SECTION - A

There are FOUR questions in this section. Answer any THREE.

1. (a) Define model and entailment for propositional logic sentences with illustrative examples. What is a Horn clause? (9)
   (b) What is a unit clause and the full resolution rule? Briefly explain the soundness of the resolution rule. What are the rules for converting a propositional logic sentence to Conjunctive Normal Form (CNF)? Show how the half-adder circuit can be described by a CNF sentence. (18)
   (c) Define validity and satisfiability in propositional logic. How are they closely related to each other? (8)

2. (a) What is an intended interpretation in First-Order Logic (FOL)? Show how alternative interpretations are possible by using an illustrative example. What is the database semantics? (9)
   (b) What is a planning graph? What are the three conditions for mutex relations between two actions at a given level? (12)
   (c) Prove that the GraphPlan algorithm is complete by showing that it terminates and return failure if there is no possible solution. (14)

3. (a) What is a relaxed problem in the context of planning heuristics? Explain the ignore-pre-conditions and the ignore-delete-list heuristics for the blocksworld problem domain. (10)
   (b) What is the subgoal independence assumption? How does the state abstraction technique make it easier to find a solution plan in the air cargo problem domain? (10)
   (c) Find out the max-level, the level-sum, and the set-level heuristic value for the problem “have cake and eat cake too” in the cake domain by using a planning graph. What is a serial planning graph? (15)

4. (a) Briefly explain how you can represent temporal and resource constraints for the job shop scheduling problem. How does aggregation technique help in the representation? (9)
   (b) Why is the problem of finding a schedule with resource conflicts harder than the critical path problems? (8)
   (c) Consider a job shop scheduling problem where you have two jobs, each of the form [AddEngine, Addwheels, Inspect]. For the first job J1, the durations of three activities are...
30, 30, and 10, respectively. Also, for the second job J2, the durations of three activities are 60, 15, and 10, respectively. Assume, you have one engine hoist, one wheel station, two inspectors, and 500 nuts. Find out the makespan by minimum slack algorithm. What is the makespan, if you have two engine hoists, one wheel station, one inspector, 500 nuts with the duration of the activities of second job J2 being 40, 15, and 10, respectively.

SECTION – B

There are FOUR questions in this section. Answer any THREE.

5.  (a) Explain, giving a specific example, why chronological backtraking might be sub-optimal in solving Constraint Satisfaction Problems (CSPs).

(b) Describe the AC-3 algorithm with pseudo code for enforcing arc consistency in solving CSPs. Suggest a way in which the concept of arc consistency, (also known as 2-consistency) can be extended to sets of three, rather than two variables. Suggest a modified version of the AC-3 algorithm that can be used to enforce 3-consistency.

(c) Using an appropriate example, describe how we can apply forward checking in the process of solving a CSP.

6.  (a) Define what it means for a search algorithm to be complete and optimal. Explain why these two criteria are important for a search algorithm.

(b) Compare and contrast heuristic search and exhaustive search. Which compromises are accepted by a heuristic approach? Illustrate your answer with examples of heuristics.

(c) Describe the operation of the A* heuristic search algorithm. Prove that the A* heuristic search algorithm is optimal when applied in conjunction with a monotonic heuristic.

7.  (a) Describe the Minimax Algorithm for searching game trees. Suggest the modifications required to this algorithm in order to apply it to realistic games.

(b) Explain how the Alpha-Beta Algorithm is a better way than conventional algorithms to search game trees. The algorithm depends on certain assumptions about how the game is played. What are those?

(c) Provide a detailed description of the Iterative Deepening A* (IDA*) algorithm. Your answer should include a clear statement of the algorithm in pseudo-code, and a general description of how it works.
8. (a) Using an appropriate figure, explain the pitfalls of greedy search algorithms. How can the main pitfall of this algorithm be solved by applying it in conjunction with simulated annealing. Your answer should include a clear statement of the algorithm in pseudo-code, and a general description of how it works. (20)

(b) Describe the basic evolutionary algorithm with its all components. (15)
1. (a) Consider the following scenario:
A language teacher wants to register a particular student for an online French course. After he logs in, he is shown a list of students. When he selects a particular student, a list of languages is displayed. After he selects a language (say, French), he is shown a list of course on French that the selected student has not taken yet. When he selects a course, the course assignment is complete.

Make a list of the inconsistencies in the class diagram given below. Don't redraw the diagram.

(b) Graphically show the variation of resource consumption during the lifetime of a system.

(c) Name three types of questions to avoid during an interview. Give one example of each.

(d) Name two sampling techniques in the context of requirement analysis.
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2. (a) Refer to the scenario mentioned in 1(a). Now, draw a collaboration diagram which accurately represents the scenario.

Note that, solving 1(a) is not mandatory for this step. However, make sure that the function names accurately represent the tasks they perform.

(b) Mention the five stages of the Agile Development life cycle. Draw the Systems Development Life Cycle.

(c) Write one/two word answers to the following questions on Sequence Diagrams.

(i) The execution of an operation in a sequence diagram is shown by __________.
(ii) An asynchronous message is drawn with ____________________.
(iii) Returns are drawn with ____________________.
(iv) Is focus of control the same as activation?
(v) What is the one major difference between sequence diagrams and collaboration diagrams?

