

Competitive Programming Team Book

21 de maio de 2025

Conteúdo

- 1 dp
- 2 geometry
- 3 graphs
- 4 math
- 5 presets
- 6 ranges
- 7 strings

1 dp

1 LIS.cpp

```
3 #include "../presets/base.cpp"
// Lis O(n log k)
8 void print_LIS(vector<int> &P, vector<int> &A, int i) {
    if (P[i] == -1) cout << A[i];
14    print_LIS(P, A, P[i]);
    cout << " "<<A[i];
15 }

15 int n,k = 0; // n is the number of elements and k is the length
    length of actual LIS.
17 vector<int> L(n,0), L_id(n), p(n);
// L has the values of the last element of LIS with length i
// L_id is the position of the element L[i] in original array
// P is the position of the element that added before this
// number.
// If we just need the length of the LIS, the vectors L_id and p
// are unnecessary
int lis(vector<int> &A){
    for (int i = 0; i < n; ++i) { // O(n)
        int pos = lower_bound(L.begin(), L.begin()+k, A[i]) - L.begin
        ();
        L[pos] = A[i];
        L_id[pos] = i;
        p[i] = pos ? L_id[pos-1] : -1;
        if (pos == k) {
            k = pos+1;
        }
    }
}
```

box_stacking.cpp

```
#include "../presets/base.cpp"

// We use the LIS idea of stacking values, finding the the largest
// height.
// As we can rotate the boxes and repeat them, we can get all
// permutations
// of height, length and depth and sort them to get the best order
// (a sequence
// that can maximize the stacking

int boxStacking(vector<vector<int>>& b_ext) {
    vector<vector<int>> boxes;
    for (auto box: b_ext) {
        boxes.push_back({box[0],box[1],box[2]});
        boxes.push_back({box[0],box[2],box[1]});
        boxes.push_back({box[1],box[0],box[2]});
        boxes.push_back({box[1],box[2],box[0]});
        boxes.push_back({box[2],box[0],box[1]});
        boxes.push_back({box[2],box[1],box[0]});
    }
    sort(boxes.rbegin(), boxes.rend());
    int n = boxes.size();
    // Use an array
    vector<int> dp(n, 0);
    int ans=0;

    for(int i=0;i<n;i++) {
        auto box = boxes[i];
        for(int j=0;j<i;j++) {
            if (box[0] < boxes[j][0] && box[1] < boxes[j][1]) {
                dp[i] = max(dp[j], dp[i]);
            }
        }
        dp[i] += box[2];
        ans = max(ans, dp[i]);
    }

    return ans;
}
```

edit_distance.cpp

```
#include "../presets/base.cpp"

int editDistance(string a, string b) {
    if (a.size() > b.size()) swap(a,b);
    int n = a.size(), m =b.size();

    vector<vector<int>> dp_(n+1, vector<int>(m+1, 0));
    for(int i=0;i<=n;i++) {
        dp_[i][0] = i;
    }
    for(int i=0;i<=m;i++) {
        dp_[0][i] = i;
    }

    for(int i=1;i<=n;i++) {
        for(int j=1;j<=m;j++) {
            if (a[i-1] == b[j-1]) {
                dp_[i][j] = dp_[i-1][j-1];
            } else {
                dp_[i][j] = min({dp_[i-1][j], dp_[i][j-1], dp_[i-1][j-1]})
                + 1;
            }
        }
    }

    return dp_[n][m];
}
```

subset_sum.cpp

```
vector<vector<bool>> dp(n+1, vector<bool>(max_sum+1, false));
dp[0][0] = true;
for(int j = 0; j<=max_sum; j++){
    for(int i = 1; i<=n; i++){
        dp[i][j] = dp[i-1][j] || (j >= w[i-1] ? dp[i-1][j-w[i-1]] : 0)
        ;
    }
}
```

tsp.cpp

```
#include "../presets/base.cpp"

const int MAXN = 20;
int dp[MAXN][1<<MAXN], cost[MAXN][MAXN];

// Is necessary change too many things during the contest
// but, its a good base for the problem
int tsp (int n) {
    memset(dp, 0x3f, sizeof(dp));

    for(int i=0;i<n-1;i++) {
        dp[i][1 << i] = cost[0][i+1];
    }

    for(int i=1;i<1<<(n-1);i++){
        for(int j=0;j<n-1;j++) {
            if (!(i & (1 << j))) continue; // not visited yet
            int value = dp[j][i];
            int u = j + 1;
            for(int k =0;k<n-1;k++) {
                if ((i & (1 << k))) continue; // already visited
                int newmask = i|(1 << k);
                dp[k][newmask] = min(dp[k][newmask], value + cost[u][k+1])
            }
        }
    }
    // INF
    int ans = INF;
    for(int i = 0;i<(n-1);i++){
        ans = min(ans, dp[i][(1<<(n-1))-1] + cost[i+1][0]);
    }

    return ans;
}
```

