

Data Structure And Application (1333203) - Summer 2024 Solution

Milav Dabgar

June 12, 2024

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 creation objects with attributes and behaviors.

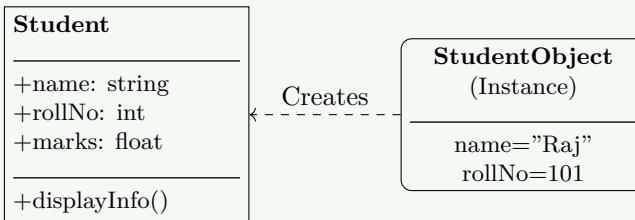


Figure 1. Class and Object Relationship

Listing 1. Class and Object Example

```

1  class Student:
2      def __init__(self, name, rollNo, marks):
3          self.name = name
4          self.rollNo = rollNo
5          self.marks = marks
6
7      def displayInfo(self):
8          print(f"Name: {self.name}, Roll No: {self.rollNo}, Marks: {self.marks}")
9
10 # Creating object
11 student1 = Student("Raj", 101, 85.5)
12 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	@class-method	cls	Operate on class data	Can access/modify class state
Static Method	@staticmethod	None	Utility functions	Cannot access instance or class state

Listing 2. Method Types Example

```

1  class Student:
2      school = "ABC School" # class variable
3
4      def __init__(self, name):
5          self.name = name # instance variable
6
7      def instance_method(self): # instance method
8          return f"Hi {self.name} from {self.school}"
9
10     @classmethod
11     def class_method(cls): # class method
12         return f"School is {cls.school}"
13
14     @staticmethod
15     def static_method(): # static method
16         return "This is a utility function"

```

Mnemonic

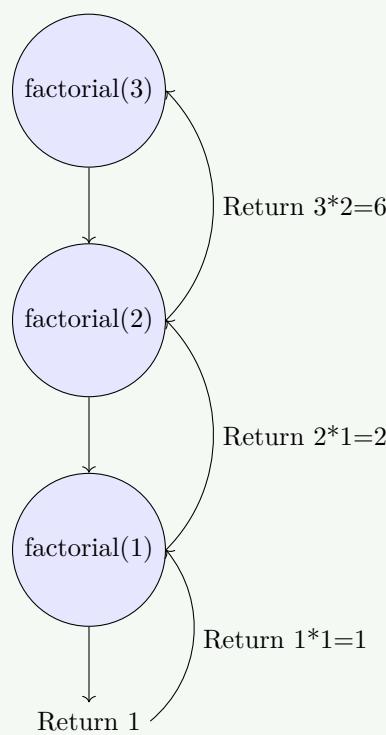
“ICS: Instance-Self, Class-Cls, Static-Solo”

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.

**Figure 2.** 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.

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	O(1)

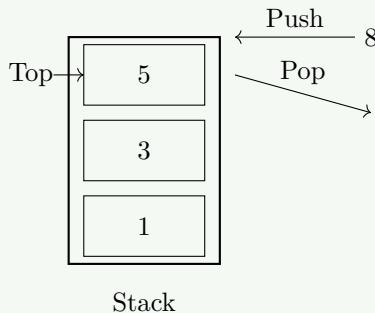


Figure 3. Stack Push and Pop

Listing 3. Stack Implementation

```

1 class Stack:
2     def __init__(self):
3         self.items = []
4
5     def push(self, item):
6         self.items.append(item)
7
8     def pop(self):
9         if not self.isEmpty():
10            return self.items.pop()
11
12    def peek(self):
13        if not self.isEmpty():
14            return self.items[-1]
15
16    def isEmpty(self):
17        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.

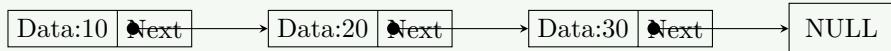


Figure 4. Singly Linked List

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) linked list, O(n) array

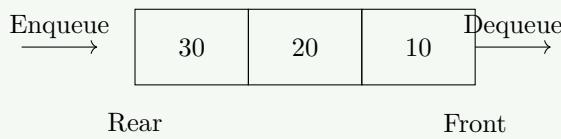


Figure 5. Queue Operations

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 prec)
C	+ /	A B C	Add to output
+	+	A B C /	Pop /, push +
D	+	A B C / + D	Add to output
End		A B C / + D +	Pop remaining

Final Postfix: ABC/+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

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.

