

## 1 IDID

```
dp[i] = min(dp[j] + cost(j+1, i)) given that cost() is QF
long long solveID(int n, long long cost(int, int)) {
    vector<long long> dp(n+1), opt(n+1);
    deque<pair<int, int>> dq;
    dq.push_back({0, 1}); dp[0] = 0;
    for (int i=1; i<=n; i++) {
        opt[i] = dq.front().first;
        dp[i] = dp[opt[i]] + cost(opt[i]+1, i);
        if (i == n) break;
    }
    dq[0].second++;
    if (dq.size() > 1 && dq[0].second == dq[1].second)
        dq.pop_front();
    int en = n;
    while(dq.size()) {
        int o = dq.back().first, st = dq.back().second;
        if (dp[o]+cost(o+1, st) >= dp[i]+cost(i+1, st))
            dq.pop_back();
        else {
            int lo = st, hi = en;
            while (lo < hi) {
                int mid = (lo+hi+1)/2;
                if (dp[o]+cost(o+1, mid) < dp[i]+cost(i+1, mid))
                    lo = mid;
                else hi = mid-1;
            }
            if (lo < n) dq.push_back({i, lo+1});
            break;
        }
        en = st-1;
    }
    if (dq.empty()) dq.push_back({i, i+1});
}
return dp[n];
}
```

## 2 2-Sat

```
int n;
vector<vector<int>> adj, adj_t;
vector<bool> used, assignment;
vector<int> order, comp;
void dfs1(int v) {
    used[v] = true;
    for (int u : adj[v]) { if (!used[u])
        dfs1(u);
    }
    order.push_back(v);
}
void dfs2(int v, int cl) {
    comp[v] = cl;
    for (int u : adj_t[v]) { if (comp[u] == -1)
        dfs2(u, cl);
    }
}
bool solve_2SAT() {
    order.clear(); used.assign(n, false);
    for (int i = 0; i < n; ++i) { if (!used[i])
        dfs1(i);
    }
    comp.assign(n, -1);
    for (int i = 0, j = 0; i < n; ++i) {
        int v = order[n - i - 1];
        if (comp[v] == -1) dfs2(v, j++);
    }
    assignment.assign(n / 2, false);
    for (int i = 0; i < n; i += 2) {
        if (comp[i] == comp[i + 1]) return false;
        assignment[i / 2] = comp[i] > comp[i + 1];
    }
}
```

```
}
return true;
}
void add_disjunction(int a, bool na, int b, bool nb) {
    // na and nb signify whether a and b are to be negated
    a = 2*a ^ na; b = 2*b ^ nb;
    int neg_a = a ^ 1; int neg_b = b ^ 1;
    adj[neg_a].push_back(b); adj[neg_b].push_back(a);
    adj_t[b].push_back(neg_a); adj_t[a].push_back(neg_b);
}
```

## 3 Aho

```
const int K = 26;
struct Node{
public:
    vector<int>nxt; vector<int>go;
    int suf ; int ssuf;
    bool leaf;
    int parent; int ch;
    Node(int p=-1, int ch = -1) {
        this->parent = p; this->ch = ch;
        nxt.resize(K, -1); go.resize(K, -1);
        leaf = false; suf = -1;
        ssuf = -1;
    }
};
struct AhoCorasick{
    vector<Node>nodes;
    AhoCorasick() {
        nodes.emplace_back(Node());
    }
    int get_num(char ch) {
        int ret = ch-'a'; return ret;
    }
    void add_string(string &s) {
        int v = 0;
        for(int i=0; i<s.size(); i++) {
            int now = get_num(s[i]);
            if(nodes[v].nxt[now]==-1) {
                nodes[v].nxt[now] = nodes.size();
                nodes.emplace_back(v, now);
            }
            v = nodes[v].nxt[now];
        }
        nodes[v].leaf = true;
    }
    int go(int v, int ch) {
        int &ret = nodes[v].go[ch];
        if(ret!=-1) return ret;
        if(nodes[v].nxt[ch]!=-1) {
            return ret = nodes[v].nxt[ch];
        }
        if(v==0) { return ret = 0; }
        return ret = go(get_link(v), ch);
    }
    int get_link(int v) {
        int &ret = nodes[v].suf;
        if(ret!=-1) return ret;
        if(v==0 || nodes[v].parent==0)
            { return ret = 0; }
        return ret = go(get_link(nodes[v].parent) ,
            nodes[v].ch);
    }
    int exit_link(int v) {
        int &ret = nodes[v].ssuf;
        if(ret!=-1) return ret;
        if(v==0 || nodes[v].parent==0)
            { return ret = 0; }
        int s = get_link(v);
        if(nodes[s].leaf)
            { return ret = s; }
    }
}
```

```
return ret = exit_link(s);
}
void feed(string &s) {
    int v = 0;
    for(int i=0; i<s.size(); i++) {
        int ch = get_num(s[i]);
        v = go(v, ch); int u = v ;
        while(u!=0)
            { u = exit_link(u); }
    }
};
```

## 4 ArticulationBridge

```
vector<bool> visited;
vector<int> tin, low;
int timer;

void dfs(int v, int p = -1) {
    visited[v] = true;
    tin[v] = low[v] = timer++;
    for (int to : adj[v]) {
        if (to == p) continue;
        if (visited[to]) {
            low[v] = min(low[v], tin[to]);
        } else {
            dfs(to, v);
            low[v] = min(low[v], low[to]);
            if (low[to] > tin[v])
                IS_BRIDGE(v, to);
        }
    }
}

void find_bridges() {
    timer = 0;
    visited.assign(n, false);
    tin.assign(n, -1);
    low.assign(n, -1);
    for (int i = 0; i < n; ++i) {
        if (!visited[i])
            dfs(i);
    }
}
```

## 5 ArticulationPoint

```
vector<bool> visited;
vector<int> tin, low;
int timer;

void dfs(int v, int p = -1) {
    visited[v] = true;
    tin[v] = low[v] = timer++;
    int children=0;
    for (int to : adj[v]) {
        if (to == p) continue;
        if (visited[to]) {
            low[v] = min(low[v], tin[to]);
        } else {
            dfs(to, v);
            low[v] = min(low[v], low[to]);
            if (low[to] >= tin[v] && p!=-1)
                IS_CUTPOINT(v);
            ++children;
        }
    }
    if(p == -1 && children > 1)
        IS_CUTPOINT(v);
}
```

```
void find_cutpoints() {
    timer = 0;
    visited.assign(n, false);
    tin.assign(n, -1);
    low.assign(n, -1);
    for (int i = 0; i < n; ++i) {
        if (!visited[i])
            dfs(i);
    }
}
```

## 6 BIT2D

```
struct FenwickTree2D {
    vector<vector<int>> bit;
    int n, m;

    // init(...) { ... }

    int sum(int x, int y) {
        int ret = 0;
        for (int i = x; i >= 0; i = (i & (i + 1)) - 1)
            for (int j = y; j >= 0; j = (j & (j + 1)) - 1)
                ret += bit[i][j];
        return ret;
    }

    void add(int x, int y, int delta) {
        for (int i = x; i < n; i = i | (i + 1))
            for (int j = y; j < m; j = j | (j + 1))
                bit[i][j] += delta;
    }
};
```

## 7 Berlekamp

```
#define SZ 233333
const int MOD=1e9+7;
ll qp(ll a,ll b){
    ll x=1; a%=MOD;
    while(b) {
        if(b&1) x=x*a%MOD;
        a=a*a%MOD; b>>=1;
    }
    return x;
}

namespace linear_seq{
    inline vector<int> BM(vector<int> x){
        vector<int> ls,cur; int lf,ld;
        for(int i=0; i<int(x.size()); ++i) {
            ll t=0;
            for(int j=0; j<int(cur.size()); ++j)
                t=(t+x[i-j-1]*(ll)cur[j])%MOD;
            if((t-x[i])%MOD==0) continue;
            if(!cur.size()) {
                cur.resize(i+1); lf=i; ld=(t-x[i])%MOD;
                continue;
            }
            ll k=-(x[i]-t)*qp(ld,MOD-2)%MOD;
            vector<int> c(i-lf-1); c.push_back(k);
            for(int j=0; j<int(ls.size()); ++j)
                c.push_back(-ls[j]*k%MOD);
            if(c.size()<cur.size()) c.resize(cur.size());
            for(int j=0; j<int(cur.size()); ++j)
                c[j]=(c[j]+cur[j])%MOD;
            if(i-lf+(int)ls.size()>=(int)cur.size())
                ls=cur,lf=i,ld=(t-x[i])%MOD; cur=c;
        }
        for(int i=0; i<int(cur.size()); ++i)
            cur[i]=(cur[i]%MOD+MOD)%MOD;
        return cur;
    }
}
```

```
int m; ll a[SZ],h[SZ],t_[SZ],s[SZ],t[SZ];
inline void mull(ll*p,ll*q){
    for(int i=0; i<m+m; ++i) t_[i]=0;
    for(int i=0; i<m; ++i) if(p[i])
        for(int j=0; j<m; ++j)
            t_[i+j]=(t_[i+j]+p[i]*q[j])%MOD;
    for(int i=m+m-1; i>=m; --i) if(t_[i])
        for(int j=m-1; ~j; --j)
            t_[i-j-1]=(t_[i-j-1]+t_[i]*h[j])%MOD;
    for(int i=0; i<m; ++i) p[i]=t_[i];
}

inline ll calc(ll K){
    for(int i=m; ~i; --i) s[i]=t[i]=0;
    s[0]=1;
    if(m!=1) t[1]=1; else t[0]=h[0];
    while(K){if(K&1)mull(s,t);mull(t,t);K>>=1;}
    ll su=0;
    for(int i=0; i<m; ++i) su=(su+s[i]*a[i])%MOD;
    return (su%MOD+MOD)%MOD;
}

inline int work(vector<int> x,ll n){
    if(n<int(x.size())) return x[n];
    vector<int> v=BM(x); m=v.size();
    if(!m) return 0;
    for(int i=0; i<m; ++i) h[i]=v[i],a[i]=x[i];
    return calc(n);
}

using linear_seq::work;
```

## 8 CHT

```
bool Q;

struct Line{
    mutable ll k, m, p; // slope, y-intercept, last optimal
    x
    bool operator<(const Line& o) const {
        return Q ? p < o.p : k < o.k;
    }
};

struct LineContainer : multiset<Line>{
    const ll inf = LLONG_MAX;
    ll div(ll a, ll b) // floored division {
        if (b < 0)
            a *= -1, b *= -1;
        if (a >= 0)
            return a / b;
        return -((-a + b - 1) / b);
    }

    // updates x->p, determines if y is unneeded
    bool isect(iterator x, iterator y) {
        if (y == end()) {
            x->p = inf;
            return 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) // gives max value {
        assert(!empty());
        Q = 1;
        auto l = *lower_bound({0, 0, x});
        Q = 0;
        return l.k * x + l.m;
    }
};
```

## 9 CRT

```
/** Works for non-coprime moduli.
    Returns {0,0} if solution does not exist or input is
    invalid.
    Otherwise, returns {x,L}, where x is the solution
    unique to mod L

*/
constexpr long long safe_mod(long long x, long long m) {
    x %= m;
    if (x < 0) x += m;
    return x;
}

constexpr std::pair<long long, long long> inv_gcd(long
    long a, long long b) {
    a = safe_mod(a, b);
    if (a == 0) return {b, 0};
    long long s = b, t = a;
    long long m0 = 0, m1 = 1;
    while (t) {
        long long u = s / t;
        s -= t * u;
        m0 -= m1 * u;
        auto tmp = s;
        s = t;
        t = tmp;
        tmp = m0;
        m0 = m1;
        m1 = tmp;
    }
    if (m0 < 0) m0 += b / s;
    return {s, m0};
}

std::pair<long long, long long> crt(const
    std::vector<long long>& r,
    const std::vector<long long>& m) {
    assert(r.size() == m.size());
    int n = int(r.size());
    long long r0 = 0, m0 = 1;
    for (int i = 0; i < n; i++) {
        assert(1 <= m[i]);
        long long r1 = safe_mod(r[i], m[i]), m1 = m[i];
        if (m0 < m1) {
            std::swap(r0, r1);
            std::swap(m0, m1);
        }
        if (m0 % m1 == 0) {
            if (r0 % m1 != r1) return {0, 0};
            continue;
        }
        long long g, im;
        std::tie(g, im) = inv_gcd(m0, m1);
        long long u1 = (m1 / g);
        if ((r1 - r0) % g) return {0, 0};
        long long x = (r1 - r0) / g % u1 * im % u1;
        r0 += x * m0;
        m0 *= u1;
        if (r0 < 0) r0 += m0;
    }
}
```

```
return {r0, m0};
}
```

## 10 Centroid

```
class CentroidDecomposition{
public:
    vector<vector<int>> >adj;
    vector<int>sz,parent;
    vector<bool>vis;
    int n,root;
    CentroidDecomposition(vector<vector<int>> >&a) {
        adj = a; n = adj.size(); sz.resize(n);
        parent.resize(n,-1);
        vis.resize(n,false);
        build(0,-1);
    }
    void build(int s, int p) {
        dfs(s,p);
        int c= centroid(s,p,sz[s]); vis[c]= true;
        if(p!=-1) { parent[c] = p; }
        else { root = c; }
        for(auto it:adj[c]) { if(vis[it]) continue;
            build(it,c);
        }
    }
    void dfs(int s, int p) {
        sz[s] = 1;
        for(auto i:adj[s]) { if(i==p || vis[i]) continue;
            dfs(i,s); sz[s]+= sz[i];
        }
    }
    int centroid(int s,int p, int total) {
        for(auto i:adj[s]) { if(i==p || vis[i]) continue;
            if(sz[i]*2>total) return centroid(i,s,total);
        }
        return s;
    }
};
```

## 11 ContinuedFraction

*/\*Description: Given f and N, finds the smallest fraction p/q in [0, 1] such that f(p/q) is true, and p, q less than N. You may want to throw an exception from f if it finds an exact solution, in which case N can be removed.*  
*Usage: fracBS([f](Frac f) { return f.p>=3\*f.q; }, 10);*  
*// {1,3} Time: O(log(N)) Status: fuzzz-tested for n <= 300 \*/*

```
typedef __int128_t lll;
struct Frac{
    lll p, q;
};
template<class F>
Frac fracBS(F f, lll N){
    bool dir = 1, A = 1, B = 1;
    Frac lo{0, 1}, hi{1, 0};
    if (f(lo))
        return lo;
    assert(f(hi));
    while (A || B) {
        lll adv = 0, step = 1;
        for (int si = 0; step; (step *= 2) >= si) {
            adv += step;
            Frac mid{lo.p * adv + hi.p, lo.q * adv + hi.q};
            if ((mid.p < 0 ? -mid.p : mid.p) > N || mid.q > N ||
                dir == !f(mid)) { adv -= step; si = 2;
            }
        }
        hi.p += lo.p * adv; hi.q += lo.q * adv;
```

```
    dir = !dir; swap(lo, hi);
    A = B; B = !!adv;
}
return dir ? hi : lo;
}
int main(){
    Frac target = fracBS([&](Frac fr) {
        if (fr.q == 0) return true;
        return minfr < fr;
    }, mid);
}
```

## 12 DC DP

```
int dp_before[N],dp_cur[N],cnt[N],l=0,r=-1,cur;
void add(int idx){
    cnt[a[idx]]++; if(cnt[a[idx]]==1)cur++;
}
void remove(int idx){
    cnt[a[idx]]--; if(cnt[a[idx]]==0) cur--;
}
int cost(int L,int R){
    while (l > L) { l--; add(l); }
    while (r < R) { r++; add(r); }
    while (l < L) { remove(l); l++; }
    while (r > R) { remove(r);r--;}
    return cur;
}
void compute(int l, int r, int optl, int optr){
    if (l > r) return;
    int mid = (l + r) >> 1;
    pair<int, int> best = {-1e9, -1};
    for (int k = optl; k <= min(mid, optr); k++) {
        if(best.second==-1) { best = {dp_before[k] +cost(k+1,
            mid), k};}
        else { best = max(best, {dp_before[k] +cost(k+1, mid),
            k}); }
    }
    dp_cur[mid] = best.first; int opt = best.second;
    compute(l, mid - 1, optl, opt);compute(mid + 1, r, opt,
        optr);
}
```

## 13 DEBUG TEMPLATE

```
void err(istream_iterator<string> it) {cout<<endl;}
template<typename T, typename... Args>
void err(istream_iterator<string> it, T a, Args... args){
    cout << *it << " = " << a << " ";err(++it, args...);
}
template<class T1, class T2>
ostream &operator <<(ostream &os, pair<T1,T2>&p) {
    os<<"{"<<p.first<<" , "<<p.second<<"} ";
    return os;
}
#define debug(args...) { string _s = #args;
    replace(_s.begin(), _s.end(), ',', ' ');
    stringstream _ss(_s); istream_iterator<string>
        _it(_ss); err(_it, args); }
```

## 14 DSU Rollback

```
struct dsu_save {
    int v, rnkv, u, rnku;
    dsu_save() {}
    dsu_save(int _v, int _rnkv, int _u, int _rnku)
        : v(_v), rnkv(_rnkv), u(_u), rnku(_rnku) {}
};
struct dsu_with_rollback {
    vector<int> p, rnk;
```

```
int comps;
stack<dsu_save> op;
dsu_with_rollback() {}
dsu_with_rollback(int n) {
    p.resize(n);
    rnk.resize(n);
    for (int i = 0; i < n; i++) {
        p[i] = i;
        rnk[i] = 0;
    }
    comps = n;
}
int find_set(int v) {
    return (v == p[v]) ? v : find_set(p[v]);
}
bool unite(int v, int u) {
    v = find_set(v);
    u = find_set(u);
    if (v == u)
        return false;
    comps--;
    if (rnk[v] > rnk[u])
        swap(v, u);
    op.push(dsu_save(v, rnk[v], u, rnk[u]));
    p[v] = u;
    if (rnk[u] == rnk[v])
        rnk[u]++;
    return true;
}
void rollback() {
    if (op.empty())
        return;
    dsu_save x = op.top();
    op.pop();
    comps++;
    p[x.v] = x.v;
    rnk[x.v] = x.rnkv;
    p[x.u] = x.u;
    rnk[x.u] = x.rnku;
}
};
struct query {
    int v, u;
    bool united;
    query(int _v, int _u) : v(_v), u(_u) {}
};
struct QueryTree {
    vector<vector<query>> t;
    dsu_with_rollback dsu;
    int T;
    QueryTree() {}
    QueryTree(int _T, int n) : T(_T) {
        dsu = dsu_with_rollback(n);
        t.resize(4 * T + 4);
    }
    void add_to_tree(int v, int l, int r, int ul, int ur,
        query& q) {
        if (ul > ur)
            return;
        if (l == ul && r == ur) {
            t[v].push_back(q);
            return;
        }
        int mid = (l + r) / 2;
        add_to_tree(2 * v, l, mid, ul, min(ur, mid), q);
        add_to_tree(2 * v + 1, mid + 1, r, max(ul, mid + 1),
            ur, q);
    }
    void add_query(query q, int l, int r) {
        add_to_tree(1, 0, T - 1, l, r, q);
    }
```

```

}
void dfs(int v, int l, int r, vector<int>& ans) {
    for (query& q : t[v]) {
        q.united = dsu.unite(q.v, q.u);
    }
    if (l == r)
        ans[l] = dsu.comps;
    else {
        int mid = (l + r) / 2;
        dfs(2 * v, l, mid, ans);
        dfs(2 * v + 1, mid + 1, r, ans);
    }
    for (query q : t[v]) {
        if (q.united)
            dsu.rollback();
    }
}
vector<int> solve() {
    vector<int> ans(T);
    dfs(1, 0, T - 1, ans);
    return ans;
}
};

```

## 15 Dinic

```

const long long flow_inf = 1e18;
struct FlowEdge {
    int v,u,id; long long cap, flow = 0;
    FlowEdge(int v, int u, long long cap,int id=-1) : v(v),
        u(u), cap(cap),id(id) {}
};
struct Dinic {
    vector<FlowEdge> edges; vector<vector<int>> > adj;
    int n, m = 0; int s, t;
    vector<int> level, ptr,flow_through; queue<int> q;
    vector<bool>vis; int maxid=0;
    Dinic() {} Dinic(int n) : n(n) {
        vis.resize(n); adj.resize(n);
        level.resize(n); ptr.resize(n);
    }
    void add_edge(int v, int u, long long cap,int id=-1) {
        edges.emplace_back(v, u, cap,id);
        edges.emplace_back(u, v, 0);
        adj[v].push_back(m);
        adj[u].push_back(m + 1);
        m += 2;
        if(id!=-1)maxid++;
    }
    void dfs2(int s) {
        vis[s] = 1;
        for(int i:adj[s]) {
            int id = i; int u = edges[id].v;
            int v = edges[id].u;
            if(edges[id].flow!=edges[id].cap && !vis[v]) {
                dfs2(v);
            }
        }
    }
    vector<int> getMinCut() {
        dfs2(s); vector<int>ret;
        for(int i=0; i<n; i++) {
            if(vis[i]) ret.push_back(i);
        }
        return ret;
    }
    bool bfs() {
        while (!q.empty()) {
            int v = q.front(); q.pop();
            for (int id : adj[v]) {

