

Experiment 6

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Semester: 6th

Date of Performance:28/02/2025

Subject Name: Advanced Programming Lab-2 **Subject Code:** 22ITP-351

1. Aim 1 : Maximum Depth of Binary Tree

Given the root of a binary tree, return its maximum depth.

A binary tree's maximum depth is the number of nodes along the longest path from the root node down to the farthest leaf node.

2. Validate Binary Search Tree :

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

A valid BST is defined as follows:

- left subtree of a node contains only nodes with keys less than the node's key.
- The right subtree of a node contains only nodes with keys greater than the node's key.
- Both the left and right subtrees must also be binary search trees.

3. Symmetric Tree:

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

4. Binary Tree Level Order Traversal:

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).

5. Convert Sorted Array to Binary Search Tree:

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

6. Binary Tree Inorder Traversal:

Given the root of a binary tree, return the inorder traversal of its nodes' values.

7. Binary Tree Zigzag Level Order Traversal :

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).

8. Construct Binary Tree from Inorder and Postorder Traversal:

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.

9. Kth Smallest Element in a BST :

Given the root of a binary search tree, and an integer k, return the k^{th} smallest value (1-indexed) of all the values of the nodes in the tree.

10. Populating Next Right Pointers in Each Node :

You are given a perfect binary tree where all leaves are on the same level, and every parent has two children. The binary tree has the following definition:

```
struct Node {  
    int val;  
    Node *left;  
    Node *right;  
    Node *next;  
}
```

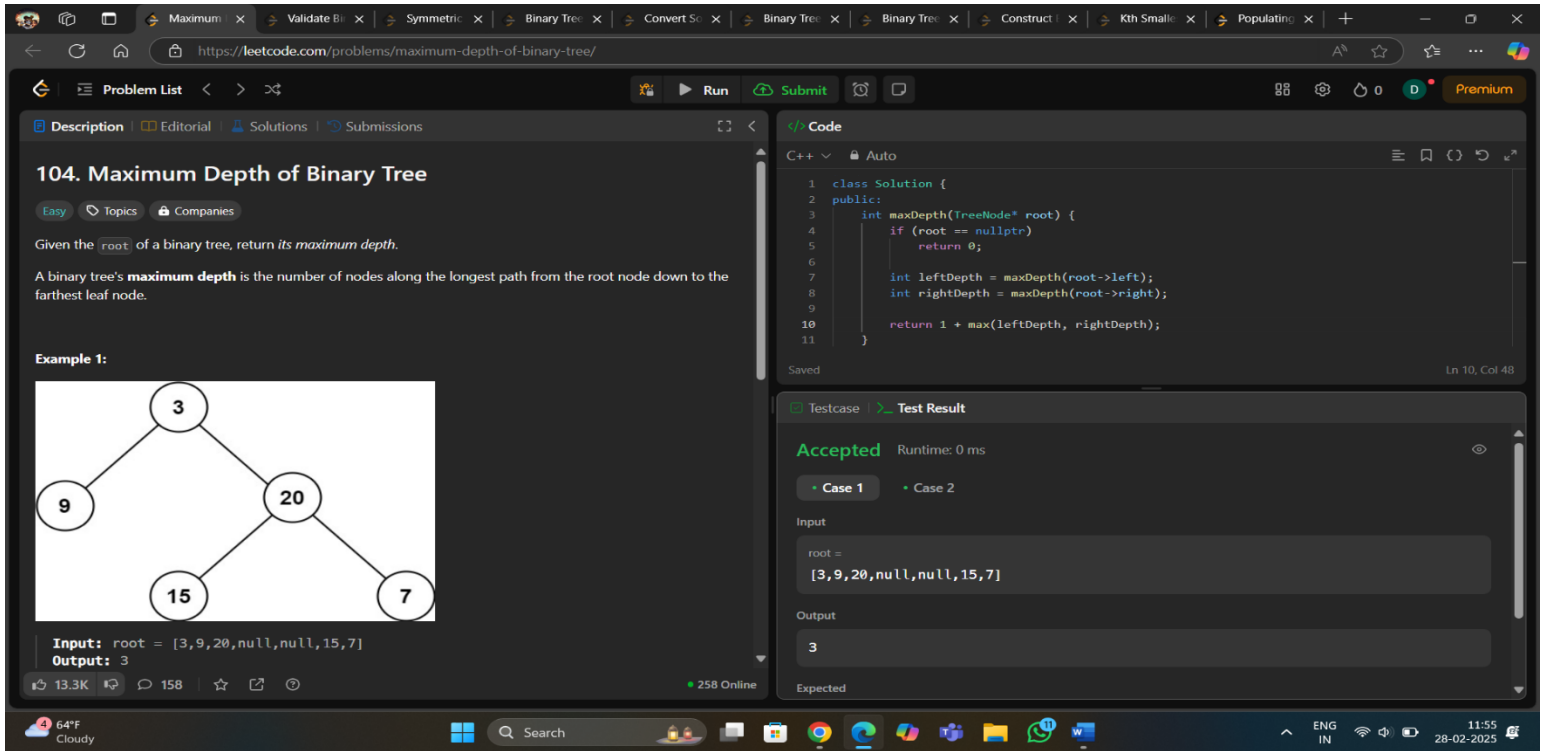
Populate each next pointer to point to its next right node. If there is no next right node, the next pointer should be set to NULL.

Initially, all next pointers are set to NULL.

11.Objective :

1. Learn how to recursively or iteratively compute the height (or depth) of a binary tree.
2. Understand the properties of a Binary Search Tree (BST).
3. Understand mirror properties of a binary tree.
4. Learn Breadth-First Search (BFS) using queues.
5. Learn how to construct a height-balanced BST from a sorted array.
6. Understand inorder traversal (left-root-right).
7. Extend BFS level-order traversal to include zigzag ordering.
8. Understand tree reconstruction from traversal orders.
9. Use inorder traversal (sorted order) to efficiently find the kth smallest element.
10. Understand tree linking using level pointers.

12.Implementation of Code/Output 1 :



104. Maximum Depth of Binary Tree

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Given the `root` of a binary tree, return its *maximum depth*.

A binary tree's **maximum depth** is the number of nodes along the longest path from the root node down to the farthest leaf node.

