d) $\{a^n b^i \mid i \in \{n, 3n, 5n\}, n \geq 0\}$

$= a^n b^n \cup a^n b^{3n} \cup a^n b^{5n}$ is CFL since each of the three parts is a CFL and closure under union guarantees that result also is a CFL.

32. Let the set of functional dependencies F = {QR → S, R → P, S → Q} hold on a relation schema X = (PQRS). X is not in BCNF. Suppose X is decomposed into two schemas Y and Z, where Y = (PR) and Z = (QRS).

Consider the two statements given below.

I. Both Y and Z are in BCNF.

II. Decomposition of X into Y and Z is dependency preserving and lossless.

Which of the above statements is/are correct?

A. Both I and II

B. I only

C. II only

D. Neither I nor II

Ans. C

Sol. X(PQRS) {QR → S, R → P, S → Q} decomposed into

Y(PR) Z(QRS)

{R → P} {QR → S, S → Q}

Candidate key : R Candidate key : QR,RS

Relation Y in BCNF Relation Z in 3NF but not in BCNF

Common attribute between Y and Z relations is R which is key for relation Y.

So that given decomposition is lossless join decomposition.

R → P in Y

$\left.\begin{matrix} QR \to S \\ S \to Q \end{matrix}\right\}$ are in Z

and dependency preserving decomposition.

Hence, C is the correct answer.

33. Assume that in a certain computer, the virtual addresses are 64 bits long and the physical addresses are 48 bits long. The memory is word addressable. The page size is 8 kB and the word size is 4 bytes. The Translation Look-aside Buffer (TLB) in the address translation path has 128 valid entries. At most how many distinct virtual addresses can be translated without any TLB miss?

A. 16×2^{10}

B. 256×2^{10}

C. 4×2^{20}

D. 8×2^{20}

Ans. B

Sol. 1 word = 4 bytes

Page size = 8 kB = 2^{13} B

Number of words in 1 page $= \frac{2^{13}}{2^2} = 2^{11}$

TLB can hold 128 valid entries so, at most 128×2^{11} memory address can be addressed without TLB miss.

$128 \times 2^{11} = 256 \times 2^{10}$

34. Consider the following sets:

S1 Set of all recursively enumerable languages over the alphabet {0,1}

S2 Set of all syntactically valid C programs

S3 Set of all languages over the alphabet {0,1}

S4 Set of all non-regular languages over the alphabet {0,1}

Which of the above sets are uncountable?

A. S1 and S2 B. S3 and S4

C. S2 and S3 D. S1 and S4

Ans. B

Sol.

S_1: The set L_{RE} is known to be countably infinite since it corresponds with set of turing machines.

S_2: Since syntactically valid C programs surely run-on Turing machines, this set is also a subset of set of Turing machines, which is countable.

S_3: Set of all languages = 2^{Σ} which is known to be uncountable. Σ^* countably infinite

$\Rightarrow 2^{\Sigma}$ is uncountable.

S_4: Set of all non-regular languages includes set $L_{NOT\ RE}$ which is uncountable infinite and hence is uncountable.

So, S_3 and S_4 are uncountable.

Hence, B is the correct answer.

35. Consider the first order predicate formula φ:

$\forall x\ [(\forall z\ z|x \Rightarrow ((z=x) \vee (z=1))) \Rightarrow \exists w\ (w>x) \wedge (\forall z\ z|w \Rightarrow ((w=z) \vee (z=1)))]$

Here 'a|b' denotes that 'a divides b', where a and b are integers. Consider the following sets:

S1: {1,2, 3,…,100}

S2: Set of all positive integers

S3: Set of all integers

Which of the above sets satisfy φ?

A. S1 and S2 B. S1 and S3

C. S2 and S3 D. S1, S2 and S3

Ans. C

Sol.

$\forall x[\forall z \otimes x \Rightarrow ((z = x) \vee (z = 1)) \Rightarrow \exists w\ (w > x) \wedge (\forall z\ z \otimes w \Rightarrow ((w = z) \vee (z = 1)))]$

The predicate φ simply says that if z is a prime number in the set then there exists another prime number is the set which is larger.

Clearly φ is true in S_2 and S_3 since in set of all integers as well as all positive integers, there is a prime number greater than any given prime number.

