MADE EASY

# GATE 2026

## Computer Science-1

**Forenoon Session**

Detailed Solutions

## Exam held on 08-02-2026

**MADE EASY Corporate Office:**

44-A/1, Kalu Sarai, Near Hauz Khas Metro Station, New Delhi-110016

**Centres :** Delhi, Hyderabad, Jaipur, Bhopal, Pune | **www.madeeasy.in** | **Ph: 9021300500**

## SECTION - A GENERAL APTITUDE

Q.1 The antonym of the word protagonist is ________.

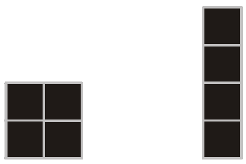
(a) agnostic
(b) antagonist
(c) arsonist
(d) anarchist

Ans. (b)

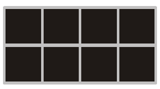
- A protagonist is the main character or leading figure in a story.
- The opposite is the antagonist, who opposes the protagonist.

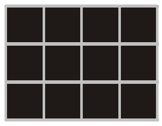
End of Solution

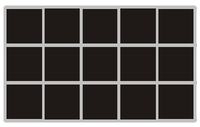
Q.2 The figure shows two 4-tile patterns.

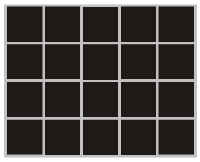


Either one or both of the patterns can be used any number of times and in any orientation to construct a new pattern. Which one of the options below cannot be constructed by using only these two 4-tile patterns assuming there are no overlaps among them?

(a)


(b)


(c)


(d)


Ans. (c)

This is a $3 \times 5$ rectangle

So, total tiles = 15

15 is not divisible by 4

Since each piece covers exactly 4 tiles, we can never form 15 tiles.

End of Solution

**Q.3** Consider a knock-out women's badminton singles tournament where there are no ties. The loser in each game is eliminated from the tournament. Every player plays until she is defeated or remains the last undefeated player. The last undefeated player is declared the winner of the tournament. If there are 64 players in the beginning of the tournament, how many games should be played in total to declare the winner of the tournament?

(a) 127 (b) 64
(c) 63 (d) 32

**Ans.** (c)

Every game eliminates exactly one player.
We start with 64 players.
To get 1 winner, we must eliminate the other 63 players.
So the number of games played equals the number of eliminations.

$$\text{Total games} = n - 1$$
$$= 64 - 1 = 63$$

End of Solution

**Q.4** A student needs to enroll for a minimum of 60 credits. A student cannot enroll for more than 70 credits. The credits are divided amongst project and three distinct sets of courses namely, core courses, specialization courses, and elective courses. It is compulsory for a student to enroll for exactly 15 credits of core courses and exactly 20 credits of project. In addition, a student has to enroll for a minimum of 10 credits of specialization courses. The maximum credits of elective courses that a student can enroll for is ______.

(a) 10 (b) 15
(c) 20 (d) 25

**Ans.** (d)

Given:

Minimum total credits = 60
Maximum total credits = 70
Core courses = Exactly 15 credits
Project = Exactly 20 credits
Specialization courses = Minimum 10 credits
Minimum mandatory credits = 15 + 20 + 10 = 45 credits
So, Maximum electives = 70 − 45 = 25 credits

End of Solution

Q.5 'When the teacher is in the room, all students stand silently.'
If the above statement is true, which one of the following statements is not necessarily true?
(a) If any student is not standing silently, then the teacher is not in the room.
(b) When the teacher is in the room, all students are silent.
(c) If all students are standing, then the teacher is in the room.
(d) When the teacher is in the room, all students are standing.

Ans. (c)
If all students are standing then the teacher must be in the room is not necessarily true, because students might stand for some other reason even when the teacher is absent. Hence, option (c) is not necessarily true.

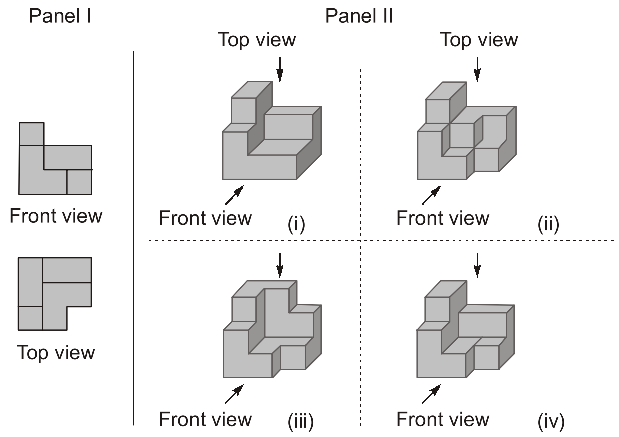
End of Solution

Q.6 Combinatorics deals with problems involving counting. For example, "How many distinct arrangements of N distinct objects in M spaces on a circle are possible?" is a typical problem in combinatorics. This kind of counting is sometimes used in the modeling of several physical phenomena. Often, in such models, the different combinatorial possibilities are assigned probability values. Assigning probabilities enables the computation of the average values of physical quantities.
Consider the following statements:
P : Combinatorics is always invoked in the modeling of physical phenomena.
Q : Modeling some physical phenomena involves assigning probabilities to combinatorial possibilities in order to compute average values of physical quantities.
Based on the passage above, what can be inferred about statements P and Q?
(a) P is False and Q is False
(b) P is False and Q is True
(c) P is True and Q is False
(d) P is True and Q is True

Ans. (b)
The passage says combinations is some times used in modelling physical phenomenal, not always. Therefore statement P, which says it is always invoked, in false.
The passage also clearly states that in some models probabilities are assigned to combinational possibilities to compute average values of physical quantities, which directly supports statement Q. Hence, P is false and Q is true, so the correct answer is option (b).

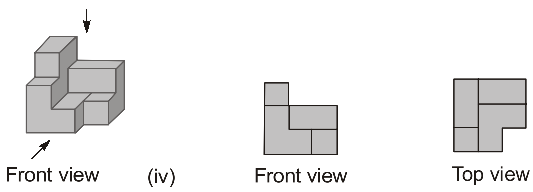
End of Solution

**Q.7** In Panel I of the figure below, the front view and top view of a structure are shown. Which one of the 3D structures shown in Panel II possesses the views shown in Panel I?




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

**Ans. (d)**



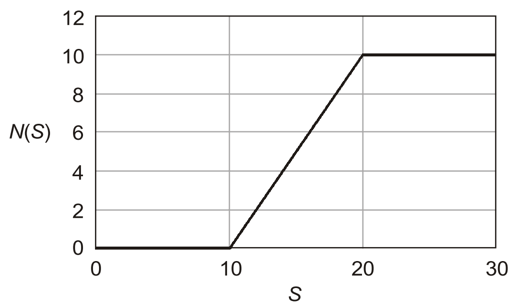

Option (d) is correct because its 3D structure produces the same L-shaped front view with a taller left column and lower right extension and its top view exactly matches the give L-shaped block arrangement without any extra or missing blocks.

*End of Solution*

**Q.8** For positive real numbers $S$ and $K$, the function $H_K(S)$ is defined as: $H_K(S) = \max(S - K, 0)$. The max function is defined as:

$$\max(a, b) = \begin{cases} a, & \text{when } a > b \\ b, & \text{when } a \leq b \end{cases}$$

The graph below shows the plot of a function $N(S)$ versus $S$. $N(S)$ can be expressed as _____.



(a) $H_{10}(S) - H_{20}(S)$
(b) $H_{10}(S) - 2H_{20}(S)$
(c) $-H_{10}(S) + H_{20}(S)$
(d) $H_{15}(S) - H_{20}(S)$

**Ans.** (a)

This exactly matches the graph.

Given: $H_k(S) = \max(S - K, 0)$

$H_{10}(S) = \max(S - 10, 0) \rightarrow$ Starts increasing after 10

$H_{20}(S) = \max(S - 20, 0) \rightarrow$ Starts increasing after 20

If we compute $H_{10}(S) - H_{20}(S)$

Before 10 → Both 0 → Result 0

Between 10 and 20 → Equals S – 10

After 20 → Equals (S – 10) – (S – 20) = 10

End of Solution

**Q.9** In the 2020 summer Olympics' Javelin throw finals, Neeraj Chopra exhibited a spectacular performance to win the gold medal. The silver medal was won by Jakub Vadlejch and the bronze medal was won by Vitezlav Vesely. There were six rounds of throws with each athlete having one throw per round. The best of all the throws of each athlete is considered for the medal. Following were the observations about the throws:

(i) The first and second rounds were dominated by Neeraj Chopra with a gold medal performance in his second throw, while the other two athletes did not have any medal winning throws in these rounds.

(ii) The throws in the last round by both Jakub Vadlejch and Vitezlav Vesely were fouls and were not considered for scoring.

(iii) After four rounds, Vitezlav Vesely was in the second position and could not improve upon his best throw in the succeeding rounds.

(iv) In the fourth round, the throw by Jakub Vadlejch was the best in that round.

In which round did Vitezlav Vesely have his best throw?

(a) Third
(b) Fourth
(c) Fifth
(d) Sixth

**Ans.** (a)

- Neeraj's gold - wining throw was in round 2, So no one else's best throw was in rounds 1 or 2.
- After four rounds, Vesely was in second position and could not improve later, so his best throw occurred in one of the first four rounds.
- In round 4, the best throw was by Jakub, so Vesely's best was not in round 4. Therefore, Vesely's best throw must have been in round 3.

