

Competitive Programming Notebook

Programadores Roblox

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1 Graph

1.1 Edmonds-karp

```

1 // Edmonds-Karp com scaling O(E log(F))
2
3 int n, m;
4 const int MAXN = 510;
5 vector<vector<int>> capacity(MAXN, vector<int>(MAXN, 0));
6 vector<vector<int>> adj(MAXN);
7
8 int bfs(int s, int t, int scale, vector<int>& parent) {
9   fill(parent.begin(), parent.end(), -1);
10  parent[s] = -2;
11  queue<pair<int, int>> q;
12  q.push({s, LLONG_MAX});
13
14  while (!q.empty()) {
15    int cur = q.front().first;
16    int flow = q.front().second;
17    q.pop();
18
19    for (int next : adj[cur]) {
20      if (parent[next] == -1 && capacity[cur][next] >=
21          scale) {
22        parent[next] = cur;
23        int new_flow = min(flow, capacity[cur][next]);
24
25        if (next == t)
26          return new_flow;
27        q.push({next, new_flow});
28      }
29    }
30  }
31  return 0;
32
33 int maxflow(int s, int t) {
34  int flow = 0;
35  vector<int> parent(MAXN);
36  int new_flow;
37  int scaling = 111 << 62;
38
39  while (scaling > 0) {
40    while (new_flow = bfs(s, t, scaling, parent)) {
41      if (new_flow == 0) continue;
42      flow += new_flow;
43      int cur = t;
44
45      while (cur != s) {
46        int prev = parent[cur];
47        capacity[prev][cur] -= new_flow;
48        capacity[cur][prev] += new_flow;
49        cur = prev;
50      }
51      scaling /= 2;
52    }
53
54  }
55  return flow;

```

1.2 Eulerian Path

```

1 /**
2  * versao que assume: #define int long long
3  *
4  * Retorna um caminho/ciclo euleriano em um grafo (se existir).
5  * - g: lista de adjacencia (vector<vector<int>>).
6  * - directed: true se o grafo for dirigido.
7  * - s: vertice inicial.
8  * - e: vertice final (opcional). Se informado, tenta caminho
9  *     de s ate e.
10 * - O(Nlog(N))
11 * Retorna vetor com a sequencia de vertices, ou vazio se
12 *     impossivel.
13 */
14 vector<int> eulerian_path(const vector<vector<int>>& g, bool
15   directed, int s, int e = -1) {
16  int n = (int)g.size();
17  // copia das adjacencias em multiset para permitir
18  // remocao especifica
19  vector<multiset<int>> h(n);

```

```

16  vector<int> in_degree(n, 0);
17  vector<int> result;
18  stack<int> st;
19  // preencher h e indegrees
20  for (int u = 0; u < n; ++u) {
21    for (auto v : g[u]) {
22      ++in_degree[v];
23      h[u].emplace(v);
24    }
25  }
26  st.emplace(s);
27  if (e != -1) {
28    int out_s = (int)h[s].size();
29    int out_e = (int)h[e].size();
30    int diff_s = in_degree[s] - out_s;
31    int diff_e = in_degree[e] - out_e;
32    if (diff_s * diff_e != -1) return {};
33  }
34  for (int u = 0; u < n; ++u) {
35    if (e != -1 && (u == s || u == e)) continue;
36    int out_u = (int)h[u].size();
37    if (in_degree[u] != out_u || (!directed && (in_degree
38 [u] & 1))) {
39      return {};
40    }
41  }
42  while (!st.empty()) {
43    int u = st.top();
44    if (h[u].empty()) {
45      result.emplace_back(u);
46      st.pop();
47    } else {
48      int v = *h[u].begin();
49      auto it = h[u].find(v);
50      if (it != h[u].end()) h[u].erase(it);
51      --in_degree[v];
52      if (!directed) {
53        auto it2 = h[v].find(u);
54        if (it2 != h[v].end()) h[v].erase(it2);
55        --in_degree[u];
56      }
57      st.emplace(v);
58    }
59  }
60  if (in_degree[u] != 0) return {};
61  reverse(result.begin(), result.end());
62  return result;
63}
64

```

1.3 Kosaraju

```

1 bool vis[MAXN];
2 vector<int> order;
3 int component[MAXN];
4 int N, m;
5 vector<int> adj[MAXN], adj_rev[MAXN];
6
7 // dfs no grafo original para obter a ordem (pos-order)
8 void dfs1(int u) {
9  vis[u] = true;
10  for (int v : adj[u]) {
11    if (!vis[v]) {
12      dfs1(v);
13    }
14  }
15  order.push_back(u);
16}
17
18 // dfs o grafo reverso para encontrar os SCCs
19 void dfs2(int u, int c) {
20  component[u] = c;
21  for (int v : adj_rev[u]) {
22    if (component[v] == -1) {
23      dfs2(v, c);
24    }
25  }
26}
27
28 int kosaraju() {
29  order.clear();
30  fill(vis + 1, vis + N + 1, false);
31  for (int i = 1; i <= N; i++) {
32    if (!vis[i]) {
33      dfs1(i);

```

```

34     }
35 }
36 fill(component + 1, component + N + 1, -1);
37 int c = 0;
38 reverse(order.begin(), order.end());
39 for (int u : order) {
40     if (component[u] == -1) {
41         dfs2(u, c++);
42     }
43 }
44 return c;
45 }

1.4 Min Cost Max Flow

1 // Encontra o menor custo para passar K de fluxo em um grafo
2 // com N vertices
3 // Funciona com multiplas arestas para o mesmo par de
4 // vertices
5 // Para encontrar o min cost max flow eh so fazer K =
6 // infinito
7
8 struct Edge {
9     int from, to, capacity, cost, id;
10}
11
12 const int INF = LLONG_MAX;
13
14 void shortest_paths(int n, int v0, vector<int>& dist, vector<
15     int>& edge_to) {
16     dist.assign(n, INF);
17     dist[v0] = 0;
18     vector<bool> in_queue(n, false);
19     queue<int> q;
20     q.push(v0);
21     edge_to.assign(n, -1);
22     while (!q.empty()) {
23         int u = q.front();
24         q.pop();
25         in_queue[u] = false;
26         for (auto [v, id] : adj[u]) {
27             if (edges[id].capacity > 0 && dist[v] > dist[u] +
28                 edges[id].cost) {
29                 dist[v] = dist[u] + edges[id].cost;
30                 edge_to[v] = id;
31                 if (!in_queue[v]) {
32                     in_queue[v] = true;
33                     q.push(v);
34                 }
35             }
36         }
37     }
38 }
39 void add_edge(int from, int to, int capacity, int cost){
40     edges.push_back({from, to, capacity, cost, (int)edges.
41     size()});
42     edges.push_back({to, from, 0, -cost, (int)edges.size()});
43     // reversa
44 }
45 int min_cost_flow(int N, int K, int s, int t) {
46     adj.assign(N, vector<array<int, 2>>());
47     for (Edge e : edges) {
48         adj[e.from].push_back({e.to, e.id});
49     }
50     int flow = 0;
51     int cost = 0;
52     vector<int> dist, edge_to;
53     while (flow < K) {
54         shortest_paths(N, s, dist, edge_to);
55         if (dist[t] == INF)
56             break;
57
58         // find max flow on that path
59         int f = K - flow;
60         int cur = t;
61         while (cur != s) {
62             f = min(f, edges[edge_to[cur]].capacity);
63

```

```

64             cur = edges[edge_to[cur]].from;
65         }
66
67         // apply flow
68         flow += f;
69         cost += f * dist[t];
70         cur = t;
71         while (cur != s) {
72             int edge = edge_to[cur];
73             int rev_edge = edge^1;
74
75             edges[edge].capacity -= f;
76             edges[rev_edge].capacity += f;
77             cur = edges[edge].from;
78         }
79
80         if (flow < K)
81             return -1;
82     else
83         return cost;
84 }
85 }

1.5 Topological Sort

1 vector<int> adj[MAXN];
2 vector<int> estado(MAXN); // 0: nao visitado 1: processamento
3 2: processado
4 vector<int> ordem;
5 bool temCiclo = false;
6 void dfs(int v) {
7     if(estado[v] == 1) {
8         temCiclo = true;
9         return;
10    }
11    if(estado[v] == 2) return;
12    estado[v] = 1;
13    for(auto &nei : adj[v]) {
14        if(estado[nei] != 2) dfs(nei);
15    }
16    estado[v] = 2;
17    ordem.push_back(v);
18    return;
19 }

1.6 Diametro

1 /*
2 O(N + M), retorna cara mais distante, len
3 do caminho em arestas e os caras do caminho em um vetor
4 Para pegar o diametro da arvore, chamar duas vezes
5 auto [a, DA, PA] = calc(1);
6 auto [b, len_diametro, caminho_diametro] = calc(a);
7 */
8 auto calc = [&](int S) -> tuple<int, int, vector<int>> {
9     queue<pair<int, int>> q;
10    q.push({S, 0});
11    vector<int> dp(n + 1, -1), pai(n + 1, 0);
12    dp[S] = 0;
13    pai[S] = -1;
14    int longe = S;
15    int dist = 0;
16    while (!q.empty()){
17        auto [u, d] = q.front();
18        q.pop();
19        if (d > dist){
20            dist = d;
21            longe = u;
22        }
23        for (int v : adj[u]){
24            if (dp[v] == -1){
25                dp[v] = d + 1;
26                pai[v] = u;
27                q.push({v, d + 1});
28            }
29        }
30    }
31    int cur = longe;
32    vector<int> caminho;
33    while (cur != -1){
34        caminho.push_back(cur);
35        cur = pai[cur];
36    }

