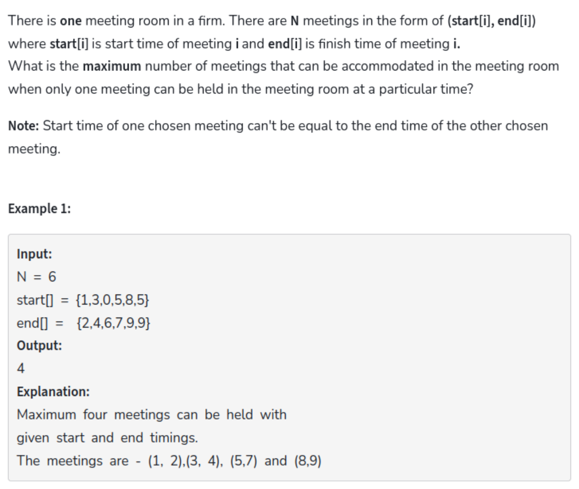
Greedy Algorithm → local optimum

* N meetings in one room :-



There is **one** meeting room in a firm. There are **N** meetings in the form of **(start[i], end[i])** where **start[i]** is start time of meeting **i** and **end[i]** is finish time of meeting **i**.
What is the **maximum** number of meetings that can be accommodated in the meeting room when only one meeting can be held in the meeting room at a particular time?

Note: Start time of one chosen meeting can't be equal to the end time of the other chosen meeting.

Example 1:

```
Input:
N = 6
start[] = {1,3,0,5,8,5}
end[] =  {2,4,6,7,9,9}
Output:
4
Explanation:
Maximum four meetings can be held with
given start and end timings.
The meetings are - (1, 2),(3, 4), (5,7) and (8,9)
```

→ Sort on the basis of end time

(1,2) (3,4) (0,6) (5,7) (8,9) (5,9)

mEnd = 0

if(mEnd < startVal) → meeting can be conducted.

-1 < 1 ✓

mEnd = 2

3<0 ✗

2 < 3 ✓

mEnd = 3.

3<5 ✓

7<8 ✓

⇒ 4 ans

8<5 ✗

```
class Solution
{
    public:
    //Function to find the maximum number of meetings that can
    //be performed in a meeting room.
    static bool cmp(pair<int, int> a, pair<int, int> b) {
        return a.second < b.second;
    }
    int maxMeetings(int start[], int end[], int n)
    {
        vector<pair<int, int>> v;
        for(int i = 0; i < n; i++) {
            v.push_back({start[i], end[i]});
        }
        sort(v.begin(), v.end(), cmp);

        int count = 1;
        int ansEnd = v[0].second;

        for(int i = 1; i < n; i++) {
            if(ansEnd < v[i].first) {
                count++;
                ansEnd = v[i].second;
            }
        }
        return count;
    }
};
```

Time Complexity : O(nlogn)

Space complexity : O(n)

* Shop in Candy store :-

In a candy store, there are **N** different types of candies available and the prices of all the N different types of candies are provided to you.
You are now provided with an attractive offer.
For every candy you buy from the store and get **K** other candies (all are different types) for free.
Now you have to answer two questions. Firstly, you have to find what is the **minimum amount of money** you have to spend to buy all the **N** different candies. Secondly, you have to find what is the **maximum amount of money** you have to spend to buy all the N different candies.
In both the cases you must utilize the offer i.e. you buy one candy and get **K** other candies for free.

Example 1:

Input:
N = 4
K = 2
candies[] = {3 2 1 4}

Output:
3 7

Explanation:
As according to the offer if you buy one candy you can take at most two more for free. So in the first case, you buy the candy which costs 1 and takes candies worth 3 and 4 for free, also you buy candy worth 2 as well.
So **min cost** : 1+2 =3.
In the second case, you can buy the candy which costs 4 and takes candies worth 1 and 2 for free, also you need to buy candy worth 3 as well.
So **max cost :** 3+4 =7.

```
class Solution
{
public:
    vector<int> candyStore(int candies[], int N, int K)
    {
        sort(candies, candies + N);
        int mini = 0;
        int buy = 0;
        int free = N - 1;
        while(buy <= free) {
            mini = mini + candies[buy++];
            free = free - K;
        }

        int maxi = 0;
        buy = N -1;
        free = 0;

        while(free <= buy) {
            maxi += candies[buy--];
            free += K;
        }
        return {mini, maxi};
    }
};
```

Check if possible to survive island:-

Geekina got stuck on an island. There is only one shop on this island and it is open on all days of the week except for Sunday. Consider following constraints:

- N – The maximum unit of food you can buy each day.
- S – Number of days you are required to survive.
- M – Unit of food required each day to survive.