Example 1:

```

graph TD
    3((3)) --> 9((9))
    3 --> 20((20))
    20 --> 15((15))
    20 --> 7((7))
  
```

Input: `root = [3,9,20,null,null,15,7]`
Output: `3`

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```

class Solution {
public:
    int maxDepth(TreeNode* root) {
        if (root == nullptr)
            return 0;

        int leftDepth = maxDepth(root->left);
        int rightDepth = maxDepth(root->right);

        return 1 + max(leftDepth, rightDepth);
    }
};
  
```

Accepted Runtime: 0 ms

Case 1 Case 2

Input

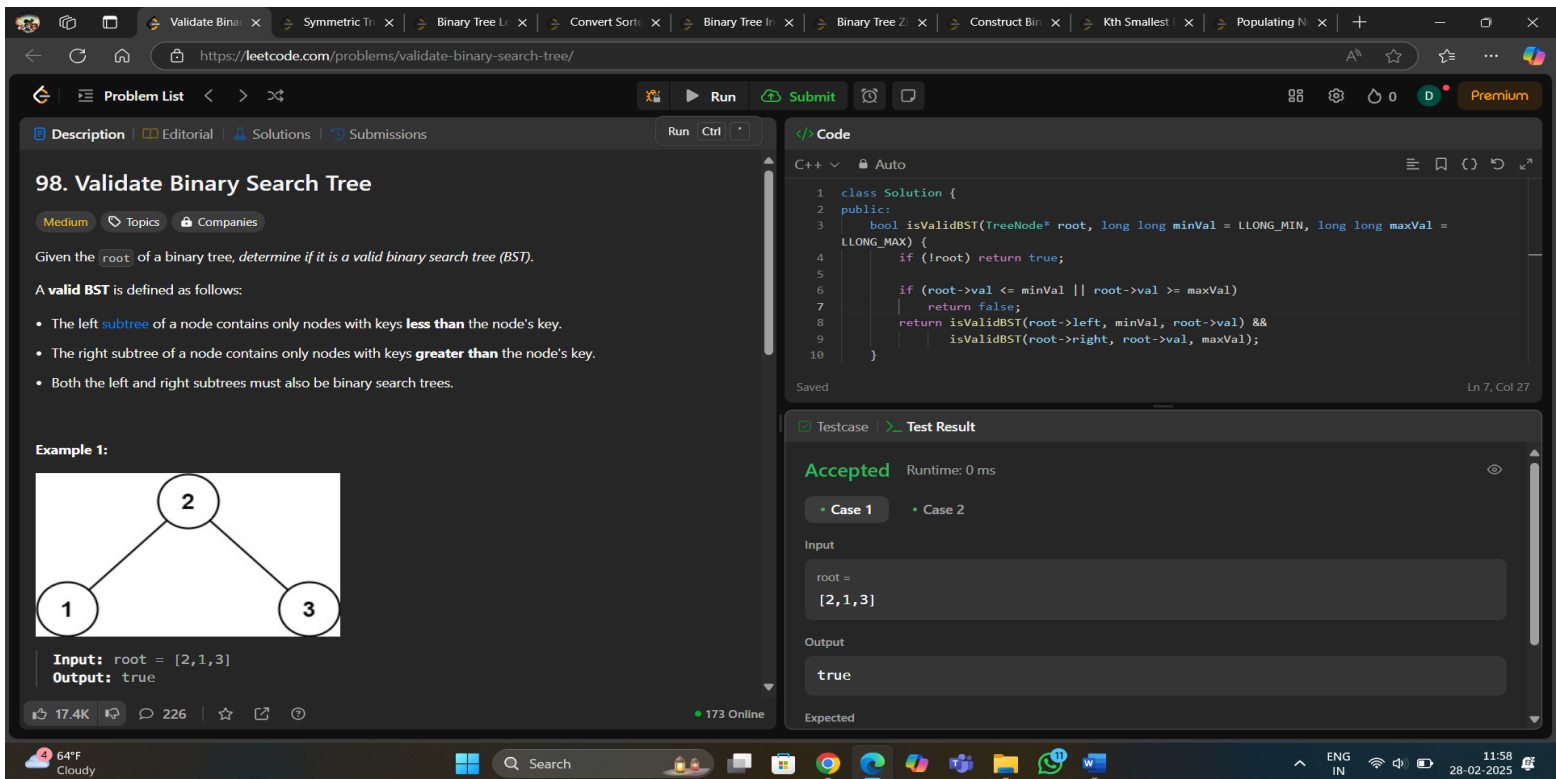
`root = [3,9,20,null,null,15,7]`

Output

`3`

Expected

13.Code 2 :



98. Validate Binary Search Tree

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

A **valid BST** is defined as follows:

- The left *subtree* of a node contains only nodes with keys **less than** the node's key.
- The right *subtree* of a node contains only nodes with keys **greater than** the node's key.
- Both the left and right subtrees must also be binary search trees.

Example 1:

```

graph TD
    2((2)) --> 1((1))
    2 --> 3((3))
  
```

Input: `root = [2,1,3]`
Output: `true`

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```

class Solution {
public:
    bool isValidBST(TreeNode* root, long long minVal = LLONG_MIN, long long maxVal = LLONG_MAX) {
        if (!root) return true;

        if (root->val <= minVal || root->val >= maxVal)
            return false;

        return isValidBST(root->left, minVal, root->val) &&
            isValidBST(root->right, root->val, maxVal);
    }
};
  