```

```
37     return { longe, dist, caminho };
38 }
```

1.7 Floyd Warshall

```
1 // SSP e acha ciclos.
2 // Bom com constraints menores.
3 // O(n^3)
4
5 int dist[501][501];
6
7 void floydWarshall() {
8     for(int k = 0; k < n; k++) {
9         for(int i = 0; i < n; i++) {
10             for(int j = 0; j < n; j++) {
11                 dist[i][j] = min(dist[i][j], dist[i][k] +
12                     dist[k][j]);
13             }
14         }
15     }
16
17 void solve() {
18     int m, q;
19     cin >> n >> m >> q;
20     for(int i = 0; i < n; i++) {
21         for(int j = i; j < n; j++) {
22             if(i == j) {
23                 dist[i][j] = dist[j][i] = 0;
24             } else {
25                 dist[i][j] = dist[j][i] = lINF;
26             }
27         }
28     }
29     for(int i = 0; i < m; i++) {
30         int u, v, w;
31         cin >> u >> v >> w; u--; v--;
32         dist[u][v] = min(dist[u][v], w);
33         dist[v][u] = min(dist[v][u], w);
34     }
35     floydWarshall();
36     while(q--) {
37         int u, v;
38         cin >> u >> v; u--; v--;
39         if(dist[u][v] == lINF) cout << -1 << '\n';
40         else cout << dist[u][v] << '\n';
41     }
}
```

1.8 Khan

```
1 // topo-sort DAG
2 // lexicograficamente menor.
3 // N: numero de vértices (1-indexado)
4 // adj: lista de adjacencia do grafo
5
6 const int MAXN = 5 * 1e5 + 2;
7 vector<int> adj[MAXN];
8 int N;
9
10 vector<int> kahn() {
11     vector<int> indegree(N + 1, 0);
12     for (int u = 1; u <= N; u++) {
13         for (int v : adj[u]) {
14             indegree[v]++;
15         }
16     }
17     priority_queue<int, vector<int>, greater<int>> pq;
18     for (int i = 1; i <= N; i++) {
19         if (indegree[i] == 0) {
20             pq.push(i);
21         }
22     }
23     vector<int> result;
24     while (!pq.empty()) {
25         int u = pq.top();
26         pq.pop();
27         result.push_back(u);
28         for (int v : adj[u]) {
29             indegree[v]--;
30             if (indegree[v] == 0) {
31                 pq.push(v);
32             }
33         }
34     }
}
```

```
35     if (result.size() != N) {
36         return {};
37     }
38     return result;
39 }
```

1.9 Lca

```
1 // LCA - CP algorithm
2 // preprocessing O(NlogN)
3 // lca O(logN)
4 // Uso: criar LCA com a quantidade de vértices (n) e lista de
5 // adjacencias (adj)
6 // chamar a função preprocess com a raiz da árvore
7
8 struct LCA {
9     int n, l, timer;
10    vector<vector<int>> adj;
11    vector<int> tin, tout;
12    vector<vector<int>> up;
13
14 LCA(int n, const vector<vector<int>>& adj) : n(n), adj(
15     adj) {}
16
17 void dfs(int v, int p) {
18     tin[v] = ++timer;
19     up[v][0] = p;
20     for (int i = 1; i <= l; ++i)
21         up[v][i] = up[up[v][i-1]][i-1];
22     for (int u : adj[v]) {
23         if (u != p)
24             dfs(u, v);
25     }
26     tout[v] = ++timer;
27 }
28
29 bool is_ancestor(int u, int v) {
30     return tin[u] <= tin[v] && tout[u] >= tout[v];
31 }
32
33 int lca(int u, int v) {
34     if (is_ancestor(u, v))
35         return u;
36     if (is_ancestor(v, u))
37         return v;
38     for (int i = l; i >= 0; --i) {
39         if (!is_ancestor(up[u][i], v))
40             u = up[u][i];
41     }
42     return up[u][0];
43 }
44
45 void preprocess(int root) {
46     tin.resize(n);
47     tout.resize(n);
48     timer = 0;
49     l = ceil(log2(n));
50     up.assign(n, vector<int>(l + 1));
51     dfs(root, root);
52 }
53 }
```

1.10 Kruskal

```
1 // Ordena as arestas por peso, insere se ja nao estiver no
2 // mesmo componente
3 // O(E log E)
4
5 struct Edge {
6     int u, v, w;
7     bool operator <(Edge const & other) {
8         return weight < other.weight;
9     }
10
11 vector<Edge> kruskal(int n, vector<Edge> edges) {
12     vector<Edge> mst;
13     DSU dsu = DSU(n + 1);
14     sort(edges.begin(), edges.end());
15     for (Edge e : edges) {
16         if (dsu.find(e.u) != dsu.find(e.v)) {
17             mst.push_back(e);
18         }
19     }
20 }
```

```

18         dsu.join(e.u, e.v);
19     }
20 }
21 return mst;
22 }
```

1.11 Dijkstra

```

1 // SSP com pesos positivos.
2 // O((V + E) log V).
3
4 vector<int> dijkstra(int S) {
5     vector<bool> vis(MAXN, 0);
6     vector<ll> dist(MAXN, LLONG_MAX);
7     dist[S] = 0;
8     priority_queue<pii, vector<pii>, greater<pii>> pq;
9     pq.push({0, S});
10    while(pq.size()) {
11        ll v = pq.top().second;
12        pq.pop();
13        if(vis[v]) continue;
14        vis[v] = 1;
15        for(auto &[peso, vizinho] : adj[v]) {
16            if(dist[vizinho] > dist[v] + peso) {
17                dist[vizinho] = dist[v] + peso;
18                pq.push({dist[vizinho], vizinho});
19            }
20        }
21    }
22    return dist;
23 }
```

1.12 Dinitz

```

1 // Complexidade: O(V^2E)
2
3 struct FlowEdge {
4     int from, to;
5     long long cap, flow = 0;
6     FlowEdge(int from, int to, long long cap) : from(from),
7             to(to), cap(cap) {}
7 };
8
9 struct Dinic {
10    const long long flow_inf = 1e18;
11    vector<FlowEdge> edges;
12    vector<vector<int>> adj;
13    int qntV, qntE = 0;
14    int source, sink;
15    vector<int> level, ptr;
16    queue<int> q;
17
18    Dinic(int qntV, int source, int sink) : qntV(qntV),
19        source(source), sink(sink) {
20        adj.resize(qntV);
21        level.resize(qntV);
22        ptr.resize(qntV);
23    }
24
25    void add_edge(int from, int to, long long cap) {
26        edges.emplace_back(from, to, cap);
27        edges.emplace_back(to, from, 0);
28        adj[from].push_back(qntE);
29        adj[to].push_back(qntE + 1);
30        qntE += 2;
31    }
32
33    bool bfs() {
34        while (!q.empty()) {
35            int from = q.front();
36            q.pop();
37            for (int id : adj[from]) {
38                if (edges[id].cap == edges[id].flow)
39                    continue;
40                if (level[edges[id].to] != -1)
41                    continue;
42                level[edges[id].to] = level[from] + 1;
43                q.push(edges[id].to);
44            }
45        }
46        return level[sink] != -1;
47    }
48
49    long long dfs(int from, long long pushed) {
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83 }
```

```

49     if (pushed == 0)
50         return 0;
51     if (from == sink)
52         return pushed;
53     for (int& cid = ptr[from]; cid < (int)adj[from].size
54     (), cid++) {
55         int id = adj[from][cid];
56         int to = edges[id].to;
57         if (level[from] + 1 != level[to])
58             continue;
59         long long tr = dfs(to, min(pushed, edges[id].cap
60         - edges[id].flow));
61         if (tr == 0)
62             continue;
63         edges[id].flow += tr;
64         edges[id ^ 1].flow -= tr;
65     }
66     return 0;
67 }
68 long long max_flow() {
69     long long f = 0;
70     while (true) {
71         fill(level.begin(), level.end(), -1);
72         level[source] = 0;
73         q.push(source);
74         if (!bfs())
75             break;
76         fill(ptr.begin(), ptr.end(), 0);
77         while (long long pushed = dfs(source, flow_inf))
78             f += pushed;
79     }
80     return f;
81 }
82 }
```

1.13 Acha Pontes

```

1 vector<int> d, low, pai;           // d[v] Tempo de descoberta (
2                                     discovery time)
3 vector<bool> vis;
4 vector<int> pontos_articulacao;
5 vector<pair<int, int>> pontes;
6 int tempo;
7 vector<vector<int>> adj;
8
9 void dfs(int u) {
10    vis[u] = true;
11    tempo++;
12    d[u] = low[u] = tempo;
13    int filhos_dfs = 0;
14    for (int v : adj[u]) {
15        if (v == pai[u]) continue;
16        if (vis[v]) { // back edge
17            low[u] = min(low[u], d[v]);
18        } else {
19            pai[v] = u;
20            filhos_dfs++;
21            dfs(v);
22            low[u] = min(low[u], low[v]);
23            if (pai[u] == -1 && filhos_dfs > 1) {
24                pontos_articulacao.push_back(u);
25            }
26            if (pai[u] != -1 && low[v] >= d[u]) {
27                pontos_articulacao.push_back(u);
28            }
29            if (low[v] > d[u]) {
30                pontes.push_back({min(u, v), max(u, v)});
31            }
32        }
33    }
34 }
```

