Algorithm and Problem Solving Quick Guide in C++

Data Structures, Algorithms and Coding Interview Problem Patterns in C++

rfdavid, 2025

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INTRODUCTION

Motivation

The tech industry hiring standard is based on algorithm and data structure.

There are plenty of free resources available around algorithms and data structures. The purpose of this project is to be a quick guide where you can learn and review algorithms and data structures.

Some of the intended **key features:**

- Non-verbose, short-structured, and easy to follow descriptions
- Slide-based, practical for reviewing
- Free and open-source

⭐ **If you like, please add a star at *github.com/rfdavid/cpp-algo-cheatsheet***

Some Useful Links

Tech Interview Handbook
https://www.techinterviewhandbook.org
A very well-structured resource for interview preparation

Blind 75 Leetcode Questions
https://leetcode.com/discuss/general-discussion/460599/blind-75-leetcode-questions

Blind 75

- Blind 75 is a popular list of algorithm problems that intends to cover the main data structures and patterns.
- It is a curated list of 75 popular coding questions created by an ex-Meta Staff Engineer

Array

✓ Two Sum
✓ Best Time to Buy and Sell Stock
✓ Contains Duplicate
✓ Product of Array Except Self
✓ Maximum Subarray
✓ Maximum Product Subarray
✓ Find Minimum in Rotated Sorted Array
Search in Rotated Sorted Array
3 Sum
✓ Container With Most Water

Binary

✓ Sum of Two Integers
✓ Number of 1 Bits
✓ Counting Bits
✓ Missing Number
✓ Reverse Bits

Dynamic Programming

✓ Climbing Stairs
Coin Change
Longest Increasing Subsequence
✓ Longest Common Subsequence
Word Break
Combination Sum
House Robber
House Robber II
Decode Ways
✓ Unique Paths
Jump Game

Matrix

✓ Set Matrix Zeroes
✓ Spiral Matrix
✓ Rotate Image
Word Search

Blind 75

Tree

- ✓ Maximum Depth of Binary Tree
- ✓ Same Tree
- ✓ Invert/Flip Binary Tree
- ✓ Binary Tree Maximum Path Sum
- ✓ Binary Tree Level Order Traversal
- ✓ Serialize and Deserialize Binary Tree
- ✓ Subtree of Another Tree

Construct Binary Tree from Preorder and Inorder Traversal

Validate Binary Search Tree

- ✓ Kth Smallest Element in a Binary Search Tree

Lowest Common Ancestor of Binary Search Tree

Implement Trie (Prefix Tree)

Add and Search Word

Word Search II

Heap

- ✓ Top K Frequent Elements

Find Median from Data Stream

String

- ✓ Longest Substring Without Repeating Characters
- ✓ Longest Repeating Character Replacement
- ✓ Minimum Window Substring
- ✓ Valid Anagram
- ✓ Group Anagrams
- ✓ Valid Parentheses
- ✓ Valid Palindrome

Longest Palindromic Substring

Palindromic Substrings

Encode and Decode Strings ⭐

Linked List

- ✓ Reverse a Linked List
- ✓ Detect Cycle in a Linked List
- ✓ Merge Two Sorted Lists
- ✓ Merge K Sorted Lists
- ✓ Remove Nth Node From End Of List
- ✓ Reorder List

Graph

- ✓ Clone Graph
- ✓ Course Schedule
- ✓ Pacific Atlantic Water Flow
- ✓ Number of Islands
- ✓ Longest Consecutive Sequence

Alien Dictionary ⭐

- ✓ Graph Valid Tree ⭐
- ✓ Number of Connected Components In an Undirected Graph ⭐

Interval

- ✓ Insert Interval
- ✓ Merge Intervals
- ✓ Non-overlapping Intervals
- ✓ Meeting Rooms ⭐

Meeting Rooms II ⭐

⭐ = leetcode premium

Other problems

Tree

- ✓ Maximum Level Sum of a Binary Tree
- ✓ Minimum Number of Increments on Subarrays to Form a Target Array
- ✓ Leaf-Similar Trees
- ✓ Count Good Nodes in Binary Tree

Min Cost Climbing Stairs

Longest Palindromic Subsequence

⭐ = leetcode premium

Time Complexity

If the input gets bigger, how many steps does the algorithm take?

- Measure of how much the execution time of an algorithm grows relative to the size of its input (usually called n)
- Expressed in **Big-O notation** (e.g. O(1), O(n), O(n^2), etc) to describe the **upper bound** of how fast the algorithm's runtime grows
- Asymptotic notations

  Big-O (O) – Upper Bound (**Worst-case**): Describes the maximum amount of time/memory an algorithm could take.

  Theta Θ – Tight Bound (**Exact**): describes both the **upper** and **lower bound** (the **exact** growth rate)

  Omega (Ω) – Lower Bound (**Best-case**): describes the minimum time/space the algorithm needs.

Time Complexity

Examples

O(1)

Examples	Problems
Accessing an array element (`arr[i]`)	Hash table lookups
Swapping two variables	Checking if a number is even/odd
Stack/Queue `push` or `pop`	Returning first element of a list

O(log n)

Binary Search	Search in sorted array
Balanced BST insert/find (AVL, Red-Black Tree)	Find k-th smallest in BST
Finding floor/ceil in sorted array	Finding square root with binary search

O(n)

Linear Search	Maximum subarray sum (Kadane's algo)
Finding min/max in an array	Counting frequencies with hash map
Traversing linked list or array	One-pass string processing problems

Time Complexity

O(n log n)

Merge Sort / Heap Sort	Sorting an array
Efficient algorithms for Closest Pair	Finding inversion count in array
Heapify operations	Kth largest element with heap

$O(n^2)$

Bubble Sort / Insertion Sort	Two Sum (brute force)
Checking all pairs in array	Longest Palindromic Substring (DP)
Floyd-Warshall algorithm	Edit Distance (DP)

$O(n^3)$

Matrix multiplication (naive)	Boolean matrix multiplication
DP on subsequences of length 3	Some DP path-finding problems
Floyd-Warshall for dense graphs	Counting triangles in graph

$O(2^n)$

Recursive Fibonacci (no memo)	Subset sum (brute force)
Backtracking for combinations/permutations	N-Queens
Traveling Salesman (brute force)	All subsets of array (power set)

Time Complexity

O(n!)

Generating all permutations	Traveling Salesman (brute force)
Brute-force anagram check	Word ladder with all transformations
Solving puzzles with all arrangements	Hamiltonian Path

O(V + E)

DFS / BFS (adjacency list)	DFS / BFS (adjacency list)

O(E log V)

Dijkstra with priority queue	Dijkstra with priority queue

O(VE)

Bellman-Ford

$O(V^3)$

Floyd-Warshall

O(E log E)

Kruskal's MST algorithm

V = vertices (nodes)
E = edges

Time Complexity

Examples

O(1)

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O(log n)

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Balanced BST insert/find (AVL, Red-Black Tree)	Find k-th smallest in BST
Finding floor/ceil in sorted array	Finding square root with binary search

Space Complexity

As the input size n grows, how much extra memory does the algorithm need to run?

- Measure of how much memory an algorithm uses relative to **input size**
- Expressed in **Big-O notation** (e.g. O(1), O(n), O(n^2), etc)
- It includes auxiliary space (extra memory used by the algorithm, not counting the input itself) and sometimes considers input space depending on the context
- Count only extra space needed **(exclude output)**
- The space complexity of a recursive tree traversal is **O(h),** where h is the height of the tree. This is because each recursive call adds a frame to the call stack, and in the worst case, the maximum stack depth is proportional to the tree's height

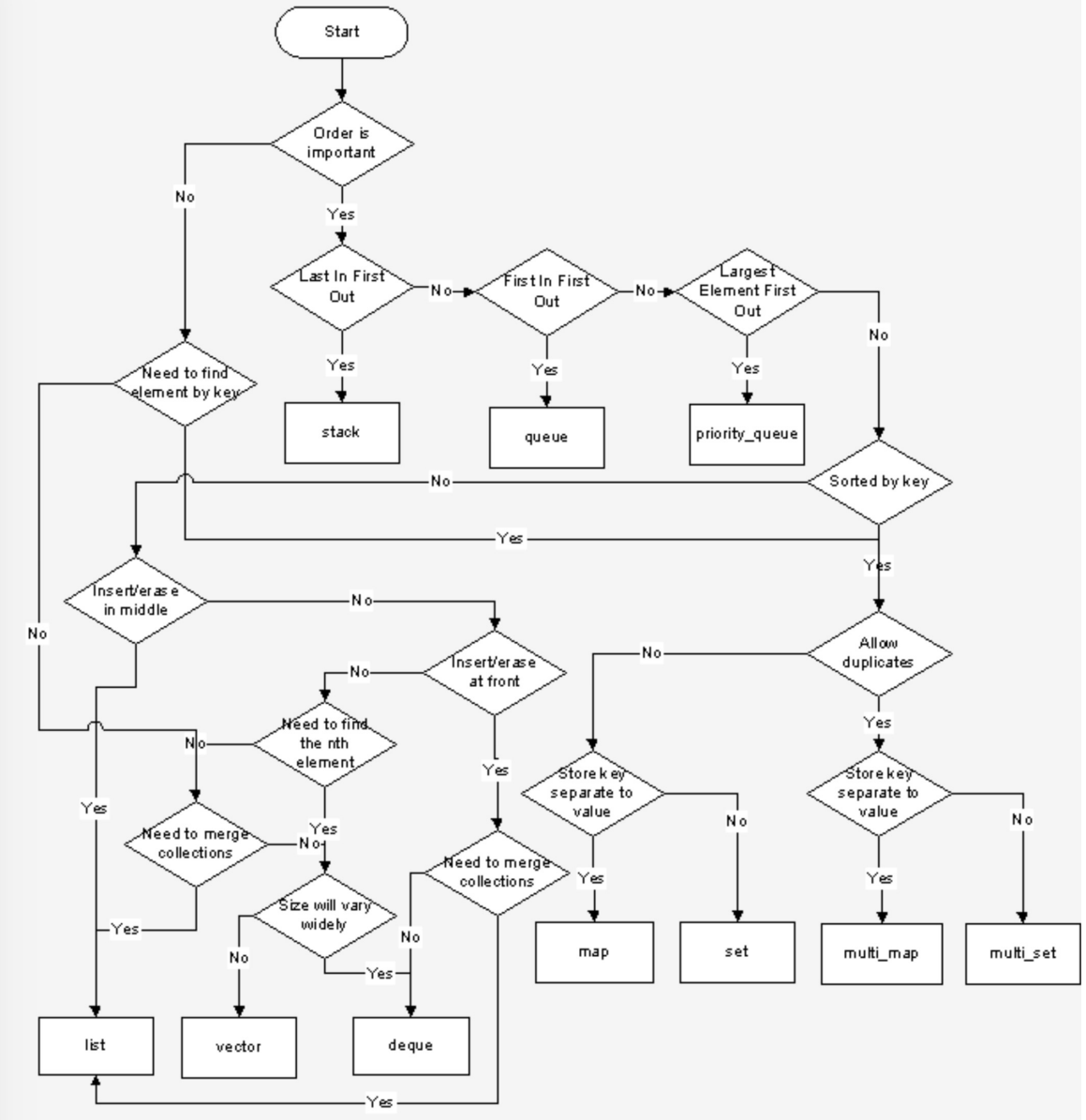
Space Complexity

Examples

Algorithm / Operation	Space Complexity	Explanation
Swap two integers	O(1)	Only uses constant space
Iterate through array and sum values	O(1)	No extra memory used besides accumulator
Store array copy	O(n)	Needs space to store the copied array
Recursive factorial (factorial(n))	O(n)	n stack frames in the call stack
Binary search (recursive)	O(log n)	Recursive depth is log(n) for sorted array
Binary search (iterative)	O(1)	No extra space beyond a few variables
Merge sort	O(n)	Needs temp arrays to merge subarrays
Quick sort (in-place)	O(log n)	Call stack for recursive calls
Depth-first search (recursive) in tree	O(h)	h = height of the tree (stack frames)
Breadth-first search (using queue)	O(n)	Stores all nodes at current level in queue
DP with full 2D table (e.g., LCS)	O(m*n)	Stores results of all subproblems
Optimized Fibonacci with two variables	O(1)	Only tracks last two results
Memoized Fibonacci (top-down DP)	O(n)	Memoization table + recursion stack
Using a hash map to count frequencies	O(n)	Stores one count per element
Storing all substrings of a string	O(n^2)	Total number of substrings is ~n^2
Adjacency list for graph with V nodes, E edges	O(V + E)	One list per node, total edges stored

DATA STRUCTURES IN C++

Data Structure Decision Diagram



- The following diagram gives you the direction to which data structure to use in C++ according to the problem you are trying to solve

Note: I don't have the source of this diagram. If you know it, please drop me a msg so I can add it here.

