Subject Name Solutions

1333203 – Summer 2024

Semester 1 Study Material

Detailed Solutions and Explanations

Question 1(a) [3 marks]

Define linear data structure and give its examples.

Solution

A linear data structure is a collection of elements arranged in sequential order where each element has exactly one predecessor and one successor (except first and last elements).

Table 1: Linear Data Structures Examples

Data Structure	Description
Array	Fixed-size collection of elements accessed by index
Linked List	Chain of nodes with data and reference to next node
Stack	LIFO (Last In First Out) structure
Queue	FIFO (First In First Out) structure

Mnemonic

"ALSQ are in a Line"

Question 1(b) [4 marks]

Define time and space complexity.

Solution

Time and space complexity measure algorithm efficiency in terms of execution time and memory usage as input size grows.

Table 2: Complexity Comparison

Complexity Type	Definition	Measurement	Importance
Time Complexity	Measures execution time required by an algorithm as a function of input size	Big O notation (O(n), O(1), O(n^2))	Determines how fast an algorithm runs
Space Complexity	Measures memory space required by an algorithm as a function of input size	Big O notation (O(n), O(1), O(n^2))	Determines how much memory an algorithm needs

Mnemonic

"TS: Time-Speed and Space-Storage"

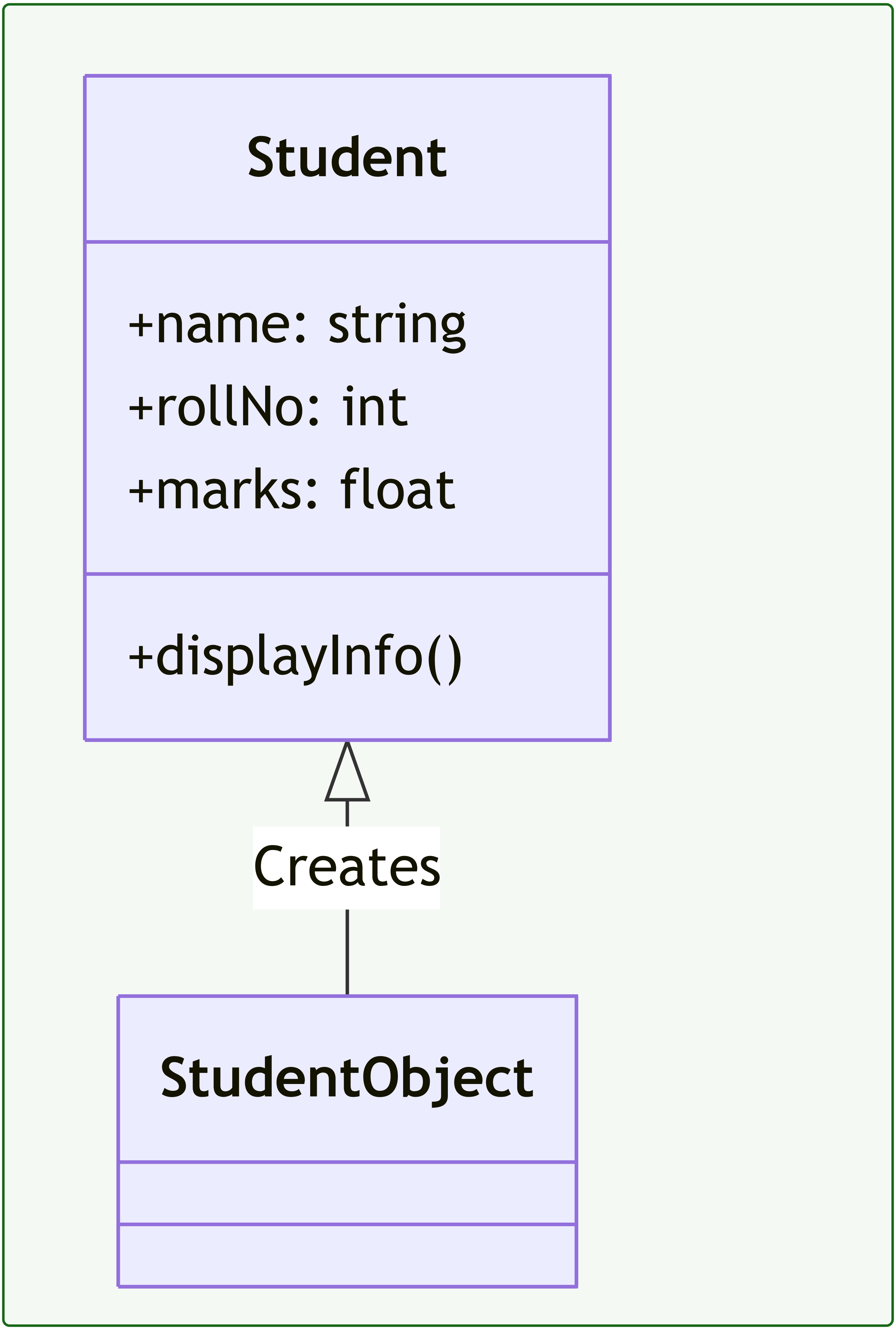
Question 1(c) [7 marks]

