Experiment-6

Student Name: Anushka **UID: 22BET10126**
Branch: BE-IT **Section/Group: 22BET_IOT-702/B**
Semester: 6th **Date of Performance:28th Feb, 2025**
Subject Name: Advanced Programming Lab-2
Subject Code: 22ITP-351

Problem-1

1. **Aim:** Given the root of a binary tree, return its maximum depth.

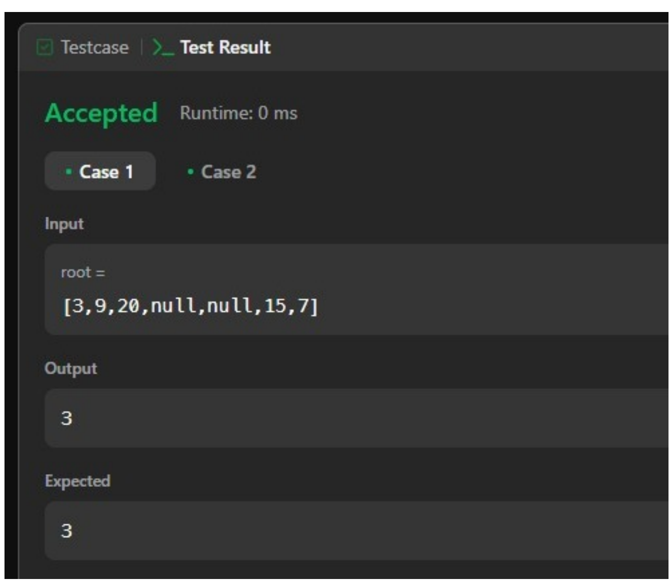
2. **Code:**

```
import java.util.*;

class Solution {

public List<List<Integer>> zigzagLevelOrder(TreeNode root) {

List<List<Integer>> result = new ArrayList<>();

if (root == null) return result;


Queue<TreeNode> queue = new LinkedList<>();

queue.offer(root);

boolean leftToRight = true; // To track direction of traversal


while (!queue.isEmpty()) {

int levelSize = queue.size();

List<Integer> level = new ArrayList<>(levelSize);


for (int i = 0; i < levelSize; i++) {

TreeNode node = queue.poll();
```

```
// Add node value based on current direction
if (leftToRight) {
level.add(node.val); // left-to-right order
} else {
level.add(0, node.val); // right-to-left order (insert at start)
}

// Add children to queue for next level
if (node.left != null) queue.offer(node.left);
if (node.right != null) queue.offer(node.right);
}

// Add current level to result
result.add(level);
// Flip direction for next level
leftToRight = !leftToRight;
}

return result;
}
}

// Definition for a binary tree node
class TreeNode {
int val;
TreeNode left;
TreeNode right;
```

```
TreeNode(int val) { this.val = val; }
}

// Test the code
public class Main {
public static void main(String[] args) {
Solution solution = new Solution();

// Example tree: [3,9,20,null,null,15,7]
TreeNode root = new TreeNode(3);
root.left = new TreeNode(9);
root.right = new TreeNode(20);
root.right.left = new TreeNode(15);
root.right.right = new TreeNode(7);
System.out.println(solution.zigzagLevelOrder(root));
}
```

3. Output:



Problem-2

1. **Aim:** Given the root of a binary tree, determine if it is a valid binary search tree (BST).