Vectors

- std::vector is a sequence container that encapsulates dynamic sized arrays*

*https://en.cppreference.com/w/cpp/container/vector

Linked List

- desc

Stack

- desc

*https://en.cppreference.com/w/cpp/container/vector

Queue

- desc

*https://en.cppreference.com/w/cpp/container/vector

Heap

- desc

Hash Table

- desc

Tree

- desc

ARRAY

Arrays

Characteristics

- **Memory layout**: hold values in a **contiguous** block of memory.
- **Fixed Size**: the size of an array is defined when it is created and cannot be changed. However, high-level languages have different implementations, making it dynamic.
- **Homogeneous elements:** all elements are of the same data type (int, float, char…)
- **Efficiency**: accessing elements by index is very efficient *O(1)*, since each index maps directly to a memory location. Also, range scans benefit from CPU cache lines since arrays are stored in contiguous blocks of memory.

Arrays – Kadane's algorithm

- Kadane's algorithm is a dynamic programming algorithm to solve **maximum subarray sum**
- At every **index i**:

  start a new subarray at **i**

  extend the previous subarray to include **array[i]**
- **Algorithm**

1. Initialize:

```
int maxSoFar = array[0];
int maxEndingHere = array[0];
```

2. Loop through the array

```
for (int i = 1; i < array.size(); ++i) {
    maxEndingHere = max(array[i], maxEndingHere + array[i]);
    maxSoFar = max(maxSoFar, maxEndingHere);
}
```

3. Return maxSoFar;

Problem – 217. Contains Duplicate

Easy

LeetCode leetcode.com/problems/contains-duplicate

Problem

- You are given an array of numbers
- Return any value that appears at least twice

Solution – Contains Duplicate

Easy

LeetCode leetcode.com/problems/contains-duplicate

Solution

- Loop through the array
- Check if the value is in a hash table
- Return **true** if the value exist
- The problem requires at least twice, but one modification may be having a specific count

Code – Contains Duplicate

Easy

LeetCode leetcode.com/problems/contains-duplicate/

Code

Time: **O(n)** Space: **O(n)**

```
bool containsDuplicate(vector<int>& nums) {
    unordered_map<int, int> seen;
    for (int i = 0; i < nums.size(); ++i) {
        seen[nums[i]]++;
        if (seen[nums[i]] == 2) {
            return true;
        }
    }
    return false;
}
```

Problem – 1. Two Sum

Easy

LeetCode leetcode.com/problems/two-sum

Problem

- Given an **array** of numbers and a **target**, example: **array [2,7,11,15]** and **target 9**
- Return indices of two numbers where they add up to **target**
- **Output**: [0,1]

```
array[0] + array[1] = 2 + 7 = 9
```

Solution – Two Sum

Easy

LeetCode leetcode.com/problems/two-sum

Solution

- Iterative over each number in the array
- Calculate the difference between target and each number, example:

  `array[0] = 2, target 9, then 9 - 2 = 7`
- Now we know we need the number **7** to sum up to **9**
- Check in a *hashmap* if we have 7 in some part of the array

  `hash[7] exists?`
- If yes, return the current index and the index of 7
- If not, store the index of the current number in the hashmap for future evaluation

  `hash[2] = 0`

Code – Two Sum

Easy

LeetCode leetcode.com/problems/two-sum

Code

Time: **O(n)** Space: **O(n)**

```
vector<int> twoSum(vector<int>& nums, int target) {
    std::unordered_map<int, int> numMap;
    // n being the size of nums
    for (int i = 0; i < nums.size(); i++) {
        // current number of the array
        int number = nums[i];
        int diff = target - number;

        // check if the difference is in some part of the array
        // by using a hashmap
        if (numMap.find(diff) != numMap.end()) {
            return { numMap[diff], i};
        }

        // register the current number index
        numMap[number] = i;
    }
    // no matches
    return {};
}
```

Problem – 238. Product of Array Except Self

Medium

LeetCode leetcode.com/problems/product-of-array-except-self

Problem Statement

- ...

Solution – 238. Product of Array Except Self

Medium

LeetCode leetcode.com/problems/product-of-array-except-self

Solution

- ...

Code – 238. Product of Array Except Self

Medium

LeetCode leetcode.com/problems/product-of-array-except-self

Code

Time: **O(n)** Space: **O(1)**

- ...

Problem – 53. Maximum Subarray

Medium

LeetCode leetcode.com/problems/maximum-subarray

Problem Statement / Solution / Code

Time: **O(-)** Space: **O(-)**

- ...

Problem – 152. Maximum Product Subarray

Medium

LeetCode leetcode.com/problems/maximum-product-subarray

Problem Statement / Solution / Code

Time: O() Space: O()

- ...

Problem – 153. Find Minimum in Rotated Sorted Array

Medium

LeetCode leetcode.com/problems/find-minimum-in-rotated-sorted-array

Problem Statement / Solution / Code

Time: **O(n)** Space: **O(n)**

- ...

Problem - Best Time to Buy and Sell Stock

Easy

LeetCode leetcode.com/problems/best-time-to-buy-and-sell-stock

Problem Statement

- You are given an integer **array** of stock prices
- Choose a **price[i]** to buy and **price[i]** to sell where you achieve maximum profits
- **Example:**

```
prices = [9, 1, 3, 4]
```

- **Output**: [1,3]

```
array[3] - array[1] = 4 + 1 = 3
```

Solution - Best Time to Buy and Sell Stock

Easy

LeetCode leetcode.com/problems/best-time-to-buy-and-sell-stock

Solution

- Initialize **profit = 0**
- Initialize **lowestBuyPrice = prices[0]**
- Loop through the prices
- Track the lowest buy price → **min(lowestBuyPrice, prices[i])**
- Check if selling "today" will make the maximum profit and update profit:

  max(prices[i] – buy > profit, profit)
- Update profit

  max(prices[i] - buy

Code - Best Time to Buy and Sell Stock

Easy

LeetCode leetcode.com/problems/best-time-to-buy-and-sell-stock

Code (simplified)

Time: **O(n)** Space: **O(n)**

```
int maxProfit(vector<int>& prices) {
    int profit = 0;
    int buy = prices[0];
    for (auto i = 1; i < prices.size(); i++) {
        buy = min(buy, prices[i]);
        profit = max(profit, prices[i] - buy)
    }
    return profit;
}
```

Code - Best Time to Buy and Sell Stock

Easy

LeetCode leetcode.com/problems/best-time-to-buy-and-sell-stock

Code (optimized)

Time: **O(n)** Space: **O(n)**

- Same logic, but with better branch prediction and less computation

```
int maxProfit(vector<int>& prices) {
    int profit = 0;
    int buy = prices[0];
    for (auto i = 1; i < prices.size(); i++) {
        if (prices[i] < buy) {
            buy = prices[i];
        } else if (prices[i] - buy > profit) {
              profit = prices[i] - buy;
        }
    }
    return profit;
}
```

Problem - Best Time to Buy and Sell Stock II

Medium

LeetCode leetcode.com/problems/best-time-to-buy-and-sell-stock-ii

Problem Statement

- You are given an integer **array** of stock prices
- Choose a **price[i]** to buy and **price[i]** to sell where you achieve maximum profits
- You can buy/sell **multiple times**, but only hold **at most one** transaction at a time
- Output is the **maximum profits**
- **Example:**

  `prices = [9, 1, 3, 4]`

  Output: 2 + 1 = 3

  buy (price = 1), **sell** (price = 3), **profit** = 2

  buy (price = 3), **sell** (price = 4), **profit** = 1

Solution - Best Time to Buy and Sell Stock II

Medium

LeetCode leetcode.com/problems/best-time-to-buy-and-sell-stock-ii

Solution

- Loop through the array starting from index 1
- If current **price[i]** is lower than previous **price[i - 1]**, buy and sell
- **Example:**

```
prices = [1, 8, 4]      prices[0] = 1, prices[1] = 8, prices[2] = 4
prices[0] < prices[1] → true, profit = 8 - 1 = 7
prices[2] < prices[1] → false, do nothing
```

Code - Best Time to Buy and Sell Stock II

Medium

LeetCode leetcode.com/problems/best-time-to-buy-and-sell-stock-ii

Code

Time: **O(n)** Space: **O(n)**

```
int maxProfit(vector<int>& prices) {
    int profit = 0;
    for (int i = 1; i < prices.size(); ++i) {
        if (prices[i] > prices[i-1]) {
            profit += prices[i] - prices[i -1];
        }
    }
    return profit;
}
```

Problem - Best Time to Buy and Sell Stock IV

Hard

LeetCode leetcode.com/problems/best-time-to-buy-and-sell-stock-iv

Problem Statement

- ...

Solution - Best Time to Buy and Sell Stock IV

Hard

leetcode.com/problems/best-time-to-buy-and-sell-stock-iv

Solution

- ...