End of Solution

**Q.10** An unbiased six-faced dice whose faces are marked with numbers 1, 2, 3, 4, 5, and 6 is rolled twice in succession and the number on the top face is recorded each time. The probability that the number appearing in the second roll is an integer multiple of the number appearing in the first roll is ________

(a) $\frac{1}{6}$
(b) $\frac{5}{18}$
(c) $\frac{7}{18}$
(d) $\frac{5}{6}$

**Ans.** (c)

Total outcomes when rolling twice = $6 \times 6 = 36$

Count favorable cases whereas second number is a multiple of the first:

If first roll is 1 $\rightarrow$ Multiples : 1, 2, 3, 4, 5, 6 $\rightarrow$ 6
If first roll is 2 $\rightarrow$ Multiples : 2, 4, 6 $\rightarrow$ 3
If first roll is 3 $\rightarrow$ Multiples : 3, 6 $\rightarrow$ 2
If first roll is 4 $\rightarrow$ Multiples : 4 $\rightarrow$ 1
If first roll is 5 $\rightarrow$ Multiples : 5 $\rightarrow$ 1
If first roll is 6 $\rightarrow$ Multiples : 6 $\rightarrow$ 1

Total favourable = $6 + 3 + 2 + 1 + 1 + 1 = 14$

$$\text{Probability} = \frac{14}{16} = \frac{7}{18}$$

*End of Solution*

■■■■

## SECTION - B TECHNICAL

**Q.11** An urn contains one red ball and one blue ball. At each step, a ball is picked uniformly at random from the urn, and this ball together with another ball of the same color is put back in the urn. The probability that there are equal number of red and blue balls after two steps is

(a) $\frac{1}{4}$ (b) $\frac{1}{3}$

(c) $\frac{1}{2}$ (d) $\frac{2}{3}$

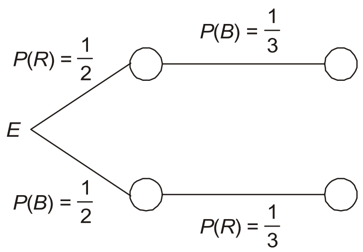
**Ans.** (b)

1 red, 1 blue

$\therefore$ $\boxed{\begin{matrix}1R \\ 1B\end{matrix}}$

$E_1 \rightarrow$ drawing red in 1st and blue in 2nd trial.

$E_2 \rightarrow$ drawing blue in 1st and red in 1st trial.




$$\therefore \quad P(E) = \frac{1}{2}\times\frac{1}{3}+\frac{1}{2}\times\frac{1}{3} = \frac{1}{2}\left[\frac{2}{3}\right] = \frac{1}{3}$$

End of Solution

**Q.12** Consider $4 \times 4$ matrices with their elements from $\{0, 1\}$. The number of such matrices with even number of 1s in every row and every column is

(a) 512
(b) 1025
(c) 1023
(d) 255

**Ans.** (a)

Total number of $4 \times 4$ binary matrices

Each entry can be 0 or 1.

$$\text{Total matrices} = 2^{16}$$

Even number of 1s in each row

Consider one row.

Each row has 4 entries.

$$\text{Total possible rows} = 2^4 = 16$$

Exactly half of them have even number of 1s.

$$\text{Even parity rows} = \frac{2^4}{2} = 2^3 = 8$$

For 4 rows:

Matrices with even parity in all rows $= (2^3)^4 = 2^{12}$

Now impose column conditions at this stage: $2^{12}$ matrices satisfy row parity.

Now observe:

If the first 3 columns have even number of 1s, then automatically the 4th column will also have even number of 1s.

Reason:

Total sum of all entries = Sum of row sums

Since every row sum is even,

Total sum is even

If first 3 columns are even, their total is even.

Thus 4th column must also be even.

Hence only 3 independent column conditions.

Each column condition halves the count.

$2^{12} \rightarrow 2_{11} \rightarrow 2_{10} \rightarrow 2^9$

End of Solution

**Q.13** For $n > 1$, the maximum multiplicity of any eigenvalue of an $n \times n$ matrix with elements from $\mathbb{R}$ is

(a) $n$
(b) $n - 1$
(c) 1
(d) $n + 1$

**Ans.** (a)

For $n > 1$, multiplicity of $\lambda$ = arithmetic mean of $\lambda$.

Any $\lambda$ can repeat maximum '$n$' number of times.

End of Solution

**Q.14** Match each addressing mode in **List I** with a data element or an element of a data structure (in a high-level language) in **List II**:

| List I | | List II | |
|---|---|---|---|
| **P.** | Immediate | **1.** | Element of an array |
| **Q.** | Indirect | **2.** | Pointer |
| **R.** | Base with index | **3.** | Element of a record |
| **S.** | Base with offset/displacement | **4.** | Constant |

(a) P–4, Q–3, R–1, S–2
(b) P–4, Q–2, R–1, S–3
(c) P–1, Q–4, R–3, S–2
(d) P–2, Q–3, R–1, S–4

**Ans.** (b)

- Immediate AM → Constants
- Indirect AM → Pointers
- Base with index AM → Element of an array
- Base with offset/displacement AM → Element of a record

*End of Solution*

**Q.15** Consider a processor P whose instruction set architecture is the load-store architecture. The instruction format is such that the first operand of any instruction is the destination operand.
Which one of the following sequences of instructions corresponds to the high-level language statement Z = X + Y?
**Note:** X, Y, and Z are memory operands. R0, R1, and R2 are registers.

(a) ADD Z, X, Y

(b) LOAD R0, X
ADD Z, R0, Y

(c) ADD R0, X, Y
STORE Z, R0

(d) LOAD R0, X
LOAD R1, Y
ADD R2, R0, R1
STORE Z, R2

**Ans.** (d)

Load-store architecture is a reg-reg reference CPU organization so, both of the ALU operands are always required in the registers.
LOAD R0, X
LOAD R1, Y
ADD R2, R0, R1
STORE Z, R2

*End of Solution*

Q.16 Which one of the following dependencies among the register operands of different instructions can cause a data hazard in a pipelined processor?
(a) Read-after-read
(b) Read-after-write
(c) Write-after-read
(d) Write-after-write

Ans. (b)

By default program execution sequence is inorder execution.
So, true data dependency causes the RAW hazard.
Here, WAR and WAW hazards are not considered because these dependencies are out-of-order execution dependencies.

End of Solution

Q.17 Consider the following recurrence relations:
For all $n > 1$,

$$T_1(n) = 4T_1\left(\frac{n}{2}\right) + T_2(n)$$

$$T_2(n) = 5T_2\left(\frac{n}{4}\right) + \theta(\log_2 n)$$

Assume that for all $n \le 1$, $T_1(n) = 1$ and $T_2(n) = 1$.
Which one of the following options is correct?
(a) $T_1(n) = \theta(n^2)$
(b) $T_1(n) = \theta(n^2 \log_2 n)$
(c) $T_1(n) = \theta(n^{\log_4 5})$
(d) $T_1(n) = \theta(n^{\log_4 5} \log_2 n)$

Ans. (a)

$$T_1(n) = 4T_1\left(\frac{n}{2}\right) + T_2(n)$$

$$T_2(n) = 5T_2\left(\frac{n}{4}\right) + \theta(\log n)$$

Apply Master theorem's for $T_2(n)$

$$f(n) = \theta(\log n),\ n^{\log_b^a} = n^{\log_4^5}$$

Case (1) applicable

$$T_2(n) = \theta(n^{\log_2^5})$$

$$T_1(n) = 4T_1\left(\frac{n}{2}\right) + \theta(n^{\log_2^5})$$

Apply Master theorem's for $T_1(n)$

$$f(n) = \theta(n^{\log_2^5}),\ n^{\log_b^a} = n^2$$

Case (1) applicable

$$T_1(n) = \theta(n^2)$$

End of Solution

Q.18 With respect to a TCP connection between a client and a server, which one of the following statements is true?

(a) The client and server use a two-way handshake mechanism before the start of data transmission.

(b) The server cannot initiate closing of the connection before the client initiates closing of the connection.

(c) The TCP connection is half-duplex.

(d) The client and server can initiate closing of the connection at the same time.

Ans. (d)

Client and server can close connection at same time. This paradigm is Catted Simultaneous close in TCP client sends FIN segment, at same time server sends FIN segment.
TCP protocol (defined in RFC 793) allows simultaneous close.
Closing state appears only in Simultaneous close Both Sides go to TIME-WAIT

End of Solution

Q.19 Which of the following statements is/are true with respect to the interaction of a web browser with a web server using HTTP 1.1?

(a) HTTP 1.1 facilitates downloading multiple objects of the same webpage over the same TCP connection, if the objects are stored in the same server.

(b) HTTP 1.1 facilitates downloading multiple objects of the same webpage over the same TCP connection, even if they are stored in different servers.

(c) HTTP 1.1 facilitates sending a request for downloading one object without waiting for a previously requested object to be downloaded completely.

(d) HTTP 1.1 facilitates downloading multiple webpages on the same server to be downloaded over a single TCP connection.

Ans. (a, c, d)

- HTTP 1.1 means persistent http
  Persistent http will be help by for web client to access the multiple objects from webserver in single TCP connection, So (a) is correct.
- HTTP is client server protocols.
  TCP connection is established between single client to single server so it is not possible to access object from different servers. Option (b) is false.
- HTTP/1.1 supports pipelining. Option (c) is true.
- It is possible to download multiple web pages using hyperlink. Option (d) is true.