1.14 Bellman Ford

```

1 struct Edge {
2     int u, v, w;
3 };
4
5 // se x = -1, nao tem ciclo
```

```

6 // se x != -1, pegar pais de x pra formar o ciclo
7
8 int n, m;
9 vector<Edge> edges;
10 vector<int> dist(n);
11 vector<int> pai(n, -1);
12
13 for (int i = 0; i < n; i++) {
14     x = -1;
15     for (Edge &e : edges) {
16         if (dist[e.u] + e.w < dist[e.v]) {
17             dist[e.v] = max(-INF, dist[e.u] + e.w);
18             pai[e.v] = e.u;
19             x = e.v;
20         }
21     }
22 }
23
24 // achando caminho (se precisar)
25 for (int i = 0; i < n; i++) x = pai[x];
26
27 vector<int> ciclo;
28 for (int v = x;; v = pai[v]) {
29     ciclo.push_back(v);
30     if (v == x && ciclo.size() > 1) break;
31 }
32 reverse(ciclo.begin(), ciclo.end());

```

1.15 Lca Jc

```

1 const int MAXN = 200005;
2 int N;
3 int LOG;
4
5 vector<vector<int>> adj;
6 vector<int> profundidade;
7 vector<vector<int>> cima; // cima[v][j] eh o 2^j-esimo
8 // ancestral de v
9 void dfs(int v, int p, int d) {
10     profundidade[v] = d;
11     cima[v][0] = p; // o pai direto eh o 2^0-Ãºltimo ancestral
12     for (int j = 1; j < LOG; j++) {
13         // se o ancestral 2^(j-1) existir, calculamos o 2^j
14         if (cima[v][j - 1] != -1) {
15             cima[v][j] = cima[cima[v][j - 1]][j - 1];
16         } else {
17             cima[v][j] = -1; // nao tem ancestral superior
18         }
19     }
20     for (int nei : adj[v]) {
21         if (nei != p) {
22             dfs(nei, v, d + 1);
23         }
24     }
25 }
26
27 void build(int root) {
28     LOG = ceil(log2(N));
29     profundidade.assign(N + 1, 0);
30     cima.assign(N + 1, vector<int>(LOG, -1));
31     dfs(root, -1, 0);
32 }
33
34 int get_lca(int a, int b) {
35     if (profundidade[a] < profundidade[b]) {
36         swap(a, b);
37     }
38     // sobe 'a' ate a mesma profundidade de 'b'
39     for (int j = LOG - 1; j >= 0; j--) {
40         if (profundidade[a] - (1 << j) >= profundidade[b]) {
41             a = cima[a][j];
42         }
43     }
44     // se 'b' era um ancestral de 'a', entÃ£o 'a' agora Ã©
45     // igual a 'b'
46     if (a == b) {
47         return a;
48     }
49     // sobe os dois juntos ate encontrar os filhos do LCA
50     for (int j = LOG - 1; j >= 0; j--) {
51         if (cima[a][j] != -1 && cima[a][j] != cima[b][j]) {
52             a = cima[a][j];
53             b = cima[b][j];
54         }
55     }
56 }

```

```

54     }
55     return cima[a][0];
56 }

```

2 General

2.1 Count Permutations

```

1 // Returns the number of distinct permutations
2 // that are lexicographically less than the string t
3 // using the provided frequency (freq) of the characters
4 // O(n*freq.size())
5 int countPermLess(vector<int> freq, const string &t) {
6     int n = t.size();
7     int ans = 0;
8
9     vector<int> fact(n + 1, 1), invfact(n + 1, 1);
10    for (int i = 1; i <= n; i++)
11        fact[i] = (fact[i - 1] * i) % MOD;
12    invfact[n] = fexp(fact[n], MOD - 2, MOD);
13    for (int i = n - 1; i >= 0; i--)
14        invfact[i] = (invfact[i + 1] * (i + 1)) % MOD;
15
16    // For each position in t, try placing a letter smaller
17    // than t[i] that is in freq
18    for (int i = 0; i < n; i++) {
19        for (char c = 'a'; c < t[i]; c++) {
20            if (freq[c - 'a'] > 0) {
21                freq[c - 'a']--;
22                int ways = fact[n - i - 1];
23                for (int f : freq)
24                    ways = (ways * invfact[f]) % MOD;
25                ans = (ans + ways) % MOD;
26                freq[c - 'a']++;
27            }
28            if (freq[t[i] - 'a'] == 0) break;
29            freq[t[i] - 'a']--;
30        }
31    }
32    return ans;

```

2.2 Mex

```

1 struct MEX {
2     map<int, int> f;
3     set<int> falta;
4     int tam;
5     MEX(int n) : tam(n) {
6         for (int i = 0; i <= n; i++) falta.insert(i);
7     }
8     void add(int x) {
9         f[x]++;
10        if (f[x] == 1 && x >= 0 && x <= tam) {
11            falta.erase(x);
12        }
13    }
14    void rem(int x) {
15        if (f.count(x) && f[x] > 0) {
16            f[x]--;
17            if (f[x] == 0 && x >= 0 && x <= tam) {
18                falta.insert(x);
19            }
20        }
21    }
22    int get() {
23        if (falta.empty()) return tam + 1;
24        return *falta.begin();
25    }
26 };

```

2.3 Bitwise

```

1 int check_kth_bit(int x, int k) {
2     return (x >> k) & 1;
3 }
4
5 void print_on_bits(int x) {
6     for (int k = 0; k < 32; k++) {
7         if (check_kth_bit(x, k)) {
8             cout << k << ' ';
9         }

```

```

10    }
11    cout << '\n';
12 }
13
14 int count_on_bits(int x) {
15     int ans = 0;
16     for (int k = 0; k < 32; k++) {
17         if (check_kth_bit(x, k)) {
18             ans++;
19         }
20     }
21     return ans;
22 }
23
24 bool is_even(int x) {
25     return ((x & 1) == 0);
26 }
27
28 int set_kth_bit(int x, int k) {
29     return x | (1 << k);
30 }
31
32 int unset_kth_bit(int x, int k) {
33     return x & (~(1 << k));
34 }
35
36 int toggle_kth_bit(int x, int k) {
37     return x ^ (1 << k);
38 }
39
40 bool check_power_of_2(int x) {
41     return count_on_bits(x) == 1;
42 }

```

2.4 Brute Choose

```

1 vector<int> elements;
2 int N, K;
3 vector<int> comb;
4
5 void brute_choose(int i) {
6     if (comb.size() == K) {
7         for (int j = 0; j < comb.size(); j++) {
8             cout << comb[j] << ',';
9         }
10    cout << '\n';
11    return;
12 }
13 if (i == N) return;
14 int r = N - i;
15 int preciso = K - comb.size();
16 if (r < preciso) return;
17 comb.push_back(elements[i]);
18 brute_choose(i + 1);
19 comb.pop_back();
20 brute_choose(i + 1);
21 }

```

2.5 Struct

```

1 struct Pessoa{
2     // Atributos
3     string nome;
4     int idade;
5
6     // Comparador
7     bool operator<(const Pessoa& other) const{
8         if(idade != other.idade) return idade > other.idade;
9         else return nome > other.nome;
10    }
11 }

```

3 Stress

3.1 Gen

```

1 // pre-compilar os headers:
2 // compilar template com g++ -H e procurar onde esta stdc++.h
3 // criar a pasta bits e incluir com "" ou inves de <>
4 // compilar stress com: g++ -pipe -O3 -flto -march=native -
      -mtune=native gen.cpp
5 // faz bastante diferen a no runtime

```

```

6 #include <bits/stdc++.h>
7 #include <cstdlib>
8 #include <ctime>
9 using namespace std;
10
11
12 int randi(int L, int R) { return L + rand() % (R - L + 1); }
13 char randc(char L, char R) { return char(L + rand() % (R - L
+ 1)); }
14
15 int main(int argc, char** argv) {
16     if (argc > 1) srand(atoi(argv[1]));
17     else srand(time(0));
18
19     int n = randi(1, 100);
20     cout << n << '\n';
21     for (int i = 0; i < n; i++) {
22         cout << randi(-10, 20) << ',';
23     }
24     cout << '\n';
25 }

```

4 Search and sort

4.1 Monotonic Stack

```

1 vector<int> find_esq(vector<int> &v, bool maior) {
2     int n = v.size();
3     vector<int> result(n);
4     stack<int> s;
5
6     for (int i = 0; i < n; i++) {
7         while (!s.empty() && (maior ? v[s.top()] <= v[i] : v[
8             s.top()] >= v[i])) {
9             s.pop();
10        }
11        if (s.empty()) {
12            result[i] = -1;
13        } else {
14            result[i] = v[s.top()];
15        }
16        s.push(i);
17    }
18    return result;
19
20 vector<int> find_dir(vector<int> &v, bool maior) {
21     int n = v.size();
22     vector<int> result(n);
23     stack<int> s;
24     for (int i = n - 1; i >= 0; i--) {
25         while (!s.empty() && (maior ? v[s.top()] <= v[i] : v[
26             s.top()] >= v[i])) {
27             s.pop();
28        }
29        if (s.empty()) {
30            result[i] = -1;
31        } else {
32            result[i] = v[s.top()];
33        }
34        s.push(i);
35    }
36    return result;
37 }

```

4.2 Merge Sort

```

1 int mergeAndCount(vector<int>& v, int l, int m, int r) {
2     int x = m - 1 + 1;
3     int y = r - m;
4     vector<int> left(x), right(y);
5     for (int i = 0; i < x; i++) left[i] = v[l + i];
6     for (int j = 0; j < y; j++) right[j] = v[m + 1 + j];
7     int i = 0, j = 0, k = l;
8     int swaps = 0;
9     while (i < x && j < y) {
10        if (left[i] <= right[j]) {
11            v[k++] = left[i++];
12        } else {
13            v[k++] = right[j++];
14            swaps += (x - i);
15        }
16    }