3. (a) Consider the following scenario:
Suppose, you want to design an information system for a multi-seller online shopping site. Anyone can search for products, or view some exciting sale offers. In both cases, you will be shown a product list. After you click on a product from the list, you can view the details. Also, in that page, there has to be options for adding the product to the cart (provided that it is available), ranking the supplier of that particular product, and writing a review. After a user has added something to his cart, he can proceed to checkout. In this phase, the system needs to check whether the user is logged in. If the user is an unregistered one, he needs to be requested to sign in. When the user has successfully ordered his product, and is logged into the system, he can view or handle his order status. Now, complete the Use-case Diagram given below. In case of any extends use-case, clearly mention the extension point. In addition to labeling the existing relationships, you can also add new ones.

However, you must not rename the existing use cases. Note that, you can add new use-cases to the diagram, but it is not strictly required.
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Contd., Q. No. 3

(b) (i) Name the types of structural things in UML.

(ii) Name four types of relationships in UML class diagram.

4. (a) Define data partitioning and data replication.
Consider a shoe manufacturing company called ABC Limited. The company has numerous branches in 21 countries, and maintains digital records of all purchases made in all branches using a relational database. Among many tables, there is a Customer table, which contains the names, addresses and contact information of all the customers of all branches. There is also a Shoe table, which contains the names and details of all shoes manufactured by the company.
Will you apply data partitioning and/or data replication? Why?

(b) (i) Name the five layers of computing in the context of application architecture.
(ii) Depending on the placement of these layers, application architecture can be divided into four groups. Name them.
(iii) For each group in (ii), mention where the computing layers are placed by filling the table given below. In place of Layer n/Group n, write the actual name of the layer/group.

<table>
<thead>
<tr>
<th>Layer 1</th>
<th>Layer 2</th>
<th>Layer 3</th>
<th>Layer 4</th>
<th>Layer 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group B</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group D</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(c) Define Openness and Closedness in the context of organizational environments.

SECTION - B
There are FOUR questions in this section. Answer any THREE.

5. (a) The following diagram states that Modules 1, 2 and 3 are available for integration, whereas, below modules are still under development that cannot be integrated at this point of time. Hence, Stubs are used to test the modules. Write down the order of integration testing if BFS used.
(b) Consider the following C code (contains goto statements). Draw a flow graph from the code (give node name same as the equivalent label name in the code). Find the cyclomatic complexity of the graph. Find out the independent paths.

```c
void function() {
    A: statement A;
    if (condition 0) {
        if (condition 1) {
            B: statement B;
            if (condition 2) {
                C: statement C;
                if (condition 3) goto B;
            } else {
                E: statement E;
                goto F;
            }
        } else {
            D: statement D;
            if (condition 4) goto E;
            else { F: statement F; }
        }
    } else {
        E: statement E;
        goto F;
    }
}
```

(c) Consider the following diagram. List all the errors present in this diagram. You do not need to consider any naming convention error like process should be named as verb-adj-noun.

(In this diagram, E1, E2 ... are external entities; P1, P2 ... are processes; D1, D2 ... are data stores and df1, df2 ... are data flows.)
(d) Write down the name of attributes while defining a data store.

6. (a) Consider the following process in Diagram 0 of a system.

A Child diagram is drawn in order to decompose the process 1.0. Now label the data flows in Child diagram correctly according to the parent diagram. Also, mention suitable numbers for processes in Child diagrams.
(b) There are two-system analysts in Markov Company. First analyst wants to quit from the job as early as possible but before he leaves, he wants to show profit for the project in earliest possible time. However, second analyst is loyal to the company and he wants to make more profit considering the total time line of the project. Now the project has two options for development. The revenue and costs of each method is given below (in dollar).

<table>
<thead>
<tr>
<th>Year</th>
<th>COTS method</th>
<th>SaaS method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>cost</td>
<td>revenue</td>
</tr>
<tr>
<td>1</td>
<td>10000</td>
<td>5000</td>
</tr>
<tr>
<td>2</td>
<td>1000</td>
<td>5000</td>
</tr>
<tr>
<td>3</td>
<td>2000</td>
<td>4000</td>
</tr>
<tr>
<td>4</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>5</td>
<td>1000</td>
<td>1500</td>
</tr>
</tbody>
</table>

(Consider discount rate $i = 10\%$)

(i) Which method will the First analyst choose? When can he leave the company?
(ii) Which method will the Second analyst choose?