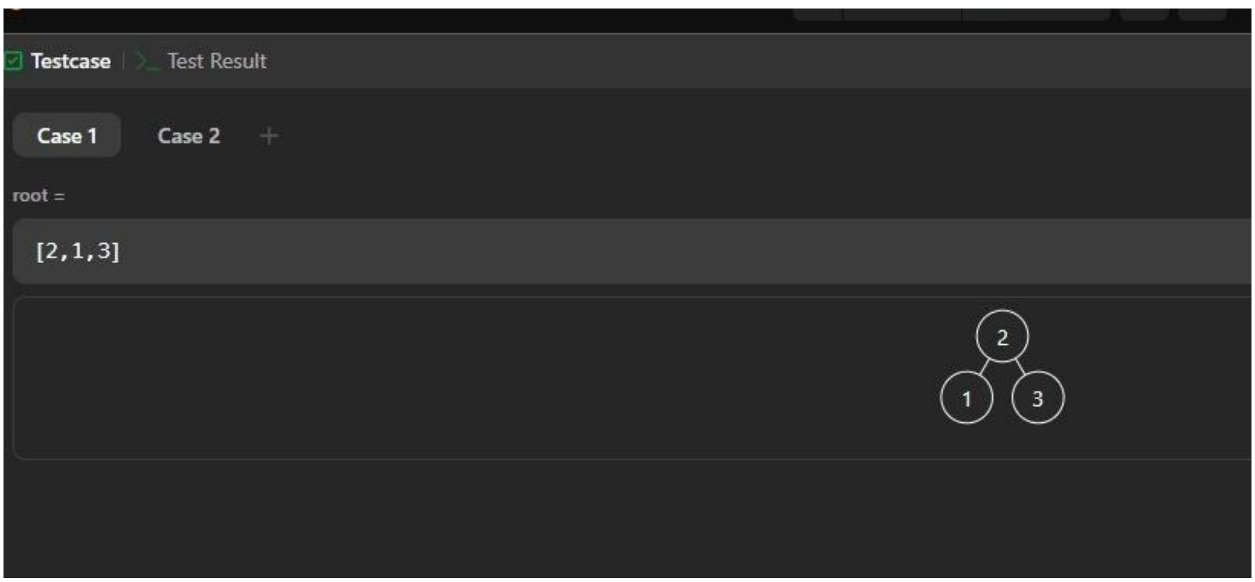
2. **Code:**

```
// Definition for a binary tree node.
class TreeNode {
    int val;
    TreeNode left;
    TreeNode right;

    TreeNode(int val) {
        this.val = val;
        this.left = null;
        this.right = null;
    }
}

public class Solution {

    // Function to check if a tree is a valid BST
    public boolean isValidBST(TreeNode root) {
        return validate(root, Long.MIN_VALUE, Long.MAX_VALUE);
    }

    // Helper function for BST validation with range limits
    private boolean validate(TreeNode node, long min, long max) {
        if (node == null) {
```

```
            return true; // An empty tree is a valid BST
        }
        if (node.val <= min || node.val >= max) {
            return false; // Violates the BST property
        }
        // Check left and right subtrees with updated ranges
        return validate(node.left, min, node.val) && validate(node.right, node.val, max);
    }

    // Sample tree builder
    public TreeNode buildSampleTree1() {
        TreeNode root = new TreeNode(2);
        root.left = new TreeNode(1);
        root.right = new TreeNode(3);
        return root; // Valid BST
    }

    public TreeNode buildSampleTree2() {
        TreeNode root = new TreeNode(5);
        root.left = new TreeNode(1);
        root.right = new TreeNode(4);
        root.right.left = new TreeNode(3);
        root.right.right = new TreeNode(6);
        return root; // Invalid BST
    }

    public static void main(String[] args) {
        Solution solution = new Solution();
```

```
        TreeNode root1 = solution.buildSampleTree1();
        System.out.println("Tree 1 is a valid BST: " + solution.isValidBST(root1));

        TreeNode root2 = solution.buildSampleTree2();
        System.out.println("Tree 2 is a valid BST: " + solution.isValidBST(root2));
    }
}
```

