ARRAY

Arrays

- **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.

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 – 1. 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 – 1. 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 – 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

- 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 – 217. 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) {
        if (seen[nums[i]] == 1) {
            return true;
        }
        seen[nums[i]]++;
    }
    return false;
}
```

Another solution (less flexible)

```
bool containsDuplicate(vector<int>& nums) {
    unordered_map<int, bool> seen;
    for (const auto& num : nums) {
        if (seen[num]) {
            return true;
        }
        seen[num] = true;
    }
    return false;
}
```

Problem – 238. Product of Array Except Self

Medium

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

Problem Statement

- You are given an integer array **nums**
- Return another array where each element is multiplied by all the elements except itself
- Example:

```
nums = [14,2,5,99]

nums[0] = 2 * 5 * 99 (all except 14)

nums[1] = 14 * 5 * 99 (all except 2)

nums[2] = 14 * 2 * 99

nums[3] = 14 * 2 * 5
```

Solution – 238. Product of Array Except Self

Medium

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

Solution

- Go over the array once and calculate the product of the left side. Example:

```
nums = [14,2,5]
left[0] = 1  (think of multiplying all elements before 14, so 1 because there is none)
left[1] = 14 (all elements from the left multiplied, except 2)
left[2] = 14 * 2 = 28 (all elements from the left multiplied, except 5)
left = [1, 14, 28]
```

- Using the same logic, do the same calculation but starting from the right

```
right[2] = 1 (no elements after 5)
right[1] = 5 (only 5 after 2)
right[0] = 2 * 5 = 10
right = [10, 5, 1]
```

- Multiply each element from left and right:

```
left ⊙ right = [1, 14, 28] ⊙ [10,5,1] = [10, 70, 28]
```

Code – 238. Product of Array Except Self

Medium

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

Code

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

```
vector<int> productExceptSelf(vector<int>& nums) {
    int n = nums.size();
    vector<int> output(n, 1);
    vector<int> right(n, 1);

    // calculate left first
    for (int i = 1; i < n; ++i) {
        output[i] = nums[i - 1] * output[i - 1];
    }
    // calculate right
    for (int i = n - 1; i >= 0; --i) {
        right[i] = nums[i + 1] * right[i + 1];
        output[i] = output[i] * right[i];
    }

    /* or you can save some space using this logic,
      although I don't find it as intuitive as the previous one
    int right = 1;
    for (int i = n - 1; i >= 0; --i) {
        output[i] *= right;
        right *= nums[i];
    */

    return output;
}
```

Code – 238. Product of Array Except Self

Medium

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

Code (better)

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

```
vector<int> productExceptSelf(vector<int>& nums) {
    vector<int> res;

    int prefix = 1;
    for (int i = 0; i < nums.size(); ++i) {
        res.push_back(prefix);
        prefix *= nums[i];
    }

    int suffix = 1;
    for (int i = nums.size() - 1; i >= 0; --i) {
        res[i] *= suffix;
        suffix *= nums[i];
    }

    return res;
}
```

Problem – 53. Maximum Subarray

Medium

LeetCode leetcode.com/problems/maximum-subarray

Problem

- You are given an array nums
- Find the subarray with the largest sum
- **Example:**

  `nums = [-2,1,-3,4,-1,2,1,-5,4]`

  `output = 6`

  The subarray `[4,-1,2,1]` has the largest sum 6.

Problem – 53. Maximum Subarray

Medium

LeetCode leetcode.com/problems/maximum-subarray

Solution

- Use Kadane's algorithm to find the maximum sum of a contiguous subarray in linear time
- Core idea:

  at each index, either:

  1. start a new subarray at **nums[i]** or
  2. extend the current one by adding **nums[i]**

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 – 53. Maximum Subarray

Medium

LeetCode leetcode.com/problems/maximum-subarray

Code

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

```
int maxSubArray(vector<int>& nums) {
    int maxSum = nums[0];
    int currentSum = nums[0];
    for (int i = 1; i < nums.size(); ++i) {
        currentSum = max(nums[i], currentSum + nums[i]);
        maxSum = max(maxSum, currentSum);
    }
    return maxSum;
}
```

Problem – 152. Maximum Product Subarray

Medium

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

Problem

- You are given an array **nums**
- Find a subarray that has the largest product and return the product
- The array may contain negative numbers
- **Example:**

  `nums = [2, 3, -2, 4]`

  `output = 6`

  `[2,3]` has the largest `6 (2 * 3)`

Problem – 152. Maximum Product Subarray

Medium

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

Solution

- Use a modified version of Kadane's algorithm
- Keep track of the minimum and maximum product
- Once the current number is negative, swap minimum product with maximum product
- Check the largest product between maximum product and the final result

Problem – 152. Maximum Product Subarray

Medium

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

Code

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