End of Solution

**Q.20** Let $n > 1$. Consider an $n \times n$ matrix $M$ with its elements from $\mathbb{R}$. Let the vector $(0, 1, 0, 0, ..., 0) \in \mathbb{R}^n$ be in the null space of $M$.

Which of the following options is/are always correct?

(a) Determinant of $M$ is 1

(b) Determinant of $M$ is 0

(c) Rank of $M$ is 1

(d) There are at least two non-zero vectors in the null space of $M$

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

Given,

$$X = (0, 1, 0, 0, ..., 0)^T \in \text{null space } (A)$$

So, $Ax = 0$

Since, $X \neq 0$

It is a non-zero vector.

$$Ax = 0 \text{ has a non-zero solution}$$

$\Rightarrow$ Homogeneous system has non-trivial solution.

$\Rightarrow$ $A$ is singular

$\Rightarrow$ $|A| = 0$

Also, $X \neq 0 \in$ null space $(A)$ then for any scalar $c \in \mathbb{R}$

$c\,X \in$ null space $(A)$

Hence there are infinitely many non-zero vector in the null space.

$\Rightarrow$ Atleast two non-zero vectors exists in null space $(A)$.

*End of Solution*

**Q.21** Consider the following Boolean expression of a function $F$:

$$F(P, Q) = (\bar{P} + Q) \oplus (\bar{P}Q)$$

Which of the following expressions is/are equivalent to $F$?

(a) $\overline{P \oplus Q}$

(b) $P \oplus Q$

(c) $\bar{P} \oplus Q$

(d) $\bar{P} \oplus \bar{Q}$

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

$$X \oplus Y = (\bar{X} + \bar{Y})(X + Y)$$

$$(\bar{P} + Q) \oplus \bar{P}Q \Rightarrow (\overline{\bar{P} + Q} + \overline{\bar{P}Q}) \cdot (\bar{P} + Q + \bar{P}Q)$$

$\Rightarrow$ $(P\bar{Q} + P + \bar{Q}) \cdot (\bar{P} + Q)$

$\Rightarrow$ $(P + \bar{Q}) \cdot (\bar{P} + Q)$

$\Rightarrow$ $\overline{P \oplus Q}$

*End of Solution*

**Q.22** Consider the 8-bit signed integers $X$, $Y$ and $Z$ represented using the sign-magnitude form. The binary representations of $X$ and $Y$ are as follows:

$X$ : 10110100 $Y$ : 01001100

Which of the following operations to compute $Z$ result(s) in an arithmetic overflow?

(a) $Z = X + Y$
(b) $Z = X - Y$
(c) $Z = -X + Y$
(d) $Z = -X - Y$

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

8 bit sign-magnitude range is

$\{-(2^{8-1} - 1) \text{ to } +(2^{8-1} - 1)\}$

$\{-127 \text{ to } +127\}$

$X$ : 10110100 $\Rightarrow -52$

$Y$ : 01001100 $\Rightarrow +76$

$X + Y \Rightarrow -52 + (76) = +24$

$X - Y \Rightarrow -52 - (+76) = -128$ (overflow)

$-X + Y \Rightarrow -(-52) + (+76) = +128$ (overflow)

$-X - Y \Rightarrow -(-52) - (+76) = -24$

End of Solution

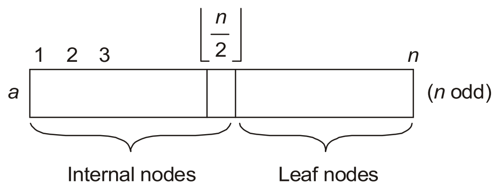
**Q.23** Let $n$ be an odd number greater than 100. Consider a binary minheap with $n$ elements stored in an array $P$ whose index starts from 1.

Which of the following indices of $P$ do/does NOT correspond to any leaf node of the minheap?

(a) $\frac{n+1}{2}$
(b) $\frac{n-1}{2}$
(c) $\frac{n-3}{2}$
(d) $n$

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

$n$ is odd and greater than 100 binary minheap array index start from 1.




Index: $\frac{n+1}{2} = \left\lfloor \frac{n}{2} \right\rfloor + 1$ : First leaf node

$\frac{n-1}{2} = \left\lfloor \frac{n}{2} \right\rfloor$ : Last internal node

$\frac{n-3}{2}$ : Internal node $\left[ < \frac{n-1}{2} \right]$

$n$ : Last leaf node

End of Solution

**Q.24** Consider a hash table $P[0, 1, ..., 10]$ that is initially empty. The hash table is maintained using open addressing with linear probing. The hash function used is $h(x) = (x + 7) \bmod 11$. Consider the following sequence of insertions performed on $P$:

1, 13, 22, 15, 11, 24

Which of the following positions in the hash table is/are empty after these insertions are performed?

(a) 0 (b) 10
(c) 2 (d) 1

**Ans.** (c)

1, 13, 22, 15, 11, 24

$$\begin{aligned}
h(1) &= (1 + 7) \bmod 11 = 8 \\
h(13) &= (13 + 7) \bmod 11 = 20 \bmod 11 = 9 \\
h(22) &= (22 + 7) \bmod 11 = 29 \bmod 11 = 7 \\
h(15) &= (15 + 7) \bmod 11 = 22 \bmod 11 = 0 \\
h(11) &= (11 + 7) \bmod 11 = 18 \bmod 11 = 7 - C \\
&= (7 + 1) \bmod 11 = 8 - C \\
&= (9 + 1) \bmod 11 = 10 - C \\
h(14) &= (24 + 7) \bmod 11 = 31 \bmod 11 = 9 - C
\end{aligned}$$

| | |
|---|---|
| 0 | 15 |
| 1 | 24 |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |
| 7 | 22 |
| 8 | 1 |
| 9 | 13 |
| 10 | 11 |

So, it is insert 24 at 1.

*End of Solution*

**Q.25** Consider the following grammar where $S$ is the start symbol, and $a$ and $b$ are terminal symbols.

$S \to aSbS \mid bS \mid \epsilon$

Which of the following statements is/are true?

(a) The grammar is ambiguous.
(b) The string *abb* has two distinct derivations in this grammar.
(c) The string *abab* has only one rightmost derivation.
(d) The language generated by the grammar is undecidable.

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

$S \to aSbS \mid bS \mid \epsilon$

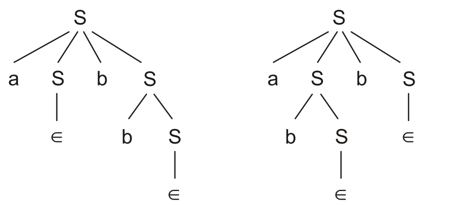



*abb* has 2 different parse trees.

$\therefore$ Grammar is ambiguous.

$S \to a\underline{S}bs$ $\quad\quad$ $S \to a\underline{S}bs$

$\to a\in b\underline{S}$ $\quad\quad$ $\to ab\underline{S}\,bS$

$\to abb\underline{S}$ $\quad\quad$ $\to ab\in b\underline{S}$

$\to abb\in$ $\quad\quad$ $\to abb\in$

$\to abb$ $\quad\quad$ $\to abb$

The string *abb* has 2 distinct derivations.

$S \to aSb\underline{S}$

$\to aSbaSb\underline{S}$

$\to aSbaSb\in$

$\to a\underline{S}ba\in b$

$\to a\in bab$

$\to abab$

$\therefore$ *abab* has only one right most derivation.

End of Solution

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**Q.26** Let *M* be a non-deterministic finite automaton (NFA) with 6 states over a finite alphabet. Which of the following options CANNOT be the number of states in the minimal deterministic finite automaton (DFA) that is equivalent to *M*?

(a) 32 $\quad\quad$ (b) 65

(c) 1 $\quad\quad$ (d) 128

**Ans.** (b, d)

The maximum number of states of a DFA equivalent to NFA of $n$ states in $2^n$.

Here NFA has 6. The equivalent DFA has maximum $2^6$ states.

$\therefore$ The DFA can't have 65 or 128 states.

End of Solution

---

**Q.27** Consider the following C statements:

```
char *str1 = "Hello;     /* Statement S1 */
char *str2 = "Hello;";   /* Statement S2 */
int *str3 = "Hello";     /* Statement S3 */
```

Which of the following options is/are correct?

(a) S1 and S2 have syntactic errors

(b) S2 has a lexical error and S3 has a syntactic error

(c) S1 has a lexical error and S3 has a semantic error

(d) S1 has a syntactic error and S3 has a semantic error

**Ans.** (c)

S1 is having unmatched string.

$\therefore$ S1 is lexical error.

No error in S2.

S3 is defined as integer data type but assigned a string.

$\therefore$ S3 is semantic error.

End of Solution

**Q.28** Which of the following statements is/are true?
(a) LL(1) parser uses backtracking
(b) For a grammar to be LL(1), it must be left-recursive
(c) For a grammar to be LL(1), it must be left-factored
(d) The LL(1) parsers are more powerful than the SLR parsers

**Ans.** (c)

A grammar must be left factored in the case of LL(1).
LL(1) uses non backtracking.
If a grammar is left recursive then it is not LL(1).
There is no relation between LL(1) and SLR(1).

