

1. A company wants to form a committee of 4 members from a group of 10 employees. Once the committee is selected, one of the 4 members is to be appointed as the Chairperson and another as the Secretary, while the remaining two will serve as regular members without any specific roles. Find the total number of ways to form the committee and assign these roles. (5 Marks)

2. Let G be the group of all invertible $n \times n$ real matrices under matrix multiplication and H , the multiplicative group of nonzero real numbers. Define a map:

$$\phi: G \rightarrow H \text{ by } \phi(A) = \det(A)$$
 - (a) Is ϕ a group homomorphism? Find the kernel of ϕ .
 - (b) Is ϕ a group isomorphism? Justify. (5 Marks)

3. A group of students in a school took two standardized tests: Test I and Test II. The results showed that 30% of the students passed neither test, 50% passed Test I and 60% passed Test II (some students passed both tests). If a student is selected at random, determine the probability distribution of the random variable Y , where Y represents the number of tests the student passed. (5 Marks)

4. A 5-stage pipeline suffers frequent RAW hazards and branch penalties. Suggest a hardware-level redesign to reduce CPI without reducing clock frequency. Justify your design choices. (5 Marks)

5. Design a hardware datapath for implementing Booth's multiplication algorithm for signed 8-bit numbers. Explain control signal sequencing and prove why arithmetic right shift is mandatory. What architectural modifications are needed to support 16-bit scaling? (5 Marks)

6. In a multiprocessor system, analyze why direct mapping may lead to severe performance degradation. Suggest architectural improvements without increasing cache size. (5 Marks)

7. Compare Dijkstra's and Floyd-Warshall algorithms in terms of correctness conditions, time complexity, space usage, and application scenarios. When is Floyd-Warshall preferred? (5 Marks)
8. Analyze the time complexity of union-find with path compression and union by rank. Why does it achieve nearly constant time? Provide intuition behind inverse Ackermann function. (5 Marks)
9. Prove that the height of a Red-Black Tree with n nodes is at most $2 \cdot \log(n+1)$. Explain the role of black-height in maintaining balance. (5 Marks)
10. Explain primary and secondary clustering in open addressing. Compare linear probing, quadratic probing and double hashing in terms of clustering effect and performance. (5 Marks)
11. A simple calculator application is required to perform different types of operations based on the type and number of inputs provided. In some situations, the calculator must add two integers, in others it must add three integers, sometimes it must add two decimal (double) values, and in certain cases it must concatenate two strings together.

Design and implement a Java program to model this calculator in such a way that the same method name is used to perform all these operations. The program should clearly demonstrate the concept of **method overloading**. Appropriate method definitions must be provided so that the correct operation is performed automatically depending on the arguments passed.

In the main method, create an object of the calculator class and invoke the different versions of the method with suitable arguments. The output should clearly display the results of each operation to justify that the appropriate overloaded method has been executed.

Use proper syntax, meaningful method signatures, and clear output statements in your program. (5 Marks)

12. In an organization, different categories of employees receive bonuses based on their role. All employees have a name and a salary, and generally receive a bonus equal to 5% of their salary. However, managers receive a higher bonus which is calculated differently. In addition to their salary, managers are given an extra incentive, and their total bonus is calculated as 10% of the salary plus the incentive amount.

Write a Java program to model the above scenario using inheritance. The program should clearly demonstrate the concept of **method overriding** and **runtime polymorphism**. The bonus calculation for managers which is defined as a subclass of class employee must redefine the general bonus calculation behaviour appropriately, while still making use of the original implementation wherever necessary.

In your program, ensure that employee details are displayed properly and that the bonus calculation is invoked using a superclass reference pointing to a subclass object. The output should clearly indicate that the method executed corresponds to the actual object created at runtime.

Use appropriate constructors, access modifiers and meaningful output statements to justify the concept being demonstrated. (5 Marks)

13. Apply Karnaugh map to simplify the following function: (5 Marks)

$\Sigma m(1, 7, 8, 15)$ with don't care terms $d(3, 11, 13)$.