Code - Best Time to Buy and Sell Stock IV

Hard

LeetCode leetcode.com/problems/best-time-to-buy-and-sell-stock-iv

Code (simplified)

Time: **O(n)** Space: **O(n)**

```
int maxProfit(vector<int>& prices) {
    int profit = 0;
    int buy = prices[0];
    for (auto i = 1; i < prices.size(); i++) {
        buy = min(buy, prices[i]);
        profit = max(profit, prices[i] - buy)
    }
    return profit;
}
```

STRING

Problem – 3. Longest Substring Without Repeating Characters

Medium

LeetCode leetcode.com/problems/longest-substring-without-repeating-characters

Problem Statement

- You are given a string and the goal is to find the longest substring without repeating characters
- **Example**

  Input: “abcdb”

  Output: 4 (abcd since “b” is repeated)

Solution – 3. Longest Substring Without Repeating Characters

Medium

LeetCode leetcode.com/problems/longest-substring-without-repeating-characters

Solution

- Use sliding window algorithm (left and right)
- Loop through the string
- Try to find if the current character is already added by using unordered set or bitmap
- If added, remove from the set alongside with others using left pointer
- If not, add to the unordered set or bitmap
- Maximum length will be right – left + 1

Example – 3. Longest Substring Without Repeating Characters

Medium

LeetCode leetcode.com/problems/longest-substring-without-repeating-characters

Example

- String: abcbd. Our goal is to return 3 (**abc**bd)
- Initialize `maxLength = 0`
- Loop through the string

Iteration 1: `left = 0, right = 0, string[left] = 'a',`
`bitmap = ['a']` ('a' is not in bitmap, add), `maxLength = max(maxLength, right - left + 1) = 1`

Iteration 2: `left = 0, right = 1, string[right] = 'b'`
`bitmap = ['a','b'], maxLength = 2`

Iteration 3: `left = 0, right = 2, string[right] = 'c'`
`bitmap = ['a','b', 'c'], maxLength = 3`

Iteration 4: `left = 0, right = 3, string[right] = 'b'`
`bitmap = ['a','b','c','b']`
'b' is already in the bitmap. start "clearing" the character using left:

Iteration 4a: `left = 0, string[left] = 'a'` is different from 'b', so remove 'a'
`bitmap = ['b', 'c','b']`

Iteration 4b: `left = 1, string[left] = 'b'` is the same as the repeated one, remove
`bitmap = ['c','b']`

Iteration 5: `left = 1, right = 4, string[right] = 'd'`
`bitmap = ['c','b','d']`

Code – 3. Longest Substring Without Repeating Characters

Medium

Code (unordered_set)

- Use unordered_set when question requires unicode chars

```
int lengthOfLongestSubstring(string s) {
    int maxLength = 0;
    int left = 0, right = 0;
    // track the seen characters
    unordered_set<char> seen;
    for (right = 0; right < s.size(); ++right) {
        char currentChar = s[right];
        // if currentChar is in the set, clean
        // the character and everything from left of it
        // basically, reset the longest substring
        while (seen.count(currentChar)) {
            char c = s[left];
            seen.erase(c);
            left++;
        }
        // insert the current read character
        seen.insert(currentChar);
        // set max length
        maxLength = max(maxLength, right - left + 1);
    }
    return maxLength;
}
```

Code – 3. Longest Substring Without Repeating Characters

Medium

Code (bitmap)

- Using bitset: create a bitmask with 128 bits where each bit represent a character
- Optimal solution for ASCII since ASCII size is 127 characters
- Unicode / UTF-8 can represent over 1.1 million characters, so use **unordered_set** approach instead

```
int lengthOfLongestSubstring(string s) {
    std::bitset<128> bitmask;
    uint32_t left = 0;
    uint32_t maxLength = 0;

    for (uint32_t right = 0; right < s.length(); ++right) {
        uint32_t bitIndex = s[right];
        // if char is already in the bitmask, move left until we reset the bits
        while (bitmask.test(bitIndex)) {
            bitmask.reset(s[left]);
            ++left;
        }

        bitmask.set(bitIndex);
        maxLength = std::max(maxLength, right - left + 1);
    }
    return maxLength;
}
```

Problem – 424. Longest Repeating Character Replacement

Medium

LeetCode https://leetcode.com/problems/longest-repeating-character-replacement

Problem Statement / Solution / Code

Time: **O(-)** Space: **O(-)**

- ...

Problem – 76. Maximum Window Substring

Hard

LeetCode leetcode.com/problems/minimum-window-substring

Problem Statement / Solution / Code

Time: **O(-)** Space: **O(-)**

- ...

Problem – 242. Valid Anagram

Easy

LeetCode leetcode.com/problems/valid-anagram

Problem Statement / Solution / Code

Time: **O(-)** Space: **O(-)**

- ...

Problem – 49. Group Anagrams

Medium

LeetCode leetcode.com/problems/group-anagrams

Problem Statement / Solution / Code

Time: **O(-)** Space: **O(-)**

- ...

Problem – Valid Parentheses

Easy

LeetCode leetcode.com/problems/valid-parentheses

Problem Statement

- You are given a string containing only the characters **'(', ')', '{', '}', '[' and ‘]’**
- A valid input have closed brackets by its own type
- **Example**

  ()[]{} → valid

  []{}(→ invalid

  {()} → valid

Solution – Valid Parentheses

Easy

LeetCode leetcode.com/problems/valid-parentheses

Solution

- Loop through the string
- If **open** brackets **([{** push to a stack
- If **closed** brackets:

  pop the last added bracket

  check if the **closed** bracket corresponds to the **popped** bracket

  if not, return false
- after the loop, **return true** if the **size** of the stack is empty (all brackets closed)

Code – Valid Parentheses

Easy

LeetCode leetcode.com/problems/valid-parentheses

Code

Time: **O(n)** Space: **O(n)**

```
bool isValid(string s) {
    // stack (LIFO)
    std::stack<char> brackets;
    // O(n)
    for (int i = 0; i < s.size(); ++i) {
        char bracket = s[i];
        if (bracket == '(' || bracket == '[' || bracket == '{') {
            brackets.push(bracket);
        } else {
            if (brackets.size() == 0) return false;
            char lastBracket = brackets.top();
            if (bracket == ')' && lastBracket != '(') return false;
            if (bracket == '}' && lastBracket != '{') return false;
            if (bracket == ']' && lastBracket != '[') return false;
            brackets.pop();
        }
    }
    // all brackets must be closed
    return brackets.size() == 0;
}
```

Problem – 125. Valid Palindrome

Easy

LeetCode leetcode.com/problems/valid-palindrome

Problem Statement / Solution / Code

Time: **O(-)** Space: **O(-)**

- ...

Problem – Minimum Number of Increments on Subarrays

Hard

LeetCode leetcode.com/problems/minimum-number-of-increments-on-subarrays-to-form-a-target-array

Problem Statement

- You are given an array of integers initialized with zeros (e.g. **[0,0,0,0]**)
- The goal is to reach some target (e.g. **[1, 2, 2, 3]**)
- The valid operations is to increment a subarray by one
- The output is the total number of operations

  In this case:

  [1,1,1,1] → increment the subarray starting from 0 to total size

  [1,2,2,2] → increment the subarray starting from 1 to total size

  [1,2,2,3] → increment the subarray starting and ending from the last element

  Output: 3 (total number of operations)

Solution – Minimum Number of Increments on Subarrays

Hard

LeetCode leetcode.com/problems/minimum-number-of-increments-on-subarrays-to-form-a-target-array

Solution

- Explain…

Code (2) – Minimum Number of Increments on Subarrays

Hard

LeetCode leetcode.com/problems/minimum-number-of-increments-on-subarrays-to-form-a-target-array

Code (optimized)

```
int minNumberOperations(vector<int>& target) {
    return target[0] +
        inner_product(target.begin() + 1, target.end(),
                target.begin(), 0,
                plus<int>(),
                [](int curr, int prev) { return max(curr - prev, 0); });
}
```

Code – Minimum Number of Increments on Subarrays

Hard

LeetCode leetcode.com/problems/minimum-number-of-increments-on-subarrays-to-form-a-target-array

Code

```
int minNumberOperations(vector<int>& target) {
    int totalOp = target[0];
    for (int i = 1; i < target.size(); ++i) {
        // can't reuse
        if (target[i - 1] < target[i]) {
            totalOp += target[i] - target[i - 1];
        }
    }
    return totalOp;
}
```

TWO POINTERS

Problem – 11. Container With Most Water

Medium

LeetCode leetcode.com/problems/container-with-most-water

Problem Statement

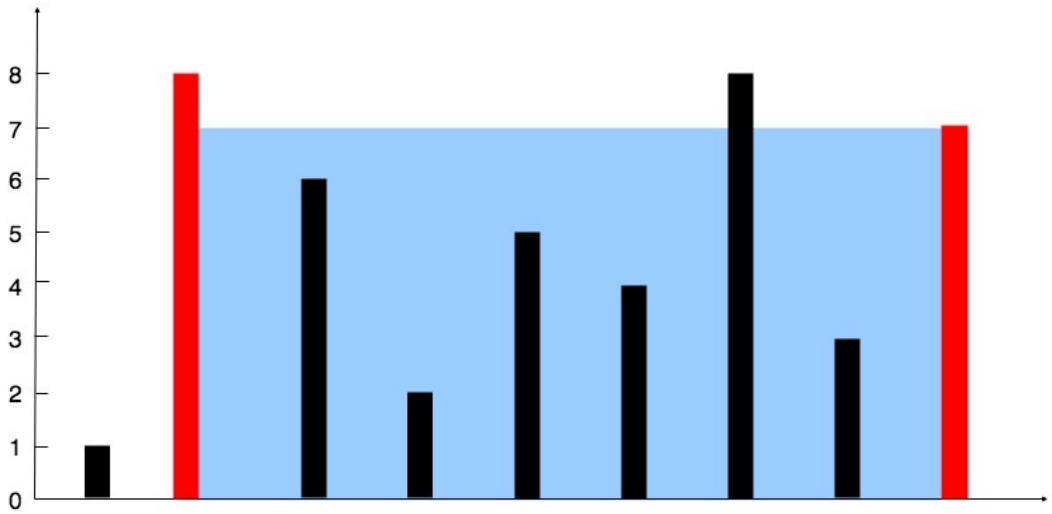
- You are given an integer array **height**
- Find two lines that together with x-axis form a container with most water
- Example:

Input:

height = [1,8,6,2,5,4,8,3,7]

Output:

49



Solution – Container With Most Water

Medium

LeetCode leetcode.com/problems/container-with-most-water

Solution

- Initialize the maximum area **maxArea = 0**
- Initialize two pointers, **left = 0** and **right = height.size – 1**
- Loop while pointer **left < right**
- Calculate the area:

  area = min(height[left], height[right]) * (right – left)
- Update the global maximum area:

  maxArea = max(maxArea, area)
- Move the smallest pointer (increment **left** or decrement **right**)
- Return **maxArea**

Code – Container With Most Water

Medium

LeetCode leetcode.com/problems/container-with-most-water

Code

```
int maxArea(vector<int>& height) {
    // initialize the two pointers (left and right)
    int left = 0;
    int right = height.size() - 1;
    int maxArea = 0;
    while (left < right) {
        // calculate the area, think about the x-axis and y-axis
        int area = min(height[left], height[right]) * (right - left);
        // update maximum area
        maxArea = max(area, maxArea);
        // is the left pointer (y) smaller than right?
        if (height[left] < height[right]) {
            // move left pointer to right
            left++;
        } else {
            // otherwise, move right pointer to left
            right--;
        }
    }
    return maxArea;
}
```

BINARY

Bit Manipulation in C

- **Operators**

  & AND **|** OR **^** XOR **~** NOT **<<** LEFT SHIFT **>>** RIGHT SHIFT

- **Common Operations**

  set bit: `num |= (1 << pos)`

  clear bit: `num &= ~(1 << pos)`

  toggle bit: `num ^= (1 << pos)`

  check bit: `(num & (1 << pos)) != 0`

  extract bit: `(num >> pos) & 1`

  extract a range of bits: `(num >> pos) & ((1 << length) - 1)`

- **Example**

```
void copyBit(int *dst, int src, int srcPos, int dstPos) {
      int bit = (src >> srcPos) & 1;  // extract bit
      *dst &= ~(1 << dstPos);  // clear destination bit
      *dst |= (bit << dstPos);  // set destination bit
}
```

Binary

- In C++, **`std::bitset`** represents a fixed-size sequence of N bits
- Example:

```
std::bitset<8> bitmask;
bitmask.reset(1)
bitmask.set(1)
if (bitmask.test(1)) { // true
```

…

- **reset** : set bit to false
- **set** : set a specific bit
- **test** : check a specific bit
- **count** : return the number of bits set to true
- **flip** : toggle the value of the bits (if true, set to false and vice-versa)

Problem – 371. Sum of Two Integers

Medium

LeetCode leetcode.com/problems/sum-of-two-integers

Problem

- ...

Problem – 371. Sum of Two Integers

Medium

LeetCode leetcode.com/problems/sum-of-two-integers

Solution

- ...

Problem – 371. Sum of Two Integers

Medium

LeetCode leetcode.com/problems/sum-of-two-integers

Code

Time: **O(-)** Space: **O(-)**

- ...

Problem – 191. Number of 1 Bits

Easy

LeetCode leetcode.com/problems/number-of-1-bits

Problem

- ...