*End of Solution*

---

**Q.29** With respect to deadlocks in an operating system, which of the following statements is/are FALSE?
(a) Banker's algorithm is used to prevent deadlocks
(b) Deadlock formation can be prevented by ensuring that the hold and wait condition is not allowed
(c) An assignment edge in a resource allocation graph is marked from a process to a resource
(d) A safe state guarantees that all processes can finish without formation of a deadlock

**Ans.** (a, c)

(a) Banker's algorithm ensures that the system never enters an unsafe state by carefully allocating resources. This technique is classified under deadlock avoidance, not prevention. So, option (a) is false.
(b) Deadlock requires four necessary conditions: mutual exclusion, hold and wait, no preemption, and circular wait. If the hold and wait condition is eliminated, one of the necessary conditions is removed. Hence, deadlock cannot occur. So, option (b) is true.
(c) In a Resource Allocation Graph (RAG):
- A request edge goes from process → resource.
- An assignment edge goes from resource → process. Thus, the given statement reverses the direction. So, option (c) is false.

(d) By definition, in a safe state, there exists a safe sequence in which all processes can complete execution. Therefore, deadlock will not occur. So, option (d) is true.

*End of Solution*

---

Q.30 Let $P$, $Q$, $R$ and $S$ be the attributes of a relation in a relational schema. Let $X \to Y$ indicate functional dependency in the context of a relational database, where $X, Y \subseteq \{P, Q, R, S\}$ Which of the following options is/are always true?

(a) If $(\{P, Q\} \to \{R\}$ and $\{P\} \to \{R\})$, then $\{Q\} \to \{R\}$
(b) If $\{P, Q\} \to \{R\}$, then $(\{P\} \to \{R\}$ or $\{Q\} \to \{R\})$
(c) If $(\{P\} \to \{R\}$ and $\{Q\} \to \{S\})$, then $\{P, Q\} \to \{R, S\}$
(d) If $\{P\} \to \{R\}$, then $\{P, Q\} \to \{R\}$

Ans. (c, d)

Let $P$, $Q$, $R$, $S$ attributes

$\{PQ \to R,\ P \to R\} \Rightarrow Q \to R$ : False

$Q^+ = \{Q\}$

$\{PQ \to R\} \Rightarrow \{P \to R \text{ or } Q \to R\}$ : False

$P^+ = \{P\}$

$\{P \to R,\ Q \to S\} \Rightarrow \{PQ \to RS\}$ : True

$[PQ]^+ = PQRS$

$P \to R \Rightarrow PQ \to R$ : True

$[PQ]^+ = PQR$

End of Solution

Q.31 In the context of relational database normalization, which of the following statements is/are true?

(a) It is always possible to obtain a dependency-preserving 3NF decomposition of a relation
(b) It is always possible to obtain a dependency-preserving 1NF decomposition of a relation
(c) It is not always possible to obtain a dependency-preserving BCNF decomposition of a relation
(d) It is not always possible to obtain a dependency-preserving 2NF decomposition of\ a relation

Ans. (a, b, c)

- Always possible to decompose dependency preserving 3NF decomposition of a relation.
- Not always possible to decompose dependency preserving BCNF decomposition of a relation.

End of Solution

**Q.32** Consider the function $f : \mathbb{R} \to \mathbb{R}$ defined as follows:

$$f(x) = \begin{cases} c_1 e^x - c_2 \log_e\left(\frac{1}{x}\right), & \text{if } x > 0 \\ 3, & \text{otherwise} \end{cases}$$

where $c_1, c_2 \in \mathbb{R}$.

If $f$ is continuous at $x = 0$, then $c_1 + c_2$ = ________. (answer in integer)

**Ans.** (3)

$$f(x) = \begin{cases} C_1 e^x - C_2 \log x, & x > 0 \\ 3, & x \le 0 \end{cases}$$

$\because$ $f(x)$ is continuous at $x = 0$

$$\lim_{x \to 0} f(x) = 3$$

$$\lim_{x \to 0} C_1 e^x + C_2 \log x = 3$$

$$C_1 + C_2 \log 0 = 3$$

Possible if $C_2 = 0$

$\therefore$ $C_2 = 0,\ C_1 = 3$

$$C_1 + C_2 = 3$$

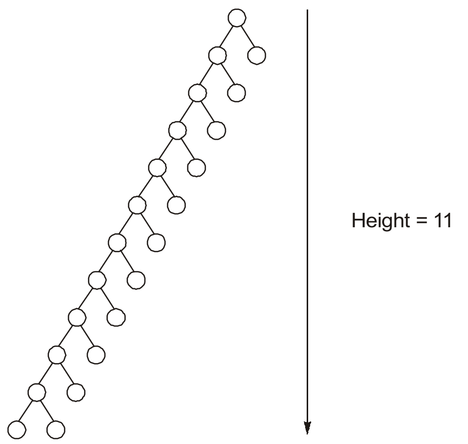
*End of Solution*

**Q.33** The height of a binary tree is the number of edges in the longest path from the root to a leaf in the tree. The maximum possible height of a full binary tree with 23 nodes is ________. (answer in integer)

**Ans.** (11)

Full binary tree: Every internal node must have 2 childs.

Maximum height for 23 nodes: Tree must be skewed one end and because of full binary tree every internal nodes must have two childs.




*End of Solution*

Q.34 Consider the following program in C:

```
#include <stdio.h>
void func(int i, int j) {
    if(i < j) {
        int i = 0;
        while (i < 10) {
            j += 2;
            i++;
        }
    }
    printf("%d", i);
}
int main() {
    int i = 9, j = 10;
    func(i, j);
    return 0;
}
```

The output of the program is ________. (answer in integer)

**Note:** Assume that the program compiles and runs successfully.

**Ans.** (9)

f(9, 10)

if (9 < 10) ⇒ True

i $\boxed{\cancel{0}}$ $\cancel{1}$ $\cancel{2}$ $\cancel{3}$ $\cancel{4}$ $\cancel{5}$ $\cancel{6}$ $\cancel{7}$ $\cancel{8}$ $\cancel{9}$ 10

j $\boxed{\cancel{10}}$ $\cancel{12}$ $\cancel{14}$ $\cancel{16}$ $\cancel{18}$ $\cancel{20}$ $\cancel{22}$ $\cancel{26}$ $\cancel{27}$ $\cancel{28}$ 30

printf('''%d', i) = 9

End of Solution

Q.35 Consider a system consisting of $k$ instances of a resource $R$, being shared by 5 processes. Assume that each process requires a maximum of two instances of resource $R$ and a process can request or release only one instance at a time. Further, a process can request the second instance of the resource only after acquiring the first instance.

The minimum value of K for the system to be deadlock-free is ________. (answer in integer)

**Ans.** (6)

| $P_1$ | $P_2$ | $P_3$ | $P_4$ | $P_5$ |
|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 1 |
| 1 | | | | |

= 6

or

$$m = n \times (R - 1) + 1 = 5 \times (2 - 1) + 1$$

$$\Rightarrow \quad 5 + 1 = 6$$

End of Solution

Q.36 Consider the real valued variables $X$, $Y$ and $Z$ represented using the IEEE 754 single-precision floating-point format. The binary representations of $X$ and $Y$ in hexadecimal notation are as follows:

$X$ : 35C00000 $Y$ : 34A00000

Let $Z = X + Y$.

Which one of the following is the binary representation of $Z$, in hexadecimal notation?

(a) 35C80000 (b) 35CC0000
(c) 35E80000 (d) 35EC0000

**Ans. (c)**

$X : (35C00000)_H$

| 0 | 011 0101 1 | 100 0000..... |
|---|---|---|
| S | BE | M |

Bias: +127

Value: $(-1)^0\ (1.1000\ .....) \times 2^{107\ -\ 127} + (1.1000\ .....) \times 2^{-20}$

$Y : (34A00000)_H$

| 0 | 011 0100 1 | 010 0000..... |
|---|---|---|
| S | BE | M |

Bias: +127

Value: $(-1)^0\ (1.010000\ .....) \times 2^{105\ -\ 127} + (1.010000\ .....) \times 2^{-22}$

Now align '$Y$' to right 2 times

$Y : +\ 0.0101000\ .....\times 2^{-22\ +\ 2}$

$Y : +\ 0.0101000\ .....\times 2^{-20}$

$(X + Y)$:

$$\begin{array}{r} 1.100000..... \\ 0.010100..... \\ \hline 1.110100..... \\ \hline \end{array}$$

$Z : 1.110100\ .....\times 2^{-20}$

$$\begin{aligned} \text{BE} &= \text{AE} + \text{Bias} \\ &= (-20) + (+127) = 107 \\ &= 01101011 \end{aligned}$$

| 0 | 011 0101 1 | 110 10000..... |
|---|---|---|

$\underbrace{}_{3}\ \underbrace{}_{5}\ \underbrace{}_{E}\ \underbrace{}_{8}\ 0000$

Answer is $(35E80000)_H$

End of Solution

**Q.37** Consider a 2-bit saturating up/down counter that performs the saturating up count when the input $P$ is 0, and the saturating down count when $P$ is 1. The Next State table of the counter is as shown. The counter is built as a synchronous sequential circuit using $D$ flip-flops.

| Input | Current state | | Next state | |
|---|---|---|---|---|
| $P$ | $Q_1$ | $Q_0$ | $Q_1^+$ | $Q_0^+$ |
| 0 | 0 | 0 | 0 | 1 |
| 0 | 0 | 1 | 1 | 0 |
| 0 | 1 | 0 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 |
| 1 | 0 | 0 | 0 | 0 |
| 1 | 0 | 1 | 0 | 0 |
| 1 | 1 | 0 | 0 | 1 |
| 1 | 1 | 1 | 1 | 0 |

Which one of the following options corresponds to the expressions for the inputs of the $D$ flip-flops, $D_1$ and $D_0$?