```

```

                if (edges[id].cap - edges[id].flow < 1)
                    continue;
                if (level[edges[id].u] != -1) continue;
                level[edges[id].u] = level[v] + 1;
                q.push(edges[id].u);
            }
        }
        return level[t] != -1;
    }
    long long dfs(int v, long long pushed) {
        if (pushed == 0) return 0;
        if (v == t) return pushed;
        for (int& cid = ptr[v]; cid < (int)adj[v].size(); cid++){
            int id = adj[v][cid]; int u = edges[id].u;
            if (level[v] + 1 != level[u] ||
                edges[id].cap - edges[id].flow < 1) continue;
            long long tr = dfs(u, min(pushed, edges[id].cap -
                edges[id].flow));
            if (tr == 0) continue;
            edges[id].flow += tr; edges[id ^ 1].flow -= tr;
            return tr;
        }
        return 0;
    }
    long long flow(int _s,int _t) {
        s=_s; t=_t; long long f = 0;
        while (true) {
            fill(level.begin(), level.end(), -1);
            level[s] = 0; q.push(s);
            if (!bfs()) break;
            fill(ptr.begin(), ptr.end(), 0);
            while (long long pushed = dfs(s, flow_inf)){
                f += pushed;
            }
        }
        flow_through.assign(maxid+1, 0);
        for(int i = 0; i < n; i++){
            for(auto j : adj[i]) {
                int idx = j;
                FlowEdge e = edges[idx];
                if(e.id >= 0)flow_through[e.id] = e.flow;
            }
        }
        return f;
    }
};
/*for bipartite graph*/
class Minimum_node_cover
{
    map<pair<int,int>,bool>matched;vector<vector<int>> >adj;
    vector<int>minimum_vertex,maximum_set,l,r;
    vector<bool>vis;
    /*number of nodes in dinic without source and
    destination src = 0 ,dest = sz+1
    d.flow() should be called before constructor calling*/
    Minimum_node_cover(int sz, Dinic &d){
        adj.resize(sz+5);vis.resize(sz+5);
        for(auto it:d.edges){
            if(it.u>0 && it.u<=sz && it.v>0 && it.v<=sz &&
                it.cap==1){
                if(it.flow==1){
                    adj[it.u].push_back(it.v);
                    matched[ {it.u,it.v} ]=1;
                }
                else adj[it.v].push_back(it.u);
            }
        }
        for(auto it:d.edges){
            if(it.v==0 && it.cap==1) l.push_back(it.u);
            if(it.u==sz+1 && it.cap==1) r.push_back(it.v);

```

```

        }
        sort(l.begin(),l.end());sort(r.begin(),r.end());
        l.resize(distance(l.begin(),unique(l.begin(),l.end())));
        r.resize(distance(r.begin(),unique(r.begin(),r.end())));
        for(auto it:d.edges){
            if(it.v==0 && it.cap==1 && it.flow==0){
                if(!vis[it.u]) dfs2(it.u, 1);
            }
        }
        for(int i:l){
            if(!vis[i]) minimum_vertex.push_back(i);
            else maximum_set.push_back(i);
        }
        for(int i:r){
            if(vis[i]) minimum_vertex.push_back(i);
            else maximum_set.push_back(i);
        }
    }
    void dfs2(int s, bool bam){
        vis[s] = 1;
        if(bam){
            for(int i:adj[s]){
                if(vis[i]) continue;
                if(matched[ {s,i} ]==0) dfs2(i,0);
            }
        }
        else{
            for(int i:adj[s]){
                if(vis[i]) continue;
                if(matched[ {s,i} ]==1) dfs2(i,1);
            }
        }
    }
};
//flow_through[i] = extra flow beyond 'low' sent through
//edge i
struct LR_Flow{
    Dinic F;int n, s, t;
    struct edge{
        int u, v, l, r, id;
    };
    vector<edge> edges;
    LR_Flow() {}
    LR_Flow(int _n){
        n = _n + 2;s = n - 2, t = n - 1;;
        edges.clear();
    }
    void add_edge(int u, int v, int l, int r, int id = -1){
        assert(0 <= l && l <= r);
        edges.push_back({u, v, l, r, id});
    }
    bool feasible(int _s=-1,int _t=-1,int L=-1, int R=-1){
        if (L != -1) edges.push_back({_t, _s, L, R, -1});
        F = Dinic(n); long long target = 0;
        for (auto e : edges){
            int u = e.u, v = e.v, l = e.l, r = e.r, id = e.id;
            if (l != 0){
                F.add_edge(s, v, l, r);F.add_edge(u, t, l); target += l;
            }
            F.add_edge(u, v, r - l, id);
        }
        auto ans = F.flow(s, t);
        if (L != -1)edges.pop_back();
        if (ans < target)return 0; //not feasible
        return 1;
    }
    int max_flow(int _s, int _t){//-1 means flow is not
        //feasible
        int mx = 1e5 + 9;
        if (!feasible(_s, _t, 0, mx))return -1;

```

```

    return F.flow(_s, _t);
}
int min_flow(int _s, int _t){ // -1 means flow is not feasible
    int mx = 1e9; int ans = -1, l = 0, r = mx;
    while (l <= r){
        int mid = l + r >> 1;
        if (feasible(_s, _t, 0, mid))
            ans = mid, r = mid - 1;
        else l = mid + 1;
    }
    return ans;
}
};

```

## 16 Diophantine

```

int gcd(int a, int b, int& x, int& y) {
    if (b == 0) {
        x = 1;
        y = 0;
        return a;
    }
    int x1, y1;
    int d = gcd(b, a % b, x1, y1);
    x = y1;
    y = x1 - y1 * (a / b);
    return d;
}

bool find_any_solution(int a, int b, int c, int &x0, int
    &y0, int &g) {
    g = gcd(abs(a), abs(b), x0, y0);
    if (c % g) {
        return false;
    }

    x0 *= c / g;
    y0 *= c / g;
    if (a < 0) x0 = -x0;
    if (b < 0) y0 = -y0;
    return true;
}

void shift_solution(int &x, int &y, int a, int b, int
    cnt) {
    x += cnt * b;
    y -= cnt * a;
}

int find_all_solutions(int a, int b, int c, int minx,
    int maxx, int miny, int maxy) {
    int x, y, g;
    if (!find_any_solution(a, b, c, x, y, g))
        return 0;
    a /= g;
    b /= g;

    int sign_a = a > 0 ? +1 : -1;
    int sign_b = b > 0 ? +1 : -1;

    shift_solution(x, y, a, b, (minx - x) / b);
    if (x < minx)
        shift_solution(x, y, a, b, sign_b);
    if (x > maxx)
        return 0;
    int lx1 = x;

    shift_solution(x, y, a, b, (maxx - x) / b);
    if (x > maxx)
        shift_solution(x, y, a, b, -sign_b);
    int rx1 = x;

    shift_solution(x, y, a, b, -(miny - y) / a);

```

```

    if (y < miny)
        shift_solution(x, y, a, b, -sign_a);
    if (y > maxy)
        return 0;
    int lx2 = x;

    shift_solution(x, y, a, b, -(maxy - y) / a);
    if (y > maxy)
        shift_solution(x, y, a, b, sign_a);
    int rx2 = x;

    if (lx2 > rx2)
        swap(lx2, rx2);
    int lx = max(lx1, lx2);
    int rx = min(rx1, rx2);

    if (lx > rx)
        return 0;
    return (rx - lx) / abs(b) + 1;
}

```

## 17 DiscreteLog

```

// Returns minimum x for which a ^ x % m = b % m.
O(sqrt(m))
int solve(int a, int b, int m){
    // if (a == 0)
    // return b == 0 ? 1 : -1;
    a %= m, b %= m; int k = 1, add = 0, g;
    while ((g = __gcd(a, m)) > 1) {
        if (b == k) return add;
        if (b % g) return -1;
        b /= g, m /= g, ++add; k = (k * 11l * a / g) % m;
    }
    int n = sqrt(m) + 1; int an = 1;
    for (int i = 0; i < n; ++i) an = (an * 11l * a) % m;
    unordered_map<int, int> vals;
    for (int q = 0, cur = b; q <= n; ++q) {
        vals[cur] = q; cur = (cur * 11l * a) % m;
    }
    for (int p = 1, cur = k; p <= n; ++p) {
        cur = (cur * 11l * an) % m;
        if (vals.count(cur)) { int ans = n * p - vals[cur] +
            add;
            return ans;
        }
    }
    return -1;
}

```

## 18 EulerTour

```

vector<multiset<int>> adj; vector<int> ans;
void euler_circuit(int src){
    stack<int> st; st.push(src);
    while(!st.empty()){
        int v = st.top();
        if(adj[v].size()==0){
            ans.push_back(v); st.pop();
        }
        else{
            int f = *adj[v].begin();
            adj[v].erase(adj[v].begin());
            adj[f].erase(adj[f].find(v));
            st.push(f);
        }
    }
}

```

## 19 FFT

```

struct CD {
    double x, y;
    CD(double x=0, double y=0) :x(x), y(y) {}
    CD operator+(const CD& o) { return {x+o.x, y+o.y};}
    CD operator-(const CD& o) { return {x-o.x, y-o.y};}
    CD operator*(const CD& o) { return {x*o.x-y*o.y,
        x*o.y+o.x*y};}
    void operator /= (double d) { x/=d; y/=d;}
    double real() {return x;}
    double imag() {return y;}
};
CD conj(const CD &c) {return CD(c.x, -c.y);}

typedef long long LL;
const double PI = acos(-1.0L);
namespace FFT {
    int N;
    vector<int> perm;
    vector<CD> wp[2];
    void precalculate(int n) {
        assert((n & (n-1)) == 0);
        N = n;
        perm = vector<int> (N, 0);
        for (int k=1; k<N; k<=1) {
            for (int i=0; i<k; i++) {
                perm[i] <= 1;
                perm[i+k] = 1 + perm[i];
            }
        }
        wp[0] = wp[1] = vector<CD>(N);
        for (int i=0; i<N; i++) {
            wp[0][i] = CD( cos(2*PI*i/N), sin(2*PI*i/N) );
            wp[1][i] = CD( cos(2*PI*i/N), -sin(2*PI*i/N) );
        }
    }
    void fft(vector<CD> &v, bool invert = false) {
        if (v.size() != perm.size()) precalculate(v.size());
        for (int i=0; i<N; i++)
            if (i < perm[i])
                swap(v[i], v[perm[i]]);
        for (int len = 2; len <= N; len *= 2) {
            for (int i=0, d = N/len; i<N; i+=len) {
                for (int j=0, idx=0; j<len/2; j++, idx += d) {
                    CD x = v[i+j];
                    CD y = wp[invert][idx]*v[i+j+len/2];
                    v[i+j] = x+y;
                    v[i+j+len/2] = x-y;
                }
            }
        }
        if (invert) {
            for (int i=0; i<N; i++) v[i]/=N;
        }
    }
    void pairfft(vector<CD> &a, vector<CD> &b, bool invert
        = false) {
        int N = a.size();
        vector<CD> p(N);
        for (int i=0; i<N; i++) p[i] = a[i] + b[i] * CD(0, 1);
        fft(p, invert);
        p.push_back(p[0]);

        for (int i=0; i<N; i++) {
            if (invert) {
                a[i] = CD(p[i].real(), 0);
                b[i] = CD(p[i].imag(), 0);
            }
        }
        else {
            a[i] = (p[i]+conj(p[N-i]))*CD(0.5, 0);
            b[i] = (p[i]-conj(p[N-i]))*CD(0, -0.5);
        }
    }
}

```

```

    }
  }
}
vector<LL> multiply(const vector<LL> &a, const
    vector<LL> &b) {
    int n = 1;
    while (n < a.size() + b.size()) n<=1;
    vector<CD> fa(a.begin(), a.end()), fb(b.begin(),
        b.end());
    fa.resize(n); fb.resize(n);
    // fft(fa); fft(fb);
    pairfft(fa, fb);
    for (int i=0; i<n; i++) fa[i] = fa[i] * fb[i];
    fft(fa, true);
    vector<LL> ans(n);
    for (int i=0; i<n; i++) ans[i] = round(fa[i].real());
    return ans;
}
const int M = 1e9+7, B = sqrt(M)+1;
vector<LL> anyMod(const vector<LL> &a, const vector<LL>
    &b) {
    int n = 1;
    while (n < a.size() + b.size()) n<=1;
    vector<CD> al(n), ar(n), bl(n), br(n);
    for (int i=0; i<a.size(); i++) al[i] = a[i]%M/B, ar[i]
        = a[i]%M%B;
    for (int i=0; i<b.size(); i++) bl[i] = b[i]%M/B, br[i]
        = b[i]%M%B;
    pairfft(al, ar); pairfft(bl, br);
    // fft(al); fft(ar); fft(bl); fft(br);
    for (int i=0; i<n; i++) {
        CD ll = (al[i] * bl[i]), lr = (al[i] * br[i]);
        CD rl = (ar[i] * bl[i]), rr = (ar[i] * br[i]);
        al[i] = ll; ar[i] = lr;
        bl[i] = rl; br[i] = rr;
    }
    pairfft(al, ar, true); pairfft(bl, br, true);
    // fft(al, true); fft(ar, true); fft(bl, true); fft(br,
        true);
    vector<LL> ans(n);
    for (int i=0; i<n; i++) {
        LL right = round(br[i].real()), left =
            round(al[i].real());
        LL mid = round(round(bl[i].real()) +
            round(ar[i].real()));
        ans[i] = ((left%M)*B*B + (mid%M)*B + right)%M;
    }
    return ans;
}
}

```

## 20 FWHT

```

const int inv2 = (mod + 1) >> 1;
const int M = (1 << 20);
const int OR = 0;
const int AND = 1;
const int XOR = 2;
struct FWHT{
    int P1[M], P2[M];
    void wt(int *a, int n, int flag = XOR) {
        if (n == 0)
            return;
        int m = n / 2;
        wt(a, m, flag);
        wt(a + m, m, flag);
        for (int i = 0; i < m; i++) {
            int x = a[i], y = a[i + m];
            if (flag == OR)
                a[i] = x, a[i + m] = (x + y) % mod;

```

```

        if (flag == AND)
            a[i] = (x + y) % mod, a[i + m] = y;
        if (flag == XOR)
            a[i] = (x + y) % mod, a[i + m] = (x - y + mod) % mod;
        }
    }
    void iwt(int* a, int n, int flag = XOR) {
        if (n == 0)
            return;
        int m = n / 2;
        iwt(a, m, flag);
        iwt(a + m, m, flag);
        for (int i = 0; i < m; i++) {
            int x = a[i], y = a[i + m];
            if (flag == OR)
                a[i] = x, a[i + m] = (y - x + mod) % mod;
            if (flag == AND)
                a[i] = (x - y + mod) % mod, a[i + m] = y;
            if (flag == XOR)
                a[i] = 1LL * (x + y) * inv2 % mod, a[i + m] = 1LL *
                    (x - y + mod) * inv2 % mod; // replace inv2 by
                    >>1 if not required
        }
    }
    vector<int> multiply(int n, vector<int> A, vector<int>
        B, int flag = XOR) {
        assert(__builtin_popcount(n) == 1);
        A.resize(n);
        B.resize(n);
        for (int i = 0; i < n; i++)
            P1[i] = A[i];
        for (int i = 0; i < n; i++)
            P2[i] = B[i];
        wt(P1, n, flag);
        wt(P2, n, flag);
        for (int i = 0; i < n; i++)
            P1[i] = 1LL * P1[i] * P2[i] % mod;
        iwt(P1, n, flag);
        return vector<int> (P1, P1 + n);
    }
    vector<int> pow(int n, vector<int> A, long long k, int
        flag = XOR) {
        assert(__builtin_popcount(n) == 1);
        A.resize(n);
        for (int i = 0; i < n; i++)
            P1[i] = A[i];
        wt(P1, n, flag);
        for (int i = 0; i < n; i++)
            P1[i] = POW(P1[i], k);
        iwt(P1, n, flag);
        return vector<int> (P1, P1 + n);
    }
} t;
int32_t main(){
    int n;
    cin >> n;
    vector<int> a(M, 0);
    for(int i = 0; i < n; i++) {
        int k;
        cin >> k;
        a[k]++;
    }
    vector<int> v = t.pow(M, a, n+1, AND);
    int ans = 1;
    for(int i = 1; i < M; i++)
        ans += v[i] > 0;
    cout << ans << '\n';
    return 0;
}

```

## 21 Fibonacci Shortcut

```

pair<int, int> fib (int n) {
    if (n == 0) return {0, 1};
    auto p = fib(n >> 1);
    int c = p.first * (2 * p.second - p.first);
    int d = p.first * p.first + p.second * p.second;
    if (n & 1) return {d, c + d};
    else return {c, d};
}

```

## 22 FloorCeilChange

```

vector<int> where_floor_changes(int n){
    int now=1; vector<int>v;
    while(now<=n) {
        v.push_back(now); now=n/(n/now)+1;
    }
    return v;
}
vector<pair<int,int>> where_ceil_changes(int m){
    vector<pair<int,int>>v; int l=1;
    while(l<=m) {
        if(l==m) { v.push_back({m,m}); break;}
        int cl=(m+l-1)/l;
        int r=(m+cl-2)/(cl-1)-1;
        r=min(r,m); r=max(r,l);
        v.push_back({l,r});
        if(r==m) break;
        l=r+1;
    }
    return v;
}

```

## 23 Floorsum

```

// floor( (a*i+b)/m ) for 0 <= i <= n-1
ll floor_sum(ll n, ll m, ll a, ll b) {
    ll ans = 0;
    if (a >= m) {
        ans += (n - 1) * n * (a / m) / 2;
        a %= m;
    }
    if (b >= m) {
        ans += n * (b / m);
        b %= m;
    }
    ll y_max = (a * n + b) / m, x_max = (y_max * m - b);
    if (y_max == 0) return ans;
    ans += (n - (x_max + a - 1) / a) * y_max;
    ans += floor_sum(y_max, a, m, (a - x_max % a) % a);
    return ans;
}

```

## 24 Gauss

```

const double EPS = 1e-9;
const int INF = 2;
int gauss (vector < vector<double> > a, vector<double> &
    ans) {
    int n = (int) a.size();
    int m = (int) a[0].size() - 1;
    vector<int> where (m, -1);
    for (int col=0, row=0; col<m && row<n; ++col) {
        int sel = row;
        for (int i=row; i<n; ++i)
            if (abs (a[i][col]) > abs (a[sel][col]))
                sel = i;
        if (abs (a[sel][col]) < EPS)
            continue;
        for (int i=col; i<=m; ++i)

```

```

    swap(a[sel][i], a[row][i]);
    where[col] = row;

    for (int i=0; i<n; ++i)
        if (i != row) {
            double c = a[i][col] / a[row][col];
            for (int j=col; j<=m; ++j)
                a[i][j] -= a[row][j] * c;
        }
    ++row;
}

ans.assign(m, 0);
for (int i=0; i<m; ++i)
    if (where[i] != -1)
        ans[i] = a[where[i]][m] / a[where[i]][i];
for (int i=0; i<n; ++i) {
    double sum = 0;
    for (int j=0; j<=m; ++j)
        sum += ans[j] * a[i][j];
    if (abs(sum - a[i][m]) > EPS)
        return 0;
}

for (int i=0; i<m; ++i)
    if (where[i] == -1)
        return INF;
return 1;
}

```

## 25 Geo 2D

```

const double pi = 4 * atan(1); const double eps = 1e-6;
inline int dcmp (double x) { if (fabs(x) < eps) return 0; else return x < 0 ? -1 : 1; }
double fix_acute(double th) {return th<-pi ? (th+2*pi): th>pi ? (th-2*pi) : th;}
inline double getDistance (double x, double y) { return sqrt(x * x + y * y); }
inline double torad(double deg) { return deg / 180 * pi; }

struct Pt {
    double x, y;
    Pt (double x = 0, double y = 0): x(x), y(y) {}
    void read () { scanf("%lf%lf", &x, &y); }
    void write () { printf("%lf %lf", x, y); }
    bool operator == (const Pt& u) const { return dcmp(x - u.x) == 0 && dcmp(y - u.y) == 0; }
    bool operator != (const Pt& u) const { return !(this == u); }
    bool operator < (const Pt& u) const { return dcmp(x - u.x) < 0 || (dcmp(x-u.x)==0 && dcmp(y-u.y) < 0); }
    bool operator > (const Pt& u) const { return u < *this; }
    bool operator <= (const Pt& u) const { return *this < u || *this == u; }
    bool operator >= (const Pt& u) const { return *this > u || *this == u; }
    Pt operator + (const Pt& u) { return Pt(x + u.x, y + u.y); }
    Pt operator - (const Pt& u) { return Pt(x - u.x, y - u.y); }
    Pt operator * (const double u) { return Pt(x * u, y * u); }
    Pt operator / (const double u) { return Pt(x / u, y / u); }
    double operator * (const Pt& u) { return x*u.y - y*u.x; }
};

typedef Pt Vector;
typedef vector<Pt> Polygon;
struct Line {

