

DEPARTMENT OF COMPUTER SCIENCE & ENGINEERING

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Winter Domain Camp Day 2

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Problem 1: Majority Elements

Given an array `nums` of size `n`, return the majority element. The majority element is the element that appears more than $\lfloor n / 2 \rfloor$ times. You may assume that the majority element always exists in the array.

Solution :

```
#include <iostream>
```

```
#include <vector>
```

```
int majorityElement(const std::vector<int>& nums) {
```

```
    int candidate = 0, count = 0;
```

```
    // Phase 1: Find the candidate
```

```
    for (int num : nums) {
```

```
        if (count == 0) {
```

```
            candidate = num;
```

```
            count = 1;
```

```
        } else if (num == candidate) {
```

```
            count++;
```

```
        } else {
```

```
            count--;
```

```
        }
```

```
    }
```

```
    // Phase 2: Verify the candidate (Optional since problem guarantees majority  
    element)
```

```
    count = 0;
```

```
    for (int num : nums) {
```

```
        if (num == candidate) {
```

```
            count++;
```

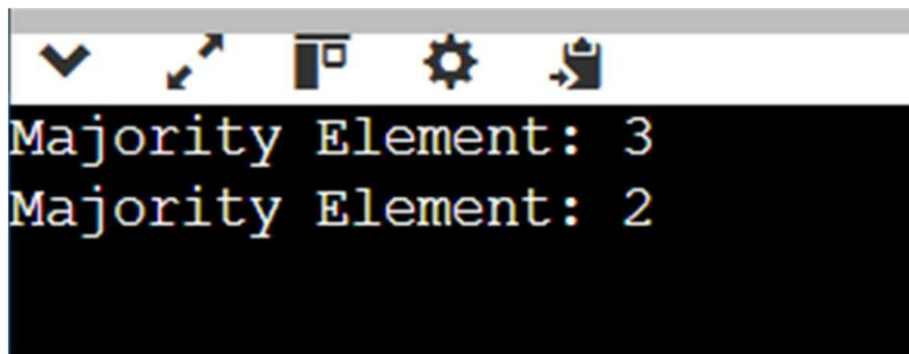
```
        }
```

```
}

if (count > nums.size() / 2) {
    return candidate;
}

throw std::runtime_error("No majority element found.");
}

int main() {
    std::vector<int> nums = {2, 2, 1, 1, 1, 2, 2};
    try {
        std::cout << "Majority Element: " << majorityElement(nums) << std::endl;
    } catch (const std::exception& e) {
        std::cerr << e.what() << std::endl;
    }
    return 0;
}
```

Output:

```
Majority Element: 3
Majority Element: 2
```

Problem 2: Pascal's Triangle

Given an integer numRows, return the first numRows of Pascal's triangle. In Pascal's triangle, each number is the sum of the two numbers directly above it

Solution:

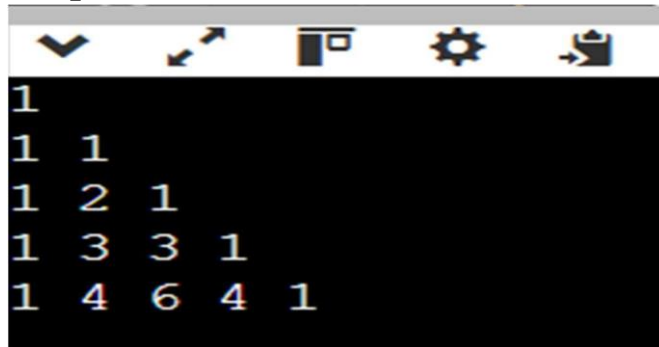
```
#include <iostream>
#include <vector>

std::vector<std::vector<int>> generate(int numRows) {
    std::vector<std::vector<int>> triangle(numRows);
```

```
for (int i = 0; i < numRows; ++i) {
    triangle[i].resize(i + 1, 1);
    for (int j = 1; j < i; ++j) {
        triangle[i][j] = triangle[i - 1][j - 1] + triangle[i - 1][j];
    }
}
return triangle;}

int main() {
    int numRows = 5; // Example input
    auto result = generate(numRows);
    for (const auto& row : result) {
        for (int num : row) std::cout << num << " ";
        std::cout << "\n";
    }
    return 0;}
```

Output:



```
1
1 1
1 2 1
1 3 3 1
1 4 6 4 1
```

Problem 3: Single Number

Given a non-empty array of integers nums, every element appears twice except for one. Find that single one. You must implement a solution with a linear runtime complexity and use only constant extra space.

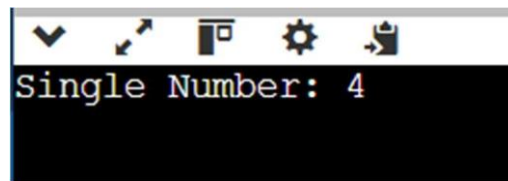
Solution:

```
#include <iostream>
#include <vector>

int singleNumber(const std::vector<int>& nums) {
    int result = 0;
    for (int num : nums) {
        result ^= num;
    }
    return result;
}
```

}

```
int main() {  
    std::vector<int> nums = {4, 1, 2, 1, 2}; // Example input  
    std::cout << "Single Number: " << singleNumber(nums) << std::endl;  
    return 0;  
}
```

Output:**Problem 4:** Merge Two Sorted Lists

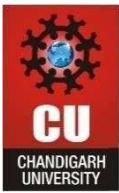
You are given the heads of two sorted linked lists list1 and list2. Merge the two lists into one sorted list. The list should be made by splicing together the nodes of the first two lists. Return the head of the merged linked list.