Problem – 191. Number of 1 Bits

Easy

LeetCode leetcode.com/problems/number-of-1-bits

Solution

- ...

Problem – 191. Number of 1 Bits

Easy

LeetCode leetcode.com/problems/number-of-1-bits

Code

- ...

Problem – 191. Number of 1 Bits

Easy

LeetCode leetcode.com/problems/number-of-1-bits

Problem Statement / Solution / Code

Time: **O(-)** Space: **O(-)**

- ...

Problem – 338. Counting Bits

Easy

LeetCode leetcode.com/problems/counting-bits

Problem Statement / Solution / Code

Time: **O(-)** Space: **O(-)**

- ...

Problem – 338. Counting Bits

Easy

LeetCode leetcode.com/problems/counting-bits

Problem

- ...

Problem – 338. Counting Bits

Easy

LeetCode leetcode.com/problems/counting-bits

Solution

- ...

Problem – 338. Counting Bits

Easy

LeetCode leetcode.com/problems/counting-bits

Code

Time: **O(-)** Space: **O(-)**

- ...

Problem – 268. Missing Number

Easy

LeetCode https://leetcode.com/problems/missing-number

Problem

- ...

Problem – 268. Missing Number

Easy

LeetCode https://leetcode.com/problems/missing-number

Solution

- ...

Problem – 268. Missing Number

Easy

LeetCode https://leetcode.com/problems/missing-number

Code

Time: **O(-)** Space: **O(-)**

- ...

Problem – 190. Reverse Bits

Easy

LeetCode leetcode.com/problems/reverse-bits

Problem

- ...

Problem – 190. Reverse Bits

Easy

LeetCode leetcode.com/problems/reverse-bits

Solution

- ...

Problem – 190. Reverse Bits

Easy

LeetCode leetcode.com/problems/reverse-bits

Code

Time: **O(-)** Space: **O(-)**

- ...

Negabinary

- Non-standard positional numeral system that uses base of -2
- Allow representing negative numbers in binary
- Example:

  1101_{-2}

  $(-2)^3 + (-2)^2 + 0 + (-2)^0 = -8 + 4 + 0 + 1 = -3$

Summing Negabinary

- Add as a regular binary number, but with **negative carry**

  $0 + 0 = 0$

  $1 + 0 = 1$

  $1 + 1 = 0$ with a negative carry 1

  1 $+ 1 = 0$ (subtract)

  1 $+ 0 = 1$ with a positive carry 1

Negabinary

Example 1

```
  11 1
   1011
 + 1110
------
 = 110001
```

red 1 = negative carry

green 1 = regular carry

1 + 0 = 1

1 + 1 = 0 with negative carry 1

1 + 1 = 0

1 + 1 = 0 with negative carry 1

1 + 0 = 1 with positive carry 1

1 + 0 = 1

Example 2

```
  1111
  101010
+ 101100
--------
= 11110110
```

Reference

https://math.stackexchange.com/questions/3251605/how-to-add-negabinary-numbers

Problem 1073 – Adding Two Negabinary Numbers

Medium

https://leetcode.com/problems/adding-two-negabinary-numbers

Given two numbers **arr1** and **arr2** in base -2, return the result of adding them together.

Each number is given in *array format*: as an array of 0s and 1s, from most significant bit to least significant bit. For example, **arr = [1,1,0,1]** represents the number **(-2)^3 + (-2)^2 + (-2)^0 = -3.** A number **arr** in array, format is also guaranteed to have no leading zeros: either **arr == [0]** or **arr[0] == 1.**

Return the result of adding **arr1** and **arr2** in the same format: as an array of 0s and 1s with no leading zeros.

Example 1

Input: arr1 = [1,1,1,1,1], arr2 = [1,0,1]

Output: [1,0,0,0,0]

Explanation: arr1 represents 11, arr2 represents 5, the output represents 16.

Example 2

Input: arr1 = [0], arr2 = [0]

Output: [0]

Example 3

Input: arr1 = [0], arr2 = [1]

Output: [1]

Solution 1073 – Adding Two Negabinary Numbers

Medium

https://leetcode.com/problems/adding-two-negabinary-numbers

GRAPH (DFS)

Problem - Keys and Rooms

Medium

https://leetcode.com/problems/keys-and-rooms

```
int maxProfit(vector<int>& prices) {
    int profit = 0;
    int buy = prices[0];
    for (auto i = 1; i < prices.size(); i++) {
        if (prices[i] < buy) {
            buy = prices[i];
        } else if (prices[i] - buy > profit) {
              profit = prices[i] - buy;
        }
    }
    return profit;
}
```

Problem – Clone Graph

Medium

LeetCode https://leetcode.com/problems/clone-graph

Problem Statement

- Given a node reference, create a deep copy of the graph
- The class node has two variables: val and neighbours

```
class Node {
  public int val;
  public List<Node> neighbors;
}
```

- **Output** is the node reference of the copy

Solution – Clone Graph

Medium

LeetCode https://leetcode.com/problems/clone-graph

Solution

- First check the edge cases (is the node null?)
- Create a hash map to store the nodes that is already created

  `unordered<int, Node*> graph;`
- Check if the current node already exists in the graph
- If not, create a new Node object and store in the hashmap
- Visit all the neighbors and add the neighbors to this current node

Code – Clone Graph

Medium

LeetCode https://leetcode.com/problems/clone-graph

```
std::unordered_map<int, Node*> graph;

Node* cloneGraph(Node* node) {
    if (node == NULL) {
        return NULL;
    }
    // does this node object exists?
    if (graph.find(node->val) == graph.end()) {
        // node wasn't visited yet, store in the hashmap
        graph[node->val] = new Node(node->val);
        // visit all neighnours
        for (const auto& n : node->neighbors) {
            graph[node->val]->neighbors.push_back(cloneGraph(n));
        }
    }
    return graph[node->val];
}
```

Problem – 207. Course Schedule

Medium

LeetCode leetcode.com/problems/course-schedule

Problem

- ...

Solution – 207. Course Schedule

Medium

LeetCode leetcode.com/problems/course-schedule

Solution

- ...

Code – 207. Course Schedule

Medium

LeetCode leetcode.com/problems/course-schedule

Code

Time: **O(-)** Space: **O(-)**

- ...

Problem – 417. Pacific Atlantic Water Flow

Medium

LeetCode leetcode.com/problems/pacific-atlantic-water-flow

Problem

- ...

Solution – 417. Pacific Atlantic Water Flow

Medium

LeetCode leetcode.com/problems/pacific-atlantic-water-flow

Solution

- ...

Code – 417. Pacific Atlantic Water Flow

Medium

LeetCode leetcode.com/problems/pacific-atlantic-water-flow

Code

Time: **O(-)** Space: **O(-)**

- ...

Problem – 200. Number of Islands

Medium

LeetCode leetcode.com/problems/number-of-islands

Problem

- ...

Solution – 200. Number of Islands

Medium

LeetCode leetcode.com/problems/number-of-islands

Solution

- ...

Code – 200. Number of Islands

Medium

LeetCode leetcode.com/problems/number-of-islands

Code

Time: **O(-)** Space: **O(-)**

- ...

Problem – 128. Longest Consecutive Sequence

Medium

LeetCode leetcode.com/problems/longest-consecutive-sequence

Problem

- ...

Solution – 128. Longest Consecutive Sequence

Medium

LeetCode leetcode.com/problems/longest-consecutive-sequence

Solution

- ...

Code – 128. Longest Consecutive Sequence

Medium

LeetCode leetcode.com/problems/longest-consecutive-sequence

Code

Time: **O(-)** Space: **O(-)**

- ...

Problem – 261. Graph Valid Tree

Medium

LeetCode leetcode.com/problems/graph-valid-tree

Problem

- ...

Solution – 261. Graph Valid Tree

Medium

LeetCode leetcode.com/problems/graph-valid-tree

Solution

- ...

Code – 261. Graph Valid Tree

Medium

LeetCode leetcode.com/problems/graph-valid-tree

Code

Time: **O(-)** Space: **O(-)**

- ...

Problem – 323. Number of Connected Components

Medium

LeetCode leetcode.com/problems/number-of-connected-components-in-an-undirected-graph

Problem

- ...

Problem – 323. Number of Connected Components

Medium

LeetCode leetcode.com/problems/number-of-connected-components-in-an-undirected-graph

Solution

- ...

Problem – 323. Number of Connected Components

Medium

LeetCode leetcode.com/problems/number-of-connected-components-in-an-undirected-graph

Code

Time: **O(-)** Space: **O(-)**

- ...

GRAPH (BFS)

Problem – Maximum Level Sum of a Binary Tree

Medium

LeetCode https://leetcode.com/problems/maximum-level-sum-of-a-binary-tree

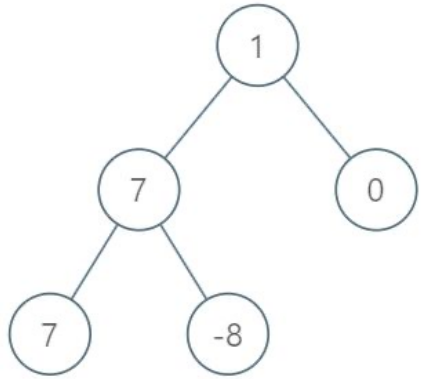
Problem Statement

- Given the root of a binary tree, find the smallest level with the maximum sum
- For example, the tree below has the follow sums for each level:

  level 1 (root) = 1

  level 2 = 7 + 0 = 7

  level 3 = 7 – 8 = -1
- Therefore, **level 2** has the maximum sum



Solution – Maximum Level Sum of a Binary Tree

Medium

LeetCode https://leetcode.com/problems/maximum-level-sum-of-a-binary-tree

Solution

- Have a queue with the nodes for the current level
- Sum the values from that level by taking the nodes from the queue
- Example, we know that level 1 has one node. Hence, pop the first node from the queue

  If level 2 has 2 nodes, pop two nodes, sum the values
- In addition, add left and right to the end of the queue to process the next level

Code – Maximum Level Sum of a Binary Tree

Medium

LeetCode https://leetcode.com/problems/maximum-level-sum-of-a-binary-tree

```
int maxLevelSum(TreeNode* root) {
    std::queue<TreeNode*> nodes;
    int currentLevel = 0;
    int maxLevel = 1;
    int maxSum = INT_MIN;

    nodes.push(root);

    // traverse the graph
    while(!nodes.empty()) {
        int levelSum = 0;
        int levelSize = nodes.size();
        currentLevel++;

        // sum the values in current level
        for (int i = 0; i < levelSize; ++i) {
            TreeNode* node = nodes.front();
            levelSum += node->val;
            nodes.pop();

            if (node->left) nodes.push(node->left);
            if (node->right) nodes.push(node->right);
        }

        if (levelSum > maxSum) {
            maxLevel = currentLevel;
            maxSum = levelSum;
        }
    }

    return maxLevel;
}
```

SHORTEST PATH

Shortest Path Algorithms

Algorithms

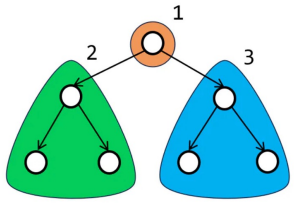
- BFS
- Dijkstra
- Bellman-Ford
- Floyd-Warshall
- A* search
- Johnson's
- SPFA (Shortest Path Faster)
- Bidirectional Search

TREE

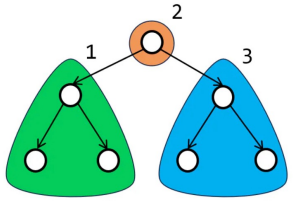
Tree Traversals

Depth-First Traversals

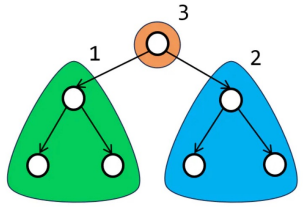
- **Pre-order**: Root – Left – Right



- **In-order**: Left – Root – Right



- **Post-order**: Left – Right – Root



Breadth-First Traversal (Level Order Traversal)

Visit every node on a level before moving to a lower level.