Explain the concept of class and object with example.

Solution

Classes and objects are fundamental OOP concepts where classes are blueprints for creating objects with attributes and behaviors.

Diagram: Class and Object Relationship


Student
+name: string
+rollNo: int
+marks: float
+displayInfo()
Creates
StudentObject

Code Example:

```
class Student:
    def __init__(self, name, rollNo, marks):
        self.name = name
        self.rollNo = rollNo
        self.marks = marks

    def displayInfo(self):
        print(f"Name: {self.name}, Roll No: {self.rollNo}, Marks: {self.marks}")

# Creating object
student1 = Student("Raj", 101, 85.5)
student1.displayInfo()
```

- **Class**: Blueprint defining attributes (name, rollNo, marks) and methods (displayInfo)
- **Object**: Instance (student1) created from the class with specific values

Mnemonic

"CAR - Class defines Attributes and Routines"

Question 1(c) OR [7 marks]

Explain instance method, class method and static method with example.

Solution

Python supports three method types: instance, class, and static methods, each serving different purposes.

Table 3: Comparison of Method Types

Method Type	Decorator	First Parameter	Purpose	Access
Instance Method	None	self	Operate on instance data	Can access/-modify instance state
Class Method	@classmethod	cls	Operate on class data	Can access/-modify class state
Static Method	@staticmethod	None	Utility functions	Cannot access instance or class state

Code Example:

```
class Student:
    school = "ABC School"  # class variable

    def __init__(self, name):
        self.name = name  # instance variable

    def instance_method(self):  # instance method
        return f"Hi {self.name} from {self.school}"

    @classmethod
    def class_method(cls):  # class method
        return f"School is {cls.school}"

    @staticmethod
    def static_method():  # static method
        return "This is a utility function"
```

Mnemonic

"ICS: Instance-Self, Class-Cls, Static-Solo"

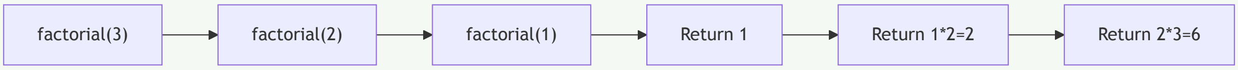
Question 2(a) [3 marks]

Explain concept of recursive function.

Solution

A recursive function is a function that calls itself during its execution to solve smaller instances of the same problem.

Diagram: Recursive Function Execution



Mnemonic

"BASE and RECURSE - Base case stops, Recursion repeats"

Question 2(b) [4 marks]

Define stack and queue.

Solution

Stack and queue are linear data structures with different access patterns for data insertion and removal.

Table 4: Stack vs Queue

Feature	Stack	Queue
Access Pattern	LIFO (Last In First Out)	FIFO (First In First Out)
Operations	Push (insert), Pop (remove)	Enqueue (insert), Dequeue (remove)
Access Points	Single end (top)	Two ends (front, rear)
Visualization	Like plates stacked vertically	Like people in a line
Applications	Function calls, undo operations	Print jobs, process scheduling

Mnemonic

"SLIFF vs QFIFF - Stack-LIFO vs Queue-FIFO"

Question 2(c) [7 marks]

Explain basic operations on stack.