Solution:

```
#include <iostream>
```

```
struct ListNode {  
    int val;  
    ListNode* next;  
    ListNode(int x) : val(x), next(nullptr) { }  
};
```

```
ListNode* mergeTwoLists(ListNode* list1, ListNode* list2) {  
    if (!list1) return list2;  
    if (!list2) return list1;  
    if (list1->val < list2->val) {  
        list1->next = mergeTwoLists(list1->next, list2);  
        return list1;  
    } else {
```



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```
list2->next = mergeTwoLists(list1, list2->next);  
return list2;  
}  
}
```

```
void printList(ListNode* head) {  
    while (head) {  
        std::cout << head->val << " ";  
        head = head->next;  
    }  
}
```

```
int main() {  
    ListNode* list1 = new ListNode(1);  
    list1->next = new ListNode(2);  
    list1->next->next = new ListNode(4);  
  
    ListNode* list2 = new ListNode(1);  
    list2->next = new ListNode(3);  
    list2->next->next = new ListNode(4);  
  
    ListNode* mergedList = mergeTwoLists(list1, list2);  
    printList(mergedList);  
  
    return 0;  
}
```

Output:



Problem 5: Linked List Cycle.

Given head, the head of a linked list, determine if the linked list has a cycle in it. There is a cycle in a linked list if there is some node in the list that can be reached again by continuously following the next pointer. Internally, pos is used to denote the index of the node that tail's next pointer is connected to. Note that pos is not passed as a parameter. Return true if there is a cycle in the linked list. Otherwise, return false.

Solution:

```
#include <iostream>
```

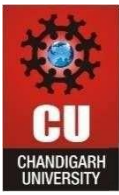
```
struct ListNode {
    int val;
    ListNode* next;
    ListNode(int x) : val(x), next(nullptr) {}
};

bool hasCycle(ListNode* head) {
    if (!head) return false;
    ListNode *slow = head, *fast = head;

    while (fast && fast->next) {
        slow = slow->next;          // Move slow pointer by 1 step
        fast = fast->next->next;     // Move fast pointer by 2 steps

        if (slow == fast) {        // Cycle detected
            return true; } }
    return false; // No cycle}

int main() {
    // Example 1: Creating a cycle in the list
    ListNode* head = new ListNode(3);
    head->next = new ListNode(2);
    head->next->next = new ListNode(0);
    head->next->next->next = new ListNode(-4);
    head->next->next->next->next = head->next; // Cycle starts at node with
    value 2
```

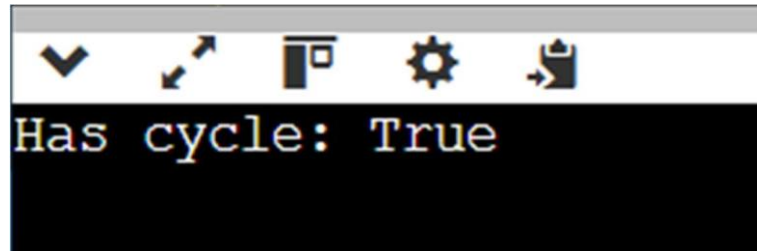


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```
std::cout << "Has cycle: " << (hasCycle(head) ? "True" : "False") << std::endl;  
  
return 0;  
}
```

Output:



Problem 6: Remove Element

Given an integer array `nums` sorted in non-decreasing order, remove the duplicates in-place such that each unique element appears only once. The relative order of the elements should be kept the same. Then return the number of unique elements in `nums`. Consider the number of unique elements of `nums` to be `k`, to get accepted, you need to do the following things: Change the array `nums` such that the first `k` elements of `nums` contain the unique elements in the order they were present in `nums` initially. The remaining elements of `nums` are not important as well as the size of `nums`. Return `k`.

Solution:

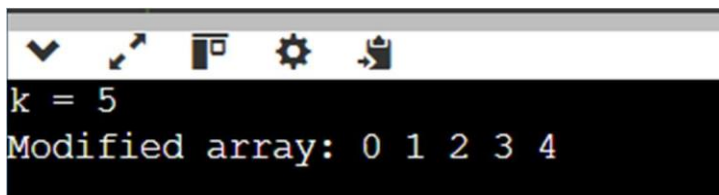
```
#include <iostream>
#include <vector>

int removeDuplicates(std::vector<int>& nums) {
    if (nums.empty()) return 0;

    int k = 1; // Pointer for the next unique element
    for (int i = 1; i < nums.size(); ++i) {
        if (nums[i] != nums[i - 1]) {
            nums[k++] = nums[i]; // Move the unique element to the front
        }
    }
    return k; // Number of unique elements
}

int main() {
    std::vector<int> nums = {0,0,1,1,1,2,2,3,3,4};
    int k = removeDuplicates(nums);

    std::cout << "k = " << k << std::endl;
    std::cout << "Modified array: ";
    for (int i = 0; i < k; ++i) {
        std::cout << nums[i] << " ";
    }
    std::cout << std::endl;
    return 0;}
```

Output:

```
k = 5
Modified array: 0 1 2 3 4
```


Problem 7: Baseball Game :

You are keeping the scores for a baseball game with strange rules. At the beginning of the game, you start with an empty record. You are given a list of strings operations, where operations[i] is the ith operation you must apply to the record and is one of the following: An integer x. Record a new score of x. '+'. Record a new score that is the sum of the previous two scores. 'D'. Record a new score that is the double of the previous score. 'C'. Invalidate the previous score, removing it from the record. Return the sum of all the scores on the record after applying all the operations. The test cases are generated such that the answer and all intermediate calculations fit in a 32-bit integer and that all operations are valid.

Solution:

```
#include <iostream>
#include <vector>
#include <string>
```

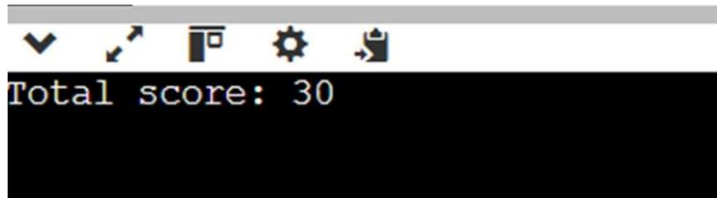
```
int calPoints(std::vector<std::string>& ops) {
    std::vector<int> record;
    for (const auto& op : ops) {
        if (op == "C") {
            record.pop_back(); // Remove the last score
        } else if (op == "D") {
            record.push_back(2 * record.back()); // Double the last score
        } else if (op == "+") {
            record.push_back(record[record.size() - 1] + record[record.size() - 2]); //
Sum of last two scores
        } else {
            record.push_back(std::stoi(op)); // Add the integer score
        }
    }

    int total = 0;
    for (int score : record) {
        total += score;
    }

    return total;
}

int main() {
    std::vector<std::string> ops = {"5","2","C","D","+"};
```

```
std::cout << "Total score: " << calPoints(ops) << std::endl; // Output: 30
return 0;
}Output:
```

**Problem 8: Container With Most Water**

You are given an integer array `height` of length `n`. There are `n` vertical lines drawn such that the two endpoints of the `i`th line are `(i, 0)` and `(i, height[i])`. Find two lines that together with the x-axis form a container, such that the container contains the most water. Return the maximum amount of water a container can store.