```

```

    double a, b, c;
    Line (double a = 0, double b = 0, double c = 0): a(a), b(b), c(c) {}
};

struct Segment {
    Pt a; Pt b;
    Segment() {}
    Segment(Pt aa, Pt bb) {a=aa, b=bb;}
};

struct DirLine {
    Pt p; Vector v;
    double ang;
    DirLine () {}
    DirLine (Pt p, Vector v): p(p), v(v) { ang = atan2(v.y, v.x); }
    bool operator < (const DirLine& u) const { return ang < u.ang; }
};

namespace Punctual {
    double getDistance (Pt a, Pt b) { double x=a.x-b.x, y=a.y-b.y; return sqrt(x*x + y*y); }
};

namespace Vectorial {
    double getDot (Vector a, Vector b) { return a.x * b.x + a.y * b.y; }
    double getCross (Vector a, Vector b) { return a.x * b.y - a.y * b.x; }
    double getLength (Vector a) { return sqrt(getDot(a, a)); }
    double getPLength (Vector a) { return getDot(a, a); }
    double getAngle (Vector u) { return atan2(u.y, u.x); }
    double getSignedAngle (Vector a, Vector b) {return getAngle(b)-getAngle(a);}
    Vector rotate (Vector a, double rad) { return Vector(a.x*cos(rad)-a.y*sin(rad), a.x*sin(rad)+a.y*cos(rad)); }
    Vector ccw (Vector a, double co, double si) {return Vector(a.x*co-a.y*si, a.y*co+a.x*si);}
    Vector cw (Vector a, double co, double si) {return Vector(a.x*co+a.y*si, a.y*co-a.x*si);}
    Vector scale (Vector a, double s = 1.0) {return a / getLength(a) * s;}
    Vector getNormal (Vector a) { double l = getLength(a); return Vector(-a.y/l, a.x/l); }
};

namespace ComplexVector {
    typedef complex<double> Pt;
    typedef Pt Vector;
    double getDot (Vector a, Vector b) { return real(conj(a)*b); }
    double getCross (Vector a, Vector b) { return imag(conj(a)*b); }
    Vector rotate (Vector a, double rad) { return a*exp(Pt(0, rad)); }
};

namespace Linear {
    using namespace Vectorial;
    Line getLine (double x1, double y1, double x2, double y2) { return Line(y2-y1, x1-x2, y1*x2-x1*y2); }
    Line getLine (double a, double b, Pt u) { return Line(a, -b, u.y * b - u.x * a); }
    bool getIntersection (Line p, Line q, Pt& o) { if (fabs(p.a * q.b - q.a * p.b) < eps) return false; o.x = (q.c * p.b - p.c * q.b) / (p.a * q.b - q.a * p.b); o.y = (q.c * p.a - p.c * q.a) / (p.b * q.a - q.b * p.a); return true; }
};

```

```

}

bool getIntersection (Pt p, Vector v, Pt q, Vector w, Pt& o) { if (dcmp(getCross(v, w)) == 0) return false; Vector u = p - q; double k = getCross(w, u) / getCross(v, w); o = p + v * k; return true; }

double getDistanceToLine (Pt p, Pt a, Pt b) { return fabs(getCross(b-a, p-a) / getLength(b-a)); }
double getDistanceToSegment (Pt p, Pt a, Pt b) { if (a == b) return getLength(p-a); Vector v1 = b - a, v2 = p - a, v3 = p - b; if (dcmp(getDot(v1, v2)) < 0) return getLength(v2); else if (dcmp(getDot(v1, v3)) > 0) return getLength(v3); else return fabs(getCross(v1, v2) / getLength(v1)); }

double getDistanceSegToSeg (Pt a, Pt b, Pt c, Pt d) { double Ans=INT_MAX; Ans=min(Ans, getDistanceToSegment(a, c, d)); Ans=min(Ans, getDistanceToSegment(b, c, d)); Ans=min(Ans, getDistanceToSegment(c, a, b)); Ans=min(Ans, getDistanceToSegment(d, a, b)); return Ans; }

Pt getPtToLine (Pt p, Pt a, Pt b) { Vector v = b-a; return a+v*(getDot(v, p-a) / getDot(v,v)); }

bool onSegment (Pt p, Pt a, Pt b) { return dcmp(getCross(a-p, b-p)) == 0 && dcmp(getDot(a-p, b-p)) <= 0; }

bool haveIntersection (Pt a1, Pt a2, Pt b1, Pt b2) { if (onSegment(a1, b1, b2)) return true; if (onSegment(a2, b1, b2)) return true; if (onSegment(b1, a1, a2)) return true; if (onSegment(b2, a1, a2)) return true; //Case of touch double c1=getCross(a2-a1, b1-a1), c2=getCross(a2-a1, b2-a1), c3=getCross(b2-b1, a1-b1), c4=getCross(b2-b1, a2-b1); return dcmp(c1)*dcmp(c2) < 0 && dcmp(c3)*dcmp(c4) < 0; }

bool onLeft (DirLine l, Pt p) { return dcmp(l.v * (p-l.p)) >= 0; }

namespace Triangular {
    using namespace Vectorial;
    double getAngle (double a, double b, double c) { return acos((a*a+b*b-c*c) / (2*a*b)); }
    double getArea (double a, double b, double c) { double s = (a+b+c)/2; return sqrt(s*(s-a)*(s-b)*(s-c)); }
    double getArea (double a, double h) { return a * h / 2; }
    double getArea (Pt a, Pt b, Pt c) { return fabs(getCross(b - a, c - a)) / 2; }
    double getDirArea (Pt a, Pt b, Pt c) { return getCross(b - a, c - a) / 2; }
    //ma/mb/mc = length of median from side a/b/c
    double getArea (double ma, double mb, double mc) {double s=(ma+mb+mc)/2; return 4/3.0 * sqrt(s*(s-ma)*(s-mb)*(s-mc));}
    //ha/hb/hc = length of perpendicular from side a/b/c
    double getArea (double ha, double hb, double hc) {double H=(1/ha+1/hb+1/hc)/2; double _A_ = 4 * sqrt(H * (H-1/ha)*(H-1/hb)*(H-1/hc)); return 1.0/_A_; }
}

bool PtInTriangle (Pt a, Pt b, Pt c, Pt p) { double s1 = getArea(a,b,c);

```

```

double s2 = getArea(p,b,c) + getArea(p,a,b) +
    getArea(p,c,a);
return dcmp(s1 - s2) == 0;
};
namespace Polygonal {
using namespace Vectorial;
using namespace Linear;
using namespace Triangular;
double getSignedArea (Pt* p, int n) {
double ret = 0;
for (int i = 0; i < n-1; i++)
    ret += (p[i]-p[0]) * (p[i+1]-p[0]);
return ret/2;
}
int getConvexHull (Pt* p, int n, Pt* ch) {
sort(p, p + n);
// preparing lower hull
int m = 0;
for (int i = 0; i < n; i++){
while (m > 1 && dcmp(getCross(ch[m-1]-ch[m-2],
    p[i]-ch[m-1])) <= 0) m--;
ch[m++] = p[i];
}
// preparing upper hull
int k = m;
for (int i = n-2; i >= 0; i--){
while (m > k && dcmp(getCross(ch[m-1]-ch[m-2],
    p[i]-ch[m-2])) <= 0) m--;
ch[m++] = p[i];
}
if (n > 1) m--;
return m;
}
int isPtInPolygon (Pt o, Pt* p, int n) {
int wn = 0;
for (int i = 0; i < n; i++) {
int j = (i + 1) % n;
if (onSegment(o, p[i], p[j]) || o == p[i]) return 0;
int k = dcmp(getCross(p[j] - p[i], o-p[i]));
int d1 = dcmp(p[i].y - o.y);
int d2 = dcmp(p[j].y - o.y);
if (k > 0 && d1 <= 0 && d2 > 0) wn++;
if (k < 0 && d2 <= 0 && d1 > 0) wn--;
}
return wn ? -1 : 1;
}
void rotatingCalipers(Pt *p, int n, vector<Segment>&
    sol) {
sol.clear();
int j = 1; p[n] = p[0];
for (int i = 0; i < n; i++) {
while (getCross(p[j+1]-p[i+1], p[i]-p[i+1]) >
    getCross(p[j]-p[i+1], p[i]-p[i+1]))
    j = (j+1) % n;
sol.push_back(Segment(p[i],p[j]));
sol.push_back(Segment(p[i + 1],p[j + 1]));
}
}
void rotatingCalipersGetRectangle (Pt *p, int n,
    double& area, double& perimeter) {
p[n] = p[0];
int l = 1, r = 1, j = 1;
area = perimeter = 1e20;
for (int i = 0; i < n; i++) {
Vector v = (p[i+1]-p[i]) / getLength(p[i+1]-p[i]);
while (dcmp(getDot(v, p[r%n]-p[i]) - getDot(v,
    p[(r+1)%n]-p[i])) < 0) r++;

```

```

while (j < r || dcmp(getCross(v, p[j%n]-p[i]) -
    getCross(v, p[(j+1)%n]-p[i])) < 0) j++;
while (l < j || dcmp(getDot(v, p[l%n]-p[i]) -
    getDot(v, p[(l+1)%n]-p[i])) > 0) l++;
double w = getDot(v, p[r%n]-p[i]) - getDot(v,
    p[l%n]-p[i]);
double h = getDistanceToLine (p[j%n], p[i], p[i+1]);
area = min(area, w * h);
perimeter = min(perimeter, 2 * w + 2 * h);
}
}
Polygon cutPolygon (Polygon u, Pt a, Pt b) {
Polygon ret;
int n = u.size();
for (int i = 0; i < n; i++) {
Pt c = u[i], d = u[(i+1)%n];
if (dcmp((b-a)*(c-a)) >= 0) ret.push_back(c);
if (dcmp((b-a)*(d-c)) != 0) {
Pt t;
getIntersection(a, b-a, c, d-c, t);
if (onSegment(t, c, d))
    ret.push_back(t);
}
}
return ret;
}
int halfPlaneIntersection(DirLine* li, int n, Pt* poly)
{
sort(li, li + n);
int first, last;
Pt* p = new Pt[n];
DirLine* q = new DirLine[n];
q[first=last=0] = li[0];
for (int i = 1; i < n; i++) {
while (first < last && !onLeft(li[i], p[last-1]))
    last--;
while (first < last && !onLeft(li[i], p[first]))
    first++;
q[++last] = li[i];
if (dcmp(q[last].v * q[last-1].v) == 0) {
last--;
if (onLeft(q[last], li[i].p)) q[last] = li[i];
}
if (first < last)
    getIntersection(q[last-1].p, q[last-1].v, q[last].p,
        q[last].v, p[last-1]);
}
while (first < last && !onLeft(q[first], p[last-1]))
    last--;
if (last - first <= 1) { delete [] p; delete [] q;
    return 0; }
getIntersection(q[last].p, q[last].v, q[first].p,
    q[first].v, p[last]);
int m = 0;
for (int i = first; i <= last; i++) poly[m++] = p[i];
delete [] p; delete [] q;
return m;
}
Polygon simplify (const Polygon& poly) {
Polygon ret;
int n = poly.size();
for (int i = 0; i < n; i++) {
Pt a = poly[i];
Pt b = poly[(i+1)%n];
Pt c = poly[(i+2)%n];
if (dcmp((b-a)*(c-b)) != 0 && (ret.size() == 0 || b
    != ret[ret.size()-1]))
    ret.push_back(b);
}
return ret;
}

```

```

}
Pt ComputeCentroid( Pt* p, int n){
Pt c(0,0);
double scale = 6.0 * getSignedArea(p,n);
for (int i = 0; i < n; i++){
int j = (i+1) % n;
c = c + (p[i]+p[j])*(p[i].x*p[j].y - p[j].x*p[i].y);
}
return c / scale;
}
// pt must be in ccw order with no three collinear Pts
// returns inside = 1, on = 0, outside = -1
int PtInConvexPolygon(Pt* pt, int n, Pt p){
assert(n >= 3);
int lo = 1, hi = n - 1;
while(hi - lo > 1){
int mid = (lo + hi) / 2;
if(getCross(pt[mid] - pt[0], p - pt[0]) > 0) lo = mid;
else hi = mid;
}
bool in = PtInTriangle(pt[0], pt[lo], pt[hi], p);
if(!in) return -1;
if(getCross(pt[lo] - pt[lo-1], p - pt[lo-1]) == 0)
    return 0;
if(getCross(pt[hi] - pt[lo], p - pt[lo]) == 0) return
    0;
if(getCross(pt[hi] - pt[(hi+1)%n], p - pt[(hi+1)%n])
    == 0) return 0;
return 1;
}
// Calculate [ACW, CW] tangent pair from an external Pt
#define CW -1
#define ACW 1
int direction(Pt st, Pt ed, Pt q) {return
    dcmp(getCross(ed - st, q - ed));}
bool isGood(Pt u, Pt v, Pt Q, int dir) {return
    direction(Q, u, v) != -dir;}
Pt better(Pt u, Pt v, Pt Q, int dir) {return
    direction(Q, u, v) == dir ? u : v;}
Pt tangents(Pt* pt, Pt Q, int dir, int lo, int hi){
while(hi - lo > 1){
int mid = (lo + hi)/2;
bool pvs = isGood(pt[mid], pt[mid - 1], Q, dir);
bool nxt = isGood(pt[mid], pt[mid + 1], Q, dir);
if(pvs && nxt) return pt[mid];
if(!(pvs || nxt)){
Pt p1 = tangents(pt, Q, dir, mid+1, hi);
Pt p2 = tangents(pt, Q, dir, lo, mid - 1);
return better(p1, p2, Q, dir);
}
if(!pvs){
if(direction(Q, pt[mid], pt[lo]) == dir) hi = mid -
    1;
else if(better(pt[lo], pt[hi], Q, dir) == pt[lo]) hi
    = mid - 1;
else lo = mid + 1;
}
if(!nxt){
if(direction(Q, pt[mid], pt[lo]) == dir) lo = mid +
    1;
else if(better(pt[lo], pt[hi], Q, dir) == pt[lo]) hi
    = mid - 1;
else lo = mid + 1;
}
}
Pt ret = pt[lo];
for(int i = lo + 1; i <= hi; i++) ret = better(ret,
    pt[i], Q, dir);
return ret;
}

```



```
// [ACW, CW] Tangent
pair<Pt, Pt> get_tangents(Pt* pt, int n, Pt Q){
    Pt acw_tan = tangents(pt, Q, ACW, 0, n - 1);
    Pt cw_tan = tangents(pt, Q, CW, 0, n - 1);
    return make_pair(acw_tan, cw_tan);
}
};
struct Circle {
    Pt o; double r;
    Circle () {}
    Circle (Pt o, double r = 0): o(o), r(r) {}
    void read () { o.read(), scanf("%lf", &r); }
    Pt pt(double rad) { return Pt(o.x + cos(rad)*r, o.y +
        sin(rad)*r); }
    double getArea (double rad) { return rad * r * r / 2; }
    //area of the circular sector cut by a chord with
    //central angle alpha
    double sector(double alpha) {return r * r * 0.5 *
        (alpha - sin(alpha));}
};
namespace Circular {
    using namespace Linear;
    using namespace Vectorial;
    using namespace Triangular;
    int getLineCircleIntersection (Pt p, Pt q, Circle o,
        double& t1, double& t2, vector<Pt>& sol) {
        Vector v = q - p;
        //sol.clear();
        double a = v.x, b = p.x - o.o.x, c = v.y, d = p.y -
            o.o.y;
        double e = a*a+c*c, f = 2*(a*b+c*d), g =
            b*b+d*d-o.r*o.r;
        double delta = f*f - 4*e*g;
        if (dcmp(delta) < 0) return 0;
        if (dcmp(delta) == 0) {
            t1 = t2 = -f / (2 * e);
            sol.push_back(p + v * t1);
            return 1;
        }
        t1 = (-f - sqrt(delta)) / (2 * e); sol.push_back(p + v
            * t1);
        t2 = (-f + sqrt(delta)) / (2 * e); sol.push_back(p + v
            * t2);
        return 2;
    }
    // signed area of intersection of circle(c.o, c.r) and
    // triangle(c.o, s.a, s.b) [cross(a-o, b-o)/2]
    double areaCircleTriIntersection(Circle c, Segment s){
        using namespace Linear;
        double OA = getLength(c.o - s.a);
        double OB = getLength(c.o - s.b);
        // sector
        if (dcmp(getDistanceToSegment(c.o, s.a, s.b) - c.r) >=
            0)
            return fix_acute(getSignedAngle(s.a - c.o, s.b -
                c.o)) * (c.r*c.r) / 2.0;
        // triangle
        if (dcmp(OA - c.r) <= 0 && dcmp(OB - c.r) <= 0)
            return getCross(c.o-s.b,s.a-s.b) / 2.0;
        // three part: (A, a) (a, b) (b, B)
        vector<Pt> Sect; double t1, t2;
        getLineCircleIntersection(s.a, s.b, c, t1, t2, Sect);
        return areaCircleTriIntersection(c, Segment(s.a,
            Sect[0]))
            + areaCircleTriIntersection(c, Segment(Sect[0],
                Sect[1]))
            + areaCircleTriIntersection(c, Segment(Sect[1], s.b));
    }
    // area of intersection of circle(c.o, c.r) and simple
    // polyson(p[])

```

```
double areaCirclePolygon(Circle c, Polygon p){
    double res = .0;
    int n = p.size();
    for (int i = 0; i < n; ++ i)
        res += areaCircleTriIntersection(c, Segment(p[i],
            p[(i+1)%n]));
    return fabs(res);
}
// interior (d < R - r) ----> -2
// interior tangents (d = R - r) ----> -1
// concentric (d = 0)
// secants (R - r < d < R + r) ----> 0
// exterior tangents (d = R + r) ----> 1
// exterior (d > R + r) ----> 2
int getPos(Circle o1, Circle o2) {
    using namespace Vectorial;
    double d = getLength(o1.o - o2.o);
    int in = dcmp(d - fabs(o1.r - o2.r)), ex = dcmp(d -
        (o1.r + o2.r));
    return in<0 ? -2 : in==0 ? -1 : ex==0 ? 1 : ex>0 ? 2 : 0;
}
int getCircleCircleIntersection (Circle o1, Circle o2,
    vector<Pt>& sol) {
    double d = getLength(o1.o - o2.o);
    if (dcmp(d) == 0) {
        if (dcmp(o1.r - o2.r) == 0) return -1;
        return 0;
    }
    if (dcmp(o1.r + o2.r - d) < 0) return 0;
    if (dcmp(fabs(o1.r-o2.r) - d) > 0) return 0;
    Vector v = o2.o - o1.o;
    double co = (o1.r*o1.r + getPLength(v) - o2.r*o2.r) /
        (2 * o1.r * getLength(v));
    double si = sqrt(fabs(1.0 - co*co));
    Pt p1 = scale(cw(v,co, si), o1.r) + o1.o;
    Pt p2 = scale(ccw(v,co, si), o1.r) + o1.o;
    sol.push_back(p1);
    if (p1 == p2) return 1;
    sol.push_back(p2);
    return 2;
}
double areaCircleCircle(Circle o1, Circle o2){
    Vector AB = o2.o - o1.o; double d = getLength(AB);
    if(d >= o1.r + o2.r) return 0;
    if(d + o1.r <= o2.r) return pi * o1.r * o1.r;
    if(d + o2.r <= o1.r) return pi * o2.r * o2.r;
    double alfa1 = acos((o1.r * o1.r + d * d - o2.r *
        o2.r) / (2.0 * o1.r * d));
    double alfa2 = acos((o2.r * o2.r + d * d - o1.r *
        o1.r) / (2.0 * o2.r * d));
    return o1.sector(2*alfa1) + o2.sector(2*alfa2);
}
int getTangents (Pt p, Circle o, Vector* v) {
    Vector u = o.o - p;
    double d = getLength(u);
    if (d < o.r) return 0;
    else if (dcmp(d - o.r) == 0) {
        v[0] = rotate(u, pi / 2);
        return 1;
    } else {
        double ang = asin(o.r / d);
        v[0] = rotate(u, -ang);
        v[1] = rotate(u, ang);
        return 2;
    }
}
int getTangentPts (Pt p, Circle o, vector<Pt>& v) {
    Vector u = p - o.o ;double d = getLength(u);
    if (d < o.r) return 0;