(c) Draw a sample wireframing for YouTube home page. (Assume that you have already logged in gmail)

(d) Explain the following terms in the context of input and output design. (Any three)

(i) Grid structure in website
(ii) Non-responsive design
(iii) Context of data in dashboard
(iv) Auto focus in form design

7. (a) The RELIABLE CONSTRUCTION COMPANY has made the winning bid to construct a new plant for a major manufacturer. The following table lists the necessary activities for the construction. From the table, first draw a Gantt chart. Then convert it to Pert diagram (Edge represented as task).
Finally, find all the paths with their duration and report the critical path. (You may use Edge label to represent a path. For example start_node-A-B-C-D-G-H-M-finish_node will be a path) 

(4+7+4=15)

<table>
<thead>
<tr>
<th>Activity</th>
<th>Activity Description</th>
<th>Immediate Predecessors</th>
<th>Estimated Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Excavate</td>
<td></td>
<td>2 weeks</td>
</tr>
<tr>
<td>B</td>
<td>Lay the foundation</td>
<td>A, C</td>
<td>4 weeks</td>
</tr>
<tr>
<td>C</td>
<td>Put up the rough wall</td>
<td>B, G</td>
<td>10 weeks</td>
</tr>
<tr>
<td>D</td>
<td>Install the exterior plumbing</td>
<td>C, E</td>
<td>6 weeks</td>
</tr>
<tr>
<td>E</td>
<td>Install the interior plumbing</td>
<td>F, G</td>
<td>4 weeks</td>
</tr>
<tr>
<td>G</td>
<td>Put up the exterior siding</td>
<td>D</td>
<td>7 weeks</td>
</tr>
<tr>
<td>H</td>
<td>Do the exterior painting</td>
<td>E, G</td>
<td>9 weeks</td>
</tr>
<tr>
<td>I</td>
<td>Do the electrical work</td>
<td>C</td>
<td>7 weeks</td>
</tr>
<tr>
<td>J</td>
<td>Put up the wallboard</td>
<td>F, I, J</td>
<td>8 weeks</td>
</tr>
<tr>
<td>K</td>
<td>Install the flooring</td>
<td>J, L</td>
<td>4 weeks</td>
</tr>
<tr>
<td>L</td>
<td>Do the interior painting</td>
<td>J, H, M, N</td>
<td>5 weeks</td>
</tr>
<tr>
<td>M</td>
<td>Install the interior finishes</td>
<td>K, L</td>
<td>2 weeks</td>
</tr>
</tbody>
</table>

Table for Question 7(a)

(b) For the previous problem, suppose RELIABLE CONSTRUCTION COMPANY has also a fund of 150,000$ to speed up the project. Time-cost trade-off data has been shown on the following table. Given the constraint, which activities can be crashed? Also, find the critical path with duration after crashing.

(10)

<table>
<thead>
<tr>
<th>Activity</th>
<th>Normal Time</th>
<th>Crash Time</th>
<th>Normal Cost</th>
<th>Crash Cost</th>
<th>Reduction in Time</th>
<th>Crash Cost per Week Saved</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2 weeks</td>
<td>1 week</td>
<td>$180,000</td>
<td>$280,000</td>
<td>1 week</td>
<td>$100,000</td>
</tr>
<tr>
<td>B</td>
<td>4 weeks</td>
<td>2 weeks</td>
<td>$260,000</td>
<td>$300,000</td>
<td>2 weeks</td>
<td>$10,000</td>
</tr>
<tr>
<td>C</td>
<td>10 weeks</td>
<td>7 weeks</td>
<td>$620,000</td>
<td>$680,000</td>
<td>3 weeks</td>
<td>$10,000</td>
</tr>
<tr>
<td>D</td>
<td>6 weeks</td>
<td>4 weeks</td>
<td>$260,000</td>
<td>$340,000</td>
<td>2 weeks</td>
<td>$10,000</td>
</tr>
<tr>
<td>E</td>
<td>4 weeks</td>
<td>3 weeks</td>
<td>$300,000</td>
<td>$400,000</td>
<td>1 week</td>
<td>$10,000</td>
</tr>
<tr>
<td>F</td>
<td>5 weeks</td>
<td>3 weeks</td>
<td>$200,000</td>
<td>$300,000</td>
<td>2 weeks</td>
<td>$10,000</td>
</tr>
<tr>
<td>G</td>
<td>7 weeks</td>
<td>4 weeks</td>
<td>$90,000</td>
<td>$1,000</td>
<td>3 weeks</td>
<td>$10,000</td>
</tr>
<tr>
<td>H</td>
<td>9 weeks</td>
<td>6 weeks</td>
<td>$200,000</td>
<td>$300,000</td>
<td>3 weeks</td>
<td>$10,000</td>
</tr>
<tr>
<td>I</td>
<td>7 weeks</td>
<td>5 weeks</td>
<td>$200,000</td>
<td>$300,000</td>
<td>2 weeks</td>
<td>$10,000</td>
</tr>
<tr>
<td>J</td>
<td>8 weeks</td>
<td>6 weeks</td>
<td>$200,000</td>
<td>$320,000</td>
<td>2 weeks</td>
<td>$10,000</td>
</tr>
<tr>
<td>K</td>
<td>4 weeks</td>
<td>3 weeks</td>
<td>$100,000</td>
<td>$200,000</td>
<td>2 weeks</td>
<td>$10,000</td>
</tr>
<tr>
<td>L</td>
<td>5 weeks</td>
<td>3 weeks</td>
<td>$300,000</td>
<td>$350,000</td>
<td>2 weeks</td>
<td>$10,000</td>
</tr>
<tr>
<td>M</td>
<td>2 weeks</td>
<td>1 week</td>
<td>$100,000</td>
<td>$200,000</td>
<td>1 week</td>
<td>$10,000</td>
</tr>
<tr>
<td>N</td>
<td>6 weeks</td>
<td>3 weeks</td>
<td>$130,000</td>
<td>$210,000</td>
<td>3 weeks</td>
<td>$10,000</td>
</tr>
</tbody>
</table>

Table for Question 7(b)

(c) (i) In your thesis, you have provided a new method NMT (Neural Machine Translation) for text classification. You compare your method with other techniques and the comparison is given below.