```

Accepted Runtime: 0 ms

Case 1 Case 2

Input

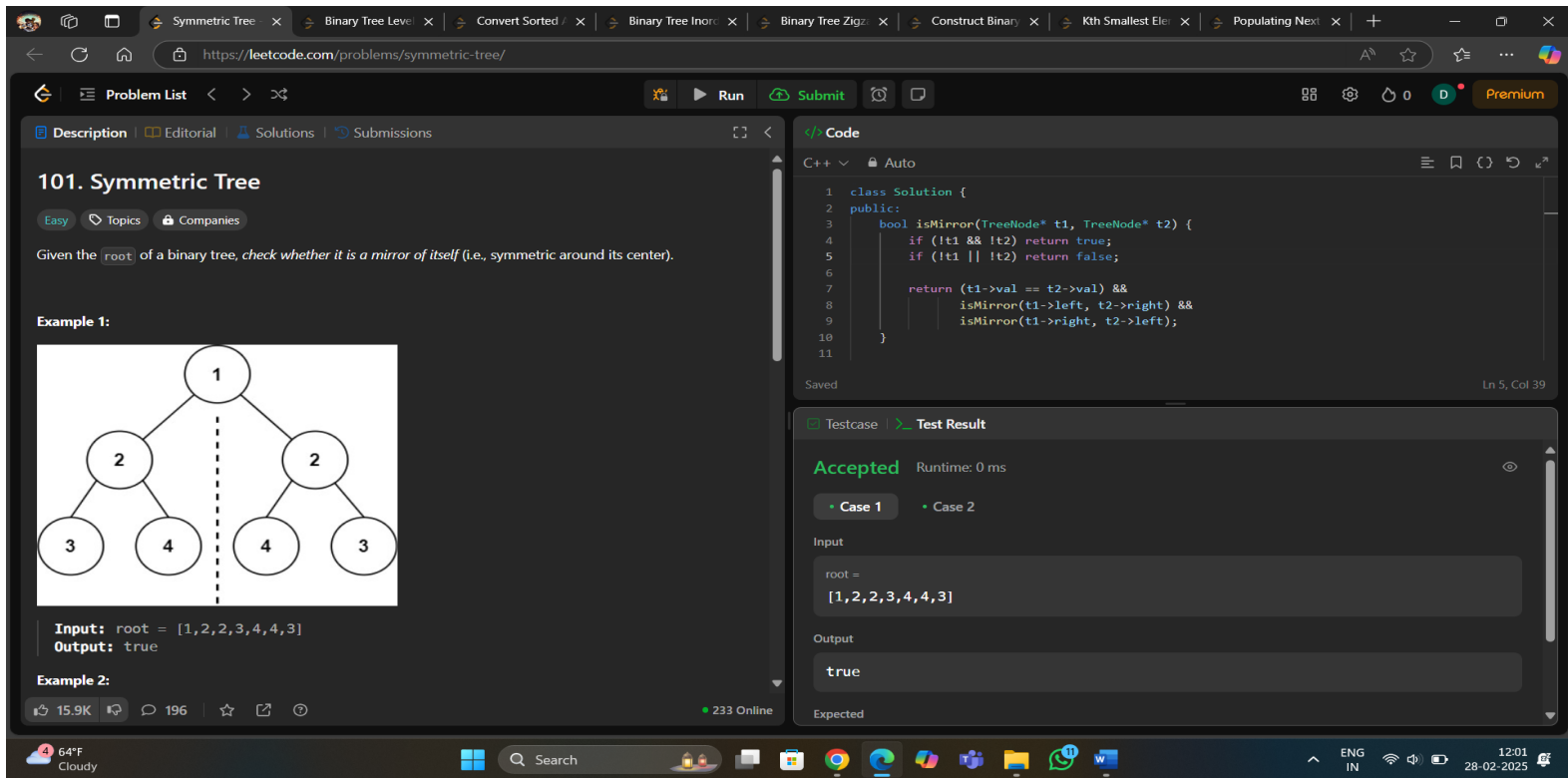
`root = [2,1,3]`

Output

`true`

Expected

14.Code 3 :



101. Symmetric Tree

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

Example 1:

```

graph TD
    1((1)) --- 2L((2))
    1 --- 2R((2))
    2L --- 3L((3))
    2L --- 4L((4))
    2R --- 4R((4))
    2R --- 3R((3))
  
```

Input: `root = [1,2,2,3,4,4,3]`
Output: `true`

Example 2:

Input: `root = [1,2,2,null,3,null,3]`
Output: `false`

```

class Solution {
public:
    bool isMirror(TreeNode* t1, TreeNode* t2) {
        if (!t1 && !t2) return true;
        if (!t1 || !t2) return false;
        return (t1->val == t2->val) &&
            isMirror(t1->left, t2->right) &&
            isMirror(t1->right, t2->left);
    }
}
  
