

10 <sup>1</sup>	+1	+3	+7	+9	+13	+19	+21	+27	-3	-5	-7	-8
10 <sup>2</sup>	+1	+3	+7	+9	+13	+27	+31	+37	-3	-11	-17	-21
10 <sup>3</sup>	+9	+13	+19	+21	+31	+33	+39	+49	-3	-9	-17	-23
10 <sup>4</sup>	+7	+9	+37	+39	+61	+67	+69	+79	-27	-33	-51	-59
10 <sup>5</sup>	+3	+19	+43	+49	+57	+69	+103	+109	-9	-11	-29	-39
10 <sup>6</sup>	+3	+33	+37	+39	+81	+99	+117	+121	-17	-21	-39	-41
10 <sup>7</sup>	+19	+79	+103	+121	+139	+141	+169	+189	-9	-27	-29	-57
10 <sup>8</sup>	+7	+37	+39	+49	+73	+81	+123	+127	-11	-29	-41	-59
10 <sup>9</sup>	+7	+9	+21	+33	+87	+93	+97	+103	-63	-71	-107	-117
10 <sup>10</sup>	+19	+33	+61	+69	+97	+103	+121	+141	-33	-57	-71	-119
10 <sup>11</sup>	+3	+19	+57	+63	+69	+73	+91	+103	-23	-53	-57	-93
10 <sup>12</sup>	+39	+61	+63	+91	+121	+163	+169	+177	-11	-39	-41	-63
10 <sup>13</sup>	+37	+51	+99	+129	+183	+259	+267	+273	-29	-137	-201	-237
10 <sup>14</sup>	+31	+67	+97	+99	+133	+139	+169	+183	-27	-29	-41	-69
10 <sup>15</sup>	+37	+91	+159	+187	+223	+241	+249	+259	-11	-53	-117	-123
10 <sup>16</sup>	+61	+69	+79	+99	+453	+481	+597	+613	-63	-83	-113	-149
10 <sup>17</sup>	+3	+13	+19	+21	+49	+81	+99	+141	-3	-23	-39	-57
10 <sup>18</sup>	+3	+9	+31	+79	+177	+183	+201	+283	-11	-33	-123	-137

```

const int A = 27; // Alphabet size
struct SuffixTree {
    struct Node { // [l, r) !!!
        int l, r, link, par, nxt[A];
        Node(): l(-1), r(-1), link(-1), par(-1) { fill(nxt, nxt + A, -1); }
        Node(int _l, int _r, int _link, int _par):
            l(_l), r(_r), link(_link), par(_par) { fill(nxt, nxt + A, -1); }
        int &next(int c) { return nxt[c]; }
        int get_len() const { return r - l; };
    };
    struct State { int v, len; };
    vector<Node> t; State cur_state; vector<int> s;
    SuffixTree(): cur_state({0, 0}) { t.push_back(Node()); }
    State go(State st, int l, int r) { // v -> v + s[l, r) !!!
        while(l < r) {
            if(st.len == t[st.v].get_len()) {
                State nx = State({ t[st.v].next(s[l]), 0 });
                if(nx.v == -1) return nx; st = nx; continue; }
            if(s[ t[st.v].l + st.len ] != s[l]) return State({-1, -1});
            if(r - l < t[st.v].get_len() - st.len) return State({st.v, st.len + r - l});
            l += t[st.v].get_len() - st.len, st.len = t[st.v].get_len();}return st;}
    int get_vertex(State st) {if(t[st.v].get_len() == st.len) return st.v;
        if(st.len == 0) return t[st.v].par;
        Node &v = t[st.v]; Node &pv = t[v.par]; Node add(v.l, v.l + st.len, -1, v.par);
        pv.next(s[v.l]) = (int)t.size(); add.next(s[v.l + st.len]) = st.v;
        v.par = (int)t.size(), v.l += st.len, t.push_back(add);return (int)t.size() - 1;}
    int get_link(int v) {
        if(t[v].link != -1) return t[v].link;
        if(t[v].par == -1) return 0;
        int to = get_link(t[v].par);
        to = get_vertex(go(State({to, t[to].get_len()}), t[v].l + (t[v].par == 0), t[v].r));
        return t[v].link = to;}
    void add_symbol(int c) {

```

```

s.push_back(c); while(1) {
    State hlp = go( cur_state, (int)s.size() - 1, (int)s.size() );
    if(hlp.v != -1) { cur_state = hlp; break; }
    int v = get_vertex(cur_state); Node add((int)s.size() - 1, +inf, -1, v);
    t.push_back(add); t[v].next(c) = (int)t.size() - 1;
    cur_state.v = get_link(v), cur_state.len = t[cur_state.v].get_len();
    if(!v) break;}}};

```

```

const int LOG = 21;
struct SuffixArray {
    vector< int > p, c[LOG];
    SuffixArray() = default;
    SuffixArray(string s) {
        s.push_back(0);
        int n = (int)s.size();
        vector<int> pn, cn, cnt;
        p.resize(n);
        for(int i = 0; i < LOG; i++) c[i].resize(n);
        pn.resize(n), cn.resize(n), cnt.assign(300, 0);
        for (int i = 0; i < n; i++) cnt[s[i]]++;
        for (int i = 1; i < (int) cnt.size(); i++) cnt[i] += cnt[i - 1];
        for (int i = n - 1; i >= 0; i--) p[--cnt[s[i]]] = i;
        for (int i = 1; i < n; i++) {
            c[0][p[i]] = c[0][p[i - 1]];
            if(s[p[i]] != s[p[i - 1]]) c[0][p[i]]++;}
        for (int lg = 0, k = 1; k < n; k <= 1, lg++) {
            for (int i = 0; i < n; i++)
                if((pn[i] = p[i] - k) < 0) pn[i] += n;
            cnt.assign(n, 0);
            for (int i = 0; i < n; i++) cnt[c[lg][pn[i]]]++;
            for (int i = 1; i < (int) cnt.size(); i++) cnt[i] += cnt[i - 1];
            for (int i = n - 1; i >= 0; i--) p[--cnt[c[lg][pn[i]]]] = pn[i];
            for (int l1, r1, l2, r2, i = 1; i < n; i++) {
                cn[p[i]] = cn[p[i - 1]];
                l1 = p[i - 1], r1 = (l1 + k) % n;
                l2 = p[i], r2 = (l2 + k) % n;
                if(c[lg][l1] != c[lg][l2] || c[lg][r1] != c[lg][r2]) cn[p[i]]++;}
            c[lg + 1] = cn;
        }p.erase(p.begin(), p.begin() + 1);}
    int get_lcp(int i, int j) {
        int res = 0; for (int lg = LOG - 1; lg >= 0; lg--) {
            if (i + (1 << lg) > (int) p.size() || j + (1 << lg) > (int) p.size()) continue;
            if (c[lg][i] == c[lg][j])
                i += (1 << lg), j += (1 << lg), res += (1 << lg);}return res;}};

```

```

struct suf_auto {
    vector<int> base, suf, len;
    vector<vector<int>> g;
    int last, sz;
    suf_auto(): base(26, -1), g(1, base), suf(1, -1), len(1, 0), last(0), sz(1){}
    void add_string(const string &s) {

```

```

    for (char c : s) {
        c -= 'a';
        int cur = last;
        last = sz++;
        g.push_back(base);
        suf.emplace_back();
        len.push_back(len[cur] + 1);
        while (cur != -1 && g[cur][c] == -1)
            g[cur][c] = last, cur = suf[cur];
        if (cur == -1) {
            suf[last] = 0;
            continue;
        }
        int nx = g[cur][c];
        if (len[nx] == len[cur] + 1) {
            suf[last] = nx;
            continue;
        }
        int cl = sz++;
        g.push_back(g[nx]);
        suf.push_back(suf[nx]);
        len.push_back(len[cur] + 1);
        suf[last] = suf[nx] = cl;
        while (cur != -1 && g[cur][c] == nx)
            g[cur][c] = cl, cur = suf[cur];
    }
}
};