```
int maxProduct(vector<int>& nums) {
    int result = nums[0];
    int maxProd = nums[0];
    int minProd = nums[0];
    for (int i = 1; i < nums.size(); ++i) {
        if (nums[i] < 0) {
            swap(minProd, maxProd);
        }

        minProd = min(nums[i], nums[i] * minProd); // -2
        maxProd = max(nums[i], nums[i] * maxProd); // -30

        result = max(result, maxProd);
    }
    return result;
}
```

Problem – 153. Find Minimum in Rotated Sorted Array

Medium

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

Problem

- You are given a sorted array but “rotated”
- Rotated means the elements are displaced in order
- Return the **minimum element**
- **Example:**

  `nums = [3,4,5,1,2]`

  `output = 1` (minimum element)

Solution – 153. Find Minimum in Rotated Sorted Array

Medium

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

Solution

- Perform an adapted binary search
- Example:

  `[3,4,5,1,2]`

  left = 3, **mid = 5, right =2**

  You find mid (5), but have to go right, so adjust left:

```
if (mid > right)
    left = mid + 1
else
    right = mid
```

Code – 153. Find Minimum in Rotated Sorted Array

Medium

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

Code

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

```
int findMin(vector<int>& nums) {
    int left = 0;
    int right = nums.size() - 1;
    while (left < right) {
        int mid = left + (right - left) / 2;
        if (nums[mid] > nums[right]) {
            left = mid + 1;
        } else {
            right = mid;
        }
    }
    return nums[left];
}
```

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(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;
}
```

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(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

Problem

- 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(1)**

```
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 – 33. Search in Rotated Sorted Array

Medium

LeetCode leetcode.com/problems/search-in-rotated-sorted-array

Problem

- Variation of *Find Minimum in Sorted Rotated Array problem*
- You are given a sorted **array** but "rotated" and a target number **n**
- Rotated means the elements are displaced in order
- Search the number **n** and return its index
- **Example**

  `nums = [4,5,6,7,0,1,2], target = 0`

  Output: 4

  4 is the index where the target number **0** is located

Problem – 33. Search in Rotated Sorted Array

Medium

LeetCode leetcode.com/problems/search-in-rotated-sorted-array

Solution

- Perform a binary search with some modification
- One side is always sorted, so find which side (left or right)
- Check if the target is in the range of the sorted side and adjust mid

  Example:

  [2,4,5,6,7,0,1] target = 0

  1. Find mid (6)
  2. Find the sorted side (left) = [2,4,5]
  3. Check if your target is in this side. Is **target** between 2 and 5?
  4. Adjust mid to search at the other side if not, otherwise continue searching at the same side

Problem – 33. Search in Rotated Sorted Array

Medium

LeetCode leetcode.com/problems/search-in-rotated-sorted-array

Code

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

```
int search(vector<int>& nums, int target) {
    int left = 0;
    int right = nums.size() - 1;

    while (left <= right) {
        int mid = left + (right - left) / 2;
        if (nums[mid] == target) return mid;

        // figure it out the sorted side
        if (nums[mid] >= nums[0]) {
            // left side is sorted
            // is target within this range?
            if (target >= nums[0] && target < nums[mid]) {
                right = mid - 1;
            } else {
                left = mid + 1;
            }
        } else {
            // right side is sorted
            // is target within this range?
            if (target <= nums[right] && target > nums[mid]) {
                left = mid + 1;
            } else {
                right = mid - 1;
            }
        }
    }
    return -1;
}
```

Problem – 15. 3Sum

Medium

LeetCode leetcode.com/problems/3sum

Problem

- You are given an array of integer **nums**
- Find distinct triples that the final sum is equal to zero
- **Example**:

  `nums = [-1,0,1,2,-1,-4]`

  Output:

  `[[-1,-1,2],[-1,0,1]]`

  Explanation:

  `nums[0] + nums[1] + nums[2] = (-1) + 0 + 1 = 0.`

  `nums[1] + nums[2] + nums[4] = 0 + 1 + (-1) = 0.`

  `nums[0] + nums[3] + nums[4] = (-1) + 2 + (-1) = 0.`

  The distinct triplets are `[-1,0,1]` and `[-1,-1,2]`.

Solution – 15. 3Sum

Medium

LeetCode leetcode.com/problems/3sum

Solution

- Use three pointers: **i, j** and **k**
- Sort the array. This is necessary to move the pointers **j** and **k**
- Pointer **i** starts at the beginning the array
- Pointer **j** starts at i + 1 (second position)
- Pointer **k** starts at the end of the array
- Pointer **i** always move forward until the end of the array
- For each value of **i,** j and k will move either forward or backward, depending on the results of the sum
- Once find a sum == 0, add to a set to guarantee no duplicates

Code – 15. 3Sum

Medium

LeetCode leetcode.com/problems/3sum

Code

Time: **O(n² log n)** Space: **O(n²)**