(a) $D_1 = PQ_1 + \bar{P}Q_0 + Q_1Q_0$ $\quad D_0 = PQ_0 + \bar{P}Q_1 + Q_1\overline{Q_0}$

(b) $D_1 = \bar{P}Q_1 + \bar{P}Q_0 + Q_1Q_0$ $\quad D_0 = \bar{P}\overline{Q_0} + \bar{P}Q_1 + Q_1\overline{Q_0}$

(c) $D_1 = \bar{P}\overline{Q_1} + \bar{P}Q_0 + Q_1Q_0$ $\quad D_0 = \bar{P}Q_0 + \bar{P}Q_1 + Q_1\overline{Q_0}$

(d) $D_1 = P\overline{Q_1} + \bar{P}Q_0 + Q_1Q_0$ $\quad D_0 = P\overline{Q_0} + \bar{P}Q_1 + Q_1\overline{Q_0}$

**Ans. (b)**

| $P$ | $Q_1$ | $Q_0$ | $Q_1^+$ | $Q_0^+$ |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 1 |
| 0 | 0 | 1 | 1 | 0 |
| 0 | 1 | 0 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 |
| 1 | 0 | 0 | 0 | 0 |
| 1 | 0 | 1 | 0 | 0 |
| 1 | 1 | 0 | 0 | 1 |
| 1 | 1 | 1 | 1 | 0 |

$$Q_0^+ = D_0 = \Sigma m(0, 2, 3, 6)$$

| $P \backslash Q_1Q_0$ | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 0 | (0) | 1 (1) | 1 (3) | 1 (2) |
| 1 | (4) | (5) | 1 (7) | (6) |

$D_1 = \bar{P} \cdot Q_1 + Q\, Q_0 + \bar{P} \cdot Q_0$

| $P \backslash Q_1Q_0$ | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 0 | 1 (0) | (1) | 1 (3) | 1 (2) |
| 1 | (4) | (5) | (7) | 1 (6) |

$D_0 = Q_1 \cdot \overline{Q}_0 + \bar{P} \cdot \overline{Q}_0 + \bar{P} \cdot Q_1$

End of Solution

**Q.38** The size of the physical address space of a processor is $2^{32}$ bytes. The capacity of a cache memory unit is $2^{23}$ bytes. The cache block size is 128 bytes. The cache memory unit can be built as a direct mapped cache or as a $K$-way set-associative cache, where $K = 2^L$ and $L \in \{1, 2, 3\}$. Let the length of the TAG field be $M$ bits for the direct mapped cache, and $N$ bits for the set-associative cache.

Which one of the following options is true?

(a) $N = M + L$
(b) $N = M - L$
(c) $N = M + K$
(d) $N = M - K$

**Ans.** (a)

Direct cache address format:

| tag | LO | WO |
|---|---|---|

$m$-bit

Set associative cache address format:

| tag | SO | WO |
|---|---|---|

$n$-bit

Here, N-value increases depends on the associativity of a cache.

i.e., $$S = \frac{\text{Number of lines}}{P\text{-way}} = \frac{\text{Number of lines}}{2^L} = 2^{(LO-L)}$$

So, index value decreases w.r.t. $P$-value.

$\therefore$ Tag space increases w.r.t. associativity.

Hence, $N = (M + L)$

*End of Solution*

**Q.39** Consider the following code snippet in C language that computes the number of nodes in a non-empty singly linked list pointed to by the pointer variable head.

```
struct node{
    int elt;
    struct node *next;
};
int getListSize (struct node *head)
{
    if( E1 ) return 1;
    return E2;
}
```

Which one of the following options gives the correct replacements for the expressions E1 and E2?

(a) E1: head == NULL
E2: 1 + getListSize(head)
(b) E1: head → next == NULL
E2: 1 + getListSize(head → next)
(c) E1: head == NULL
E2: 1 + getListSize(head → next)
(d) E1: head → next == NULL
E2: 1 + getListSize(head)

**Ans. (b)**

In a recursive function for a linked list, the base case occurs when the list is empty or when the next node is NULL.

Since head is a pointer to the current node:

- The last node in a linked list has head → next == NULL.
- So the base case should check head → next == NULL, not head == NULL (because the problem says non-empty list).

**Recursive call**

For a linked list, the size of the list can be computed as:

size(head) = 1+size(head → next)

- We add 1 for the current node.
- Then recursively call the function on the next node.

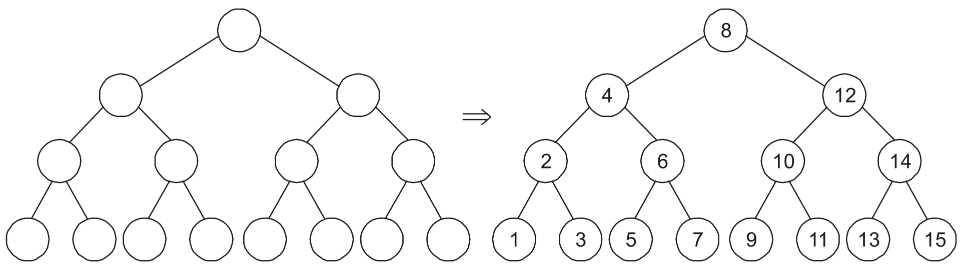
End of Solution

**Q.40** Let $P$ be the set of all integers from 1 to 15. Consider any order of insertion of the elements of $P$ into a binary search tree that creates a complete binary tree.

Which one of the following elements can NEVER be the third element that is inserted?

(a) 4 (b) 2
(c) 10 (d) 5

**Ans. (d)**




Complete binary tree with keys 1 to 15 is binary search tree

- First key to insert is 8.
- $2^{nd}$ keys must be 4 or 12.
- If $2^{nd}$ key 4 then 3rd key can be any of 2, 6, 12.
- If $2^{nd}$ key 12 then 3rd key can be any of 4, 10, 14.

End of Solution

**Q.41** Let $G(V, E)$ be an undirected, edge-weighted graph with integer weights. The weight of a path is the sum of the weights of the edges in that path. The length of a path is the number of edges in that path.

Let $s \in V$ be a vertex in $G$. For every $u \in V$ and for every $k \geq 0$, let $d_k(u)$ denote the weight of a shortest path (in terms of weight) from $s$ to $u$ of length at most $k$. If there is no path from $s$ to $u$ of length at most $k$, then $d_k(u) = \infty$.

Consider the statements:

S1: For every $k \geq 0$ and $u \in V$, $d_{k+1}(u) \leq d_k(u)$.

S2: For every $(u, v) \in E$, if $(u, v)$ is part of a shortest path (in terms of weight) from $s$ to $v$, then for every $k \geq 0$, $d_k(u) \leq d_k(v)$.

Which one of the following options is correct?

(a) Only S1 is true
(b) Only S2 is true
(c) Both S1 and S2 are true
(d) Neither S1 nor S2 is true

**Ans.** **(a)**

$G(V, E)$ undirected edge weighted graph with integer weights.

Weight of a path is sum of the weights of the edges in that path.

Length of the path is the number of edges in that path.

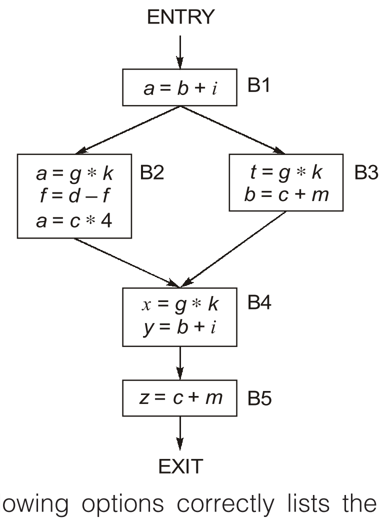
$d_k(u)$ weights of shortest path from $s$ to $u$ of length at most $k$.

$S_1$ : For every $k \geq 0$ and $u \in$ vertex $d_{k+1}(u) \leq d_k(u)$ is true because when allowed more edges is expands the set of allowed shortest paths.

$S_2$ is false.

*End of Solution*

**Q.42** Consider the control flow graph shown in the figure.




Which one of the following options correctly lists the set of redundant expressions (common sub-expressions) in the basic blocks B4 and B5?

**Note:** All the variables are integers.

(a) B4: $\{b + i\}$
B5: $\{c + m\}$

(b) B4: $\{g * k\}$
B4: $\{c + m\}$

(c) B4: $\{g * k,\ b + i\}$
B5: $\{\ \}$

(d) B4: $\{g * k\}$
B5: $\{\ \}$

**Ans. (d)**

In B2 and B3 $g * k$ is evaluated.

$\therefore$ In B4 $g * k$ evaluation can be eliminated.

In B5, $c + m$ has to be evaluated in the path B1 $\rightarrow$ B2 $\rightarrow$ B4 $\rightarrow$ B5.

**End of Solution**

**Q.43** Consider a relational database schema with two relations $R(P, Q)$ and $S(X, Y)$. Let $E = \{\langle u\rangle \mid \exists v\, \exists w\, \langle u, v\rangle \in R \wedge \langle v, w\rangle \in S\}$ be a tuple relational calculus expression. Which one of the following relational algebraic expressions is equivalent to $E$?