```

```

vector<int> get_lcp(const string& s, const vector<int>& suf) {
    int n = (int)suf.size(); vector<int> back(n), lcp(n - 1);
    for(int i = 0; i < n; i++) back[suf[i]] = i;
    for(int i = 0, k = 0; i < n; i++) {
        int x = back[i]; k = max(0, k - 1);
        if (x == n - 1) { k = 0; continue; }
        while(suf[x] + k < n && suf[x + 1] + k < n && s[suf[x] + k] == s[suf[x + 1] + k]) k++;
        lcp[x] = k; } return lcp; }

```

```

struct Edge {
    int fr, to, id;
    int get(int v) { return v == fr ? to : fr; }
};
void dfs(const vector<vector<Edge>> &g, vector<int> &fup, vector<int> &tin,
vector<int> &used, int &timer, int v, int par = -1) {
    tin[v] = fup[v] = timer++; used[v] = 1;
    for (Edge e : g[v]) {
        int to = e.get(v);
        if (to == par) continue;
        if (used[to]) { fup[v] = min(fup[v], tin[to]);
        } else { dfs(g, fup, tin, used, timer, to, v);
            fup[v] = min(fup[v], fup[to]); } }
}
void paintEdges(const vector<vector<Edge>> &g, vector<int> &fup,

```

```

vector<int> &tin, vector<int> &used,
vector<int> &colors, int v, int curColor, int &maxColor, int par = -1) {
used[v] = 1;
for (Edge e : g[v]) {
    int to = e.get(v);
    if (to == par) continue;
    if (!used[to]) {
        if (tin[v] <= fup[to]) { int tmpColor = maxColor++;
            colors[e.id] = tmpColor;
            paintEdges(g, fup, tin, used, colors, to, tmpColor, maxColor, v);
        } else { colors[e.id] = curColor;
            paintEdges(g, fup, tin, used, colors, to, curColor, maxColor, v);}
    } else if (tin[to] < tin[v]) { colors[e.id] = curColor;}}}
vector<vector<Edge>> get2components(const vector<vector<Edge>> &g,
int m, const vector<Edge> &es) {
int n = (int)g.size(); vector<int> fup(n), tin(n), used(n);
vector<int> colors(m);
int timer; used.assign(n, 0); timer = 0;
for (int v = 0; v < n; v++) { if (used[v]) continue;
    dfs(g, fup, tin, used, timer, v);}
used.assign(n, 0); timer = 0; for (int v = 0; v < n; v++) {
    if (used[v]) continue;
    paintEdges(g, fup, tin, used, colors, v, timer, timer, -1); }
vector<vector<Edge>> res(timer);
for (int i = 0; i < m; i++) { res[colors[i]].push_back(es[i]); }
return res;}

```

```

pair<vector<int>, vector<int>> manacker(const string& s) { // -> {d0, d1}. RUN test!
int n = (int) s.size();
vector<int> d0(n), d1(n);
for (int l = 0, r = -1, i = 0; i < n; i++) { // d1
    d1[i] = i <= r ? min(r - i, d1[l + r - i]) : 0;
    while (i >= d1[i] && i + d1[i] < n && s[i - d1[i]] == s[i + d1[i]]) d1[i]++;
    d1[i]--; if (i + d1[i] > r) l = i - d1[i], r = i + d1[i];}
for (int l = 0, r = -1, i = 0; i < n; i++) {
    d0[i] = i < r ? min(r - i, d0[l + r - i - 1]) : 0;
    while (i >= d0[i] && i + d0[i] + 1 < n && s[i - d0[i]] == s[i + d0[i] + 1]) d0[i]++;
    if (d0[i] > 0 && i + d0[i] > r) l = i - d0[i] + 1, r = i + d0[i];}
return {d0, d1};}

```

```

vector<int> get_pi(const string& s) {
int n = (int) s.size(); vector<int> p(n);
for (int j, i = 1; i < n; i++) {
    for (j = p[i - 1]; j > 0 && s[i] != s[j]; j = p[j - 1]);
    p[i] = (j += (s[i] == s[j]));} return p;}

```

```

vector<int> get_z(const string& s) {
int n = (int) s.size(); vector<int> z(n);
for (int l = 0, r = -1, i = 1; i < n; i++) {
    z[i] = i <= r ? min(r - i, z[i - l]) : 0;

```

```

while (i + z[i] < n && s[z[i]] == s[i + z[i]]) z[i]++;
if (i + z[i] > r) l = i, r = i + z[i]; return z;}

```

```

struct Tandem {int l, r, k; /*[l, l + 2 * k), [l + 1, l + 1 + 2 * k), ..., [r, r + 2 * k)*/};
const int SIZE = (2e5 + 5) * 30; // (n)*log(n)
const int MAXL = (2e5 + 5) * 4; // (n)*4, 4 = big const
Tandem tds[SIZE], hlp[MAXL]; int tsz;
void rec(const string& s, int L, int R) {
    if (R - L + 1 <= 1) return;
    int M = (L + R) / 2; rec(s, L, M); rec(s, M + 1, R); int nu = M - L + 1, nv = R - M;
    string vu = s.substr(M + 1, nv) + "#" + s.substr(L, nu);
    string urvr = vu; reverse(urvr.begin(), urvr.end());
    vector<int> z1 = get_z(urvr), z2 = get_z(vu);
    for (int x = L; x <= R; x++) {
        if (x <= M) {
            int k = M + 1 - x, k1 = L < x ? z1[nu - x + L] : 0;
            int k2 = z2[nv + 1 + x - L], lsh = max(0, k - k2), rsh = min(k1, k - 1);
            if (lsh <= rsh) tds[tsz++] = {x - rsh, x - lsh, k};
        } else {
            int k = x - M, k1 = x < R ? z2[x - M] : 0;
            int k2 = z1[nu + nv - x + M + 1], lsh = max(1, k - k1), rsh = min(k2, k - 1);
            if (lsh <= rsh) tds[tsz++] = {x - rsh + 1 - k, x - lsh + 1 - k, k};}}
void compress() { // O(n*log(n)*log(n)) can be replace with count sort (O(n*log(n)))
    // O(n*log(n)) --> O(n) !!! BE careful with ML !!!
    sort(tds, tds + tsz, [](const Tandem& t1, const Tandem& t2) {
        return t1.k < t2.k || (t1.k == t2.k && t1.l < t2.l);});
    int hlp_sz = 0; for (int i = 0; i < tsz; i++) { int j = i;
        while (j + 1 < tsz && tds[i].k == tds[j + 1].k && tds[j].r + 1 == tds[j + 1].l) j++;
        hlp[hlp_sz++] = {tds[i].l, tds[j].r, tds[j].k}; i = j;}
    memcpy(tds, hlp, sizeof(Tandem) * hlp_sz); tsz = hlp_sz;}
void main_lorentz(const string &s) {
    // n = 10^6 time = 1.8 sec MEM = nlog(n) * 12 bytes
    int n = (int) s.size(); tsz = 0; rec(s, 0, n - 1); compress();}

```

```

const int A = 26; // alph size
struct Aho {
    struct Node {
        int nxt[A], go[A], par, pch, link, good;
        Node(): par(-1), pch(-1), link(-1), good(-1) {
            fill(nxt, nxt + A, -1); fill(go, go + A, -1);}};
    vector<Node> a; Aho() { a.emplace_back(); }
    int add_string(const string& s) {
        int v = 0; for (char cc : s) {
            int c = cc - '0'; if (a[v].nxt[c] == -1) {
                a[v].nxt[c] = (int) a.size();
                a.emplace_back();
                a.back().par = v, a.back().pch = c;}
            v = a[v].nxt[c];} a[v].good = 1; return v;}
    int go(int v, int c) {
        if (a[v].go[c] == -1){
            if (a[v].nxt[c] != -1) a[v].go[c] = a[v].nxt[c];