```

Accepted Runtime: 0 ms

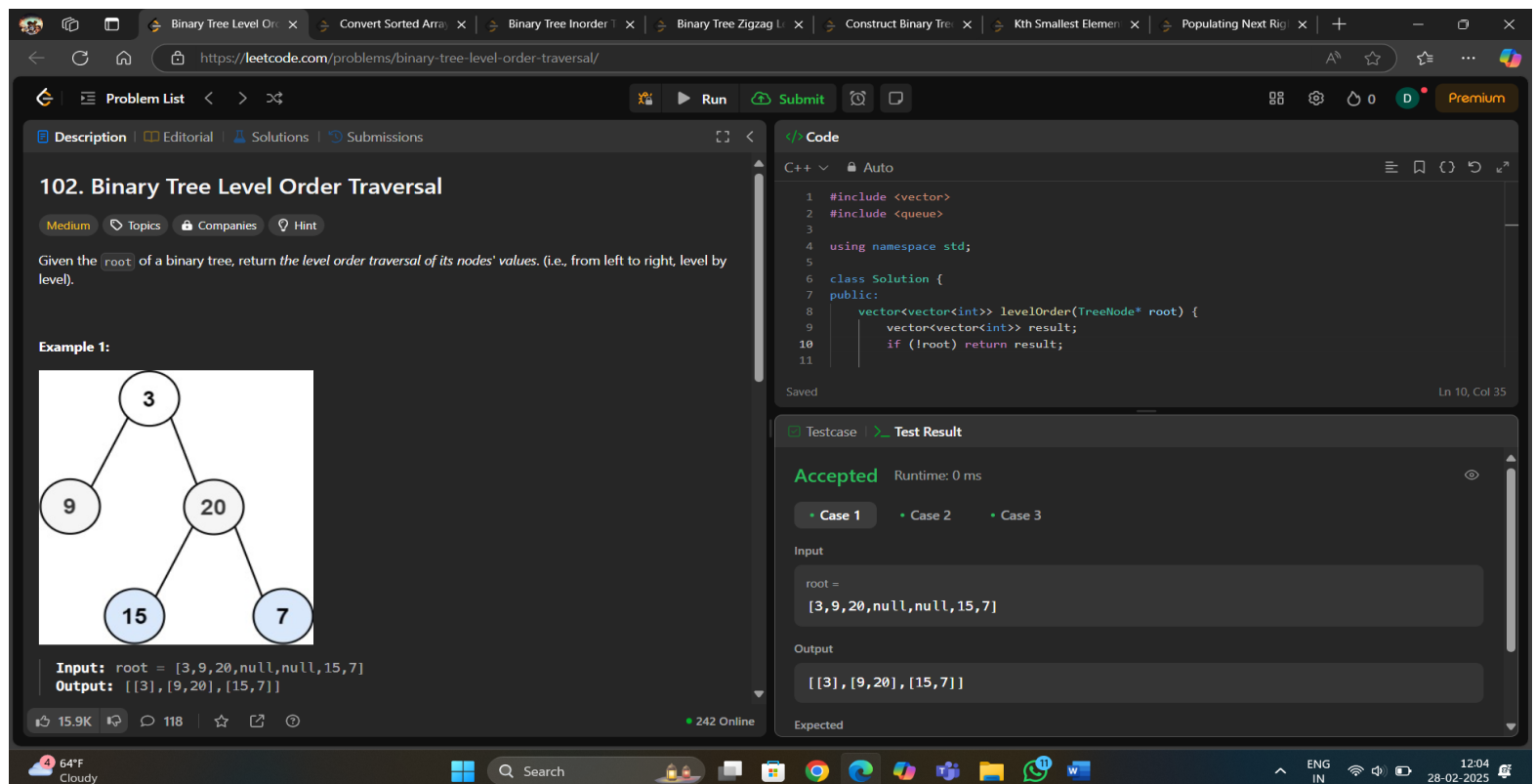
Case 1

Input: `root = [1,2,2,3,4,4,3]`

Output: `true`

Expected: `true`

15.Code 4 :



102. Binary Tree Level Order Traversal

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).

Example 1:

```

graph TD
    3((3)) --- 9((9))
    3 --- 20((20))
    9 --- 15((15))
    20 --- 7((7))
  
```

Input: `root = [3,9,20,null,null,15,7]`
Output: `[[3], [9,20], [15,7]]`

```

#include <vector>
#include <queue>
using namespace std;
class Solution {
public:
    vector<vector<int>> levelOrder(TreeNode* root) {
        vector<vector<int>> result;
        if (!root) return result;
        queue<TreeNode*> q;
        q.push(root);
        while (!q.empty()) {
            int size = q.size();
            vector<int> level;
            for (int i = 0; i < size; i++) {
                TreeNode* node = q.front();
                q.pop();
                level.push_back(node->val);
                if (node->left) q.push(node->left);
                if (node->right) q.push(node->right);
            }
            result.push_back(level);
        }
        return result;
    }
}
  
```

Accepted Runtime: 0 ms

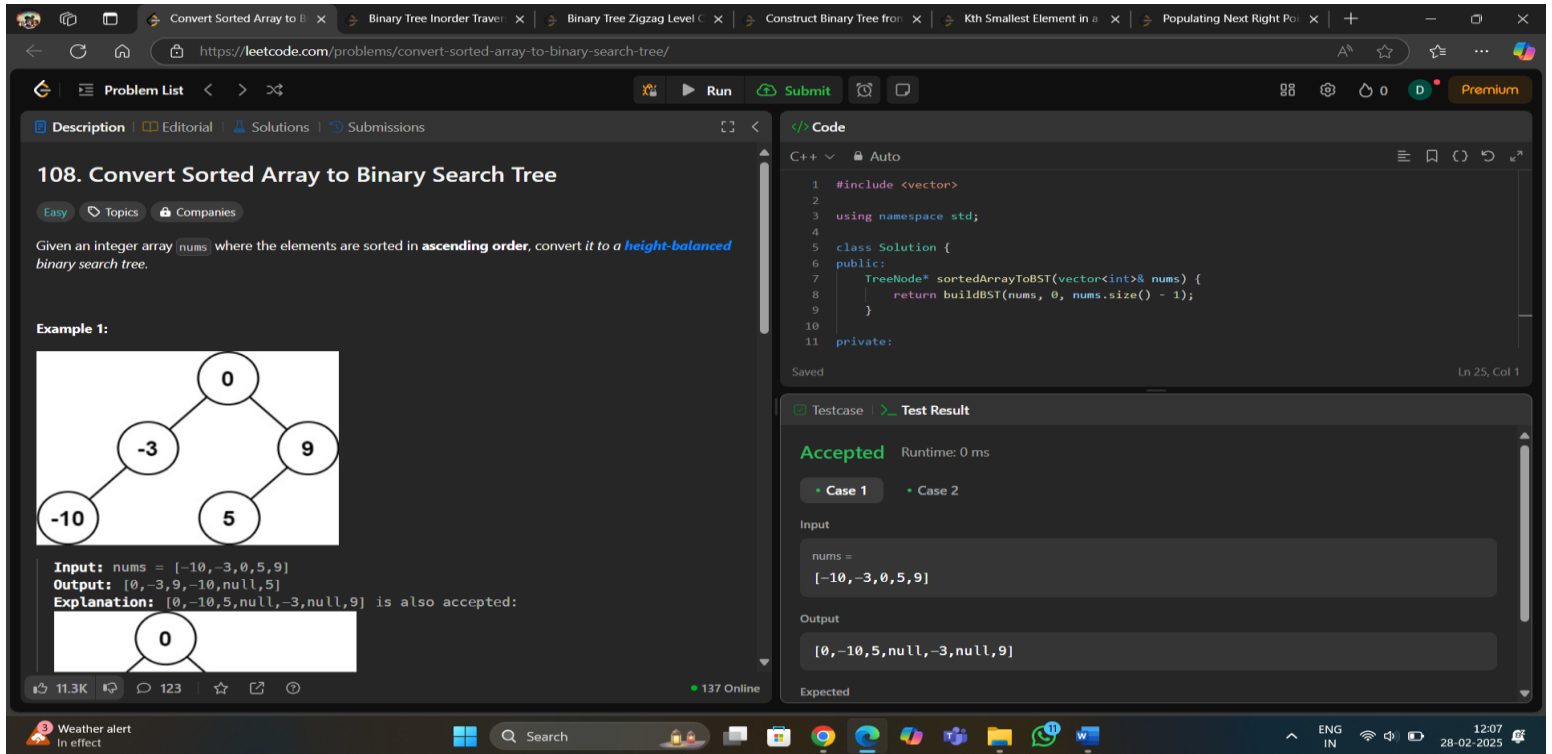
Case 1

Input: `root = [3,9,20,null,null,15,7]`

Output: `[[3], [9,20], [15,7]]`

Expected: `[[3], [9,20], [15,7]]`

16.Code 5 :