<table>
<thead>
<tr>
<th>Method</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>NMT</td>
<td>78%</td>
</tr>
<tr>
<td>LSTM</td>
<td>74%</td>
</tr>
<tr>
<td>CNN</td>
<td>75%</td>
</tr>
<tr>
<td>SVM</td>
<td>68%</td>
</tr>
</tbody>
</table>

Contd ......... P/8
It can be seen that the accuracy of each method does not differ much. Draw an appropriate graph to bias the readers so that your method seems to outperform other techniques.

(ii) Moreover, the accuracy of your method does not increase so much if the iteration number increases. For example, accuracy of your method and LSTM is shown below over iteration number.

<table>
<thead>
<tr>
<th>Iteration</th>
<th>NMT Accuracy</th>
<th>LSTM Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>70</td>
<td>60</td>
</tr>
<tr>
<td>200</td>
<td>72</td>
<td>65</td>
</tr>
<tr>
<td>300</td>
<td>75</td>
<td>70</td>
</tr>
<tr>
<td>400</td>
<td>78</td>
<td>74</td>
</tr>
</tbody>
</table>

Present these data in graphs in a biased way so that your method seems to improve better as iteration number increases. (Hints: You need to use separate graph for each method) (5+5=10)

8. (a) Identify the mistakes in the following customer registration form.

(b) Suppose, one sunny morning in 4-1, you woke up at 11 am and opened your mail. You found that you have been hired as a part-time developer of a startup company called Pounopunik App Solution. You went to the company with great enthusiasm but found out that the office consists of 2 rooms only. The company has one system analyst, two full-time developers and five part-time developers including you. You need to work 20 hours per week and may need to do some round the clock work to meet deadline.

The Pounopunik App Solution has the task of developing mobile ERP solution and feedback support for a large multi-national company X. The timeline of the project is 9 months. Now buying license from SAP mobile solution nearly costs 1500$ and requirement criteria of company X is hardly similar to this SAP mobile version. Assume that developing mobile ERP solution is being done for the first time in Bangladesh.
Currently the office has one desktop and one laptop. Since all the part-time developers are CSE students, they have their own laptops.

(i) Given the scenario, which hardware alternative should *Pounopunik App Solution* choose? Point out reasons behind your decision.

(ii) Which software alternative should the startup choose to develop the mobile ERP according to the given scenario? State your reasons.

(c) According to the scenario in previous question, *Pounopunik App Solution* has started to develop in full swing. It has bought a printer, a projector and other stationary items. The works have been done in full swing for three months. However, due to the ineffective decision making of the system analyst, the company lost a competitive edge. In the meantime, another software company has brought the mobile ERP solution in the market, which declines the image of your startup.

Identify the tangible and intangible costs associated with *Pounopunik App Solution* according to the above scenario.

(d) Consider the following specifications.

**Input:** length of three sides of a triangle: a, b, c

**Output:** true if each side is a positive number less or equal to 20 and the triangle is Isosceles (2 sides are equal), false otherwise.

**Precondition:** the sides form a triangle (You do not need to consider cases like a+b<=c)

(i) First, write down all valid and invalid equivalence classes for this problem. (For example, V1: 0 <a, b, c<=20; V2: a==b and a!=c are two valid equivalent classes. On the other hand, X1: a>20, X2: a==b==c are two invalid equivalent classes.)

(ii) Generate test cases covering all classes. Use the following table structure. Try to minimize the number of tests. (First few entries have been shown for your convenience)

<table>
<thead>
<tr>
<th>Test no</th>
<th>Test data</th>
<th>Expected outcome</th>
<th>Class covered</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5, 5, 2</td>
<td>T</td>
<td>V1, V2</td>
</tr>
<tr>
<td>2</td>
<td>22, 14, 14</td>
<td>F</td>
<td>X1</td>
</tr>
<tr>
<td>3</td>
<td>7, 7, 7</td>
<td>F</td>
<td>X2</td>
</tr>
</tbody>
</table>

---

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Contd. Q. No. 8(b)
1. (a) Briefly describe first fit and next fit memory management algorithms. Which one performs better in practice? Consider a swapping system in which memory consists of the following hole sizes in memory order: 10 MB, 4 MB, 20 MB, 18 MB, 7 MB, 9 MB, 12 MB, and 15 MB. Which hole is taken for successive segment requests of (i) 12 MB, (ii) 10 MB, and (iii) 9 MB for best fit and worst fit? (10)

(b) Suppose that a machine has 38-bit virtual addresses and 32-bit physical addresses. Now answer the following in this context.

i. What is the main advantage of a multilevel page table over a single-level one? (10)

ii. With a two-level page table, 16-KB pages, and 4-byte entries, how many bits should be allocated for the top-level page table field and how many for the next level page table field?