3. Output:



Problem-3

1. Aim: Given the root of a binary tree, check whether it is a mirror of itself (i.e., symmetric around its center).

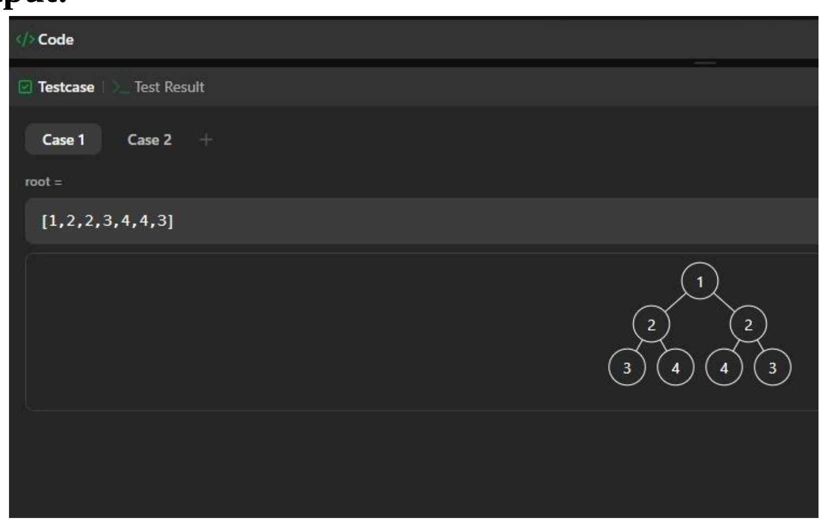
2. Code:

```
// Definition for a binary tree node.
```

```
class TreeNode {
    int val;
    TreeNode left;
    TreeNode right;

    TreeNode(int val) {
        this.val = val;
        this.left = null;
        this.right = null;
    }
}

public class Solution {

    // Main function to check if tree is symmetric
    public boolean isSymmetric(TreeNode root) {
        if (root == null) {
            return true; // An empty tree is symmetric
        }
        return isMirror(root.left, root.right);
    }
    // Helper function to check if two trees are mirror images
    private boolean isMirror(TreeNode t1, TreeNode t2) {
        if (t1 == null && t2 == null) {
            return true; // Both are null, symmetric
        }
        if (t1 == null || t2 == null) {
            return false; // One is null, not symmetric
        }
        // Check values and cross symmetry of subtrees
        return (t1.val == t2.val)
                && isMirror(t1.left, t2.right)
                && isMirror(t1.right, t2.left);
    }
    // Sample tree builder for [1,2,2,3,4,4,3] (symmetric tree)
    public TreeNode buildSampleTree1() {
        TreeNode root = new TreeNode(1);
        root.left = new TreeNode(2);
```

```
        root.right = new TreeNode(2);
        root.left.left = new TreeNode(3);
        root.left.right = new TreeNode(4);
        root.right.left = new TreeNode(4);
        root.right.right = new TreeNode(3);
        return root;
    }
    // Sample tree builder for [1,2,2,null,3,null,3] (asymmetric tree)
    public TreeNode buildSampleTree2() {
        TreeNode root = new TreeNode(1);
        root.left = new TreeNode(2);
        root.right = new TreeNode(2);
        root.left.right = new TreeNode(3);
        root.right.right = new TreeNode(3);
        return root;
    }
    public static void main(String[] args) {
        Solution solution = new Solution();
        TreeNode root1 = solution.buildSampleTree1();
        System.out.println("Tree 1 is symmetric: " + solution.isSymmetric(root1)); // true
        TreeNode root2 = solution.buildSampleTree2();
        System.out.println("Tree 2 is symmetric: " + solution.isSymmetric(root2)); // false
    }
}
```

3. Output:



Problem-4

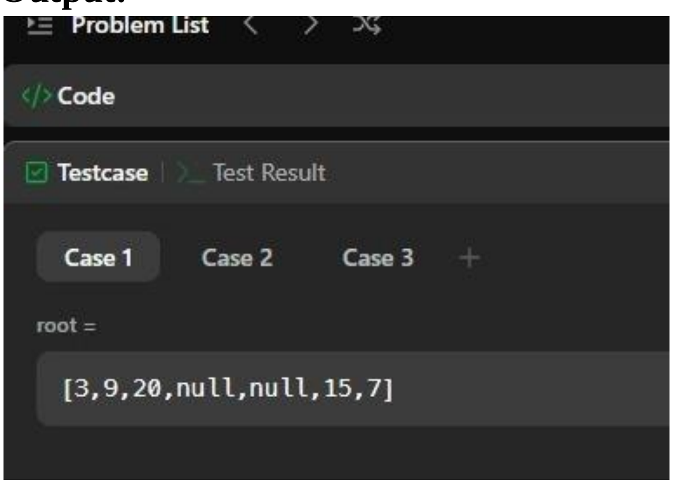
1. **Aim:** Given the root of a binary tree, return the level order traversal of its nodes' values. (i.e., from left to right, level by level).

2. **Code:**

```
// Definition for a binary tree node.
import java.util.*;
class TreeNode {
    int val;
    TreeNode left;
    TreeNode right;
    TreeNode(int val) {
        this.val = val;
        this.left = null;
        this.right = null;
    }
}
public class Solution {
    // Function to perform level order traversal
    public List<List<Integer>> levelOrder(TreeNode root) {
        List<List<Integer>> result = new ArrayList<>();
        if (root == null) {
            return result; // Return empty list for null root
        }
        Queue<TreeNode> queue = new LinkedList<>();
        queue.add(root);
        while (!queue.isEmpty()) {
            int levelSize = queue.size();
            List<Integer> currentLevel = new ArrayList<>()
            // Process all nodes at current level
            for (int i = 0; i < levelSize; i++) {
                TreeNode node = queue.poll();
                currentLevel.add(node.val);

                if (node.left != null) {
                    queue.add(node.left); // Add left child
```

```
                }
                if (node.right != null) {
                    queue.add(node.right); // Add right child
                }
            }
            result.add(currentLevel); // Add level nodes to result
        }
        return result;
    }
    // Sample tree: [3,9,20,null,null,15,7]
    public TreeNode buildSampleTree() {
        TreeNode root = new TreeNode(3);
        root.left = new TreeNode(9);
        root.right = new TreeNode(20);
        root.right.left = new TreeNode(15);
        root.right.right = new TreeNode(7);
        return root;
    }
    public static void main(String[] args) {
        Solution solution = new Solution();
        TreeNode root = solution.buildSampleTree();
        System.out.println("Level Order Traversal: " + solution.levelOrder(root));
}}
```