```
vector<vector<int>> threeSum(vector<int>& nums) {
    set<vector<int>> triplets;
    sort(nums.begin(), nums.end());
    for (int i = 0; i < nums.size() - 2; ++i) {
        int j = i + 1;
        int k = nums.size() - 1;
        // it is a solution
        while (j < k) {
            int sum = nums[i] + nums[j] + nums[k];
            if (sum == 0) {
                triplets.insert({nums[i], nums[j], nums[k]});
                j++;
                k--;
            }
            if (sum < 0) {
                j++;
            } else {
                k--;
            }
        }
    }
    vector<vector<int>> result;
    // convert the solutions to the expected return
    for (const auto& t : triplets) {
        result.push_back(t);
    }

    return result;
}
```

Note: why not a unordered_set which is hash-based?

Problem – 11. Container With Most Water

Medium

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

Problem Statement

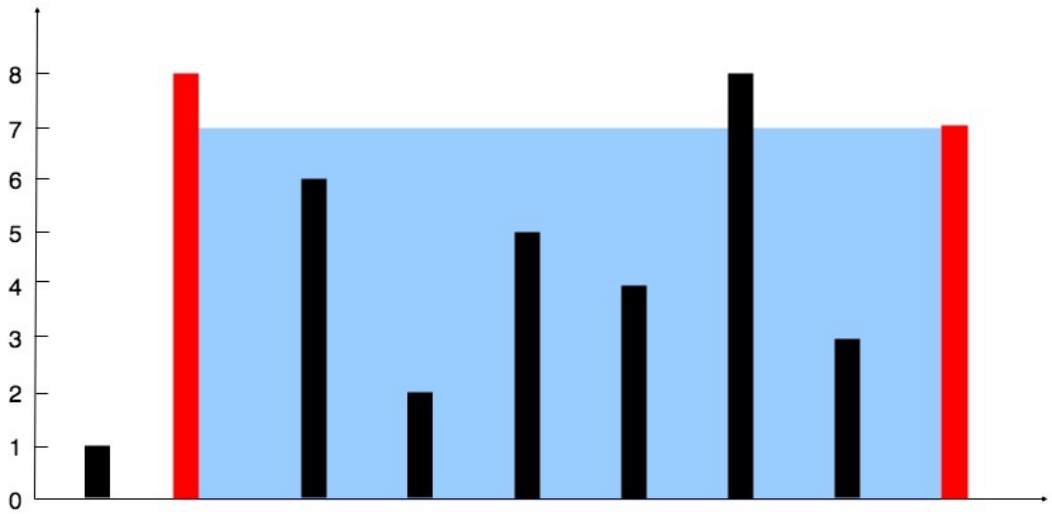
- You are given an integer array **height**
- Find two lines that together with x-axis form a container with most water
- Example:

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 – 11. Container With Most Water

Medium

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

Code

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

```
int maxArea(vector<int>& height) {
    // left and right = positions
    int left = 0;
    int right = height.size() - 1;
    int maxArea = 0;
    while (left < right) {
        int area = min(height[left], height[right]) * (right - left);
        maxArea = max(maxArea, area);
        // adjust left and right based on 'greedy' algorithm
        // move from the lowest height
        if (height[left] < height[right]) {
            left++;
        } else {
            right--;
        }
    }
    return maxArea;
}
```

Problem – 268. Missing Number

Easy

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

Problem

- You are given an **array of nums** with **n** distinct numbers
- Return only the number in the range that is missing from the array
- **Example**:

  `nums = [3, 0, 1]`

  Output: 2

  from the sequence `0,1,x,3` the missing number x is 2

Solution – 268. Missing Number

Easy

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

Solution

- You have an array with **size n**. Example:

  `nums = [3,0,1]`

  `size = 3`

- It is expected the sum **0 + 1 + 2 + … + n**:

  `0 + 1 + 2 + 3  = 6`

- The **expected sum** can be calculated with **Gauss Formula**: $\frac{n(n+1)}{2}$

  `n = 3`

  `n * (n + 1) / 2  = 3 * (3 + 1) / 2 = 6`

- Once you know the expected sum, calculate the sum from the elements of the array:

  `sum = 3 + 0 + 1 = 4`

- Subtract from the expected value to find out the number:

  6 – 4 = **2 is the missing number**

Code – 268. Missing Number

Easy

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

Code

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

```cpp
int missingNumber2(vector<int>& nums) {
    int n = nums.size();
    // Gauss's formula: the sum of numbers 0 to n is n * (n + 1) / 2
    int expected = n * (n + 1) / 2;
    // calculate actual sum
    int actual = std::accumulate(nums.begin(), nums.end(), 0);
    // result is the expected - actual
    return expected - actual;
}
```