(c) What are the advantages of segmentation over paging? Describe with necessary diagrams how MULTICS incorporates segmentation with paging. (10)

(d) The average process size is s bytes, the page size is p bytes, and each page entry is e bytes. Deduce the equation for optimal page size. (5)

2. (a) Suppose that the WSClock page replacement algorithm uses at τ of 2 ticks, and the system state is the following:

<table>
<thead>
<tr>
<th>Page#</th>
<th>Time stamp</th>
<th>V</th>
<th>R</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>9</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>9</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Here, the three flag bits V, R, and M stand for Valid, Referenced, and Modified, respectively.

(i) If a clock interrupt occurs at tick 10, show the contents of the new table entries with explanation. (10)

(ii) Suppose that instead of a clock interrupt, a page fault occurs at tick 10 due to a read request to page 3. Show the contents of the new table entries with explanation. Contd. ......... P/2
(b) A computer has four-page frames. The time of loading, time of last access, and the R and M bits for each page are as shown below (the times are in clock ticks):

<table>
<thead>
<tr>
<th>Page</th>
<th>Time of loading</th>
<th>Last ref.</th>
<th>R</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>230</td>
<td>265</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>140</td>
<td>270</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>110</td>
<td>285</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>126</td>
<td>280</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

i. Which page will NRU algorithm replace?
ii. Which page will FIFO algorithm replace?
iii. Which page will LRU algorithm replace?
iv. Which page will second chance algorithm replace?
(c) "Page fault cost varies" - is this statement true or false? Give appropriate reasoning of your answer. Briefly describe copy on write technique for the fork system call.
(d) Using the page table below, give the physical address corresponding to each of the following virtual addresses: (i) 20, (ii) 4100, and (iii) 8300

Contd. ........ P/3
CSE 313

3. (a) Briefly describe resource allocation graph with examples. Write down the algorithm that uses resource allocation graph to detect deadlock with one resource of each type. (10)

(b) Write down the algorithm for deadlock detection with multiple resources of each type with describing each of the matrices (C, R, E, A) the algorithm requires. (10)

Consider the following state of a system with four processes, P1, P2, P3, and P4, and five types of resources, RS1, RS2, RS3, RS4, and RS5:

Using the above deadlock detection algorithm, find out whether there is a deadlock in the system and identify the processes that are deadlocked.

(c) Briefly describe the four conditions for resource deadlock. By attacking which condition, you can achieve the most feasible deadlock prevention technique? How can you prove the correctness of this technique? (10)

(d) Two processes, A and B, each need three records, 1, 2, and 3, in a database. If A asks for them in the order 1, 2, 3, and B asks for them in the same order, deadlock is not possible. However, if B asks for them in the order 3, 2, 1, then deadlock is possible. What fraction of all the combinations is guaranteed to be deadlock free? (5)

4. (a) Suppose you are writing a program to print your first name using the printer. Describe how you can achieve that using, (i) Programmed I/O, (ii) Interrupt driven I/O, and (iii) I/O using DMA with small code segments identifying key features. (10)

(b) Disk requests come in to the disk driver for cylinders 10, 22, 20, 2, 40, 6, and 38, in that order. A seek takes 6 ms per cylinder. How much seek time is needed for (i) First-come, first served, (ii) Shortest Seek First, (iii) Elevator algorithm (initially moving upward). In all cases, the arm is initially at cylinder 20. (10)

(c) What is meant by stable storage? Describe three operations to accomplish stable storage. Prove with example that stable writes can survive CPU crashes. (10)

(d) What is a cache coherence protocol? What happens (based on this protocol) if a CPU attempts to write a word that is in one or more remote caches? (5)

SECTION – B

There are FOUR questions in this section. Answer any THREE.

5. (a) What is abstraction? Briefly explain using an example how an operating system helps an application programmer by providing abstractions. (5)

(b) Briefly explain dual mode operation. How can a user program access services provided by an operating system? (5+5=10)
(c) The following processes arrive at a system according to the table below. Assume that the process switching time is 0 second. Calculate average turnaround and response time for (i) FCFS Scheduling and (ii) Round Robin Scheduling with quantum of 2 seconds.

<table>
<thead>
<tr>
<th>Process</th>
<th>Arrival Time (sec)</th>
<th>CPU Burst Time (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>B</td>
<td>1.8</td>
<td>6</td>
</tr>
<tr>
<td>C</td>
<td>3.2</td>
<td>4</td>
</tr>
<tr>
<td>D</td>
<td>5.6</td>
<td>5</td>
</tr>
<tr>
<td>E</td>
<td>7.9</td>
<td>2</td>
</tr>
</tbody>
</table>

6. (a) Briefly describe the states of a typical process with a diagram. Mention how transitions occur between the states.

(b) Mention the advantages and disadvantages of implementing threads in the Kernel.

(c) How can you differentiate a program from a process? How a program becomes a process?

(d) What makes context switching a costly operation? How threads are helpful over processes in this regard?

(e) "Each user level thread needs its own stack" - do you agree with the statement? Why or why not?

7. (a) How can you use semaphore to ensure (i) mutual exclusion, (ii) access to limited resource, and (iii) synchronization? Briefly explain each case with appropriate pseudo-code(s).

(b) When multiple co-operating processes communicate, special attention is required so that the system does not get stuck because of deadlocks. Providing proper synchronization mechanism to ensure liveliness and controlling access to shared resources are also some factors which makes the job quite difficult.