Image credits:
https://deriveit.org/coding/tree-dfs-113

Tree Traversals

Depth-First Traversals

Use a recursive algorithm to traverse according to the order

- **Pre-order**: Root – Left – Right

```
if (!root) return;
doSomething();
visit(node->left);
visit(node->right);
```

- **In-order**: Left – Root – Right

```
if (!root) return;
visit(node->left);
doSomething();
visit(node->right);
```

- **Post-order**: Left – Right – Root

```
if (!root) return;
visit(node->left);
visit(node->right);
doSomething();
```

Tree Traversals

Example of pre-order and in-order

```
struct TreeNode {
    int val;
    TreeNode *left, *right;
    TreeNode(int x) : val(x), left(nullptr), right(nullptr) {}
};

// Pre-order traversal
void preorderTraversal(TreeNode* root) {
    if (root == nullptr) return;
    cout << root->val << " ";
    preorderTraversal(root->left);
    preorderTraversal(root->right);
}

// In-order traversal
void inorderTraversal(TreeNode* root) {
    if (root == nullptr) return;
    inorderTraversal(root->left);
    cout << root->val << " ";
    inorderTraversal(root->right);
}
```

Tree Traversals

Example of post-order and level-order

```
struct TreeNode {
    int val;
    TreeNode *left, *right;
    TreeNode(int x) : val(x), left(nullptr), right(nullptr) {}
};

// Post-order traversal
void postorderTraversal(TreeNode* root) {
    if (root == nullptr) return;
    postorderTraversal(root->left);
    postorderTraversal(root->right);
    cout << root->val << " ";
}

// Level-order traversal using a queue
void levelOrderTraversal(TreeNode* root) {
    if (root == nullptr) return;
    queue<TreeNode*> q;
    q.push(root);
    while (!q.empty()) {
        TreeNode* current = q.front();
        q.pop();
        cout << current->val << " ";
        if (current->left != nullptr) q.push(current->left);
        if (current->right != nullptr) q.push(current->right);
    }
}
```

BFS Using Stack

BFS with std::stack

- This might be useful for problems when you want to return and resume (for example, 872. Leaf-Similar Trees)

```
struct TreeNode {
    int val;
    TreeNode *left, *right;
    TreeNode(int x) : val(x), left(nullptr), right(nullptr) {}
};

// Pre-order traversal
void bfs(std::stack<TreeNode*>& tree) {
    while(!tree.empty()) {
        TreeNode* root = tree.top();
        tree.pop();
        // do something ...
        if (root->right) tree.push(root->right);
        if (root->left) tree.push(root->left);
    }
}
```

Problem – 100. Same Tree

Easy

LeetCode leetcode.com/problems/same-tree

Problem

- You are given the root of two trees
- Write a function to check if they are the same
- **Example:**

  p = [1,2,3], q = [1,2,3]

  Output: true

Problem – 100. Same Tree

Easy

LeetCode leetcode.com/problems/same-tree

Solution

- Traverse both trees (**p** and **q**) recursively and check if the nodes are the same
- Start by the base case:

  are **p** and **q** null? return true
- One of them are null? return false, because they should be the same
- Finally, check if **p->val** is equal to **q->val** and also for both and left, recursively

Problem – 100. Same Tree

Easy

LeetCode leetcode.com/problems/same-tree

Code

Time: **O(n)** where n is the number of nodes Space: **O(h)** where h is the height of the tree. Best case is usually O(log n) for balanced trees, but skewed trees is usually O(n)

```
bool isSameTree(TreeNode* p, TreeNode* q) {
    // base case: leaf is null. If both are null, then return true
    if (!p && !q) return true;
    // if both are not NULL, then they must have value.
    // If one of them doesn't have value, then they're different, return false
    if (!p || !q) return false;
    // they must have the same value
    // as any other nodes in the tree
    return p->val == q->val &&
           isSameTree(p->left, q->left) &&
           isSameTree(p->right, q->right);
}
```

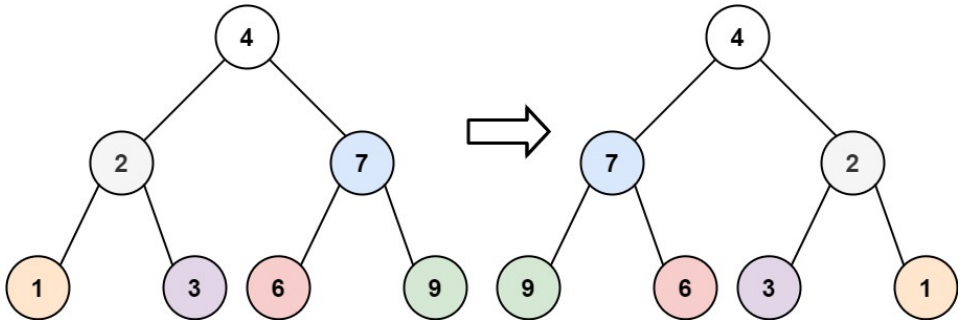
Problem – 226. Invert Binary Tree

Easy

LeetCode leetcode.com/problems/invert-binary-tree

Problem

- You are given the root of a binary tree
- Invert the tree and return the root
- **Example:**



Problem – 226. Invert Binary Tree

Easy

LeetCode leetcode.com/problems/invert-binary-tree

Solution

- Recursively traverse the tree
- Create a new pointer **temp** that points to **left** node
- Set **left** node to **right**
- Set **right** node to **temp**
- Call the function recursively for **left** and **right**
- Return root

Problem – 226. Invert Binary Tree

Easy

LeetCode leetcode.com/problems/invert-binary-tree

Code

Time: **O(n)** Space: **O(h)** where h is the height of the tree

```
TreeNode* invertTree(TreeNode* root) {
    // base case
    if (!root) return nullptr;

    // create a new pointer to left
    TreeNode* temp = root->left;
    // invert
    root->left = root->right;
    root->right = temp;

    // recursively invert left and right
    invertTree(root->left);
    invertTree(root->right);

    return root;
}
```

Problem – Maximum Depth of Binary Tree

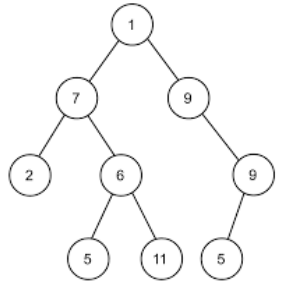
Easy

LeetCode https://leetcode.com/problems/maximum-depth-of-binary-tree

Problem Statement

- Given the root of a binary tree, find the *maximum depth*
- **Example:**

  root = [1,7,9,2,6,null,9,null,null,5,11,5,null]
- **Output**: 4



Solution – Maximum Depth of Binary Tree

Easy

LeetCode https://leetcode.com/problems/maximum-depth-of-binary-tree

Solution

- Perform **post-order** traversal: left - right - root
- Recursively go left and right to find each value
- Return the max of each one

Code – Maximum Depth of Binary Tree

Easy

LeetCode https://leetcode.com/problems/maximum-depth-of-binary-tree

```
int maxDepth(TreeNode* root) {
    if (!root) return 0;
    // find max left
    int maxLeft = maxDepth(root->left);
    // find max right
    int maxRight = maxDepth(root->right);
    // return max +1 (account for root)
    return std::max(maxLeft, maxRight) + 1;
}
```

Problem – Path Sum

Easy

LeetCode https://leetcode.com/problems/path-sum

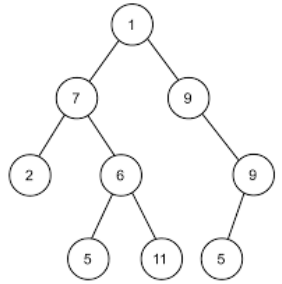
Problem Statement

- It is given the **root** of a binary tree and an integer **target sum**
- **Example:**

  root = [1,7,9,2,6,null,9,null,null,5,11,5,null]

  target sum = 10
- Return true if there is a path from root to leaf that adds up to 10
- **Output**: true

  Node 1 + Node 7 + Node 2 = 10



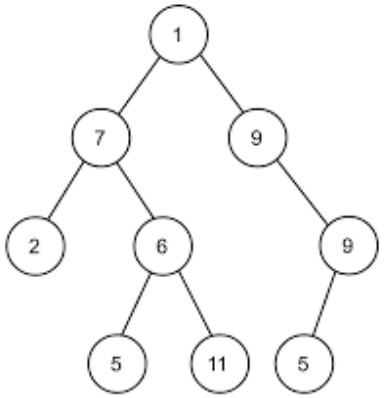
Solution – Path Sum

Easy

LeetCode https://leetcode.com/problems/path-sum

Solution

- Start from root node (1)
- Subtract from target number (example 10 – 1 = 9)
- Continue going down the tree, until the target is 0, return true
- After visiting all nodes, if the target is not zero, return false



Code – Path Sum

Easy

LeetCode https://leetcode.com/problems/path-sum

```
bool hasPathSum(TreeNode* root, int targetSum) {
    if (!root) {
        return false;
    }
    // we want targetSum to be zero
    targetSum -= root->val;
    // if there is no left, no right, we've reached the end of the path
    // so if the targetSum is zero, then the nodes summed up to the targetSum
    if (!root->left && !root->right && targetSum == 0) {
        return true;
    }
    // propagate to left and right
    return hasPathSum(root->left, targetSum) || hasPathSum(root->right, targetSum);
}
```

Also, a small performance tweak can be made by avoiding writing *targetSum*: *`targetSum -= root->val`*

This will avoid a memory write access, making the calculation directly in the CPU, but also at a cost of readability

```
    if (!root->left && !root->right && targetSum - root->val == 0) {
     …
    return hasPathSum(root->left, targetSum - root->val) || hasPathSum(root->right, targetSum - root->val);
```

Problem – 297. Serialize and Deserialize Binary Tree

Hard

LeetCode leetcode.com/problems/serialize-and-deserialize-binary-tree

Problem

- Design an algorithm to serialize and deserialize a binary tree
- You have to build two interfaces: serialize that returns a string, and deserialize that returns the whole tree as TreeNode pointer
- The string can be represented at any format (comma-separated, space separated etc)

Solution – 297. Serialize and Deserialize Binary Tree

Hard

LeetCode leetcode.com/problems/serialize-and-deserialize-binary-tree

Solution

- **Serialize**: traverse the tree pre-order, and append its value to a string

  Null value should also be represented

  Example: [1,2,null,null,3 ...]

  Call “traverse” to do it recursively

- **Deserialize**: split the string into tokens

  read each token and re-build the tree by adding a new node

  Call “buildTree” to do it recursively

Code – 297. Serialize and Deserialize Binary Tree

Hard

LeetCode leetcode.com/problems/serialize-and-deserialize-binary-tree

Code

Time: O() Space: O()

```
string serialize(TreeNode* root) {
    // traverse the tree in pre-order: root, left, right
    // generate a string with comma separator,
    // example: 1,2,N,N,3 ...
    string result;
    traverse(root, result);
    return result;
}

TreeNode* deserialize(string data) {
    // split the input data
    vector<string> tokens = split(data);
    // index to be used to access the elements from tokens recursively.
    // Hence, we need to create it here to pass by reference.
    // Note that index is bounded by the number of tokens, so it won't overflow
    int index = 0;
    TreeNode* root = buildTree(tokens, index);
    return root;
}
```

continue...