Solution:

```
#include <iostream>
#include <vector>
```

```
int maxArea(std::vector<int>& height) {
    int left = 0, right = height.size() - 1, maxArea = 0;

    while (left < right) {
        int width = right - left;
        int h = std::min(height[left], height[right]);
        maxArea = std::max(maxArea, width * h);

        if (height[left] < height[right]) {
            ++left;
        } else {
            --right;
        }
    }

    return maxArea;
}
```

```
int main() {  
    std::vector<int> height = {1,8,6,2,5,4,8,3,7};  
    std::cout << "Max area: " << maxArea(height) << std::endl; // Output: 49  
    return 0;  
}
```

Output:



```
Max area: 49
```

Problem 9: Jump Game II

You are given a 0-indexed array of integers `nums` of length `n`. You are initially positioned at `nums[0]`. Each element `nums[i]` represents the maximum length of a forward jump from index `i`. In other words, if you are at `nums[i]`, you can jump to any `nums[i + j]` where: $0 \leq j \leq \text{nums}[i]$ and $i + j < n$. Return the minimum number of jumps to reach `nums[n - 1]`. The test cases are generated such that you can reach `nums[n - 1]`.

Solution:

```
#include <iostream>  
#include <vector>
```

```
int jump(std::vector<int>& nums) {  
    int n = nums.size();  
    int jumps = 0, farthest = 0, currentEnd = 0;  
  
    for (int i = 0; i < n - 1; ++i) {  
        farthest = std::max(farthest, i + nums[i]); // Update the farthest point we can reach  
  
        if (i == currentEnd) {  
            jumps++; // We make a jump when we reach the current end  
            currentEnd = farthest; // Move to the farthest point we can reach  
  
            if (currentEnd >= n - 1) break; // If we can reach the end, stop  
        }  
    }  
}
```

```

    return jumps;
}

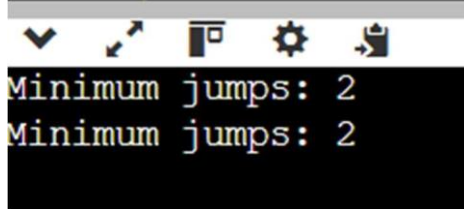
int main() {
    std::vector<int> nums1 = {2,3,1,1,4};
    std::cout << "Minimum jumps: " << jump(nums1) << std::endl; // Output: 2

    std::vector<int> nums2 = {2,3,0,1,4};
    std::cout << "Minimum jumps: " << jump(nums2) << std::endl; // Output: 2

    return 0;
}

```

Output:



```

Minimum jumps: 2
Minimum jumps: 2

```

Problem 10: Design Circular Queue

Calculate the sum of the digits of a given number n. For example, for the number 12345, the sum of the digits is $1+2+3+4+5=15$. To solve this, you will need to extract each digit from the number and calculate the total sum.

Solution:

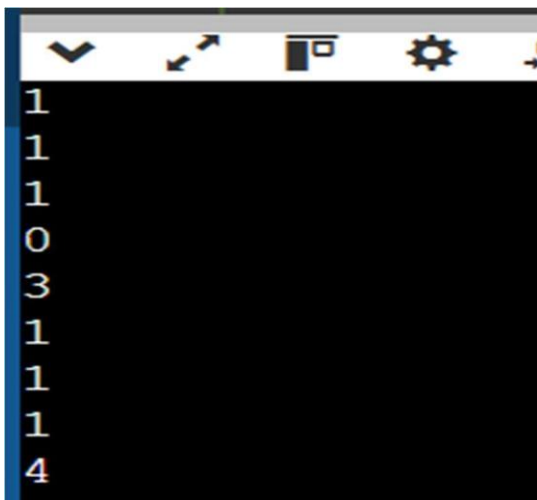
```

#include <iostream>
#include <vector>
class MyCircularQueue {
private:
    std::vector<int> queue;
    int front, rear, size, capacity;
public:
    MyCircularQueue(int k) : queue(k), front(-1), rear(-1), size(0), capacity(k) {}
    bool enQueue(int value) {
        if (size == capacity) return false;
        if (size == 0) front = 0;
        rear = (rear + 1) % capacity;
        queue[rear] = value;
        size++;
        return true;
    }
}

```

```
bool deQueue() {
    if (size == 0) return false;
    if (front == rear) front = rear = -1;
    else front = (front + 1) % capacity;
    size--;
    return true;}
int Front() {
    return size == 0 ? -1 : queue[front];}
int Rear() {
    return size == 0 ? -1 : queue[rear];}
bool isEmpty() {
    return size == 0;}
bool isFull() {
    return size == capacity;}};
int main() {
    MyCircularQueue q(3);
    std::cout << q.enqueue(1) << std::endl; // True
    std::cout << q.enqueue(2) << std::endl; // True
    std::cout << q.enqueue(3) << std::endl; // True
    std::cout << q.enqueue(4) << std::endl; // False (full)
    std::cout << q.Rear() << std::endl;    // 3
    std::cout << q.isFull() << std::endl;  // True
    std::cout << q.deQueue() << std::endl; // True
    std::cout << q.enqueue(4) << std::endl; // True
    std::cout << q.Rear() << std::endl;    // 4
    return 0;}
```

Output:



```
1
1
1
0
3
1
1
1
1
4
```

Problem 11: Cherry Pickup II

You are given a rows x cols matrix grid representing a field of cherries where `grid[i][j]` represents the number of cherries that you can collect from the (i, j) cell. You have two robots that can collect cherries for you: Robot #1 is located at the top-left corner (0, 0), and Robot #2 is located at the top-right corner (0, cols - 1). Return the maximum number of cherries collection using both robots by following the rules below: From a cell (i, j), robots can move to cell (i + 1, j - 1), (i + 1, j), or (i + 1, j + 1). When any robot passes through a cell, It picks up all cherries, and the cell becomes an empty cell. When both robots stay in the same cell, only one takes the cherries. Both robots cannot move outside of the grid at any moment. Both robots should reach the bottom row in grid.