```

```

        else a[v].go[c] = v ? go(get_link(v), c) : 0;
    } return a[v].go[c];}
int get_link(int v) {
    if (a[v].link == -1) {
        if (!v || !a[v].par) a[v].link = 0;
        else a[v].link = go(get_link(a[v].par), a[v].pch);
    } return a[v].link;}
int is_good(int v) {
    if (v <= 0) return false;
    if (a[v].good != -1) return a[v].good;
    return a[v].good = is_good(get_link(v));}};

```

```

vector<int> Hungarian(const vector< vector<int> >& a){ // ALARM: INT everywhere
    int n = (int)a.size();
    vector<int> row(n), col(n), pair(n, -1), back(n, -1), prev(n, -1);
    auto get = [&](int i, int j){ return a[i][j] + row[i] + col[j];};
    for(int v = 0; v < n; v++){
        vector<int> min_v(n, v), A_plus(n), B_plus(n);
        A_plus[v] = 1; int j_b;
        while(true){
            int pos_i = -1, pos_j = -1;
            for(int j = 0; j < n; j++){
                if(!B_plus[j] && (pos_i == -1 ||
                    get(min_v[j], j) < get(pos_i, pos_j))) {
                    pos_i = min_v[j], pos_j = j;
                }
            }
            int weight = get(pos_i, pos_j);
            for(int i = 0; i < n; i++) if(!A_plus[i]) row[i] += weight;
            for(int j = 0; j < n; j++) if(!B_plus[j]) col[j] -= weight;
            B_plus[pos_j] = 1, prev[pos_j] = pos_i;
            int x = back[pos_j];
            if(x == -1) { j_b = pos_j; break;}
            A_plus[x] = 1;
            for(int j = 0; j < n; j++)
                if(get(x, j) < get(min_v[j], j))
                    min_v[j] = x;
        }
        while(j_b != -1){
            back[j_b] = prev[j_b];
            swap(pair[prev[j_b]], j_b);
        }
    }
    return pair;
}

```

```

struct GeneralMatching { // O(n^3)
    int n = 0, cc = 10; // [0, n)
    vector<vector<int>> g; // undirected
    vector<int> mt, used, base, p, color;
    queue<int> q;
}

```

```

GeneralMatching(int nn): n(nn), mt(n, -1), used(n), base(n), p(n), color(n), g(n) {}
void add_edge(int u, int v) {g[u].push_back(v), g[v].push_back(u);}
void add(int v) {if (!used[v])used[v] = 1, q.push(v);}
int get_lca(int u, int v) {
    cc++; while (1) { u = base[u], color[u] = cc;if (mt[u] == -1) break; u = p[mt[u]];}
    while (1) { v = base[v]; if (color[v] == cc) break;v = p[mt[v]];}return v;}
void mark_path(int v, int child, int b) {
    while (base[v] != b) {
        color[base[v]] = color[base[mt[v]]] = cc;
        p[v] = child, child = mt[v], v = p[child];}}
int bfs(int root) {
    add(root);while (!q.empty()) {
        int v = q.front(); q.pop();
        for (int to : g[v]) {
            if (base[v] == base[to] || mt[v] == to) continue;
            else if (used[to]) {
                int w = get_lca(v, to);
                cc++, mark_path(v, to, w), mark_path(to, v, w);
                for (int i = 0; i < n; i++)
                    if (color[base[i]] == cc) base[i] = w, add(i);
            } else if (p[to] == -1) {
                p[to] = v; if (mt[to] == -1) return to; add(mt[to]);}}}
    return -1;}
void xor_path(int v) {
    while (v != -1) { int pv = p[v], ppv = mt[pv]; mt[v] = pv, mt[pv] = v; v = ppv;}}
bool inc(int root) {
    used.assign(n, 0), p.assign(n, -1), iota(base.begin(), base.end(), 0);
    while (!q.empty()) q.pop(); int v = bfs(root); if (v == -1) return false;
    xor_path(v); return true}
void match() {for (int i = 0; i < n; i++) if (mt[i] == -1) inc(i);}}

```

```

struct Line {
    ll k, b;
    int type;
    ld x;
    Line(): k(0), b(0), type(0), x(0) { }
    Line(ll _k, ll _b, ld _x = 1e18, int _type = 0):
        k(_k), b(_b), x(_x), type(_type) { }
    bool operator<(const Line& other) const {
        if(type + other.type > 0) { return x < other.x;
        }else { return k < other.k; }
    }
    ld intersect(const Line& other) const {
        return ld(b - other.b) / ld(other.k - k);
    }
    ll get_func(ll x0) const {
        return k * x0 + b;
    }
};

struct CHT {
    set< Line > qs;

```

```

set< Line > :: iterator fnd, help;
bool hasr(const set< Line > :: iterator& it) {
    return it != qs.end() && next(it) != qs.end(); }
bool hasl(const set< Line > :: iterator& it) {
    return it != qs.begin(); }
bool check(const set< Line > :: iterator& it) {
    if(!hasr(it)) return true;
    if(!hasl(it)) return true;
    return it->intersect(*prev(it)) < it->intersect(*next(it)); }
void update_intersect(const set< Line > :: iterator& it) {
    if(it == qs.end()) return;
    if(!hasr(it)) return;
    Line tmp = *it;
    tmp.x = tmp.intersect(*next(it));
    qs.insert(qs.erase(it), tmp);
}
void add_line(Line L) {
    if(qs.empty()) { qs.insert(L); return; }
    {
        fnd = qs.lower_bound(L);
        if(fnd != qs.end() && fnd->k == L.k) {
            if(fnd->b >= L.b) return;
            else qs.erase(fnd);
        }
    }
    fnd = qs.insert(L).first;
    if(!check(fnd)) { qs.erase(fnd); return; }
    while(hasr(fnd) && !check(help = next(fnd))) { qs.erase(help); }
    while(hasl(fnd) && !check(help = prev(fnd))) { qs.erase(help); }
    if(hasl(fnd)) { update_intersect(prev(fnd)); }
    update_intersect(fnd);
}
ll get_max(ld x0) {
    if(qs.empty()) return -inf64;
    fnd = qs.lower_bound(Line(0, 0, x0, 1));
    if(fnd == qs.end()) fnd--;
    ll res = -inf64; int i = 0;
    while(i < 2 && fnd != qs.end()) {
        res = max(res, fnd->get_func(x0));
        fnd++;
        i++;
    }
    while(i-- > 0) fnd--;
    while(i < 2) {
        res = max(res, fnd->get_func(x0));
        if(hasl(fnd)) {
            fnd--; i++;
        }else {
            break;
        }
    }
    return res;
}