Code – 297. Serialize and Deserialize Binary Tree

Hard

LeetCode leetcode.com/problems/serialize-and-deserialize-binary-tree

```
TreeNode* buildTree(vector<string>& tokens, int& index) {
        // read the current token based on the index
        const string& token = tokens[index];
        // increment index before checking for null
        ++index;
        // base case: null node
        if (token == "N") {
            return nullptr;
        }
        // build root
        TreeNode* node = new TreeNode(stoi(token));
        // build left
        node->left = buildTree(tokens, index);
        // build right
        node->right = buildTree(tokens, index);
        return node;
    }
```

```
// traverse in pre-order (root, left, right)
// and append the values to the string 's'
// append 'N' if it is NULL
void traverse(TreeNode* root, string& s) {
    if (!s.empty()) s += ",";
    // base case, we need to append null
    if (!root) {
        s += "N";
        return;
    }
    // visit root
    s += to_string(root->val);
    // visit left
    traverse(root->left, s);
    // visit right
    traverse(root->right, s);
}

// helper function in C++ to split string
vector<string> split(const string& s) {
    vector<string> result;
    stringstream ss(s);
    string token;
    while(getline(ss, token, ',')) {
        result.push_back(token);
    }
    return result;
}
```

Code – 297. Serialize and Deserialize Binary Tree

Hard

LeetCode leetcode.com/problems/serialize-and-deserialize-binary-tree

Some interesting alternative to split

- C++ 23 have an interesting way to split using std::views::split

```
vector<string> split(string s) {
    auto result = s |
        views::split(',') |
        views::transform([](auto&& subRange) {
                return string(subRange.start(), subRange.end());
                });
}
```

- To understand, this follow a structure similar to unix pipes:

  echo "123,N,556" | split | transform

- std::views::split returns ranges, something like:

  [range("123"), range("N"), range("556")]

- std::views::transform converts each subrange into an actual string

Problem – Kth Smallest Element in a BST

Medium

LeetCode leetcode.com/problems/kth-smallest-element-in-a-bst

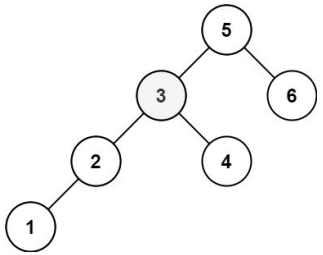
Problem Statement / Solution

- You are given the **root** of a binary search tree and an **integer k**
- Find the k^{th} smallest value
- **Example**

  From all values in the tree: 1,2,3,4,5,6

  k = 3 so find the 3^{th} smallest value

  Output is 3: 1,2,**3**,4,5,6 (3th)



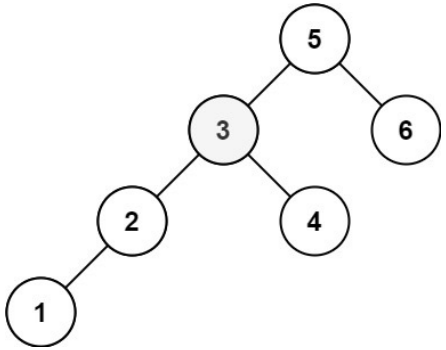
Solution – Kth Smallest Element in a BST

Medium

LeetCode leetcode.com/problems/kth-smallest-element-in-a-bst

Solution

- Note that the smallest element is in the left leaf
- Therefore, there is an order from small → big values from left → root → right
- Perform in-order traversal **k** times and stop in the desired node



Code – Kth Smallest Element in a BST

Medium

LeetCode leetcode.com/problems/kth-smallest-element-in-a-bst

Code

Time: **O(k)** Space: **O(h)** where **h** is the height of the tree

```
// in-order traversal: left, node: right
void traverse(TreeNode* node, int& k, int& result) {
    // base case
    if (!node) return;
    // visit left first
    traverse(node->left, k, result);
    // visit node
    k--;
    if (k == 0) {
        result = node->val;
        return;
    }
    // visit right
    traverse(node->right, k, result);
}

int kthSmallest(TreeNode* root, int k) {
    // perform pre-order traversal
    int result;
    traverse(root, k, result);
    return result;
}
```

Problem – 124. Binary Tree Maximum Path Sum

Hard

LeetCode leetcode.com/problems/binary-tree-maximum-path-sum

Problem

- ...

Problem – 124. Binary Tree Maximum Path Sum

Hard

LeetCode leetcode.com/problems/binary-tree-maximum-path-sum

Solution

- ...

Problem – 124. Binary Tree Maximum Path Sum

Hard

LeetCode leetcode.com/problems/binary-tree-maximum-path-sum

Code

Time: **O(-)** Space: **O(-)**

- ...

Problem – 102. Binary Tree Level Order Traversal

Medium

LeetCode leetcode.com/problems/binary-tree-level-order-traversal

Problem Statement / Solution / Code

Time: **O(-)** Space: **O(-)**

- ...

Problem – 572. Subtree of Another Tree

Easy

LeetCode leetcode.com/problems/subtree-of-another-tree

Problem Statement / Solution / Code

Time: **O(-)** Space: **O(-)**

- ...

Problem – 872. Leaf-Similar Trees

Easy

LeetCode leetcode.com/problems/leaf-similar-trees

Problem Statement

- You are given two trees
- The goal is to compare if they have the same leaves
- The leaves should be in the same order
- Example:

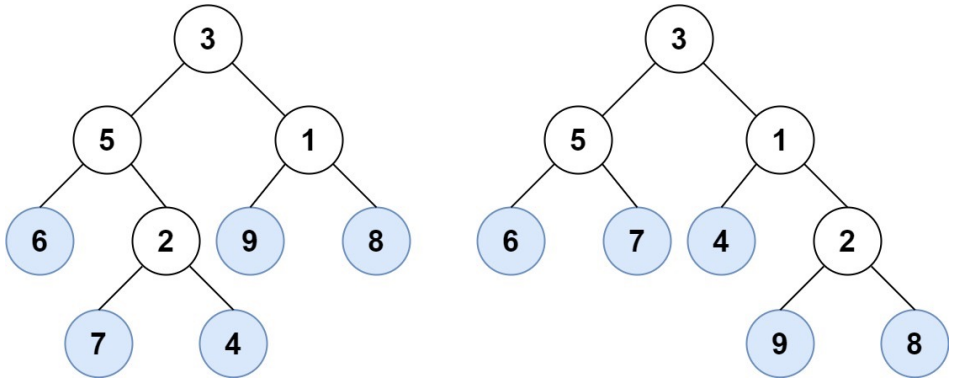
  First tree:

  leaves = 6,7,4,9,8 (blue nodes)

  Second tree:

  leaves = 6,7,4,9,8

- Return true if the leaves are the same



Solution – Leaf-Similar Trees

Easy

LeetCode leetcode.com/problems/leaf-similar-trees

Solution

- Get the first leaf value from tree 1
- Get the first leaf value from tree 2
- Compare, if they are different, return false immediately
- Otherwise, continue finding the next leaf value for tree 1 and 2

Implementation

- Create two stacks **stack<TreeNode*> left** and **stack<TreeNode*> right**
- Add the

Code – Leaf-Similar Trees

Easy

LeetCode leetcode.com/problems/leaf-similar-trees

Code

Time: **O(n + m)** where n and m are the numbers of nodes for trees 1 and 2 Space: **O(h1 + h2)** where h1 and h2 represents the height of the tree

```
// returns the value of the leaf, or -1 if empty
int getLeaf(stack<TreeNode*>& tree) {
    // tree is a reference, we will always pop an element from it
    while(!tree.empty()) {
        // get the top element from the stack
        TreeNode* node = tree.top();
        // already visited, so remove from stack
        tree.pop();
        // is this a leaf?
        if (!node->left && !node->right) {
            // yes, return the value
            return node->val;
        }
        // push the right FIRST to the stack
        if (node->right) tree.push(node->right);
        // left should be on top of the stack
        if (node->left) tree.push(node->left);
    }
    return -1;
}
```

```
bool leafSimilar(TreeNode* root1, TreeNode* root2) {
    // initialize the stacks, add root1 and root2
    std::stack<TreeNode*> leftTree, rightTree;
    leftTree.push(root1);
    rightTree.push(root2);

    while(true) {
        // get the leaves to compare
        int leaf1 = getLeaf(leftTree);
        int leaf2 = getLeaf(rightTree);
        // exit immediately if one leaf is different
        if (leaf1 != leaf2) return false;
        // stop when there are no leaves left
        if (leaf1 == -1 || leaf2 == -1) break;
    }
    return true;
}
```

Problem – 1448. Count Good Nodes in Binary Tree

Medium

LeetCode leetcode.com/problems/count-good-nodes-in-binary-tree

Problem Statement

- You are given a binary tree and have to find "**good**" **nodes**
- A **good node** is a **node** where the values in the path are always than the **node**
- The **root node** is always a **good node**
- Example:

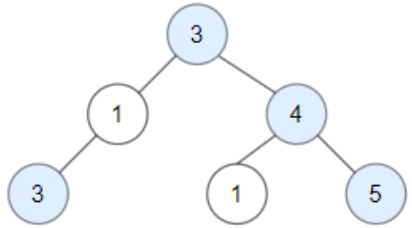
  - root 3 is a good node

  left side:

  - left **leaf 1** is not a good node because **1 < 3**
  - **leaf 3** is a good node because **3 > 1** and **3 == 3**

  right side:

  - **leaf 4** is a good node because **4 > 3**
  - **leaf 1** is not a good node because **1 < 4**
  - **leaf 5** is a good node because **5 > 4 > 3**



Solution – 1448. Count Good Nodes in Binary Tree

Medium

LeetCode leetcode.com/problems/count-good-nodes-in-binary-tree

Solution

- ...

Code – 1448. Count Good Nodes in Binary Tree

Medium

LeetCode leetcode.com/problems/count-good-nodes-in-binary-tree

Code

Time: **O(n + m)** where n and m are the numbers of nodes for trees 1 and 2 Space: **O(h1 + h2)** where h1 and h2 represents the height of the tree

```
// returns the value of the leaf, or -1 if empty
int getLeaf(stack<TreeNode*>& tree) {
    // tree is a reference, we will always pop an element from it
    while(!tree.empty()) {
        // get the top element from the stack
        TreeNode* node = tree.top();
        // already visited, so remove from stack
        tree.pop();
        // is this a leaf?
        if (!node->left && !node->right) {
            // yes, return the value
            return node->val;
        }
        // push the right FIRST to the stack
        if (node->right) tree.push(node->right);
        // left should be on top of the stack
        if (node->left) tree.push(node->left);
    }
    return -1;
}
```

```
bool leafSimilar(TreeNode* root1, TreeNode* root2) {
    // initialize the stacks, add root1 and root2
    std::stack<TreeNode*> leftTree, rightTree;
    leftTree.push(root1);
    rightTree.push(root2);

    while(true) {
        // get the leaves to compare
        int leaf1 = getLeaf(leftTree);
        int leaf2 = getLeaf(rightTree);
        // exit immediately if one leaf is different
        if (leaf1 != leaf2) return false;
        // stop when there are no leaves left
        if (leaf1 == -1 || leaf2 == -1) break;
    }
    return true;
}
```

Code – Count Good Nodes in Binary Tree

Medium

LeetCode leetcode.com/problems/count-good-nodes-in-binary-tree

Code (recursive)

Time**: O(n + m)** where n and m are the numbers of nodes for trees 1 and 2 Space**: O(h1 + h2)** where h1 and h2 represents the height of the tree

INTERVAL

greedy strategy: sort by the end time

Because ending earlier gives **more room** for future intervals. It’s a classic greedy trick: choose the interval that **frees up time** as quickly as possible.