However, in S_1 : {1, 2, 3, ...100} φ is false since for prime number 97 ∈ S_1 there exists no prime number in the set which is greater.

So correct answer is C.

36. Consider the following grammar and the semantic actions to support the inherited type declaration attributes. Let X_1, X_2, X_3, X_4, X_5, and X_6 be the placeholders for the non-terminals D, T, L or L1 in the following table:

Production rule	Semantic action
D → T L	X_1.type = X_2.type
T → int	T.type = int
T → float	T.type = float
L → L_1, id	X_3.type = X_4.type addType(id.entry, X_5.type)
L → id	addType(id.entry, X_6.type)

Which one of the following are the appropriate choices for X_1, X_2, X_3 and X_4?

A. X_1 = L, $X_2 = T$, $X_3 = L_1$, $X_4 = L$

B. X_1 = L, $X_2 = L$, $X_3 = L_1$, $X_4 = T$

C. X_1 = L, $X_2 = L$, $X_3 = L_1$, $X_4 = T$

D. X_1 = L, $X_2 = L$, $X_3 = T$, $X_4 = L_1$

Ans. A

Sol.

SDT for inserting type information in the symbol table

D → TL {L.idtype = T.stype}

T → int {T.stype = int}

T → float {T.stype = float}

L → L1, id {L1.itype = L.itype}

addtype(id.entry, L.itype)

L → id addtype(id.entry, L.itype)

37. There are n unsorted arrays: A_1, A_2, …, A_n. Assume that n is odd. Each of A_1, A_2, …, A_n contains n distinct elements. There are no common elements between any two arrays. The worst-case time complexity of computing the median of the medians of A_1, A_2, …, A_n is

A. O(n) B. O(n log n)

C. $O(n^2)$ D. $\Omega(n^2 \log n)$

Ans. C

Sol. Given that all lists are unsorted, therefore we can't apply Binary search.

one way to find median is sorting the list, it takes Θ(nlogn), But without sorting we can find median in O(n).

For one list it takes O(n), then for n-lists it takes O(n2).

So, now median of every list in our hand!

note that these medians are also not sorted!

Therefore, make all these medians as one list, then with in O(n) time we can find the median of medians.

$T.C=O(n^2)+O(n)=O(n^2)$.

38. Let G be any connected, weighted, undirected graph.

I. G has a unique minimum spanning tree, if no two edges of G have the same weight.

II. G has a unique minimum spanning tree, if, for every cut of G, there is a unique minimum-weight edge crossing the cut.

Which of the above two statements is/are TRUE?

A. I only B. II only

C. Both I and II D. Neither I nor II

Ans. C

Sol.

If no two edges of G have same weight surely G will have unique spanning tree is true.

So I is true

Also if, for every cut of G, there is a unique minimum weight edge crossing the cut then G will have unique spanning tree is also true. So II is true

[Note: The converse of II is not true, but that is not relevant to this question]

So, both I and II are true.

39. Consider the following snapshot of a system running n concurrent processes. Process i is holding X_i instances of a resource R, $1 \le i \le n$. Assume that all instances of R are currently in use. Further, for all i, process i can place a request for at most Y_i additional instances of R while holding the X_i instances it already has. Of the n processes, there are exactly two processes p and q such that $Yp = Yq = 0$. Which one of the following conditions guarantees that no other process apart from p and q can complete execution?

A. $X_p + X_q <$ Min $\{Y_k \mid 1 \le k \le n, k \ne p, k \ne q\}$

B. $X_p + X_q <$ Max $\{Y_k \mid 1 \le k \le n, k \ne p, k \ne q\}$

C. Min $(X_p, X_q) \ge$ Min $\{Y_k \mid 1 \le k \le n, k \ne p, k \ne q\}$

D. Min $(X_p, X_q) \le$ Max $\{Y_k \mid 1 \le k \le n, k \ne p, k \ne q\}$

Ans. A

Sol. The process P holds X_p resources currently and it doesn't request any new resources. Therefore, after some time, it will complete its execution and release the resources which it holds.

The process Q holds X_q resources currently and it doesn't request any new resources. Therefore, after some time, it will complete its execution and release the resources which it holds.