Currently, it's Monday, and she needs to survive for the next S days.
Find the minimum number of days on which you need to buy food from the shop so that she can survive the next S days, or determine that it isn't possible to survive.

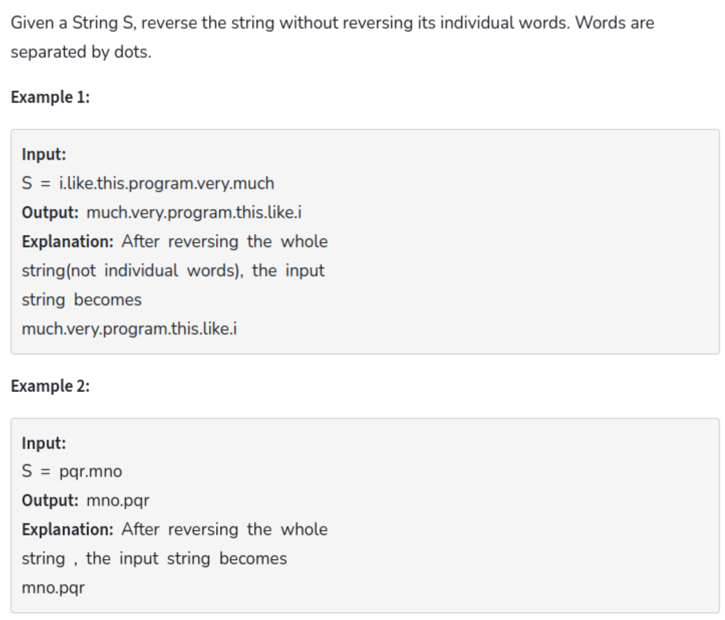
Example 1:

Input: S = 10, N = 16, M = 2
Output: 2
Explaination: One possible solution is to buy a box on the first day (Monday), it's sufficient to eat from this box up to 8th day (Monday) inclusive. Now, on the 9th day (Tuesday), you buy another box and use the chocolates in it to survive the 9th and 10th day.

```
class Solution{
public:
    int minimumDays(int S, int N, int M){
        int sundays = S / 7;

        int buyingDays = S - sundays;
        int totalFood = S * M;
        int ans = 0;
        if(totalFood % N == 0) ans = totalFood / N;
        else ans = totalFood / N + 1;
        if(ans <= buyingDays) return ans;
        return -1;
    }
};
```

Reverse Words in a given string:-


Given a String S, reverse the string without reversing its individual words. Words are separated by dots.

Example 1:

Input:
S = i.like.this.program.very.much
Output: much.very.program.this.like.i
Explanation: After reversing the whole string(not individual words), the input string becomes much.very.program.this.like.i

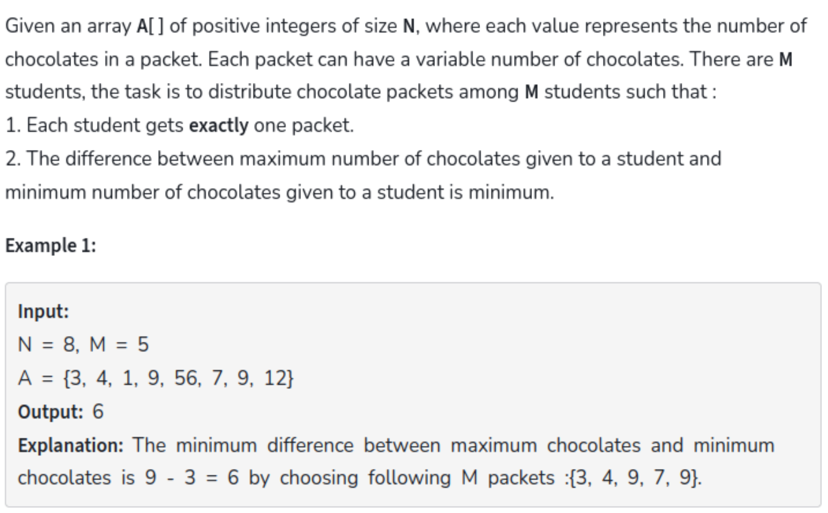
Example 2:

Input:
S = pqr.mno
Output: mno.pqr
Explanation: After reversing the whole string , the input string becomes mno.pqr

```
class Solution
{
    public:
    //Function to reverse words in a given string.
    string reverseWords(string S)
    {
        string ans = "";
        string temp = "";
        for(int i = S.length() - 1; i >= 0; i--) {
            if(S[i] == '.') {
                reverse(temp.begin(), temp.end());
                ans = ans + temp;
                ans.push_back('.');
                temp = "";
            } else {
                temp.push_back(S[i]);

            }
        }
        reverse(temp.begin(), temp.end());
        ans = ans + temp;
        return ans;
    }
};
```

Chocolate Distribution Problem:-

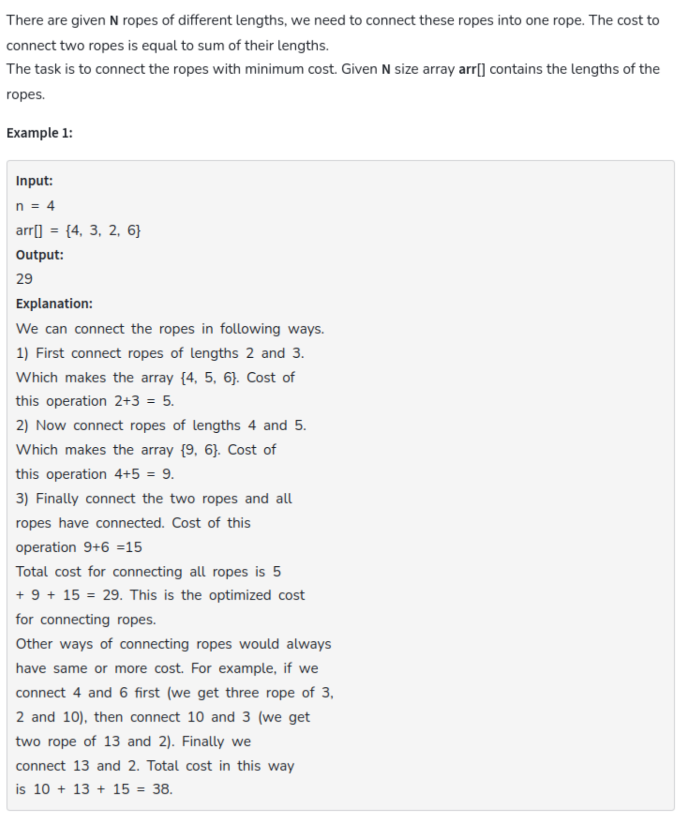

Given an array **A[ ]** of positive integers of size **N**, where each value represents the number of chocolates in a packet. Each packet can have a variable number of chocolates. There are **M** students, the task is to distribute chocolate packets among **M** students such that :
1. Each student gets **exactly** one packet.
2. The difference between maximum number of chocolates given to a student and minimum number of chocolates given to a student is minimum.

Example 1:

Input:
N = 8, M = 5
A = {3, 4, 1, 9, 56, 7, 9, 12}
Output: 6
Explanation: The minimum difference between maximum chocolates and minimum chocolates is 9 - 3 = 6 by choosing following M packets :{3, 4, 9, 7, 9}.

```
class Solution{
    public:
    long long findMinDiff(vector<long long> a, long long n, long long
        sort(a.begin(), a.end());
        int i = 0, j = m -1;
        int mini = INT_MAX;
        while(j < a.size()) {
            int diff = a[j] - a[i];
            mini = min(mini, diff);
            i++;
            j++;
        }
        return mini;
    }
};
```

Minimum cost of ropes :-



There are given **N** ropes of different lengths, we need to connect these ropes into one rope. The cost to connect two ropes is equal to sum of their lengths.
The task is to connect the ropes with minimum cost. Given **N** size array **arr[]** contains the lengths of the ropes.