Solution:

```
#include <iostream>
#include <vector>
using namespace std;
```

```
class Solution {
public:
    int cherryPickup(vector<vector<int>>& grid) {
        int rows = grid.size(), cols = grid[0].size();
        vector<vector<vector<int>>> dp(rows, vector<vector<int>>(cols,
vector<int>(cols, -1)));
        return dfs(0, 0, cols - 1, grid, dp);
    }
}
```

private:

```
    int dfs(int row, int col1, int col2, vector<vector<int>>& grid,
vector<vector<vector<int>>>& dp) {
        int rows = grid.size(), cols = grid[0].size();
        if (col1 < 0 || col2 < 0 || col1 >= cols || col2 >= cols) return 0;
        if (dp[row][col1][col2] != -1) return dp[row][col1][col2];

        int cherries = grid[row][col1];
        if (col1 != col2) cherries += grid[row][col2];
        if (row < rows - 1) {
            int maxCherries = 0;
            for (int d1 = -1; d1 <= 1; d1++) {
```

```

        for (int d2 = -1; d2 <= 1; d2++) {
            maxCherries = max(maxCherries, dfs(row + 1, col1 + d1, col2 + d2,
grid, dp));
        }
    }
    cherries += maxCherries;
}
return dp[row][col1][col2] = cherries;
}
};

int main() {
    Solution sol;
    vector<vector<int>> grid1 = {{3,1,1},{2,5,1},{1,5,5},{2,1,1}};
    cout << sol.cherryPickup(grid1) << endl; // Output: 24

    vector<vector<int>> grid2 =
{{1,0,0,0,0,0,1},{2,0,0,0,0,3,0},{2,0,9,0,0,0,0},{0,3,0,5,4,0,0},{1,0,2,3,0,0,6}};
    cout << sol.cherryPickup(grid2) << endl; // Output: 28
    return 0;
}

```

Output:



Problem 12: Maximum Number of Darts Inside of a Circular Dartboard

Alice is throwing n darts on a very large wall. You are given an array `darts` where `darts[i] = [xi, yi]` is the position of the i th dart that Alice threw on the wall. Bob knows the positions of the n darts on the wall. He wants to place a dartboard of radius r on the wall so that the maximum number of darts that Alice throws lie on the dartboard. Given the integer r , return the maximum number of darts that can lie on the dartboard.

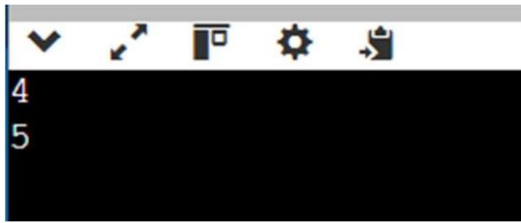
Solution:

```
#include <iostream>
#include <vector>
#include <cmath>
using namespace std;

class Solution {
public:
    int numPoints(vector<vector<int>>& darts, int r) {
        int maxCount = 1, n = darts.size();
        for (int i = 0; i < n; ++i) {
            for (int j = i + 1; j < n; ++j) {
                double dx = darts[j][0] - darts[i][0], dy = darts[j][1] - darts[i][1];
                double dist = sqrt(dx * dx + dy * dy);
                if (dist > 2 * r) continue;
                double midX = (darts[i][0] + darts[j][0]) / 2.0, midY = (darts[i][1] +
darts[j][1]) / 2.0;
                double angle = sqrt(r * r - (dist / 2) * (dist / 2)), norm = dist ? r / dist :
0;
                maxCount = max(maxCount, count(darts, midX - norm * dy, midY +
norm * dx, r));
            }
        }
        return maxCount;
    }

private:
    int count(const vector<vector<int>>& darts, double cx, double cy, int r) {
        int c = 0;
        for (auto& dart : darts)
            if (pow(dart[0] - cx, 2) + pow(dart[1] - cy, 2) <= r * r + 1e-7) ++c;
        return c;
    }
};

int main() {
    Solution sol;
    vector<vector<int>> darts = {{-2, 0}, {2, 0}, {0, 2}, {0, -2}};
    cout << sol.numPoints(darts, 2) << endl; // Output: 4
}
```

Problem 13: Design Skiplist

Design a Skiplist without using any built-in libraries. A skiplist is a data structure that takes $O(\log(n))$ time to add, erase and search. Comparing with treap and red-black tree which has the same function and performance, the code length of Skiplist can be comparatively short and the idea behind Skiplists is just simple linked lists.