Listing 4. Creating Linked List

```

1  class Node:
2      def __init__(self, data):
3          self.data = data
4          self.next = None
5
6  class LinkedList:
7      def __init__(self):
8          self.head = None
9
10     def append(self, data):
11         new_node = Node(data)
12         # If empty list, set new node as head
13         if self.head is None:
14             self.head = new_node
15             return
16         # Traverse to the end and add node
17         last = self.head
18         while last.next:
19             last = last.next
20         last.next = new_node
  
```

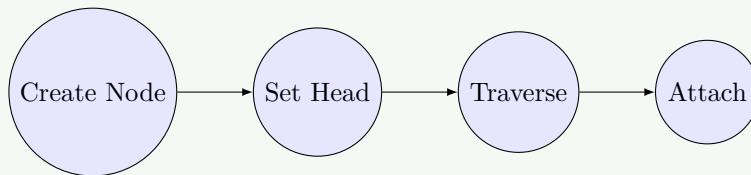


Figure 6. Creation Process

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

Listing 5. Insertion Operations

```

1  class Node:
2      def __init__(self, data):
3          self.data = data
4          self.next = None
5
6  class LinkedList:
7      def __init__(self):
  
```

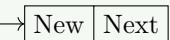
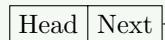
```

8     self.head = None
9
10    # Insert at beginning (prepend)
11    def insert_at_beginning(self, data):
12        new_node = Node(data)
13        new_node.next = self.head
14        self.head = new_node
15
16    # Insert at end (append)
17    def insert_at_end(self, data):
18        new_node = Node(data)
19        if self.head is None:
20            self.head = new_node
21            return
22        current = self.head
23        while current.next:
24            current = current.next
25        current.next = new_node

```



Insert at Beginning



Insert at End

Figure 7. Insertion Visualization**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**Listing 6.** Count Nodes

```

1  def count_nodes(self):
2      count = 0
3      current = self.head
4
5      # Traverse the list and count nodes
6      while current:
7          count += 1
8          current = current.next
9
10     return count

```

Mnemonic

“CIT - Count Incrementally while Traversing”

Question 3(b) OR [4 marks]

Match appropriate options from column A and B

Solution

Table 10. Match Columns

Column A	Column B	Match
1. Singly Linked List	c. Nodes contain data and reference to next	1-c
2. Doubly Linked List	d. Nodes contain data, next and prev	2-d
3. Circular Linked List	b. Last node points to first node	3-b
4. Node	a. Basic unit containing data and references	4-a

Singly: $A \rightarrow B \rightarrow NULL$

Doubly: $A \leftrightarrow B \leftrightarrow NULL$

Circular: $A \rightarrow B \rightarrow A$

Figure 8. Linked List Types

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

Deletion complexity depends on position.

Table 11. Deletion Comparison

Position	Approach	Complexity
First Node	Change head pointer	$O(1)$
Last Node	Traverse to second-last node	$O(n)$

Listing 7. Deletion Code

```

1 def delete_first(self):
2     if self.head is None: return
3     self.head = self.head.next
4
5 def delete_last(self):
6     if self.head is None: return
7     if self.head.next is None:
8         self.head = None
9         return
10    current = self.head
11    while current.next.next:
12        current = current.next
13    current.next = None

```

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.



Figure 9. Doubly Linked List

Mnemonic

“PDN - Previous, Data, Next”

Question 4(b) [4 marks]

Explain concept of linear search.

Solution

Linear search sequentially checks each element.

Table 12. Linear Search

Aspect	Description
Working	Check each element start to end
Time Complexity	O(n) worst/average
Best Case	O(1)

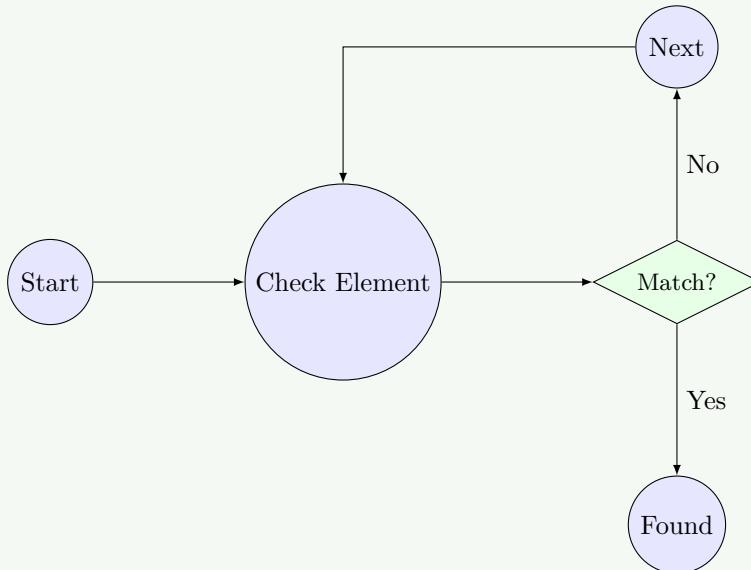


Figure 10. Linear Search Flow

Mnemonic

“SCENT - Search Consecutively Each element until Target”

Question 4(c) [7 marks]

Write a code to implement binary search algorithm.

Solution

Binary search divides the search interval in half.