To pass this exam, you might have studied some of the classical IPC problems and their solution approaches. However here we are asking you to design a new problem. Think of a non-classical IPC problem. You don't need to solve the problem. Rather, clearly mention the IPC issues in this problem.

8. (a) What is a race condition? Why cooperating processes are necessary?

(b) What is disk fragmentation? Briefly explain how implementing files using contiguous allocation leads to this problem.

(c) Briefly describe a strategy to check consistency of blocks in a file system.

(d) Show the structure of an i-node in UNIX V7 file system.
SECTION – A

There are FOUR questions in this section. Answer any THREE.

1. (a) A certain word is equally likely to be in any one of three different files. Let, \( P_i \) be the probability that you will find the word upon making a quick examination of file \( i \), if the word is, in fact, in file \( i \), for \( i = 1, 2, 3 \). Given \( P_1 = \frac{1}{2}, P_2 = \frac{1}{3}, P_3 = \frac{1}{4} \). Suppose you look into file 2 and do not find the word. What is the probability that the word is in file 2?

(b) Two chips are drawn at random without replacement from a box that contains five chips numbered 1 through 5. If the sum of chips drawn is even, the random variable \( X \) equals 5; if the sum of chips drawn is odd, then \( X = -3 \).

(i) Find the moment-generating function (mgf) for \( X \).

(ii) Use the mgf to find the first and second moments.

(iii) Find the expected value and variance of \( X \).

(c) It is known that DVDs produced by a certain company will be defective with probability 0.01, independent of each other. The company sells the DVDs in packages of size 10 and offers a money-back guarantee that if at least 1 of the 10 DVDs in a package is defective, money will be returned. If someone buys 3 packages, what is the probability that he or she will return exactly 1 of them?

2. (a) Each element in a sequence of binary data is either 1 with probability \( p \) or 0 with probability \( 1 - p \). A maximal subsequence of consecutive values having identical outcomes is called a run. For instance, if the outcome sequence is 1, 1, 0, 1, 1, 1, 0, the first run is of length 2, the second is of length 1, and the third is of length 3.

(i) Find the expected length of the first run.

(ii) Find the expected length of the second run.

(b) A prisoner is trapped in a cell containing three doors. The first door leads to a tunnel that returns him to his cell after two days of travel. The second leads to a tunnel that returns him to his cell after three days of travel. The third door leads immediately to freedom. Assuming that the prisoner is always equally likely to choose among those doors that he has not used, what is the expected number of days until he reaches freedom? (In this version, for instance, if the prisoner initially tries door 1, then when he returns to the cell, he will now select only from doors 2 and 3.)
CSE 301
Contd ... Q. No. 2

(c) A computer receives requests for elements stored in its memory. Consider \( n \) elements \( e_1, e_2, \ldots, e_n \) are initially arranged in some ordered list. At each unit of time a request is made for one of these elements, \( e_i \), independently of the past, with probability \( P_i \). After being requested, the element is then moved to the front of the list. That is, for instance, if the present ordering is \( e_1, e_2, e_3, e_4 \) and \( e_3 \) is requested, then the next ordering is \( e_3, e_1, e_2, e_4 \). Determine the expected position of the element requested after this process has been in operation for a long time.

3. (a) A professor continually gives exams to her students. She can give three possible types of exams, and her class is graded as either having done well or badly. Let \( P_i \) denote the probability that the class does well on a type \( i \) exam, and suppose that \( P_1 = 0.3, P_2 = 0.6, \) and \( P_3 = 0.9 \). If the class does well on an exam, then the next exam is equally likely to be any of the three types. If the class does badly, then the next exam is always type 1. What proportion of exams are type \( i \), for \( i = 1, 2, 3 \)?

(b) A particle moves among \( n + 1 \) vertices that are situated on a circle in the following manner. At each step it moves to the next vertex either in the clockwise direction with probability \( p \) or the counterclockwise direction with probability \( q = 1 - p \). Starting at a specified vertex, call it vertex 0, let \( T \) be the time of the first return to vertex 0. Find the probability that all vertices have been visited by time \( T \).

(c) Consider a Poisson process with rate \( \lambda \), and let us denote the time of the first event by \( T_1 \). Further, for \( n > 1 \), let \( T_n \) denote the elapsed time between the \((n-1)\)st and the \(n\)th event. The sequence \( \{T_n, n=1,2,\ldots\} \) is called the sequence of inter-arrival times. Show that \( T_n, n=1,2,\ldots \), are independent identically distributed exponential random variables having mean \( 1/\lambda \).

(d) Suppose that \( X_1 \) and \( X_2 \) are independent exponential random variables with respective means \( 1/\mu_1 \) and \( 1/\mu_2 \); what is \( P\{X_1 < X_2\} \)?

4. (a) Consider a shoe shine shop consisting of two chairs. Suppose that an entering customer will first go to chair 1. When his work is completed in chair 1, he will go either to chair 2 if that chair is empty or else wait in chair 1 until chair 2 becomes empty. Suppose that a potential customer will enter this shop as long as chair 1 is empty. (Thus, for instance, a potential customer might enter even if there is a customer in chair 2.) Suppose that potential customers arrive in accordance with a Poisson process at rate \( \lambda \), and that the service times for the two chairs are independent and have respective exponential rates of \( \mu_1 \) and \( \mu_2 \).
CSE 301
Contd... Q. No. 4(a)

(i) Draw a state diagram of the system and write down balance equations for each state.
(ii) What proportion of potential customers enters the system?
(iii) What is the mean number of customers in the system?
(iv) What is the average amount of time that an entering customer spends in the system?

