

# **Algorithm and Problem Solving Cheatsheet in C++**

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

**rfdavid, 2025**

[rfdavid.com](https://rfdavid.com)

**MOTIVATION**

# 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 learned 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\*\*](https://github.com/rfdavid/cpp-algo-cheatsheet)

# Some Useful Links

## **Tech Interview Handbook**

<https://www.techinterviewhandbook.org>

A very well-structured resource for interview preparation

## **TUF**

<https://takeuforward.org/interviews/blind-75-leetcode-problems-detailed-video-solutions>

Contains explanation and some videos for the problems from blind 75 list

## **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 Problem](#)  
[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 BST](#)
- [Lowest Common Ancestor of BST](#)
- [Implement Trie \(Prefix Tree\)](#)
- [Add and Search Word](#)
- [Word Search II](#)

## Heap

- [Merge K Sorted Lists](#)
- [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](#) ★

# Other problems

## Tree

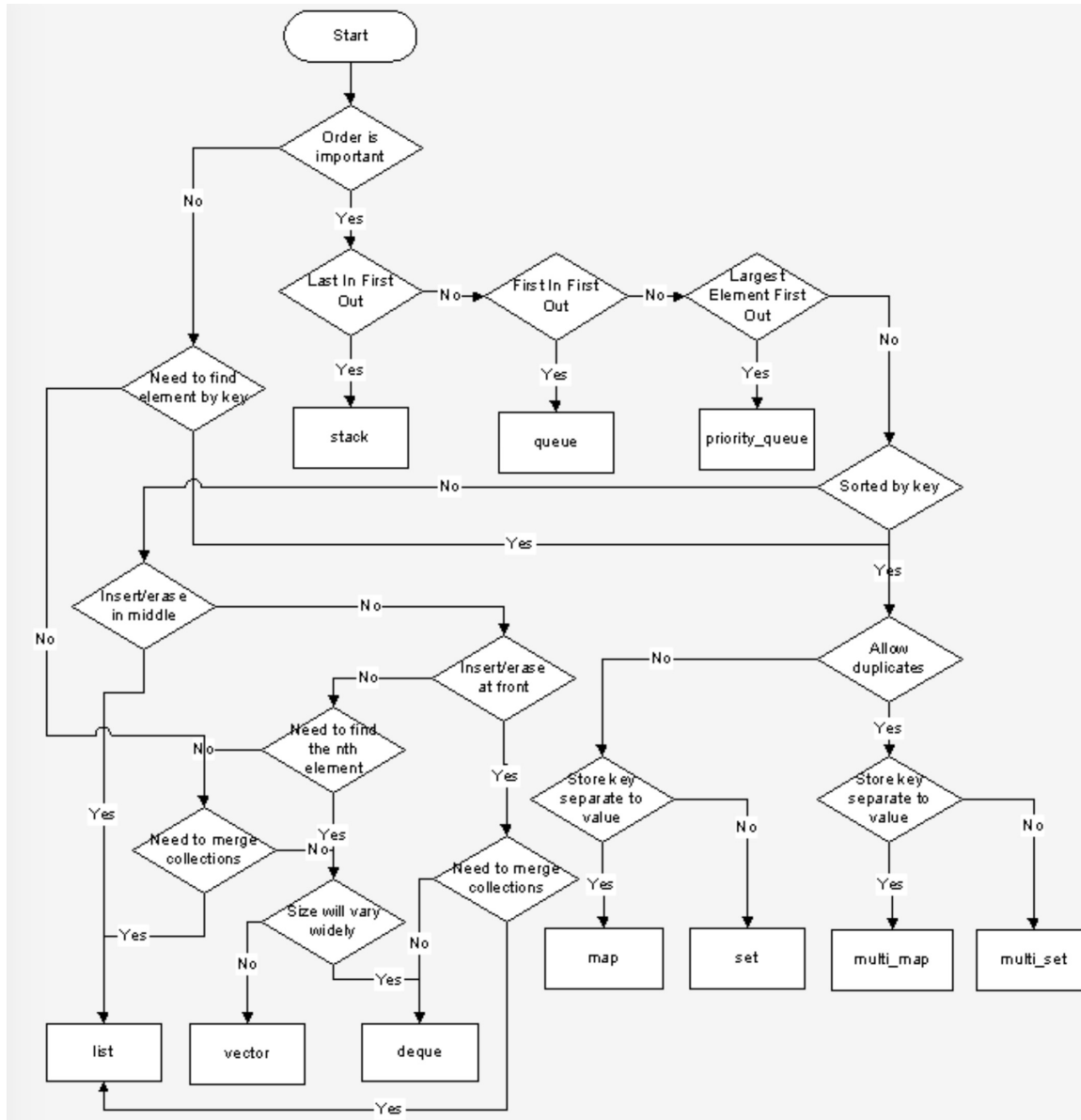
- ✓ [Maximum Level Sum of a Binary Tree](#)
- ✓ [Minimum Number of Increments on Subarrays to Form a Target Array](#)