```

```

17     while (i < x) v[k++] = left[i++];
18     while (j < y) v[k++] = right[j++];
19 } 
20 }
21 int mergeSort(vector<int>& v, int l, int r) {
22     int swaps = 0;
23     if (l < r) {
24         int m = l + (r - 1) / 2;
25         swaps += mergeSort(v, l, m);
26         swaps += mergeSort(v, m + 1, r);
27         swaps += mergeAndCount(v, l, m, r);
28     }
29 }
30 return swaps;
31 }
```

5 String

5.1 Z Function

```

1 vector<int> z_function(string s) {
2     int n = s.size();
3     vector<int> z(n);
4     int l = 0, r = 0;
5     for(int i = 1; i < n; i++) {
6         if(i < r) {
7             z[i] = min(r - i, z[i - 1]);
8         }
9         while(i + z[i] < n && s[z[i]] == s[i + z[i]]) {
10             z[i]++;
11         }
12         if(i + z[i] > r) {
13             l = i;
14             r = i + z[i];
15         }
16     }
17     return z;
18 }
```

5.2 Trie

```

1 // Trie por array
2 int trie[MAXN][26];
3 int tot_nos = 0;
4 vector<bool> acaba(MAXN, false);
5 vector<int> contador(MAXN, 0);
6
7 void insere(string s) {
8     int no = 0;
9     for(auto &c : s) {
10         if(trie[no][c - 'a'] == 0) {
11             trie[no][c - 'a'] = ++tot_nos;
12         }
13         no = trie[no][c - 'a'];
14         contador[no]++;
15     }
16     acaba[no] = true;
17 }
18
19 bool busca(string s) {
20     int no = 0;
21     for(auto &c : s) {
22         if(trie[no][c - 'a'] == 0) {
23             return false;
24         }
25         no = trie[no][c - 'a'];
26     }
27     return acaba[no];
28 }
29
30 int isPref(string s) {
31     int no = 0;
32     for(auto &c : s) {
33         if(trie[no][c - 'a'] == 0){
34             return -1;
35         }
36         no = trie[no][c - 'a'];
37     }
38     return contador[no];
39 }
```

5.3 Kmp

```

1 vector<int> kmp(string &s) {
2     int m = s.size();
3     vector<int> lsp(m, 0);
4     for (int i = 1, j = 0; i < m; i++) {
5         while (j > 0 && s[j] != s[i]) j = lsp[j - 1];
6         if (s[i] == s[j]) j++;
7     }
8     return lsp;
10 }
```

5.4 Hashing

```

1 // String Hash template
2 // constructor(s) - O(|s|)
3 // query(l, r) - returns the hash of the range [l,r] from
4 // left to right - O(1)
5 // query_inv(l, r) from right to left - O(1)
6 // patrocinado por tiagodfs
7 mt19937 rng(time(nullptr));
8
9 struct Hash {
10     const int X = rng();
11     const int MOD = 1e9+7;
12     int n; string s;
13     vector<int> h, hi, p;
14     Hash() {}
15     Hash(string s): s(s), n(s.size()), h(n), hi(n), p(n) {
16         for (int i=0;i<n;i++) p[i] = (i ? X*p[i-1]:1) % MOD;
17         for (int i=0;i<n;i++)
18             h[i] = (s[i] + (i ? h[i-1]:0) * X) % MOD;
19         for (int i=n-1;i>=0;i--)
20             hi[i] = (s[i] + (i+1<n ? hi[i+1]:0) * X) % MOD;
21     }
22     int query(int l, int r) {
23         int hash = (h[r] - (l ? h[l-1]*p[r-l+1]%MOD : 0));
24         return hash < 0 ? hash + MOD : hash;
25     }
26     int query_inv(int l, int r) {
27         int hash = (hi[l] - (r+1 < n ? hi[r+1]*p[r-l+1] % MOD
28 : 0));
29         return hash < 0 ? hash + MOD : hash;
30     }
31 }
```

6 Geometry

6.1 Convex Hull

```

1 #include <bits/stdc++.h>
2
3 using namespace std;
4 #define int long long
5 typedef int cod;
6
7 struct point
8 {
9     cod x,y;
10    point(cod x = 0, cod y = 0): x(x), y(y)
11    {}
12
13    double modulo()
14    {
15        return sqrt(x*x + y*y);
16    }
17
18    point operator+(point o)
19    {
20        return point(x+o.x, y+o.y);
21    }
22    point operator-(point o)
23    {
24        return point(x - o.x , y - o.y);
25    }
26    point operator*(cod t)
27    {
28        return point(x*t, y*t);
29    }
30    point operator/(cod t)
31    {
32        return point(x/t, y/t);
33    }
34 }
```

```

35     cod operator*(point o)
36     {
37         return x*o.x + y*o.y;
38     }
39     cod operator^(point o)
40     {
41         return x*o.y - y * o.x;
42     }
43     bool operator<(point o)
44     {
45         if( x != o.x) return x < o.x;
46         return y < o.y;
47     }
48 }
49 }

51 int ccw(point p1, point p2, point p3)
52 {
53     cod cross = (p2-p1) ^ (p3-p1);
54     if(cross == 0) return 0;
55     else if(cross < 0) return -1;
56     else return 1;
57 }

58 vector<point> convex_hull(vector<point> p)
59 {
60     sort(p.begin(), p.end());
61     vector<point> L,U;
62
63     //Lower
64     for(auto pp : p)
65     {
66         while(L.size() >= 2 and ccw(L[L.size()-2], L.back(),
67 , pp) == -1)
68         {
69             // Às -1 pq eu nã±o quero excluir os colineares
70             L.pop_back();
71         }
72         L.push_back(pp);
73     }
74
75     reverse(p.begin(), p.end());
76
77     //Upper
78     for(auto pp : p)
79     {
80         while(U.size() >= 2 and ccw(U[U.size()-2], U.back(),
81 pp) == -1)
82         {
83             U.pop_back();
84         }
85         U.push_back(pp);
86     }
87
88     L.pop_back();
89     L.insert(L.end(), U.begin(), U.end()-1);
90     return L;
91 }

92 cod area(vector<point> v)
93 {
94     int ans = 0;
95     int aux = (int)v.size();
96     for(int i = 2; i < aux; i++)
97     {
98         ans += ((v[i] - v[0])^ (v[i-1] - v[0]))/2;
99     }
100    ans = abs(ans);
101    return ans;
102 }

103 int bound(point p1 , point p2)
104 {
105     return __gcd(abs(p1.x-p2.x), abs(p1.y-p2.y));
106 }
107 }

108 //teorema de pick [Pontos = A - (bound+points)/2 + 1]
109
110 int32_t main()
111 {
112
113     int n;
114     cin >> n;
115
116     vector<point> v(n);
117     for(int i = 0; i < n; i++)
118     {

```

```

119         cin >> v[i].x >> v[i].y;
120     }
121
122     vector<point> ch = convex_hull(v);
123
124     cout << ch.size() << '\n';
125     for(auto p : ch) cout << p.x << " " << p.y << "\n";
126
127     return 0;
128 }


```

6.2 Inside Polygon

```

1 // Convex O(logn)
2
3 bool insideT(point a, point b, point c, point e){
4     int x = ccw(a, b, e);
5     int y = ccw(b, c, e);
6     int z = ccw(c, a, e);
7     return !( (x==1 or y==1 or z==1) and (x==-1 or y==-1 or z
8 ==-1));
9
10 bool inside(vp &p, point e){ // ccw
11     int l=2, r=(int)p.size()-1;
12     while(l<r){
13         int mid = (l+r)/2;
14         if(ccw(p[0], p[mid], e) == 1)
15             l=mid+1;
16         else{
17             r=mid;
18         }
19     }
20     // bordo
21     // if(r==(int)p.size()-1 and ccw(p[0], p[r], e)==0)
22     // return false;
23     // if(r==2 and ccw(p[0], p[1], e)==0) return false;
24     // if(ccw(p[r], p[r-1], e)==0) return false;
25     return insideT(p[0], p[r-1], p[r], e);
26
27
28 // Any O(n)
29
30 int inside(vp &p, point pp){
31     // 1 - inside / 0 - boundary / -1 - outside
32     int n = p.size();
33     for(int i=0;i<n;i++){
34         int j = (i+1)%n;
35         if(line({p[i], p[j]}).inside_seg(pp))
36             return 0;
37     }
38     int inter = 0;
39     for(int i=0;i<n;i++){
40         int j = (i+1)%n;
41         if(p[i].x <= pp.x and pp.x < p[j].x and ccw(p[i], p[j
42 ], pp)==1)
43             inter++; // up
44         else if(p[j].x <= pp.x and pp.x < p[i].x and ccw(p[i]
45 ], p[j], pp)==-1)
46             inter++; // down
47     }
48     if(inter%2==0) return -1; // outside
49     else return 1; // inside
}


```

6.3 Point Location

```

1
2 int32_t main(){
3     sws;
4
5     int t; cin >> t;
6
7     while(t--){
8
9         int x1, y1, x2, y2, x3, y3; cin >> x1 >> y1 >> x2 >>
10 y2 >> x3 >> y3;
11
12         int deltax1 = (x1-x2), deltay1 = (y1-y2);
13
14         int compx = (x1-x3), compy = (y1-y3);
15
16     }
17
18 }


```

```

15     int ans = (deltax1*compy) - (compx*deltay1);
16
17     if(ans == 0){cout << "TOUCH\n"; continue;}
18     if(ans < 0){cout << "RIGHT\n"; continue;}
19     if(ans > 0){cout << "LEFT\n"; continue;}
20 }
21 return 0;
22 }
```