Total available resources after completion of P and $Q=X_p+X_q$.

If these resources cannot satisfy any process new requests, then no process will be able to completes its execution.

$X_p+X_q <$ Min$\{Y_k \mid 1 \le k \le n, k \ne p, k \ne q\} \Rightarrow$ delivers that no process going to completes except P and Q.

Answer is (A)

40. Consider the following statements:

I. The smallest element in a max-heap is always at a leaf node.

II. The second largest element in a max-heap is always a child of the root node

III. A max-heap can be constructed from a binary search tree in $\Theta(n)$ time

IV. A binary search tree can be constructed from a max-heap in $\Theta(n)$ time

Which of the above statements are TRUE?

A. I, II and III B. I, II and IV

C. I, III and IV D. II, III and IV

Ans. A

Sol.

The smallest element in a max-heap is always at a leaf node – TRUE because by definition of a max-heap every parent node must be larger than its child node.

The second largest element in a max-heap is always a child of a root node – TRUE. The k^{th} largest element cannot have more than k−1 parents (larger value nodes) and so cannot be lower than level k.

A max heap can be constructed from a binary search tree in Θ(n) time. Build heap for any array of size n (even unsorted) can be done in O(n) time.

Thus, A is the correct answer.

41. Consider the following four processes with arrival times (in milliseconds) and their length of CPU bursts (in milliseconds) as shown below:

Process	P1	P2	P3	P4
Arrival time	0	1	3	4
CPU burst time	3	1	3	Z

These processes are run on a single processor using preemptive Shortest Remaining Time First scheduling algorithm. If the average waiting time of the processes is 1 millisecond, then the value of Z is_____.

Ans. 2

Sol. Till time = 4 units, this is the Gantt chart:

At this point P4 arrives with burst 2 & P3 is in queue with burst 3.

P1 & P2 have executed with P1 incurred delay of 1 unit & P2 with 0 units.

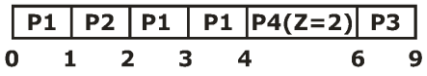
Hence, Average = 0+1+x/4 =1

⇒ x=3, the next delay should be at 3. It would happen if assume Z=2.

It executes and completes at 6.

P3 will wait totally for 3 units.

Hence, Average =1.



Z=2

42. The index node (inode) of a Unix-like file system has 12 direct, one single-indirect and one double-indirect pointers. The disk block size is 4 kB, and the disk block address is 32-bits long. The maximum possible file size is (rounded off to 1 decimal place) _____ GB.

Ans. 4

Sol.

Given 12 direct, 1 single indirect, 1 double indirect pointer.

Size of Disk block = 4kB

Disk Block Address = 32 bit = 4B

Number of addresses = Size of disk block/address size =

Maximum possible file size = 12 * 4kB + 2^{10} * 4kB + 2^{10} * 2^{10} * 4kB

= 4.00395 GB ≃ 4 GB

Hence 4GB is the correct answer.

43. Consider the augmented grammar given below:

S' → S

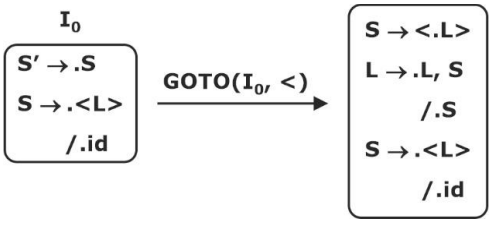
S → ⟨L⟩ | id

L → L, S | S

Let I_0 = CLOSURE ({[S' → •S]}). The number of items in the set GOTO (I_0, ⟨) is: _____.

Ans. 5

Sol.



Total number of items in the set GOTO $(I_0, \langle)$ is 5.

44. Consider the following matrix:

$$R = \begin{pmatrix} 1 & 2 & 4 & 8 \\ 1 & 3 & 9 & 27 \\ 1 & 4 & 16 & 64 \\ 1 & 5 & 25 & 125 \end{pmatrix}$$

The absolute value of the product of Eigen values of R is _____.

Ans. 12

Sol.