# 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

- desc

# Queue

- desc

# Heap

- desc

# Hash Table

- desc

# Tree

- desc



# ARRAY

## 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 – Two Sum

Easy



LeetCode

[leetcode.com/problems/two-sum](https://leetcode.com/problems/two-sum)

## Problem Statement

- 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]

$\text{array}[0] + \text{array}[1] = 2 + 7 = 9$



LeetCode

[leetcode.com/problems/two-sum](https://leetcode.com/problems/two-sum)

## Solution

- Iterative over each number in the array
- Calculate the difference between target and each number, example:  
 $\text{array}[0] = 2, \text{ target } 9, \text{ then } 9 - 2 = 7$
- 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  
 $\text{hash}[7] \text{ exists?}$
- 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  
 $\text{hash}[2] = 0$

# Code – Two Sum

Easy



LeetCode

[leetcode.com/problems/two-sum](https://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 - Best Time to Buy and Sell Stock

Easy



LeetCode

[leetcode.com/problems/best-time-to-buy-and-sell-stock](https://leetcode.com/problems/best-time-to-buy-and-sell-stock)

## Problem Statement

- Given an **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]

$\text{array}[3] - \text{array}[1] = 4 - 1 = 3$

# Solution - Best Time to Buy and Sell Stock

Easy



LeetCode

[leetcode.com/problems/best-time-to-buy-and-sell-stock](https://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](https://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](https://leetcode.com/problems/best-time-to-buy-and-sell-stock)

## Code (optimized) Time: $O(n)$ Space: $O(1)$

- 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](https://leetcode.com/problems/best-time-to-buy-and-sell-stock-ii)

## Problem Statement

■ ...

# Solution - Best Time to Buy and Sell Stock II

Medium



LeetCode

[leetcode.com/problems/best-time-to-buy-and-sell-stock-ii](https://leetcode.com/problems/best-time-to-buy-and-sell-stock-ii)

## Solution

■ ...

# Code - Best Time to Buy and Sell Stock II

Medium



LeetCode

[leetcode.com/problems/best-time-to-buy-and-sell-stock-ii](https://leetcode.com/problems/best-time-to-buy-and-sell-stock-ii)

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

```
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;  
}
```

# Problem - Best Time to Buy and Sell Stock IV

Hard

 [leetcode.com/problems/best-time-to-buy-and-sell-stock-iv](https://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](https://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](https://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 – Valid Parentheses

Easy



LeetCode

[leetcode.com/problems/valid-parentheses](https://leetcode.com/problems/valid-parentheses)

## Problem Statement

- Given a string ...

# Solution – Valid Parentheses

Easy



LeetCode

[leetcode.com/problems/valid-parentheses](https://leetcode.com/problems/valid-parentheses)

## Solution

- Explain...

# Code – Valid Parentheses

Easy



LeetCode

[leetcode.com/problems/valid-parentheses](https://leetcode.com/problems/valid-parentheses)

## Code

```
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 – Minimum Number of Increments on Subarrays

Hard



LeetCode

[leetcode.com/problems/minimum-number-of-increments-on-subarrays-to-form-a-target-array](https://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](https://leetcode.com/problems/minimum-number-of-increments-on-subarrays-to-form-a-target-array)

## Solution

- Explain...

# Code – Minimum Number of Increments on Subarrays

Hard



LeetCode

[leetcode.com/problems/minimum-number-of-increments-on-subarrays-to-form-a-target-array](https://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;  
}
```

# Code [2] – Minimum Number of Increments on Subarrays

Hard



LeetCode

[leetcode.com/problems/minimum-number-of-increments-on-subarrays-to-form-a-target-array](https://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); });  
}
```



**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 3 – Longest Substring Without Repeating Characters

Medium

 [leetcode.com/problems/longest-substring-without-repeating-characters](https://leetcode.com/problems/longest-substring-without-repeating-characters)

Given a string, the goal is to find the longest substring without repeating characters.

For example, given a string “abcbd”, it should return 4:

**abcd** since “b” is repeated

# Solution 3 – Longest Substring Without Repeating Characters

Medium

- Using bitset: create a bitmask with 128 bits where each bit represent a character
- Use sliding window represented by **left** and **right**
- Set the bit to true for each character found
- Check if it is repeated and reset the bit