6.4 Lattice Points

```

1 ll gcd(ll a, ll b) {
2     return b == 0 ? a : gcd(b, a % b);
3 }
4 ll area_triangulo(ll x1, ll y1, ll x2, ll y2, ll x3, ll y3) {
5     return abs(x1 * (y2 - y3) + x2 * (y3 - y1) + x3 * (y1 - y2));
6 }
7 ll pontos_borda(ll x1, ll y1, ll x2, ll y2) {
8     return gcd(abs(x2 - x1), abs(y2 - y1));
9 }
10
11 int32_t main() {
12     ll x1, y1, x2, y2, x3, y3;
13     cin >> x1 >> y1;
14     cin >> x2 >> y2;
15     cin >> x3 >> y3;
16     ll area = area_triangulo(x1, y1, x2, y2, x3, y3);
17     ll tot_borda = pontos_borda(x1, y1, x2, y2) +
18         pontos_borda(x2, y2, x3, y3) + pontos_borda(x3, y3, x1,
19         y1);
20
21     ll ans = (area - tot_borda) / 2 + 1;
22     cout << ans << endl;
23 }
```

7 Primitives

8 DP

8.1 Edit Distance

```

1 vector<vector<int>> dp(n+1, vector<int>(m+1, LLONG_MIN));
2 for(int j = 0; j <= m; j++) dp[0][j] = j;
3 for(int i = 0; i <= n; i++) dp[i][0] = i;
4 for(int i = 1; i <= n; i++) {
5     for(int j = 1; j <= m; j++) {
6         if(a[i-1] == b[j-1]) {
7             dp[i][j] = dp[i-1][j-1];
8         } else {
9             dp[i][j] = min({dp[i-1][j] + 1, dp[i][j-1] +
10                 1, dp[i-1][j-1] + 1});
11     }
12 }
13 cout << dp[n][m];
14 }
```

8.2 Lis

```

1 int lis_nlogn(vector<int> &v) {
2     vector<int> lis;
3     lis.push_back(v[0]);
4     for (int i = 1; i < v.size(); i++) {
5         if (v[i] > lis.back()) {
6             // estende a lis
7             lis.push_back(v[i]);
8         } else {
9             // encontra o primeiro elemento em lis que >= v[i]
10         }
11         auto it = lower_bound(lis.begin(), lis.end(), v[i]);
12         *it = v[i];
13     }
14     return lis.size();
15 }
16 // lis na tree do problema da sub
```

```

18 const int MAXN_TREE = 100001;
19 vector<int> adj[MAXN_TREE];
20 int values[MAXN_TREE];
21 int ans = 0;
22
23 void dfs(int u, int p, vector<int>& tails) {
24     auto it = lower_bound(tails.begin(), tails.end(), values[u]);
25     int prev = -1;
26     bool coloquei = false;
27     if (it == tails.end()) {
28         tails.push_back(values[u]);
29         coloquei = true;
30     } else {
31         prev = *it;
32         *it = values[u];
33     }
34     ans = max(ans, (int)tails.size());
35     for (int v : adj[u]) {
36         if (v != p) {
37             dfs(v, u, tails);
38         }
39     }
40     if (coloquei) {
41         tails.pop_back();
42     } else {
43         *it = prev;
44     }
45 }
```

8.3 Bitmask

```

1 // dp de intervalos com bitmask
2 int prox(int idx) {
3     return lower_bound(S.begin(), S.end(), array<int, 4>{S[
4         idx][1], 011, 011, 011}) - S.begin();
5 }
6 int dp[1002][(int)(1ll << 10)];
7
8 int rec(int i, int vis) {
9     if (i == (int)S.size()) {
10         if (__builtin_popcountll(vis) == N) return 0;
11         return LLONG_MIN;
12     }
13     if (dp[i][vis] != -1) return dp[i][vis];
14     int ans = rec(i + 1, vis);
15     ans = max(ans, rec(prox(i), vis | (1ll << S[i][3])) + S[i]
16 [1][2]);
17     return dp[i][vis] = ans;
18 }
```

8.4 Digit

```

1 vector<int> digits;
2
3 int dp[20][10][2][2];
4
5 int rec(int i, int last, int flag, int started) {
6     if (i == (int)digits.size()) return 1;
7     if (dp[i][last][flag][started] != -1) return dp[i][last][
8         flag][started];
9     int lim;
10    if (flag) lim = 9;
11    else lim = digits[i];
12    int ans = 0;
13    for (int d = 0; d <= lim; d++) {
14        if (started && d == last) continue;
15        int new_flag = flag;
16        int new_started = started;
17        if (d > 0) new_started = 1;
18        if (!flag && d < lim) new_flag = 1;
19        ans += rec(i + 1, d, new_flag, new_started);
20    }
21    return dp[i][last][flag][started] = ans;
22 }
```

8.5 Disjoint Blocks

```

1 // num max de subarrays disjuntos com soma x usando apenas
2 // prefixo i (ou seja, considerando prefixo a[1..i]).
3 int disjointSumX(vector<int> &a, int x) {
4     int n = a.size();
```

```

5     map<int, int> best; // best[pref] = melhor dp visto para esse pref
6     best[0] = 0;
7     int pref = 0;
8     vector<int> dp(n + 1, 0); // dp[0] = 0
9     for (int i = 1; i <= n; i++) {
10        pref += a[i - 1];
11        dp[i] = dp[i - 1];
12        auto it = best.find(pref - x);
13        if (it != best.end()) {
14            dp[i] = max(dp[i], it->second + 1);
15        }
16        best[pref] = max(best[pref], dp[i]);
17    }
18    return dp[n];
19 }

```

8.6 Lis Seg

```

1 // comprime coordenadas pra quando ai <= 1e9
2 vector<int> vals(a.begin(), a.end());
3 sort(vals.begin(), vals.end());
4 vals.erase(unique(vals.begin(), vals.end()), vals.end());
5 auto id = [&](int x) -> int {
6     return lower_bound(vals.begin(), vals.end(), x) - vals.begin();
7 };
8 for (int i = 0; i < n; i++) a[i] = id(a[i]);
9 // fim da parte de compr
10 SegTree seg(n);
11 // dp[i]: lis que termina em i
12 vector<int> dp(n, 1); // dp[i] = 1 base case
13 for (int i = 0; i < n; i++) {
14     if (a[i] > 0) dp[i] = seg.query(0, max(0ll, a[i] - 1)) +
15         1;
16     seg.update(a[i], dp[i]);
17 }
17 cout << *max_element(dp.begin(), dp.end()) << '\n';

```

8.7 Lcs

```

1 string s1, s2;
2 int dp[1001][1001];
3 int lcs(int i, int j) {
4     if (i < 0 || j < 0) return 0;
5     if (dp[i][j] != -1) return dp[i][j];
6     if (s1[i] == s2[j]) return dp[i][j] = 1 + lcs(i - 1, j - 1);
7     else return dp[i][j] = max(lcs(i - 1, j), lcs(i, j - 1));
8 }

```

8.8 Knapsack

```

1 // dp[i][j] => i-esimo item com j-carga sobrando na mochila
2 // O(N * W)
3 vector<vector<int>> dp(N + 1, vector<int>(W + 1, 0));
4 for (int i = 1; i <= N; i++) dp[i][0] = 0;
5 for (int j = 0; j <= W; j++) dp[0][j] = 0;
6 for (int i = 1; i <= N; i++) {
7     for (int j = 0; j <= W; j++) {
8         dp[i][j] = dp[i - 1][j];
9         if (j >= items[i-1].first) {
10             dp[i][j] = max(dp[i][j], dp[i - 1][j - items[i -
1].first] + items[i-1].second);
11         }
12     }
13 }
14 cout << dp[N][W] << '\n';

```

9 Math

9.1 Base Calc

```

1 int char_to_val(char c) {
2     if (c >= '0' && c <= '9') return c - '0';
3     else return c - 'A' + 10;
4 }
5
6 char val_to_char(int val) {
7     if (val >= 0 && val <= 9) return val + '0';
8     else return val - 10 + 'A';

```

```

9 }
10 int to_base_10(string &num, int bfrom) {
11     int result = 0;
12     int pot = 1;
13     for (int i = num.size() - 1; i >= 0; i--) {
14         if (char_to_val(num[i]) >= bfrom) return -1;
15         result += char_to_val(num[i]) * pot;
16         pot *= bfrom;
17     }
18     return result;
19 }
20
21 string from_base_10(int n, int bto) {
22     if (n == 0) return "0";
23     string result = "";
24     while (n > 0) {
25         result += val_to_char(n % bto);
26         n /= bto;
27     }
28     reverse(result.begin(), result.end());
29     return result;
30 }
31
32 string convert_base(string &num, int bfrom, int bto) {
33     int n_base_10 = to_base_10(num, bfrom);
34     return from_base_10(n_base_10, bto);
35 }
36 }

```

9.2 Equacao Diofantina

```

1 int extended_gcd(int a, int b, int& x, int& y) {
2     if (a == 0) {
3         x = 0;
4         y = 1;
5         return b;
6     }
7     int x1, y1;
8     int gcd = extended_gcd(b % a, a, x1, y1);
9     x = y1 - (b / a) * x1;
10    y = x1;
11    return gcd;
12 }
13
14 bool solve(int a, int b, int c, int& x0, int& y0) {
15     int x, y;
16     int g = extended_gcd(abs(a), abs(b), x, y);
17     if (c % g != 0) {
18         return false;
19     }
20     x0 = x * (c / g);
21     y0 = y * (c / g);
22     if (a < 0) x0 = -x0;
23     if (b < 0) y0 = -y0;
24     return true;
25 }