108. Convert Sorted Array to Binary Search Tree

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

Example 1:

Input: `nums = [-10,-3,0,5,9]`
Output: `[0,-3,9,-10,null,5]`
Explanation: `[0,-10,5,null,-3,null,9]` is also accepted:

```

graph TD
    0((0)) --- -3((-3))
    0 --- 9((9))
    -3 --- -10((-10))
    9 --- 5((5))
  
```

Code:

```

1 #include <vector>
2 using namespace std;
3
4 class Solution {
5 public:
6     TreeNode* sortedArrayToBST(vector<int>& nums) {
7         return buildBST(nums, 0, nums.size() - 1);
8     }
9 private:
10
11 
```

Testcase: Accepted Runtime: 0 ms

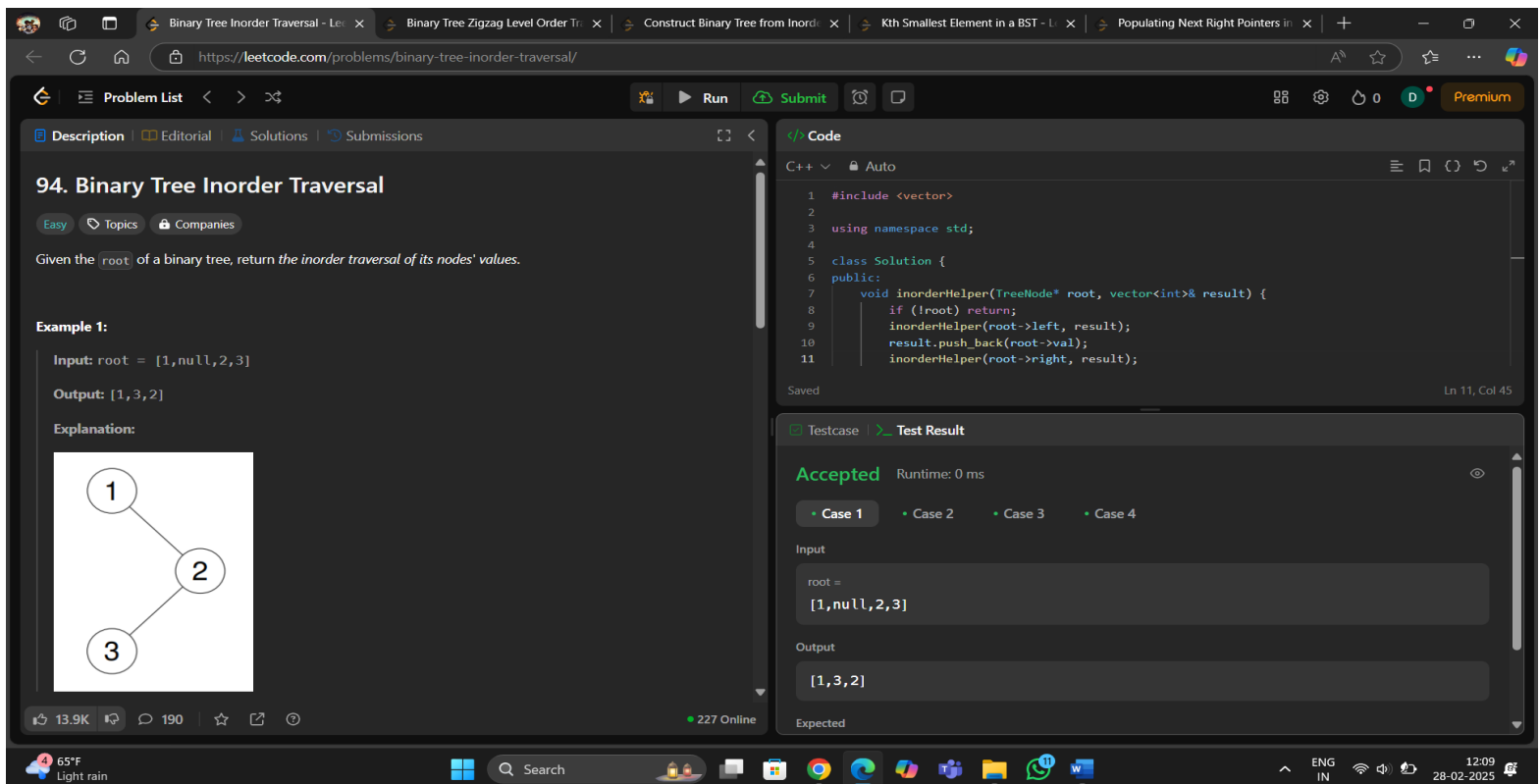
Case 1:

Input: `nums = [-10,-3,0,5,9]`

Output: `[0,-10,5,null,-3,null,9]`

Expected:

17.Code 6 :



94. Binary Tree Inorder Traversal

Given the `root` of a binary tree, return the *inorder traversal of its nodes' values*.

Example 1:

Input: `root = [1,null,2,3]`
Output: `[1,3,2]`
Explanation:

```

graph TD
    1((1)) --- 2((2))
    2 --- 3((3))
  
```

Code:

```

1 #include <vector>
2 using namespace std;
3
4 class Solution {
5 public:
6     void inorderHelper(TreeNode* root, vector<int>& result) {
7         if (!root) return;
8         inorderHelper(root->left, result);
9         result.push_back(root->val);
10        inorderHelper(root->right, result);
11    }
12 
```