3. Output:



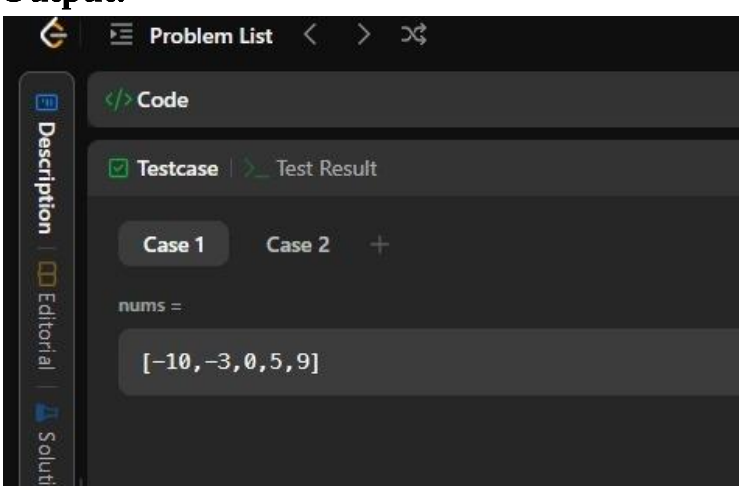
Problem-5

1. **Aim:** Given an integer array nums where the elements are sorted in ascending order, convert it to a height-balanced binary search tree
2. **Code:**

```
// Definition for a binary tree node.
class TreeNode {
    int val;
    TreeNode left;
    TreeNode right;

    TreeNode(int val) {
        this.val = val;
        this.left = null;
        this.right = null;
    }
}

public class Solution {

    // Main function to convert sorted array to height-balanced BST
    public TreeNode sortedArrayToBST(int[] nums) {
        if (nums == null || nums.length == 0) {
            return null;
        }
        return buildBST(nums, 0, nums.length - 1);
    }
    // Helper function using recursive approach (divide and conquer)
    private TreeNode buildBST(int[] nums, int left, int right) {
        if (left > right) {
            return null; // Base case: no elements to form a tree
        }
        int mid = left + (right - left) / 2; // Find middle element
        TreeNode root = new TreeNode(nums[mid]); // Make mid element root
        // Recursively build left and right subtrees
        root.left = buildBST(nums, left, mid - 1);
        root.right = buildBST(nums, mid + 1, right);
```

```
        return root;
    }
    // Inorder traversal to print tree nodes
    public void inorderTraversal(TreeNode root) {
        if (root == null) {
            return;
        }
        inorderTraversal(root.left);
        System.out.print(root.val + " ");
        inorderTraversal(root.right);
    }
    public static void main(String[] args) {
        Solution solution = new Solution();
        int[] nums1 = {-10, -3, 0, 5, 9};
        TreeNode root1 = solution.sortedArrayToBST(nums1);
        System.out.print("Inorder Traversal of BST (Example 1): ");
        solution.inorderTraversal(root1);
        System.out.println();
        int[] nums2 = {1, 3};
        TreeNode root2 = solution.sortedArrayToBST(nums2);
        System.out.print("Inorder Traversal of BST (Example 2): ");
        solution.inorderTraversal(root2);
    }
}
```