Problem – 57. Insert Interval

Medium

LeetCode leetcode.com/problems/insert-interval

Problem Statement

- You are given an array of **intervals,** where **intervals[i] = [$start_i$, end_i]** and **newInterval = [start, end]**
- **newInterval** must be inserted into **intervals**
- Overlapping intervals must be merged
- Example

  intervals = [[1,2],[3,5],[6,7],[8,10],[12,16]] **newInterval** = [4,8]

  Output: [[1,2],[3,10],[12,16]]

Solution – 57. Insert Interval

Medium

LeetCode leetcode.com/problems/insert-interval

Solution

- Sort intervals by the first element (start)
- Initialize **result**
- Solve in three loops:
  1. While there is no overlap with **newInterval**, add to **intervals[i]** to **result**
  2. While it overlaps, merge **newInterval**
  3. While until the end intervals and add the remaining **intervals[i]**

Code – 57. Insert Interval

Medium

LeetCode leetcode.com/problems/insert-interval

Code

Time: **O(n)** Space: **O(n)** where n is the size of intervals

```
vector<vector<int>> insert(vector<vector<int>>& intervals, vector<int>& newInterval) {
    vector<vector<int>> result;
    int tupleIndex = 0;
    int totalTuples = intervals.size();
    // 1. check if it overlaps
    // 1 ------ 2
    //              4 ----- 8
    while (tupleIndex < totalTuples && intervals[tupleIndex][1] < newInterval[0]) {
        result.push_back(intervals[tupleIndex]);
        ++tupleIndex;
    }


    // 2. merge overlap. We already know there is an overlap here,
    // otherwise it should be sorted out in the previous step
    // 3 ---- 5
    //     4 ----- 8
    while (tupleIndex < totalTuples && intervals[tupleIndex][0] <= newInterval[1]) {
        newInterval[0] = min(newInterval[0], intervals[tupleIndex][0]);
        newInterval[1] = max(newInterval[1], intervals[tupleIndex][1]);
        ++tupleIndex;
    }
    result.push_back(newInterval);


    // 3. add remaining parts
    while (tupleIndex < totalTuples) {
        result.push_back(intervals[tupleIndex]);
        ++tupleIndex;
    }
    return result;
}
```

Problem – 56. Merge Intervals

Medium

LeetCode leetcode.com/problems/merge-intervals

Problem Statement

- ...

Solution – 56. Merge Intervals

Medium

LeetCode leetcode.com/problems/merge-intervals

Solution

- ...

Code – 56. Merge Intervals

Medium

LeetCode leetcode.com/problems/merge-intervals

Code

Time: **O(n)** Space: **O(n)**

- ...

Problem – 435. Non-overlapping Intervals

Medium

LeetCode leetcode.com/problems/non-overlapping-intervals

Problem Statement

- ...

Solution – 435. Non-overlapping Intervals

Medium

LeetCode leetcode.com/problems/non-overlapping-intervals

Solution

- ...

Code – 435. Non-overlapping Intervals

Medium

LeetCode leetcode.com/problems/non-overlapping-intervals

Code

Time: **O(n)** Space: **O(n)**

- ...

LINKED LIST

Problem – 206. Reverse Linked List

Easy

LeetCode leetcode.com/problems/reverse-linked-list

Problem Statement / Solution / Code

Time: **O(n)** Space: **O(n)**

- ...

Problem – 141. Linked List Cycle

Easy

LeetCode leetcode.com/problems/linked-list-cycle

Problem Statement / Solution / Code

Time: **O(n)** Space: **O(n)**

- ...

Problem – 21. Merge Two Sorted Lists

Easy

LeetCode leetcode.com/problems/merge-two-sorted-lists

Problem Statement / Solution / Code

Time: **O(n)** Space: **O(n)**

- ...

Problem – 23. Merge k Sorted Lists

Hard

LeetCode leetcode.com/problems/merge-k-sorted-lists

Problem Statement / Solution / Code

Time: **O(n)** Space: **O(n)**

- ...

Problem – 19. Remove Nth Node From End of List

Medium

LeetCode leetcode.com/problems/remove-nth-node-from-end-of-list

Problem Statement / Solution / Code

Time: **O(n)** Space: **O(n)**

- ...

Problem – 143. Reorder List

Medium

LeetCode leetcode.com/problems/reorder-list

Problem Statement / Solution / Code

Time: **O(n)** Space: **O(n)**

- ...

Problem – 24. Swap Nodes in Pair

Medium

https://leetcode.com/problems/swap-nodes-in-pairs

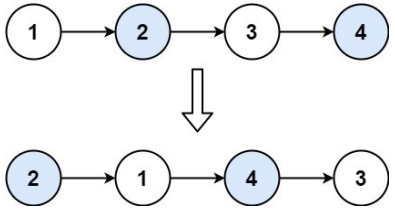
Problem

Given a linked list, swap every two adjacent nodes and return its head. You must solve the problem without modifying the values in the list's nodes (i.e., only nodes themselves may be changed.)

Example 1

Input: head = [1,2,3,4]

Output: [2,1,4,3]



Example 2

Input: head = []

Output: []

Example 3:

Example 3

Input: head = [1]

Output: [1]

Solution – Swap Nodes in Pair

Medium

https://leetcode.com/problems/swap-nodes-in-pairs

```
ListNode* swapPairs(ListNode* head) {
    if (head == NULL || head->next == NULL) {
        return head;
    }
    ListNode *node = head;
    ListNode *prev = NULL;
    head = head->next;

    while (node && node->next) {
        ListNode *second = node->next;
        ListNode *next_pair = second->next;
        second->next = node;
        node->next = next_pair;
        if (prev) {
            prev->next = second;
        }
        prev = node;
        node = next_pair;
    }
    return head;
}
```

Solution (recursive) – Swap Nodes in Pair

Medium

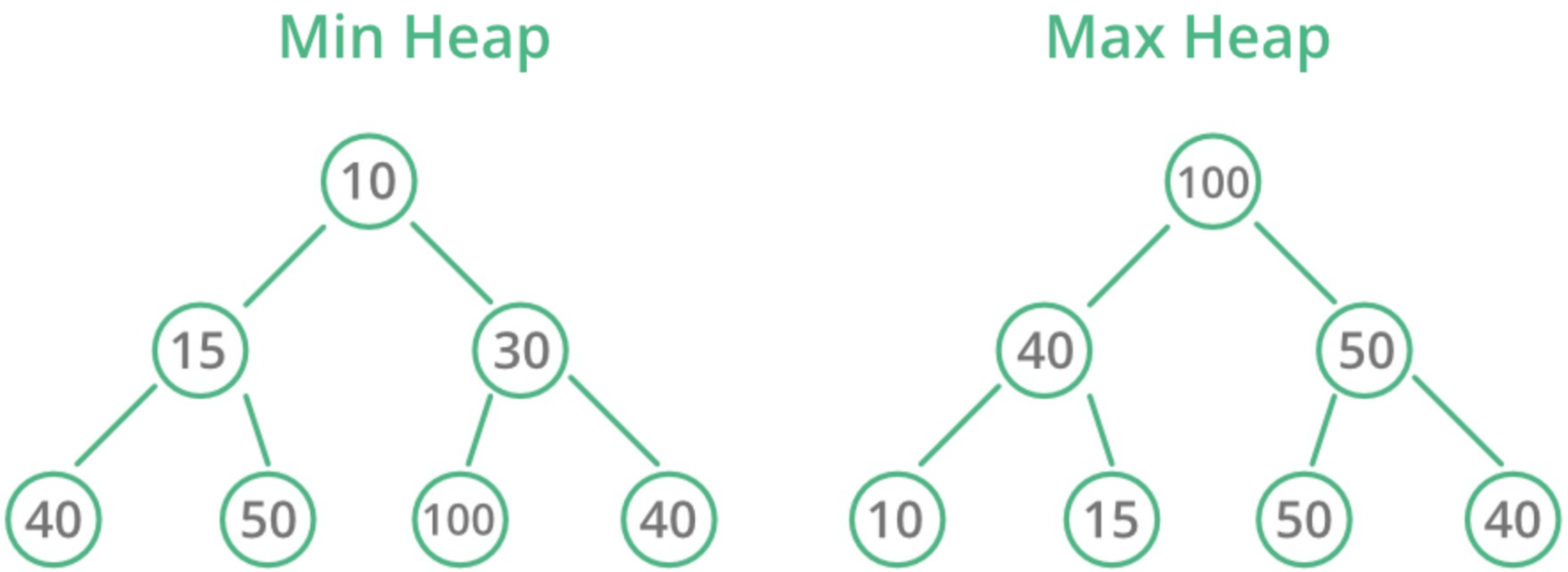
https://leetcode.com/problems/swap-nodes-in-pairs

```
ListNode* swapPairs(ListNode* head) {
    if(!head || !head->next)
        return head;
    ListNode* newHead = head->next;
    head->next = swapPairs(head->next->next);
    newHead->next = head;
    return newHead;
}
```

HEAP / PRIORITY QUEUE

Heap

- **Heap** is a complete binary tree that satisfy the heap property (max or min)
- **Min heap**: root node contains the minimum value
- **Max heap**: root node contains the maximum value



Heap in C++

Two main ways to implement:

1. Using **std::make_heap** from **<algorithm>**

```
std::make_heap(RandomIt first, RandomIt last)
std::push_heap(RandomIt first, RandomIt last)
std::pop_heap(RandomIt first, RandomIt last)
std::sort_heap(RandomIt first, RandomIt last)
```

2. Using **std::priority_queue** from **<queue>** **(recommended)**

```
std::priority_queue<T, Container, Compare>
```

Heap in C++ – std::priority_queue example

Min heap

`std::priority_queue<int, std::vector<int>, std::greater<int>>`

Max heap

`std::priority_queue<int>` or

`std::priority_queue<int, std::vector<int> std::less<int>>`

```
// Min heap
std::priority_queue<int, std::vector<int>, std::greater<int>> minHeap;

minHeap.push(3);
minHeap.push(6);
minHeap.push(4);
// remove top element (3)
minHeap.pop();
// root node (top) is now 4
std::cout << minHeap.top();
```

Problem – Kth Largest Element in an Array

Medium

https://leetcode.com/problems/kth-largest-element-in-an-array

Problem

Given an integer array **nums** and an integer **k**, return the **k**th largest element in the array.

Note that it is the **k**th largest element in the sorted order, not the **k**th distinct element.