Solution

Stack operations follow LIFO (Last In First Out) principle with the following basic operations:

Table 5: Stack Operations

Operation	Description	Time Complexity
Push	Insert element at the top	O(1)
Pop	Remove element from the top	O(1)
Peek/Top	View top element without removing	O(1)
isEmpty	Check if stack is empty	O(1)
isFull	Check if stack is full (for array implementation)	O(1)

Diagram: Stack Operations

```
       +---+    Push
       | 8 | <-------
Top -> +---+
       | 5 |    Pop
       +---+ -------->
       | 3 |
       +---+
       | 1 |
       +---+
```

Code Example:

```
class Stack:
    def __init__(self):
        self.items = []

    def push(self, item):
        self.items.append(item)

    def pop(self):
        if not self.isEmpty():
            return self.items.pop()

    def peek(self):
        if not self.isEmpty():
            return self.items[-1]

    def isEmpty(self):
        return len(self.items) == 0
```

Mnemonic

"PIPES - Push In, Pop Exit, See top"

Question 2(a) OR [3 marks]

Define singly linked list.

Solution

A singly linked list is a linear data structure with a collection of nodes where each node contains data and a reference to the next node.

Diagram: Singly Linked List

```
    +----------+    +----------+    +----------+    +----------+
    | Data:10  |    | Data:20  |    | Data:30  |    | Data:40  |
    |  Next:--|--->|  Next:--|--->|  Next:--|--->|  Next:/0|
    +----------+    +----------+    +----------+    +----------+
     Head Node                                       Tail Node
```

Mnemonic

"DNL - Data and Next Link"

Question 2(b) OR [4 marks]

Explain Enqueue and Dequeue operations on Queue.

Solution

Enqueue and Dequeue are the primary operations for adding and removing elements in a queue data structure.

Table 6: Queue Operations

Operation	Description	Implementation	Time Complexity
Enqueue	Add element at the rear end	queue.append(element)	O(1)
Dequeue	Remove element from the front end	element = queue.pop(0)	O(1) with linked list, O(n) with array

Diagram: Queue Operations

```
      Enqueue                          Dequeue
     -------->                        --------->
     +------+    +------+    +------+   +------+
Rear |  30  |    |  20  |    |  10  |  Front
     +------+    +------+    +------+
```

Mnemonic

"ERfDFr - Enqueue at Rear, Dequeue from Front"

Question 2(c) OR [7 marks]

Convert expression A+B/C+D to postfix and evaluate postfix expression using stack assuming some values for A, B, C and D.

Solution

Converting and evaluating the expression "A+B/C+D" using stack:

Step 1: Convert to Postfix

Table 7: Infix to Postfix Conversion

Symbol	Stack	Output	Action
A		A	Add to output
+	+	A	Push to stack
B	+	A B	Add to output
/	+ /	A B	Push to stack (higher precedence)
C	+ /	A B C	Add to output
+	+	A B C /	Pop all higher/equal precedence, push +
D	+	A B C / + D	Add to output
End		A B C / + D +	Pop remaining operators

Final Postfix: A B C / + D +

Step 2: Evaluate with values A=5, B=10, C=2, D=3

Table 8: Postfix Evaluation

Symbol	Stack	Calculation
5 (A)	5	Push value
10 (B)	5, 10	Push value
2 (C)	5, 10, 2	Push value
/	5, 5	10/2 = 5
+	10	5+5 = 10
3 (D)	10, 3	Push value
+	13	10+3 = 13

Result: 13

> **Mnemonic**
>
> "PC-SE - Push operands, Calculate when operators, Stack holds Everything"

Question 3(a) [3 marks]

Enlist applications of Linked List.

> **Solution**
>
> Linked lists are versatile data structures with many practical applications.

Table 9: Applications of Linked List

Application	Why Linked List is Used
Dynamic Memory Allocation	Efficient insertion/deletion without reallocation
Implementing Stacks & Queues	Can grow and shrink as needed
Undo Functionality	Easy to add/remove operations from history
Hash Tables	For handling collisions via chaining
Music Playlists	Easy navigation between songs (next/previous)

> **Mnemonic**
>
> "DSUHM - Dynamic allocation, Stacks & queues, Undo, Hash tables, Music players"

Question 3(b) [4 marks]

Explain creation of singly linked list in python.