```

```
else if (dcmp(d - o.r) == 0) {
    v.push_back(o.o+u);
    return 1;
} else {
    double ang = acos(o.r / d);
    u = u / getLength(u) * o.r;
    v.push_back(o.o+rotate(u, -ang));
    v.push_back(o.o+rotate(u, ang));
    return 2;
}
}
int getTangents (Circle o1, Circle o2, Pt* a, Pt* b) {
    int cnt = 0;
    if (dcmp(o1.r-o2.r) < 0) { swap(o1, o2); swap(a, b); }
    double d2 = getPLength(o1.o - o2.o);
    double rdif = o1.r - o2.r, rsum = o1.r + o2.r;
    if (dcmp(d2 - rdif * rdif) < 0) return 0;
    if (dcmp(d2) == 0 && dcmp(o1.r - o2.r) == 0) return -1;
    double base = getAngle(o2.o - o1.o);
    if (dcmp(d2 - rdif * rdif) == 0) {
        a[cnt] = o1.pt(base); b[cnt] = o2.pt(base); cnt++;
        return cnt;
    }
    double ang = acos( (o1.r - o2.r) / sqrt(d2) );
    a[cnt] = o1.pt(base+ang); b[cnt] = o2.pt(base+ang);
    cnt++;
    a[cnt] = o1.pt(base-ang); b[cnt] = o2.pt(base-ang);
    cnt++;
    if (dcmp(d2 - rsum * rsum) == 0) {
        a[cnt] = o1.pt(base); b[cnt] = o2.pt(pi+base); cnt++;
    }
    else if (dcmp(d2 - rsum * rsum) > 0) {
        double ang = acos( (o1.r + o2.r) / sqrt(d2) );
        a[cnt] = o1.pt(base+ang); b[cnt] =
            o2.pt(pi+base+ang); cnt++;
        a[cnt] = o1.pt(base-ang); b[cnt] =
            o2.pt(pi+base-ang); cnt++;
    }
    return cnt;
}
Circle CircumscribedCircle(Pt p1, Pt p2, Pt p3) {
    double Bx = p2.x - p1.x, By = p2.y - p1.y;
    double Cx = p3.x - p1.x, Cy = p3.y - p1.y;
    double D = 2 * (Bx * Cy - By * Cx);
    double cx = (Cy * (Bx * Bx + By * By) - By * (Cx * Cx
        + Cy * Cy)) / D + p1.x;
    double cy = (Bx * (Cx * Cx + Cy * Cy) - Cx * (Bx * Bx
        + By * By)) / D + p1.y;
    Pt p = Pt(cx, cy);
    return Circle(p, getLength(p1 - p));
}
Circle InscribedCircle(Pt p1, Pt p2, Pt p3) {
    double a = getLength(p2 - p3); double b = getLength(p3
        - p1);
    double c = getLength(p1 - p2);
    Pt p = (p1 * a + p2 * b + p3 * c) / (a + b + c);
    return Circle(p, getDistanceToLine(p, p1, p2));
}
//distance From P : distance from Q = rp : rq
Circle getApolloniusCircle(const Pt& P, const Pt& Q,
    double rp, double rq ){
    rq *= rq ; rp *= rp ;
    double a = rq - rp ;
    assert(dcmp(a));
    double g = rq * P.x - rp * Q.x ; g /= a ;
    double h = rq * P.y - rp * Q.y ; h /= a ;
    double c = rq*P.x*P.x-rp*Q.x*Q.x+rq*P.y*P.y-rp*Q.y*Q.y
        ;
    c /= a ;
    Pt o(g,h);

```

```

    double R = g*g +h*h - c ;
    R = sqrt(R);
    return Circle(o,R);
}
};
//Polar Sort
inline bool up (Pt p) {
    return p.y > 0 or (p.y == 0 and p.x >= 0);
}
sort(v.begin(), v.end(), [] (Pt a, Pt b) {
    return up(a) == up(b) ? a.x * b.y > a.y * b.x : up(a)
        < up(b);
});

```

## 26 Geo 3D

```

const double pi = 4 * atan(1);
const double eps = 1e-10;
inline int dcmp (double x) { if (fabs(x) < eps) return
    0; else return x < 0 ? -1 : 1; }
inline double torad(double deg) { return deg / 180 * pi;
}
struct Point{
    double x, y;
    Point (double x = 0, double y = 0): x(x), y(y) {}
    Point operator + (const Point& u) { return Point(x +
        u.x, y + u.y); }
    Point operator - (const Point& u) { return Point(x -
        u.x, y - u.y); }
    Point operator * (const double u) { return Point(x * u,
        y * u); }
    Point operator / (const double u) { return Point(x / u,
        y / u); }
    double operator * (const Point& u) { return x*u.y -
        y*u.x; }
};
struct Pt3D{
    double x, y, z;
    Pt3D() {}
    void read () {cin>>x>>y>>z;}
    void write () {cout<<x<<" --- "<<y<<" --- "<<z<<"\n";}
    Pt3D(double x, double y, double z) : x(x), y(y), z(z) {}
    Pt3D(const Pt3D &p) : x(p.x), y(p.y), z(p.z) {}
    Pt3D operator + (Pt3D b) {return Pt3D(x+b.x,y+b.y,
        z+b.z);}
    Pt3D operator - (Pt3D b) {return Pt3D(x-b.x,y-b.y,
        z-b.z);}
    Pt3D operator * (double b) {return Pt3D(x*b,y*b, z*b);}
    Pt3D operator / (double b) {return Pt3D(x/b,y/b, z/b);}
    bool operator < (Pt3D b) {return
        make_pair(make_pair(x,y),z) <
        make_pair(make_pair(b.x,b.y),b.z);}
    bool operator == (Pt3D b) {return dcmp(x-b.x)==0 &&
        dcmp(y-b.y) == 0 && dcmp(z-b.z) == 0;}
};
typedef Pt3D Vector3D;
typedef vector<Point> Polygon;
typedef vector<Pt3D> Polyhedron;
namespace Vectorial{
    double getDot (Vector3D a, Vector3D b) {return
        a.x*b.x+a.y*b.y+a.z*b.z;}
    Vector3D getCross(Vector3D a, Vector3D b) {return
        Pt3D(a.y*b.z-a.z*b.y, a.z*b.x-a.x*b.z,
        a.x*b.y-a.y*b.x);}
    double getLength (Vector3D a) {return sqrt(getDot(a,
        a)); }
    double getPLength (Vector3D a) {return getDot(a, a); }
    Vector3D unitVector(Vector3D v) {return v/getLength(v);}
    double getUnsignedAngle(Vector3D u,Vector3D v){

```

```

        double cosTheta =
            getDot(u,v)/getLength(u)/getLength(v);
        cosTheta = max(-1.0,min(1.0,cosTheta));
        return acos(cosTheta);
    }
    Vector3D rotate(Vector3D v,Vector3D a,double rad){
        a = unitVector(a);
        return v * cos(rad) + a * (1 - cos(rad)) * getDot(a,v)
            + getCross(a,v) * sin(rad);
    }
}
struct Line3D{
    Vector3D v; Pt3D o;
    Line3D() {}
    Line3D(Vector3D v,Pt3D o):v(v),o(o){}
    Pt3D getPoint(double t) {return o + v*t;}
};
namespace Linear{
    using namespace Vectorial;
    double getDistSq(Line3D l, Pt3D p) {return
        getPLength(getCross(l.v,p-l.o))/getPLength(l.v);}
    double getDistLinePoint(Line3D l, Pt3D p) {return
        sqrt(getDistSq(l,p));}
    bool cmp(Line3D l,Pt3D p, Pt3D q) {return getDot(l.v,p)
        < getDot(l.v,q);}
    Pt3D projection(Line3D l,Pt3D p) {return l.o + l.v *
        getDot(l.v,p-l.o)/getPLength(l.v);}
    Pt3D reflection(Line3D l,Pt3D p) {return
        projection(l,p)+projection(l,p)-p;}
    double getAngle(Line3D l,Line3D m) {return
        getUnsignedAngle(l.v,m.v);}
    bool isParallel(Line3D p,Line3D q) {return
        dcmp(getPLength(getCross(p.v,q.v))) == 0;}
    bool isPerpendicular(Line3D p,Line3D q) {return
        dcmp(getDot(p.v,q.v)) == 0;}
    double getDist(Line3D l, Line3D m){
        Vector3D n = getCross(l.v, m.v);
        if(getPLength(n) == 0) return getDistLinePoint(l,m.o);
        else return fabs(getDot(m.o-l.o , n)) / getLength(n);
    }
    Pt3D getClosestPointOnLine1(Line3D l,Line3D m){
        Vector3D n = getCross(l.v, m.v);
        Vector3D n2 = getCross(m.v, n);
        return l.o + l.v * getDot(m.o-l.o, n2) / getDot(l.v,
            n2);
    }
}
struct Plane{
    Vector3D n; //normal n
    double d; //getDot(n,p) = d for any point p on the plane
    Plane() {}
    Plane(Vector3D n, double d) : n(n), d(d) {}
    Plane(Vector3D n, Pt3D p) : n(n), d(Vectorial ::
        getDot(n,p)) {}
    Plane(const Plane &p) : n(p.n), d(p.d) {}
};
namespace Planar{
    using namespace Vectorial;
    Plane getPlane(Pt3D a,Pt3D b,Pt3D c) {return
        Plane(getCross(b-a,c-a),a);}
    Plane translate(Plane p,Vector3D t) {return Plane(p.n,
        p.d+getDot(p.n,t).);}
    Plane shiftUp(Plane p,double dist) {return Plane(p.n,
        p.d+dist*getLength(p.n).);}
    Plane shiftDown(Plane p,double dist) {return Plane(p.n,
        p.d-dist*getLength(p.n).);}
    double getSide(Plane p,Pt3D a) {return
        getDot(p.n,a)-p.d;}
}

```

```

double getDistance(Plane p,Pt3D a) {return
    fabs(getSide(p,a))/getLength(p.n).;}
Pt3D projection(Plane p,Pt3D a) {return
    a-p.n*getSide(p,a)/getPLength(p.n).;}
Pt3D reflection(Plane p,Pt3D a) {return
    a-p.n*getSide(p,a)/getPLength(p.n)*2.;}
bool intersect(Plane p, Line3D l, Pt3D &a){
    if(dcmp(getDot(p.n,l.v)) == 0) return false;
    a = l.o - l.v * getSide(p,l.o) / getDot(p.n,l.v);
    return true;
}
bool intersect(Plane p,Plane q,Line3D& l){
    l.v = getCross(p.n,q.n);
    if(dcmp(getPLength(l.v)) == 0) return false;
    l.o = getCross(q.n*p.d - p.n*q.d , l.v) /
        getPLength(l.v);
    return true;
}
double getAngle(Plane p,Plane q) {return
    getUnsignedAngle(p.n,q.n).;}
bool isParallel(Plane p,Plane q) {return
    dcmp(getPLength(getCross(p.n,q.n))) == 0;}
bool isPerpendicular(Plane p,Plane q) {return
    dcmp(getDot(p.n,q.n)) == 0;}
bool getAngle(Plane p,Line3D l) {return pi/2.0 -
    getUnsignedAngle(p.n,l.v).;}
bool isParallel(Plane p,Line3D l) {return
    dcmp(getDot(p.n,l.v)) == 0;}
bool isPerpendicular(Plane p,Line3D l) {return
    dcmp(getPLength(getCross(p.n,l.v))) == 0;}
Line3D perpThrough(Plane p,Pt3D a) {return
    Line3D(p.n,a).;}
Plane perpThrough(Line3D l,Pt3D a) {return
    Plane(l.v,a).;}
//Modify p.n if necessary with respect to the reference
//point
Vector3D rotateCCW90(Plane p,Vector3D d) {return
    getCross(p.n,d).;}
Vector3D rotateCW90(Plane p,Vector3D d) {return
    getCross(d,p.n).;}
pair<Pt3D, Pt3D> TwoPointsOnPlane(Plane p){
    Vector3D N = p.n; double D = p.d;
    assert(dcmp(N.x) != 0 || dcmp(N.y) != 0 || dcmp(N.z)
        != 0);
    if(dcmp(N.x) == 0 && dcmp(N.y) == 0) return
        {Pt3D(1,0,D/N.z), Pt3D(0,1,D/N.z).};
    if(dcmp(N.y) == 0 && dcmp(N.z) == 0) return
        {Pt3D(D/N.x,1,0), Pt3D(D/N.x,0,1).};
    if(dcmp(N.z) == 0 && dcmp(N.x) == 0) return
        {Pt3D(1,D/N.y,0), Pt3D(0,D/N.y,1).};
    if(dcmp(N.x) == 0) return {Pt3D(1,D/N.y,0),
        Pt3D(0,0,D/N.z).};
    if(dcmp(N.y) == 0) return {Pt3D(0,1,D/N.z),
        Pt3D(D/N.x,0,0).};
    if(dcmp(N.z) == 0) return {Pt3D(D/N.x,0,1),
        Pt3D(0,0,D/N.y,0).};
    if(dcmp(D)!=0) return {Pt3D(D/N.x,0,0),
        Pt3D(0,0,D/N.y,0).};
    return {Pt3D(N.y,-N.x,0), Pt3D(-N.y,N.x,0).};
}
Point From3Dto2D(Plane p, Pt3D a){
    assert( dcmp(getSide(p,a)) == 0 );
    auto Pair = TwoPointsOnPlane(p);
    Pt3D A = Pair.first;
    Pt3D B = Pair.second;
    Vector3D Z = p.n; Z = Z / getLength(Z);
    Vector3D X = B - A; X = X / getLength(X);
    Vector3D Y = getCross(Z,X);
}

```

```

Vector3D v = a - A;
assert( dcmp(getDot(v,Z)) == 0);
return Point(getDot(v,X),getDot(v,Y));
}
Pt3D From2Dto3D(Plane p, Point a){
    auto Pair = TwoPointsOnPlane(p);
    Pt3D A = Pair.first;
    Pt3D B = Pair.second;
    Vector3D Z = p.n; Z = Z / getLength(Z);
    Vector3D X = B - A; X = X / getLength(X);
    Vector3D Y = getCross(Z,X);
    return A + X * a.x + Y * a.y;
}
}
struct Sphere{
    Pt3D c;
    double r;
    Sphere() {}
    Sphere(Pt3D c, double r) : c(c), r(r) {}
    //Spherical cap with polar angle theta
    double Height(double alpha) {return r*(1-cos(alpha));}
    double BaseRadius(double alpha) {return r*sin(alpha);}
    double Volume(double alpha) {double h = Height(alpha);
        return pi*h*h*(3*r-h)/3.0;}
    double SurfaceArea(double alpha) {double h =
        Height(alpha); return 2*pi*r*h;}
};
namespace Spherical{
    using namespace Vectorial;
    using namespace Planar;
    using namespace Linear;
    Sphere CircumscribedSphere(Pt3D a,Pt3D b,Pt3D c,Pt3D d){
        assert( dcmp(getSide(getPlane(a,b,c), d)) != 0);
        Plane U = Plane(a-b, (a+b)/2);
        Plane V = Plane(b-c, (b+c)/2);
        Plane W = Plane(c-d, (c+d)/2);
        Line3D l1,l2;
        bool ret1 = intersect(U,V,l1);
        bool ret2 = intersect(V,W,l2);
        assert(ret1 == true && ret2 == true);
        assert( dcmp(getDist(l1,l2)) == 0);
        Pt3D C = getClosestPointOnLine1(l1,l2);
        return Sphere(C, getLength(C-a));
    }
}
pair<double,double> SphereSphereIntersection(Sphere
    s1,Sphere s2){
    double d = getLength(s1.c-s2.c);
    if(dcmp(d - s1.r - s2.r) >= 0) return {0,0};
    double R1 = max(s1.r,s2.r); double R2 = min(s1.r,s2.r);
    double y = R1 + R2 - d;
    double x = (R1*R1 - R2*R2 + d*d) / (2*d);
    double h1 = R1 - x;
    double h2 = y - h1;
    double Volume = pi*h1*h1*(3*R1-h1)/3.0 +
        pi*h2*h2*(3*R2-h2)/3.0;
    double SurfaceArea = 2*pi*R1*h1 + 2*pi*R2*h2;
    return make_pair(SurfaceArea,Volume);
}
Pt3D getPointOnSurface(double r,double Lat,double Lon){
    Lat = torad(Lat); //North-South
    Lon = torad(Lon); //East-West
    return Pt3D(r*cos(Lat)*cos(Lon), r*cos(Lat)*sin(Lon),
        r*sin(Lat));
}
int intersect(Sphere s,Line3D l, vector<Pt3D>& ret){
    double h2 = s.r*s.r - getDistSq(l,s.c);
    if(dcmp(h2)<0) return 0;
    Pt3D p = projection(l,s.c);
    if(dcmp(h2) == 0) {ret.push_back(p); return 1;}
}

```

```

Vector3D h = l.v * sqrt(h2) / getLength(l.v);
ret.push_back(p-h); ret.push_back(p+h); return 2;
}
double GreatCircleDistance(Sphere s,Pt3D a,Pt3D b){
    return s.r * getUnsignedAngle(a-s.c, b-s.c);
}
}
namespace Poly{
    using namespace Vectorial;
    Sphere SmallestEnclosingSphere(Polyhedron p){
        int n = p.size();
        Pt3D C(0,0,0);
        for(int i=0; i<n; i++) C = C + p[i];
        C = C / n;
        double P = 0.1;
        int pos = 0;
        int Accuracy = 70000;
        for (int i = 0; i < Accuracy; i++) {
            pos = 0;
            for (int j = 1; j < n; j++){
                if(getPLength(C - p[j]) > getPLength(C - p[pos]))
                    pos = j;
            }
            C = C + (p[pos] - C)*P;
            P *= 0.998;
        }
        return Sphere(C, getPLength(C - p[pos]));
    }
}

```

## 27 HLD

```

struct HLD{
    vector<int> parent, depth, heavy, head, pos;
    int cur_pos; segtree seg;
    int dfs(int v, vector<vector<int>> const& adj) {
        int size = 1; int max_c_size = 0;
        for (int c : adj[v]) {
            if (c != parent[v]) {
                parent[c] = v, depth[c] = depth[v] + 1;
                int c_size = dfs(c, adj);
                size += c_size;
                if (c_size > max_c_size) max_c_size = c_size,
                    heavy[v] = c;
            }
        }
        return size;
    }
    void decompose(int v, int h, vector<vector<int>> const&
        adj) {
        head[v] = h, pos[v] = cur_pos++;
        if (heavy[v] != -1)
            decompose(heavy[v], h, adj);
        for (int c : adj[v]) {
            if (c != parent[v] && c != heavy[v])
                decompose(c, c, adj);
        }
    }
    void init(vector<vector<int>> const& adj, vector<ll>&a)
        {
            int n = adj.size();
            parent = vector<int>(n); depth = vector<int>(n);
            heavy = vector<int>(n, -1); head = vector<int>(n);
            pos = vector<int>(n); cur_pos = 0;
            dfs(0, adj); decompose(0, 0, adj);
            vector<ll>tmp(n);
            for(int i=0; i<n; i++) {
                tmp[pos[i]] = a[i];
            }
        }
}

```

```

seg.init(n,tmp);
}
int query(int a, int b) {
    ll res = 0;
    for (; head[a] != head[b]; b = parent[head[b]]) {
        if (depth[head[a]] > depth[head[b]])
            swap(a, b);
        int cur_heavy_path_max = seg.query(pos[head[b]],
            pos[b]);
        res += cur_heavy_path_max;
    }
    if (depth[a] > depth[b])
        swap(a, b);
    int last_heavy_path_max = seg.query(pos[a], pos[b]);
    //edge pos[a]+1
    res += last_heavy_path_max;
    return res;
}
void update(int a, int b, int x) {
    for (; head[a] != head[b]; b = parent[head[b]]) {
        if (depth[head[a]] > depth[head[b]]) swap(a, b);
        seg.update(pos[head[b]], pos[b], x);
    }
    if (depth[a] > depth[b]) swap(a, b);
    seg.update(pos[a], pos[b],x);
}
}

```

## 28 Hackenbush

```

struct hackenbush {
    int n;
    vector<vector<int>> adj;
    hackenbush(int n) : n(n), adj(n) { }
    void add_edge(int u, int v) {
        adj[u].push_back(v);
        if (u != v) adj[v].push_back(u);
    }
    // r is the only root connecting to the ground
    int Grundy(int r) {
        vector<int> num(n), low(n);
        int t = 0;
        function<int(int, int)> dfs = [&](int p, int u) {
            num[u] = low[u] = ++t;
            int ans = 0;
            for (int v : adj[u]) {
                if (v == p) { p += 2 * n; continue; }
                if (num[v] == 0) {
                    int res = dfs(u, v);
                    low[u] = min(low[u], low[v]);
                    if (low[v] > num[u]) ans ^= (1 + res) ^ 1; // bridge
                    else ans ^= res; // non bridge
                } else low[u] = min(low[u], num[v]);
            }
            if (p > n) p -= 2 * n;
            for (int v : adj[u])
                if (v != p && num[u] <= num[v]) ans ^= 1;
            return ans;
        };
        return dfs(-1, r);
    }
};
int main() {
    int cases; scanf("%d", &cases);
    for (int icase = 0; icase < cases; ++icase) {
        int n; scanf("%d", &n);
        vector<int> ground(n);
        int r;
        for (int i = 0; i < n; ++i) {
            scanf("%d", &ground[i]);
        }
    }
}

```

```

    if (ground[i] == 1) r = i;
}
int ans = 0;
hackenbush g(n);
for (int i = 0; i < n - 1; ++i) {
    int u, v;
    scanf("%d %d", &u, &v);
    --u; --v;
    if (ground[u]) u = r;
    if (ground[v]) v = r;
    if (u == v) ans ^= 1;
    else g.add_edge(u, v);
}
int res = ans ^ g.grundy(r);
printf("%d\n", res != 0);
}
}

```

## 29 Hashing 2D

```

int mods[2] = {1000000007, 1000000009};
int bases[2] = {137, 281};
int pwbase[2][MAX];
void Preprocess(){
    pwbase[0][0] = pwbase[1][0] = 1;
    for(int i = 0; i < 2; i++) {
        for(int j = 1; j < MAX; j++) {
            pwbase[i][j] = (pwbase[i][j - 1] * 111 * bases[i]) %
                mods[i];
        }
    }
}
struct Hashing{
    int hsh[2][MAX];
    string str;
    void setstr(string &_str) {
        str = _str;
        hsh[0][str.size()] = 0;
        hsh[1][str.size()] = 0;
        Build();
    }
    void Build() {
        for(int i = str.size() - 1; i >= 0; i--) {
            for(int j = 0; j < 2; j++) {
                hsh[j][i] = ((hsh[j][i + 1] * 111 * bases[j] %
                    mods[j]) + str[i]);
                if(hsh[j][i] >= mods[j])
                    hsh[j][i] -= mods[j];
            }
        }
    }
    pair<int,int> GetHash(int i, int j) {
        assert(i <= j);
        int tmp1 = (hsh[0][i] - (hsh[0][j + 1] * 111 *
            pwbase[0][j - i + 1]) % mods[0]);
        int tmp2 = (hsh[1][i] - (hsh[1][j + 1] * 111 *
            pwbase[1][j - i + 1]) % mods[1]);
        if(tmp1 < 0)
            tmp1 += mods[0];
        if(tmp2 < 0)
            tmp2 += mods[1];
        return make_pair(tmp1, tmp2);
    }
};