2 geometry

convex_hull.cpp

```
#include "geometry.cpp"
// From geometry using: Point, point::orientation,
struct Convex_hull{
    static bool cw(const point&a, const point&b, const point&c, bool
        include_collinear){
        // Easy to change to ccw, just change all the calls of cw to
        ccw
        int o = orientation(a-c, b-c);
        return o < 0 || (include_collinear && o == 0);
    }
    friend void graham_scan(vector<point> &a, bool include_collinear
        = false){
        point p0 = *min_element(a.begin(), a.end(), point::smallest_y)
        ;
        point::translat = p0;
        sort(a.begin(), a.end(), point::cw_cmp);
        // Often it will be requested to sort ccw, so just change the
        algorithm for that and it already works.
        if(include_collinear){
            int i = (int)a.size()-1;
            while(i >= 0 && collinear(p0, a[i], a.back())) i--;
            reverse(a.begin()+i+1, a.end());
        }
        vector<point> st;
        for(int i = 0; i<(int)a.size(); i++){
            while(st.size() > 1 && !cw(st[st.size()-2], st.back(), a[i],
                include_collinear))
                st.pop_back();
            st.push_back(a[i]);
        }
        if(include_collinear == false && st.size() == 2 && st[0] == st
            [1])
            st.pop_back();
        a = st;
    }
};
```

convex_hull_trick.cpp

```
#include <bits/stdc++.h>
using namespace std;
#define ll long long
```

```

// Essa bizarrisse funcionou melhor do que a outra bizarrisse do
// cp algorithms então vamos com ela
// Teoricamente é pior na inserção de linhas, pois é  $n \log n$ 
// enquanto a outra é linear
// Porém funciona para mais casos pois a manutenção é dinâmica, não
// o exige pré ordenamento

struct Line {
    mutable ll k, m, p;
    bool operator<(const Line& o) const { return k < o.k; }
    bool operator<(ll x) const { return p < x; }
};

struct LineContainer : multiset<Line, less<>> {
    // (for doubles, use inf = 1/.0, div(a,b) = a/b)
    static const ll inf = LLONG_MAX;
    ll div(ll a, ll b) { // floored division
        return a / b - ((a ^ b) < 0 && a % b); }
    bool isect(iterator x, iterator y) {
        if (y == end()) return x->p = inf, 0;
        if (x->k == y->k) x->p = x->m > y->m ? inf : -inf;
        else x->p = div(y->m - x->m, x->k - y->k);
        return x->p >= y->p;
    }
    void add(ll k, ll m) {
        auto z = insert({k, m, 0}), y = z++, x = y;
        while (isect(y, z)) z = erase(z);
        if (x != begin() && isect(--x, y)) isect(x, y = erase(y));
        while ((y = x) != begin() && (--x)->p >= y->p)
            isect(x, erase(y));
    }
    ll query(ll x) {
        assert(!empty());
        auto l = *lower_bound(x);
        return l.k * x + l.m;
    }
};

```

geometry.cpp

```

#include "../presets/base.cpp"
const ld eps = 1e-9, inf = 1e9;

```

```

struct point {
    ld x, y;
    point(ld x = 0, ld y = 0) : x(x), y(y) {}
    static point origin;
    static point translat;

    friend point operator+(const point p, const point q) {
        return point(p.x + q.x, p.y + q.y);
    }
    friend point operator-(const point p, const point q) {
        return point(p.x - q.x, p.y - q.y);
    }
    friend point operator*(const point p, const ld k) {
        return point(p.x * k, p.y * k);
    }
    friend ld dot(const point p, const point q) {
        return p.x * q.x + p.y * q.y;
    }
    friend ld cross(const point p, const point q) {
        return p.x * q.y - p.y * q.x;
    }
    friend ld dist(const point &p, const point &q) {
        return sqrt(fabs(dot(p - q, p - q)));
    }
    friend ld proj(const point &p, const point &q) {
        return dot(p, q) / (dist(p, q));
    }
    bool operator<(const point &p) const { // Return smallest (x, y)
        return x < p.x || (x == p.x && y < p.y);
    }
    static bool smallest_y(const point&p, const point&q){
        return p.y < q.y || (p.y == q.y && p.x < q.x);
    }
    static bool angle_cmp(const point &p, const point &q) {
        auto op = p - translat;
        auto oq = q - translat;
        ld a = atan2l(op.y, op.x), b = atan2l(oq.y, oq.x);
        return a < b;
    }
    friend int orientation(const point &p, const point &q) {
        ld o = cross(p, q);
        if (o < 0) return -1; // clockwise
        if (o > 0) return 1; // counter clockwise
        return 0; // collinear
    }
};