Example 1:

```
Input:
n = 4
arr[] = {4, 3, 2, 6}
Output:
29
Explanation:
We can connect the ropes in following ways.
1) First connect ropes of lengths 2 and 3.
Which makes the array {4, 5, 6}. Cost of
this operation 2+3 = 5.
2) Now connect ropes of lengths 4 and 5.
Which makes the array {9, 6}. Cost of
this operation 4+5 = 9.
3) Finally connect the two ropes and all
ropes have connected. Cost of this
operation 9+6 =15
Total cost for connecting all ropes is 5
+ 9 + 15 = 29. This is the optimized cost
for connecting ropes.
Other ways of connecting ropes would always
have same or more cost. For example, if we
connect 4 and 6 first (we get three rope of 3,
2 and 10), then connect 10 and 3 (we get
two rope of 13 and 2). Finally we
connect 13 and 2. Total cost in this way
is 10 + 13 + 15 = 38.
```

```cpp
class Solution{
    public:
    //Function to return the minimum cost of connecting the ropes.
    long long minCost(long long arr[], long long n) {
        priority_queue<long long, vector<long long>, greater<long long>> pq;

        for(int i = 0; i < n; i++) pq.push(arr[i]);
        long long ans = 0;

        while(pq.size() > 1) {
            long long a = pq.top();
            pq.pop();

            long long b = pq.top();
            pq.pop();

            long long sum = a + b;

            ans += sum;
            pq.push(sum);
        }
        return ans;
    }
};
```

Huffman Coding

Given a string **S** of distinct character of size **N** and their corresponding frequency **f[ ]** i.e. character **S[i]** has **f[i]** frequency. Your task is to build the Huffman tree print all the huffman codes in preorder traversal of the tree.

Note: While merging if two nodes have the same value, then the node which occurs at first will be taken on the left of Binary Tree and the other one to the right, otherwise Node with less value will be taken on the left of the subtree and other one to the right.

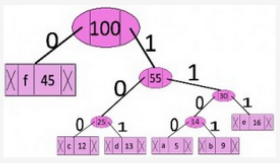
Example 1:

```
S = "abcdef"
f[] = {5, 9, 12, 13, 16, 45}
```

Output:

```
0 100 101 1100 1101 111
```

Explanation:



```
HuffmanCodes will be:
f : 0
c : 100
d : 101
a : 1100
b : 1101
e : 111
Hence printing them in the PreOrder of Binary
Tree.
```

Your Task:

You don't need to read or print anything. Your task is to complete the function **huffmanCodes()** which takes the given string **S**, frequency array **f[ ]** and number of characters **N** as input parameters and returns a vector of strings containing all huffman codes in order of preorder traversal of the tree.

```cpp
class Node{
    public:
        int data;
        Node* left;
        Node* right;

        Node(int d) {
            data = d;
            left = NULL;
            right = NULL;
        }
};

class cmp{
    public:
        bool operator()(Node* a, Node* b) {
            return a->data > b->data;
        }
};

class Solution
{
        public:
            void traverse(Node* root, vector<string> &ans, string temp) {
            if(root->left == NULL && root->right == NULL) {
                ans.push_back(temp);
                return;
            }
            traverse(root->left, ans, temp + '0');
            traverse(root->right, ans, temp + '1');
        }

                vector<string> huffmanCodes(string S,vector<int> f,int N)
                {
                    priority_queue<Node*, vector<Node*>, cmp> pq;
                    for(int i = 0; i < N; i++) {
                        Node* temp = new Node(f[i]);
                        pq.push(temp);
                    }
                    while(pq.size() > 1) {
                        Node* left = pq.top();
                        pq.pop();
                        Node* right = pq.top();
                        pq.pop();

                        Node* newNode = new Node(left->data + right->data);
                        newNode->left = left;
                        newNode->right = right;
                        pq.push(newNode);
                    }

                    Node* root = pq.top();
                    vector<string> ans;
                    string temp = "";
                    traverse(root, ans, temp);
                    return ans;
                }
};
```

Fractional Knapsack

Given weights and values of **N** items, we need to put these items in a knapsack of capacity **W** to get the **maximum** total value in the knapsack.