```

## 30 Hopcroft

// If input graph is not given in L-R manner, make it so by coloring.

```

// Input graph must be bipartite
const int N=200*200+5;
struct HopcroftKarp
{
    static const int inf = 1e9; int n;
    vector<int> l, r, d; vector<vector<int>> g;
    HopcroftKarp(int _n, int _m) {
        n = _n; int p = _n + _m + 1;
        g.resize(p); l.resize(p, 0); r.resize(p, 0);
        d.resize(p, 0);
    }
    void add_edge(int u, int v) {
        g[u].push_back(v + n); //right id is increased by n,
        so is l[u]
    }
    bool bfs() {
        queue<int> q;
        for (int u = 1; u <= n; u++) {
            if (!l[u])
                d[u] = 0, q.push(u);
            else
                d[u] = inf;
        }
        d[0] = inf;
        while (!q.empty()) {
            int u = q.front(); q.pop();
            for (auto v : g[u]) { if (d[r[v]] == inf) {
                d[r[v]] = d[u] + 1; q.push(r[v]);
            }
        }
    }
    return d[0] != inf;
}
bool dfs(int u) {
    if (!u) return true;
    for (auto v : g[u]) { if (d[r[v]] == d[u] + 1 &&
        dfs(r[v])) {
            l[u] = v; r[v] = u;
            return true;
        }
    }
    d[u] = inf;
    return false;
}
int maximum_matching(){
    int ans = 0;
    while (bfs()){ for(int u = 1; u <= n; u++)
        if (!l[u] && dfs(u)) ans++;
    }
    return ans;
}
};

```

## 31 Hungarian

```

namespace wm{
    bool vis[N]; int U[N], V[N], P[N];
    int way[N], minv[N], match[N], ar[N][N];
    ///n=no of row, m=no of col, l
    based, flag=MAXIMIZE/MINIMIZE
    ///match[i]=the column to which row i is matched
    int hungarian(int n, int m, int mat[N][N], int flag){
        clr(U), clr(V), clr(P), clr(ar), clr(way);
        for (int i = 1; i <= n; i++){
            for (int j = 1; j <= m; j++){
                ar[i][j] = mat[i][j];
                if (flag == MAXIMIZE) ar[i][j] = -ar[i][j];
            }
        }
        if (n > m) m = n;
    }
}

```

```

int i, j, a, b, c, d, r, w;
for (i = 1; i <= n; i++){
    P[0] = i, b = 0;
    for (j=0; j<=m; j++) minv[j]=inf, vis[j] = 0;
    do{
        vis[b] = true; a = P[b], d = 0, w = inf;
        for (j = 1; j <= m; j++){
            if (!vis[j]){
                r = ar[a][j] - U[a] - V[j];
                if (r < minv[j]) minv[j] = r, way[j]=b;
                if (minv[j] < w) w = minv[j], d = j;
            }
        }
        for (j = 0; j <= m; j++){
            if (vis[j]) U[P[j]] += w, V[j] -= w;
            else minv[j] -= w;
        }
        b = d;
    } while (P[b] != 0);
    do{
        d = way[b]; P[b] = P[d], b = d;
    } while (b != 0);
}
for (j = 1; j <= m; j++) match[P[j]] = j;
return (flag == MINIMIZE) ? -V[0] : V[0];
}
}

```

## 32 IntersectingSegmentSweepLine

```

struct seg {
    pt p, q; int id;
    double get_y(double x) const {
        if (abs(p.x - q.x) < EPS) return p.y;
        return p.y + (q.y - p.y) * (x - p.x) / (q.x - p.x);
    }
};

bool intersect1d(double l1, double r1, double l2, double
    r2) {
    if (l1 > r1) swap(l1, r1);
    if (l2 > r2) swap(l2, r2);
    return max(l1, l2) <= min(r1, r2) + EPS;
}

int vec(const pt& a, const pt& b, const pt& c) {
    double s = (b.x - a.x) * (c.y - a.y) - (b.y - a.y) *
        (c.x - a.x);
    return abs(s) < EPS ? 0 : s > 0 ? +1 : -1;
}

bool intersect(const seg& a, const seg& b) {
    return intersect1d(a.p.x, a.q.x, b.p.x, b.q.x) &&
        intersect1d(a.p.y, a.q.y, b.p.y, b.q.y) &&
        vec(a.p, a.q, b.p) * vec(a.p, a.q, b.q) <= 0 &&
        vec(b.p, b.q, a.p) * vec(b.p, b.q, a.q) <= 0;
}

bool operator<(const seg& a, const seg& b){
    double x = max(min(a.p.x, a.q.x), min(b.p.x, b.q.x));
    return a.get_y(x) < b.get_y(x) - EPS;
}

struct event {
    double x; int tp, id;
    event() {}
    event(double x, int tp, int id) : x(x), tp(tp), id(id) {}
};

bool operator<(const event& e) const {
    if (abs(x - e.x) > EPS) return x < e.x;
    return tp > e.tp;
}

```

```

}
};
set<seg> s;
vector<set<seg>::iterator> where;
set<seg>::iterator prev(set<seg>::iterator it) {
    return it == s.begin() ? s.end() : --it;
}
set<seg>::iterator next(set<seg>::iterator it) {
    return ++it;
}
pair<int, int> solve(const vector<seg>& a) {
    int n = (int)a.size(); vector<event> e;
    for (int i = 0; i < n; ++i) {
        e.push_back(event(min(a[i].p.x, a[i].q.x), +1, i));
        e.push_back(event(max(a[i].p.x, a[i].q.x), -1, i));
    }
    sort(e.begin(), e.end()); s.clear();
    where.resize(a.size());
    for (size_t i = 0; i < e.size(); ++i) {
        int id = e[i].id;
        if (e[i].tp == +1) {
            set<seg>::iterator nxt = s.lower_bound(a[id]), prv =
                prev(nxt);
            if (nxt != s.end() && intersect(*nxt, a[id]))
                return make_pair(nxt->id, id);
            if (prv != s.end() && intersect(*prv, a[id]))
                return make_pair(prv->id, id);
            where[id] = s.insert(nxt, a[id]);
        } else {
            set<seg>::iterator nxt = next(where[id]), prv =
                prev(where[id]);
            if (nxt != s.end() && prv != s.end() &&
                intersect(*nxt, *prv))
                return make_pair(prv->id, nxt->id);
            s.erase(where[id]);
        }
    }
    return make_pair(-1, -1);
}

```

### 33 KnuthDP

```

int n,k;int a[N];ll dp[N][N];int opt[N][N];int
cost[N][N];
void TEST_CASES(){
    memset(dp,0,sizeof dp);
    for(int i=1;i<=n;i++){opt[0][i] = 0;}
    for(int i=1;i<=k;i++){opt[i][n+1] = n;}
    for(int group = 1;group<=k;group++){
        for(int i=n;i>=1;i--){
            for(int last = opt[group-1][i];last<=
                opt[group][i+1];last++){
                ll val = dp[group-1][last] + cost[last+1][i];
                if(val>dp[group][i]){
                    dp[group][i] = val;
                    opt[group][i] = last;
                }
            }
        }
    }
    cout<<dp[k][n]<<"\n";
}

```

### 34 LCA

```

template <class T>
struct RMQ { // 0-based
    vector<vector<T>> rmq;
    T kInf = numeric_limits<T>::max();

```

```

void build(const vector<T>& V) {
    int n = V.size(), on = 1, dep = 1;
    while (on < n) on *= 2, ++dep;
    rmq.assign(dep, V);
    for (int i = 0; i < dep - 1; ++i)
        for (int j = 0; j < n; ++j) {
            rmq[i + 1][j] = min(rmq[i][j], rmq[i][min(n - 1, j +
                (1 << i))]);
        }
}
T query(int a, int b) { // [a, b)
    if (b <= a) return kInf;
    int dep = 31 - __builtin_clz(b - a); // log(b - a)
    return min(rmq[dep][a], rmq[dep][b - (1 << dep)]);
}
};
struct LCA { // 0-based
    vector<int> enter, depth, exxit;
    vector<vector<int>> G;
    vector<pair<int, int>> linear;
    RMQ<pair<int, int>> rmq;
    int timer = 0;
    LCA() {}
    LCA(int n) : enter(n, -1), exxit(n, -1), depth(n),
        G(n), linear(2 * n) {}
    void dfs(int node, int dep) {
        linear[timer] = {dep, node};
        enter[node] = timer++;
        depth[node] = dep;
        for (auto vec : G[node])
            if (enter[vec] == -1) {
                dfs(vec, dep + 1);
                linear[timer++] = {dep, node};
            }
        exxit[node] = timer;
    }
    void add_edge(int a, int b) {
        G[a].push_back(b);
        G[b].push_back(a);
    }
    void build(int root) {
        dfs(root, 0);
        rmq.build(linear);
    }
    int query(int a, int b) {
        a = enter[a], b = enter[b];
        return rmq.query(min(a, b), max(a, b) + 1).second;
    }
    int dist(int a, int b) {
        return depth[a] + depth[b] - 2 * depth[query(a, b)];
    }
};

```

### 35 LCABinaryLift

```

int n, l;
vector<vector<int>> adj;
int timer;
vector<int> tin, tout;
vector<vector<int>> up;
void dfs(int v, int p){
    tin[v] = ++timer;
    up[v][0] = p;
    for (int i = 1; i <= l; ++i)
        up[v][i] = up[up[v][i-1]][i-1];
    for (int u : adj[v]) {
        if (u != p)
            dfs(u, v);
    }
    tout[v] = ++timer;
}

```

```

}
bool is_ancestor(int u, int v){
    return tin[u] <= tin[v] && tout[u] >= tout[v];
}
int lca(int u, int v){
    if (is_ancestor(u, v))
        return u;
    if (is_ancestor(v, u))
        return v;
    for (int i = l; i >= 0; --i) {
        if (!is_ancestor(up[u][i], v))
            u = up[u][i];
    }
    return up[u][0];
}
void preprocess(int root) {
    tin.resize(n);
    tout.resize(n);
    timer = 0;
    l = ceil(log2(n));
    up.assign(n, vector<int>(l + 1));
    dfs(root, root);
}

```

### 36 LCT rooted

```

typedef pair< int, int >Linear;
Linear compose(const Linear &p, const Linear &q)
{
    return Linear(mul(p.first, q.first),
        sum(mul(q.second, p.first), p.second));
}
struct SplayTree
{
    struct Node {
        int ch[2] = {0, 0}, p = 0;
        long long self = 0, path = 0; // Path aggregates
        long long sub = 0, vir = 0; // Subtree aggregate
        int size = 1; bool flip = 0; // Lazy tags
        Linear _self{1, 0}, shoja{1, 0}, ulta{1, 0};
    };
    vector<Node> T;
    SplayTree(int n) : T(n + 1) {
        T[0].size = 0;
    }
    void push(int x) {
        if (!x || !T[x].flip)
            return;
        int l = T[x].ch[0], r = T[x].ch[1];
        T[l].flip ^= 1, T[r].flip ^= 1;
        swap(T[x].ch[0], T[x].ch[1]); T[x].flip = 0;
        swap(T[x].shoja, T[x].ulta);
    }
    void pull(int x) {
        int l=T[x].ch[0],r=T[x].ch[1];
        push(l);
        push(r);
        T[x].size = T[l].size + T[r].size + 1;
        T[x].path = T[l].path + T[x].self + T[r].path;
        T[x].sub=T[x].vir+T[l].sub+T[r].sub+T[x].self;
        T[x].shoja = compose(T[r].shoja,
            compose(T[x]._self, T[l].shoja));
        T[x].ulta = compose(T[l].ulta,
            compose(T[x]._self, T[r].ulta));
    }
    void set(int x, int d, int y) {
        T[x].ch[d] = y; T[y].p = x; pull(x);
    }
    void splay(int x) {
        auto dir = [&](int x)

```

```

{
    int p = T[x].p;
    if (!p) return -1;
    return T[p].ch[0]==x?0:T[p].ch[1]==x?1:-1;
};
auto rotate = [&](int x)
{
    int y = T[x].p,z=T[y].p,dx=dir(x),dy=dir(y);
    set(y, dx, T[x].ch[!dx]); set(x, !dx, y);
    if (~dy) set(z, dy, x);
    T[x].p = z;
};
for (push(x); ~dir(x); )
{
    int y = T[x].p,z = T[y].p;
    push(z); push(y); push(x);
    int dx = dir(x), dy = dir(y);
    if (~dy) rotate(dx!=dy?x:y);
    rotate(x);
}
}
int KthNext(int x, int k) {
    assert(k > 0); splay(x);
    x = T[x].ch[1];
    if (T[x].size < k) return -1;
    while (true)
    {
        push(x); int l = T[x].ch[0], r = T[x].ch[1];
        if (T[l].size+1 == k) return x;
        if (k <= T[l].size) x = l;
        else k -= T[l].size+1, x = r;
    }
};
struct LinkCut : SplayTree
{
    LinkCut(int n) : SplayTree(n) {}
    int access(int x) {
        int u = x, v = 0;
        for (; u; v = u, u = T[u].p)
        {
            splay(u); int& ov = T[u].ch[1];
            T[u].vir += T[ov].sub; T[u].vir -= T[v].sub;
            ov = v; pull(u);
        }
        splay(x);
        return v;
    }
    void reroot(int x) {
        access(x); T[x].flip ^= 1; push(x);
    }
    ///makes v parent of u !(u must be a root)
    void Link(int u, int v) {
        reroot(u); access(v); T[v].vir += T[u].sub;
        T[u].p = v; pull(v);
    }
    ///removes edge between u and v
    void Cut(int u, int v) {
        int _u = FindRoot(u); reroot(u);
        access(v); T[v].ch[0] = T[u].p = 0;
        pull(v); reroot(_u);
    }
    ///Rooted tree LCA.Returns 0 if u v not connected
    int LCA(int u, int v) {
        if (u == v) return u;
        access(u); int ret = access(v);
        return T[u].p ? ret : 0;
    }
    ///Query subtree of u where v is outside the sbtr

```

```

long long Subtree(int u, int v) {
    int _v = FindRoot(v); reroot(v); access(u);
    long long ans = T[u].vir + T[u].self;
    reroot(_v);
    return ans;
}
long long Path(int u, int v) {
    int _u = FindRoot(u); reroot(u); access(v);
    long long ans = T[v].path;
    reroot(_u);
    return ans;
}
Linear_Path(int u, int v) {
    reroot(u); access(v);
    return T[v].shoja;
}
void Update(int u, long long v) {
    access(u); T[u].self = v; pull(u);
}
void _Update(int u, Linear v) {
    access(u); T[u].self = v;
    pull(u);
}
int FindRoot(int u) {
    access(u);
    while (T[u].ch[0]) { u = T[u].ch[0]; push(u); }
    access(u);
    return u;
}
///k-th node (0-indexed) on the path from u to v
int KthOnPath(int u, int v, int k) {
    if (u == v) return k == 0 ? u : -1;
    int _u = FindRoot(u);
    reroot(u); access(v);
    int ans = KthNext(u, k); reroot(_u);
    return ans;
}
};

```

## 37 LIS

```

int lis(vector<int> const& a) {
    int n = a.size();
    const int INF = 1e9;
    vector<int> d(n+1, INF);
    d[0] = -INF;

    for (int i = 0; i < n; i++) {
        int j = upper_bound(d.begin(), d.end(), a[i]) -
            d.begin();
        if (d[j-1] < a[i] && a[i] < d[j])
            d[j] = a[i];
    }

    int ans = 0;
    for (int i = 0; i <= n; i++) {
        if (d[i] < INF)
            ans = i;
    }
    return ans;
}

```

## 38 MO

```

struct query{int l,r,idx;};
int block;
bool comp1(query p,query q){
    if (p.l / block != q.l / block) {
        if(p.l==q.l) return p.r<q.r;
        return p.l < q.l;
    }
}

```

```

return (p.l / block & 1) ? (p.r < q.r) : (p.r > q.r);
}
void mos_algorithm(int n, vector<query>&queries){
    vector<int> answers(queries.size());
    block = (int)sqrt(n);
    sort(queries.begin(), queries.end(),comp1);
    int cur_l = 0;
    int cur_r = -1;
    for (query q : queries) {
        while (cur_l > q.l) {cur_l--; add(cur_l);}
        while (cur_r < q.r) {cur_r++;add(cur_r);}
        while (cur_l < q.l) {Remove(cur_l);cur_l++;}
        while (cur_r > q.r) {Remove(cur_r);cur_r--;}
        answers[q.idx] = get_answer();
    }
    for(int i:answers) {cout<<i<<"\n";}
}

```

## 39 Manacher

```

vector<int> d1(n);
for (int i = 0, l = 0, r = -1; i < n; i++) {
    int k = (i > r) ? 1 : min(d1[l + r - i], r - i + 1);
    while (0 <= i - k && i + k < n && s[i - k] == s[i + k])
        k++;
    d1[i] = k--;
    if (i + k > r){
        l = i - k;
        r = i + k;
    }
}
vector<int> d2(n);
for (int i = 0, l = 0, r = -1; i < n; i++) {
    int k = (i > r) ? 0 : min(d2[l + r - i + 1], r - i + 1);
    while (0 <= i - k - 1 && i + k < n && s[i - k - 1] ==
        s[i + k]) {
        k++;
    }
    d2[i] = k--;
    if (i + k > r) {
        l = i - k - 1;
        r = i + k;
    }
}
}

```

## 40 MatrixDeterminant

```

double det = 1;
for (int i=0; i<n; ++i) {
    int k = i;
    for (int j=i+1; j<n; ++j)
        if (abs (a[j][i]) > abs (a[k][i]))
            k = j;
    if (abs (a[k][i]) < EPS) {
        det = 0;
        break;
    }
    swap (a[i], a[k]);
    if (i != k)
        det = -det;
    det *= a[i][i];
    for (int j=i+1; j<n; ++j)
        a[i][j] /= a[i][i];
    for (int j=0; j<n; ++j)
        if (j != i && abs (a[j][i]) > EPS)
            for (int k=i+1; k<n; ++k)
                a[j][k] -= a[i][k] * a[j][i];
}
}

```

41 MatrixExpo

```
/* try to avoid vector. Possibly use STL array or pointers */
void multiply(vector<vector<int> >&a, vector<vector<int> >&b){
    int n = a.size(), m= a[0].size(), l = b[0].size();
    vector<vector<int> >ret(n,vector<int>(l));
    for(int i=0; i<n; i++) {
        for(int k=0; k<m; k++) {
            for(int j=0; j<l; j++) {
                ret[i][j] = add(ret[i][j],
                                gun(a[i][k],b[k][j],mod),mod);
            }
        }
    }
    swap(ret,a);
}

void bigmod(vector<vector<int> >&a, int p){
    int n = a.size();
    assert(a.size()==a[0].size());
    vector<vector<int> >res(n,vector<int> (n));
    for(int i=0; i<n; i++) {
        for(int j=0; j<n; j++) {
            res[i][j] = 0;
            if(i==j)
                res[i][j]=1;
        }
    }
    while(p) {
        if(p&1) {
            multiply(res,a);
        }
        multiply(a,a);
        p>>=1;
    }
    swap(a, res);
}
```

42 MillerRabin

```
using u64 = uint64_t;
using u128 = __uint128_t;

u64 binpower(u64 base, u64 e, u64 mod) {
    u64 result = 1;
    base %= mod;
    while (e) {
        if (e & 1)
            result = (u128)result * base % mod;
        base = (u128)base * base % mod;
        e >>= 1;
    }
    return result;
}

bool check_composite(u64 n, u64 a, u64 d, int s) {
    u64 x = binpower(a, d, n);
    if (x == 1 || x == n - 1)
        return false;
    for (int r = 1; r < s; r++) {
        x = (u128)x * x % n;
        if (x == n - 1)
            return false;
    }
    return true;
};

bool MillerRabin(u64 n) { // returns true if n is prime,
    else returns false.
    if (n < 2)
```

```
return false;

int r = 0;
u64 d = n - 1;
while ((d & 1) == 0) {
    d >>= 1;
    r++;
}

for (int a : {2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31, 37}) {
    if (n == a)
        return true;
    if (check_composite(n, a, d, r))
        return false;
}
return true;
}
```