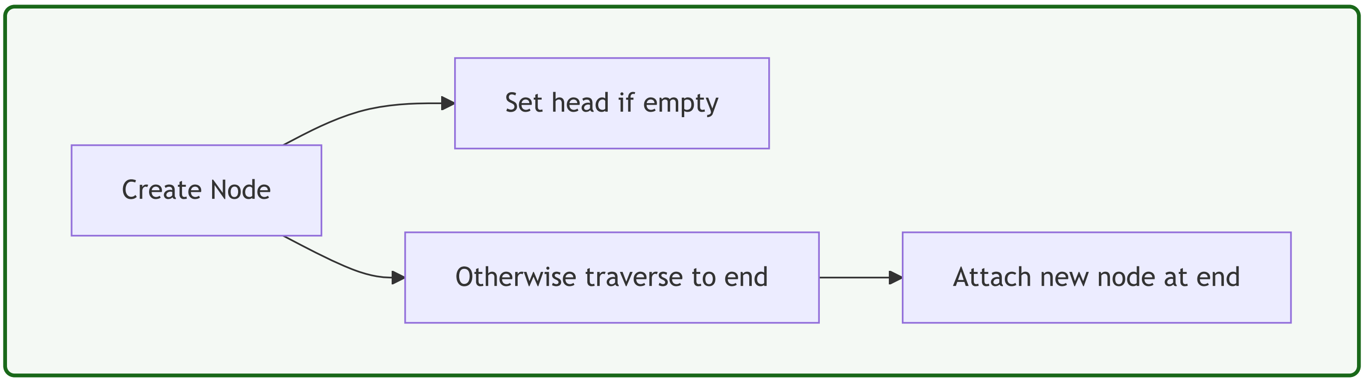
> **Solution**
>
> Creating a singly linked list in Python involves defining a Node class and implementing basic operations.
>
> **Code Example:**

```python
class Node:
    def __init__(self, data):
        self.data = data
        self.next = None

class LinkedList:
    def __init__(self):
        self.head = None

    def append(self, data):
        new_node = Node(data)
        # If empty list, set new node as head
        if self.head is None:
            self.head = new_node
            return
        # Traverse to the end and add node
        last = self.head
        while last.next:
            last = last.next
        last.next = new_node
```

Diagram: Creating a Linked List



Mnemonic

"CHEN - Create nodes, Head first, End attachment, Next pointers"

Question 3(c) [7 marks]

Write a code to insert a new node at the beginning and end of singly linked list.

Solution

Adding nodes at the beginning and end of a singly linked list requires different approaches.

Code Example:

```
class Node:
    def __init__(self, data):
        self.data = data
        self.next = None

class LinkedList:
    def __init__(self):
        self.head = None

    # Insert at beginning (prepend)
    def insert_at_beginning(self, data):
        new_node = Node(data)
        new_node.next = self.head
        self.head = new_node

    # Insert at end (append)
    def insert_at_end(self, data):
        new_node = Node(data)
        # If empty list
        if self.head is None:
            self.head = new_node
            return

        # Traverse to last node
        current = self.head
        while current.next:
            current = current.next

        # Attach new node
        current.next = new_node
```

Diagram: Insertion Operations

```
Insert at Beginning:         Insert at End:
+----------+       +------+     +------+     +------+     +----------+
| New Node|------>| Head|     | Head|---->| ... |---->| New Node|
+----------+       +------+     +------+     +------+     +----------+
```

Mnemonic

"BEN - Beginning is Easy and Next-based, End Needs traversal"

Question 3(a) OR [3 marks]

Write a code to count the number of nodes in singly linked list.

Solution

Counting nodes requires traversing the entire linked list from head to tail.