(b) Suppose that customers arrive at a single-server service station in accordance with a Poisson process having rate \( \lambda \). That is the times between successive arrivals are independent exponential random variables having mean \( 1/\lambda \). Each customer, upon arrival, goes directly into service if the server is free and, if not, the customer joins the queue. When the server finishes serving a customer, the customer leaves the system, and the next customer in line, if there is any, enters service. The successive service times are assumed to be independent exponential random variable having mean \( 1/\mu \). This system is called the M/M/1 queue. For the M/M/1 queuing system, compute

(i) the average number of customers in the system,
(ii) the average time a customer spends in the system,
(iii) the average number of customers in the queue and
(iv) the average time a customer spends in the queue.

(c) Consider a network of three stations with a single server at each station. Customers arrive at stations 1, 2, 3 in accordance with Poisson processes having respective rates 5, 10, and 15. The service times at the three stations are exponential with respective rates 10, 50, and 100. A customer completing service at station 1 is equally likely to (i) go to station 2, (ii) go to station 3, or (iii) leave the station. A customer departing service at station 2 always goes to station 3. A departure from service at station 3 is equally likely to either go to station 2 or leave the system.

(i) What is the average number of customers in the system (consisting of all three stations)?
(ii) What is the average time a customer spends in the system?

SECTION - B
There are FOUR questions in this section. Answer any THREE.

5. (a) Find the solution to the following recurrence relation.
\[ a_0 = 1 \]
\[ a_1 = 9 \]
\[ a_{n+2} - 17a_{n+1} + 70a_n = 6 \text{ where } (n \geq 2) \]

(b) What is spectrum (\( \text{Spec}(\gamma) \)) of a real number? Let \( n \) be an arbitrary positive integer. Let \( p \) be the number of elements of \( \text{Spec}(\sqrt{2}) \) that are less than or equal to \( n \). Let \( q \) be the number of elements of \( \text{Spec}(2+\sqrt{2}) \) that are less than or equal to \( n \). Prove that \( p + q = n \).
6. (a) Find a closed form of the sum \( \sum_{1 \leq k \leq n} k^2 c^d \) where \( c \) and \( d \) are non-negative integer constants.

(b) Derive, with detailed reasoning, the \( L \) and \( R \) matrices for Stern-Brocot tree. Using these, write down the algorithm for representing any positive fraction \( a/b \), with \( a \perp b \), as a string of the letters \( L \) and \( R \).

7. (a) Find, through detailed steps, the number of ways a rooted ordered binary tree can be constructed from \( n \) vertices.

(b) Deduce the recurrence relation for the Stirling numbers of the first and second kind.

(c) State and prove the inversion formula.

8. (a) Prove, with detailed reasoning, that the number of partitions of a positive integer into distinct summands is identical to the number of partitions of that integer into odd summands.

(b) A ship carries 48 flags, 12 each of the colors red, white, blue and black. 12 of these flags are placed on a vertical pole in order to communicate a signal to other ships. How many of the signals have at least three white flags or no white flags at all?
1. (a) A network engineer is, first, given two options to send routing decision making related information over a packet switching datagram subnet under his control. The first option is to send distances of neighbors to all other routers (classical LSR), and the second option is to send distances of all other routers to neighbors (classical DVR). The engineer chooses the second option, i.e., to send distances of all other routers to neighbors, in a classical manner. This gives him to have two advantages – (i) simplicity, and (ii) fully distributed routing algorithm. However, here, he faces two key limitations – (i) slow convergence even after incorporating "Split Horizon" and "Forced Update", and (ii) no provision of incorporating multiple paths. Now, considering the limitations, the network engineer changes his strategy from "sending distances of all other routers to only the neighbors" to "sending distances of all other routers to all other routers" (thus, it is now neither classical LSR nor classical DVR). After adopting this approach, the engineer performs necessary processing over all available information in a router. Accordingly, he claims that both the limitations get solved keeping the two advantages and incurring no more added limitation. Considering the changes made by the engineer, i.e., "sending distances of all other routers to all other routers", you need to pinpoint which of the above-mentioned limitations (if any) can actually be solved and what additional problems (if any) can get created. Elaborate your answer with necessary figures and elaborations.

(b) "Border Gateway Protocol (BGP) adopts Path Vector Protocol to allow policy making, to avoid loops, and to permit transits between customer-provider or even between two peers" – validate or invalidate this statement with necessary figures and elaborations.

2. (a) Both IPv4 and IPv6 define ranges of IP addresses as private IP addresses to enable using behind a NAT. A network engineer is given a task of configuring his network hosts' IP address behind a NAT, where sometimes he needs to enable fragmentation for some of his applications. Either of the two possible solutions for fragmentation, namely transparent fragmentation and non-transparent fragmentation will be made available to him in case he needs to do fragmentation. Considering the above-mentioned aspects, you need to identify which one (or even none, or both) between IPv4 and IPv6 the network engineer can adopt. You need to make your judgment with proper reasoning and necessary elaborations.