43 MinCostFlow1

```
#define fst first
#define snd second
#define all(c) ((c).begin()), ((c).end())
#define TEST(s) if (!(s)) { cout << __LINE__ << " " <<
    #s << endl; exit(-1); }

const long long INF = 1e9;
struct graph {
    typedef int flow_type;
    typedef int cost_type;
    struct edge {
        int src, dst;
        flow_type capacity, flow;
        cost_type cost;
        size_t rev;
    };
    void add_edge(int src, int dst, flow_type cap,
        cost_type cost) {
        adj[src].push_back({src, dst, cap, 0, cost,
            adj[dst].size()});
        adj[dst].push_back({dst, src, 0, 0, -cost,
            adj[src].size()-1});
    }
    int n;
    vector<vector<edge>> adj;
    graph(int n) : n(n), adj(n) { }

    pair<flow_type, cost_type> min_cost_max_flow(int s,
        int t) {
        flow_type flow = 0;
        cost_type cost = 0;

        for (int u = 0; u < n; ++u)
            for (auto &e: adj[u]) e.flow = 0;

        vector<cost_type> p(n, 0);

        auto rcost = [&](edge e) { return e.cost + p[e.src] -
            p[e.dst]; };
        for (int iter = 0; ; ++iter) {
            vector<int> prev(n, -1); prev[s] = 0;
            vector<cost_type> dist(n, INF); dist[s] = 0;
            if (iter == 0) {
                vector<int> count(n); count[s] = 1;
                queue<int> que;
                for (que.push(s); !que.empty(); ) {
                    int u = que.front(); que.pop();
                    count[u] = -count[u];
                    for (auto &e: adj[u]) {
                        if (e.capacity > e.flow && dist[e.dst] > dist[e.src]
                            + rcost(e)) {
                            dist[e.dst] = dist[e.src] + rcost(e);
```

```
prev[e.dst] = e.rev;
                            if (count[e.dst] <= 0) {
                                count[e.dst] = -count[e.dst] + 1;
                                que.push(e.dst);
                            }
                        }
                    }
                } else {
                    typedef pair<cost_type, int> node;
                    priority_queue<node, vector<node>, greater<node>> que;
                    que.push({0, s});
                    while (!que.empty()) {
                        node a = que.top(); que.pop();
                        if (a.snd == t) break;
                        if (dist[a.snd] > a.fst) continue;
                        for (auto e: adj[a.snd]) {
                            if (e.capacity > e.flow && dist[e.dst] > a.fst +
                                rcost(e)) {
                                dist[e.dst] = dist[e.src] + rcost(e);
                                prev[e.dst] = e.rev;
                                que.push({dist[e.dst], e.dst});
                            }
                        }
                    }
                }
                if (prev[t] == -1) break;

                for (int u = 0; u < n; ++u)
                    if (dist[u] < dist[t]) p[u] += dist[u] - dist[t];

                function<flow_type(int,flow_type)> augment = [&](int
                    u, flow_type cur) {
                    if (u == s) return cur;
                    edge &r = adj[u][prev[u]], &e = adj[r.dst][r.rev];
                    flow_type f = augment(e.src, min(e.capacity - e.flow,
                        cur));
                    e.flow += f; r.flow -= f;
                    return f;
                };
                flow_type f = augment(t, INF);
                flow += f;
                cost += f * (p[t] - p[s]);
            }
        }
        return {flow, cost};
    }
};
```

44 MinCostFlow2

```
struct Edge{
    int u, v;
    long long cap, cost;

    Edge(int _u, int _v, long long _cap, long long _cost) {
        u = _u;
        v = _v;
        cap = _cap;
        cost = _cost;
    }
};

struct MinCostFlow{
    int n, s, t;
    long long flow, cost;
    vector<vector<int> > graph;
    vector<Edge> e;
    /* if cost is double, dist should be double*/
    vector<long long> dist;
    vector<int> parent;

    MinCostFlow(int _n) {
        /* 0-based indexing*/
```

```

    n = _n;
    graph.assign(n, vector<int> ());
}

void addEdge(int u, int v, long long cap, long long
    cost, bool directed = true) {
    graph[u].push_back(e.size());
    e.push_back(Edge(u, v, cap, cost));

    graph[v].push_back(e.size());
    e.push_back(Edge(v, u, 0, -cost));

    if(!directed)
        addEdge(v, u, cap, cost, true);
}

pair<long long, long long> getMinCostFlow(int _s, int
    _t) {
    s = _s;
    t = _t;
    flow = 0, cost = 0;

    while(SPFA()) {
        flow += sendFlow(t, 1LL<<62);
    }

    return make_pair(flow, cost);
}

bool SPFA() {
    parent.assign(n, -1);
    dist.assign(n, 1LL<<62);
    dist[s] = 0;
    vector<int> queueTime(n, 0);
    queueTime[s] = 1;
    vector<bool> inqueue(n, 0);
    inqueue[s] = true;
    queue<int> q;
    q.push(s);
    bool negativecycle = false;

    while(!q.empty() && !negativecycle) {
        int u = q.front();
        q.pop();
        inqueue[u] = false;

        for(int i = 0; i < graph[u].size(); i++) {
            int eIdx = graph[u][i];
            int v = e[eIdx].v;
            ll w = e[eIdx].cost, cap = e[eIdx].cap;

            if(dist[u] + w < dist[v] && cap > 0) {
                dist[v] = dist[u] + w;
                parent[v] = eIdx;

                if(!inqueue[v]) {
                    q.push(v);
                    queueTime[v]++;
                    inqueue[v] = true;

                    if(queueTime[v] == n+2) {
                        negativecycle = true;
                        break;
                    }
                }
            }
        }
    }

    return dist[t] != (1LL<<62);
}

long long sendFlow(int v, long long curFlow) {

```

```

    if(parent[v] == -1)
        return curFlow;
    int eIdx = parent[v];
    int u = e[eIdx].u;
    ll w = e[eIdx].cost;

    long long f = sendFlow(u, min(curFlow, e[eIdx].cap));

    cost += f*w;
    e[eIdx].cap -= f;
    e[eIdx^1].cap += f;

    return f;
}
};

```

## 45 MinimumStack

```

void small_left(vector<int>& v, vector<int>& res){
    stack<pair<int, int> > stk;
    stk.push(make_pair(INT_MIN, v.size()));//initial value
    for (int i = v.size()-1; i >= 0; i--) {
        while (stk.top().first > v[i]) {
            res[stk.top().second] = i;
            stk.pop();
        }
        stk.push(make_pair(v[i], i));
    }
    while (stk.top().second < v.size()) {
        res[stk.top().second] = -1;
        stk.pop();
    }
}

```

## 46 Minkowski

```

void reorder_polygon(vector<pt> & P){
    size_t pos = 0;
    for(size_t 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<pt> minkowski(vector<pt> P, vector<pt> 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<pt> result;
    size_t i = 0, j = 0;
    while(i < P.size() - 2 || j < Q.size() - 2){
        result.push_back(P[i] + Q[j]);
        auto cross = (P[i + 1] - P[i]).cross(Q[j + 1] - Q[j]);
        if(cross >= 0) ++i;
        if(cross <= 0) ++j;
    }
    return result;
}

```

## 47 Miscellaneous

```

for(int i=a._Find_first(); i< a.size(); i =
    a._Find_next(i))
    mt19937 rng(chrono::steady_clock::now().
        time_since_epoch().count());
int getrand(int a, int b){
    int x = uniform_int_distribution<int>(a, b)(rng);
    return x;
}

```

```

l1.splice(l1.end(), l2);

merge(a.begin(), a.end(),
    b.begin(), b.end(),
    back_inserter(c));
#pragma GCC optimize("Ofast")
#pragma GCC
    target("sse,sse2,sse3,ssse3,sse4,popcnt,abm,mmx,
    avx,avx2,fma")
#pragma GCC optimize("unroll-loops")
#pragma GCC optimize("O3")

struct custom_hash {
    static uint64_t splitmix64(uint64_t x) {
        x += 0x9e3779b97f4a7c15;
        x = (x ^ (x >> 30)) * 0xbf58476d1ce4e5b9;
        x = (x ^ (x >> 27)) * 0x94d049bb133111eb;
        return x ^ (x >> 31);
    }

    size_t operator()(uint64_t x) const {
        static const uint64_t FIXED_RANDOM =
            chrono::steady_clock::now().
            time_since_epoch().count();
        return splitmix64(x + FIXED_RANDOM);
    }
};

unordered_map<long long, int, custom_hash> safe_map;

struct hash_pair {
    template <class T1, class T2>
    size_t operator()(const pair<T1, T2>& p) const {
        auto hash1 = hash<T1>{}(p.first);
        auto hash2 = hash<T2>{}(p.second);
        return hash1 ^ hash2;
    }
};

unordered_map<pair<int, int>, int, hash_pair> mp;
//mod inverse for all m
inv[1] = 1;
for(int i = 2; i < m; ++i)
    inv[i] = m - (m/i) * inv[m/i] % m;
//ordered set
#include <ext/pb_ds/assoc_container.hpp>
using namespace __gnu_pbds;
typedef tree<int,null_type,less<int >,rb_tree_tag,
    tree_order_statistics_node_update>indexed_set;
//submask supermask
for (int s=m; s; s=(s-1)&m)
for (int mask=need; mask < (1<<n) ; mask = (mask+1)&need)
string str="abc def gh",buf;stringstream ss(str);
while(ss >> buf) cout << buf << endl;

```

## 48 Mo with update

```

const int N = 1e5 +5;
const int P = 2000; //block size = (2*n^2)^(1/3)
struct query{int t, l, r, k, i;};
vector<query> q;vector<array<int, 3>> upd;
vector<int> ans;vector<int>a;
void mos_algorithm(){
    sort(q.begin(), q.end(), [](const query &a, const query
        &b) {
        if (a.t / P != b.t / P) return a.t < b.t;
        if (a.l / P != b.l / P) return a.l < b.l;
        if ((a.l / P) & 1) return a.r < b.r;
        return a.r > b.r;
    });

    for (int i = upd.size() - 1; i >= 0; --i)
        a[upd[i][0]] = upd[i][1];
    int L = 0, R = -1, T = 0;

```



```

auto apply = [&](int i, int fl) {
    int p = upd[i][0]; int x = upd[i][fl + 1];
    if (L <= p && p <= R) {rem(a[p]);add(x);}
    a[p] = x;
};
ans.clear();ans.resize(q.size());
for (auto qr : q) {
    int t = qr.t, l = qr.l, r = qr.r, k = qr.k;
    while (T < t) apply(T++, 1);
    while (T > t) apply(--T, 0);
    while (R < r) add(a[++R]);
    while (L > l) add(a[--L]);
    while (R > r) rem(a[R--]);
    while (L < l) rem(a[L++]);
    ans[qr.i] = get_answer();
}
}

void TEST_CASES(int cas){
    int n, m; cin>>n>>m;
    a.resize(n);
    for(int i=0;i<n;i++){ cin>>a[i]; }
    for(int i=0;i<m;i++){
        int tp;scanf("%d", &tp);
        if (tp == 1) {
            int l, r, k;cin>>l>>r>>k;
            q.push_back({upd.size(), l - 1, r - 1, k, q.size()});
        }
        else {
            int p, x;cin>>p>>x;
            --p;upd.push_back({p, a[p], x});
            a[p] = x;
        }
    }
    mos_algorithm();
}

```

## 49 Monotone Queue

```

vector<int>dp(n,0);
vector<int>newdp(n);
for(int i=1; i<=m; i++){
    int koto = d*(a[i].t - a[i-1].t);
    deque<pair<int,int>> dq;
    int l = 0, r = -1;
    for(int j=0; j<n; j++){
        int eil = max(0ll, j-koto), eir = min(n-1, j+koto);
        while(!dq.empty() && dq.front().first < eil) {
            dq.pop_front();
        }
        while(r!= eir) {
            r++;
            int val = dp[r];
            int idx = r;
            while(!dq.empty() && dq.back().second <= val) {
                dq.pop_back();
            }
            dq.push_back({idx, val});
        }
        newdp[j] = a[i].b - abs(a[i].a - j-1) +
            dq.front().second;
    }
    swap(dp, newdp);
}
cout<<*max_element(dp.begin(), dp.end())<<"\n";

```

## 50 NTT

```

namespace NTT {
    vector<int> perm, wp[2];

```

```

const int mod = 998244353, G = 3; ///G is the primitive root of M
int root, inv, N, invN;
int power(int a, int p) {
    int ans = 1;
    while (p) {
        if (p & 1) ans = (1LL*ans*a)%mod;
        a = (1LL*a*a)%mod;
        p >>= 1;
    }
    return ans;
}

void precalculate(int n) {
    assert( (n&(n-1)) == 0 && (mod-1)%n==0);
    N = n;
    invN = power(N, mod-2);
    perm = wp[0] = wp[1] = vector<int>(N);

    perm[0] = 0;
    for (int k=1; k<N; k<=1)
        for (int i=0; i<k; i++) {
            perm[i] <= 1;
            perm[i+k] = 1 + perm[i];
        }

    root = power(G, (mod-1)/N);
    inv = power(root, mod-2);
    wp[0][0]=wp[1][0]=1;
    for (int i=1; i<N; i++) {
        wp[0][i] = (wp[0][i-1]*1LL*root)%mod;
        wp[1][i] = (wp[1][i-1]*1LL*inv)%mod;
    }

    void fft(vector<int> &v, bool invert = false) {
        if (v.size() != perm.size()) precalculate(v.size());
        for (int i=0; i<N; i++)
            if (i < perm[i])
                swap(v[i], v[perm[i]]);

        for (int len = 2; len <= N; len *= 2) {
            for (int i=0, d = N/len; i<N; i+=len) {
                for (int j=0, idx=0; j<len/2; j++, idx += d) {
                    int x = v[i+j];
                    int y = (wp[invert][idx]*1LL*v[i+j+len/2])%mod;
                    v[i+j] = (x+y)%mod ? x+y-mod : x+y;
                    v[i+j+len/2] = (x-y)%mod ? x-y : x-y+mod;
                }
            }
        }
        if (invert) {
            for (int &x : v) x = (x*1LL*invN)%mod;
        }
    }

    vector<int> multiply(vector<int> a, vector<int> b) {
        int n = 1;
        while (n < a.size()+ b.size()) n<=1;
        a.resize(n);
        b.resize(n);

        fft(a);
        fft(b);
        for (int i=0; i<n; i++) a[i] = (a[i] * 1LL * b[i])%mod;
        fft(a, true);
        return a;
    }
};

```

## 51 Nearest Point Pair

```

#define x first
#define y second

```

```

long long dist2(pair<int, int> a, pair<int, int> b) {
    return 1LL * (a.x - b.x) * (a.x - b.x) + 1LL * (a.y - b.y) * (a.y - b.y);
}

pair<int, int> closest_pair(vector<pair<int, int>> a) {
    int n = a.size();
    assert(n >= 2);
    vector<pair<pair<int, int>, int>> p(n);
    for (int i = 0; i < n; i++) p[i] = {a[i], i};
    sort(p.begin(), p.end());
    int l = 0, r = 2;
    long long ans = dist2(p[0].x, p[1].x);
    pair<int, int> ret = {0, 1};
    while (r < n) {
        while (l < r && 1LL * (p[r].x.x - p[l].x.x) *
            (p[r].x.x - p[l].x.x) >= ans) l++;
        for (int i = l; i < r; i++) {
            long long nw = dist2(p[i].x, p[r].x);
            if (nw < ans) {
                ans = nw;
                ret = {p[i].y, p[r].y};
            }
        }
        r++;
    }
    return ret;
}

```

## 52 PalindromicTree

```

/*-> diff(v) = len(v) - len(link(v))
-> series link will lead from the vertex v to the vertex u corresponding to the maximum suffix palindrome of v which satisfies diff(v) != diff(u)
-> path within series links to the root contains only O(log n) vertices
-> cnt contains the number of palindromic suffixes of the node*/

struct PalindromicTree {
    struct node {
        int nxt[26], len, st, en, link, diff, slink, cnt, oc;
    };
    string s;vector<node> t;
    int sz, last;
    PalindromicTree() {}
    PalindromicTree(string _s) {
        s = _s;
        int n = s.size();
        t.clear();
        t.resize(n + 9);sz = 2, last = 2;
        t[1].len = -1, t[1].link = 1;
        t[2].len = 0, t[2].link = 1;
        t[1].diff = t[2].diff = 0;
        t[1].slink = 1;t[2].slink = 2;
    }
    int extend(int pos) { // returns 1 if it creates a new palindrome
        int cur = last, curlen = 0;
        int ch = s[pos] - 'a';
        while (1) {curlen = t[cur].len;
            if (pos - 1 - curlen >= 0 && s[pos - 1 - curlen] == s[pos]) break;
            cur = t[cur].link;
        }
        if (t[cur].nxt[ch]) {last = t[cur].nxt[ch];
            t[last].oc++;
            return 0;
        }
        sz++;last = sz;
        t[sz].oc = 1;t[sz].len = t[cur].len + 2;

```

```

t[cur].nxt[ch] = sz;t[sz].en = pos;
t[sz].st = pos - t[sz].len + 1;
if (t[sz].len == 1) {
    t[sz].link = 2;t[sz].cnt = 1;
    t[sz].diff = 1;t[sz].slink = 2;
    return 1;
}
while (1) {
    cur = t[cur].link;curlen = t[cur].len;
    if (pos - 1 - curlen >= 0 && s[pos - 1 - curlen] ==
        s[pos]) {
        t[sz].link = t[cur].nxt[ch];
        break;
    }
}
t[sz].cnt = 1 + t[t[sz].link].cnt;
t[sz].diff = t[sz].len - t[t[sz].link].len;
if (t[sz].diff == t[t[sz].link].diff) t[sz].slink =
    t[t[sz].link].slink;
else t[sz].slink = t[sz].link;
return 1;
}
void calc_occurrences() {
    for (int i = sz; i >= 3; i--) t[t[i].link].oc +=
        t[i].oc;
}
vector<array<int, 2>> minimum_partition() { //(even,
    odd), 1 indexed
    int n = s.size();
    vector<array<int, 2>> ans(n + 1, {0, 0}), series_ans(n
        + 5, {0, 0});
    ans[0][1] = series_ans[2][1] = 1e9;
    for (int i = 1; i <= n; i++) {
        extend(i - 1);
        for (int k = 0; k < 2; k++) {
            ans[i][k] = 1e9;
            for (int v = last; t[v].len > 0; v = t[v].slink) {
                series_ans[v][!k] = ans[i - (t[t[v].slink].len +
                    t[v].diff)][!k];
                if (t[v].diff == t[t[v].link].diff)
                    series_ans[v][!k] = min(series_ans[v][!k],
                        series_ans[t[v].link][!k]);
                ans[i][k] = min(ans[i][k], series_ans[v][!k] + 1);
            }
        }
    }
    return ans;
}
} t;
int32_t main() {
    string s;cin >> s;
    PalindromicTree t(s);
    for (int i = 0; i < s.size(); i++) t.extend(i);
    t.calc_occurrences();
    long long ans = 0;
    for (int i = 3; i <= t.sz; i++) ans += t.t[i].oc;
    cout << ans << '\n';
    //auto ans = t.minimum_partition();
    // for (int i = 1; i <= s.size(); i++) {
    //     cout << (ans[i][1] == 1e9 ? -1 : ans[i][1]) << ' ';
    //     cout << (ans[i][0] == 1e9 ? -2 : ans[i][0]) <<
    //         '\n';
    // }
}

```

## 53 Partition

```

int p[MAX];
inline int Add(int a,int b){return (a+b)%mod;}

int PartitionFunction(){

```

```

p[0] = 1;
for(int i = 1; i < MAX; i++){
    int j = 1, r = 1;
    while(i - (3*j*j - j) / 2 >= 0){
        p[i] = Add(p[i], p[i - (3*j*j - j) / 2] * r);

        if(i - (3*j*j + j) / 2 >= 0)
            p[i] = Add(p[i], p[i - (3*j*j + j) / 2] * r);

        j += 1;
        r *= -1;
    }
    if(p[i]<0) p[i]+=mod;
}
}

```

## 54 Phi

```

int phi[N+1];
void phi_1_to_n(int n) {
    phi[0] = 0;phi[1] = 1;
    for (int i = 2; i <= n; i++)phi[i] = i;
    for (int i = 2; i <= n; i++) {
        if (phi[i] == i) { for (int j = i; j <= n; j += i)
            phi[j] -= phi[j] / i;
        }
    }
}

```

## 55 PointOrderingByAngle

```

typedef pair<int,int> pii;
struct point{
    int x, y;
    bool operator <(point &p) const{
        if(x==p.x){
            return y > p.y;
        }
        return x<p.x;
    }
};
struct line{
    point p1, p2;
    line(){ }
    line(point &p, point &q){
        p1 = p;
        p2 = q;
    }
    bool operator <(line &p){
        ll a = (p1.x- p2.x);
        ll b = (p1.y-p2.y);
        ll c = (p.p1.x- p.p2.x);
        ll d = (p.p1.y-p.p2.y);
        return a*d < b*c;
    }
};
void TEST_CASES(int cas){
    int n;
    scanf("%d",&n);
    map<pii, int>mp;
    vector<point>v(n);
    for(int i=0; i<n; i++){
        v[i].read();
    }
    sort(v.begin(),v.end());
    for(int i=0; i<n; i++){
        mp[ {v[i].x, v[i].y} ] = i;
    }
    vector<line>lines;
    for(int i=0; i<n; i++){
        for(int j=i+1; j<n; j++){

```

```

        lines.emplace_back(v[i],v[j]);
    }
}
sort(lines.begin(),lines.end());
for(line &l: lines){
    point p1= l.p1;
    point p2 = l.p2;
    int idx1 = mp[ {p1.x,p1.y}];
    int idx2 = mp[ {p2.x, p2.y}];
    //Do your work
    //Swap indexes
    v[idx1] = l.p2;
    v[idx2] = l.p1;
    mp[ {v[idx1].x, v[idx1].y} ] = idx1;
    mp[ {v[idx2].x, v[idx2].y} ] = idx2;
}
}