3. Output:



Problem-6

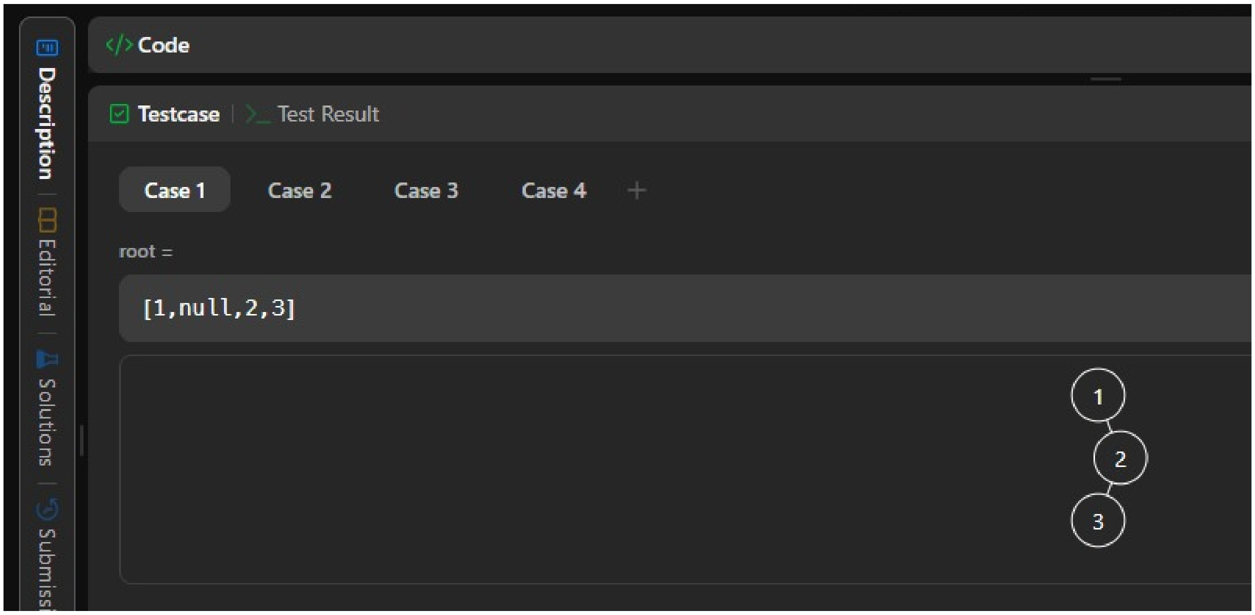
1. **Aim:** Given the root of a binary tree, return the inorder traversal of its nodes' values.
2. **Code:**

```
// Definition for a binary tree node
import java.util.*;

class TreeNode {
    int val;
    TreeNode left;
    TreeNode right;

    TreeNode(int val) {
        this.val = val;
        this.left = null;
        this.right = null;
    }
}

public class Solution {

    // Recursive Inorder Traversal
    public List<Integer> inorderTraversalRecursive(TreeNode root) {
        List<Integer> result = new ArrayList<>();
        inorderHelper(root, result);
        return result;
    }

    private void inorderHelper(TreeNode node, List<Integer> result) {
        if (node == null) {
            return;
        }
        inorderHelper(node.left, result); // Left subtree
        result.add(node.val);             // Node itself
        inorderHelper(node.right, result);// Right subtree
    }
```

```
    // Iterative Inorder Traversal using Stack
    public List<Integer> inorderTraversalIterative(TreeNode root) {
        List<Integer> result = new ArrayList<>();
        Stack<TreeNode> stack = new Stack<>();
        TreeNode current = root;

        while (current != null || !stack.isEmpty()) {
            while (current != null) { // Reach leftmost node
                stack.push(current);
                current = current.left;
            }
            current = stack.pop(); // Process node
            result.add(current.val);
            current = current.right; // Move to right subtree
        }
        return result;
    }

    // Sample tree builder for testing
    public TreeNode buildSampleTree() {
        TreeNode root = new TreeNode(1);
        root.right = new TreeNode(2);
        root.right.left = new TreeNode(3);
        return root;
    }

    public static void main(String[] args) {
        Solution solution = new Solution();

        // Sample tree: [1, null, 2, 3]
        TreeNode root = solution.buildSampleTree();

        System.out.println("Recursive Inorder Traversal: " +
solution.inorderTraversalRecursive(root));
        System.out.println("Iterative Inorder Traversal: " +
solution.inorderTraversalIterative(root));
    }
```

```
}
```

3. Output:



Problem-7

1. **Aim:** Given two integer arrays inorder and postorder where inorder is the inorder traversal of a binary tree and postorder is the postorder traversal of the same tree, construct and return the binary tree.
2. **Code:**