Note: Unlike 0/1 knapsack, you are **allowed** to break the item here.

Example 1:

Input:
N = 3, W = 50
value[] = {60,100,120}
weight[] = {10,20,30}
Output:
240.000000
Explanation:
Take the item with value 60 and weight 10, value 100 and weight 20 and split the third item with value 120 and weight 30, to fit it into weight 20. so it becomes (120/30)*20=80, so the total value becomes 60+100+80.0=240.0
Thus, total maximum value of item we can have is 240.00 from the given capacity of sack.

```
class Solution
{
    public:
    //Function to get the maximum total value in the knapsack.
    static bool cmp(pair<double, Item>a, pair<double, Item> b) {
        return a.first > b.first;
    }
    double fractionalKnapsack(int W, Item arr[], int n)
    {
        vector<pair<double, Item>> v;
        for(int i = 0; i < n; i++) {
            double perUnitVal = (1.0 * arr[i].value) / arr[i].weight;
            pair<double, Item> p = {perUnitVal, arr[i]};
            v.push_back(p);
        }
        sort(v.begin(), v.end(), cmp);

        double totalVal = 0;

        for(int i = 0; i < n; i++) {
            if(v[i].second.weight > W) {
                totalVal += W * v[i].first;
                W = 0;
            } else {
                totalVal += v[i].second.value;
                W -= v[i].second.weight;
            }
        }
        return totalVal;
    }

};
```

Job Sequencing Problem

Given a set of **N** jobs where each **job$_i$** has a deadline and profit associated with it.

Each job takes ***1*** unit of time to complete and only one job can be scheduled at a time. We earn the profit associated with job if and only if the job is completed by its deadline.

Find the number of jobs done and the **maximum profit**.

Note: Jobs will be given in the form (Job$_{id}$, Deadline, Profit) associated with that Job. Deadline of the job is the time before which job needs to be completed to earn the profit.

→ Sort on the basis of profit.

Example 1:

Input:
N = 4
Jobs = {(1,4,20),(2,1,10),(3,1,40),(4,1,30)}
Output:
2 60
Explanation:
Job$_1$ and Job$_3$ can be done with maximum profit of 60 (20+40).

→ Can use disjoint set to reduce the complexity

```
class Solution
{
    public:
    //Function to find the maximum profit and the number of jobs done.
    static bool cmp(Job a, Job b) {
        return a.profit > b.profit;
    }
    vector<int> JobScheduling(Job arr[], int n)
    {
        sort(arr, arr + n, cmp);

        int maxiDeadline = INT_MIN;

        for(int i = 0; i < n; i++) {
            maxiDeadline = max(maxiDeadline, arr[i].dead);
        }
        int count = 0, maxProfit = 0;
        vector<int> schedule(maxiDeadline + 1, -1);
        for(int i = 0; i < n; i++) {
            int currProfit = arr[i].profit;
            int currJobId = arr[i].id;
            int currDead = arr[i].dead;

            for(int k = currDead; k > 0; k--) {
                if(schedule[k] == -1) {
                    count++;
                    maxProfit += currProfit;
                    schedule[k] = currJobId;
                    break;
                }
            }
        }
        return {count, maxProfit};
    }
};
```

IPO

Suppose LeetCode will start its **IPO** soon. In order to sell a good price of its shares to Venture Capital, LeetCode would like to work on some projects to increase its capital before the **IPO**. Since it has limited resources, it can only finish at most `k` distinct projects before the **IPO**. Help LeetCode design the best way to maximize its total capital after finishing at most `k` distinct projects.

You are given `n` projects where the `i`th project has a pure profit `profits[i]` and a minimum capital of `capital[i]` is needed to start it.

Initially, you have `w` capital. When you finish a project, you will obtain its pure profit and the profit will be added to your total capital.

Pick a list of **at most** `k` distinct projects from given projects to **maximize your final capital**, and return *the final maximized capital*.

The answer is guaranteed to fit in a 32-bit signed integer.