Solution:

```
#include <iostream>
#include <cstdlib>
#include <ctime>
#include <vector>

using namespace std;

// Node structure for Skiplist
struct Node {
    int value;
    vector<Node*> forward; // Pointers to next nodes at each level

    Node(int value, int level) : value(value), forward(level, nullptr) {}
};

// Skiplist class
class Skiplist {
private:
    int maxLevel;           // Maximum level for the skiplist
    float probability;      // Probability of promoting a node to a higher level
    Node* header;           // Header node

    // Random level generator function
    int randomLevel() {
        int level = 1;
        while ((rand() % 2) < probability && level < maxLevel) {
```

```
        level++;  
    }  
    return level;  
}
```

public:

```
Skiplist(int maxLevel = 16, float probability = 0.5)  
: maxLevel(maxLevel), probability(probability) {  
    header = new Node(-1, maxLevel); // Header node with a dummy value  
}  
  
// Search for a value in the Skiplist  
bool search(int target) {  
    Node* current = header;  
    for (int i = maxLevel - 1; i >= 0; --i) {  
        while (current->forward[i] != nullptr && current->forward[i]->value <  
target) {  
            current = current->forward[i];  
        }  
    }  
    current = current->forward[0];  
    return (current != nullptr && current->value == target);  
}  
  
// Insert a value into the Skiplist  
void insert(int value) {  
    vector<Node*> update(maxLevel, nullptr);  
    Node* current = header;  
  
    for (int i = maxLevel - 1; i >= 0; --i) {  
        while (current->forward[i] != nullptr && current->forward[i]->value <  
value) {  
            current = current->forward[i];  
        }  
        update[i] = current;  
    }  
  
    current = current->forward[0];  
    if (current == nullptr || current->value != value) {  
        int level = randomLevel();  
        Node* newNode = new Node(value, level);
```

```
        for (int i = 0; i < level; ++i) {
            newNode->forward[i] = update[i]->forward[i];
            update[i]->forward[i] = newNode;
        }
    }
}

// Erase a value from the Skiplist
void erase(int value) {
    vector<Node*> update(maxLevel, nullptr);
    Node* current = header;

    for (int i = maxLevel - 1; i >= 0; --i) {
        while (current->forward[i] != nullptr && current->forward[i]->value <
value) {
            current = current->forward[i];
        }
        update[i] = current;
    }

    current = current->forward[0];
    if (current != nullptr && current->value == value) {
        for (int i = 0; i < maxLevel; ++i) {
            if (update[i]->forward[i] != current) break;
            update[i]->forward[i] = current->forward[i];
        }
        delete current;
    }
}

// Print the Skiplist
void print() {
    for (int i = 0; i < maxLevel; ++i) {
        Node* current = header->forward[i];
        cout << "Level " << i << ": ";
        while (current != nullptr) {
            cout << current->value << " ";
            current = current->forward[i];
        }
        cout << endl;
    }
}
```

```
};

int main() {
    srand(time(0)); // Seed for random level generation

    Skiplist skiplist;

    // Insert values into the Skiplist
    skiplist.insert(30);
    skiplist.insert(40);
    skiplist.insert(50);
    skiplist.insert(60);
    skiplist.insert(70);
    skiplist.insert(90);

    // Print the Skiplist
    cout << "Skiplist after insertions:" << endl;
    skiplist.print();

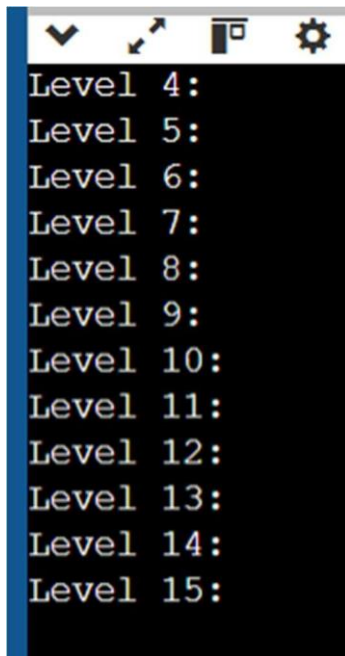
    // Insert additional values
    skiplist.insert(80);
    skiplist.insert(45);

    cout << "Skiplist after adding 80 and 45:" << endl;
    skiplist.print();

    // Search for some values
    cout << "Searching for 45: " << (skiplist.search(45) ? "Found" : "Not Found")
    << endl;
    cout << "Searching for 100: " << (skiplist.search(100) ? "Found" : "Not
    Found") << endl;

    // Erase a value
    skiplist.erase(50);
    cout << "Skiplist after removing 50:" << endl;
    skiplist.print();

    return 0;
}Output:
```



Problem 14: All O`one Data Structure

Design a data structure to store the strings' count with the ability to return the strings with minimum and maximum counts. Implement the AllOne class: ● AllOne() Initializes the object of the data structure. ● inc(String key) Increments the count of the string key by 1. If key does not exist in the data structure, insert it with count 1. ● dec(String key) Decrements the count of the string key by 1. If the count of key is 0 after the decrement, remove it from the data structure. It is guaranteed that key exists in the data structure before the decrement. ● getMaxKey() Returns one of the keys with the maximal count. If no element exists, return an empty string "". ● getMinKey() Returns one of the keys with the minimum count. If no element exists, return an empty string "".

Solution:

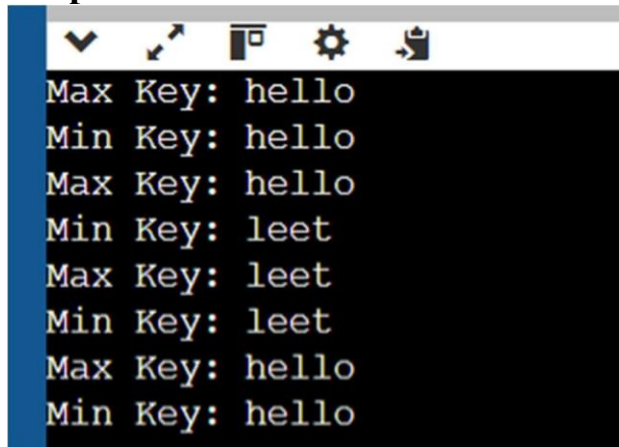
```
#include <iostream>
#include <unordered_map>
#include <string>
#include <list>
#include <map>
using namespace std;
class AllOne {
private:
    // Hash map to store the count of each key
    unordered_map<string, int> keyCount;
```

```
// Map to store the strings by their counts, ordered by counts
map<int, list<string>> countKeys;
public:
    AllOne() {}
    // Increment the count of a string by 1
    void inc(string key) {
        int count = keyCount[key];
        // Remove the key from its old count list
        if (count > 0) {
            countKeys[count].remove(key);
            if (countKeys[count].empty()) {
                countKeys.erase(count);
            }
        }
        // Increment the count and add the key to the new count list
        keyCount[key] = count + 1;
        countKeys[count + 1].push_back(key);
    }
    // Decrement the count of a string by 1
    void dec(string key) {
        int count = keyCount[key];
        // Remove the key from its current count list
        countKeys[count].remove(key);
        if (countKeys[count].empty()) {
            countKeys.erase(count);
        }
        // If count becomes 0, remove the key from keyCount
        if (count == 1) {
            keyCount.erase(key);
        } else {
            keyCount[key] = count - 1;
            countKeys[count - 1].push_back(key);
        }
    }
    // Get the key with the maximum count
    string getMaxKey() {
        if (countKeys.empty()) return "";
        // Get the last element (maximum count)
        return countKeys.rbegin()->second.front();
    }

    // Get the key with the minimum count
    string getMinKey() {
        if (countKeys.empty()) return "";
        // Get the first element (minimum count)
        return countKeys.begin()->second.front();
    }
}
```

```
};  
  
int main() {  
    AllOne allOne;  
  
    allOne.inc("hello");  
    allOne.inc("hello");  
    cout << "Max Key: " << allOne.getMaxKey() << endl; // "hello"  
    cout << "Min Key: " << allOne.getMinKey() << endl; // "hello"  
  
    allOne.inc("leet");  
    cout << "Max Key: " << allOne.getMaxKey() << endl; // "hello"  
    cout << "Min Key: " << allOne.getMinKey() << endl; // "leet"  
  
    allOne.dec("hello");  
    cout << "Max Key: " << allOne.getMaxKey() << endl; // "hello"  
    cout << "Min Key: " << allOne.getMinKey() << endl; // "leet"  
  
    allOne.dec("leet");  
    cout << "Max Key: " << allOne.getMaxKey() << endl; // "hello"  
    cout << "Min Key: " << allOne.getMinKey() << endl; // "hello"  
  
    return 0;  
}
```

Output:



```
Max Key: hello  
Min Key: hello  
Max Key: hello  
Min Key: leet  
Max Key: leet  
Min Key: leet  
Max Key: hello  
Min Key: hello
```

Problem 15: Find Minimum Time to Finish All Jobs

You are given an integer array `jobs`, where `jobs[i]` is the amount of time it takes to complete the *i*th job. There are *k* workers that you can assign jobs to. Each job should be assigned to exactly one worker. The working time of a worker is the sum of the time it takes to complete all jobs assigned to them. Your goal is to devise an optimal assignment such that the maximum working time of any worker is minimized. Return the minimum possible maximum working time of any assignment.

Solution:

```
#include <iostream>
#include <vector>
#include <numeric>
#include <algorithm>
```

```
using namespace std;
```

```
// Helper function to check if we can distribute jobs with max workload <= mid
bool canAssignJobs(const vector<int>& jobs, int k, int mid) {
```

```
    int currentSum = 0;
```

```
    int workersUsed = 1; // Start with one worker
```

```
    for (int job : jobs) {
```

```
        if (currentSum + job > mid) {
```

```
            // Need a new worker since current worker cannot take this job
```

```
            workersUsed++;
```

```
            currentSum = job;
```

```
            if (workersUsed > k) return false; // More workers than allowed
```

```
        } else {
```

```
            currentSum += job;
```

```
        }
```

```
    }
```

```
    return true;
```

```
}
```

```
int minimumTimeRequired(vector<int>& jobs, int k) {
```

```
    int left = *max_element(jobs.begin(), jobs.end()); // Max job time
```

```
    int right = accumulate(jobs.begin(), jobs.end(), 0); // Sum of all jobs
```

```
    while (left < right) {
```

```
        int mid = left + (right - left) / 2;
```



```

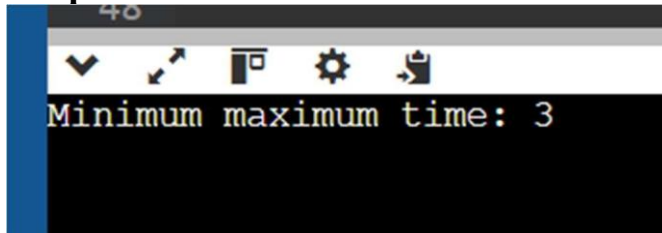
        if (canAssignJobs(jobs, k, mid)) {
            right = mid; // Try for a smaller max workload
        } else {
            left = mid + 1; // Increase the allowed max workload
        }
    }

    return left;
}

int main() {
    vector<int> jobs = {3, 2, 3};
    int k = 3;
    cout << "Minimum maximum time: " << minimumTimeRequired(jobs, k) <<
endl;
    return 0;
}

```

Output:



Problem 16: Minimum Number of People to Teach:

On a social network consisting of m users and some friendships between users, two users can communicate with each other if they know a common language. You are given an integer n , an array `languages`, and an array `friendships` where: There are n languages numbered 1 through n , `languages[i]` is the set of languages the i th user knows, and `friendships[i] = [ui, vi]` denotes a friendship between the users ui and vi . You can choose one language and teach it to some users so that all friends can communicate with each other. Return the minimum number of users you need to teach. Note that friendships are not transitive, meaning if x is a friend of y and y is a friend of z , this doesn't guarantee that x is a friend of z .