```

9.3 Mod Inverse

```

1 array<int, 2> extended_gcd(int a, int b) {
2     if (b == 0) return {1, 0};
3     auto [x, y] = extended_gcd(b, a % b);
4     return {y, x - (a / b) * y};
5 }
6
7 int mod_inverse(int a, int m) {
8     auto [x, y] = extended_gcd(a, m);
9     return (x % m + m) % m;
10 }

```

9.4 Fft

```

1 // multiplica dois polinomios em O(NlogN)
2
3 using cd = complex<double>;
4 const double PI = acos(-1);
5
6 void fft(vector<cd> &A, bool invert) {
7     int N = size(A);
8
9     for (int i = 1, j = 0; i < N; i++) {
10        int bit = N >> 1;
11        for (; j & bit; bit >>= 1)

```

```

12     j ^= bit;
13     j ^= bit;
14
15     if (i < j)
16         swap(A[i], A[j]);
17 }
18
19 for (int len = 2; len <= N; len <<= 1) {
20     double ang = 2 * PI / len * (invert ? -1 : 1);
21     cd wlen(cos(ang), sin(ang));
22     for (int i = 0; i < N; i += len) {
23         cd w(1);
24         for (int j = 0; j < len/2; j++) {
25             cd u = A[i+j], v = A[i+j+len/2] * w;
26             A[i+j] = u + v;
27             A[i+j+len/2] = u-v;
28             w *= wlen;
29         }
30     }
31 }
32
33 if (invert) {
34     for (auto &x : A)
35         x /= N;
36 }
37 }
38
39 vector<int> multiply(vector<int> const& A, vector<int> const&
40     B) {
41     vector<cd> fa(begin(A), end(A)), fb(begin(B), end(B));
42     int N = 1;
43     while (N < size(A) + size(B))
44         N <<= 1;
45     fa.resize(N);
46     fb.resize(N);
47
48     fft(fa, false);
49     fft(fb, false);
50     for (int i = 0; i < N; i++)
51         fa[i] *= fb[i];
52     fft(fa, true);
53
54     vector<int> result(N);
55     for (int i = 0; i < N; i++)
56         result[i] = round(fa[i].real());
57     return result;
58 }
```

9.5 Fexp

```

1 // a^e mod m
2 // O(log n)
3
4 int fexp(int a, int e, int m) {
5     a %= m;
6     int ans = 1;
7     while (e > 0){
8         if (e & 1) ans = ans*a % m;
9         a = a*a % m;
10        e /= 2;
11    }
12    return ans%m;
13 }
```

9.6 Divisores

```

1 // Retorna um vetor com os divisores de x
2 // eh preciso ter o crivo implementado
3 // O(divisores)
4
5 vector<int> divs(int x){
6     vector<int> ans = {1};
7     vector<array<int, 2>> primos; // {primo, expoente}
8
9     while (x > 1) {
10         int p = crivo[x], cnt = 0;
11         while (x % p == 0) cnt++, x /= p;
12         primos.push_back({p, cnt});
13     }
14
15     for (int i=0; i<primos.size(); i++){
16         int cur = 1, len = ans.size();
17
18         for (int j=0; j<primos[i][1]; j++) {

```

```

19             cur *= primos[i][0];
20             for (int k=0; k<len; k++)
21                 ans.push_back(cur*ans[k]);
22         }
23     }
24
25     return ans;
26 }
```

9.7 Crivo

```

1 // O(n * log(log(n)))
2 bool composto[MAX]
3 for(int i = 1; i <= n; i++) {
4     if(composto[i]) continue;
5     for(int j = 2*i; j <= n; j += i)
6         composto[j] = 1;
7 }
```

9.8 Combinatorics

```

1 const int N = 200005;
2 const int MOD = 1e9 + 7;
3 // DEFINE INT LONG LONG PLMDS
4 int fat[N], fati[N];
5
6 // (a^b) % m em O(log b)
7 // coloque o fexp
8
9 int inv(int n) { return fexp(n, MOD - 2); }
10
11 void precalc() {
12     fat[0] = 1;
13     fati[0] = 1;
14     for (int i = 1; i < N; i++) fat[i] = (fat[i - 1] * i) %
15         MOD;
16     fati[N - 1] = inv(fat[N - 1]);
17     for (int i = N - 2; i >= 0; i--) fati[i] = (fati[i + 1] *
18         (i + 1)) % MOD;
19 }
20
21 int choose(int n, int k) {
22     if (k < 0 || k > n) return 0;
23     return (((fat[n] * fati[k]) % MOD) * fati[n - k]) % MOD;
24 }
25
26 // n! / (n-k)!
27 int perm(int n, int k) {
28     if (k < 0 || k > n) return 0;
29     return (fat[n] * fati[n - k]) % MOD;
30 }
31
32 // C_n = (1 / (n+1)) * C(2n, n)
33 int catalan(int n) {
34     if (n < 0 || 2 * n >= N) return 0;
35     int c2n_n = choose(2 * n, n);
36     return (c2n_n * inv(n + 1)) % MOD;
37 }
```

9.9 Segment Sieve

```

1 // Retorna quantos primos tem entre [l, r] (inclusivo)
2 // precisa de um vetor com os primos ate sqrt(r)
3 int seg_sieve(int l, int r){
4     if (l > r) return 0;
5     vector<bool> is_prime(r - l + 1, true);
6     if (l == 1) is_prime[0] = false;
7
8     for (int p : primos){
9         if (p * p > r) break;
10        int start = max(p * p, (l + p - 1) / p * p);
11        for (int j = start; j <= r; j += p){
12            if (j >= l) {
13                is_prime[j - 1] = false;
14            }
15        }
16    }
17
18    return accumulate(all(is_prime), 0ll);
19 }
```

9.10 Discrete Log

```

1 // returns minimum x for which a^x = b (mod m), a and m are coprime.
2 // if the answer dont need to be greater than some value, the vector<int> can be removed
3 int discrete_log(int a, int b, int m) {
4   a %= m, b %= m;
5   int n = sqrt(m) + 1;
6
7   int an = 1;
8   for (int i = 0; i < n; ++i)
9     an = (an * 1ll * a) % m;
10
11  unordered_map<int, vector<int>> vals;
12  for (int q = 0, cur = b; q <= n; ++q) {
13    vals[cur].push_back(q);
14    cur = (cur * 1ll * a) % m;
15  }
16
17  int res = LLONG_MAX;
18
19  for (int p = 1, cur = 1; p <= n; ++p) {
20    cur = (cur * 1ll * an) % m;
21    if (vals.count(cur)) {
22      for (int q: vals[cur]) {
23        int ans = n * p - q;
24        res = min(res, ans);
25      }
26    }
27  }
28  return res;
29 }

```

9.11 Menor Fator Primo

```

1 const int MAXN = 1000001;
2 int spf[MAXN];
3 vector<int> primos;
4
5 void crivo() {
6   for (int i = 0; i < MAXN; i++) spf[i] = [i];
7   for (int i = 2; i * i < MAXN; i++) {
8     if (spf[i] == i) {
9       for (int j = i * i; j < MAXN; j += i) {
10         if (spf[j] == j) {
11           spf[j] = i;
12         }
13       }
14     }
15   }
16   for (int i = 2; i < MAXN; i++) {
17     if (spf[i] == i) {
18       primos.push_back(i);
19     }
20   }
21 }
22
23 map<int, int> fatora(int n) {
24   map<int, int> fatores;
25   while (n > 1) {
26     fatores[spf[n]]++;
27     n /= spf[n];
28   }
29   return fatores;
30 }
31
32 int numero_de_divisores(int n) {
33   if (n == 1) return 1;
34   map<int, int> fatores = fatorar(n);
35   int nod = 1;
36   for (auto &[primo, expoente] : fatores) nod *= (expoente + 1);
37   return nod;
38 }
39
40 // DEFINE INT LONG LONG
41 int soma_dos_divisores(int n) {
42   if (n == 1) return 1;
43   map<int, int> fatores = fatorar(n);
44   int sod = 1;
45   for (auto &[primo, expoente] : fatores) {
46     int termo_soma = 1;
47     int potencia_primo = 1;
48     for (int i = 0; i < expoente; i++) {
49       potencia_primo *= primo;
50       termo_soma += potencia_primo;
51     }

```

9.12 Exgcd

```

1 // O retorno da funcao eh {n, m, g}
2 // e significa que gcd(a, b) = g e
3 // n e m sao inteiros tais que an + bm = g
4 array<ll, 3> exgcd(int a, int b) {
5   if(b == 0) return {1, 0, a};
6   auto [m, n, g] = exgcd(b, a % b);
7   return {n, m - a / b * n, g};
8 }

```

9.13 Totient

```

1 // phi(n) = n * (1 - 1/p1) * (1 - 1/p2) * ...
2 int phi(int n) {
3   int result = n;
4   for (int i = 2; i * i <= n; i++) {
5     if (n % i == 0) {
6       while (n % i == 0)
7         n /= i;
8       result -= result / i;
9     }
10  }
11  if (n > 1) // SE n sobrou, ele ÃE um fator primo
12    result -= result / n;
13  return result;
14 }
15
16 // crivo phi
17 const int MAXN_PHI = 1000001;
18 int phiv[MAXN_PHI];
19 void phi_sieve() {
20   for (int i = 0; i < MAXN_PHI; i++) phiv[i] = i;
21   for (int i = 2; i < MAXN_PHI; i++) {
22     if (phiv[i] == i) {
23       for (int j = i; j < MAXN_PHI; j += i) phiv[j] -=
24         phiv[j] / i;
25     }
26   }