```



```
    }  
};
```

Be careful with overflow

mod	$12 \cdot 2^{10} + 1$	$13 \cdot 2^{10} + 1$	$15 \cdot 2^{10} + 1$	$57 \cdot 2^{10} + 1$	$58 \cdot 2^{10} + 1$	$60 \cdot 2^{10} + 1$	$148 \cdot 2^{10} + 1$
root	49	7	84	29	9	21	38
mod	$6 \cdot 2^{11} + 1$	$9 \cdot 2^{11} + 1$	$20 \cdot 2^{11} + 1$	$56 \cdot 2^{11} + 1$	$65 \cdot 2^{11} + 1$	$140 \cdot 2^{11} + 1$	$150 \cdot 2^{11} + 1$
root	7	19	32	16	39	106	91
mod	$3 \cdot 2^{12} + 1$	$10 \cdot 2^{12} + 1$	$15 \cdot 2^{12} + 1$	$66 \cdot 2^{12} + 1$	$70 \cdot 2^{12} + 1$	$75 \cdot 2^{12} + 1$	$127 \cdot 2^{12} + 1$
root	41	28	19	114	19	41	71
mod	$136 \cdot 2^{12} + 1$	$141 \cdot 2^{12} + 1$	$5 \cdot 2^{13} + 1$	$8 \cdot 2^{13} + 1$	$14 \cdot 2^{13} + 1$	$51 \cdot 2^{13} + 1$	$78 \cdot 2^{13} + 1$
root	66	114	12	13	2	67	87
mod	$90 \cdot 2^{13} + 1$	$113 \cdot 2^{13} + 1$	$4 \cdot 2^{14} + 1$	$7 \cdot 2^{14} + 1$	$9 \cdot 2^{14} + 1$	$63 \cdot 2^{14} + 1$	$69 \cdot 2^{14} + 1$
root	96	63	15	15	22	94	86
mod	$73 \cdot 2^{14} + 1$	$139 \cdot 2^{14} + 1$	$2 \cdot 2^{15} + 1$	$5 \cdot 2^{15} + 1$	$17 \cdot 2^{15} + 1$	$81 \cdot 2^{15} + 1$	$110 \cdot 2^{15} + 1$
root	31	20	9	7	19	89	117
mod	$114 \cdot 2^{15} + 1$	$135 \cdot 2^{15} + 1$	$1 \cdot 2^{16} + 1$	$12 \cdot 2^{16} + 1$	$18 \cdot 2^{16} + 1$	$55 \cdot 2^{16} + 1$	$88 \cdot 2^{16} + 1$
root	27	126	3	3	14	30	10
mod	$102 \cdot 2^{16} + 1$	$112 \cdot 2^{16} + 1$	$117 \cdot 2^{16} + 1$	$6 \cdot 2^{17} + 1$	$9 \cdot 2^{17} + 1$	$21 \cdot 2^{17} + 1$	$51 \cdot 2^{17} + 1$
root	51	83	15	8	74	83	43
mod	$53 \cdot 2^{17} + 1$	$63 \cdot 2^{17} + 1$	$104 \cdot 2^{17} + 1$	$108 \cdot 2^{17} + 1$	$123 \cdot 2^{17} + 1$	$3 \cdot 2^{18} + 1$	$22 \cdot 2^{18} + 1$
root	47	10	13	54	26	5	74
mod	$28 \cdot 2^{18} + 1$	$52 \cdot 2^{18} + 1$	$54 \cdot 2^{18} + 1$	$63 \cdot 2^{18} + 1$	$108 \cdot 2^{18} + 1$	$127 \cdot 2^{18} + 1$	$147 \cdot 2^{18} + 1$
root	79	4	25	70	108	99	34
mod	$11 \cdot 2^{19} + 1$	$14 \cdot 2^{19} + 1$	$26 \cdot 2^{19} + 1$	$54 \cdot 2^{19} + 1$	$57 \cdot 2^{19} + 1$	$71 \cdot 2^{19} + 1$	$134 \cdot 2^{19} + 1$
root	12	25	2	106	20	86	49
mod	$7 \cdot 2^{20} + 1$	$13 \cdot 2^{20} + 1$	$22 \cdot 2^{20} + 1$	$66 \cdot 2^{20} + 1$	$67 \cdot 2^{20} + 1$	$106 \cdot 2^{20} + 1$	$115 \cdot 2^{20} + 1$
root	5	3	50	54	7	85	138
mod	$148 \cdot 2^{20} + 1$	$11 \cdot 2^{21} + 1$	$33 \cdot 2^{21} + 1$	$39 \cdot 2^{21} + 1$	$53 \cdot 2^{21} + 1$	$54 \cdot 2^{21} + 1$	$63 \cdot 2^{21} + 1$
root	81	38	45	94	54	134	46
mod	$110 \cdot 2^{21} + 1$	$119 \cdot 2^{21} + 1$	$123 \cdot 2^{21} + 1$	$25 \cdot 2^{22} + 1$	$27 \cdot 2^{22} + 1$	$33 \cdot 2^{22} + 1$	$55 \cdot 2^{22} + 1$
root	68	135	95	21	66	30	63
mod	$90 \cdot 2^{22} + 1$	$99 \cdot 2^{22} + 1$	$20 \cdot 2^{23} + 1$	$56 \cdot 2^{23} + 1$	$77 \cdot 2^{23} + 1$	$107 \cdot 2^{23} + 1$	$119 \cdot 2^{23} + 1$
root	139	65	4	53	19	45	31
mod	$132 \cdot 2^{23} + 1$	$10 \cdot 2^{24} + 1$	$28 \cdot 2^{24} + 1$	$66 \cdot 2^{24} + 1$	$73 \cdot 2^{24} + 1$	$108 \cdot 2^{24} + 1$	$120 \cdot 2^{24} + 1$
root	64	2	40	8	149	126	21
mod	$148 \cdot 2^{24} + 1$						
root	25						

```
const int mod = 998244353;  
const int root = 31;  
const int LOG = 23;  
const int N = 1e5 + 5;  
vec<int> G[LOG + 1];  
vec<int> rev[LOG + 1];  
inline void _add(int &x, int y);  
inline int _sum(int a, int b);  
inline int _sub(int a, int b);  
inline int _mul(int a, int b);  
inline int _binpow(int x, int p);
```

```

inline int _rev(int x);
void precalc() {
    for(int start = root, lvl = LOG; lvl >= 0; lvl--, start = _mul(start, start)) {
        int tot = 1 << lvl;
        G[lvl].resize(tot);
        for(int cur = 1, i = 0; i < tot; i++, cur = _mul(cur, start)) {
            G[lvl][i] = cur;
        }
    }
    for(int lvl = 1; lvl <= LOG; lvl++) {
        int tot = 1 << lvl;
        rev[lvl].resize(tot);
        for(int i = 1; i < tot; i++) {
            rev[lvl][i] = ((i & 1) << (lvl - 1)) | (rev[lvl][i >> 1] >> 1);
        }
    }
}

void fft(vec< int > &a, int sz, bool invert) {
    int n = 1 << sz;
    for(int j, i = 0; i < n; i++) {
        if((j = rev[sz][i]) < i) {
            swap(a[i], a[j]);
        }
    }
    for(int f1, f2, lvl = 0, len = 1; len < n; len <= 1, lvl++) {
        for(int i = 0; i < n; i += (len << 1)) {
            for(int j = 0; j < len; j++) {
                f1 = a[i + j];
                f2 = _mul(a[i + j + len], G[lvl + 1][j]);
                a[i + j] = _sum(f1, f2);
                a[i + j + len] = _sub(f1, f2);
            }
        }
    }
    if(invert) {
        reverse(a.begin() + 1, a.end());
        int rn = _rev(n);
        for(int i = 0; i < n; i++) {
            a[i] = _mul(a[i], rn);
        }
    }
}

vec< int > multiply(const vec< int > &a, const vec< int > &b) {
    vec< int > fa(ALL(a));
    vec< int > fb(ALL(b));
    int n = (int)a.size();
    int m = (int)b.size();
    int maxnm = max(n, m), sz = 0;
    while((1 << sz) < maxnm) sz++; sz++;
    fa.resize(1 << sz);
    fb.resize(1 << sz);

```

```

fft(fa, sz, false);
fft(fb, sz, false);
int SZ = 1 << sz;
for(int i = 0; i < SZ; i++) { fa[i] = _mul(fa[i], fb[i]); }
fft(fa, sz, true);
while((int)fa.size() > 1 && !fa.back()) fa.pop_back();
return fa;
}