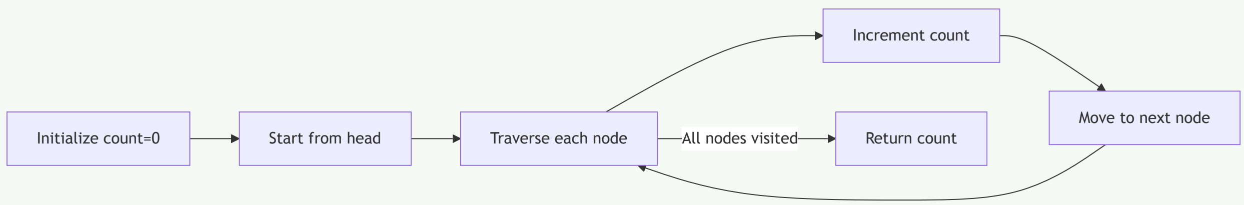
Code Example:

```
def count_nodes(self):
    count = 0
    current = self.head

    # Traverse the list and count nodes
    while current:
        count += 1
        current = current.next

    return count
```

Diagram: Counting Nodes



Mnemonic

"CIT - Count Incrementally while Traversing"

Question 3(b) OR [4 marks]

Match appropriate options from column A and B

Solution

The matching between different linked list types and their characteristics:

Table 10: Matching Linked List Types with Characteristics

Column A	Column B	Match
1. Singly Linked List	c. Nodes contain data and a reference to the next node	1-c
2. Doubly Linked List	d. Nodes contain data and references to both the next and previous nodes	2-d
3. Circular Linked List	b. Nodes form a loop where the last node points to the first node	3-b
4. Node in a Linked List	a. Basic unit containing data and references	4-a

Diagram: Different Linked List Types

```
Singly Linked:    A->B->C->D->null
Doubly Linked:    A<->B<->C<->D<->null
Circular Linked:  A->B->C->D-+
                  ^          |
                  +----------+
```

Mnemonic

"SDCN - Single-Direction, Double-Direction, Circular-Connection, Node-Component"

Question 3(c) OR [7 marks]

Explain deletion of first and last node in singly linked list.

Solution

Deleting nodes from a singly linked list varies in complexity based on the position (first vs. last).

Table 11: Deletion Comparison

Position	Approach	Time Complexity	Special Case
First Node	Change head pointer	O(1)	Check if list is empty
Last Node	Traverse to second-last node	O(n)	Handle single node list

Code Example:

```
def delete_first(self):
    # Check if list is empty
    if self.head is None:
        return

    # Update head to second node
    self.head = self.head.next

def delete_last(self):
    # Check if list is empty
    if self.head is None:
        return

    # If only one node
    if self.head.next is None:
        self.head = None
        return

    # Traverse to second last node
    current = self.head
    while current.next.next:
        current = current.next

    # Remove last node
    current.next = None
```

Diagram: Deletion Operations

```
Delete First:                Delete Last:
+------+     +------+        +------+     +------+     +------+
| Head|---->| Next|    =>    | Head|---->| Next|---->| Last|    =>
+------+     +------+        +------+     +------+     +------+
                             +------+     +------+
                             | Head|---->| Next|--X
                             +------+     +------+
```

Mnemonic

"FELO - First is Easy, Last needs One-before-last"

Question 4(a) [3 marks]

Explain concept of doubly linked list.

Solution

A doubly linked list is a bidirectional linear data structure with nodes containing data, previous, and next references.

Diagram: Doubly Linked List

```
    +--------------------+     +--------------------+     +--------------------+
    | prev | data | next|      | prev | data | next|      | prev | data | next|
NULL<------|  10  |---->|<----|  20  |---->|<-----|  30  |----->NULL         |
    +--------------------+     +--------------------+     +--------------------+
```

Mnemonic

"PDN - Previous, Data, Next"

Question 4(b) [4 marks]

Explain concept of linear search.