Solution:

```
#include <iostream>
#include <vector>
#include <unordered_set>
#include <unordered_map>

using namespace std;

class UnionFind {
public:
    UnionFind(int n) {
        parent.resize(n);
        size.resize(n, 1);
        for (int i = 0; i < n; ++i) parent[i] = i;
    }

    int find(int u) {
        if (parent[u] != u) {
            parent[u] = find(parent[u]); // Path compression
        }
        return parent[u];
    }

    void unionSets(int u, int v) {
        int rootU = find(u);
        int rootV = find(v);
        if (rootU != rootV) {
            if (size[rootU] < size[rootV]) swap(rootU, rootV);
            parent[rootV] = rootU;
            size[rootU] += size[rootV];
        }
    }

private:
    vector<int> parent;
    vector<int> size;
};

int minimumTeachings(int n, vector<vector<int>>& languages,
vector<vector<int>>& friendships) {
    int m = languages.size(); // Number of users
```

```
// Step 1: Union-Find initialization for users
UnionFind uf(m);

// Step 2: Union users who share a common language
unordered_map<int, vector<int>> languageUsers;
for (int i = 0; i < m; ++i) {
    for (int lang : languages[i]) {
        languageUsers[lang].push_back(i);
    }
}

// Union users based on shared languages
for (auto& [lang, users] : languageUsers) {
    for (int i = 0; i < users.size(); ++i) {
        for (int j = i + 1; j < users.size(); ++j) {
            uf.unionSets(users[i], users[j]);
        }
    }
}

// Step 3: Union users based on friendships
for (auto& friendship : friendships) {
    int u = friendship[0] - 1;
    int v = friendship[1] - 1;
    if (uf.find(u) != uf.find(v)) {
        uf.unionSets(u, v);
    }
}

// Step 4: Find the connected components and check if they can communicate
unordered_map<int, unordered_set<int>> components;
for (int i = 0; i < m; ++i) {
    int root = uf.find(i);
    for (int lang : languages[i]) {
        components[root].insert(lang);
    }
}

// Step 5: Determine how many users need to be taught a new language
int result = 0;
for (auto& [component, langs] : components) {
```

// If no language is shared among users in this component, we need to teach at least one user

```
    if (langs.empty()) {  
        result++;  
    }  
}  
  
return result;  
}  
  
int main() {  
    vector<vector<int>> languages1 = {{1}, {2}, {1, 2}};  
    vector<vector<int>> friendships1 = {{1, 2}, {1, 3}, {2, 3}};  
    int n1 = 2;  
    cout << "Minimum number of users to teach: " << minimumTeachings(n1,  
languages1, friendships1) << endl;  
  
    vector<vector<int>> languages2 = {{2}, {1, 3}, {1, 2}, {3}};  
    vector<vector<int>> friendships2 = {{1, 4}, {1, 2}, {3, 4}, {2, 3}};  
    int n2 = 3;  
    cout << "Minimum number of users to teach: " << minimumTeachings(n2,  
languages2, friendships2) << endl;  
  
    return 0;  
}
```

Output:**Output**

```
Minimum number of users to teach: 0  
Minimum number of users to teach: 0
```

Problem 17: Count Ways to Make Array With Product

You are given a 2D integer array, queries. For each queries[i], where queries[i] = [ni, ki], find the number of different ways you can place positive integers into an array of size ni such that the product of the integers is ki. As the number of ways may be too large, the answer to the ith query is the number of ways modulo $10^9 + 7$. Return an integer array answer where answer.length == queries.length, and answer[i] is the answer to the ith query.

Solution:

```
#include <iostream>
#include <vector>
#include <cmath>
```

```
const int MOD = 1e9 + 7;
const int MAXN = 10000;
```

```
// Precompute factorials and modular inverses using Fermat's Little Theorem
std::vector<long long> factorial(MAXN + 1), inv_factorial(MAXN + 1);
```

```
// Function to compute  $x^y \% MOD$ 
long long mod_exp(long long x, long long y, long long mod) {
    long long result = 1;
    while (y > 0) {
        if (y % 2 == 1) result = (result * x) % mod;
        x = (x * x) % mod;
        y /= 2;
    }
    return result;
}
```

```
// Function to precompute factorials and their inverses
void precompute() {
    factorial[0] = inv_factorial[0] = 1;
    for (int i = 1; i <= MAXN; ++i) {
        factorial[i] = (factorial[i - 1] * i) % MOD;
    }
    inv_factorial[MAXN] = mod_exp(factorial[MAXN], MOD - 2, MOD); //
    Using Fermat's little theorem
    for (int i = MAXN - 1; i >= 1; --i) {
        inv_factorial[i] = (inv_factorial[i + 1] * (i + 1)) % MOD;
    }
}
```

```
}

// Function to compute binomial coefficient C(n, k) % MOD
long long binomial(int n, int k) {
    if (k > n || k < 0) return 0;
    return (factorial[n] * inv_factorial[k] % MOD) * inv_factorial[n - k] % MOD;
}

// Function to get the prime factorization of a number
std::vector<std::pair<int, int>> prime_factors(int k) {
    std::vector<std::pair<int, int>> factors;
    for (int i = 2; i * i <= k; ++i) {
        if (k % i == 0) {
            int count = 0;
            while (k % i == 0) {
                k /= i;
                count++;
            }
            factors.push_back({i, count});
        }
    }
    if (k > 1) {
        factors.push_back({k, 1});
    }
    return factors;
}

// Function to solve each query
long long solve(int n, int k) {
    // Prime factorize k
    auto factors = prime_factors(k);

    long long result = 1;
    for (const auto& factor : factors) {
        int prime = factor.first;
        int exponent = factor.second;
        // Calculate number of ways to split exponent of this prime into n parts
        result = (result * binomial(exponent + n - 1, n - 1)) % MOD;
    }

    return result;
}
```

```
std::vector<int> waysToPlaceIntegers(std::vector<std::vector<int>>& queries) {
    precompute(); // Precompute factorials and inverses
    std::vector<int> result;

    for (auto& query : queries) {
        int n = query[0];
        int k = query[1];
        result.push_back(solve(n, k));
    }

    return result;
}

int main() {
    // Example usage
    std::vector<std::vector<int>> queries1 = {{2, 6}, {5, 1}, {73, 660}};
    std::vector<int> result1 = waysToPlaceIntegers(queries1);

    for (int r : result1) {
        std::cout << r << " ";
    }
    std::cout << std::endl;

    std::vector<std::vector<int>> queries2 = {{1, 1}, {2, 2}, {3, 3}, {4, 4}, {5,
5}};
    std::vector<int> result2 = waysToPlaceIntegers(queries2);

    for (int r : result2) {
        std::cout << r << " ";
    }
    std::cout << std::endl;

    return 0;
}
```

Output:

Output

4 1 50734910
1 2 3 10 5

Problem 18: Maximum Twin Sum of a Linked List

In a linked list of size n , where n is even, the i th node (0-indexed) of the linked list is known as the twin of the $(n-1-i)$ th node, if $0 \leq i \leq (n/2) - 1$. • For example, if $n = 4$, then node 0 is the twin of node 3, and node 1 is the twin of node 2. These are the only nodes with twins for $n = 4$. The twin sum is defined as the sum of a node and its twin. Given the head of a linked list with even length, return the maximum twin sum of the linked list.