```

```

struct Complex {
    ld rl = 0, im = 0;
    Complex() = default;
    Complex(ld x, ld y = 0): rl(x), im(y) { }
    Complex & operator = (const Complex &o) {
        if(this != &o) {
            rl = o.rl;
            im = o.im;
        }
        return *this;
    }
    Complex operator + (const Complex &o) const { return {rl + o.rl, im + o.im}; }
    Complex operator - (const Complex &o) const { return {rl - o.rl, im - o.im}; }
    Complex operator * (const Complex &o) const {
        return {rl * o.rl - im * o.im, rl * o.im + im * o.rl}; }
    Complex & operator *= (const Complex &o) {
        (*this) = (*this) * o;
        return *this;
    }
    Complex operator / (const Complex &o) const {
        ld md = o.rl * o.rl + o.im * o.im;
        return {(rl * o.rl + im * o.im) / md, (im * o.rl - rl * o.im) / md};
    }
    Complex & operator /= (int k) {
        rl /= k;
        im /= k;
        return *this;
    }
    ld real() const { return rl; }
    ld imag() const { return im; }
};

typedef Complex base;
const int LOG = 20;
const int N = 1 << LOG;
int rev[N];
vec< base > PW[LOG + 1];
void precalc() {
    for(int i = 1; i < N; i++) {
        rev[i] = (rev[i >> 1] >> 1) | ((i & 1) << (LOG - 1));
    }
    for(int lvl = 0; lvl <= LOG; lvl++) {
        int sz = 1 << lvl;
        ld alpha = 2 * pi / sz;
    }
}

```

```

    base root(cos(alpha), sin(alpha));
    base cur = 1;
    PW[lvl].resize(sz);
    for(int j = 0; j < sz; j++) {
        PW[lvl][j] = cur;
        cur *= root;
    }
}

void fft(base *a, bool invert = 0) {
    for(int j, i = 0; i < N; i++) {
        if((j = rev[i]) > i) swap(a[i], a[j]);
    }
    base u, v;
    for(int lvl = 0; lvl < LOG; lvl++) {
        int len = 1 << lvl;
        for(int i = 0; i < N; i += (len << 1)) {
            for(int j = 0; j < len; j++) {
                u = a[i + j];
                v = a[i + j + len] *
                    (invert?PW[lvl+1][j?(len << 1)-j:0]:PW[lvl+1][j]);
                a[i + j] = u + v;
                a[i + j + len] = u - v;
            }
        }
    }
    if(invert) {
        for(int i = 0; i < N; i++) {
            a[i] /= N;
        }
    }
}

```

```

int fact[N];
int rfact[N];

void precalc2() {
    fact[0] = 1;
    for (int i = 1; i < N; i++) {
        fact[i] = _mul(fact[i - 1], i);
    }
    rfact[N - 1] = _rev(fact[N - 1]);
    for (int i = N - 2; i >= 0; i--) {
        rfact[i] = _mul(rfact[i + 1], i + 1);
    }
}

int getMulOnSegment(int l, int r) {
    assert(l <= r);
    if (l == 0 && r == 0) return 1;
    if (r <= 0) {

```

```

    int res = getMulOnSegment(-r, -l);
    int cnt = r - l + 1;
    if (cnt % 2) {
        res = (-res % mod + mod) % mod;
    }
    return res;
}
if (l < 0) {
    int resl = getMulOnSegment(0, -l);
    if (l % 2) {
        resl = (-resl % mod + mod) % mod;
    }
    int resr = getMulOnSegment(0, r);
    return _mul(resl, resr);
}
assert(l >= 0);
int res = fact[r];
if (l > 0) {
    res = _mul(res, rfact[l - 1]);
}
return res;
}

vector<int> extrapolate(vector<int> y, int m) {
    vector<int> yy = y;
    int n = (int)y.size() - 1;
    for (int i = 0; i <= n; i++) {
        yy[i] = _mul(y[i], _rev(getMulOnSegment(i - n, i - 0)));
    }
    vector<int> ff(n + m + 1);
    for (int i = 1; i <= n + m; i++) {
        ff[i] = _mul(fact[i - 1], rfact[i]);
    }
    vector<int> ss = multiply(yy, ff);
    for (int i = 1; i <= m; i++) {
        int cc = getMulOnSegment(i, n + i);
        int Si = ss[n + i];
        y.push_back(_mul(cc, Si));
    }
    return y;
}
}

```

```

// diff[v] = len[v] - len[link[v]]
// slink[v], diff[v] != diff[slink[v]], len[slink[v]] <-- max, slink path O(log(n))
// len[quickLink[v]] <-- max, preceded in v by as symbol different from b,
// where b = v[|v| - |link[v]|] -- preceding the suffix link[v] in v, qlink path O(log(n))

struct pal_tree {
    int sz;
    vector<unordered_map<int, int>> g;
    vector<int> len, suf, cn, base;

```

```

vector<int> fin;
int cur, v;
pal_tree(): g(2),sz(2),len({-1, 0}),cn({0, 0}),suf({0, 0}),cur(0),v(1){}
void add_string (const string &s) {
    for (int i = 0; i < s.length(); i++) {
        char c = s[i] - 'a';
        while (i - len[v] - 1 < 0 || s[i - len[v] - 1] - 'a' != c) v = suf[v];
        if (!g[v].count(c)) {
            g.emplace_back(); int t = len[v]; len.push_back(t + 2); int u = v;
            do { u = suf[u]; } while (u && s[i - len[u] - 1] - 'a' != c);
            suf.push_back(!g[u].count(c) ? 1 : g[u][c]);
            t = cn[suf.back()]; cn.push_back(t + 1); g[v][c] = sz++; cur++;}
        v = g[v][c]; fin.push_back(cn[v]);}return;}};

```

```

#include <ext/pb_ds/assoc_container.hpp>
#include <ext/pb_ds/tree_policy.hpp>
using namespace __gnu_pbds;
using namespace std;
typedef tree<int, null_type, less<int>,
    rb_tree_tag, tree_order_statistics_node_update> stat_set;
// insert, find_by_order, order_of_key (multiset = set<pair<int, int>>)
// =====
#include <ext/pb_ds/assoc_container.hpp>
#include <ext/pb_ds/detail/standard_policies.hpp>
using namespace __gnu_pbds;
gp_hash_table<int, int> table; // as unordered_map (instead of count use find)

```

```

struct Dinic {
    struct Edge { int fr, to, cp, id, fl; };
    int n, S, T;
    vec< Edge > es;
    vec< vec< int > > g;
    vec< int > dist, res, ptr;
    Dinic(int _n, int _S, int _T):
        n(_n), S(_S), T(_T) { g.resize(n); }
    void add_edge(int fr, int to, int cp, int id) {
        g[fr].push_back((int)es.size());
        es.push_back({fr, to, cp, id, 0});
        g[to].push_back((int)es.size());
        es.push_back({to, fr, 0, -1, 0});
    }
    bool bfs(int K) {
        dist.assign(n, inf);
        dist[S] = 0;
        queue< int > q;
        q.push(S);
        while(!q.empty()) {
            int v = q.front();
            q.pop();
            for(int ps : g[v]) {
                Edge &e = es[ps];

```

```

        if(e.fl + K > e.cp) continue;
        if(dist[e.to] > dist[e.fr] + 1) {
            dist[e.to] = dist[e.fr] + 1;
            q.push(e.to);
        }
    }
}
return dist[T] < inf;
}
int dfs(int v, int _push = INT_MAX) {
    if(v == T || !_push) return _push;
    for(int &iter = ptr[v]; iter < (int)g[v].size(); iter++) {
        int ps = g[v][ ptr[v] ];
        Edge &e = es[ps];
        if(dist[e.to] != dist[e.fr] + 1) continue;
        int tmp = dfs(e.to, min(_push, e.cp - e.fl));
        if(tmp) {
            e.fl += tmp;
            es[ps ^ 1].fl -= tmp;
            return tmp;
        }
    }
    return 0;
}
ll find_max_flow() {
    ptr.resize(n);
    ll max_flow = 0, add_flow;
    for(int K = 1 << 30; K > 0; K >= 1) {
        while(bfs(K)) {
            ptr.assign(n, 0);
            while((add_flow = dfs(S))) {
                max_flow += add_flow;
            }
        }
    }
    return max_flow;
}
void assign_result() {
    res.resize(es.size());
    for(Edge e : es) if(e.id != -1) res[e.id] = e.fl; }
int get_flow(int id) { return res[id]; }
bool go(int v, vec< int > &F, vec< int > &path) {
    if(v == T) return 1;
    for(int ps : g[v]) {
        if(F[ps] <= 0) continue;
        if(go(es[ps].to, F, path)) {
            path.push_back(ps);
            return 1;
        }
    }
}
return 0;