```

```

}
static bool cw_cmp(const point&p, const point &q){
    point v1 = p-translat;
    point v2 = q-translat;
    int o = orientation(v1, v2);
    if(o == 0){
        return dot(v1, v1) < dot(v2, v2);
    }
    return o < 0;
}
bool operator==(const point &p) {
    return (x == p.x && y == p.y);
}
friend bool collinear(point &a, point &b, point &c) {
    return orientation(a - c, b - c) == 0;
}
friend ostream &operator<<(ostream &os, const point &p) {
    os << p.x << ", " << p.y;
    return os;
}
};
point point::origin(0, 0);
point point::translat(0, 0);

struct point3d {
    ld x, y, z;
    point3d() {}
    point3d(ld x, ld y, ld z) : x(x), y(y), z(z) {}
    friend point3d operator+(const point3d &p, const point3d &q) {
        return point3d(p.x + q.x, p.y + q.y, p.z + q.z);
    }
    friend point3d operator-(const point3d &p, const point3d &q) {
        return point3d(p.x - q.x, p.y - q.y, p.z - q.z);
    }
    friend point3d operator*(const point3d &p, ld q) {
        return point3d(p.x * q, p.y * q, p.z * q);
    }
    friend point3d operator/(const point3d &p, ld q) {
        return point3d(p.x / q, p.y / q, p.z / q);
    }
    friend ld dot(const point3d &p, const point3d &q) {
        return p.x * q.x + p.y * q.y + p.z * q.z;
    }
    friend point3d cross(const point3d &p, const point3d &q) {

```

```

        return point3d(
            p.y * q.z - p.z * q.y,
            p.z * q.x - p.x * q.z,
            p.x * q.y - p.y * q.x
        );
    }
};

struct halfplane {
    point p, pq;
    ld angle;
    halfplane() {}
    halfplane(point a, point b) : p(a), pq(b - a) {
        angle = atan2l(pq.y, pq.x);
    }
    bool out(const point &r) {
        return cross(pq, r - p) < -eps;
    }
    bool operator<(const halfplane &e) const {
        return angle < e.angle;
    }
    friend point intersection(const halfplane &s, const halfplane &t)
    {
        ld alpha = cross((t.p - s.p), t.pq) / cross(s.pq, t.pq);
        return s.p + (s.pq * alpha);
    }
};

double area(const vector<point> &v) {
    double res = 0;
    for (int i = 0; i < v.size(); i++) {
        point p = i ? v[i - 1] : v.back();
        point q = v[i];
        res += (p.x - q.x) * (p.y + q.y);
    }
    return fabs(res) / 2;
}

int sgn(ld val) {
    return val > 0 ? 1 : (val == 0 ? 0 : -1);
}

point mass_center(const vector<point> &v) {
    ld x = 0, y = 0;

```

```

int n = v.size();
for (int i = 0; i < n; i++) {
    x += v[i].x;
    y += v[i].y;
}
return point(x / (ld)n, y / (ld)n);
}

bool pointInTriangle(point a, point b, point c, point p) {
    ld s1 = abs(cross(b - a, c - a));
    ld s2 = abs(cross(a - p, b - p)) + abs(cross(b - p, c - p)) +
        abs(cross(c - p, a - p));
    return s1 == s2;
}

```

half-plane_Intersection.cpp

```

#include "geometry.cpp"
#define hp halfplane
vector<point> hp_intersect(vector<hp> &h){
    point box[4] = {
        point(1e9, 1e9),
        point(-1e9, 1e9),
        point(-1e9, -1e9),
        point(1e9, -1e9)
    };
    for(int i = 0; i < 4; i++){
        hp aux(box[i], box[(i+1)%4]);
        h.push_back(aux);
    }
    sort(h.begin(), h.end());
    deque<hp> dq;
    int len = 0;
    for(int i = 0; i < h.size(); i++){
        while(len > 1 && h[i].out(intersection(dq[len-1], dq[len-2])))
        {
            dq.pop_back();
            --len;
        }
        while(len > 1 && h[i].out(intersection(dq[0], dq[1])))
        {
            dq.pop_front();
            --len;
        }
    }
}

```

```

if(len > 0 && fabs1(cross(h[i].pq, dq[len-1].pq)) < eps){
    if(dot(h[i].pq, dq[len-1].pq) < 0.0)
        return vector<point>();
    if (h[i].out(dq[len-1].p)) {
        dq.pop_back();
        --len;
    }
    else continue;
}

dq.push_back(h[i]);
++len;
}
while (len > 2 && dq[0].out(intersection(dq[len-1], dq[len-2])))
{
    dq.pop_back();
    --len;
}
while (len > 2 && dq[len-1].out(intersection(dq[0], dq[1]))) {
    dq.pop_front();
    --len;
}
if (len < 3) return vector<point>();

vector<point> ret(len);
for(int i = 0; i+1 < len; i++) {
    ret[i] = intersection(dq[i], dq[i+1]);
}
ret.back() = intersection(dq[len-1], dq[0]);
return ret;
}

```

lichatree.cpp

```

#include <bits/stdc++.h>
using namespace std;

typedef long long ftype;
typedef complex<ftype> point;
#define x real
#define y imag

ftype dot(point a, point b) {