Product of eigenvalues is same as the determinant of a matrix.

$$\begin{pmatrix} 1 & 2 & 2^2 & 2^3 \\ 1 & 3 & 3^2 & 3^3 \\ 1 & 4 & 4^2 & 4^3 \\ 1 & 5 & 5^2 & 5^3 \end{pmatrix} = \begin{pmatrix} 1 & 2 & 2^2 & 2^3 \\ 1 & 3-2 & 3^2-2^2 & 3^3-2^3 \\ 1 & 4-2 & 4^2-2^2 & 4^3-2^3 \\ 1 & 5-2 & 5^2-2^2 & 5^3-2^3 \end{pmatrix}$$

$$= (3-2)(4-2)(5-2)\begin{bmatrix} 1 & 5 & 19 \\ 1 & 6 & 28 \\ 1 & 7 & 39 \end{bmatrix}$$

$$= 1.2.3\begin{bmatrix} 1 & 5 & 19 \\ 0 & 1 & 9 \\ 0 & 2 & 20 \end{bmatrix}$$

$$= 1.2.3.2 = 12$$

45. A certain processor deploys a single-level cache. The cache block size is 8 words, and the word size is 4 bytes. The memory system uses a 60-MHz clock. To service a cache miss, the memory controller first takes 1 cycle to accept the starting address of the block, it then takes 3 cycles to fetch all the eight words of the block, and finally transmits the words of the requested block at the rate of 1 word per cycle. The maximum bandwidth for the memory system when the program running on the processor issues a series of read operations is _____× 10^6 bytes/sec.

Ans. 160

Sol.

Time to transfer a cache block =1+3+8=12 cycles.

i.e., 4 bytes ×8=32 bytes in 12 cycles.

So, memory bandwidth =32/12 cycle time=32/ 12/ (60×10^6) = 160×10^6 bytes/s

46. Let T be a full binary tree with 8 leaves. (A full binary tree has every level full.) Suppose two leaves a and b of T are chosen uniformly and independently at random. The expected value of the distance between a and b in T (i.e., the number of edges in the unique path between a and b) is (rounded off to 2 decimal places) _____.

Ans. 4.25

Sol.

See the word "independently" here. It means that choice of 'a' must not affect choice of 'b' and vice versa. This implies that both 'a' and 'b' can even be the same node.

Now, we are given that the binary tree has 8leaves. (2^3=8) ⇒we have 3 levels in the tree starting from 0. The distance I n terms of number of edges between **any two leaf nodes will always be even**. If we consider any two leaves (not necessarily distinct)

- No. of pairs with path length0= 8. (When a=b)
- No. of pairs with path length2=8. (For each of the 8 leaf nodes, we have a pair and since the selection is independent order of the pair is also significant)
- No. of pairs with path length4=16. (For each leaf node we must go two levels up and while coming down we have 2 choices. So, we get 8×2=16 pairs)
- No. of pairs with path length6=32. (For each leaf node we must go till the root, and from there while coming down it has 2×2=4 choices. Thus, we get8×4= 32 pairs.
- Total number of possible pairs=8×8=64

No. of pairs with path length 0=8.

No. of pairs with path length 1=0.

No. of pairs with path length 2=8.

No. of pairs with path length 3=0.

No. of pairs with path length 4=16.

No. of pairs with path length 5=0.

No. of pairs with path length 6=32.

Total number of possible pairs =8×8=64

So, expected path length, E(x),

=0×(8/64)+2×(8/64)+4×(16/64)+6×(32/64)=272/64=4.25

47. Suppose Y is distributed uniformly in the open interval (1, 6). The probability that the polynomial $3x^2 + 6xY + 3Y + 6$ has only real roots is (rounded off to 1 decimal place) _____.

Ans. 0.8

Sol.

It is given that, Polynomial $3x^2 + 6xY + 3Y + 6$ has only real roots

$b^2 - 4ax \geq 0$

$(6Y)^2 - 4(3)(3Y + 6) \geq 0$

$Y^2 - Y - 2 \geq 0$

$Y \in (-\infty, -1] \cap [2, \infty)$

$\Rightarrow Y \in [2, 6)$

Since Y is uniformly distributed in (1, 6)

So, we need to consider the range (2,6).