(a) $\Pi_P(R \bowtie_{R.P=S.X} S)$

(b) $\Pi_P(S \bowtie_{S.X=R.Q} R)$

(c) $\Pi_P(R \bowtie_{R.P=S.Y} S)$

(d) $\Pi_P(S \bowtie_{S.Y=R.Q} R)$

**Ans. (b)**

$R(P, Q)\ \ S(X, Y)$

$E = \{\langle u\rangle \mid \exists v\, \exists w\, \langle u, v\rangle \in R \wedge \langle v, w\rangle \in S\}$

$$R(P\ Q) = S(X, Y)$$

$\Pi_P(S \bowtie_{S.X=R.Q} R)$

**End of Solution**

**Q.44** A TCP sender successfully establishes a connection with a TCP receiver and starts the transmission of segments. The TCP congestion control mechanism's slow-start threshold is set to 10000 segments. Assume that the round-trip time is fixed at 1 millisecond. Assume that the sender always has data to send, the segments are numbered from 1, and no segment is lost. Let $t$ denote the time (in milliseconds) at which the transmission of segment number 2000 starts.

Which one of the following options is correct?

(a) $9 \le t < 10$

(b) $10 \le t < 11$

(c) $11 \le t < 12$

(d) $12 \le t < 13$

**Ans. (b)**

$$t \geq 10$$

Slow start threshold = 10000 segments

Round trip time = 1 millisec

No segment is lost and sender always has data to send.

Slow start Algorithm:

1
2
4
8
16
32
64
128
256
512
$10^{th}$ millisec completed 1024

$1024 \leq 2000 \leq 2048$

$11^{th}$ millisec with start 2048

$10 \leq t \leq 11$

**End of Solution**

---

**Q.45** Consider the implementation of sliding window protocol over a lossless link, with a window size of $W$ frames, where each frame is of size 1000 bits (including header). The bandwidth of the link is 100 kbps ($1k = 10^3$) and the one-way propagation delay is 100 milliseconds. Assume that processing times at the sender and receiver are zero and the transmission time of acknowledgements is also zero. Which one of the following options gives the minimum size of $W$ (in number of frames) required to achieve 100% link utilization?

(a) 10
(b) 21
(c) 20
(d) 11

**Ans. (b)**

Window size = $W$ frames

Frame size = 1000 bits (Header + Data)

Bandwidth of link = 100 kbps, Propagation delay = 100 millisec

% LU = 100%

$$= N \times \frac{TT}{TT + 2 \times PT} \times 100$$

$$1 = W \times \frac{10}{10 + 2 \times 100}$$

$$210 = W \times 10$$

$$21 = W$$

$\Rightarrow$ Window size = 21

**End of Solution**

Q.46 Let $f : \mathbb{R} \to \mathbb{R}$ be defined as follows:

$$f(x) = \left(\frac{|x|}{2} - x\right)\left(x - \frac{|x|}{2}\right)$$

Which of the following statements is/are true?

(a) $f$ has a local maximum

(b) $f$ has a local minimum

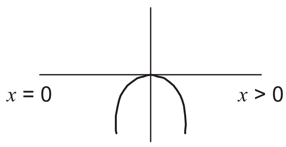
(c) $f'$ continuous over $\mathbb{R}$

(d) $f'$ is not differentiable over $\mathbb{R}$

Ans. (a, c, d)

$$f(x) = \begin{cases} \left(-\frac{x}{2} - x\right)\left(x + \frac{x}{2}\right) & x < 0 \\ \left(\frac{x}{2} - x\right)\left(x - \frac{x}{2}\right) & x \geq 0 \end{cases}$$

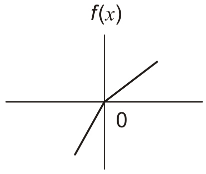
$$f(x) = \begin{cases} -\frac{9}{4}x^2 & x < 0 \\ -\frac{x^2}{4} & x \geq 0 \end{cases}$$




it continuous and smooth.

$\therefore$ $f(x)$ is differentiable at $x = 0$

$\Rightarrow$ $f'(x)$ is continuous at $x = 0$




$$f'(x) = \begin{cases} -\frac{18}{4}x & x < 0 \\ -\frac{x}{2} & x \geq 0 \end{cases}$$

$$f''(x) = \begin{cases} -\frac{9}{2} & x < 0 \\ -\frac{1}{2} & x \geq 0 \end{cases}$$

is not continuous at $x = 0$

$\therefore$ $f'$ is not differentiable at $x = 0$

End of Solution

Q.47 Let $G(V, E)$ be a simple, undirected graph. A vertex cover of $G$ is a subset $V' \subseteq V$ such that for every $(u, v) \in E$, $u \in V'$ or $v \in V'$. Let the size of the smallest vertex cover in $G$ be $k$. Let $S$ be any vertex cover of size $k$.

For a vertex $v \in V$, which of the following constraints will always ensure that $v \in S$?

(a) The degree of $v$ is at least $k + 1$

(b) The vertex $v$ is on a path of length $k + 1$

(c) The vertex $v$ is on a cycle of length $k + 1$

(d) The vertex $v$ is a part of a clique of size $k$

Ans. (a)

End of Solution

**Q.48** Consider a Boolean function $F$ with the following minterm expression:

$$F(P, Q, R, S) = \sum m(1, 2, 3, 4, 5, 7, 10, 12, 13, 14)$$

Which of the following options is/are the minimal sum-of-products expression(s) of $F$?

(a) $\bar{P}S + Q\bar{R} + \bar{P}\bar{Q}R + \bar{Q}R\bar{S}$
(b) $\bar{P}S + Q\bar{R} + \bar{P}\bar{Q}R + PR\bar{S}$
(c) $\bar{P}S + Q\bar{R} + PQ\bar{S} + PR\bar{S}$
(d) $\bar{P}S + Q\bar{R} + PQ\bar{S} + \bar{Q}R\bar{S}$

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

$$F(P, Q, R, S) = \sum m(1, 2, 3, 4, 5, 7, 10, 12, 13, 14)$$

| PQ \ RS | 00 | 01 | 11 | 10 |
|---|---|---|---|---|
| 00 | (0) | (1) 1 | (3) 1 | (2) 1 |
| 01 | (4) 1 | (5) 1 | (7) 1 | (6) |
| 11 | (12) 1 | (13) 1 | (15) | (14) 1 |
| 10 | (8) | (9) | (11) | (10) 1 |

Upon simplification (b) and (d) are options.

(b) $\bar{P}S + Q\bar{R} + \bar{P}\bar{Q}R + PR\bar{S}$

(d) $\bar{P}S + Q\bar{R} + PQ\bar{S} + \bar{Q}R\bar{S}$

*End of Solution*

**Q.49** Let $G(V, E)$ be a simple, undirected, edge-weighted graph with unique edge weights. Which of the following statements about the minimum spanning trees (MST) of $G$ is/are true?

(a) In every cycle $C$ of $G$, the edge with the largest weight in $C$ is not in any MST
(b) In every cycle $C$ of $G$, the edge with the smallest weight in $C$ is in every MST
(c) For every vertex $v \in V$, the edge with the largest weight incident on $v$ is not in any MST
(d) For every vertex $v \in V$, the edge with the smallest weight incident on $v$ is in every MST

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

$G(V, E)$ be a simple, undirected edge-weighted graph with unique edge weights

- Largest weight edge of every cycle is excluded in MST.
- Smallest weight edge of every cycle is may not in MST.
- Every largest weight incident on $v$ is may/may not in MST.
- Every smallest weight incident on $v$ is every MST.

*End of Solution*

**Q.50** Consider the following pseudocode for depth-first search (DFS) algorithm which takes a directed graph $G(V, E)$ as input, where $d[v]$ and $f[v]$ are the discovery time and finishing time, respectively, of the vertex $v \in V$.

```
DFS(G):                          Explore(G, v, t):
   unmark all v ∈ V                 mark v
   t ← 0                            t ← t + 1
   for each v ∈ V                   d[v] ← t
      if v is unmarked              for each (v, w) ∈ E
         t ← Explore(G, v, t)          if w is unmarked
      end if                              t ← Explore(G, w, t)
end f or                                  end if
                                    end f or
                                    t ← t + 1
                                    f[v] ← t
                                    return t
```

Suppose that the input directed graph $G(V, E)$ is a directed acyclic graph (DAG). For an edge $(u, v) \in E$, which of the following options will NEVER be correct?

(a) $d[u] < d[v] < f[v] < f[u]$
(b) $d[v] < d[u] < f[u] < f[v]$
(c) $d[v] < f[v] < d[u] < f[u]$
(d) $d[u] < d[v] < f[u] < f[v]$

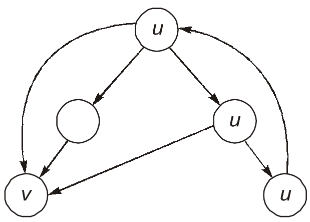
**Ans.** **(b, d)**

DFS traversal of directed graph

$d[v]$ : Explanation begin of vertex $u$.

$f[v]$ : Exploration end of vertex $u$.

No back edges possible in DFS traversal of directed acyclic graph.




If $(u, v)$ forward edge (or) tree edge $d[u] < d[v] < f[v] < f[u]$.

If $(u, v)$ back edge $d[v] < d[u] < f[u] < f[v]$ but not possible back edge in acyclic graph

If $(u, v)$ cross edge $d[v] < f[v] < d[u] < f[u]$.