```

```

    return (conj(a) * b).x();
}

ftype f(point a, ftype x) {
    return dot(a, {x, 1});
}

const int maxn = 2e5;

point line[4 * maxn];

void add_line(point nw, int v = 1, int l = 0, int r = maxn) {
    int m = (l + r) / 2;
    bool lef = f(nw, l) < f(line[v], l);
    bool mid = f(nw, m) < f(line[v], m);
    if(mid)
        swap(line[v], nw);
    if(r - l == 1)
        return;
    else if(lef != mid)
        add_line(nw, 2 * v, l, m);
    else
        add_line(nw, 2 * v + 1, m, r);
}

ftype get(int x, int v = 1, int l = 0, int r = maxn) {
    int m = (l + r) / 2;
    if(r - l == 1)
        return f(line[v], x);
    else if(x < m)
        return min(f(line[v], x), get(x, 2 * v, l, m));
    else
        return min(f(line[v], x), get(x, 2 * v + 1, m, r));
}

```

minkowski.cpp

```

// AKA ConvexHull sum, the set of points A, B, and C where C = {a+
    b | a ∈ A, b ∈ B}
#include "geometry.cpp"

void reorder_polygon(vector<point> & p){
    int pos = 0;

```

```

    for(int i = 1; i < p.size(); i++){
        if(p[i].y < p[pos].y || (p[i].y == p[pos].y && p[i].x < p[pos]
            ].x))
            pos = i;
    }
    rotate(p.begin(), p.begin() + pos, p.end());
}

vector<point> minkowski(vector<point> p, vector<point> q){
    reorder_polygon(p);
    reorder_polygon(q);
    p.push_back(p[0]);
    p.push_back(p[1]);
    q.push_back(q[0]);
    q.push_back(q[1]);
    vector<point> result;
    int i = 0, j = 0;
    while(i < p.size() - 2 || j < q.size() - 2){
        result.push_back(p[i] + q[j]);
        auto c = cross(p[i+1] - p[i], q[j+1] - q[j]);
        if(c >= 0 && i < p.size() - 2)
            ++i;
        if(c <= 0 && j < q.size() - 2)
            ++j;
    }
    return result;
}

```

pointInConvexPolygon.cpp

```

#include "geometry.cpp"
vector<point> seq;
int n; point translation;
void prepare(vector<point> &v){ // just guarantee that the sorted
    points begin at the lowest (x, y)
    int pos = 0;
    n = v.size();
    for (int i = 1; i < n; i++) {
        if (v[i] < v[pos]) pos = i;
    }
    rotate(v.begin(), v.begin() + pos, v.end());
    n--;
    seq.resize(n);

```

```

for (int i = 0; i < n; i++)
    seq[i] = v[i + 1] - v[0];
translation = v[0];
}

bool pointInConvexPolygon(point p){
    // must be a sorted convex polygon.
    p = p - translation;
    if (cross(seq[0], p) != 0 &&
        sgn(cross(seq[0], p)) != sgn(cross(seq[0], seq[n-1])))
        return false;
    if (cross(seq[n-1], p) != 0 &&
        sgn(cross(seq[n-1], p)) != sgn(cross(seq[n-1], seq[0])))
        return false;
    if (cross(seq[0], p) == 0)
        return dot(seq[0], seq[0]) >= dot(p, p);

    int l = 0, r = n-1;
    while (r - l > 1) {
        int mid = (l + r) / 2;
        int pos = mid;
        if (cross(seq[pos], p) >= 0)
            l = mid;
        else
            r = mid;
    }
    int pos = l;
    return pointInTriangle(seq[pos], seq[pos + 1], point::origin, p)
        ;
}

```

3 graphs

MST.cpp

```

#include "../presets/base.cpp"

struct DSU {
    vector<int> parent, size;
    DSU(int n) {
        parent.resize(n);
        size.resize(n);
    }

```

```

for (int i = 0; i < n; i++) {
    parent[i] = i;
    size[i] = 1;
}

int find(int x) {
    if (parent[x] == x) return x;
    return parent[x] = find(parent[x]);
}

void join(int a, int b) {
    a = find(a);
    b = find(b);
    if (a == b) return;
    if (size[a] < size[b]) swap(a, b);
    parent[b] = a;
    size[a] += size[b];
}

};

bool cmp(pair<pair<int, int>, int> &a, pair<pair<int, int>, int> &b){
    return a.second < b.second;
}

int MST(int n, vector<pair<int, int>, int> &edges, vector<pair<
    pair<int, int>, int>> &tree){
    int m = edges.size();
    sort(edges.begin(), edges.end(), cmp);
    DSU dsu(n);

    int count = 1;
    double sum = 0;
    for(int e = 0; e < m && count < n; e++){
        int u = edges[e].first.first, v = edges[e].first.second;
        double w = edges[e].second;
        if(dsu.find(u) != dsu.find(v)){
            dsu.join(u, v);
            tree.push_back({{u, v}, w});
            count++;
            sum += w;
        }
    }
    return sum;
}