Testcase: Accepted Runtime: 0 ms

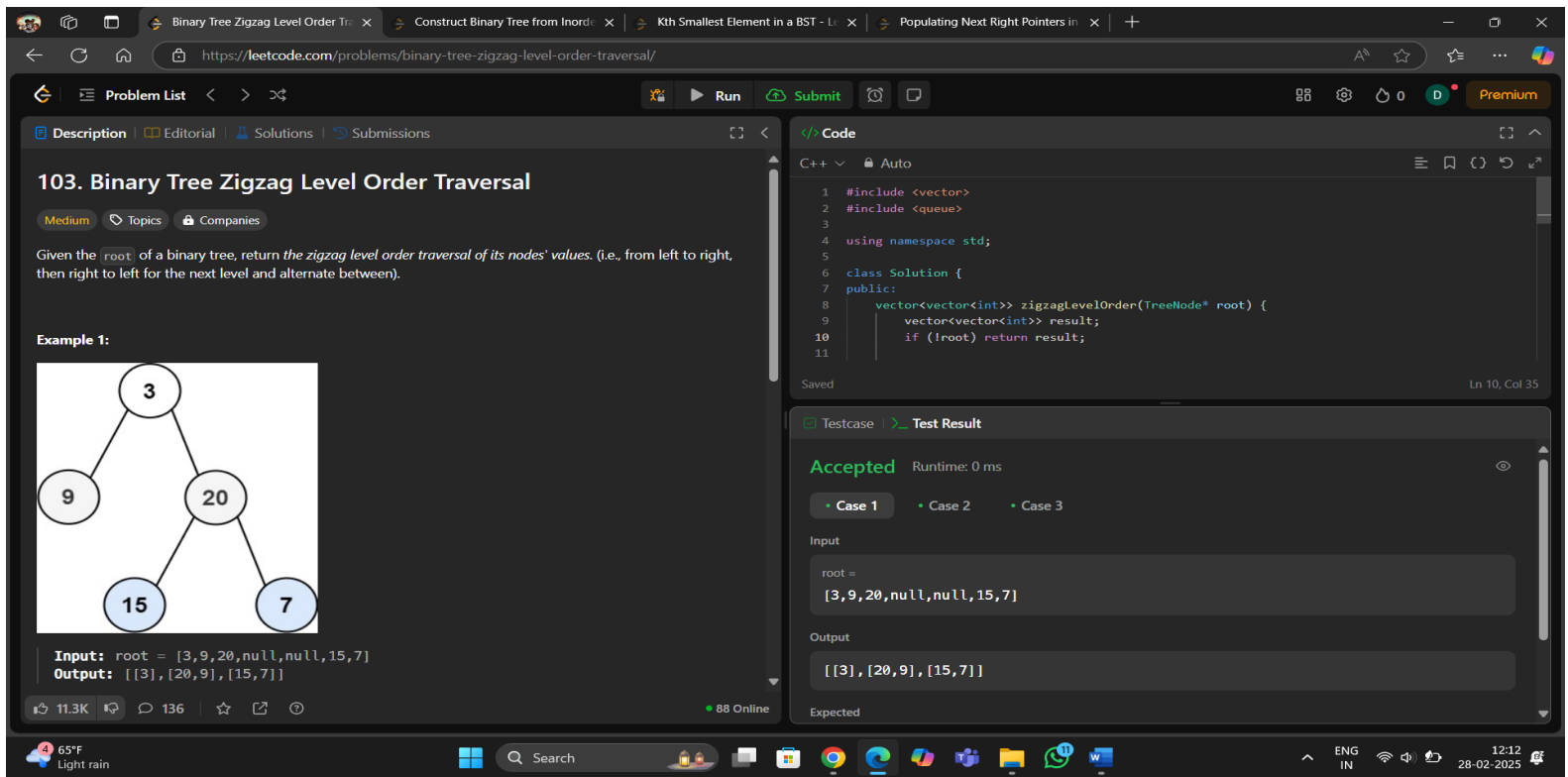
Case 1:

Input: `root = [1,null,2,3]`

Output: `[1,3,2]`

Expected:

18.Code 7 :



103. Binary Tree Zigzag Level Order Traversal

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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).

Example 1:

```

graph TD
    3((3)) --- 9((9))
    3 --- 20((20))
    9 --- 15((15))
    20 --- 7((7))
  
```

Input: `root = [3,9,20,null,null,15,7]`
Output: `[[3],[20,9],[15,7]]`

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```

1 #include <vector>
2 #include <queue>
3
4 using namespace std;
5
6 class Solution {
7 public:
8     vector<vector<int>> zigzagLevelOrder(TreeNode* root) {
9         vector<vector<int>> result;
10        if (!root) return result;
11    }
  
```

Accepted Runtime: 0 ms

Case 1 Case 2 Case 3

Input

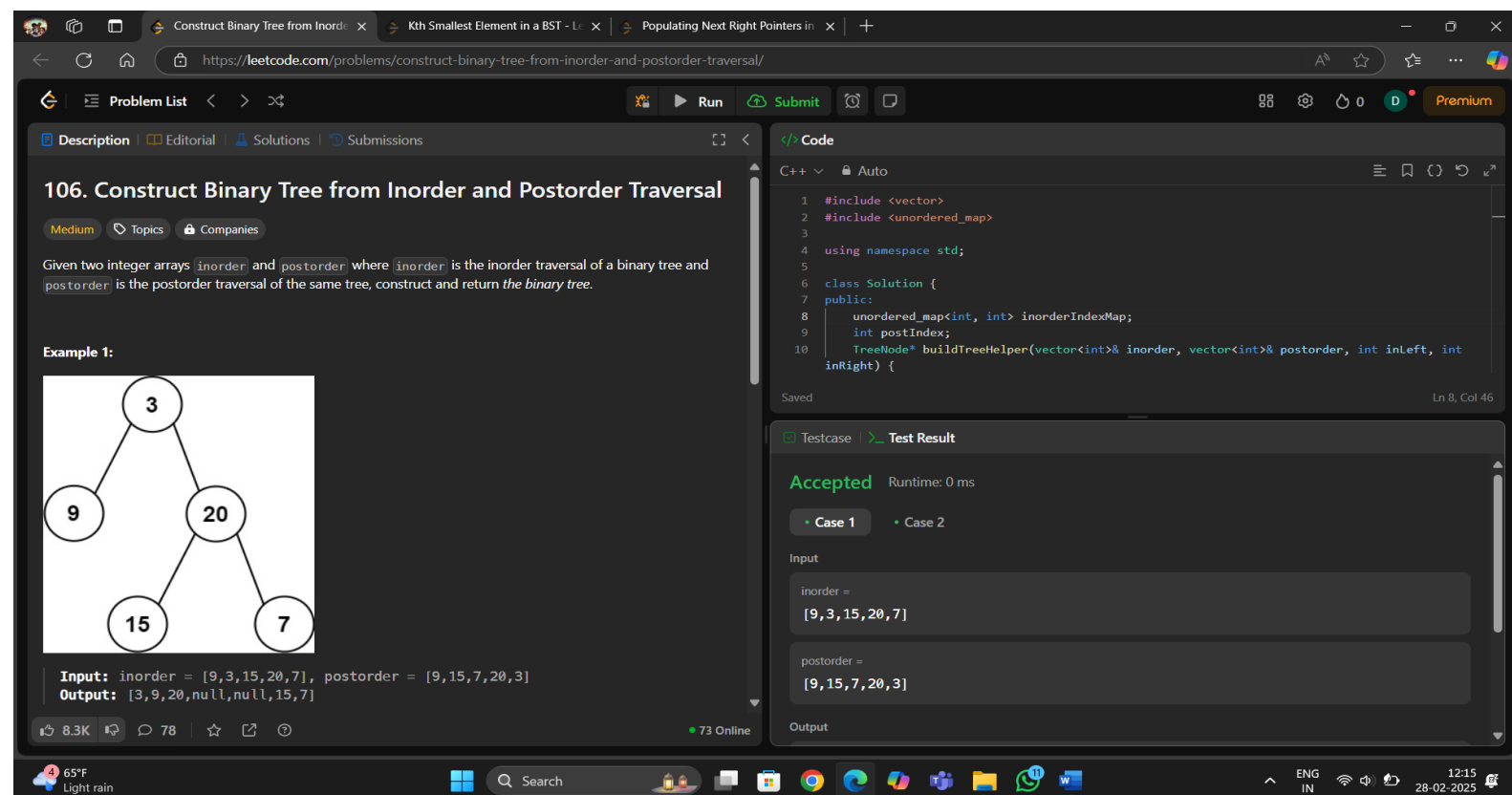
`root = [3,9,20,null,null,15,7]`

Output

`[[3],[20,9],[15,7]]`

Expected

19.Code 8 :



106. Construct Binary Tree from Inorder and Postorder Traversal

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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.

Example 1:

```

graph TD
    3((3)) --- 9((9))
    3 --- 20((20))
    9 --- 15((15))
    20 --- 7((7))
  
```

Input: `inorder = [9,3,15,20,7], postorder = [9,15,7,20,3]`
Output: `[3,9,20,null,null,15,7]`

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```

1 #include <vector>
2 #include <unordered_map>
3
4 using namespace std;
5
6 class Solution {
7 public:
8     unordered_map<int, int> inorderIndexMap;
9     int postIndex;
10    TreeNode* buildTreeHelper(vector<int>& inorder, vector<int>& postorder, int inLeft, int inRight) {
  
```

Accepted Runtime: 0 ms

Case 1 Case 2

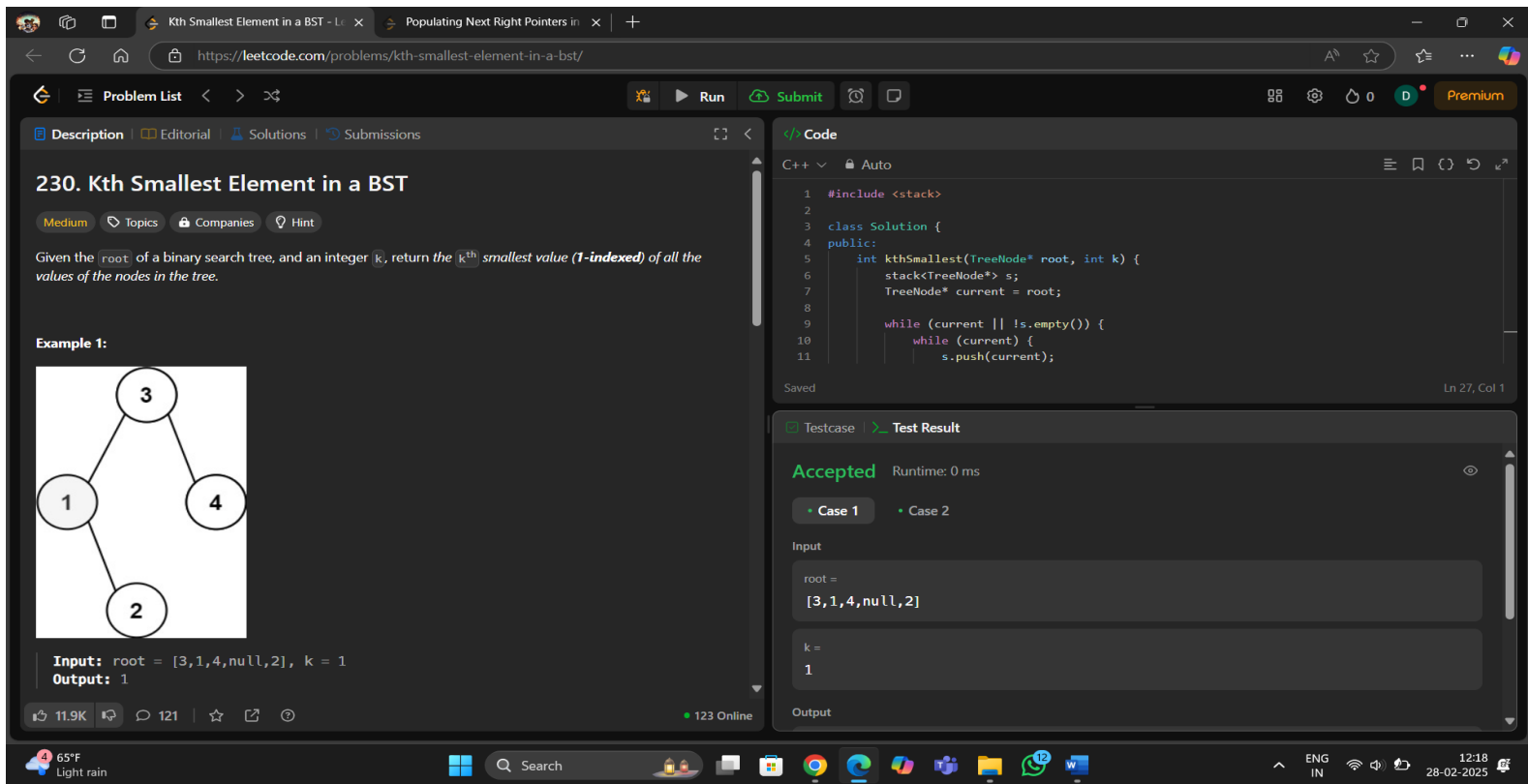
Input

`inorder = [9,3,15,20,7]`

`postorder = [9,15,7,20,3]`

Output

20.Code 9:

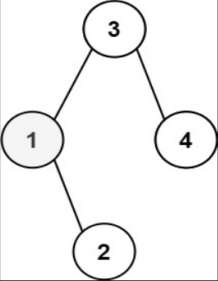


230. Kth Smallest Element in a BST

Medium Topics Companies Hint

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.