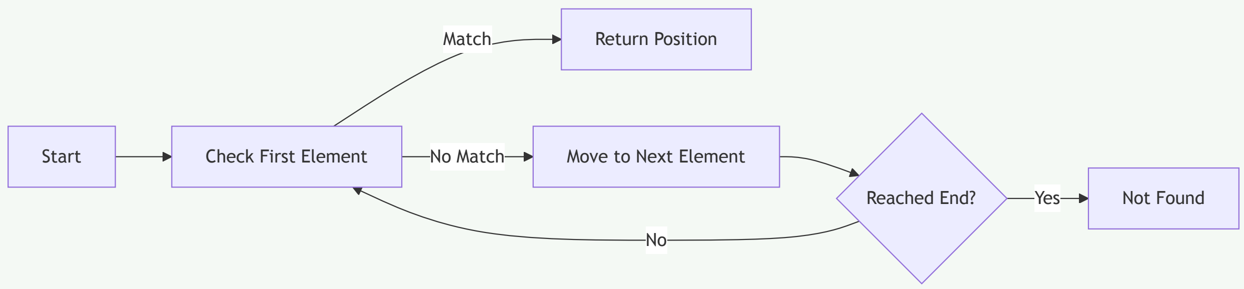
Solution

Linear search is a simple sequential search algorithm that checks each element one by one until finding the target.

Table 12: Linear Search Characteristics

Aspect	Description
Working	Sequentially check each element from start to end
Time Complexity	O(n) - worst and average case
Best Case	O(1) - element found at first position
Suitability	Small lists or unsorted data
Advantage	Simple implementation, works on any collection

Diagram: Linear Search Process



Mnemonic

"SCENT - Search Consecutively Each element until Target"

Question 4(c) [7 marks]

Write a code to implement binary search algorithm.

Solution

Binary search is an efficient algorithm for finding elements in a sorted array by repeatedly dividing the search interval in half.

Code Example:

```python
def binary_search(arr, target):
    left = 0
    right = len(arr) - 1

    while left <= right:
        mid = (left + right) // 2

        # Check if target is present at mid
        if arr[mid] == target:
            return mid

        # If target is greater, ignore left half
        elif arr[mid] < target:
            left = mid + 1

        # If target is smaller, ignore right half
        else:
            right = mid - 1

    # Target not found
    return -1
```

Diagram: Binary Search Process

```
Array: [10, 20, 30, 40, 50, 60, 70]
Search: 40

Step 1: mid = 3, arr[mid] = 40 (Found!)
 left                right
  |                     |
 [10, 20, 30, 40, 50, 60, 70]
              ^
             mid
```

Mnemonic

"MCLR - Middle Compare, Left or Right adjust"

Question 4(a) OR [3 marks]

Explain concept of selection sort algorithm.

Solution

Selection sort is a simple comparison-based sorting algorithm that divides the array into sorted and unsorted regions.

Table 13: Selection Sort Characteristics

Aspect	Description
Approach	Find minimum element from unsorted part and place at beginning
Time Complexity	$O(n^2) - worst, average, and best cases$
Space Complexity	O(1) - in-place sorting
Stability	Not stable (equal elements may change relative order)
Advantage	Simple implementation with minimal memory usage

Mnemonic

"FSMR - Find Smallest, Move to Right position, Repeat"

Question 4(b) OR [4 marks]

Explain bubble sort method.

Solution

Bubble sort is a simple sorting algorithm that repeatedly steps through the list, compares adjacent elements, and swaps them if they're in the wrong order.

Table 14: Bubble Sort Characteristics

Aspect	Description
Approach	Repeatedly compare adjacent elements and swap if needed
Passes	(n-1) passes for n elements
Time Complexity	$O(n^2) - worst and average case, O(n) - best case$
Space Complexity	O(1) - in-place sorting
Optimization	Early termination if no swaps occur in a pass

Diagram: Bubble Sort Process

```
Array: [5, 3, 8, 4, 2]

Pass 1: [3, 5, 4, 2, 8]
        ^_^ ^_^ ^_^

Pass 2: [3, 4, 2, 5, 8]
         ^_^ ^_^

Pass 3: [3, 2, 4, 5, 8]
         ^_^

Pass 4: [2, 3, 4, 5, 8] (Sorted)
         ^_^
```

Mnemonic

"CABS - Compare Adjacent, Bubble-up Swapping"

Question 4(c) OR [7 marks]

Explain the working of quick sort method with example.

Solution

Quick sort is an efficient divide-and-conquer sorting algorithm that works by selecting a pivot element and partitioning the array.