```



```
}
```

```
};
```

bellmanFord.cpp

```
#include "../presets/base.cpp"
struct Graph {
    vector<vector<pair<int, int>>> adj;
    vector<int> dist;

    void create(int numberOfVertices) {
        adj.clear();
        adj.assign(numberOfVertices, {});
    }

    void addEdge(int u, int v, int w){
        adj[u].push_back({w, v});
    }

    //1 - if has negative cycles; 0 - if not
    int bellmanFord(int s) {
        dist.clear();
        dist.assign(adj.size(), 1e9);

        dist[s] = 0;
        int cycle = 0;
        for (int k = 0; k <= adj.size(); k++) {
            for (int u = 0; u < adj.size(); u++) {
                for (pair<int, int> edge: adj[u]) {
                    int v = edge.second;
                    int w = edge.first;

                    if (dist[u]+w<dist[v]) {
                        dist[v] = dist[u]+w;
                        if (k == adj.size()) {
                            cycle = 1;
                        }
                    }
                }
            }
        }

        return cycle;
    }
}
```

centroides.cpp

```
#include "../presets/base.cpp"
struct Centroid{
    vector<int> subtree_size;
    vector<bool> is_removed;
    vector<vector<int>> adj;
    vector<vector<pair<int, int>>> ancestroids;
    Centroid(int v, vector<vector<int>> &g){
        subtree_size.assign(v, 0);
        is_removed.assign(v, false);
        ancestroids.assign(v, vector<pair<int, int>>());
        adj = g;
        build(0);
    }

    int get_subtree_size(int u, int parent = -1){
        subtree_size[u] = 1;
        for(int v: adj[u]){
            if(v == parent || is_removed[v]) continue;
            subtree_size[u] += get_subtree_size(v, u);
        }
        return subtree_size[u];
    }

    int get_centroid(int u, int tree_size, int parent = -1){
        for(int v: adj[u]){
            if(v == parent || is_removed[v]) continue;
            if(subtree_size[v] * 2 > tree_size){
                return get_centroid(v, tree_size, u);
            }
        }
        return u;
    }

    void build(int u){
        int subtree_size = get_subtree_size(u);
        int centroid = get_centroid(u, subtree_size);

        for(int v: adj[centroid]){
            if(!is_removed[v]){

```

```

        set_dists(v, centroid, centroid, 1);
    }
}
is_removed[centroid] = true;

for(int v: adj[centroid]){
    if(!is_removed[v]){
        build(v);
    }
}
}

void set_dists(int v, int centroid, int parent, int dist){
    ancestroids[v].push_back({centroid, dist});
    for(int w: adj[v]){
        if (w == parent || is_removed[w]) continue;
        set_dists(w, centroid, v, dist+1);
    }
}
};

```

dsu.cpp

```

#include "../presets/base.cpp"
struct DSU {
    vector<int> parent, size;
    void create(int n) {
        parent.resize(n);
        size.resize(n);
        for (int i = 0; i < n; i++) {
            parent[i] = i;
            size[i] = 1;
        }
    }

    int find(int x) {
        if (parent[x] == x) return x;
        return parent[x] = find(parent[x]);
    }

    void join(int a, int b) {
        a = find(a);
        b = find(b);
        if (a == b) return;
    }
}

```

```

        if (size[a] < size[b]) swap(a, b);
        parent[b] = a;
        size[a] += size[b];
    }
};

```

dyjksra.cpp

```

#include "../presets/base.cpp"
struct Graph {
    vector<vector<pair<int, int>>> adj;
    vector<int> dist;

    void create(int numberOfVertices) {
        adj.clear();
        adj.assign(numberOfVertices, {});
    }

    void addEdge(int u, int v, int w){
        adj[u].push_back({w, v});
    }

    void dyjksra(int s) {
        dist.clear();
        dist.assign(adj.size(), 1e9);

        priority_queue<pair<int, int>> q;
        q.push({0, s});

        while (!q.empty()) {
            int u = q.top().second;
            int cost = q.top().first; q.pop();

            if (cost == dist[u]) {
                for (pair<int, int> edge: adj[u]) {
                    int v = edge.second;
                    int w = edge.first;

                    if (cost+w < dist[v]) {
                        dist[v] = cost+w;
                        q.push({dist[v], v});
                    }
                }
            }
        }
    }
}

```

```

    }
  }
};

```

```

    return -v[0];
}

```

hungarian.cpp

```

// Algoritmo do cp algorithms, usa o Kuhn porém não como uma função
// externa, pois é modificado e reutilizado
#include "../presets/base.cpp"
int hungarian(vector<vector<int>> &A){
    int n = A.size()-1, m = A[0].size()-1; // For some reason, the
    // cp algorithm uses 1-index
    vector<int> u (n+1), v (m+1), p (m+1), way (m+1);
    for (int i=1; i<=n; ++i) {
        p[0] = i;
        int j0 = 0;
        vector<int> minv (m+1, INF);
        vector<bool> used (m+1, false);
        do {
            used[j0] = true;
            int i0 = p[j0], delta = INF, j1;
            for (int j=1; j<=m; ++j)
                if (!used[j]) {
                    int cur = A[i0][j]-u[i0]-v[j];
                    if (cur < minv[j])
                        minv[j] = cur, way[j] = j0;
                    if (minv[j] < delta)
                        delta = minv[j], j1 = j;
                }
            for (int j=0; j<=m; ++j)
                if (used[j])
                    u[p[j]] += delta, v[j] -= delta;
                else
                    minv[j] -= delta;
            j0 = j1;
        } while (p[j0] != 0);
        do {
            int j1 = way[j0];
            p[j0] = p[j1];
            j0 = j1;
        } while (j0);
    }
}