```

```

}
vec< pair< int, vec< int > > > decomposition() {
    find_max_flow();
    vec< int > F((int)es.size()), path, add;
    vec< pair< int, vec< int > > > dcmp;
    for(int i = 0; i < (int)es.size(); i++) F[i] = es[i].fl;
    while(go(S, F, path)) {
        int mn = INT_MAX;
        for(int ps : path) mn = min(mn, F[ps]);
        for(int ps : path) F[ps] -= mn;
        for(int ps : path) add.push_back(es[ps].id);
        reverse(ALL(add));
        dcmp.push_back({mn, add});
        add.clear();
        path.clear();
    }
    return dcmp;
}
};

```

```

struct MCMF {
    struct Edge { int fr, to, cp, fl, cs, id; };
    int n, S, T;
    vec< Edge > es;
    vec< vec< int > > g;
    vec< ll > dist, phi;
    vec< int > from;
    MCMF(int _n, int _S, int _T): n(_n), S(_S), T(_T)
    { g.resize(n); }
    void add_edge(int fr, int to, int cp, int cs, int id) {
        g[fr].push_back((int)es.size());
        es.push_back({fr, to, cp, 0, cs, id});
        g[to].push_back((int)es.size());
        es.push_back({to, fr, 0, 0, -cs, -1});
    }
    void init_phi() {
        dist.assign(n, LLONG_MAX);
        dist[S] = 0;
        for(int any, iter = 0; iter < n - 1; iter++) { // Ford Bellman
            any = 0;
            for(Edge e : es) {
                if(e.fl == e.cp) continue;
                if(dist[e.to] - dist[e.fr] > e.cs) {
                    dist[e.to] = dist[e.fr] + e.cs;
                    any = 1;
                }
            }
            if(!any) break;
        }
        phi = dist;
    }
};

```



```

bool Dijkstra() {
    dist.assign(n, LLONG_MAX);
    from.assign(n, -1);
    dist[S] = 0;
    priority_queue< pair< ll, int >, vec< pair< ll, int > >,
        greater< pair< ll, int > > > pq;
    pq.push({dist[S], S});
    while(!pq.empty()) {
        int v;
        ll di;
        tie(di, v) = pq.top();
        pq.pop();
        if(di != dist[v]) continue;
        for(int ps : g[v]) {
            Edge &e = es[ps];
            if(e.fl == e.cp) continue;
            if(dist[e.to] - dist[e.fr] > e.cs + phi[e.fr] - phi[e.to]) {
                dist[e.to] = dist[e.fr] + e.cs + phi[e.fr] - phi[e.to];
                from[e.to] = ps;
                pq.push({dist[e.to], e.to});
            }
        }
    }
    for(int v = 0; v < n; v++) {
        phi[v] += dist[v];
    }
    return dist[T] < LLONG_MAX;
}

pll find_mcmf() {
    init_phi();
    ll flow = 0, cost = 0;
    while(Dijkstra()) {
        int mn = INT_MAX;
        for(int v = T; v != S; v = es[ from[v] ].fr) {
            mn = min(mn, es[from[v]].cp - es[from[v]].fl);
        }
        flow += mn;
        for(int v = T; v != S; v = es[ from[v] ].fr) {
            es[ from[v] ].fl += mn;
            es[ from[v] ^ 1 ].fl -= mn;
        }
    }
    for(Edge &e : es) {
        if(e.fl >= 0)
            cost += 1ll * e.fl * e.cs;
    }
    return make_pair(flow, cost);
}

bool go(int v, vec< int > &F, vec< int > &path, vec< int > &used) {
    if(used[v]) return 0;
    used[v] = 1;

```

```

    if(v == T) return 1;
    for(int ps : g[v]) {
        if(F[ps] <= 0) continue;
        if(go(es[ps].to, F, path, used)) {
            path.push_back(ps);
            return 1;
        }
    }
    return 0;
}

vec< pair< int, vec< int > > > decomposition(ll &_flow, ll &_cost) {
    tie(_flow, _cost) = find_mcmf();
    vec< int > F((int)es.size()), path, add, used(n);
    vec< pair< int, vec< int > > > dcmp;
    for(int i = 0; i < (int)es.size(); i++) F[i] = es[i].fl;
    while(go(S, F, path, used)) {
        used.assign(n, 0);
        int mn = INT_MAX;
        for(int ps : path) mn = min(mn, F[ps]);
        for(int ps : path) F[ps] -= mn;
        for(int ps : path) add.push_back(es[ps].id);
        reverse(ALL(add));
        dcmp.push_back({mn, add});
        add.clear();
        path.clear();
    }
    return dcmp;
}
};

```

```

namespace FACTORIZE {
    const ll MAXX = 1000;
    const int FERMA_ITER = 30;
    // const int POLLARD_PO_ITER = 10000;
    int POLLARD_PO_ITER;
    inline ll sqr(ll n) { return n * n; }
    ll check_small(ll n) {
        for(ll x = 1; sqr(x) <= n && x <= MAXX; x++) {
            if(x > 1 && n % x == 0) {
                return x;
            } else if(sqr(x + 1) > n) {
                return -1;
            }
        }
        return -1;
    }
    ll check_square(ll n) {
        ll b1 = 0;
        ll br = 3e9+1;
        ll bm;
        while(br - b1 > 1) {

```

```

        bm = (bl + br) / 2;
        if(sqr(bm) <= n) {
            bl = bm;
        }else {
            br = bm;
        }
    }
    if(sqr(bl) == n && bl > 1) {
        return bl;
    }else {
        return -1;
    }
}

inline ll _mul(ll a, ll b, ll m) {
    static __int128 xa = 1;
    static __int128 xb = 1;
    static __int128 xm = 1;
    xa = a;
    xb = b;
    xm = m;
    return ll(xa * xb % xm);
}

/*
ll _mul(ll x, ll y, ll mod) {
    ll q = ld(x) * ld(y) / ld(mod);
    ll r = x * y - q * mod;
    return (r % mod + mod) % mod;
}*/

inline ll _binpow(ll x, ll p, ll m) {
    static ll res = 1;
    static ll tmp = 1;
    res = 1;
    tmp = x;
    while(p > 0) {
        if(p & 1ll) {
            res = _mul(res, tmp, m);
        }
        tmp = _mul(tmp, tmp, m);
        p >>= 1;
    }
    return res;
}

mt19937_64 next_rand(179);
ll gcd(ll x, ll y) { return !x ? y : gcd(y % x, x); }
bool is_prime(ll n) {
    if(n <= 1) return false;
    if(n == 2) return true;
    ll a, g;
    for(int iter = 0; iter < FERMA_ITER; iter++) {
        a = next_rand() % (n - 2);
        if(a < 0) a += n - 2;
    }
}

```

```

        a += 2;
        assert(1 < a && a < n);
        g = gcd(a, n);
        if(g != 1) { return false; }
        if(_binpow(a, n - 1, n) != 1) { return false; }
    }
    return true;
}
inline ll _func(ll x, ll n) {
    static ll result = 1;
    result = _mul(x, x, n);
    return result + 1 < n ? result + 1 : 0;
}
ll pollard_po(ll n) {
    POLLARD_PO_ITER = 5 + 3 * pow(n, 0.25);
    ll a, b, x, g;
    while(1) {
        a = next_rand() % n;
        if(a < 0) a += n;
        b = next_rand() % n;
        if(b < 0) b += n;
        for(int iter = 0; iter < POLLARD_PO_ITER; iter++) {
            x = a >= b ? a - b : b - a;
            g = gcd(x, n);
            if(1 < g && g < n) {
                return g;
            }
            a = _func(a, n);
            b = _func(_func(b, n), n);
        }
    }
}
ll get_div(ll n) {
    ll res;
    res = check_small(n);
    if(res != -1) { return res; }
    res = check_square(n);
    if(res != -1) { return res; }
    if(is_prime(n)) { return n; }
    return pollard_po(n);
}
}