Contd .......... P/2
(b) "Reverse Path Forwarding is basically intended for the purpose of broadcast routing, however, its concept can be equally applicable in Multicast routing" — validate or invalidate this statement with necessary figures and elaborations.  

3. (a) Nagel's solution and Clark's solution in flow control solve the problem with slow sender and slow receiver, respectively. You are given a task to integrate these two solutions to deal with two hosts communication using Real-time Transport Protocol (RTP), which refers to a protocol implemented in the Application layer to deal with multiplexing and de-multiplexing of several real-time streams.

You, first, need to answer whether you can perform the integration task. If you think you can perform the task, then you need to elaborate how you can do it. If you think it cannot be done, then you need to justify your thought with necessary elaborations.

(b) "A fixed value of Retransmission Timeout Timer (RTO) is better to be always in operation than to compute it after transmission of each packet due to having no computational overhead in the first case and huge computational overhead in the second case" — validate or invalidate this statement with necessary figures and elaborations.

4. (a) Can you get a saw-tooth behavior in TCP Tahoe congestion control algorithm? If so, then elaborate why and how you can get it.

If you think it is not possible to get it in TCP Tahoe, then is there any alternative to get it?

If so, then elaborate why and how you can get it in an alternative.

Your elaboration needs to have necessary figures.

(b) "Congestion collapse can only occur in case of TCP, and it is impossible in case of UDP" — validate or invalidate this statement with necessary figures and elaborations.

SECTION – B

There are FOUR questions in this section. Answer any THREE.

All the symbols have their usual meanings unless explicitly mentioned.

5. (a) What is protocol layering? Give two arguments for and two counter arguments against protocol layering?

(b) Describe briefly the delay components in the end-to-end delay (i.e., the time it takes for a packet to reach from the source to its destination) in a packet switched network.

(c) What is the advantage of using persistent HTTP over non-persistent HTTP? Illustrate with an example.

(d) Suppose Alice, using a desktop based e-mail client (such as outlook) sends a message to Bob, who accesses his mail using a web-based e-mail account (such as Gmail). Describe how the message gets from Alice's host to Bob's host. Particularly, list the series of application-layer protocols that are used to move the message between two hosts.
(e) Suppose you have just created a new e-commerce startup company called 'Tori Ghori' to sell watches and clocks online. You have registered the domain name torighori.com at a registrar. You have also procured a range of public IP addresses: 210.210.210.1-210.210.210.4 from some ISP. You plan to run your own web server and DNS server. But for e-mail, you plan to use Google's Gmail service keeping your domain name, i.e., any mail sent to an address of the form username@torighori.com, will eventually land in some Gmail inbox. Now, describe in details how and what record would you insert into the DNS database such that people can browse your website at www.torighori.com and you can also use the Gmail inbox for your incoming mails. Fill up other details as required. To verify your configuration, list the sequence of actions that will occur after your setup and configuration, when – (i) someone wants to visit the Web page www.torighori.com and (ii) sends you a mail at yourname@torighori.com.

6. (a) Consider a generator polynomial \( G = 11011 \) that has been selected for some CRC calculation. Now answer the following:

(i) Why can \( G \) be used to detect any single bit error?
(ii) Can the above \( G \) be used to detect any odd number of bit errors? Justify your answer.

(b) What are the four desirable properties of a multiple access protocol (MAC) for a broadcast channel of rate \( R \) bits per second? What are the three broad classes of MAC protocols?

(c) How does CSMA/CD work? Why does Ethernet, which runs CSMA/CD at the MAC layer, enforce a minimum frame length (e.g., 64 bytes for 10 Mbps Ethernet)?

(d) Describe the 'binary exponential backoff algorithm that is used in Ethernet. Why this algorithm is such called? What is the intuition behind the algorithm?

7. (a) Why do layer 2 Ethernet switches need to run 'Spanning Tree Protocol (STP)'? Explain with an example scenario.

(b) Describe a scenario where it is preferable to use Virtual LAN (VLAN). Why VLAN is such called? What is the function of 802.1Q protocol in a VLAN implementation?

(c) Why does 802.11 MAC protocol not implement collision detection? Describe the operation of 802.11 CSMA/CA protocol. In which step of its operation does CSMA/CA attempt to avoid collision (in comparison to CSMA/CD)? Explain. What are the functions of 'InterFrame Spacing (IFS)' intervals: DIFS and SIFS in the operation of CSMA/CA you have just described?
8. (a) Write down the events and actions of a Selective Repeat (SR) sender and an SR receiver. What consideration should be taken into account while determining the timeout value at the SR sender? (10+3)

(b) Suppose you walk into a room with your laptop, connect to a Wi-Fi access point (which is in turn connected to a gateway router through wired media), and want to download a page. What are all the protocol steps that take place, starting from powering on your laptop to getting the Web page? Assume there is nothing in your DNS or browser caches when you power on your laptop. Explicitly indicate in your steps how you obtain the IP and MAC addresses of the gateway router. (10)

(c) Describe, with a suitable diagram, data center network architecture with a hierarchical topology. What are the functions of a load balancer in such a network? (8+4)