```

kosaraju.cpp

```

#include "../presets/base.cpp"

void dfs(int u, vector<bool> &v, vector<vector<int>> &adj, vector<
    int> &out){
    v[u] = true;
    for(int e: adj[u]){
        if(!v[e]) dfs(e, v, adj, out);
    }
    out.push_back(u);
}

void SCC(vector<vector<int>> &adj, vector<vector<int>> &
    componentes){
    int n = adj.size();
    vector<vector<int>> adj_T(n, vector<int>());
    for(int i = 0; i<n; i++){
        for(int u: adj[i]){
            adj_T[u].push_back(i);
        }
    }
    vector<bool> visitados(n, false);
    vector<int> st;
    for(int i = 0; i<n; i++){
        if(visitados[i]) continue;
        dfs(i, visitados, adj_T, st);
    }
    visitados.assign(n, false);
    reverse(st.begin(), st.end());

    for(auto v: st){
        if(!visitados[v]){
            vector<int> component;
            dfs(v, visitados, adj, component);
            componentes.push_back(component);
        }
    }
}

```

kuhn.cpp

```
#include "../presets/base.cpp"
struct Kuhn{

    // Para grafos bipartidos
    int n, k; // n = primeira partição, k = segunda partição
    vector<vector<int>> g; // Lista de adjecências da primeira parti
        ção para a segunda.
    // Escolher a menor delas como a primeira durante a leitura.
    vector<int> mt;
    vector<bool> used;

    bool try_kuhn(int v) {
        if (used[v])
            return false;
        used[v] = true;
        for (int to : g[v]) {
            if (mt[to] == -1 || try_kuhn(mt[to])) {
                mt[to] = v;
                return true;
            }
        }
        return false;
    }

    void kuhn(){
        mt.assign(k, -1);
        vector<bool> used1(n, false);
        for (int v = 0; v < n; ++v) {
            for (int to : g[v]) {
                if (mt[to] == -1) {
                    mt[to] = v;
                    used1[v] = true;
                    break;
                }
            }
        }
        for (int v = 0; v < n; ++v) {
            if (used1[v])
                continue;
            used.assign(n, false);
            try_kuhn(v);
        }
    }
};
```

```
for (int i = 0; i < k; ++i)
    if (mt[i] != -1)
        // mt[i] tells what vertex of the first part is connected
        to the vertex i of the second part, or -1 if it's not
        connected.
        // So if you want the size of it, just count how many aren
        't -1.
        printf("%d %d\n", mt[i] + 1, i + 1);
    }
};
```

lca.cpp

```
#include "../presets/base.cpp"
// LCA by binary_lifting

vector<int> st, en, depth; // depth is not needed for lca but for
    the virtual_tree
vector<vector<int>> adj, up; // up is the "ancestors" vector but
    up[i][j] is the  $2^j$  ancestor of i.
int n, tmp, max_it;
void dfs(int v, int p){
    st[v] = ++tmp;
    up[v][0] = p;
    for(int i = 1; i<= max_it; i++){
        up[v][i] = up[up[v][i-1]][i-1];
    }
    for(int e: adj[v]){
        if(e != p){
            depth[e] = depth[v]+1;
            dfs(e, v);
        }
    }
    en[v] = ++tmp;
}

bool is_ancestor(int u, int v){
    return st[u] <= st[v] && en[v] <= en[u]; // v is above u
}

int lca(int u, int v){
    if(is_ancestor(u, v)) return u;
    if(is_ancestor(v, u)) return v;
```

```

for(int i = max_it; i>=0; --i){
    if(!is_ancestor(up[u][i], v)) u = up[u][i];
}
return up[u][0];
}

```

```

void pre_compute_lca(int root){
    st.resize(n); en.resize(n); depth.resize(n);
    depth[root] = 0;
    tmp = 0;
    max_it = ceil(log2(n));
    up.assign(n, vector<int>(max_it+1));
    dfs(root, root);
}

```

topological_sort.cpp

```

#include "../presets/base.cpp"

void dfs(int u, vector<bool> &v, vector<vector<int>> &adj, vector<int> &out){
    v[u] = true;
    for(int e: adj[u]){
        if(!v[e]) dfs(e, v, adj, out);
    }
    out.push_back(u);
}

void topological_sort(vector<vector<int>> &adj, vector<int> &st){
    int n = adj.size();
    vector<vector<int>> adj_aux(n);
    for(int i = 0; i<n; i++){
        for(int u: adj[i])
            adj_aux[u].push_back(i);
    }
    vector<bool> visitados(n, false);

    for(int i = 0; i<n; i++){
        if(!visitados[i]){
            dfs(i, visitados, adj_aux, st);
        }
    }
}