The probability = (1/ (6-1)) * (6-2) = 1/5 * 4 = 0.8

48. Let Σ be the set of all bijections from {1,….,5} to {1,…,5}, where id denotes the identity function, i.e. id(j) = j, $\forall j$. Let ∘ denote composition on functions. For a string $x = x_1\, x_2 \cdots x_n \in \Sigma^n$, $n \geq 0$, let ɲ $(x) = x_1 \circ x_2 \circ \cdots \circ x_n$.

Consider the language $L = \{x \in \Sigma^* | (x) = id\}$. The minimum number of states in any DFA accepting L is _____.

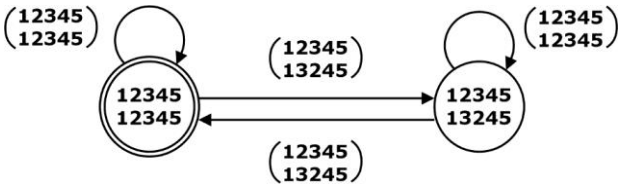
Ans. 120

Sol.

The DFA for accepting L will have 5! = 120 states, since we need one state for every possible permutation function on 5 elements. The starting state will be "id" state, named as $\begin{pmatrix}12345\\12345\end{pmatrix}$ and from there n! arrows will go the n! states each named with a distinct permutation of the set {1, 2, 3, 4, 5}. Since composition of permutation function is closed every arrow has to go to some permutation and hence some state.

Since the language only has those strings where ɲ(x) = id only the starting state ("id" state) will be the final state.

Sample machine with only 2 states is shown below:



49. Consider that 15 machines need to be connected in a LAN using 8-port Ethernet switches. Assume that these switches do not have any separate uplink ports. The minimum number of switches needed is_____.

Ans. 3

Sol. If a switch has 8 ports, then it means it can connect maximum 8 host and 2 switch can connect 16 hosts independently. But we need one port for both, to connect with each other. So, now one- one port is used from both the switches for connecting then total port available or free on both the switch is 7. So maximum 14 host can be connected but for the 15th host we need another switch.

3 switches of ethernet are required to connect 15 computers.

Hence, 3 is correct answer.

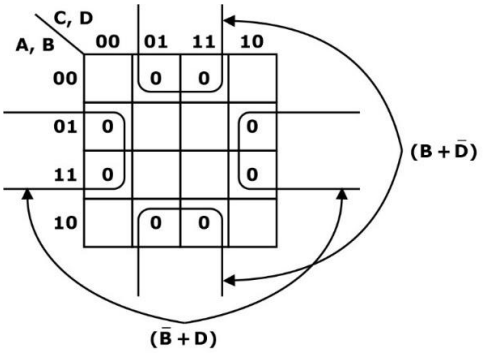
50. What is the minimum number of 2-input NOR gates required to implement a 4-variable function expressed in sum-of-minterms form as f = Σ (0, 2, 5, 7, 8, 10, 13, 15)? Assume that all the inputs and their complements are available.

Ans. 3

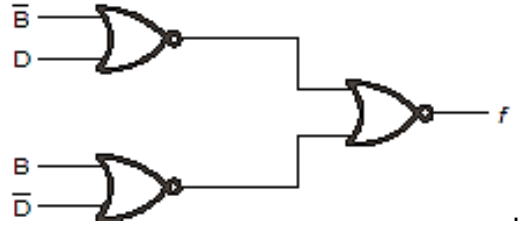
Sol.

$f = \Sigma_m (0, 2, 5, 7, 8, 10, 13, 15)$

$f = \Pi_M(1, 3, 4, 6, 9, 11, 12, 14)$



$$f = (\bar{B} + D)(B + \bar{D})$$



51. A relational database contains two tables Student and Performance as shown below:

Student

Roll_no.	Student_name
1	Amit
2	Priya
3	Vinit
4	Rohan
5	Smita

Performance

Roll_no	Subject_code	Marks
1	A	86
1	B	95
1	C	90
2	A	89
2	C	92
3	C	80

The primary key of the Student table is Roll_no. For the Performance table, the columns Roll_no. and Subject_code together form the primary key. Consider the SQL query given below:

```
SELECT S.Student_name, sum(P.Marks)
FROM Student S, Performance P
WHERE P.Marks > 84
GROUP BY S.Student_name;
```

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

Ans. 5

Sol.

```
SELECT S.Student_name,sum(P.Marks)
FROM Student S,Performance P
WHERE P.Marks>84
GROUP BY S.Student_name;
```

Student	Sum (P.Marks)
Rohan	452
Vinit	452
Priya	452
Amit	452
Smita	452

The number of rows returned is 5.