Example 1:

```
Input: k = 2, w = 0, profits = [1,2,3], capital = [0,1,1]
Output: 4
Explanation: Since your initial capital is 0, you can only start the project indexed 0.
After finishing it you will obtain profit 1 and your capital becomes 1.
With capital 1, you can either start the project indexed 1 or the project indexed 2.
Since you can choose at most 2 projects, you need to finish the project indexed 2 to get
the maximum capital.
Therefore, output the final maximized capital, which is 0 + 1 + 3 = 4.
```

Example 2:

```
Input: k = 3, w = 0, profits = [1,2,3], capital = [0,1,2]
Output: 6
```

Constraints:

- $1 <= k <= 10^5$
- $0 <= w <= 10^9$
- `n == profits.length`
- `n == capital.length`
- $1 <= n <= 10^5$
- $0 <=$ `profits[i]` $<= 10^4$
- $0 <=$ `capital[i]` $<= 10^9$

→ Approach :-

- Greedy approach using priority queue.

```
class Solution {
public:
    int findMaximizedCapital(int k, int w, vector<int>& profits, vector<int>& capital) {
        int n = profits.size();
        vector<pair<int, int>> projects;
        for(int i = 0; i < n; i++) {
            projects.push_back({capital[i], profits[i]});
        }
        sort(projects.begin(), projects.end());
        priority_queue<int> pq;

        int index = 0;
        while(k--) {
            while(index < n && projects[index].first <= w) {
                pq.push(projects[index].second);
                index++;
            }
            if(pq.empty()) break;
            w += pq.top();
            pq.pop();
        }
        return w;
    }
};
```

Maximum Elegance of a K-Length Subsequence

You are given a **0-indexed** 2D integer array `items` of length `n` and an integer `k`.

`items[i] = [profit`$_i$`, category`$_i$`]`, where `profit`$_i$ and `category`$_i$ denote the profit and category of the `i`th item respectively.

Let's define the **elegance** of a **subsequence** of `items` as `total_profit + distinct_categories`^{2}, where `total_profit` is the sum of all profits in the subsequence, and `distinct_categories` is the number of **distinct** categories from all the categories in the selected subsequence.

Your task is to find the **maximum elegance** from all subsequences of size `k` in `items`.

Return *an integer denoting the maximum elegance of a subsequence of* `items` *with size exactly* `k`.

Note: A subsequence of an array is a new array generated from the original array by deleting some elements (possibly none) without changing the remaining elements' relative order.

Example 1:

```
Input: items = [[3,2],[5,1],[10,1]], k = 2
Output: 17
Explanation: In this example, we have to select a subsequence of size 2.
We can select items[0] = [3,2] and items[2] = [10,1].
The total profit in this subsequence is 3 + 10 = 13, and the subsequence contains 2
distinct categories [2,1].
Hence, the elegance is 13 + 2^2 = 17, and we can show that it is the maximum achievable
elegance.
```

```
class Solution {
public:
    long long findMaximumElegance(vector<vector<int>>& items, int k) {
        sort(items.begin(),items.end(),greater<vector<int>>());

        int n=items.size(),i;
        vector<int> cat_used(n+1,0);

        priority_queue<int,vector<int>,greater<int>> duplicates_min;
        long long elegance=0;
        for(i=0;i<k;i++){
            elegance+=items[i][0];
            if(++cat_used[items[i][1]]>1){
                duplicates_min.push(items[i][0]);
            }
        }
        long long distinct_categories = (k-duplicates_min.size());
        elegance+=distinct_categories*distinct_categories;

        long long ans=elegance;

        if(duplicates_min.empty())return ans;

        for(;i<n;i++){
            if(++cat_used[items[i][1]]==1){
                elegance += (long long)(items[i][0]-duplicates_min.top());
                elegance += (2*distinct_categories + 1);
                ans=max(ans,elegance);
                duplicates_min.pop();
                if(duplicates_min.empty())return ans;

                distinct_categories++;
            }
        }
        return ans;
    }
};
```

- Sort the array acc^n to larger profit.
- Now take k values for ans.
- In next for loop, take the non repeating no. & find max value.
- Return the ans.

[[2,2],[8,6],[10,6],[2,4],[9,5],[4,5]]