```

## 56 PollardRho

```

typedef long long LL;
typedef unsigned long long ULL;
namespace Rho {
    ULL mult(ULL a, ULL b, ULL mod) {
        LL ret = a * b - mod * (ULL)(1.0L / mod * a * b);
        return ret + mod * (ret < 0) - mod * (ret >= (LL) mod);
    }
    ULL power(ULL x, ULL p, ULL mod){
        ULL s=1, m=x;
        while(p) {
            if(p&1) s = mult(s, m, mod);
            p>>=1;
            m = mult(m, m, mod);
        }
        return s;
    }
    vector<LL> bases = {2, 325, 9375, 28178, 450775,
        9780504, 1795265022};
    bool isprime(LL n) {
        if (n<2) return 0;
        if (n%2==0) return n==2;

        ULL s = __builtin_ctzll(n-1), d = n>>s;
        for (ULL x: bases) {
            ULL p = power(x%n, d, n), t = s;
            while (p!=1 && p!=n-1 && x%n && t--) p = mult(p, p,
                n);
            if (p!=n-1 && t != s) return 0;
        }
        return 1;
    }
    mt19937_64 rng(chrono::system_clock::now().
        time_since_epoch().count());
    ULL FindFactor(ULL n) {
        if (n == 1 || isprime(n)) return n;
        ULL c = 1, x = 0, y = 0, t = 0, prod = 2, x0 = 1, q;
        auto f = [&](ULL X) { return mult(X, X, n) + c;};

        while (t++ % 128 or gcd(prod, n) == 1) {
            if (x == y) c = rng()%(n-1)+1, x = x0, y = f(x);
            if ((q = mult(prod, max(x, y) - min(x, y), n))) prod
                = q;
            x = f(x), y = f(f(y));
        }
        return gcd(prod, n);
    }
    vector<ULL> factorize(ULL x) {
        if (x == 1) return {};
        ULL a = FindFactor(x), b = x/a;
        if (a == x) return {a};
        vector<ULL> L = factorize(a), R = factorize(b);

```

```
L.insert(L.end(), R.begin(), R.end());
return L;
}
```

## 57 Popcount Trick

```
int cnt[1<<16];
void preprocess(){
    for(int mask=0;mask<(1<<16);mask++) {
        for(int i=0;i<16;i++) {
            if(mask&(1<<i)) cnt[mask]++;
        }
    }
}

int query(ll x){
    int ans=0,G=(1<<16)-1;
    ans+=cnt[x&G];x>>=16;
    ans+=cnt[x&G];x>>=16;
    ans+=cnt[x&G];x>>=16;
    ans+=cnt[x&G];
    return ans;
}
```

## 58 PrefixFunction

```
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;
}
```

## 59 PrimitiveRoot

```
// Finds the primitive root modulo p
int generator(int p) {
    vector<int> fact;
    int phi = p-1, n = phi;
    for (int i = 2; i * i <= n; ++i) {
        if (n % i == 0) {
            fact.push_back(i);
            while (n % i == 0)
                n /= i;
        }
    }
    if (n > 1) fact.push_back(n);
    for (int res = 2; res <= p; ++res) {
        bool ok = true;
        for (int factor : fact) {
            if (powmod(res, phi / factor, p) == 1) {
                ok = false; break;
            }
        }
        if (ok) return res;
    }
    return -1;
}

// This program finds all numbers x such that x^k = a
(mod n)
int main() {
    int n, k, a;
    scanf("%d %d %d", &n, &k, &a);
```

```
if (a == 0) {
    puts("1\n0");
    return 0;
}

int g = generator(n);
int sq = (int) sqrt (n + .0) + 1;
vector<pair<int, int>> dec(sq);
for (int i = 1; i <= sq; ++i)
    dec[i-1] = {powmod(g, i * sq * k % (n - 1), n), i};
sort(dec.begin(), dec.end());
int any_ans = -1;
for (int i = 0; i < sq; ++i) {
    int my = powmod(g, i * k % (n - 1), n) * a % n;
    auto it = lower_bound(dec.begin(), dec.end(),
        make_pair(my, 0));
    if (it != dec.end() && it->first == my) {
        any_ans = it->second * sq - i;
        break;
    }
}
if (any_ans == -1) {
    puts("0");return 0;
}

// Print all possible answers
int delta = (n-1) / gcd(k, n-1);
vector<int> ans;
for (int cur = any_ans % delta; cur < n-1; cur += delta)
    ans.push_back(powmod(g, cur, n));
sort(ans.begin(), ans.end());
}
```

## 60 SCC

```
vector<vector<int>> adj, adj_rev;
vector<bool> used;
vector<int> order, component;
void dfs1(int v) {
    used[v] = true;
    for (auto u : adj[v])
        if (!used[u]) dfs1(u);
    order.push_back(v);
}

void dfs2(int v) {
    used[v] = true; component.push_back(v);
    for (auto u : adj_rev[v]) if (!used[u])
        dfs2(u);
}

int main() {
    used.assign(n, false);
    for (int i = 0; i < n; i++)
        if (!used[i]) dfs1(i);
    used.assign(n, false);
    reverse(order.begin(), order.end());
    for (auto v : order) if (!used[v]) {
        dfs2(v);
        //processing next component
        component.clear();
    }
}
```

## 61 SOSDP

```
//memory optimized, super easy to code.
for(int i = 0; i<(1<<N); ++i)
    F[i] = A[i];
for(int i = 0; i < N; ++i){
    for(int mask = 0; mask < (1<<N); ++mask) {
        if(mask & (1<<i))
            F[mask] += F[mask^(1<<i)];
    }
}
```

```
}

//supermask
for(int i = 0; i < N; ++i){
    for(int mask = (1<<N)-1; mask >=0; --mask) {
        if(!(mask & (1<<i)))
            dp[mask] += dp[mask|(1<<i)];
    }
}
```

## 62 SegSegIntersection

```
inline double cross(PT a, PT b) { return a.x * b.y - a.y
    * b.x; }
inline double cross2(PT a, PT b, PT c) { return cross(b
    - a, c - a); }
bool is_point_on_seg(PT a, PT b, PT p) {
    if (fabs(cross(p - b, a - b)) < eps) {
        if (p.x < min(a.x, b.x) || p.x > max(a.x, b.x)) return
            false;
        if (p.y < min(a.y, b.y) || p.y > max(a.y, b.y)) return
            false;
        return true;
    }
    return false;
}

bool seg_seg_intersection(PT a, PT b, PT c, PT d, PT
    &ans) {
    double oa = cross2(c, d, a), ob = cross2(c, d, b);
    double oc = cross2(a, b, c), od = cross2(a, b, d);
    if (oa * ob < 0 && oc * od < 0){
        ans = (a * ob - b * oa) / (ob - oa);
        return 1;
    }
    else return 0;
}

set<PT> seg_seg_intersection_inside(PT a, PT b, PT c, PT
    d) {
    PT ans;
    if (seg_seg_intersection(a, b, c, d, ans)) return {ans};
    set<PT> se;
    if (is_point_on_seg(c, d, a)) se.insert(a);
    if (is_point_on_seg(c, d, b)) se.insert(b);
    if (is_point_on_seg(a, b, c)) se.insert(c);
    if (is_point_on_seg(a, b, d)) se.insert(d);
    return se;
}
```

## 63 SegmentedSieve

```
vector<char> segmentedSieve(long long L, long long R) {
    // generate all primes up to sqrt(R)
    long long lim = sqrt(R);
    vector<char> mark(lim + 1, false);
    vector<long long> primes;
    for (long long i = 2; i <= lim; ++i) {
        if (!mark[i]) {
            primes.emplace_back(i);
            for (long long j = i * i; j <= lim; j += i)
                mark[j] = true;
        }
    }

    vector<char> isPrime(R - L + 1, true);
    for (long long i : primes)
        for (long long j = max(i * i, (L + i - 1) / i * i); j
            <= R; j += i)
            isPrime[j - L] = false;
    if (L == 1)
        isPrime[0] = false;
    return isPrime;
}
```

```

}

64 Segtree 2D

void build_y(int vx, int lx, int rx, int vy, int ly, int ry) {
    if (ly == ry) {
        if (lx == rx)
            t[vx][vy] = a[lx][ly];
        else
            t[vx][vy] = t[vx*2][vy] + t[vx*2+1][vy];
    } else {
        int my = (ly + ry) / 2;
        build_y(vx, lx, rx, vy*2, ly, my);
        build_y(vx, lx, rx, vy*2+1, my+1, ry);
        t[vx][vy] = t[vx][vy*2] + t[vx][vy*2+1];
    }
}

void build_x(int vx, int lx, int rx) {
    if (lx != rx) {
        int mx = (lx + rx) / 2;
        build_x(vx*2, lx, mx);
        build_x(vx*2+1, mx+1, rx);
    }
    build_y(vx, lx, rx, 1, 0, m-1);
}

int sum_y(int vx, int vy, int tly, int try_, int ly, int ry) {
    if (ly > ry)
        return 0;
    if (ly == tly && try_ == ry)
        return t[vx][vy];
    int tmy = (tly + try_) / 2;
    return sum_y(vx, vy*2, tly, tmy, ly, min(ry, tmy))
        + sum_y(vx, vy*2+1, tmy+1, try_, max(ly, tmy+1), ry);
}

int sum_x(int vx, int tlx, int trx, int lx, int rx, int ly, int ry) {
    if (lx > rx)
        return 0;
    if (lx == tlx && trx == rx)
        return sum_y(vx, 1, 0, m-1, ly, ry);
    int tmx = (tlx + trx) / 2;
    return sum_x(vx*2, tlx, tmx, lx, min(rx, tmx), ly, ry)
        + sum_x(vx*2+1, tmx+1, trx, max(lx, tmx+1), rx, ly, ry);
}

void update_y(int vx, int lx, int rx, int vy, int ly, int ry, int x, int y, int new_val) {
    if (ly == ry) {
        if (lx == rx)
            t[vx][vy] = new_val;
        else
            t[vx][vy] = t[vx*2][vy] + t[vx*2+1][vy];
    } else {
        int my = (ly + ry) / 2;
        if (y <= my)
            update_y(vx, lx, rx, vy*2, ly, my, x, y, new_val);
        else
            update_y(vx, lx, rx, vy*2+1, my+1, ry, x, y, new_val);
        t[vx][vy] = t[vx][vy*2] + t[vx][vy*2+1];
    }
}

void update_x(int vx, int lx, int rx, int x, int y, int new_val) {
    if (lx != rx) {
        int mx = (lx + rx) / 2;

```

```

    if (x <= mx)
        update_x(vx*2, lx, mx, x, y, new_val);
    else
        update_x(vx*2+1, mx+1, rx, x, y, new_val);
    }
    update_y(vx, lx, rx, 1, 0, m-1, x, y, new_val);
}

```

## 65 Segtree Lazy

```

void push(int v) {
    t[v*2] += lazy[v];
    lazy[v*2] += lazy[v];
    t[v*2+1] += lazy[v];
    lazy[v*2+1] += lazy[v];
    lazy[v] = 0;
}

void update(int v, int tl, int tr, int l, int r, int addend) {
    if (l > r)
        return;
    if (l == tl && tr == r) {
        t[v] += addend;
        lazy[v] += addend;
    } else {
        push(v);
        int tm = (tl + tr) / 2;
        update(v*2, tl, tm, l, min(r, tm), addend);
        update(v*2+1, tm+1, tr, max(l, tm+1), r, addend);
        t[v] = max(t[v*2], t[v*2+1]);
    }
}

int query(int v, int tl, int tr, int l, int r) {
    if (l > r)
        return -INF;
    if (l <= tl && tr <= r)
        return t[v];
    push(v);
    int tm = (tl + tr) / 2;
    return max(query(v*2, tl, tm, l, min(r, tm)),
        query(v*2+1, tm+1, tr, max(l, tm+1), r));
}

```

## 66 Segtree Persistent

```

const ll INF = 4e18;
//Point update and range min
struct Node {
    int l=-1,r=-1; pii val;
    Node(pii v, int l=-1, int r=-1) {
        this->l = l;
        this->r = r;
        val = v;
    }
};
vector<Node>nodes;
inline void Merge(Node &a, Node &b, Node &c) {
    a.val = min(b.val, c.val);
}

int build(int tl, int tr) {
    if (tl == tr) {
        nodes.emplace_back(make_pair(INF, -1));
        return (int)nodes.size()-1;
    }
    int tm = (tl + tr) / 2;
    int Left = build(tl, tm);
    int Right = build(tm+1, tr);
    nodes.emplace_back(make_pair(INF, -1), Left, Right);
    Merge(nodes.back(), nodes[Left], nodes[Right]);
}

```

```

return (int)nodes.size()-1;
}

int update(int v, int tl, int tr, int pos, pii val) {
    if (tl == tr) {
        nodes.emplace_back(val);
        return (int)nodes.size()-1;
    }
    int tm = (tl + tr) / 2; int Left, Right;
    if (pos <= tm) {
        Left = update(nodes[v].l, tl, tm, pos, val);
        Right = nodes[v].r;
    }
    else {
        Left = nodes[v].l;
        Right = update(nodes[v].r, tm+1, tr, pos, val);
    }
    nodes.emplace_back(make_pair(INF, -1), Left, Right);
    Merge(nodes.back(), nodes[Left], nodes[Right]);
    return (int)nodes.size()-1;
}

pii query(int v, int tl, int tr, int a, int b) {
    if (a>tr || tl>b || tl > tr) return {INF, -1};
    if (tl >= a && tr <= b) return nodes[v].val;
    int mid = (tl+tr)/2;
    return min(query(nodes[v].l, tl, mid, a, b),
        query(nodes[v].r, mid+1, tr, a, b));
}

```

## 67 Segtree beats

```

struct info{
    int maxi = 0, smaxi = -1e9, cnt = 0, lazy = 0;
    bool has=0; ll sum = 0;
};

struct segtree{
    int n;
    vector<info>t;
    segtree(int n, vector<int>&a) {
        this->n = n; t.resize(n*4);
        build(1, 0, n-1, a);
    }

    void Merge(info &node, info &l, info &r) {
        node.maxi = max(l.maxi, r.maxi);
        node.cnt = (node.maxi == l.maxi ? l.cnt : 0) +
            (node.maxi == r.maxi ? r.cnt : 0);
        node.sum = l.sum + r.sum;
        if (l.maxi != r.maxi)
            node.smaxi = max({ min(l.maxi, r.maxi), l.smaxi, r.smaxi });
        else
            node.smaxi = max(l.smaxi, r.smaxi);
    }

    void build(int node, int l, int r, vector<int>&a) {
        if (l == r) {
            t[node].maxi = a[l]; t[node].cnt = 1; t[node].sum = a[l];
            return;
        }
        int mid = (l+r)/2;
        build(node*2, l, mid, a);
        build(node*2+1, mid+1, r, a);
        Merge(t[node], t[node*2], t[node*2+1]);
    }

    void dop(int node, int add) {
        if (t[node].maxi <= add)
            return;
        t[node].sum -= t[node].maxi * 1ll * t[node].cnt;
        t[node].maxi = add;
    }
}

```

```

t[node].sum += t[node].maxi * 1ll * t[node].cnt;
t[node].lazy = add;
t[node].has = 1;
}
void push_down(int node){
if(t[node].has){
dop(node*2, t[node].lazy);
dop(node*2+1, t[node].lazy);
t[node].lazy = 0;
t[node].has = 0;
}
}
void update(int node, int l, int r, int i, int j, int add){
if(l>j || r<i || t[node].maxi <= add){
return;
}
if(l>=i && r<=j && t[node].smaxi < add){
int x = t[node].maxi - add;
t[node].sum -= t[node].maxi * 1ll * t[node].cnt;
t[node].maxi = add;
t[node].sum += t[node].maxi * 1ll * t[node].cnt;
t[node].lazy = add;
t[node].has = 1;
return;
}
int mid = (l+r)/2;
push_down(node);
update(node *2, l, mid, i, j, add);
update(node *2 +1, mid+1, r, i, j, add);
Merge(t[node], t[node *2], t[node*2+1]);
}
void update(int l, int r, int add){
update(1, 0, n-1, l, r, add);
}
pair<ll, int> query(int node, int l, int r, int i, int j){
if(l>j || r<i){
return make_pair(0, -1e9);
}
if(l>=i && r<=j){
return make_pair(t[node].sum, t[node].maxi);
}
int mid = (l+r)/2;
push_down(node);
pair<ll, int> x = query(node *2, l, mid, i, j);
pair<ll, int> y = query(node *2 +1, mid+1, r, i, j);
return make_pair(x.first+y.first, max(x.second, y.second));
}
pair<ll, int> query(int l, int r){
return query(1, 0, n-1, l, r);
}
};

```

## 68 Simplex

```

/*
* Note: Simplex algorithm on augmented matrix a of
dimension (m+1)x(n+1)
* returns 1 if feasible, 0 if not feasible, -1 if
unbounded
* returns solution in b[] in original var order, max(f)
in ret
* form: maximize sum_j(a_mj*x_j)-a_mn s.t.
sum_j(a_ij*x_j) <= a_in
* in standard form.
* To convert into standard form:
* 1. if exists equality constraint, then replace by
both >= and <=

```

```

* 2. if variable x doesn't have nonnegativity
constraint, then replace by
* difference of 2 variables like x1-x2, where x1>=0,
x2>=0
* 3. for a>=b constraints, convert to -a<=-b
* note: watch out for -0.0 in the solution, algorithm
may cycle
* EPS = 1e-7 may give wrong answer, 1e-10 is better
*/
typedef vector<ld> vd;
typedef vector<vd> vvd;
typedef vector<int> vi;
const ld EPS = 1e-10;
struct LPSolver{
int m, n; vi B, N; vvd D;
LPSolver(const vvd &A, const vd &b, const vd &c) :
m(b.size()), n(c.size()), N(n+1), B(m), D(m+2,
vd(n+2)) {
for (int i = 0; i < m; i++)
for (int j = 0; j < n; j++)
D[i][j] = A[i][j];
for (int i = 0; i < m; i++) {
B[i] = n+1; D[i][n] = -1;
D[i][n+1] = b[i];
}
for (int j = 0; j < n; j++) {
N[j] = j; D[m][j] = -c[j];
}
N[n] = -1; D[m+1][n] = 1;
}
void Pivot(int r, int s) {
ld inv = 1.0 / D[r][s];
for (int i = 0; i < m+2; i++) if (i != r)
for (int j = 0; j < n+2; j++)
if (j != s) D[i][j] -= D[r][j] * D[i][s] * inv;
for (int j = 0; j < n+2; j++) if (j != s)
D[r][j] *= inv;
for (int i = 0; i < m+2; i++) if (i != r)
D[i][s] *= -inv;
D[r][s] = inv; swap(B[r], N[s]);
}
bool Simplex(int phase) {
int x = phase == 1 ? m+1 : m;
while (true) {
int s = -1;
for (int j = 0; j <= n; j++) {
if (phase == 2 && N[j] == -1) continue;
if (s == -1 || D[x][j] < D[x][s] || D[x][j] ==
D[x][s] && N[j] < N[s])
s = j;
}
if (D[x][s] > -EPS) return true;
int r = -1;
for (int i = 0; i < m; i++) {
if (D[i][s] < EPS) continue;
if (r == -1 || D[i][n+1] / D[i][s] < D[r][n+1] /
D[r][s] ||
(D[i][n+1] / D[i][s]) == (D[r][n+1] / D[r][s])
&& B[i] < B[r])
r = i;
}
if (r == -1) return false;
Pivot(r, s);
}
}
ld Solve(vd &x) {
int r = 0;
for (int i = 1; i < m; i++)
if (D[i][n+1] < D[r][n+1])
r = i;
if (D[r][n+1] < -EPS) {

```

```

Pivot(r, n);
if (!Simplex(1) || D[m+1][n+1] < -EPS)
return -numeric_limits<ld>::infinity();
for (int i = 0; i < m; i++)
if (B[i] == -1) {
int s = -1;
for (int j = 0; j <= n; j++)
if (s == -1 || D[i][j] < D[i][s] || D[i][j] ==
D[i][s] && N[j] < N[s])
s = j;
Pivot(i, s);
}
}
if (!Simplex(2))
return numeric_limits<ld>::infinity();
x = vd(n);
for (int i = 0; i < m; i++)
if (B[i] < n) x[B[i]] = D[i][n+1];
return D[m][n+1];
};
/* Equations are of the matrix form Ax<=b, and we want
to maximize
the function c. We are given coeffs of A, b and c. In
case of minimizing,
we negate the coeffs of c and maximize it. Then the
negative of returned
'value' is the answer.
All the constraints should be in <= form. So we may need
to negate the
coeffs.
*/
int main(){
const int m = 4; const int n = 3;
ld _A[m][n] = { { 6, -1, 0 }, { -1, -5, 0 }, { 1, 5, 1 }, { -1, -5, -1 } };
ld _b[m] = { 10, -4, 5, -5 };
ld _c[n] = { 1, -1, 0 };
vvd A(m);
vd b(_b, _b+m);
vd c(_c, _c+n);
for (int i = 0; i < m; i++)
A[i] = vd(_A[i], _A[i]+n);
LPSolver solver(A, b, c);
vd x;
ld value = solver.Solve(x);
cerr << "VALUE: " << value << endl; /* VALUE: 1.29032*/
cerr << "SOLUTION: "; /*SOLUTION: 1.74194 0.451613 1*/
for (size_t i = 0; i < x.size(); i++)
cerr << " " << x[i];
}