*End of Solution*

**Q.51** Let $L_1$ and $L_2$ be two languages over a finite alphabet, such that $L_1 \cap L_2$ and $L_2$ are regular languages.
Which of the following statements is/are always true?
(a) $L_1$ is regular
(b) $L_1 \cup L_2$ is regular
(c) $\overline{L_2}$ is context free
(d) $L_1$ is context free

**Ans.** **(c)**
Given $L_1 \cap L_2$ and $L_2$ are regular.
If $L_1 \cap L_2$ is regular then $L_1$ and $L_2$ need not be regular.
But given $L_2$ is regular.
$\Rightarrow \overline{L_2}$ is also regular.
$\Rightarrow \overline{L_2}$ is CFL.

*End of Solution*

**Q.52** Consider the following context-free grammar $G$:
$S \rightarrow abaABAbba$
$A \rightarrow aaBBAb \mid bBabaa$
$B \rightarrow aBb \mid ab$
In the above grammar, $S$ is the start symbol, $a$ and $b$ are terminal symbols, and $A$ and $B$ are non-terminal symbols.
Let $L(G)$ be the language generated by the grammar $G$. For a string $s \in L(G)$, let $n_1(s)$ be the number of a's in $s$ and $n_2(s)$ be the number of b's in $s$.
Which of the following statements is/are true?
(a) There is a string $s \in L(G)$ such that $n_1(s) < n_2(s)$
(b) For every string $s \in L(G)$, $n_1(s) \geq n_2(s)$
(c) There is a string $s \in L(G)$ such that $n_1(s) > 2n_2(s)$
(d) For every string $s \in L(G)$, $n_1(s) \leq 2n_2(s)$

**Ans.** **(b, d)**
$S \rightarrow abaABAbba$
$A \rightarrow aaBBAb \mid bBabaa$
$B \rightarrow aBb \mid ab$
In the above all the productions number of a's in either equal or more than the number of b's and in any string the number of a's can be atmost twice the number of b's.
$\therefore \quad n_1(s) \geq n_2(s)$ and $n_1(s) \leq 2n_2(s)$
Correct options is (b), and (d).

*End of Solution*

Q.53 Consider the following two syntax-directed definitions SDD1 and SDD2 for type declarations.

| SDD1 | |
|---|---|
| Grammar(G1) | Semantic Rules |
| $D \rightarrow TV$ | D.type = T.type<br>V.type = T.type |
| $T \rightarrow$ int | T.type = int |
| $T \rightarrow$ float | T.type = float |
| $V \rightarrow V_1$ id | $V_1$.type = V.type<br>put(id.entry, V.type) |
| $V \rightarrow$ id | put(id.entry, V.type) |

| SDD2 | |
|---|---|
| Grammar(G2) | Semantic Rules |
| $D \rightarrow D_1$ id | D.type = $D_1$.type<br>put(id.entry, $D_1$.type) |
| $D \rightarrow T$ id | D.type = T.type<br>put(id.entry, T.type) |
| $T \rightarrow$ int | T.type = int |
| $T \rightarrow$ float | T.type = float |

*D* is the start symbol, and int, float and id are the three terminals. The non-terminal $V_1$ is the same as *V* and the non-terminal $D_1$ is the same as *D*. Here, the subscript is used to differentiate the grammar symbols on the two sides of a production. The function put updates the symbol table with the type information for an identifier.

Let *P* and *Q* be the languages specified by grammars G1 and G2, respectively.

Which of the following statements is/are true?

(a) The languages P and Q are the same
(b) SDD2 is S-attributed and contains only synthesized attributes
(c) SDD1 is L-attributed and contains only inherited attributes
(d) The specifications of SDD1 and SDD2 are such that the same entries get added to the symbol table

Ans. (a, b, d)

(a) True: Both the grammars generates the same language i.e. $(\text{int} / \text{float})\ (\text{id})^{+}$
(c) False: SDD1 is L-attributed SDT and it uses both synthesized and inherited attributes.
(b) True: SDD2 is S-attributed SDT and it uses synthesized attributes only.
(d) True: Both SDD1 and SDD2 added same entries to the symbol table.
$\therefore$ (a), (b), (d) are true and (c) is false.

End of Solution

Q.54 Consider a system that has a cache memory unit and a memory management unit (MMU). The address input to the cache memory is a physical address. The MMU has a translation lookaside buffer (TLB). Assume that when a page is evicted from the main memory, the corresponding blocks in the cache are marked as invalid.

For a given memory reference, which of the following sequences of events can NEVER happen?

(a) TLB miss, Page table hit, Cache hit
(b) TLB hit, Page table miss, Cache hit
(c) TLB miss, Page table miss, Cache hit
(d) TLB miss, Page table miss, Cache miss

Ans. (b, c)

(a) TLB miss means the translation is not in TLB, so the page table is accessed. Page table hit means the page is present in main memory.
Since cache uses physical address and the page is in memory, a cache hit is possible.
Possible

(b) If TLB hit occurs, the translation is already available. Therefore, the page table is not accessed, so a page table miss cannot occur. Hence this sequence is logically inconsistent.
Impossible

(c) Page table miss means the page is not in main memory (page fault). Given that evicted pages have their cache blocks invalidated, cache cannot contain valid data. Therefore, cache hit cannot occur.
Impossible

(d) TLB miss leads to page table access. Page table miss indicates page fault, so data is not in memory. Since cache blocks are invalidated for evicted pages, cache miss is expected.
Possible

End of Solution

Q.55 An undirected, unweighted, simple graph $G(V, E)$ is said to be 2-colorable if there exists a function $c : V \rightarrow \{0, 1\}$ such that for every $(u, v) \in E$, $c(u) \neq c(v)$.
Which of the following statements about 2-colorable graphs is/are true?

(a) If $G$ is 2-colorable, then $G$ may contain cycles of odd length
(b) If $G$ is 2-colorable, then $G$ may contain cycles of even length
(c) An optimal algorithm for testing whether $G$ is 2-colorable runs in time $\theta(|V| + |E|)$, if $G$ is represented as an adjacency list
(d) An optimal algorithm for testing whether $G$ is 2-colorable runs in time $\theta(|E| \log |V|)$, if $G$ is represented as an adjacency list

Ans. (b, c)

End of Solution

Q.56 An ISP having an address block 202.16.0.0/15 assigns a block of 6000 IP addresses to a client, using the classless internet domain routing (CIDR) super-netting approach. Which of the following address blocks can be assigned by the ISP?

(a) 202.16.0.0/19
(b) 202.17.64.0/19
(c) 202.16.32.0/19
(d) 202.17.24.0/19

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

Given, Address block = 202.16.0.0/15

Client requires 6000 IP address [8192] $2^{13} = 2^{32} - 19$

202.16.0.0

0001000.00000000.00000000

00010000.00011111.11111111

202.16.0.0/19

Option (a) is correct

202.17.64.0/19

00010001.01000000.00000000

00010001.01011111.11111111

Option (b) is correct

202.16.32.0/10

00010000.00100000.00000000

Option (c) is correct

202.17.24.0/19

00010001.00011000.00000000

Option (d) is false

End of Solution

**Q.57** Let $G$ be an undirected graph, which is a path on 8 vertices. The number of matchings in $G$ is ______. (answer in integer)

**Ans.** (34)

Let $a_n$ be the number of matchings in a path graph with n vertices. To find $a_n$ consider a specific vertex (e.g., the last vertex $v_n$):

1. **Vertex $v_n$ is not matched:** The number of ways to form matchings for the remaining $n - 1$ vertices is $a_{n-1}$.
2. **Vertex $v_n$ is matched:** It must be matched with its only neighbor $v_{n-1}$. This edge is now fixed, and neither $v_n$ nor $v_{n-1}$ can be part of any other edge. The number of ways to match the remaining $n - 2$ vertices is $a_{n-2}$.

This gives us the Fibonacci recurrence:

$$a_n = a_{n-1} + a_{n-2}$$

**Initial values:**

- $n = 1(P_1)$: 1 vertex, 0 edges. The only matching is the empty set. $\Rightarrow a_1 = 1$.
- $n = 2(P_2)$: 2 vertices, 1 edge. Matchings: { } and {($v_1$, $v_2$)}. $\Rightarrow a_2 = 1$.

$$a(2) = a(1) + a(0) = 1 + 1 = 2$$
$$a(3) = a(2) + a(1) = 2 + 1 = 3$$
$$a(4) = a(3) + a(2) = 3 + 2 = 5$$
$$a(5) = a(4) + a(3) = 5 + 3 = 8$$
$$a(6) = a(5) + a(4) = 8 + 5 = 13$$
$$a(7) = a(6) + a(5) = 13 + 8 = 21$$
$$a(8) = a(7) + a(6) = 21 + 13 = 34$$

End of Solution

**Q.58** Let $X$ be a random variable which takes values in the set {1, 2, 3, 4, 5, 6, 7, 8}. Further, $\Pr(X = 1) = \Pr(X = 2) = \Pr(X = 5) = \Pr(X = 7) = \frac{1}{6}$ and $\Pr(X = 3) = \Pr(X = 4) = \Pr(X = 6) = \Pr(X = 8) = \frac{1}{12}$.