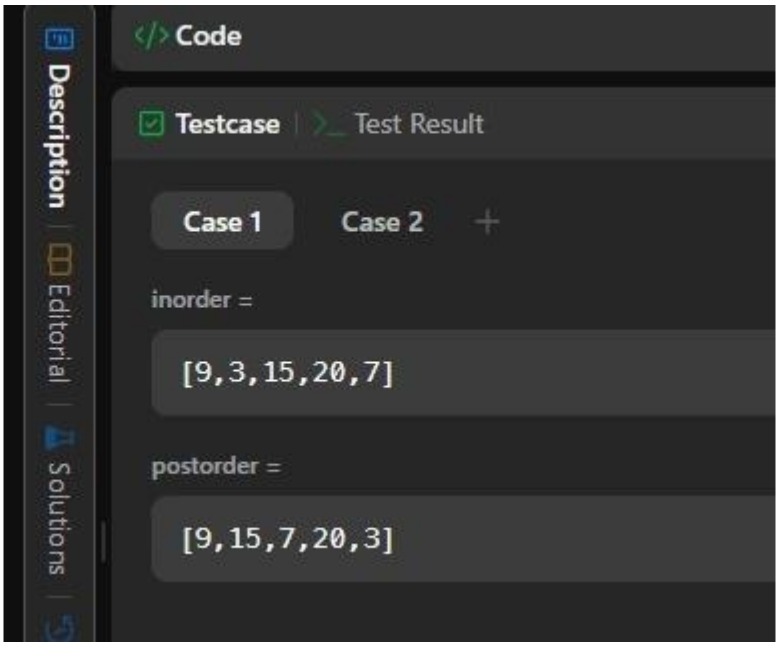
```
// Definition for a binary tree node
import java.util.*;

class TreeNode {
    int val;
    TreeNode left;
    TreeNode right;

    TreeNode(int val) {
        this.val = val;
        this.left = null;
        this.right = null;
```

```
    }
}

public class Solution {

    private Map<Integer, Integer> inorderMap; // To store index of elements in inorder
array
    private int postIndex; // Pointer for postorder array

    public TreeNode buildTree(int[] inorder, int[] postorder) {
        inorderMap = new HashMap<>();
        postIndex = postorder.length - 1;

        // Store element-to-index mapping for quick look-up
        for (int i = 0; i < inorder.length; i++) {
            inorderMap.put(inorder[i], i);
        }

        // Build the tree recursively
        return buildSubTree(postorder, 0, inorder.length - 1);
    }

    private TreeNode buildSubTree(int[] postorder, int left, int right) {
        if (left > right) {
            return null;
        }

        // Get current root value from postorder traversal
        int rootVal = postorder[postIndex--];
        TreeNode root = new TreeNode(rootVal);

        // Find root index in inorder array
        int rootIndex = inorderMap.get(rootVal);

        // Build right subtree first (because postorder visits left->right->root)
        root.right = buildSubTree(postorder, rootIndex + 1, right);
        root.left = buildSubTree(postorder, left, rootIndex - 1);
```

```
    return root;
}

// Helper method to print tree in level-order for visualization
public List<List<Integer>> levelOrder(TreeNode root) {
    List<List<Integer>> result = new ArrayList<>();
    if (root == null) return result;

    Queue<TreeNode> queue = new LinkedList<>();
    queue.offer(root);

    while (!queue.isEmpty()) {
        int levelSize = queue.size();
        List<Integer> level = new ArrayList<>();

        for (int i = 0; i < levelSize; i++) {
            TreeNode node = queue.poll();
            if (node != null) {
                level.add(node.val);
                if (node.left != null) queue.offer(node.left);
                if (node.right != null) queue.offer(node.right);
            }
        }
        result.add(level);
    }
    return result;
}

public static void main(String[] args) {
    Solution solution = new Solution();

    // Example 1
    int[] inorder1 = {9, 3, 15, 20, 7};
    int[] postorder1 = {9, 15, 7, 20, 3};
    TreeNode root1 = solution.buildTree(inorder1, postorder1);
    System.out.println("Level-order traversal: " + solution.levelOrder(root1));

    // Example 2
```

```
        int[] inorder2 = {-1};
        int[] postorder2 = {-1};
        TreeNode root2 = solution.buildTree(inorder2, postorder2);
        System.out.println("Level-order traversal: " + solution.levelOrder(root2));
    }
}
```

3. **Output:**



Problem-8

1. **Aim:**
Given the root of a binary search tree, and an integer k, return the kth smallest value (1-indexed) of all the values of the nodes in the tree.