```

9.14 Multiplicacao Matriz

```

1 // multiplica matrizes de tamanhos variados, resultando em
2 // uma matriz N*M
3 vector<vector<int>> mm(vector<vector<int>> A, vector<vector<int>> B) {
4   int N = A.size(), M = B[0].size(), K = B.size();
5   vector<vector<int>> C(N, vector<int>(M));
6
7   for (int i = 0; i < N; ++i)
8     for (int j = 0; j < M; ++j)
9       for (int k = 0; k < K; ++k)
10         C[i][j] = (C[i][j]+A[i][k] * B[k][j] % mod)%
11           mod;
12   return C;

```

10 DS

10.1 Psum 2d

```

1 vector<vector<int>> psum(h+1, vector<int>(w+1, 0));
2 for (int i=1; i<=h; i++){
3   for (int j=1; j<=w; j++){
4     cin >> psum[i][j];
5     psum[i][j] += psum[i-1][j]+psum[i][j-1]-psum[i-1][j-1];
6   }
7 }
8 // retorna a psum2d do intervalo inclusivo [(a, b), (c, d)]
9 int retangulo(int a, int b, int c, int d){
10   c = min(c, h), d = min(d, w);
11   a = max(0LL, a-1), b = max(0LL, b-1);

```

```
12     return v[c][d]-v[a][d]-v[c][b]+v[a][b];
13 }
```

10.2 Bit2d

```
1 // 1-index
2 struct BIT2d {
3     int n, m;
4     vector<vector<int>> tree;
5     BIT2d(int n, int m) : n(n), m(m) {
6         tree.assign(n + 1, vector<int>(m + 1, 0));
7     }
8     void add(int y, int x, int delta) {
9         for (int i = y; i <= n; i += i & -i) {
10            for (int j = x; j <= m; j += j & -j) {
11                tree[i][j] += delta;
12            }
13        }
14    }
15    int pref(int y, int x) {
16        int res = 0;
17        for (int i = y; i > 0; i -= i & -i) {
18            for (int j = x; j > 0; j -= j & -j) {
19                res += tree[i][j];
20            }
21        }
22        return res;
23    }
24    int query(int y1, int x1, int y2, int x2) {
25        return pref(y2, x2) - pref(y1 - 1, x2) - pref(y2, x1 - 1)
26        + pref(y1 - 1, x1 - 1);
27    }
};
```

10.3 Bit

```
1 struct BIT {
2     int n;
3     vector<int> bit;
4     BIT(int n = 0) : n(n), bit(n + 1, 0) {}
5     void add(int i, int delta) {
6         for(; i <= n; i += i & -i) bit[i] += delta;
7     }
8     int sum(int i) {
9         int r = 0;
10        for(; i > 0; i -= i & -i) r += bit[i];
11        return r;
12    }
13    int range_sum(int l, int r){
14        if (r < l) return 0;
15        return sum(r) - sum(l - 1);
16    }
17};
```

10.4 Segtree2d

```
1 // 0 index
2 struct SegTree2d {
3     int n;
4     vector<vector<int>> tree;
5     SegTree2d(int n) : n(n) {
6         tree.assign(4 * n, vector<int>(4 * n, 0));
7     }
8     void update_x(int no_y, int no_x, int lx, int rx, int x,
9     int val, bool folha_y) {
10    if (lx == rx) {
11        if (folha_y) tree[no_y][no_x] = val;
12        else tree[no_y][no_x] = tree[2 * no_y][no_x] + tree[2 *
13        no_y + 1][no_x];
14        return;
15    }
16    int mid = (lx + rx) / 2;
17    if (x <= mid) update_x(no_y, 2 * no_x, lx, mid, x, val,
18    folha_y);
19    else update_x(no_y, 2 * no_x + 1, mid + 1, rx, x, val,
20    folha_y);
21    tree[no_y][no_x] = tree[no_y][2 * no_x] + tree[no_y][2 *
22    no_x + 1];
23}
24 void update_y(int no_y, int ly, int ry, int y, int x, int
25 val) {
26    if (ly == ry) {
27        update_x(no_y, 1, 0, n - 1, x, val, true);
```

```
22         return;
23    }
24    int mid = (ly + ry) / 2;
25    if (y <= mid) update_y(2 * no_y, ly, mid, y, x, val);
26    else update_y(2 * no_y + 1, mid + 1, ry, y, x, val);
27    update_x(no_y, 1, 0, n - 1, x, val, false);
28}
29 int query_x(int no_y, int no_x, int lx, int rx, int x1, int
30 x2) {
31    if (rx < x1 || lx > x2) return 0;
32    if (lx >= x1 && rx <= x2) return tree[no_y][no_x];
33    int mid = (lx + rx) / 2;
34    return query_x(no_y, 2 * no_x, lx, mid, x1, x2) + query_x
35    (no_y, 2 * no_x + 1, mid + 1, rx, x1, x2);
36}
37 int query_y(int no_y, int ly, int ry, int y1, int y2, int
38 x1, int x2) {
39    if (ry < y1 || ly > y2) return 0;
40    if (ly >= y1 && ry <= y2) return query_x(no_y, 1, 0, n -
41    1, x1, x2);
42    int mid = (ly + ry) / 2;
43    return query_y(2 * no_y, ly, mid, y1, y2, x1, x2) +
44    query_y(2 * no_y + 1, mid + 1, ry, y1, y2, x1, x2);
45}
46 void update(int y, int x, int val) {
47    update_y(1, 0, n - 1, y, x, val);
48}
49 int query(int y1, int x1, int y2, int x2) {
50    return query_y(1, 0, n - 1, y1, y2, x1, x2);
51}
```

10.5 Segtree Lazy

```
1 /*
2 Seg com double Lazy de soma e de set
3 tipo 1 - soma em range
4 tipo 2 - set em range
5 */
6 struct SegTree {
7     int n;
8     vector<int> v, tree;
9     vector<int> lazy_soma, lazy_set;
10    SegTree(vector<int> &a) : v(a), n(a.size()) {
11        tree.resize(4 * n);
12        lazy_soma.resize(4 * n, 0);
13        lazy_set.resize(4 * n, -1);
14        build(1, 0, n - 1);
15    };
16    void build(int x, int lx, int rx) {
17        if (lx == rx) {
18            tree[x] = v[lx];
19            return;
20        }
21        int mid = (lx + rx) / 2;
22        build(2 * x, lx, mid);
23        build(2 * x + 1, mid + 1, rx);
24        tree[x] = tree[2 * x] + tree[2 * x + 1];
25    };
26    void seta(int x, int lx, int rx, int val) {
27        tree[x] = val * (rx - lx + 1);
28        lazy_set[x] = val;
29        lazy_soma[x] = 0;
30    };
31    void soma(int x, int lx, int rx, int val) {
32        tree[x] += val * (rx - lx + 1);
33        if (lazy_set[x] != -1) {
34            lazy_set[x] += val;
35        } else {
36            lazy_soma[x] += val;
37        }
38    };
39    void push(int x, int lx, int rx) {
40        int mid = (lx + rx) / 2;
41        if (lazy_set[x] != -1) {
42            if (lx != rx) {
43                seta(2 * x, lx, mid, lazy_set[x]);
44                seta(2 * x + 1, mid + 1, rx, lazy_set[x]);
45            }
46            lazy_set[x] = -1;
47        }
48        if (lazy_soma[x] != 0) {
49            if (lx != rx) {
50                soma(2 * x, lx, mid, lazy_soma[x]);
51                soma(2 * x + 1, mid + 1, rx, lazy_soma[x]);
52            }
53        }
54    };
55}
```

```

53     lazy_soma[x] = 0;
54 }
55 }
56 void update(int x, int lx, int rx, int l, int r, int val,
57             int type) {
58     push(x, lx, rx);
59     if (lx >= l && rx <= r) {
60         if (type == 1) soma(x, lx, rx, val);
61         else seta(x, lx, rx, val);
62         push(x, lx, rx);
63         return;
64     }
65     if (lx > r || rx < l) return;
66     int mid = (lx + rx) / 2;
67     update(2 * x, lx, mid, l, r, val, type);
68     update(2 * x + 1, mid + 1, rx, l, r, val, type);
69     tree[x] = tree[2 * x] + tree[2 * x + 1];
70 }
71 void update(int l, int r, int val, int type) {
72     update(1, 0, n - 1, l, r, val, type);
73 }
74 int query(int x, int lx, int rx, int l, int r) {
75     push(x, lx, rx);
76     if (lx >= l && rx <= r) return tree[x];
77     if (lx > r || rx < l) return 0;
78     int mid = (lx + rx) / 2;
79     return query(2 * x, lx, mid, l, r) + query(2 * x + 1, mid
80         + 1, rx, l, r);
81 }
82 }
83 };

```

10.6 Sparse Table

```

1 // 0-index, O(1)
2 struct SparseTable {
3     vector<vector<int>> st;
4     int max_log;
5     SparseTable(vector<int>& arr) {
6         int n = arr.size();
7         max_log = floor(log2(n)) + 1;
8         st.resize(n, vector<int>(max_log));
9         for (int i = 0; i < n; i++) {
10             st[i][0] = arr[i];
11         }
12         for (int j = 1; j < max_log; j++) {
13             for (int i = 0; i + (1 << j) <= n; i++) {
14                 st[i][j] = max(st[i][j - 1], st[i + (1 << (j
15                     - 1))] [j - 1]);
16             }
17         }
18     }
19     int query(int L, int R) {
20         int tamanho = R - L + 1;
21         int k = floor(log2(tamanho));
22         return max(st[L][k], st[R - (1 << k) + 1][k]);
23     }