```

```

class EulerTourTrees {
    /*graph - forest 1 .. n get = is connected?
    no memory leaks 1 <= n, q <= 10^5 0.7 sec*/
private:
    struct Node {
        Node *l; Node *r; Node *p;
        int prior; int cnt; int rev;
    };
};

```

```

void do_rev(Node *v) {if(v) v->rev ^= 1, swap(v->l, v->r);}
int get_cnt(Node *v) const {return v ? v->cnt : 0;}
void update(Node *v) {if(!v) return;
    v->cnt = 1 + get_cnt(v->l) + get_cnt(v->r);
    v->p = nullptr;if(v->l) v->l->p = v;if(v->r) v->r->p = v;}
void push(Node *v) {
    if(!v) return; if(v->rev) {do_rev(v->l);do_rev(v->r);v->rev ^= 1;}}
void merge(Node *&v, Node *l, Node *r) {
    if(!l || !r) {v = l ? l : r;return;}
    push(l);push(r);
    if(l->prior < r->prior) {merge(l->r, l->r, r);v = l;}else {
        merge(r->l, l, r->l);v = r;}update(v);}
void split_by_cnt(Node *v, Node *&l, Node *&r, int x) {
    if(!v) {l = r = nullptr;return;}push(v);
    if(get_cnt(v->l) + 1 <= x) {
        split_by_cnt(v->r, v->r, r, x - get_cnt(v->l) - 1);l = v;
    }else {split_by_cnt(v->l, l, v->l, x);r = v;}
    update(l);update(r);
}
void push_path(Node *v) {
    if(!v) return;push_path(v->p);push(v);}
int get_pos(Node *v) {
    push_path(v);int res = 0, ok = 1;
    while(v) {if(ok) res += get_cnt(v->l) + 1;
        ok = v->p && v->p->r == v;v = v->p;}
    return res;}
Node *get_root(Node *v) const{while(v && v->p) v = v->p;return v;}
Node *shift(Node *v) {
    if(!v) return v;int pos = get_pos(v);
    Node *nl = nullptr, *nr = nullptr;Node *root = get_root(v);
    split_by_cnt(root, nl, nr, pos - 1);do_rev(nl);do_rev(nr);
    merge(root, nl, nr);do_rev(root);return root;}
public:EulerTourTrees() = default;
EulerTourTrees(int _n): n(_n) {ptr.resize(_n + 1);
    where_edge.resize(_n + 1);}
bool get(int u, int v) const {if(u == v) return true;
    Node *ru = get_root(ptr[u].empty() ? nullptr : *ptr[u].begin());
    Node *rv = get_root(ptr[v].empty() ? nullptr : *ptr[v].begin());
    return ru && ru == rv;}
void link(int u, int v) {
    Node *ru = shift(ptr[u].empty() ? nullptr : *ptr[u].begin());
    Node *rv = shift(ptr[v].empty() ? nullptr : *ptr[v].begin());
    Node *uv = new Node();Node *vu = new Node();
    ptr[u].insert(uv);ptr[v].insert(vu);
    where_edge[u][v] = uv;where_edge[v][u] = vu;
    merge(ru, ru, uv);merge(ru, ru, rv);merge(ru, ru, vu);}
void cut(int u, int v) {
    Node *uv = where_edge[u][v];Node *vu = where_edge[v][u];
    ptr[u].erase(uv);ptr[v].erase(vu);
    Node *root = shift(uv);Node *nl = nullptr, *nm = nullptr, *nr = nullptr;
    int pos1 = get_pos(uv);int pos2 = get_pos(vu);

```

```

    if(pos1 < pos2) {split_by_cnt(root, nl, nr, pos2);
        split_by_cnt(nl, nl, vu, pos2 - 1);split_by_cnt(nl, nl, nm, pos1);
        split_by_cnt(nl, nl, uv, pos1 - 1);merge(nl, nl, nr);}else {
        split_by_cnt(root, nl, nr, pos1);split_by_cnt(nl, nl, uv, pos1 - 1);
        split_by_cnt(nl, nl, nm, pos2);split_by_cnt(nl, nl, vu, pos2 - 1);
        merge(nl, nl, nm);}delete uv;delete vu;}
private:int n = 0;vec< set< Node* > > ptr;
    vec< unordered_map< int, Node* > > where_edge; // ptr to node
};

```

```

struct Edge {
    int fr, to, w, id;
    bool operator < (const Edge& o) const { return w < o.w; };
// find oriented mst (tree)
// there are no edge --> root (root is 0)
// 0 .. n - 1, WEIGHTS AND VERTICES WILL BE CHANGED, BUT IDS ARE OK
// graph[v] = set of incoming edges (u --> v)
// return from, s.t. from[v] -- incoming edge to the 'v' in mst
vector<Edge> work(const vector<vector<Edge>>& graph) {
    int n = (int) graph.size(); vector<int> color(n), used(n, -1);
    for (int i = 0; i < n; i++) color[i] = i; vector<Edge> e(n);
    for (int i = 0; i < n; i++) {
        if (graph[i].empty()) e[i] = {-1, -1, -1, -1};
        else e[i] = *min_element(graph[i].begin(), graph[i].end());
    }
    vector<vector<int>> cycles; used[0] = -2;
    for (int s = 0; s < n; s++) {
        if (used[s] != -1) continue;
        int x = s; while (used[x] == -1) used[x] = s, x = e[x].fr;
        if (used[x] != s) continue; vector<int> cycle = {x};
        for (int y = e[x].fr; y != x; y = e[y].fr) cycle.push_back(y), color[y] = x;
        cycles.push_back(cycle);}
    if (cycles.empty())return e;
    vector<vector<Edge>> next_graph(n);
    for (int s = 0; s < n; s++)
        for (const Edge& edge : graph[s])
            if (color[edge.fr] != color[s])
                next_graph[color[s]].push_back({color[edge.fr], color[s],
                                                    edge.w - e[s].w, edge.id});
    vector<Edge> tree = work(next_graph);
    for (const auto& cycle : cycles) {
        int cl = color[cycle[0]], from = -1;
        Edge next_out = tree[cl], out{};
        for (int v : cycle) {
            tree[v] = e[v];
            for (const Edge& edge : graph[v])
                if (edge.id == next_out.id)
                    from = v, out = edge;}
        tree[from] = out;}return tree;}