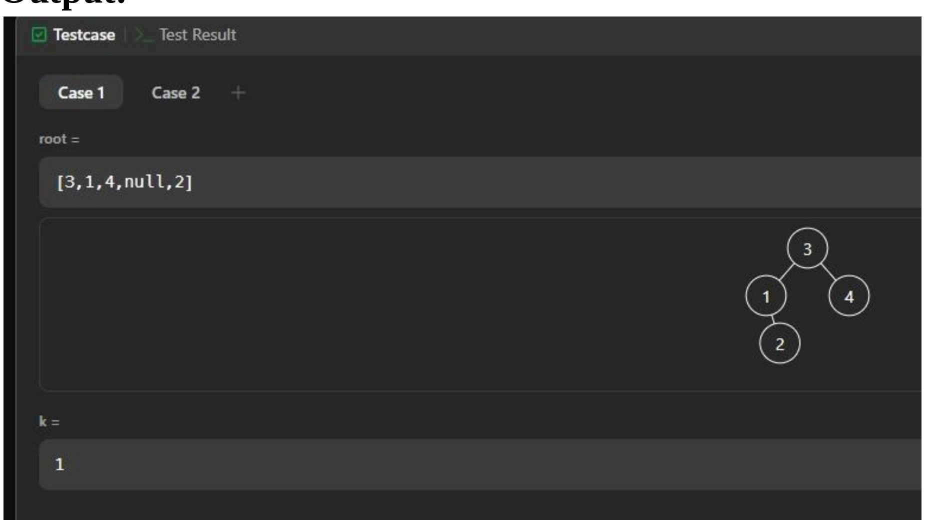
2. **Code:**

```
// Definition for a binary tree node
import java.util.*;

class TreeNode {
    int val;
    TreeNode left;
```

```
    TreeNode right;

    TreeNode(int val) {
        this.val = val;
        this.left = null;
        this.right = null;
    }
}
public class Solution {
    // Method 1: Inorder Traversal (Iterative)
    public int kthSmallest(TreeNode root, int k) {
        Stack<TreeNode> stack = new Stack<>();
        TreeNode current = root;

        while (current != null || !stack.isEmpty()) {
            // Traverse left subtree
            while (current != null) {
                stack.push(current);
                current = current.left;
            }
            // Process node
            current = stack.pop();
            k--;
            if (k == 0) {
                return current.val; // Found kth smallest element
            }
            // Move to right subtree
            current = current.right;
        }
        return -1; // Should never reach here if input is valid
    }
    // Sample tree builder for testing
    public TreeNode buildSampleTree1() {
        TreeNode root = new TreeNode(3);
        root.left = new TreeNode(1);
        root.left.right = new TreeNode(2);
        root.right = new TreeNode(4);
        return root;
```

```
    }
    public TreeNode buildSampleTree2() {
        TreeNode root = new TreeNode(5);
        root.left = new TreeNode(3);
        root.right = new TreeNode(6);
        root.left.left = new TreeNode(2);
        root.left.right = new TreeNode(4);
        root.left.left.left = new TreeNode(1);
        return root;
    }

    public static void main(String[] args) {
        Solution solution = new Solution();

        // Example 1: root = [3,1,4,null,2], k = 1
        TreeNode root1 = solution.buildSampleTree1();
        System.out.println("Kth smallest element: " + solution.kthSmallest(root1, 1)); //
Output: 1

        // Example 2: root = [5,3,6,2,4,null,null,1], k = 3
        TreeNode root2 = solution.buildSampleTree2();
        System.out.println("Kth smallest element: " + solution.kthSmallest(root2, 3)); //
Output: 3
    }
}}
```