```
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;  
}
```

# 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**

$$0 + 0 = 0$$

$$1 + 0 = 1$$

$$1 + 1 = 0 \quad \text{with a negative carry 1}$$

$$\mathbf{1} + 1 = 0 \quad (\text{subtract})$$

$$\mathbf{1} + 0 = 1 \quad \text{with a positive carry 1}$$

# Negabinary

## Example 1

$$\begin{array}{r} 11\ 1 \\ 1011 \\ + 1110 \\ \hline = 110001 \end{array}$$

$$1 + 0 = 1$$

$$1 + 1 = 0 \text{ with negative carry } 1$$

$$1 + 1 = 0$$

$$1 + 1 = 0 \text{ with negative carry } 1$$

$$1 + 0 = 1 \text{ with positive carry } 1$$

$$1 + 0 = 1$$

red 1 = negative carry

green 1 = regular carry

## Example 2

$$\begin{array}{r} 1111 \\ 101010 \\ + 101100 \\ \hline = 11110110 \end{array}$$

## 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



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 neighbours
        for (const auto& n : node->neighbors) {
            graph[node->val]->neighbors.push_back(cloneGraph(n));
        }
    }
    return graph[node->val];
}
```

# GRAPH (BFS)

# Problem – Maximum Level Sum of a Binary Tree

Medium

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

## Problem Statement

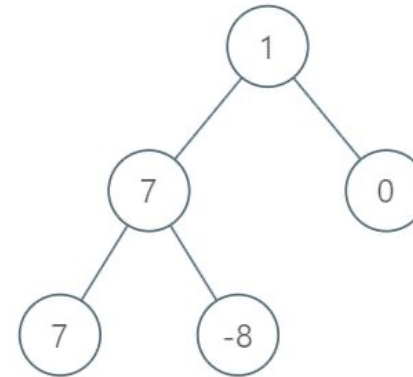
- Given the root of a binary tree, find the smallest level with the maximum sum
- For example, the tree below has the follow sums for each level:

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](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

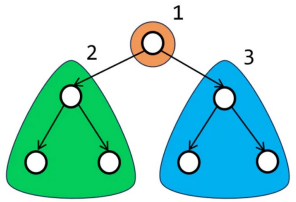
- BFS
- Dijkstra
- Bellman-Ford
- Floyd-Warshall
- A\* search
- Johnson's
- SPFA (Shortest Path Faster)
- Bidirectional Search

**TREE**

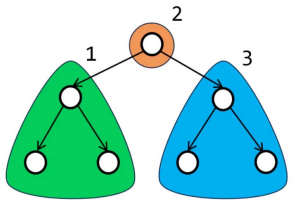
# Tree Traversals

## Depth-First Traversals

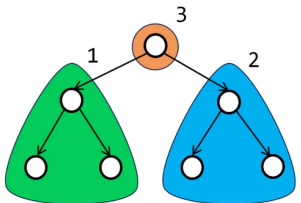
- **Pre-order:** Root - Left - Right



- **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.

# 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);
    }
}
```

# Problem – Maximum Depth of Binary Tree

Easy

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

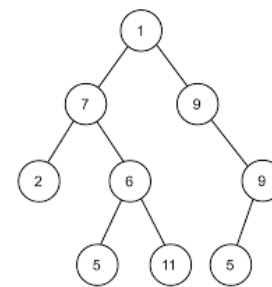
## Problem Statement

- 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

 <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:**

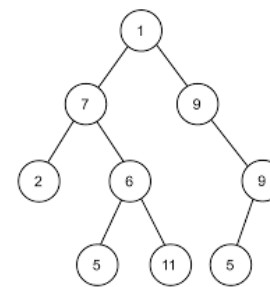
root = [1,7,9,2,6,null,9,null,null,5,11,5,null]

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

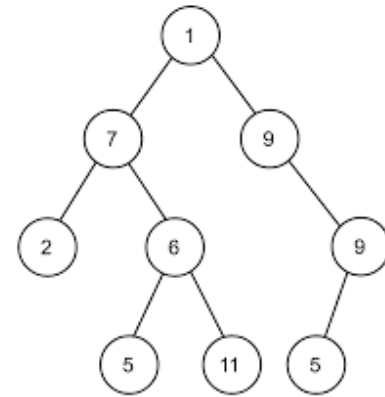


LeetCode

<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 – Kth Smallest Element in a BST

Medium

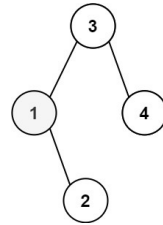
<https://leetcode.com/problems/kth-smallest-element-in-a-bst>

Given the **root** of a binary search tree, and an integer **k**, return the **k<sup>th</sup>** smallest value (1-indexed) of all the values of the nodes in the tree.

## Example 1

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

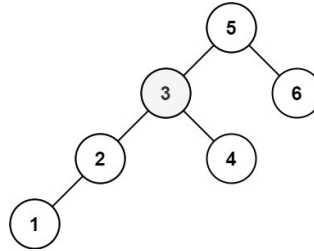
Output: 1



## Example 2

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

Output: 3





# Solution – Kth Smallest Element in a BST

Medium

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