```

**Gomory-Hu tree (Gusfield's algorithm):** label nodes from 0 to  $(|V| - 1)$  and set  $p_i = 0 \forall i > 0$ .  $\forall i > 0$ : find min-cut  $(S, T)$  between  $i$  and  $p_i$ , where  $i \in S, p_i \in T$ ; for each node  $j$ , s.t.  $i < j, j \in S, p_j = p_i$  set  $p_j = i$

```

inline ll _sum(ll a, ll b, ll m) { return a + b < m ? a + b : a + b - m;}
inline ll _sub(ll a, ll b, ll m) {return a >= b ? a - b : a - b + m;}
inline ll _mul(ll a, ll b, ll m) {return (a * b) % m;}
struct gauss_number { ll w, p, x, y;
    gauss_number(): w(0), p(2), x(0), y(0) { }
    gauss_number(ll _w, ll _p, ll _x, ll _y): w(_w), p(_p), x(_x), y(_y) {
        assert(p > 0); w %= p; if(w < 0) w += p;
        x %= p; if(x < 0) x += p; y %= p; if(y < 0) y += p;}
    gauss_number(const gauss_number& o): w(o.w), p(o.p), x(o.x), y(o.y) { }
    gauss_number operator+(const gauss_number& o) const {
        return gauss_number(w, p, _sum(x, o.x, p), _sum(y, o.y, p));}
    gauss_number operator-() const {
        return gauss_number(w, p, !x ? x : p - x, !y ? y : p - y);}
    gauss_number operator-(const gauss_number& o) const {return *this + (-o);}
    gauss_number operator*(const gauss_number& o) const {
        return gauss_number(w, p, _sum(_mul(x, o.y, p), _mul(y, o.x, p), p),
            _sum(_mul(y, o.y, p), _mul(x, _mul(o.x, w, p), p), p));}
ll binpow(ll x, ll p, ll m) {
    ll res = 1 % m, tmp = x % m;
    if(res < 0) res += m; if(tmp < 0) tmp += m;
    while(p > 0) { if(p & 1) res = _mul(res, tmp, m);
        tmp = _mul(tmp, tmp, m); p >>= 1;}return res;}
gauss_number gauss_pow(gauss_number x, ll p) {
    gauss_number res(x.w, x.p, 0, 1), tmp(x);
    while(p > 0) {if(p & 1) res = res * tmp;
        tmp = tmp * tmp; p >>= 1;} return res;}
ll find_solution(ll p, ll a) { // x^2 = a (mod p), x = ?, p is prime
    assert(0ll <= a && a < p);
    if(a == 0 || p == 2) return a;
    if(binpow(a, (p - 1) / 2, p) == p - 1) return -1ll;
    mt19937_64 rnd(42); ll k; gauss_number e(a, p, 0, 1);
    while(1) { k = rnd() % p; if(k < 0) k += p;
        gauss_number y(a, p, 1, k);
        y = gauss_pow(y, (p - 1) / 2); y.y = _sub(y.y, 1, p);
        {ll re = _mul(y.y, binpow(y.x, p - 2, p), p);
            if(_mul(re, re, p) == a) return re;}}}

```

```

ll rec(ll pos, ll lx, ll lc, ll rx, ll rc, ll coins) {
    if (!coins || !rx) return pos;
    if (pos >= rx) {
        ll t = (lx - pos + rx - 1) / rx;
        if (t * rc + lc > coins) return pos;
        pos += t * rx - lx, coins -= (t * rc + lc);}
    ll nlx = lx % rx, nlc = (lx / rx) * rc + lc;
    if (nlx == 0) return pos;
    ll t = pos / nlx;
    if (t * nlc > coins) return pos - nlx * (coins / nlc);
    coins -= t * nlc;
    pos -= t * nlx;
    return rec(pos, nlx, nlc, rx % nlx, (rx / nlx) * rc + rc, coins);}

```

```
// finds (nw_st + step * x) % mod --> min, 0 <= x <= bound
ll euclid(ll nw_st, ll step, ll mod, ll bound) {return rec(nw_st, mod, 0, step, 1, bound);}
```

```
void fwht(ll* a, ll mod) { // any mod, len(a) = 2^LOG
    ll f1, f2; // c[i^j] += a[i] * b[j] => fwht(a), fwht(b), c = a * b, fwht(c)
    for (int len = 1; len < (1 << LOG); len <= 1) {
        for (int i = 0; i < (1 << LOG); i += 2 * len) {
            for (int j = 0; j < len; j++) {
                f1 = a[i + j] + a[i + j + len], f2 = a[i + j] - a[i + j + len];
                if (f1 >= mod) f1 -= mod; if (f2 < 0) f2 += mod;
                a[i + j] = f1, a[i + j + len] = f2;}}}}}
```

```
const int X = 1.5e7;
const int MEM_K = 20;
const int MEM_N = 1e5;
int d[X];
vector<int> ps;
int mem[MEM_K][MEM_N];
void precalc() {
    for (int p = 2; p < X; p++) {
        if (!d[p])
            ps.push_back(d[p] = p);
        for (int x : ps) {
            if (x > d[p] || x * p >= X) break;
            d[x * p] = x;
        }
        d[p] = d[p - 1] + (d[p] == p);}}
ll rec(ll n, int k) {
    if (n <= 1) return 0;
    if (k == 0) return n - 1;
    if (ps[k - 1] > n) return 0;
    if (n < X && 1ll * ps[k] * ps[k] > n) return d[n] - k;
    if (k < MEM_K && n < MEM_N && mem[k][n]) return mem[k][n] - 1;
    ll res = rec(n, k - 1) - rec(n / ps[k - 1], k - 1) - 1;
    if (k < MEM_K && n < MEM_N) mem[k][n] = res + 1;
    return res;}
ll get_cnt_primes(ll n) { // # primes on [1, n], n <= 10^11, 10 queries, ~500ms
    ll m = 1; while (m * m < n) m++; assert(m <= n);
    int k = d[m]; return k + rec(n, k);}
```

$$d_i = v_i - \sum_{j < i} \frac{\langle v_i, d_j \rangle}{\langle d_j, d_j \rangle} d_j$$

$$\sum_{k=1}^n \mu(k) \lfloor \frac{n}{k} \rfloor = 1$$

$$g(n) = \sum_{d|n} f(d) \Leftrightarrow f(n) = \sum_{d|n} \mu(d) g(n/d)$$

$$\mu_A^*(a, b) = \begin{cases} 1, & a = b \\ - \sum_{a \preceq z \prec b} \mu_A^*(a, z), & a \prec b \\ 0, & b \prec a \end{cases}$$

$$\sum_{d|n} \varphi(d) = n \quad \varphi(n) = \sum_{d|n} d \cdot \mu\left(\frac{n}{d}\right)$$

$$F(N) = \sum_{n=1}^N \varphi(n) \Rightarrow F(N) = \frac{N(N+1)}{2} - \sum_{k=2}^N F\left(\lfloor \frac{N}{k} \rfloor\right)$$



$$Gx = \{y \in X | \exists a \in G: a \star x = y\}$$

$$G_x = \{a \in G: a \star x = x\}$$

$$|G| = |Gx| \cdot |G_x|$$

$$X^a = \{x \in X: a \star x = x\}$$

$$|X/G| = \frac{1}{|G|} \sum_{a \in G} |X^a| \quad \prod_{k=1}^{\infty} (1 - x^k) = \sum_{q=-\infty}^{+\infty} (-1)^q x^{\frac{3q^2+q}{2}}$$

$$\prod_{k=1}^{\infty} \frac{1}{1-x^k} = \sum_{n=0}^{+\infty} p(n)x^n \Rightarrow p(0) = 1, p(n) = \sum_{q=1}^{+\infty} (-1)^{q+1} \left[ p\left(n - \frac{3q^2-q}{2}\right) + p\left(n - \frac{3q^2+q}{2}\right) \right]$$

$$M_1 = (S, I_1) \cap M_2 = (S, I_2). J.y \rightarrow z(J - y + z \in I_1).y \leftarrow z(J - y + z \in I_2)$$

$$X_1 = \{z \in S/J: J + z \in I_1\}. X_2 = \{z \in S/J: J + z \in I_2\}. \text{ Находим кратчайший путь из } X_1 \text{ в } X_2. \text{ Ксорим.}$$

```

struct comparator {
    pll center;
    comparator(pll p) : center(p) {}
    bool operator()(const pll& p, const pll& q) const {
        pll start(1, 0);
        if (p == q) return false;
        auto op = vect(center, p), oq = vect(center, q);
        if (cp(op, oq) == 0 && dp(op, oq) > 0) return false;
        ll sop = cp(start, op), soq = cp(start, oq);
        if (sop == 0) { if (dp(start, op) > 0) { return true; } else { return soq < 0; } }
        if (soq == 0) { if (dp(start, oq) > 0) { return false; } else { return sop > 0; } }
        if ((sop > 0 && soq > 0) || (sop < 0 && soq < 0)) { return cp(op, oq) > 0; }
        return sop > 0;
    }
};

```