```

10.7 Ordered Set E Map

```

1
2 #include<ext/pb_ds/assoc_container.hpp>
3 #include<ext/pb_ds/tree_policy.hpp>
4 using namespace __gnu_pbds;
5 using namespace std;
6
7 template<typename T> using ordered_multiset = tree<T,
8         null_type, less_equal<T>, rb_tree_tag,
9         tree_order_statistics_node_update>;
10
11 template <typename T> using o_set = tree<T, null_type, less<T>,
12 >, rb_tree_tag, tree_order_statistics_node_update>;
13 template <typename T, typename R> using o_map = tree<T, R,
14         less<T>, rb_tree_tag, tree_order_statistics_node_update
15 >;
16
17 int main() {
18     int i, j, k, n, m;
19     o_set<int>st;
20     st.insert(1);
21     st.insert(2);
22     cout << *st.find_by_order(0) << endl; // k-esimo elemento

```

```

17     cout << st.order_of_key(2) << endl; // numero de elementos
2     menores que k
20     o_map<int, int>mp;
21     mp.insert({1, 10});
22     mp.insert({2, 20});
23     cout << mp.find_by_order(0)->second << endl; // k-esimo
24     elemento
25     cout << mp.order_of_key(2) << endl; // numero de elementos
26     (chave) menores que k
27     return 0;
28 }

```

10.8 Seg Lazy Pa

```

1 /* Notas
2 PA eh da forma a0 (a) e razão (d)
3 na hora de propagar o lazy
4 aplica no no S = (a0 + (a0 + (n - 1) * d)) * n / 2 (
5 variante da soma total do no)
6 pros filhos, o da esquerda eh normal
7 lazy_a[esq] += lazy_a[x]
8 lazy_d[esq] += lazy_d[x]
9 pro da direita tem que mudar o a (que eh o elemento inicial
naquele no da direita)
10 lazy_a[dir] += a + len_esq * (d)
11 lazy_d[dir] += lazy_d[x]
12 */
13 int gauss(int n, int a, int d) {
14     // (a0 + an) * n / 2
15     if (n <= 0)
16         return 0;
17     return (a + (a + (n - 1) * d)) * n / 2;
18 }
19
20 struct SegTree {
21     int n;
22     vector<int> v, lazy_a, lazy_d, tree;
23     SegTree(vector<int> &a) : v(a), n(a.size()) {
24         tree.resize(4 * n);
25         lazy_a.resize(4 * n, 0);
26         lazy_d.resize(4 * n, 0);
27         build(1, 0, n - 1);
28     }
29     void build(int x, int lx, int rx) {
30         if (lx == rx) {
31             tree[x] = v[lx];
32             return;
33         }
34         int mid = (lx + rx) / 2;
35         build(2 * x, lx, mid);
36         build(2 * x + 1, mid + 1, rx);
37         tree[x] = tree[2 * x] + tree[2 * x + 1];
38     }
39     int query(int x, int lx, int rx, int l, int r) {
40         push(x, lx, rx);
41         if (lx >= l && rx <= r)
42             return tree[x];
43         if (lx > r || rx < l)
44             return 0;
45         int mid = (lx + rx) / 2;
46         return query(2 * x, lx, mid, l, r) + query(2 * x + 1, mid
47             + 1, rx, l, r);
48     }
49     int query(int l, int r) {
50         return query(1, 0, n - 1, l, r);
51     }
52     void push(int x, int lx, int rx) {
53         if (lazy_a[x] && lazy_d[x]) {
54             int tam = rx - lx + 1;
55             tree[x] += gauss(tam, lazy_a[x], lazy_d[x]);
56             if (lx != rx) {
57                 int mid = (lx + rx) / 2;
58                 int tam_esq = mid - lx + 1;
59                 lazy_a[2 * x] += lazy_a[x];
60                 lazy_d[2 * x] += lazy_d[x];
61                 lazy_a[2 * x + 1] += (lazy_a[x] + tam_esq * lazy_d[x
62                     ]);
63                 lazy_d[2 * x + 1] += lazy_d[x];
64             }
65             lazy_a[x] = lazy_d[x] = 0;
66         }
67     }
68     void update(int x, int lx, int rx, int l, int r, int a, int
69     d) {

```

```

67   push(x, lx, rx);
68   if (lx >= l && rx <= r) {
69     lazy_a[x] += a + (lx - l) * d;
70     lazy_d[x] += d;
71     push(x, lx, rx);
72     return;
73   }
74   if (lx > r || rx < l)
75     return;
76   int mid = (lx + rx) / 2;
77   update(2 * x, lx, mid, l, r, a, d);
78   update(2 * x + 1, mid + 1, rx, l, r, a, d);
79   tree[x] = tree[2 * x] + tree[2 * x + 1];
80 }
81 void update(int l, int r, int a, int d) {
82   update(1, 0, n - 1, l, r, a, d);
83 }
84 }

```

10.9 Min Queue

```

1 struct MinQueue {
2   deque<pair<int, int>> dq;
3   void push(int val, int idx) {
4     while (!dq.empty() && dq.back().second >= val) dq.pop_back();
5     dq.emplace_back(val, idx);
6   }
7   void pop(int idx) {
8     if (!dq.empty() && dq.front().second == idx) {
9       dq.pop_front();
10    }
11  }
12  int get() {
13    return dq.front().first;
14  }
15  bool empty() {
16    return dq.empty();
17  }
18 };
19 /*
20  considerando janela de tamanho K
21 mq.push(v[i], i);
22 if (i >= k) {
23   mq.pop(i - k);
24 }
25 if (i >= k - 1) {
26   result.push_back(mq.get());
27 }
28 */

```

10.10 Segtree Iterativa

```

1 // Exemplo de uso:
2 // SegTree<int> st(vetor);
3 // range query e point update
4 template <typename T>
5 struct SegTree {
6   int n;
7   vector<T> tree;
8   T neutral_value = 0;
9   T combine(T a, T b) {
10     return a + b;
11   }
12
13   SegTree(const vector<T>& data) {
14     n = data.size();
15     tree.resize(2 * n, neutral_value);
16
17     for (int i = 0; i < n; i++)
18       tree[n + i] = data[i];
19
20     for (int i = n - 1; i > 0; --i)
21       tree[i] = combine(tree[i * 2], tree[i * 2 + 1]);
22   }
23   T range_query(int l, int r) {
24     T res_l = neutral_value, res_r = neutral_value;
25
26     for (l += n, r += n + 1; l < r; l >= 1, r >= 1) {
27       if (l & 1) res_l = combine(res_l, tree[l++]);
28       if (r & 1) res_r = combine(tree[--r], res_r);
29     }
30
31     return combine(res_l, res_r);
32   }
33 }
34 void update(int pos, T new_val) {
35   tree[pos += n] = new_val;
36   for (pos >= 1; pos > 0; pos >= 1)
37     tree[pos] = combine(tree[2 * pos], tree[2 * pos +
38     1]);
39 }

```

10.11 Merge Sort Tree

```

1 #define all(x) x.begin(), x.end()
2
3 struct MST {
4   int n;
5   vector<vector<int>> tree;
6   MST(vector<int> &a) {
7     n = a.size();
8     tree.resize(4 * n);
9     build(1, 0, n - 1, a);
10  }
11  void build(int x, int lx, int rx, vector<int> &a) {
12    if (lx == rx) {
13      tree[x] = { a[lx] };
14      return;
15    }
16    int mid = lx + (rx - lx) / 2;
17    build(2 * x, lx, mid, a);
18    build(2 * x + 1, mid + 1, rx, a);
19    auto &L = tree[2 * x], &R = tree[2 * x + 1];
20    L.resize(L.size() + R.size());
21    merge(all(L), all(R), tree[x].begin());
22  }
23  int query(int x, int lx, int rx, int l, int r, int val) {
24    if (lx > r || rx < l) return 0;
25    if (lx >= l && rx <= r) {
26      auto &v = tree[x];
27      return lower_bound(all(v), val) - v.begin();
28    }
29    int mid = lx + (rx - lx) / 2;
30    return query(2 * x, lx, mid, l, r, val) + query(2 * x +
31     1, mid + 1, rx, l, r, val);
32  }
33  int query(int l, int r, int val) {
34    if (l > r) return 0;
35    return query(1, 0, n - 1, l, r, val);
36  }
37
38 /* mst.query(l, r, l) retorna quantos caras distintos no
range
39 map<int, int> last;
40 for (int i = 0; i < n; i++) {
41   if (last.count(a[i])) {
42     esq[i] = last[a[i]];
43   } else {
44     esq[i] = -1;
45   }
46   last[a[i]] = i;
47 }
48 MST mst(esq);
49 jogar vetor de ultima aparicao na seg
50 */

```

10.12 Dsu

```

1 struct DSU {
2   vector<int> par, rank, sz;
3   int c;
4   DSU(int n) : par(n + 1), rank(n + 1, 0), sz(n + 1, 1), c(
5     n) {
6     for (int i = 1; i <= n; ++i) par[i] = i;
7   }
8   int find(int i) {
9     return (par[i] == i ? i : (par[i] = find(par[i])));
10  }
11  bool same(int i, int j) {
12    return find(i) == find(j);
13  }
14  int get_size(int i) {
15    return sz[find(i)];
16  }
17  int count() {
18    return c; // quantos componentes conexos
19  }
20 }

```

```
18      }
19      int merge(int i, int j) {
20          if ((i = find(i)) == (j = find(j))) return -1;
21          else --c;
22          if (rank[i] > rank[j]) swap(i, j);
23          par[i] = j;
24          sz[j] += sz[i];
25          if (rank[i] == rank[j]) rank[j]++;
26          return j;
27      }
28  };
```