Example 1

Input: nums = [3,2,1,5,6,4], k = 2

Output: 5

Example 2

Input: nums = [3,2,3,1,2,4,5,5,6], k = 4

Output: 4

Although this problem is classified as “medium”, in my opinion it should be classified as “easy”

Solution 1 – Kth Largest Element in an Array

Medium

https://leetcode.com/problems/kth-largest-element-in-an-array

```cpp
// SOLUTION 1

int findKthLargest(vector<int>& nums, int k) {
    std::priority_queue<int, std::vector<int>, std::greater<int>> minHeap;
    for (const auto& num : nums) {
        if (minHeap.size() < k) {
            minHeap.push(num);
        } else if (num > minHeap.top()) {
            minHeap.pop();
            minHeap.push(num);
        }
    }
    return minHeap.top();
}
```

Solution 2 – Kth Largest Element in an Array

Medium

https://leetcode.com/problems/kth-largest-element-in-an-array

```cpp
// SOLUTION 2 – Simpler approach

int findKthLargest(vector<int>& nums, int k) {
    // min heap: minimum values will be always at the top
    std::priority_queue<int, std::vector<int>, std::greater<int>> minHeap;
    for (const auto& num : nums) {
        // push each num to the heap
        minHeap.push(num);
        // we need the kth largest element only, so once after pushing more than k
        // elements, remove the smallest one (the top)
        if (minHeap.size() > k) {
            minHeap.pop();
        }
    }
    return minHeap.top();
}
```

Problem – 347. Top K Frequent Elements

Medium

LeetCode leetcode.com/problems/top-k-frequent-elements

Problem

- You are given an **array** of numbers and an **integer** k
- Return an array with the **k** most frequent elements

Example

Input:

```
nums = [1,1,1,2,2,3], k = 2
```

Output:

```
[1,2]
```

Solution – 347. Top K Frequent Elements

Medium

LeetCode leetcode.com/problems/top-k-frequent-elements

Solution (1) - hashmap + array sort

- Go over the array, count the numbers and store them in an *unordered_map*

  Example:

  ```
  nums = [1,1,1,2,2,3], k = 2
  freq[1] = 3
  freq[2] = 2
  ...
  ```

- Go over the *unordered_map*, add to an array and sort descending
- Create another array adding the **k** first elements and return

Code – 347. Top K Frequent Elements

Medium

LeetCode leetcode.com/problems/top-k-frequent-elements

Code (1) Time: **O(n log n)** Space: **O(n)**

```
vector<int> topKFrequent(vector<int>& nums, int k) {
    // 1. Create the number's frequency map
    // O(n)
    unordered_map<int, int> freq;
    for (const auto& num : nums) {
        freq[num] += 1;
    }
    // 2. Create an array with the frequencies
    vector<pair<int, int>> freqVec(freq.begin(), freq.end());
    // 3. Sort by the frequency O(n log n)
    sort(freqVec.begin(), freqVec.end(), [](auto& a, auto& b) {
            return a.second > b.second;
            });
    // 4. Create the result with the k first elements
    // O(k)
    vector<int> result;
    for (int i = 0; i < k; ++i) {
        result.push_back(freqVec[i].first);
    }
    return result;
}
```

Solution – 347. Top K Frequent Elements

Medium

LeetCode leetcode.com/problems/top-k-frequent-elements

Solution (2) - hashmap + min heap

- Go over the array, count the numbers and store them in an *unordered_map*

  Example:

  ```
  nums = [1,1,1,2,2,3], k = 2
  freq[1] = 3
  freq[2] = 2
  ...
  ```

- Go over the frequencies, add to a min heap. If the size of the heap exceeds **k**, remove the top one (the minimum value)
- Create another array result adding all elements from the heap and return it

Code – 347. Top K Frequent Elements

Medium

LeetCode leetcode.com/problems/top-k-frequent-elements

Code (2) Time: **O(n log k)** Space: **O(n)**

```cpp
vector<int> topKFrequent(vector<int>& nums, int k) {
    // 1. Create the number's frequency map
    // O(n)
    unordered_map<int, int> freq;
    for (const auto& num : nums) {
        freq[num] += 1;
    }
    // 2. Create the min heap with priority queue
    // O(n log k)
    priority_queue<pair<int, int>, vector<pair<int,int>>, greater<>> minHeap;
    for (const auto& [num, count] : freq) {
        minHeap.push({count, num});
        if (minHeap.size() > k) minHeap.pop();
    }
    // 3. build the result
    vector<int> result;
    while (!minHeap.empty()) {
        auto num = minHeap.top().second;
        minHeap.pop();
        result.push_back(num);
    }
    return result;
}
```

Solution – 347. Top K Frequent Elements

Medium

LeetCode leetcode.com/problems/top-k-frequent-elements

Solution (3) – hashmap + bucket sort

- Go over the array, count the numbers and store them in an *unordered_map*

  Example:

  `nums = [1,1,1,2,2,3], k = 2`

  `freq[1] = 3`

  `freq[2] = 2`

  ...

- Create buckets for each frequency and add the corresponding numbers:

  `bucket[1] = [3]` → *3 only appears once in nums*

  `bucket[2] = [2]` → *2 appears twice*

  `bucket[3] = [1]` → *1 appears three times*

- Go over each bucket, add to the result and return it

Code – 347. Top K Frequent Elements

Medium

LeetCode leetcode.com/problems/top-k-frequent-elements

Code (3) Time: O(n) Space: O(n)

```
vector<int> topKFrequent(vector<int>& nums, int k) {
    // Create the number's frequency map
    unordered_map<int, int> freq;
    for (const auto& num : nums) {
        freq[num]++;
    }
    // create the buckets
    // e.g. [[1,2,3],[4,5,6]] ...
    vector<vector<int>> buckets(nums.size() + 1);
    for (const auto& [num, count] : freq) {
        buckets[count].push_back(num);
    }
    // go over each bucket to build the result
    vector<int> result;
    for (int i = buckets.size() - 1; i >= 0; --i) {
        for (const auto& num : buckets[i]) {
            result.push_back(num);
            if (result.size() == k) return result;
        }
    }
    return result;
}
```

Problem – 347. Top K Frequent Elements

Medium

LeetCode leetcode.com/problems/top-k-frequent-elements

Some considerations

- Theoretically, bucket sort should be the fastest solution **O(n) < O(n log k)**
- In practice, min heap end up being faster:

  - fewer allocations: priority_queue stores flat pairs rather than inner vectors

  - better cache locality: heap is built over a single array (binary heap)

  - if **k** is small, heap touches fewer elements

MATRIX

Problem – 73. Set Matrix Zeroes

Medium

LeetCode leetcode.com/problems/set-matrix-zeroes

Problem Statement / Solution / Code

Time: **O(-)** Space: **O(-)**

- ...

Problem – 54. Spiral Matrix

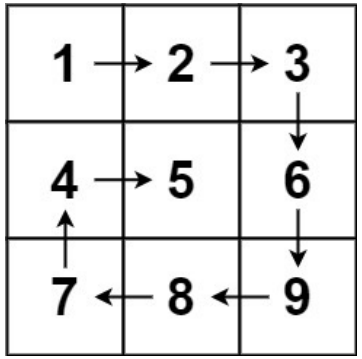
Medium

LeetCode leetcode.com/problems/spiral-matrix

Problem Statement / Solution / Code

Time: **O(-)** Space: **O(-)**

- ...



Problem – 48. Rotate Image

Medium

LeetCode leetcode.com/problems/rotate-image

Problem Statement / Solution / Code

Time: **O(-)** Space: **O(-)**

- ...

DYNAMIC PROGRAMMING

Dynamic Programming

Dynamic Programming (DP) is an algorithm technique used to solve problems that can be broken down into **simpler, overlapping subproblems.**

Key Concepts of Dynamic Programming

- **Overlapping subproblems**: a problem has overlapping subproblems if it can be broken down into subproblems.
- **Memoization (Top-Down Approach)**: store the results in a cache (typically a dictionary or array) to avoid recalculation – recursion and caching approach.
- **Tabulation (Bottom-Up Approach)**: first solve all possible subproblems iteratively, and store them in a table.

Common Patterns in Dynamic Programming

- **Toy example (Fibonacci):** Climbing Stairs, N-th Tribonacci Number, Perfect Squares
- **Constant Transition:** Min Cost Climbing Stairs, House Robber, Decode Ways, Minimum Cost For Tickets, Solving Questions With Brainpower
- **Grid:** Unique Paths, Unique Paths II, Minimum Path Sum, Count Square Submatrices with All Ones, Maximal Square, Dungeon Game
- **Dual-Sequence:** Longest Common Subsequence, Uncrossed Lines, Minimum ASCII Delete Sum for Two Strings, Edit Distance, Distinct Subsequences, Shortest Common Supersequence
- **Interval:** Longest Palindromic Subsequence, Stone Game VII, Palindromic Substrings, Minimum Cost Tree From Leaf Values, Burst Balloons, Strange Printer
- **Longest Increasing Subsequence:** Count Number of Teams, Longest Increasing Subsequence, Partition Array for Maximum Sum, Largest Sum of Averages, Filling Bookcase Shelves
- **Knapsack:** Partition Equal Subset Sum, Number of Dice Rolls With Target Sum, Combination Sum IV, Ones and Zeroes, Coin Change, Coin Change II, Target Sum, Last Stone Weight II, Profitable Schemes
- **Topological Sort on Graphs:** Longest Increasing Path in a Matrix, Longest String Chain, Course Schedule III
- **DP on Trees:** House Robber III, Binary Tree Cameras
- **Other problems:** 2 Keys Keyboard, Word Break, Minimum Number of Removals to Make Mountain Array, Out of Boundary Paths

Credits
https://www.youtube.com/watch?v=9k31KcQmS_U
https://algo.monster/problems/dp-list

Dynamic Programming – Example – Fibonacci Sequence

Naive Recursive Approach — $O(2^n)$

```
int fib(int n) {
    if (n <= 1) {
        return n;
    }
    return fib(n - 1) + fib(n - 2);
}
```

Memoization (Top-Down DP) — O(n)

```
std::unordered_map<int, int> memo;

int fib(int n) {
    if (n <= 1) {
        return n;
    }
    if (memo.find(n) != memo.end()) {
        return memo[n];
    }
    memo[n] = fib(n - 1) + fib(n - 2);
    return memo[n];
}
```

Tabulation (Bottom-up DP) — O(n)

```
int fib(int n) {
    if (n <= 1) {
        return n;
    }
    int dp[n + 1];
    dp[0] = 0;
    dp[1] = 1;
    for (int i = 2; i <= n; i++) {
        dp[i] = dp[i - 1] + dp[i - 2];
    }
    return dp[n];
}
```

Problem – Climbing Stairs

Easy

LeetCode leetcode.com/problems/climbing-stairs

Problem Statement

You need to climb a staircase with n steps to get to the top. Each time you can choose to climb either **1 step** or **2 steps** at a time. Find out how many different ways you can climb to the top of the staircase.

Example 1

Input: n = 2

Output: 2

Explanation: There are two ways to get to the top

1. Climb 1 step at a time, twice
2. Climb 2 steps in one go

Example 2:

Input: n = 3

Output: 3

Explanation: There are three ways to get to the top:

1. Climb 1 step at a time, three times
2. Climb 1 step, then 2 steps
3. Climb 2 steps, then 1 ste.

Solution – Climbing Stairs

Easy

LeetCode leetcode.com/problems/climbing-stairs

```
std::unordered_map<int, int> memo;

int climbStairs(int n) {
    // Identify the sequence, when:
    // n = 0 (0 way), there is no way to get up
    // n = 1 (1 way): only one way : 1-step
    // n = 2 (2 ways): 1s + 1s | 2s
    // n = 3 (3 ways): 1s + 1s + 1s |  1s + 2s | 2s + 1s
    // n = 4 (5 ways): 1s + 1s + 1s + 1s | 1s + 1s + 2s | 1s + 2s + 1s | 2s + 1s + 1s | 2s + 2s |

    if (n <= 2) {
        return n;
    }

    if (memo.find(n) != memo.end()) {
        return memo[n];
    }

    memo[n] = climbStairs(n - 1) + climbStairs(n - 2);
    return memo[n];
}
```

Problem – 1143. Longest Common Subsequence

Medium

LeetCode https://leetcode.com/problems/longest-common-subsequence

Problem Statement / Solution / Code

Time: **O(-)** Space: **O(-)**

- ...

Problem – 62. Unique Paths

Medium

LeetCode https://leetcode.com/problems/unique-paths

Problem Statement / Solution / Code

Time: **O(-)** Space: **O(-)**

- ...

EOF

Tips

Problem Statement / Solution / Code Time: **O(n)** Space: **O(n)**

- ...

Problem – number. name

Easy Hard Medium

LeetCode leetcode.com/problems/...

Problem Statement / Solution / Code

Time: **O(-)** Space: **O(-)**

- ...