14. Design a full adder circuit from its truth table. (5 Marks)

15. Consider the following data and register contents of the 8086 microprocessor: (5 Marks)

- DS = 2000H
- SI = 3000H
- AX = 1234H
- Memory location 2000:3050H contains 5678H
- Memory location 2000:3000H contains 9ABCH

Answer the following:

- (a) Identify the addressing mode used in the instruction:

MOV BX, AX

(1 Mark)

- (b) Identify the addressing mode used in the instruction:

MOV DX, [SI]

Also specify the data accessed and the effective address from which the data is accessed. (2 Marks)

- (c) Identify the addressing mode used in the instruction:

MOV CX, [3050H]

Also identify the physical address of the memory location. (2 Marks)

16. A software development team is developing a payroll management system in C. The program is divided into three separate source files: (5 Marks)

- main.c — contains the main() function
- salary.c — contains functions to calculate salary
- tax.c — contains functions to calculate tax

Each file is compiled separately, producing:

- main.obj
- salary.obj
- tax.obj

During execution, the program successfully compiles but shows an “undefined reference to calculate_tax” error during the build process.

- (a) At which stage (compilation, linking, or loading) does the error occur? Justify your answer. (2 Marks)
- (b) Explain the role of the linker in this situation. (1 Mark)
- (c) After successful linking, what is the role of the loader before the program starts execution? (2 Marks)

17. Compare **Recursive Descent Parser** and **Shift-Reduce Parser** with respect to the following aspects: (5 Marks)
- (a) Type of parsing approach used (top-down / bottom-up) (1 Mark)
 - (b) Handling of left-recursive grammars (1 Mark)
 - (c) Use of stack and parsing mechanism (1 Mark)
 - (d) Error detection capability. (2 Marks)

18. Consider the following set of processes arriving at time 0 in a system using Round Robin (RR) Scheduling: (5 Marks)

Process	Burst Time (ms)
P1	10
P2	5
P3	8

The time quantum is **4 ms**.

- (a) Draw the Gantt chart for the execution of processes using Round Robin scheduling. (3 Marks)
 - (b) Calculate the waiting time for each process. (2 Marks)
19. A computer system uses paging for memory management. (5 Marks)
- Logical address space size = 64 KB
 - Physical memory size = 32 KB
 - Page size = 4 KB
- (a) Calculate the number of pages in the logical address space. (1 Mark)
 - (b) Calculate the number of frames in physical memory. (1 Mark)
 - (c) Determine the number of bits required for: (3 Marks)
 - (i) Page number
 - (ii) Offset

20. Give any three differences between NoSQL databases and traditional-relational databases. (5 Marks)

An organization is developing two different software applications:

Scenario A:

A banking system that manages customer accounts, fund transfers, loan details, and transaction histories. The system must ensure strict data consistency, support complex queries involving multiple tables, and guarantee that all transactions either complete fully or roll back in case of failure.

Scenario B:

A social media analytics platform that collects large volumes of user-generated data such as posts, likes, comments, and click streams in real time. The data structure varies frequently, the system must handle high write throughput, and it should scale seamlessly across multiple servers.

Identify the most suitable type of database (relational or NoSQL) for each scenario.

21. Consider the relations: (5 Marks)

STUDENT (SID, SName, Dept)

COURSE (CID, CTitle)

ENROLLMENT (SID, CID, Grade)

where, SID is the student ID, Sname is the student name, CID is the course ID, CTitle is the course title.

Write a relational algebra expression to display the names of students and course titles for students who:

- belong to the CSE department, and
- have obtained grade 'A' in a course.

Use **selection (σ)**, **join (\bowtie)** and **projection (π)** operations.

22. (a) Explain the concept of conflict serializability in database systems.
- (b) Describe the Two-Phase Locking (2PL) protocol and explain how it helps in achieving conflict-serializable schedules. (5 Marks)

23. A communication channel of bandwidth 3 kHz is used to transmit digital data. (5 Marks)

- (a) Using Nyquist's theorem, determine the maximum data rate if the channel uses 8 distinct signal levels.
- (b) If the signal-to-noise ratio (SNR) of the channel is 30 dB, use Shannon's capacity theorem to calculate the maximum achievable channel capacity.
- (c) Based on your results, state which among the above mentioned theorem's imposes the practical limit on the data rate for this channel and justify your answer.

Note: $\log_2 (1000) \approx 9.9$.