The expected value of $X$, denoted by $E[X]$, is equal to ________. (rounded off to two decimal places)

**Ans.** (4.25) [4.24 to 4.26]

| $X$ | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| $P(X)$ | $\frac{1}{6}$ | $\frac{1}{6}$ | $\frac{1}{12}$ | $\frac{1}{12}$ | $\frac{1}{6}$ | $\frac{1}{12}$ | $\frac{1}{6}$ | $\frac{1}{12}$ |

$$E[X] = \sum x_i p_i$$

$$= \left(1\times\frac{1}{6}+2\times\frac{1}{6}+5\times\frac{1}{6}+7\times\frac{1}{6}\right)+\left(3\times\frac{1}{12}+4\times\frac{1}{12}+6\times\frac{1}{12}+8\times\frac{1}{12}\right)$$

$$= \frac{1}{12}[2+4+10+14+3+4+6+8]$$

$$= \frac{1}{12}[52] = 4.25$$

*End of Solution*

**Q.59** Consider a hard disk with a rotational speed of 15000 rpm. The time to move the read/write head from a track to its adjacent track is 1 millisecond. Initially, the head is on track 0. The number of sectors per track is 400. The sector size is 1024 bytes. It is necessary to transfer data from 10 randomly located sectors in each of the following tracks in the order: 5, 12 and 7.

The total time for the data transfer (in milliseconds) from the hard disk is ________. (rounded off to one decimal place)

**Ans.** (77.3)

| | |
|---|---|
| 15000 rev. | 60 sec |
| 1 rev. | ? |

$$1 \text{ revolution time} = \frac{60}{15000} \text{ sec} \Rightarrow 4 \text{ ms}$$

$$\therefore \quad \text{Average rotational latency} = \frac{1}{2}\times 4 \text{ ms} = 2 \text{ ms}$$

Seek time:
(1) Upto track '5' is "5 ms".
(2) Upto track '12' is "7 ms".
(3) Upto track '7' is "5 ms".
1 sector access time is

| | |
|---|---|
| 1 rev. time | 1 track data (400 sectors) |
| ? | 1 sectors |

$$\Rightarrow \frac{4 \text{ ms}}{400} \Rightarrow 0.01 \text{ ms}$$

$$\begin{aligned}\therefore \quad \text{Total time} &= [5 \text{ ms} + (2 \text{ ms} + 0.01 \text{ ms})\ 10] + [7 \text{ ms} + (2 \text{ ms} + 0.01)\ 10] \\ &\quad + [5 \text{ ms} + (2 \text{ ms} + 0.01 \text{ ms})\ 10] \\ &= 77.3 \text{ ms}\end{aligned}$$

*End of Solution*

**Q.60** The EX stage of a pipelined processor performs the memory read operations for LOAD instructions, and the operations for the arithmetic and logic instructions. Let $t_{EX}$ denote the time taken by the EX stage to perform the operation for an instruction. For each instruction type, the values of $t_{EX}$ and $M$ (the number of instructions of that type in a sequence of 100 instructions for a program $P$), are given in the table below.
The duration of the pipeline clock cycle is 1 nanosecond. Assume that the latch time for the interstage buffers in the pipeline is negligible.

| Instruction | $t_{EX}$ in nanoseconds | $M$ |
|---|---|---|
| LOAD | 1.8 | 15 |
| IMUL | 1.5 | 10 |
| IDIV | 2.5 | 5 |
| FADD | 1.7 | 10 |
| FSUB | 1.7 | 5 |
| FMUL | 2.8 | 15 |
| FDIV | 3.2 | 5 |
| All other instruction | Less than 1.0 | 35 |

When program $P$ is executed, the number of clock cycles for which the pipeline is stalled due to structural hazards in the EX stage is ______. (answer in integer)

**Ans.** (95)

Pipeline clock cycle = 1 ns

When EX-stage takes more than 1 ns then it takes more than 1 pipeline cycle.

| Instruction | Execution time | Number of cycle required |
|---|---|---|
| LOAD | 1.8 ns | $2 \Rightarrow$ stalls $(2-1) = 1$ |
| IMUL | 1.5 ns | $2 \Rightarrow (2-1) = 1$ |
| IDIV | 2.5 ns | $3 \Rightarrow (3-1) = 2$ |
| FADD | 1.7 ns | $2 \Rightarrow (2-1) = 1$ |
| FSUB | 1.7 ns | $2 \Rightarrow (2-1) = 1$ |
| FMUL | 2.8 ns | $3 \Rightarrow (3-1) = 2$ |
| FDIV | 3.2 ns | $4 \Rightarrow (4-1) = 3$ |
| Other instruction | Less than 1 ns | $1 \Rightarrow (1-1) = 0$ |

$\therefore$ Number of stalls required in EX-stage $= (15 \times 1) + (10 \times 1) + (5 \times 2) + (10 \times 1) + (5 \times 1) + (15 \times 2) + (5 \times 3) = (35 \times 0)$

$= 95$

End of Solution

**Q.61** Consider the recursive functions represented by the following code segment:

```
int bar(int n){
    if (n == 1) return 0;
    else return 1 + bar(n/2);
}
int foo(int n){
    if (n == 1) return 1;
    else return 1 + foo(bar(n));
}
```

The smallest positive integer n for which foo(n) returns 5 is ______. (answer in integer)

**Note:** Ignore syntax errors (if any) in the function.

**Ans.** (65536)

End of Solution

**Q.62** The following sequence corresponds to the preorder traversal of a binary search tree:

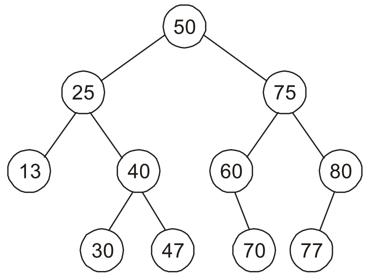
50, 25, 13, 40, 30, 47, 75, 60, 70, 80, 77

The position of the element 60 in the postorder traversal of $T$ is ______. (answer in integer)

**Note:** The position begins with 1.

**Ans.** (7)

Preorder: 50, 25, 13, 40, 30, 47, 75, 60, 70, 80, 77




Postorder ⇒ Left, right, node

| 13 | 30 | 47 | 40 | 25 | 70 | 60 | 77 | 80 | 50 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

The position of element 60 in the postorder = 7.

*End of Solution*

**Q.63** Consider the following program snippet. Assume that the program compiles and runs successfully. Further, assume that the fork( ) system call is always successful in creating a process.

```
int main( ) {
    int i;
    for (i = 0; i < 3; i++){
        if (fork() == 0){
            continue;
        }
        break;
    }
    printf("Hello!");
    return 0;
}
```

The total number of times that the printf statement gets executed is ________. (answer in integer)

**Ans.** (4)

**Execution Trace:**

1. **Iteration 1 (i = 0);**
   - Process $P_0$ (Original) forks.
   - Child $C_1$ continues to iteration i = 1.
   - Parent $P_0$ breaks and prints "Hello!" (1).

2. **Iteration 2** (i = 1);
   - Process $C_1$ forks.
   - Child $C_2$ continues to iteration i = 2.
   - Parent $C_1$ breaks and prints "Hello!" (2).
3. **Iteration 3** (i = 2);
   - Process $C_2$ forks.
   - Child $C_3$ continues. Since the loop ends (i = 3), it exits the loop naturally and prints "Hello!" (3).
   - Parent $C_2$ breaks and prints "Hello!" (4).

*End of Solution*

**Q.64** Consider a CPU that has to execute two types of processes. The first type, Actuators (A), requires a CPU burst of 6 seconds. The second type, Controllers (C), requires a CPU burst of 8 seconds. A new process of type A arrives at time $t$ = 10, 20, 30, 40, and 50 (in seconds). Similarly, a new process of type C arrives at time $t$ = 11, 22, 33, 44, and 55 (in seconds). The CPU scheduling policy is First Come First Serve (FCFS). The first process of type A starts running at $t$ = 10 seconds. The average waiting time (in seconds) for the 10 processes is ___________. (rounded off to one decimal place)

**Ans.** (9.5)

Burst time A = 6 sec, B = 8 sec

| Process | Arrival time | Burst time | CT | TAT | WT |
|---|---|---|---|---|---|
| A | 10 | 6 | 16 | 6 | 0 |
| C | 11 | 8 | 24 | 13 | 5 |
| A | 20 | 6 | 30 | 10 | 4 |
| C | 22 | 8 | 38 | 16 | 8 |
| A | 30 | 6 | 44 | 14 | 8 |
| C | 33 | 8 | 52 | 19 | 11 |
| A | 40 | 6 | 58 | 18 | 12 |
| C | 44 | 8 | 66 | 22 | 14 |
| A | 50 | 6 | 72 | 22 | 16 |
| C | 55 | 8 | 80 | 25 | 17 |

CPU idle

| | A | C | A | C | A | C | A | C | A | C |
|---|---|---|---|---|---|---|---|---|---|---|

0 10 16 24 30 38 44 52 58 66 72 80

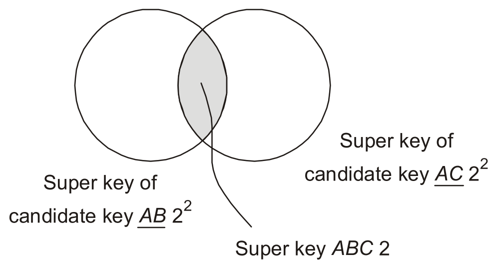
$$\text{Average waiting time} = \frac{0+5+4+8+8+11+12+14+16+17}{10} = \frac{95}{10} = 9.5$$

*End of Solution*

**Q.65** Consider a relational database schema with a relation $R(A, B, C, D)$. If $\{A, B\}$ and $\{A, C\}$ are the only two candidate keys of the relation $R$, then the number of superkeys of relation $R$ is ______. (answer in integer)

**Ans.** (6)

$\{\underline{AB}, \underline{AC}\}$ candidate keys.




Number of super keys.

$\Rightarrow \quad 2^2 + 2^2 - 2 = 6$

6 superkeys

End of Solution

■■■■