```
int kthSmallest(TreeNode* root, int k) {
    int count = 0;
    int output;
    traverse(root, count, output, k);
    return output;
}

// perform in-order traversal: left, node, right
void traverse(TreeNode* node, int& count, int &output, int k) {
    if (!node) return;
    traverse(node->left, count, output, k);
    count++;
    if (count == k) {
        output = node->val;
        return;
    }
    traverse(node->right, count, output, k);
}
```

# LINKED LIST

# Problem – Swap Nodes in Pair

Medium

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

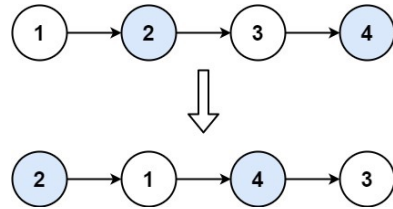
## Problem

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>

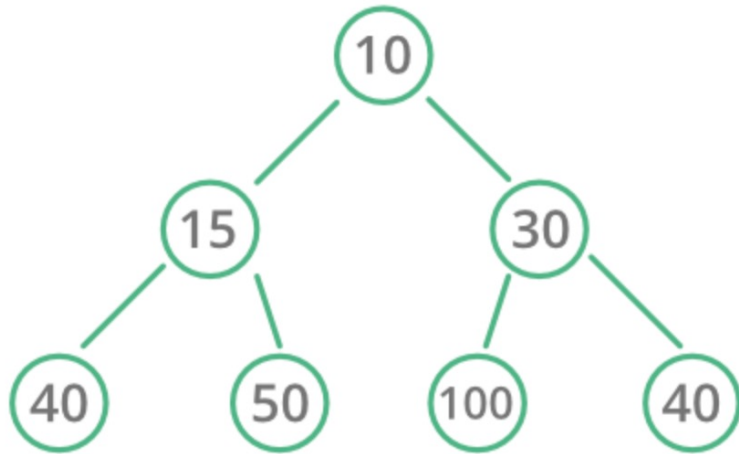
```
ListNode* swapPairs(ListNode* head) {  
    if(!head || !head->next)  
        return head;  
    ListNode* newHead = head->next;  
    head->next = swapPairs(head->next->next);  
    newHead->next = head;  
    return newHead;  
}
```

# HEAP / PRIORITY QUEUE

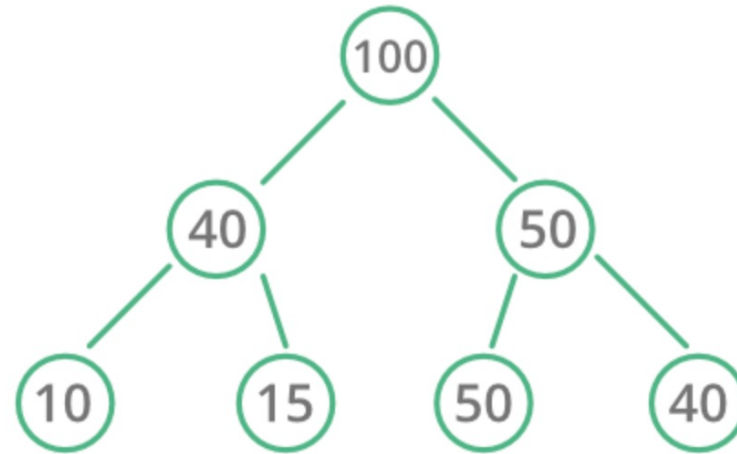
# Heap

- **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

Min Heap



Max Heap



# 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  $k^{\text{th}}$  largest element in the array. Note that it is the  $k^{\text{th}}$  largest element in the sorted order, not the  $k^{\text{th}}$  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>

// 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>

```
// 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();  
}
```

# **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.

# 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](https://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

Blind  
75

Easy



LeetCode

[leetcode.com/problems/climbing-stairs](https://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];  
}
```

**EOF**