```

virtual_tree.cpp

```

#include "lca.cpp"
// Solve problems like the query of a sum of the distance between
// all pair of given vertices in a tree
// It basically compress the tree to be just the important nodes (
// The considered vertices and their common ancestors),
// which are at most 2k-1, where k is the number of vertices
// considered (In k log k time).
struct Virtual_tree{
    vector<vector<int>> adj_vt;
    int vt_root;
    bool cmp(int u, int v){
        return st[u] < st[v];
    }
    Virtual_tree(int n, vector<int> &vert){
        adj_vt.assign(n, vector<int>());
        // Pick the needed vertices
        sort(vert.begin(), vert.end(), cmp);
        int k = vert.size();
        for(int i = 0; i < k-1; i++){
            vert.push_back(lca(vert[i], vert[i+1]));
        }
        sort(vert.begin(), vert.end(), cmp);
        vert.erase(unique(vert.begin(), vert.end()), vert.end()); //
        // Erase duplicates

        // build the actually virtual tree
        vector<int> st; st.push_back(vert[0]);

        for(int i = 1; i<vert.size(); i++){
            int u = vert[i];
            while(st.size() >= 2 && !is_ancestor(st.back(), u)){
                // add edge to the tree
                adj_vt[st[st.size()-2]].push_back(st.back());
                // here only the top -> bottom is added, which is fine as
                // we only need to transverse it from the root to the leaves.
                st.pop_back();
            }
            st.push_back(u);
        }
    }
}

```

```

while(st.size() >= 2){
    adj_vt[st[st.size()-2]].push_back(st.back());
    st.pop_back();
}
vt_root = st[0];
}
};

```

4 math

divisors.cpp

```

#include "../presets/base.cpp"
// Get all divisors via a map with the prime factors
// Probably could be done better.
void divisors(map<int, int> &factors, set<int> &d){
    d.clear(); d.insert(1);
    for(auto e: factors){
        int p = e.first;
        int exp = e.second;
        vector<int> aux;
        for(auto c : d){
            long long temp = 1;
            for(int i = 0; i < exp; i++){
                temp *= p;
                aux.push_back(c * temp);
            }
        }
        for(auto v : aux) d.insert(v);
    }
}

```

ext_euclidean.cpp

```

#include "../presets/base.cpp"
// {gcd, x, y}
tuple<int, int, int> gcd(int a, int b) {
    if(b == 0) return make_tuple(a, 1, 0);
    int q, w, e;
    tie(q, w, e) = gcd(b, a % b);
}

```

```

return make_tuple(q, e, w - e * (a / b));
}

```

factorize.cpp

```

#include "../presets/base.cpp"
// Faster option: while(a % 2) and while(a % 3) first
// and after that i = 5, i+=6, (a % i) and (a % (i+2))
void factorize(int a, map<int, int> &factors){
    for(int i = 2; i*i<=a; i++){
        while(a%i == 0){
            factors[i]++;
            a/=i;
        }
    }
    if(a > 1) factors[a]++;
}

```

fast_pow.cpp

```

#include "../presets/base.cpp"
#define md 1000000007
int fast_pow(int a, int b){ // Same logic (and almost the same
    code) can be applied
    // to all comutative and associative operations, sum
    , gcd, etc...
    int res = 1;
    while(b){
        if(b & 1){
            res = (a*b)%md;
        }
        a = (a*a)%md;
        b >>=1;
    }
    return res;
}

```

5 presets

base.cpp

```
#include<bits/stdc++.h>
#define ll long long
#define ld long double
#define INF INT_MAX

using namespace std;

void fast_io(){
    cin.tie(0);
    cout.tie(0);
    ios_base::sync_with_stdio(0);
}

int main(){
}
```

gen.cpp

```
#include <bits/stdc++.h>
using namespace std;

int rand(int a, int b){
    return a + rand()%(b - a + 1);
}

// Generate a random input for the sh script. Should be modified
// based on the real problem.
int main(int argc, char *argv[]){
    srand(atoi(argv[1]));
    int n = rand(2, 5000);
    printf("%d\n", n);
    set<int> used;
    for(int i = 0; i<n; i++){
        int x;
        do {
            x = rand(1, 5000);
        } while(used.count(x));
        printf("%d ", x);
    }
```

```
        used.insert(x);
    }
    puts("");
}
```