Table 15: Quick Sort Steps

Step	Description
1	Choose a pivot element from the array
2	Partition: Rearrange elements (smaller than pivot to left, larger to right)
3	Recursively apply quick sort to subarrays on left and right of pivot

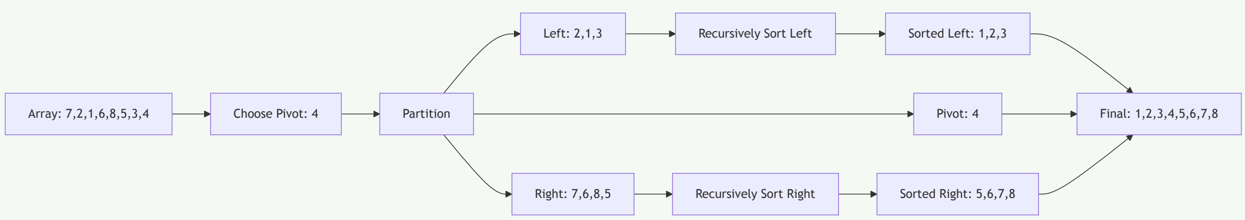
Example with Array [7, 2, 1, 6, 8, 5, 3, 4]:

```
Pivot: 4
After partition: [2, 1, 3] 4 [7, 6, 8, 5]
                 Left      P  Right

Recursively sort left: [1] 2 [3] \rightarrow [1, 2, 3]
Recursively sort right: [5] 7 [6, 8] \rightarrow [5, 6, 7, 8]

Final sorted array: [1, 2, 3, 4, 5, 6, 7, 8]
```

Diagram: Quick Sort Partitioning



Mnemonic

"PPR - Pivot, Partition, Recursive divide"

Question 5(a) [3 marks]

Explain binary tree.

Solution

A binary tree is a hierarchical data structure where each node has at most two children referred to as left and right child.

Diagram: Binary Tree

```
        A
       / \
      B   C
     / \   \
    D   E   F
```

Table 16: Binary Tree Properties

Property	Description
Node	Contains data and references to left and right children
Depth	Length of path from root to the node
Height	Length of the longest path from node to a leaf
Binary Tree	Each node has at most 2 children

Mnemonic

"RLTM - Root, Left, Two, Maximum"

Question 5(b) [4 marks]

Define the terms root, path, parent and children with reference to tree.

Solution

Trees have specific terminology to describe relationships between nodes in the hierarchy.

Table 17: Tree Terminology

Term	Definition
Root	Topmost node of the tree with no parent
Path	Sequence of nodes connected by edges from one node to another
Parent	Node that has one or more child nodes
Children	Nodes directly connected to a parent node

Diagram: Tree Terminology

```
        A  <-- Root
       / \
      B   C  <-- Children of A, A is Parent
     / \   \
    D   E   F  <-- Path from A to F: A->C->F
```

Mnemonic

"RPPC - Root at Top, Path connects, Parent above, Children below"

Question 5(c) [7 marks]

Apply preorder and postorder traversal for given below tree.

Solution

Preorder and postorder are depth-first tree traversal methods with different node visiting sequences.

Given Tree:

```
        40
       /  \
     30    50
    / \    / \
   25 35  45  60
  / \        / \
 15  28     55  70
```

Table 18: Tree Traversal Comparison

Traversal	Order	Result for Given Tree
Preorder	Root, Left, Right	40, 30, 25, 15, 28, 35, 50, 45, 60, 55, 70
Postorder	Left, Right, Root	15, 28, 25, 35, 30, 45, 55, 70, 60, 50, 40

Code Example:

```python
def preorder(root):
    if root:
        print(root.data, end=", ")  # Visit root
        preorder(root.left)         # Visit left subtree
        preorder(root.right)        # Visit right subtree

def postorder(root):
    if root:
        postorder(root.left)        # Visit left subtree
        postorder(root.right)       # Visit right subtree
        print(root.data, end=", ")  # Visit root
```

Mnemonic

"PRE-NLR, POST-LRN - Preorder (Node-Left-Right), Postorder (Left-Right-Node)"

Question 5(a) OR [3 marks]

Enlist applications of binary tree.