Listing 8. Binary Search

```

1 def binary_search(arr, target):
2     left = 0
3     right = len(arr) - 1
4
5     while left <= right:
6         mid = (left + right) // 2
7
8         if arr[mid] == target:
9             return mid
10        elif arr[mid] < target:
11            left = mid + 1
12        else:
13            right = mid - 1
14
15    return -1

```

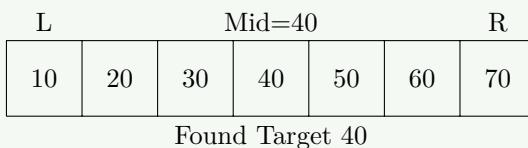


Figure 11. Binary Search Execution

Mnemonic

“MCLR - Middle Compare, Left or Right adjust”

Question 4(a) OR [3 marks]

Explain concept of selection sort algorithm.

Solution

Selection sort finds the minimum element and places it at the beginning.

- **Time Complexity:** $O(n^2)$
- **Space Complexity:** $O(1)$
- **Method:** Find smallest, swap with current position.

Mnemonic

“FSMR - Find Smallest, Move to Right position, Repeat”

Question 4(b) OR [4 marks]

Explain bubble sort method.

Solution

Bubble sort repeatedly swaps adjacent elements if they are in the wrong order.

Table 13. Bubble Sort

Complexity	$O(n^2)$
Passes	$n - 1$ passes
Type	In-place, Stable

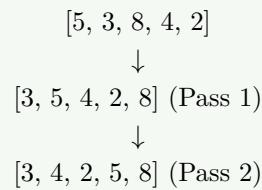


Figure 12. Bubble Sort Passes

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 selects a pivot and partitions the array.

Table 14. Quick Sort Steps

1	Choose Pivot
2	Partition: Small go Left, Large go Right
3	Recursively sort Left and Right subarrays

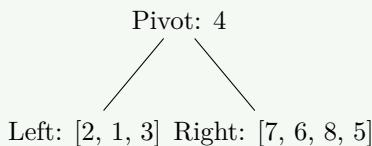


Figure 13. Quick Sort Partition

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.

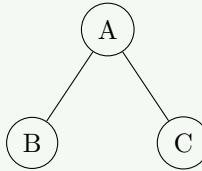


Figure 14. Binary Tree

Mnemonic

“RLTM - Root, Left, Two, Maximum”

Question 5(b) [4 marks]

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

Solution

Table 15. Tree Terminology

Term	Definition
Root	Topmost node with no parent
Path	Sequence of connected nodes
Parent	Node with one or more children
Children	Nodes connected to a parent

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

Tree: 40(Root), Left:30, Right:50...

Table 16. Traversals

Traversal	Order	Result
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

Mnemonic

“PRE-NLR, POST-LRN”

Question 5(a) OR [3 marks]

Enlist applications of binary tree.

Solution

- Binary Search Trees (Efficient searching)
- Expression Trees (Compilers)
- Huffman Coding (Compression)
- Priority Queues (Heaps)
- Decision Trees (ML)

Mnemonic

“BEHPD”

Question 5(b) OR [4 marks]

Explain insertion of a node in binary search tree.

Solution

BST Property: Left < Node < Right.

1. Start at root.
2. If New < Current, go Left.
3. If New > Current, go Right.
4. Insert at empty spot.

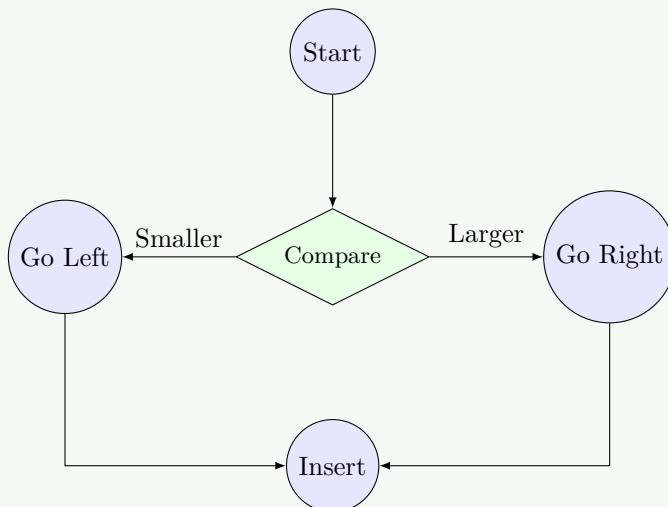


Figure 15. BST Insertion

Mnemonic

“LSRG”

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

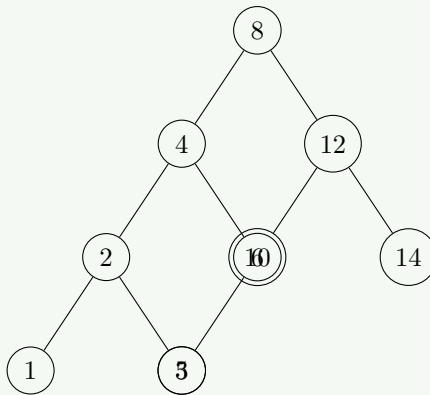


Figure 16. Constructed BST

In-order Traversal (Left, Root, Right):

1, 2, 3, 4, 5, 6, 8, 10, 12, 14

Mnemonic

“LNR - Left, Node, Right”