6 ranges

bit.cpp

```
template<int amountOfPicks>
class BIT{
public:
    int range[amountOfPicks+1];
    int read(int index) {
        index++;
        int runningSum = 0;
        while (index > 0) {
            runningSum += range[index];
            int rightMostSetBit = (index & (-index));
            index -= rightMostSetBit;
        }

        return runningSum;
    }

    int readRange(int l, int r) {
        return read(r) - read(l);
    }

    void clear() {
        memset(range, 0, sizeof(int) * amountOfPicks);
    }

    void update(int index, int x) {
        index++;
        while (index < amountOfPicks) {
            range[index] += x;
            int rightMostSetBit = (index & (-index));
            index += rightMostSetBit;
        }
    }
}
```

```

void updateRange(int l, int r, int x) {
    update(l, x);
    update(r+1, -x);
}
};

```

segtree.cpp

```

#include "../presets/base.cpp"
// To change the operation, just change conquer and RSQ and
    propagate
class SegTree{
private:
    int n;
    vector<ll> A, St, Lazy;

    int rl(int p) {return p<<1;}
    int rr(int p) {return (p<<1)+1;}

    ll conquer(ll a, ll b) {
        return a+b;
    }

    void build(int i, int l, int r) {
        if(l == r) {
            St[i] = A[l];
        } else {
            int mid = (l+r)/2;
            build(rl(i), l, mid);
            build(rr(i), mid+1, r);
            St[i] = conquer(St[rl(i)], St[rr(i)]);
        }
    }

    void propagate(int i, int l, int r) {
        if (Lazy[i] != -1) {
            St[i] = Lazy[i] * (r - l + 1);
            if (l != r) { Lazy[rl(i)] = Lazy[rr(i)] = Lazy[i]; }
            else { A[l] = Lazy[i]; }
            Lazy[i] = -1;
        }
    }
}

```

```

ll RSQ(int i, int l, int r, int tl, int tr) {
    propagate(i, tl, tr);
    if (l > tr || r < tl) return 0;
    if ((l <= tl) && (r >= tr)) return St[i];
    int mid = (tl+tr)/2;
    return conquer(RSQ(rl(i), l, r, tl, mid), RSQ(rr(i), l, r,
        min(tr,mid+1), tr));
}

```

```

void update(int i, int l, int r, int tl, int tr, int x) {
    propagate(i, l, r);
    if (l > tr || r < tl) return;
    if ((l <= tl) && (r >= tr)) {
        Lazy[i] = x;
        propagate(i, tl, tr);
    } else {
        int mid = (tl + tr) / 2;
        update(rl(i), l, r, tl, mid, x);
        update(rr(i), l, r, min(mid+1, tr), tr, x);
        St[i] = St[rl(i)] + St[rr(i)];
    }
}

public:
    SegTree(int sz): n(sz), St(4*n), Lazy(4*n, -1) {}
    SegTree(const vector<ll> &initial): SegTree(initial.size()) {
        A = initial;
        build(1, 0, n-1);
    }

    void update(int i, int j, int val) { update(1,i,j, 0,n-1, val);}
    ll RSQ(int i, int j) { return RSQ(1, i,j,0,n-1);}
};

```

sparse_table.cpp

```

#include "../presets/base.cpp"
struct SparseTable {
    vector<vector<int>>> st;
    vector<int> log;
    int n, k;
    SparseTable(vector<int> &a) {

```



```

n = a.size();
k = log2(n)+1;
st.assign(k, vector<int>(n));
copy(a.begin(), a.end(), st[0]);
log.assign(n+1, 0);
for(int i = 2; i<=n; i++) log[i] = log[i/2]+1;
// It's possible to construct the st with any operation that
satisfies f((a, b), c) = f(a, (b, c))
// just switch the min for the desired function
for (int i = 1; i <= k; i++)
    for (int j = 0; j + (1 << i) <= n; j++)
        st[i][j] = min(st[i - 1][j], st[i - 1][j + (1 << (i - 1))
]);
}
int query(int l, int r) {
    int i = log2(r - l + 1);
    return min(st[i][l], st[i][r - (1 << i) + 1]);
}
int sum_query(int l, int r){
    int sum = 0;
    for (int i = k; i >= 0; i--) {
        if ((1 << i) <= r - l + 1) {
            sum += st[i][l];
            l += 1 << i;
        }
    }
    return sum;
}
};

```

7 strings

kmp.cpp

```

#include "../presets/base.cpp"
#include "prefix_function.cpp"
vector<int> kmp(string &t, string &p){
    vector<int> lps = prefix_function(t);
    int i = 0, j = 0;
    vector<int> res;
    while (i < t.size()) {
        if (t[i] == p[j]) {

```

```

            i++, j++;
            if (j == p.size()) {
                res.push_back(i-j);
                j = lps[j-1];
            }
        } else {
            if (j != 0) {
                j = lps[j-1];
            } else {
                i++;
            }
        }
    }
    return res;
}

```

prefix_function.cpp

```

#include "../presets/base.cpp"
vector<int> prefix_function(string &s) {
    int n = (int)s.length();
    vector<int> pi(n);
    for (int i = 1; i < n; i++) {
        int j = pi[i-1];
        while (j > 0 && s[i] != s[j])
            j = pi[j-1];
        if (s[i] == s[j])
            j++;
        pi[i] = j;
    }
    return pi;
}

```