Code:

```
#include <iostream>
#include <vector>
#include <algorithm>
```

```
using namespace std;
```

```
// Definition for singly-linked list.
```

```
struct ListNode {
    int val;
    ListNode* next;
    ListNode(int x) : val(x), next(nullptr) {}
};
```

```
class Solution {
public:
```

```
    int pairSum(ListNode* head) {
        // Step 1: Store the values of the linked list in a vector
        vector<int> values;
        ListNode* current = head;
```

```
        // Traverse the linked list and add each node's value to the vector
        while (current != nullptr) {
            values.push_back(current->val);
```



```
        current = current->next;
    }

    // Step 2: Calculate the maximum twin sum
    int n = values.size();
    int maxTwinSum = 0;

    // Iterate over the first half of the list and calculate twin sums
    for (int i = 0; i < n / 2; ++i) {
        int twinSum = values[i] + values[n - 1 - i];
        maxTwinSum = max(maxTwinSum, twinSum);
    }

    return maxTwinSum;
}
};

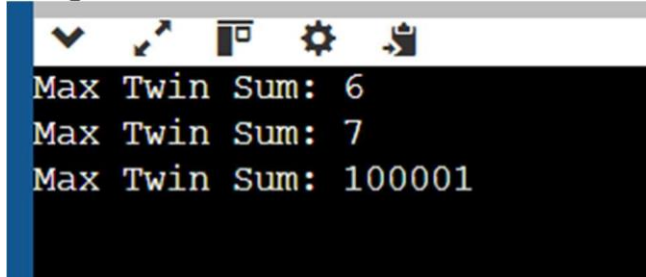
// Helper function to create a linked list from a vector
ListNode* createList(const vector<int>& nums) {
    ListNode* head = new ListNode(nums[0]);
    ListNode* current = head;
    for (int i = 1; i < nums.size(); ++i) {
        current->next = new ListNode(nums[i]);
        current = current->next;
    }
    return head;
}

int main() {
    // Example 1
    vector<int> input1 = {5, 4, 2, 1};
    ListNode* head1 = createList(input1);
    Solution sol;
    cout << "Max Twin Sum: " << sol.pairSum(head1) << endl; // Output: 6

    // Example 2
    vector<int> input2 = {4, 2, 2, 3};
    ListNode* head2 = createList(input2);
    cout << "Max Twin Sum: " << sol.pairSum(head2) << endl; // Output: 7

    // Example 3
    vector<int> input3 = {1, 100000};
```

```
ListNode* head3 = createList(input3);  
cout << "Max Twin Sum: " << sol.pairSum(head3) << endl; // Output:  
100001  
  
return 0;  
}
```

Output:

```
Max Twin Sum: 6  
Max Twin Sum: 7  
Max Twin Sum: 100001
```

Problem 19: Insert Greatest Common Divisors in Linked List

Given the head of a linked list head, in which each node contains an integer value. Between every pair of adjacent nodes, insert a new node with a value equal to the greatest common divisor of them. Return the linked list after insertion. The greatest common divisor of two numbers is the largest positive integer that evenly divides both numbers.

Solution:

```
#include <iostream>  
#include <vector> // Include the vector header  
#include <algorithm>  
using namespace std;  
  
// Definition for singly-linked list.  
struct ListNode {  
    int val;  
    ListNode* next;  
    ListNode(int x) : val(x), next(nullptr) {}  
};  
  
class Solution {  
public:  
    // Function to compute GCD of two numbers  
    int gcd(int a, int b) {  
        while (b != 0) {
```

```
        int temp = b;
        b = a % b;
        a = temp;
    }
    return a;
}
```

```
// Function to insert GCD nodes between each pair of adjacent nodes
ListNode* insertGreatestCommonDivisors(ListNode* head) {
    // Edge case: If the list is empty or has only one node, no insertion is needed
    if (!head || !head->next) return head;

    ListNode* current = head;

    // Traverse the list
    while (current && current->next) {
        int gcdValue = gcd(current->val, current->next->val); // Calculate the
GCD
        ListNode* newNode = new ListNode(gcdValue); // Create a new node
with the GCD value
        newNode->next = current->next; // Link the new node to the next node
        current->next = newNode; // Link the current node to the new node
        current = newNode->next; // Move to the next pair of nodes
    }

    return head;
}
};
```

```
// Helper function to create a linked list from a vector
ListNode* createList(const vector<int>& values) {
    if (values.empty()) return nullptr;
    ListNode* head = new ListNode(values[0]);
    ListNode* current = head;
    for (int i = 1; i < values.size(); ++i) {
        current->next = new ListNode(values[i]);
        current = current->next;
    }
    return head;
}
```

```
// Helper function to print the linked list
```

```
void printList(ListNode* head) {
    while (head) {
        cout << head->val;
        if (head->next) cout << " -> ";
        head = head->next;
    }
    cout << endl;
}

int main() {
    Solution sol;

    // Test case 1
    vector<int> values1 = {18, 6, 10, 3};
    ListNode* head1 = createList(values1);
    ListNode* result1 = sol.insertGreatestCommonDivisors(head1);
    printList(result1); // Expected: 18 -> 6 -> 6 -> 2 -> 10 -> 1 -> 3

    // Test case 2
    vector<int> values2 = {7};
    ListNode* head2 = createList(values2);
    ListNode* result2 = sol.insertGreatestCommonDivisors(head2);
    printList(result2); // Expected: 7

    return 0;
}
```

Output:

Output

```
18 -> 6 -> 6 -> 2 -> 10 -> 1 -> 3
7
```