```

## 69 Simpson

```

const int N = 1000 * 1000; // number of steps (already
multiplied by 2)
double simpson_integration(double a, double b){
double h = (b - a) / N;
double s = f(a) + f(b); // a = x_0 and b = x_2n
for (int i = 1; i <= N - 1; ++i) { // Refer to final
Simpson's formula
double x = a + h * i;
s += f(x) * ((i & 1) ? 4 : 2);
}
s *= h / 3;
return s;
}

```

## 70 StableMarriage

```
//order[i][j]=indexOfMan i in j-th
//women'sListOfPreference
//prefer[i]=listOfWomen inOrderOf decreasingPreference
int n;
int pre[N][N],order[N][N],nxt[N];
queue<int>q;
int future_wife[N],future_husband[N];
void engage(int man , int woman){
    int m1 = future_husband[woman];
    if(m1==0) {
        future_wife[man] = woman;future_husband[woman] = man;
    }
    else{
        future_wife[man] = woman;future_husband[woman] = man;
        future_wife[m1] =0;q.push(m1);
    }
}
```

```
void TEST_CASES(int cas){
    while(!q.empty())q.pop();
    cin>>n;
    for(int i=1;i<=n;i++) {
        for(int j=1;j<=n;j++) {
            cin>>pre[i][j]; pre[i][j]-= n;
        }
        nxt[i] = 1;future_wife[i] = 0;q.push(i);
    }
    for(int i=1;i<=n;i++) {
        for(int j=1;j<=n;j++) {
            int x; cin>>x;
            order[i][x] = j;
        }
        future_husband[i] = 0;
    }
    while(!q.empty()) {
        int man = q.front(); q.pop();
        int woman = pre[man][nxt[man]++];
        if(future_husband[woman]==0) {
            engage(man , woman);
        }
        else if(order[woman][man] <
            order[woman][future_husband[woman]]) {
            engage(man , woman);
        }
        else{ q.push(man); }
    }
    for(int i=1;i<=n;i++) {
        cout<<" ("<<i<<" "<<future_wife[i]+n<<")";
    }
}
```

## 71 Stirling

```
NTT ntt(mod);
vector<ll>v[MAX];

//Stirling1 (n,k) = co-eff of x^k in
//x*(x+1)*(x+2)*....(x+n-1)
int Stirling1(int n, int r) {
    int nn = 1;
    while(nn < n) nn <= 1;

    for(int i = 0; i < n; ++i) {v[i].push_back(i);
        v[i].push_back(1);}
    for(int i = n; i < nn; ++i) v[i].push_back(1);

    for(int j = nn; j > 1; j >= 1) {
        int hn = j >> 1;
        for(int i = 0; i < hn; ++i) ntt.multiply(v[i], v[i +
            hn], v[i]);
    }
```

```
}
return v[0][r];
}

NTT ntt(mod);
vector<int>a,b,res;

//Stirling2 (n,k) = co-eff of x^k in product of
//polynomials A & B
//where A(i) = (-1)^i / i! and B(i) = i^n / i!
int Stirling2(int n, int r) {
    a.resize(n+1); b.resize(n+1);
    for(int i = 0; i <= n; i++){
        a[i] = invfct[i];
        if(i % 2 == 1) a[i] = mod - a[i];
    }

    for(int i = 0; i <= n; i++){
        b[i] = bigMod(i, n, mod);
        b[i] = (b[i] *i! * invfct[i]) % mod;
    }

    NTT ntt(mod);
    ntt.multiply(a,b,res);
    return res[r];
}
```

## 72 StressTest

```
#!/bin/sh
echo "Enter the name of first File : "
read file
echo "Enter the name of second File : "
read file2
g++ -o test_gen test_gen.cpp
g++ -o $file $file.cpp
g++ -o $file2 $file2.cpp
while true
do
    ./test_gen
    ./file <input.txt> out1.txt
    ./file2 <input.txt> out2.txt
    if cmp -s "out1.txt" "out2.txt"; then
        echo "Test Case OK"
    else
        echo "ERROR ENCOUNTERED"
        break
    fi
done
```

## 73 SubsetConv

```
vector<int> SOS(vector<int> p, bool inverse, bool
    subset) {
    int k = __builtin_ctz(p.size());
    assert(p.size() == (1<<k));
    for (int i=0; i<k; i++)
    for (int mask=0; mask<(1<<k); mask++)
        if (bool(mask & (1<<i)) == subset) {
            if (!inverse) p[mask] =add(p[mask],
                p[mask^(1<<i)]);
            else p[mask] =sub(p[mask],
                p[mask^(1<<i)]);
        }
    return p;
}

vector<int> SubsetConvolution( vector<int> &a,
    vector<int> &b) {
    int k = __builtin_ctz(a.size());
    assert(a.size() == (1<<k) && b.size() == (1<<k));
    vector<int> Z(1<<k);
    vector<vector<int>> A(k+1, Z), B(k+1, Z), C(k+1, Z);
```

```
for (int mask=0; mask<(1<<k); mask++) {
    A[__builtin_popcount(mask)][mask] = a[mask];
    B[__builtin_popcount(mask)][mask] = b[mask];
}
for (int i=0; i<k; i++) {
    A[i] = SOS(A[i], 0, 1); B[i] = SOS(B[i], 0, 1);
    for (int j=0; j<=i; j++)
        for (int mask = 0; mask < (1<<k); mask++)
            C[i][mask] =add(C[i][mask],
                gun(A[j][mask],B[i-j][mask]));
    C[i] = SOS(C[i], 1, 1);
} vector<int> ans(1<<k);
for (int mask=0; mask<(1<<k); mask++) {
    ans[mask] = C[__builtin_popcount(mask)][mask];
} return ans;
}
```

## 74 Suffix Automata

```
struct state{
    int len, link;
    map<char, int> next;
    ll dp=-1; //number of paths
    ll cnt=0; //endpos size
    bool is_cloned=false;
    vector<int>inv_link;
};

struct SA {
    vector<state> st;
    int sz, last;
    void sa_init() {
        st[0].len = 0;
        st[0].link = -1;
        sz=0;
        sz++;
        last = 0;
    }
    void sa_extend(char c) {
        int cur = sz++;
        st[cur].len = st[last].len + 1;
        int p = last;
        while (p != -1 && !st[p].next.count(c)) {
            st[p].next[c] = cur;
            p = st[p].link;
        }
        if (p == -1) {
            st[cur].link = 0;
        }
        else {
            int q = st[p].next[c];
            if (st[p].len + 1 == st[q].len){
                st[cur].link = q;
            }
            else {
                int clone = sz++;
                st[clone].len = st[p].len + 1;
                st[clone].next = st[q].next;
                st[clone].link = st[q].link;
                while (p != -1 && st[p].next[c] == q) {
                    st[p].next[c] = clone;
                    p = st[p].link;
                }
                st[q].link = st[cur].link = clone;
                st[clone].is_cloned=true;
            }
        }
        last = cur;
    }
    ll run(int idx) {
        if(st[idx].dp!=-1)
```

```

    return st[idx].dp;
    if(idx!=0)
        st[idx].dp=st[idx].cnt;
    else st[idx].dp=0;
    for(char c='a';c<='z';c++) {
        if(!st[idx].next.count(c))
            continue;
        int u=st[idx].next[c];
        st[idx].dp+=run(u);
    }
    return st[idx].dp;
}

void dfs_in_tree(int idx) {
    if(st[idx].is_cloned==false) {
        st[idx].cnt=1;
    }
    for(int u:st[idx].inv_link) {
        dfs_in_tree(u);
        st[idx].cnt+=st[u].cnt;
    }
}

void build(string &s) {
    st.resize(2*(int)s.size());
    sa_init();
    for(char c:s) {
        sa_extend(c);
    }
    for(int i=1;i<sz;i++) {
        st[st[i].link].inv_link.push_back(i);
    }
    dfs_in_tree(0);
}
};

```

## 75 SuffixArray

```

const int LOG = 20;
int sa[N],Data[N],rnk[N],height[N];
int wa[N],wb[N],wvs[N],wv[N];
int lg[N], rmq[N][LOG];
void prelg() {
    lg[0] = lg[1] = 0;
    for(int i = 2; i < N; i++) {
        lg[i] = lg[i/2] + 1;
    }
}

struct SuffixArray {
    int n;
    int cmp(int *r,int a,int b,int l) {
        return (r[a]==r[b]) && (r[a+1]==r[b+1]);
    }

    void DA(int *r,int *sa,int n,int m) {
        int i,j,p,*x=wa,*y=wb,*t;
        for(i=0; i<m; i++) wws[i]=0;
        for(i=0; i<n; i++) wws[x[i]]=r[i]++;
        for(i=1; i<m; i++) wws[i]+=wws[i-1];
        for(i=n-1; i>=0; i--) sa[--wws[x[i]]]=i;
        for(j=1,p=1; p<n; j*=2,m=p) {
            for(p=0,i=n-j; i<n; i++) y[p++]=i;
            for(i=0; i<n; i++)
                if(sa[i]>=j) y[p++]=sa[i]-j;
            for(i=0; i<n; i++) wv[i]=x[y[i]];
            for(i=0; i<m; i++) wws[i]=0;
            for(i=0; i<n; i++) wws[wv[i]]++;
            for(i=1; i<m; i++) wws[i]+=wws[i-1];
            for(i=n-1; i>=0; i--) sa[--wws[wv[i]]]=y[i];
            for(t=x,x=y,y=t,p=1,x[sa[0]]=0,i=1; i<n; i++)
                x[sa[i]]=cmp(y,sa[i-1],sa[i],j)?p-1:p++;
        }
    }
};

```

```

}

void calheight(int *r,int *sa,int n) {
    int i,j,k=0;
    for(i=1; i<=n; i++) rnk[sa[i]]=i;
    for(i=0; i<n; height[rnk[i+1]]=k)
        for(k?k--:0,j=sa[rnk[i]-1]; r[i+k]==r[j+k]; k++);
}

void suffix_array (string &A) {
    n = A.size();
    Data[n]=0;
    int cnt =0;
    for (int i = 0; i < n; i++){
        Data[i] = A[i]-'a'+1; //careful
        cnt = max(cnt, Data[i]);
    }
    DA(Data,sa,n+1,cnt+1);
    calheight(Data,sa,n);
    for(int i = 0; i < n; i++)
        sa[i] = sa[i+1], height[i] = height[i+1], rnk[sa[i]]
            = i;
    range_lcp_init();
}

/** LCP for range : build of rmq table */
void range_lcp_init() {
    for(int i = 0; i < n; i++)
        rmq[i][0] = height[i];
    for(int j = 1; j < LOG; j++) {
        for(int i = 0; i < n; i++) {
            if (i+(1<<j)-1 < n)
                rmq[i][j] = min(rmq[i][j-1],rmq[i+(1<<(j-1))][j-1]);
            else break;
        }
    }
}

/** lcp between l'th to r'th suffix in suffix array */
int query_lcp(int l, int r) {
    assert(l <= r); assert(l>=0 && l<n && r>=0 && r<n);
    if(l == r) return n-sa[l];
    l++;
    int k = lg[r-l+1];
    return min(rmq[l][k],rmq[r-(1<<k)+1][k]);
}

//i and j position in original string
int getsuff(int i, int j) {
    i = rnk[i];j = rnk[j];
    return query_lcp(min(i,j),max(i,j));
}
} SA;

```

## 76 Treap

```

mt19937 rng(chrono::steady_clock::now().
time_since_epoch().count());
int getrand(int a, int b){
    int x = uniform_int_distribution<int>(a, b)(rng);
    return x;
}

struct treap{
    int prior,val,subtreeSize ;
    treap *l;treap *r;treap *parent;
    int sum,lazy;
    treap(int data) {
        val= data;prior = getrand(-2e9, 2e9);
        subtreeSize = 1;
        l=NULL;r=NULL;parent = NULL;lazy = 0;sum = data;
    }
};

typedef treap* ptreap;
int Size(ptreap t){
    if(t)return t->subtreeSize;
}

```

```

    return 0;
}

void update_size(ptreap t){
    if(t) t->subtreeSize = 1+ Size(t->l) + Size(t->r);
}

void push(ptreap t){
    if(!t || !t->lazy) {return;}
    t->val += t->lazy;t->sum += t->lazy * Size(t);
    if(t->l) t->l->lazy += t->lazy;
    if(t->r) t->r->lazy += t->lazy;
    t->lazy = 0;
}

void reset(ptreap t){
    if(t) t->sum = t->val;
}

void combine(ptreap &t, ptreap l, ptreap r){
    if(!l || !r) {if(l) {t= l;}else {t = r;}return;}
    t->sum = l->sum + r->sum;
}

void operation(ptreap t){
    if(!t)return;
    reset(t);push(t->l);push(t->r);
    combine(t,t->l);combine(t,t->r);
}

void split(ptreap t, ptreap &l, ptreap &r, int pos, int
    add =0){
    if(!t) {l = NULL;r = NULL;return;}
    push(t);
    int curr = add + Size(t->l);
    if(curr<=pos) {
        split(t->r, t->r, r, pos, curr+1);
        if(t->r != NULL) t->r->parent = t;
        if(r!=NULL) r->parent = NULL;
        l = t;
    }
    else {
        split(t->l, l, t->l,pos, add);
        if(t->l != NULL) {t->l->parent = t;
        }
        if(l!=NULL) {l->parent = NULL;}
        r =t;
    }
    update_size(t);operation(t);
}

void Merge(ptreap &t, ptreap l, ptreap r){
    push(l);push(r);
    if(!l || !r) {if(l) t= l;else t = r;}
    else if(l->prior > r->prior) {
        Merge(l->r, l->r, r);
        if(l->r != NULL) {l->r ->parent = l;}
        t= l;
    }
    else {
        Merge(r->l, l, r->l);
        if(r->l != NULL) {r->l->parent = r;}
        t = r;
    }
    update_size(t);operation(t);
}

int range_query(ptreap t, int l, int r){
    ptreap t1, t2, t3;
    split(t,t1,t2,l-1);split(t2,t2,t3,r-1);
    int ans = t2->sum;
    Merge(t,t1,t2);Merge(t,t,t3);
    return ans;
}

void range_update(ptreap t, int l,int r, int val){
    ptreap t1, t2, t3;
    split(t,t1,t2,l-1);split(t2,t2,t3,r-1);
}

```

```

t2->lazy += val;Merge(t,t1,t2);Merge(t,t,t3);
}
ptreap goup(ptreap t){
    if(t==NULL || t->parent==NULL) return t;
    return goup(t->parent);
}
void output2 (ptreap t){
    if (!t) return;
    push (t);output2 (t->l);
    cout<<t->val<<" ";output2 (t->r);
}

```

## 77 VerticalDecomposition

```

inline bool le(dbl x, dbl y){return x < y + eps;}
inline bool ge(dbl x, dbl y){return x > y - eps;}
struct Line{
    pt p[2];
    Line(){
        Line(pt a, pt b):p{a, b}{}
        pt vec()const{
            return p[1] - p[0];
        }
        pt& operator [] (size_t i){
            return p[i];
        }
};

```

```

inline bool lexComp(const pt & l, const pt & r){
    if(fabs(l.x - r.x) > eps){return l.x < r.x;}
    else return l.y < r.y;
}

```

```

vector<pt> interSegSeg(Line l1, Line l2){
    if(eq(l1.vec().cross(l2.vec()), 0)){
        if(!eq(l1.vec().cross(l2[0] - l1[0]), 0))
            return {};
        if(!lexComp(l1[0], l1[1])) swap(l1[0], l1[1]);
        if(!lexComp(l2[0], l2[1])) swap(l2[0], l2[1]);
        pt l = lexComp(l1[0], l2[0]) ? l2[0] : l1[0];
        pt r = lexComp(l1[1], l2[1]) ? l1[1] : l2[1];
        if(l == r)
            return {l};
        else return lexComp(l, r) ? vector<pt>{l, r} :
            vector<pt>();
    }
    else{
        dbl s = (l2[0] - l1[0]).cross(l2.vec()) /
            l1.vec().cross(l2.vec());
        pt inter = l1[0] + l1.vec() * s;
        if(ge(s, 0) && le(s, 1) && le((l2[0] -
            inter).dot(l2[1] - inter), 0))
            return {inter};
        else
            return {};
    }
}

```

```

inline char get_segtype(Line segment, pt other_point){
    if(eq(segment[0].x, segment[1].x))
        return 0;
    if(!lexComp(segment[0], segment[1]))
        swap(segment[0], segment[1]);
    return (segment[1] - segment[0]).cross(other_point -
        segment[0]) > 0 ? 1 : -1;
}

```

```

dbl union_area(vector<tuple<pt, pt, pt> > triangles){
    vector<Line> segments(3 * triangles.size());
}

```

```

vector<char> segtype(segments.size());
for(size_t i = 0; i < triangles.size(); i++){
    pt a, b, c;
    tie(a, b, c) = triangles[i];
    segments[3 * i] = lexComp(a, b) ? Line(a, b) : Line(b,
        a);
    segtype[3 * i] = get_segtype(segments[3 * i], c);
    segments[3 * i + 1] = lexComp(b, c) ? Line(b, c) :
        Line(c, b);
    segtype[3 * i + 1] = get_segtype(segments[3 * i + 1],
        a);
    segments[3 * i + 2] = lexComp(c, a) ? Line(c, a) :
        Line(a, c);
    segtype[3 * i + 2] = get_segtype(segments[3 * i + 2],
        b);
}
vector<dbl> k(segments.size()), b(segments.size());
for(size_t i = 0; i < segments.size(); i++){
    if(segtype[i]){
        k[i] = (segments[i][1].y - segments[i][0].y) /
            (segments[i][1].x - segments[i][0].x);
        b[i] = segments[i][0].y - k[i] * segments[i][0].x;
    }
}
dbl ans = 0;
for(size_t i = 0; i < segments.size(); i++){
    if(!segtype[i])
        continue;
    dbl l = segments[i][0].x, r = segments[i][1].x;
    vector<pair<dbl, int> > evts;
    for(size_t j = 0; j < segments.size(); j++){
        if(!segtype[j] || i == j)
            continue;
        dbl l1 = segments[j][0].x, r1 = segments[j][1].x;
        if(ge(l1, r) || ge(l, r1))
            continue;
        dbl common_l = max(l, l1), common_r = min(r, r1);
        auto pts = interSegSeg(segments[i], segments[j]);
        if(pts.empty()){
            dbl yl1 = k[j] * common_l + b[j];
            dbl yl = k[i] * common_l + b[i];
            if(lt(yl1, yl) == (segtype[i] == 1)){
                int evt_type = -segtype[i] * segtype[j];
                evts.emplace_back(common_l, evt_type);
                evts.emplace_back(common_r, -evt_type);
            }
        }
        else if(pts.size() == 1u){
            dbl yl = k[i] * common_l + b[i], yl1 = k[j] *
                common_l + b[j];
            int evt_type = -segtype[i] * segtype[j];
            if(lt(yl1, yl) == (segtype[i] == 1)){
                evts.emplace_back(common_l, evt_type);
                evts.emplace_back(pts[0].x, -evt_type);
            }
            yl = k[i] * common_r + b[i], yl1 = k[j] * common_r +
                b[j];
            if(lt(yl1, yl) == (segtype[i] == 1)){
                evts.emplace_back(pts[0].x, evt_type);
                evts.emplace_back(common_r, -evt_type);
            }
        }
        else{
            if(segtype[j] != segtype[i] || j > i){
                evts.emplace_back(common_l, -2);
                evts.emplace_back(common_r, 2);
            }
        }
    }
}

```

```

}
}
evts.emplace_back(l, 0);
sort(evts.begin(), evts.end());
size_t j = 0;
int balance = 0;
while(j < evts.size()){
    size_t ptr = j;
    while(ptr < evts.size() && eq(evts[j].first,
        evts[ptr].first)){
        balance += evts[ptr].second;
        ++ptr;
    }
    if(!balance && !eq(evts[j].first, r)){
        dbl next_x = ptr == evts.size() ? r :
            evts[ptr].first;
        ans -= segtype[i] * (k[i] * (next_x + evts[j].first)
            + 2 * b[i]) * (next_x - evts[j].first);
    }
    j = ptr;
}
}
return ans/2;
}

```

## 78 Voronoi

```

const Tf INF = 1e10;
vector<Polygon> voronoi(vector<PT> site, Tf bsq) {
    int n = site.size();
    vector<Polygon> region(n);
    PT A(-bsq, -bsq), B(bsq, -bsq),
    C(bsq, bsq), D(-bsq, bsq);
    for(int i = 0; i < n; ++i) {
        vector<DirLine> li(n - 1);
        for(int j = 0, k = 0; j < n; ++j) {
            if(i == j) continue;
            li[k++] = DirLine((site[i] + site[j]) / 2,
                rotate90(site[j] - site[i]));
        }
        li.emplace_back(A,B-A); li.emplace_back(B,C-B);
        li.emplace_back(C,D-C); li.emplace_back(D,A-D);
        region[i] = halfPlaneIntersection(li);
    }
    return region;
}

```

## 79 XORTrick

```

vector<int> basis[N];
int sz[N],a[N],LOGK = 21;
void insert_vector(vector<int>&basis ,int &sz, int mask){
    for(int i=0;i<LOGK;i++) {
        if(!(mask&(1<<i))) continue;
        if(!basis[i]) {
            basis[i] = mask; sz++; return;
        }
        mask^=basis[i];
    }
}
bool check(vector<int>&basis , int mask){
    for(int i=0;i<LOGK;i++) {
        if(!(mask&(1<<i))) continue;
        if(!basis[i]) { return 0; }
        mask ^= basis[i];
    }
    return 1;
}

```