24. Explain the working principles of Pulse Code Modulation (PCM) and Delta Modulation (DM). Compare PCM and DM in terms of sampling, quantization, bandwidth requirement, and noise performance. (5 Marks)

25. A communication service provider must support three different applications over a shared transmission medium: (5 Marks)

- Application A : Digital voice calls from multiple users, each active only for short durations
 - Application B : Several FM radio channels that must be transmitted simultaneously without interference
 - Application C : Mobile users transmitting data at the same time over the same frequency band, distinguished only by unique codes
- (a) Identify the appropriate multiple access/multiplexing technique (TDM, FDM, or CDMA) suitable for each application.
 - (b) Justify your choice for each case based on signal characteristics, bandwidth usage, and interference handling.

26. A college campus network faces the following situations: (5 Marks)

- Situation A : In a small computer lab, all connected systems receive every data frame, leading to unnecessary traffic and frequent collisions.
- Situation B : In an office LAN, data frames must be forwarded only to the intended destination system using MAC addresses to reduce network traffic.
- Situation C : Two departmental networks using different IP address ranges must communicate with each other and also access the Internet.
- Situation D : A network cable must be extended beyond its maximum permissible length because the signal becomes weak over long distances.

For each situation (A-D) :

(a) Identify the most appropriate networking device used in each situation from the list:

Hub, Switch, Router, Repeater

(b) State one function of the selected device that justifies your choice.

27. An online service provider supports different types of applications such as file transfer, video streaming, and online gaming over a computer network.

(5 Marks)

(a) Identify which transport protocol (TCP or UDP) is more suitable for file transfer and real-time video streaming, respectively.

(b) Justify your choices by comparing TCP and UDP in terms of reliability, flow control, and delay.

28. A company network uses the IP address range (5 Marks)

192.168.10.0/24.

The company web server is assigned the domain name intranet.company.com and the IP address

192.168.10.25.

Answer the following:

- (a) Identify the network address and broadcast address of the given IP block.
- (b) Provide the range of valid host IP addresses available in this network.
- (c) A user types intranet.company.com in a web browser.

Explain the DNS lookup steps involved in resolving this domain name to its IP address.

- (d) If the DNS server is down, explain what happens when the user tries to access the website and justify your answer.

29. Convert the following grammar into Chomsky normal form (5 Marks)

$S \rightarrow AAA \mid B$

$A \rightarrow aA \mid B$

$B \rightarrow \epsilon$

30. Write regular expression to accept all strings of digits such that all the 4's and 5's occur before all the 1's. (5 Marks)

31. Compare the Sigmoid and Softmax activation functions. (5 Marks)

32. What is a confusion matrix? How are accuracy, precision, recall and F1-score calculated from a confusion matrix? (5 Marks)

33. Consider the following sentences: (5 Marks)
- (a) Riya only watches animated movies.
 - (b) All movies produced by Marvel studios are super-hero action films.
 - (c) Every movie released by Disney is animated.
 - (d) Frozen is a movie released by Disney.
 - (i) Represent the sentences using first order logic.
 - (ii) Use inference to answer the question, “Will Riya watch the movie Frozen?”
34. Describe the step-by-step process of a Man-in-the-Middle attack on a Diffie-Hellman key exchange between Alice and Bob, involving an attacker, Cathy. (5 Marks)
35. Using the Playfair cipher with the keyword SYMPHONY, decrypt the cipher text NQQKYJNGHK. (5 Marks)
36. What is S/MIME? List the cryptographic algorithms that must be used in S/MIME to (5 Marks)
- (a) Create a message digest to be used in forming a digital signature.
 - (b) Encrypt message digest to form a digital signature.
 - (c) Encrypt session key for transmission with a message.
 - (d) Encrypt message for transmission with a one-time session key.
37. Write down five major differences between ReactJS and Node.js. (5 Marks)
38. What is the role of a proxy server, and how does it enhance security and performance in web applications? (5 Marks)
39. Compare and contrast the three primary cloud delivery models: IaaS, PaaS, and SaaS. Provide real-world examples for each. (5 Marks)
40. Describe the differences between Type 1 and Type 2 hypervisors with examples. In what scenarios is each type typically used? (5 Marks)