52. Consider the following C program:

```
#include<stdio.h>
int main () {
float sum = 0.0, j = 1.0, i = 2.0;
while (i/j > 0.0625) {
j = j + j;
sum = sum + i/j;
printf("%f\n", sum);
}
return 0;
}
```

The number of times the variable sum will be printed, when the above program is executed, is _____.

Ans. 5

Sol.

initially j=1.0; i=2.0

1st iteration- i/j=

$\frac{2}{1} = 2 > 0.0625$ true j=1+1=2---> print sum

2nd iteration- i/j=

$\frac{2}{2} = 1 > 0.0625$ true j=2+2=4---> print sum

3rd iteration- i/j= $\frac{2}{4} = 0.5 > 0.0625$

true j=4+4=8---> print sum

4th iteration- i/j= $\frac{2}{8} = 0.25 > 0.0625$

true j=8+8=16--->print sum

5th iteration- i/j= $\frac{2}{16} = 0.125 > 0.0625$

true j=16+16=32---> print sum

6th iteration- i/j= $\frac{2}{32} = 0.0625 \neq 0.0625$ false ---loop terminates

Hence Sum is printed 5 times.

53. Consider the following C program:

```
#include <stdio.h>
int main()
{
int a[] = {2, 4, 6, 8, 10};
int i, sum = 0, *b = a + 4;
for (i = 0; i < 5; i++)
sum = sum + (*b – i) – *(b – i);
printf ("%d\n", sum);
return 0;
}
```

The output of the above C program is _____.

Ans. 10

Sol.

sum=0,∗b=a+4 i.e. pointing to 10

sum=sum+(∗b−i)−∗(b−i)

i=0

sum=0+(10−0)−(10)=0

i=1

sum=0+(10−1)−(8)=1

i=2

sum=1+(10−2)−(6)=3

i=3

sum=3+(10−3)−(4)=6

i=4

sum=6+(10−4)−(2)=10

54. In an RSA cryptosystem, the value of the public modulus parameter n is 3007. If it is also known that $\varphi(n) = 2880$, where $\varphi()$ denotes Euler's Totient Function, then the prime factor of n which is greater than 50 is _____.

Ans. 97

Sol.

n = p × q = 3007

By RSA algorithm, n = 31 × 97 in which 97 is prime factor which greater than 50.

55. Consider the following relations P(X,Y,Z), Q(X,Y,T) and R(Y,V).

P		
X	Y	Z
X1	Y1	Z1
X1	Y1	Z2
X2	Y2	Z2
X2	Y4	Z4

Q		
X	Y	T
X2	Y1	2
X1	Y2	5
X1	Y1	6
X3	Y3	1

R	
Y	V
Y1	V1
Y3	V2
Y2	V3
Y2	V2

How many tuples will be returned by the following relational algebra query?

$$\pi_x\left(\sigma_{(P.Y=R.Y \wedge R.V=V2)}\left(P \times R\right)\right) - \pi_x\left(\sigma_{(Q.Y=R.Y \wedge Q.T>2)}\left(Q \times R\right)\right)$$

Ans. 1

Sol.

$\sigma_{(P.Y=R.Y \wedge R.V=V2)}(P \times R)$

X	Y	Z	V
X2	Y2	Z2	V2

$\Pi_x(\sigma_{(P.Y=R.Y \wedge R.V=V2)}(P \times R))$

X
X2

$\sigma_{(Q.Y=R.Y \wedge Q.T>2)}(Q \times R)$

X	Y	T	V
X1	Y1	6	V1
X1	Y2	5	V3
X1	Y2	5	V2

$\Pi_x(\sigma_{(Q.Y=R.Y \wedge Q.T>2)}(Q \times R))$

Y
X1

$\Pi_x(\sigma_{(P.Y=R.Y \wedge R.V=V2)}(P \times R))$ - $\Pi_x(\sigma_{(Q.Y=R.Y \wedge Q.T>2)}(Q \times R))$

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