Solution

Binary trees have numerous practical applications in various fields of computer science.

Table 19: Binary Tree Applications

Application	Description
Binary Search Trees	Efficient searching, insertion, and deletion operations
Expression Trees	Representing mathematical expressions for evaluation
Huffman Coding	Data compression algorithms
Priority Queues	Implementation of heap data structure
Decision Trees	Classification algorithms in machine learning

Mnemonic

"BEHPD - BST, Expression, Huffman, Priority queue, Decision tree"

Question 5(b) OR [4 marks]

Explain insertion of a node in binary search tree.

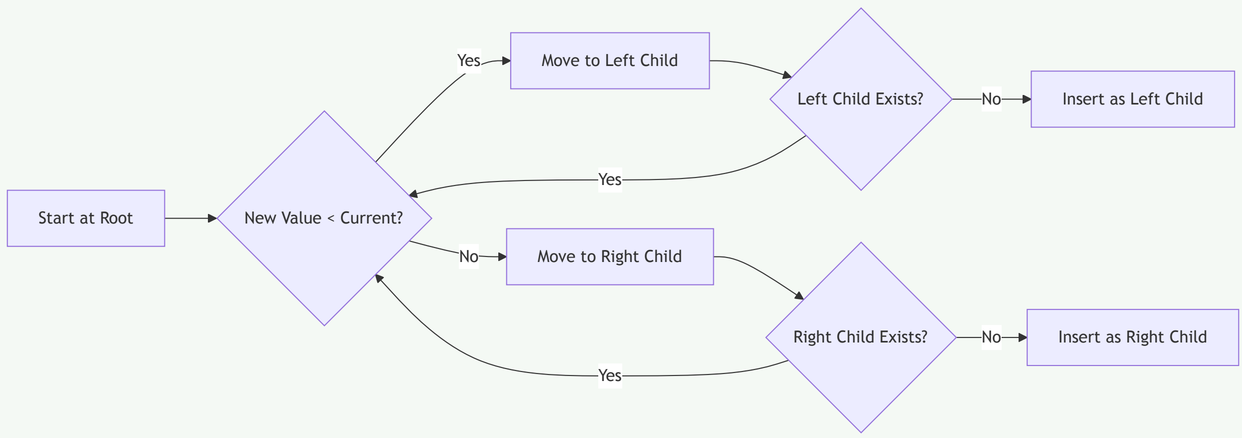
Solution

Insertion in a Binary Search Tree (BST) follows the BST property: left child < parent < right child.

Table 20: Insertion Steps in BST

Step	Description
1	Start at the root node
2	If new value < current node value, go to left subtree
3	If new value > current node value, go to right subtree
4	Repeat until finding an empty position (null pointer)
5	Insert the new node at the empty position found

Diagram: BST Insertion



Mnemonic

"LSRG - Less-go-left, Same-or-greater-go-right"

Question 5(c) OR [7 marks]

Draw Binary search tree for 8, 4, 12, 2, 6, 10, 14, 1, 3, 5 and write In-order traversal for the tree.

Solution

Binary Search Tree (BST) is constructed by inserting nodes while maintaining the BST property.
Binary Search Tree for the given elements:

```
        8
       / \
      4   12
     / \  / \
    2   6 10 14
   / \  /
  1   3 5
```

Table 21: BST Construction Process

Step	Insert	Tree Structure
1	8	Root = 8
2	4	Left of 8
3	12	Right of 8
4	2	Left of 4
5	6	Right of 4
6	10	Left of 12
7	14	Right of 12
8	1	Left of 2
9	3	Right of 2
10	5	Left of 6

In-order Traversal:
An in-order traversal visits nodes in the order: left subtree, current node, right subtree.
For the given BST, the in-order traversal is: 1, 2, 3, 4, 5, 6, 8, 10, 12, 14
Code Example:

```python
def inorder_traversal(root):
    if root:
        inorder_traversal(root.left)    # Visit left subtree
        print(root.data, end=", ")      # Visit current node
        inorder_traversal(root.right)   # Visit right subtree
```

Mnemonic

"LNR - Left, Node, Right makes sorted order in BST"