Example 1:



Input: `root = [3,1,4,null,2]`, `k = 1`
Output: `1`

```

1  #include <stack>
2
3  class Solution {
4  public:
5      int kthSmallest(TreeNode* root, int k) {
6          stack<TreeNode*> s;
7          TreeNode* current = root;
8
9          while (current || !s.empty()) {
10             while (current) {
11                 s.push(current);

```

Accepted Runtime: 0 ms

Case 1 Case 2

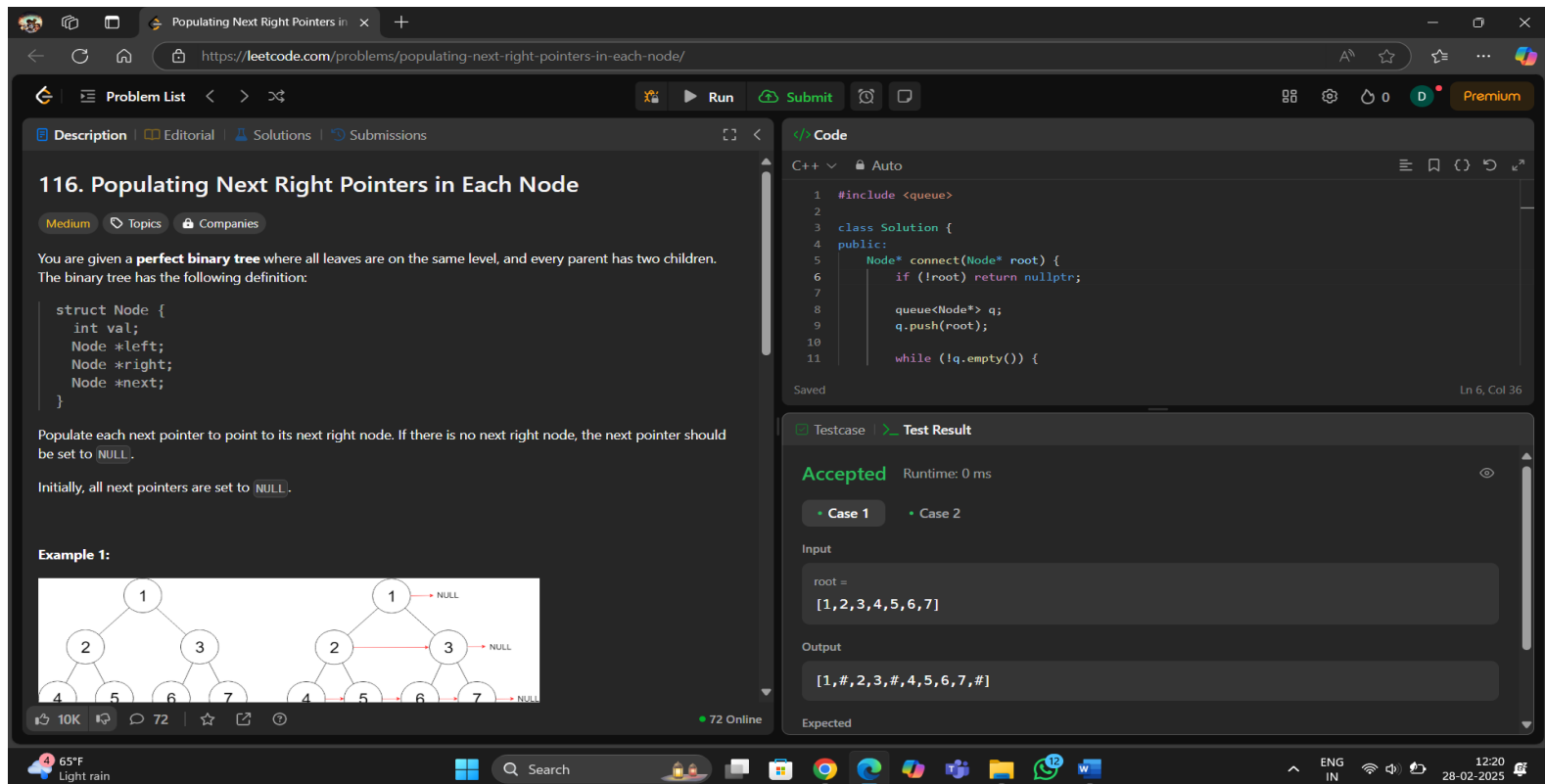
Input

`root = [3,1,4,null,2]`

`k = 1`

Output

21.Code 10 :



116. Populating Next Right Pointers in Each Node

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You are given a **perfect binary tree** where all leaves are on the same level, and every parent has two children. The binary tree has the following definition:

```

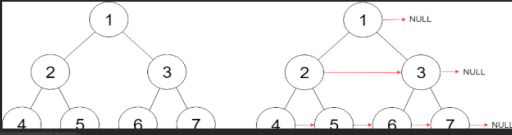
struct Node {
    int val;
    Node *left;
    Node *right;
    Node *next;
}

```

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`.

Initially, all next pointers are set to `NULL`.

Example 1:



```

1  #include <queue>
2
3  class Solution {
4  public:
5      Node* connect(Node* root) {
6          if (!root) return nullptr;
7
8          queue<Node*> q;
9          q.push(root);
10
11         while (!q.empty()) {

```

Accepted Runtime: 0 ms

Case 1 Case 2

Input

`root = [1,2,3,4,5,6,7]`

Output

`[1,#,2,3,#,4,5,6,7,#]`



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22.Learning Outcome :

1. Concepts: Depth-first search (DFS), Recursion
2. A valid BST requires every node's left child to be smaller and right child to be larger.
3. A tree is symmetric if its left subtree is a mirror of the right subtree.
4. Concepts: Recursion, Divide & Conquer, Balanced BST
5. Concepts: Inorder traversal, Recursion, Iterative (Stack)
6. Concepts: Tree Reconstruction, Recursion, Hash Map Optimization