3. Output:



Problem-9

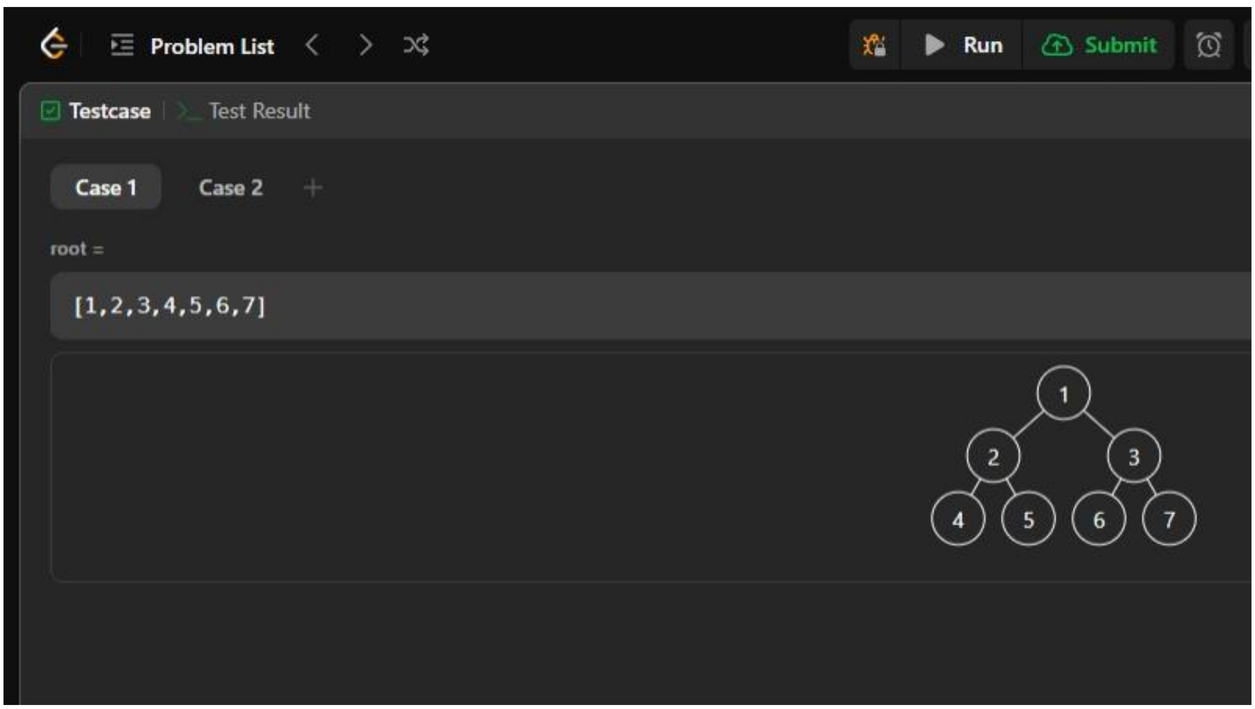
1. **Aim:** Populate each next pointer to point to its next right node. If there is no next right node, the next pointer should be set to NULL.
2. **Code:**

```
// Definition for a Node
class Node {
    public int val;
    public Node left;
    public Node right;
    public Node next;

    public Node(int val) {
        this.val = val;
        left = null;
        right = null;
        next = null;
    }
}

public class Solution {

    // Using constant space (O(1)) iterative approach
    public Node connect(Node root) {
        if (root == null) {
            return null;
        }

        Node leftmost = root;

        // Traverse level by level
        while (leftmost.left != null) {
            Node current = leftmost;

            while (current != null) {
                // Connect the left and right children of the current node
                current.left.next = current.right;
```

```
                // Connect the right child to the next left child if exists
                if (current.next != null) {
                    current.right.next = current.next.left;
                }

                // Move to the next node at the current level
                current = current.next;
            }

            // Move to the next level (leftmost node of the next level)
            leftmost = leftmost.left;
        }

        return root;
    }

    // Helper method to print the tree's next pointers (for testing)
    public void printTree(Node root) {
        Node levelStart = root;
        while (levelStart != null) {
            Node current = levelStart;
            while (current != null) {
                System.out.print(current.val + " -> ");
                current = current.next;
            }
            System.out.println("NULL");
            levelStart = levelStart.left; // move to next level
        }
    }

    public static void main(String[] args) {
        Solution solution = new Solution();

        // Construct the example tree: [1,2,3,4,5,6,7]
        Node root = new Node(1);
        root.left = new Node(2);
        root.right = new Node(3);
```

```
            root.left.left = new Node(4);
            root.left.right = new Node(5);
            root.right.left = new Node(6);
            root.right.right = new Node(7);

            // Connect nodes at each level
            solution.connect(root);

            // Print the next pointers for each level
            solution.printTree(root);
        }
    }
```

3. Output:



Problem-10

1. **Aim:** Given the root of a binary tree, return the zigzag level order traversal of its nodes' values. (i.e., from left to right, then right to left for the next level and alternate between).

2. Code:

```
import java.util.*;

class Solution {
    public List<List<Integer>> zigzagLevelOrder(TreeNode root) {
        List<List<Integer>> result = new ArrayList<>();
        if (root == null) return result;

        Queue<TreeNode> queue = new LinkedList<>();
        queue.offer(root);
        boolean leftToRight = true; // To track direction of traversal

        while (!queue.isEmpty()) {
            int levelSize = queue.size();
            List<Integer> level = new ArrayList<>(levelSize);

            for (int i = 0; i < levelSize; i++) {
                TreeNode node = queue.poll();

                // Add node value based on current direction
                if (leftToRight) {
                    level.add(node.val); // left-to-right order
                } else {
                    level.add(0, node.val); // right-to-left order (insert at start)
                }

                // Add children to queue for next level
                if (node.left != null) queue.offer(node.left);
                if (node.right != null) queue.offer(node.right);
            }

            // Add current level to result
            result.add(level);
            // Flip direction for next level
            leftToRight = !leftToRight;
        }

        return result;
```

```
        }
    }
    // Definition for a binary tree node
    class TreeNode {
        int val;
        TreeNode left;
        TreeNode right;
        TreeNode(int val) { this.val = val; }
    }
    // Test the code
    public class Main {
        public static void main(String[] args) {
            Solution solution = new Solution();
            // Example tree: [3,9,20,null,null,15,7]
            TreeNode root = new TreeNode(3);
            root.left = new TreeNode(9);
            root.right = new TreeNode(20);
            root.right.left = new TreeNode(15);
            root.right.right = new TreeNode(7);
            System.out.println(solution.zigzagLevelOrder(root));
        }
    }
```

3. Output: