

Содержание

1 Настройка CLion	1
2 Теория чисел	1
2.1 КТО	1
2.2 Алгоритм Миллера — Рабина	2
2.3 Алгоритм Берлекэмпа — Мессис	2
2.4 Линейное решето	2
3 Графы	2
3.1 SCC и 2-SAT	2
3.2 Эйлеров цикл	2
3.3 Компоненты рёберной двусвязности	2
3.4 DCP offline	3
3.5 Взвешенное паросочетание	3
4 Свёртки	5
4.1 AND, OR, XOR свёртки	5
4.2 FFT & co	5
4.3 Быстрое FFT	6
4.4 FFT в double'ax	7
5 Структуры данных	8
5.1 Дерево Фенвика	8
5.2 Дерево отрезков в точке	8
5.3 Массовое дерево отрезков	9
5.4 Битовый бор	10
5.5 Ordered set	11
5.6 Convex hull trick	11
5.7 Центроиды	11
5.8 Дерево Ли Чао	11
5.9 Min-Kinetic Segment Tree	12
6 Строковые алгоритмы	13
6.1 Префикс-функция	13
6.2 Z-функция	13
6.3 Алгоритм Манакера	13
6.4 Суфмассив	13
6.5 Алгоритм Ахо — Корасик	14
6.6 Алгоритм Ахо Корасик	14
6.7 Дерево палиндромов	14
6.8 Дерево палиндромов	14
7 Потоки	15
7.1 Алгоритм Диница	15
7.2 Mincost k-flow	15
8 Гамильтоновы путь и цикл	16
8.1 Link-cut tree	16
8.2 Undirected case	17
8.3 Directed case	17
9 Геометрия	18
9.1 Примитивы	18
9.2 Выпуклая оболочка	18
9.3 Точка внутри многоугольника	19
9.4 Касательные	19
10 Цепные дроби	19
10.1 Поиск нижней огибающей, сумма и минимум по модулю	19
10.2 Простая рекурсия	20
11 Разное	20
11.1 Компараторы	20
11.2 Трюки от Сергея Копелиовича	20
11.2.1 Быстрый ввод	20
11.2.2 Быстрый аллокатор	20
11.3 Флаги копирования	21
11.3.1 Сеточка в vim	21
11.4 Что сделать на пробном туре	21
11.5 Хеш файла без комментариев	21

1 Настройка CLion

1. В файле CMakeLists.txt дописать строчку `add_compile_definitions(LOCAL)`. Нажать появившуюся опцию в правом верхнем углу `enable auto-reload`.

2. Вбить шаблон в `main.cpp`:

```
#ifndef LOCAL
#define _GLIBCXX_DEBUG
#endif
#include<bits/stdc++.h>

using namespace std;

#define int long long
#define app push_back
#define all(x) x.begin(), x.end()
#ifdef LOCAL
#define debug(...) [](auto...a){ ((cout << a << ' '
), ...) << endl; }(__VA_ARGS__, "");
__VA_ARGS__
#define debugv(v) do { cout << #v << ": "; for (
auto x : v) cout << x << ' '; cout << endl; }
while(0)
#else
#define debug(...)
#define debugv(v)
#endif

int32_t main() {
    cin.tie(0); ios_base::sync_with_stdio(0);
    int n = 2; vector<int> a(n, n);
    debug(n); debugv(a);
}

//59124c
```

Скомпилировать, чтобы проверить отсутствие опечаток.

3. Запустить терминал (`ctrl + alt + T`)

```
$ cd workspace/CLionProjects
$ for c in {A..Z}; do cp main.cpp $c.cpp && echo "
add_executable($c $c.cpp)" >> CMakeLists.txt;
done
```

Далее отключаем подсветку и форматирование в настройках (`ctrl+alt+S`)

- Editor → Code Style → Formatter → Do not format прописать *
- Editor → Inspections → C/C++ → static analysis tools → CLang-Tidy отключить
- Editor → Inlay Hints → отключаем всё (достаточно первых трёх — code vision, parameter names, types).

Тёмная тема отключается в Appearance & Behavior → Appearance.

Чтобы добавить санитайзеры, надо дописать в CMakeLists.txt `set(CMAKE_CXX_FLAGS "-fsanitize=address -fsanitize=undefined")`

2 Теория чисел

2.1 КТО

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

int inv(int r, int m) {
    int x, y;
    gcd(r, m, x, y);
    return (x+m)%m;
}

int crt(int r, int n, int c, int m) { return r + ((c -
r) % m + m) * inv(n, m) % m * n; }

//8ed8ed
```

2.2 Алгоритм Миллера — Рабина

```
__int128 one=1;
int po(int a,int b,int p)
{
    int res=1;
    while(b) {if(b & 1) {res=(res*one*a)%p;--b;} else {a
        =(a*one*a)%p;b>>=1;}} return res;
}
bool chprime(int n) //miller-rabin
{
    if(n==2) return true;
    if(n<=1 || n%2==0) return false;
    int h=n-1;int d=0;while(h%2==0) {h/=2;++d;}
    for(int a:{2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31,
        37})
    {
        if(a==n) return true;
        int u=po(a,h,n);bool ok=0;
        if(u%n==1) continue;
        for(int c=0;c<d;++c)
        {
            if((u+1)%n==0) {ok=1;break;}
            u=(u*one*u)%n;
        }
        if(!ok) return false;
    }
    return true;
}
//86b2ed
```

2.3 Алгоритм Берлекэмп — Мессе

<https://mzhang2021.github.io/cp-blog/berlekamp-massey/>

```
template<typename T>
vector<T> berlekampMassey(const vector<T> &s) {
    int n = s.size(), l = 0, m = 1;
    vector<T> b(n), c(n);
    T ld = b[0] = c[0] = 1;
    for (int i=0; i<n; i++, m++) {
        T d = s[i];
        for (int j=1; j<=l; j++)
            d += c[j] * s[i-j];
        if (d == 0) continue;
        vector<T> temp = c;
        T coef = d / ld;
        for (int j=m; j<n; j++) c[j] -= coef * b[j-m];
        if (2 * l <= i) {
            l = i + 1 - l;
            b = temp;
            ld = d;
            m = 0;
        }
    }
    c.resize(l + 1);
    c.erase(c.begin());
    for (T &x : c)
        x = -x;
    return c;
}
//ff47ae
```

2.4 Линейное решето

```
const int N = 10000000;
int lp[N+1];
vector<int> pr;

for (int i=2; i<=N; ++i) {
    if (lp[i] == 0) {
        lp[i] = i;
        pr.push_back(i);
    }
    for (int j=0; j<pr.size() && pr[j]<=lp[i] && i*pr[j]
        <=N; ++j)
        lp[i * pr[j]] = pr[j];
}
//f514d5
```

3 Графы

3.1 SCC и 2-SAT

Алгоритм ищет сильносвязные компоненты в графе g , если есть путь $i \rightarrow j$, то $scc[i] \leq scc[j]$

```
vector<int> find_scc(vector<vector<int>> g) {
    vector<vector<int>> r(g.size());
    for (int i = 0; i < g.size(); ++i) {
        for (int j : g[i]) r[j].push_back(i);
    }
    vector<int> used(g.size()), tout(g.size());
    int time = 0;
    auto dfs = [&](auto dfs, int cur) -> void {
        if (used[cur]) return;
        used[cur] = 1;
        for (int nxt : g[cur]) {
            dfs(dfs, nxt);
        }
        tout[cur] = time++;
    };
    for (int i = 0; i < g.size(); ++i) if (!used[i]) dfs
        (dfs, i);
    vector<int> ind(g.size());
    iota(ind.begin(), ind.end(), 0);
    sort(all(ind), [&](int i, int j){return tout[i] >
        tout[j];});
    vector<int> scc(g.size(), -1);
    auto go = [&](auto go, int cur, int color) -> void {
        if (scc[cur] != -1) return;
        scc[cur] = color;
        for (int nxt : r[cur]) {
            go(go, nxt, color);
        }
    };
    int color = 0;
    for (int i : ind) {
        if (scc[i] == -1) go(go, i, color++);
    }
    return scc;
}
//08f99a
```

Чтобы решать 2-SAT, надо создать граф на $2n$ вершинах, рёбра $i \Rightarrow j$ и $(j \oplus 1) \Rightarrow (i \oplus 1)$ должны быть добавлены одновременно. После этого если $scc[2 * i] = scc[2 * i + 1]$, то решения нет; если $scc[2 * i + 0] < scc[2 * i + 1]$, то присутствует импликация $\neg i \Rightarrow i$, надо назначить $i = \text{true}$.

3.2 Эйлеров цикл

```
vector<int> euler(vector<vector<pair<int, int>>> g,
    int m, int src) { // g[cur][i] = pair{nxt, idx}
    int n = g.size();
    vector<int> used(m), it(n), cycle;
    auto dfs = [&](auto dfs, int cur) -> void {
        while (true) {
            while (it[cur] < g[cur].size() && used[g[cur][it
                [cur]].second]) it[cur]++;
            if (it[cur] == g[cur].size()) return;
            auto [nxt, idx] = g[cur][it[cur]];
            used[idx] = true;
            dfs(dfs, nxt);
            cycle.push_back(idx); // or {cur, nxt}
        }
    };
    dfs(dfs, src);
    reverse(cycle.begin(), cycle.end());
    if (cycle.size() != m) return {}; // check that all
        edges are present in the cycle, fail otherwise
    return cycle;
}
//f6b9d4
```

3.3 Компоненты рёберной двусвязности

```
int n, m;
cin >> n >> m;
vector <vector <int> > g(n + 1);
map <pair <int, int>, int> comp, col;
```

```

for (int i = 0; i < m; ++i) {
    int u, v, c; cin >> u >> v >> c; c--;
    col[{u,v}]=col[{v,u}]=c;
    g[u].push_back(v);
    g[v].push_back(u);
}
vector<int> used(n + 1);
vector<int> newCompWithoutParent(n + 1), h(n + 1), up
    (n + 1);
auto findCutPoints = [&] (auto self, int u, int p) ->
    void {
    used[u] = 1;
    up[u] = h[u];
    for (int v : g[u]) {
        if (!used[v]) {
            h[v] = h[u] + 1;
            self(self, v, u);
            up[u] = min(up[u], up[v]);
            if (up[v] >= h[u]) {
                newCompWithoutParent[v] = 1;
            }
        }
        else {
            up[u] = min(up[u], h[v]);
        }
    }
};
for (int u = 1; u <= n; ++u) {
    if (!used[u]) {
        findCutPoints(findCutPoints, u, u);
    }
}
int ptr = 0;
vector<map<int, int>> colors(m);
auto markComponents = [&] (auto self, int u, int cur)
    -> void {
    used[u] = 1;
    for (int v : g[u]) {
        if (!used[v]) {
            if (newCompWithoutParent[v]) {
                ptr++;
                self(self, v, ptr - 1);
            }
            else {
                self(self, v, cur);
            }
        }
        else if (h[v] < h[u]) {
            comp[{u,v}]=comp[{v,u}]=cur;
            int c = col[{u,v}];
            colors[cur][u] |= 1 << c;
            colors[cur][v] |= 1 << c;
        }
    }
};
used.assign(n + 1, 0);
for (int u = 1; u <= n; ++u) {
    if (!used[u]) {
        markComponents(markComponents, u, -1);
    }
}
for (int comp = 0; comp < m; ++comp) {
    vector<int> cnt(4);
    int tot = 0;
    for (auto [u, mask] : colors[comp]) {
        tot |= mask;
        cnt[bp(mask)]++;
    }
    if (bp(tot) < 3) {
        continue;
    }
    if (cnt[2] || cnt[3] > 2) {
        cout << "Yes" << endl;
        return;
    }
}
cout << "No" << endl;
//01817d

```

3.4 DCP offline

```

struct Dsu {
    int n;
    vector<pair<int &, int>> s;
    vector<int> p, sz;
    // other info

    Dsu(int n) : n(n), p(n), sz(n, 1) {
        iota(all(p), 0);
    }

    int get(int u) {
        while (u != p[u]) u = p[u];
        return u;
    }

    bool merge(int u, int v) {
        u = get(u), v = get(v);
        if (u == v) return false;
        if (sz[v] < sz[u]) swap(u, v);
        s.app({p[u], p[u]});
        s.app({sz[v], sz[v]});
        // app other info like s.app({comp, comp});
        p[u] = v;
        sz[v] += sz[u];
        return true;
    }

    void rollback(int sz) {
        while (s.size() != sz) {
            s.back().first = s.back().second;
            s.pop_back();
        }
    }
};

struct DcpOffline {
    int n;
    vector<vector<pair<int, int>>> d;

    void addEdgeOnSegment(int l, int r, int a, int b)
    {
        for (l += n, r += n; l < r; l /= 2, r /= 2) {
            if (l & 1) d[l++].app({a, b});
            if (r & 1) d[--r].app({a, b});
        }
    }

    template<typename T>
    void dfs(Dsu &dsu, T act) {
        dfs(1, 0, n, dsu, act);
    }

    template<typename T>
    void dfs(int v, int l, int r, Dsu &dsu, T act) {
        int sz = dsu.s.size();
        for (auto [u, v] : d[v]) {
            dsu.merge(u, v);
        }
        if (l + 1 == r) {
            act(l, dsu);
        }
        else {
            int m = (l + r) / 2;
            dfs(v * 2, l, m, dsu, act);
            dfs(v * 2 + 1, m, r, dsu, act);
        }
        dsu.rollback(sz);
    }

    DcpOffline(int maxt) : n(2 << __lg(maxt + 1)), d(2
        * n) {}
};
//3c4e2d

```

3.5 Взвешенное паросочетание

<https://judge.yosupo.jp/submission/201334>

```

namespace blossom {
#define d(x) (lab[x.u] + lab[x.v] - 2 * e[x.u][x.v].w)
const int N = 403*2;
const int inf = 1e18;

```

```

struct Q{ int u, v, w; } e[N][N];
vector<int> p[N];
int n, m = 0, id, h, t, lk[N], sl[N], st[N], f[N],
    b[N][N], s[N], ed[N], q[N], lab[N];
void upd(int u, int v) { if (!sl[v] || d(e[u][v])
    < d(e[sl[v]][v])) sl[v] = u; }
void ss(int v) {
    sl[v] = 0;
    for (int u = 1; u <= n; ++u) if (e[u][v].w > 0
        && st[u] != v && !s[st[u]]) upd(u, v);
}
void ins(int u){ if (u <= n) q[++t] = u; else for
(int v : p[u]) ins(v); }
void ch(int u, int w) { st[u] = w; if (u > n) for
(int v : p[u]) ch(v, w); }
int gr(int u, int v) {
    if ((v = find(all(p[u]), v) - p[u].begin()) &
    1) {
        reverse(1 + all(p[u]));
        return (int)p[u].size() - v;
    }
    return v;
}
void stm(int u, int v) {
    lk[u] = e[u][v].v;
    if (u <= n) return; Q w = e[u][v];
    int x = b[u][w.u], y = gr(u, x);
    for (int i = 0; i < y; ++i) stm(p[u][i], p[u][
    i^1]);
    stm(x, v); rotate(p[u].begin(), y+all(p[u]));
}
void aug(int u, int v) {
    int w = st[lk[u]];stm(u, v);if (!w) return;
    stm(w, st[f[w]]);
    aug(st[f[w]], w);
}
int lca(int u, int v) {
    for (id++; u|v; swap(u, v)) {
        if (!u) continue;if(ed[u] == id) return u;
        ed[u] = id; if (u = st[lk[u]]) u = st[f[u
    ]]; // =, not ==
    }
    return 0;
}
void add(int u, int a, int v) {
    int x = n + 1; while (x <= m && st[x]) ++x;
    if (x > m) ++m;
    lab[x] = s[x] = st[x] = 0;
    lk[x] = lk[a];
    p[x].clear();
    p[x].push_back(a);
#define op(q) for (int i = q, j = 0; i != a; i=st[f[j
    ]]) p[x].push_back(i), p[x].push_back(j=st[lk[i]])
    , ins(j) // also not ==
    op(u); reverse(1+all(p[x]));op(v);
    ch(x, x); for (int i = 1; i <= m; ++i) e[x][i
    ].w = e[i][x].w = 0;
    fill(b[x]+1, b[x]+n+1, 0);
    for (int u : p[x]) {
        for (int v = 1; v <= m; ++v) if (!e[x][v].
    w || d(e[u][v]) < d(e[x][v])) e[x][v] = e[u][v], e
    [v][x] = e[v][u];
        for (int v = 1; v <= n; ++v) if (b[u][v])
    b[x][v] = u;
    }
    ss(x);
}
void ex(int u) {
    for (int x : p[u]) ch(x, x);
    int a = b[u][e[u][f[u]].u], r = gr(u, a);
    for (int i = 0; i < r; i += 2) {
        int x = p[u][i], y = p[u][i + 1];
        f[x] = e[y][x].u; s[x] = 1; s[y] = 0; sl[x
    ] = 0; ss(y); ins(y);
    }
    s[a] = 1; f[a] = f[u];
    for (int i = r + 1; i < p[u].size(); ++i) s[p[
    u][i]] = -1, ss(p[u][i]);
    st[u] = 0;
}

```

```

bool on(const Q &e) {
    int u = st[e.u], v = st[e.v], a;
    if (s[v] == -1) {
        f[v] = e.u, s[v] = 1, a = st[lk[v]], sl[v]
    = sl[a] = s[a] = 0, ins(a);
    } else if (!s[v]) {
        a = lca(u, v); if (!a) return aug(u, v),
    aug(v, u), 1; else add(u, a, v);
    }
    return 0;
}
bool bfs() {
    fill(s+1, s+m+1, -1);fill(sl+1, sl+m+1, 0); //
    s is filled with -1
    h = 1, t = 0; for (int i = 1; i <= m; ++i) if
    (st[i] == i && !lk[i]) f[i] = s[i] = 0, ins(i);
    if (h > t) return 0;
    while (1) {
        while (h <= t) {
            int u = q[h++];
            if (s[st[u]] != 1) {
                for (int v = 1; v <= n; ++v) if (e
    [u][v].w > 0 && st[u] != st[v]) {
                    if (d(e[u][v])) upd(u, st[v]);
                    else if (on(e[u][v])) return 1;
                }
            }
            int x = inf;
            for (int i = n+1; i <= m; ++i) if (st[i]
    == i && s[i] == 1) x = min(x, lab[i]/2);
            for (int i = 1; i <= m; ++i) if (st[i] ==
    i && sl[i] && s[i] != 1) x = min(x, d(e[sl[i]][i])
    >>s[i]+1);
            for (int i = 1; i <= n; ++i) if (~s[st[i
    ]]) if ((lab[i] += (s[st[i]] * 2 - 1) * x) <=0)
            return 0;
            for (int i = n + 1; i <= m; ++i) if (st[i]
    == i && ~s[st[i]]) lab[i] += (2 - 4 * s[st[i]]) *
    x;
            h = 1, t = 0;
            for (int i = 1; i <= m; ++i) if (st[i] ==
    i && sl[i] && st[sl[i]] != i && !d(e[sl[i]][i]) &&
    on(e[sl[i]][i])) return 1;
            for (int i = n+1; i <= m; ++i) if (st[i]
    == i && s[i] == 1 && !lab[i]) ex(i);
        }
    }
}
pair<int, vector<array<int, 2>>> run(int N, vector
<array<int, 3>> edges) {
    for (auto &[u, v, w] : edges) ++u, ++v;
    fill(ed+1, ed+m+1, 0);
    fill(lk+1, lk+m+1, 0);
    n = m = N;
    id = 0;
    iota(st + 1, st + n + 1, 1);
    int wm = 0, weight = 0;
    for (int i = 1; i <= n; ++i) for (int j = 1; j
    <= n; ++j) e[i][j] = {i, j, 0};
    for (auto [u, v, w] : edges) wm = max(wm, e[v
    ][u].w = e[u][v].w = max(e[u][v].w, w));
    for (int i = 1; i <= n; ++i) p[i].clear();
    for (int i = 1; i <= n; ++i) for (int j = 1; j
    <= n; ++j) b[i][j] = i==j?i:0;
    fill_n(lab+1, n, wm); while (bfs());
    vector<array<int, 2>> matching;
    for (int i = 1; i <= n; ++i) if (i < lk[i])
    weight += e[i][lk[i]].w, matching.push_back({i -
    1, lk[i] - 1});
    return {weight, matching};
}

```

//24933a

4 Свёртки

4.1 AND, OR, XOR свёртки

```
const int p = 998244353;
vector<int> band(vector<int> a, vector<int> b)
{
    int n=0; while((1<<n)<a.size()) ++n;
    a.resize(1<<n); b.resize(1<<n);
    for(int i=0; i<n; ++i) for(int mask=0; mask<(1<<n); ++mask)
        if(mask & (1<<i)) {a[mask-(1<<i)]+=a[mask]; a[mask-(1<<i)]%=p;}
    for(int i=0; i<n; ++i) for(int mask=0; mask<(1<<n); ++mask)
        if(mask & (1<<i)) {b[mask-(1<<i)]+=b[mask]; b[mask-(1<<i)]%=p;}
    vector<int> c(1<<n, 0);
    for(int mask=0; mask<(1<<n); ++mask) {c[mask]=a[mask]*b[mask]; c[mask]%=p;}
    for(int i=0; i<n; ++i) for(int mask=0; mask<(1<<n); ++mask)
        if(!(mask & (1<<i))) {c[mask]-=c[mask+(1<<i)]}; c[mask]%=p;}
    return c;
}
vector<int> bor(vector<int> a, vector<int> b)
{
    int n=0; while((1<<n)<a.size()) ++n;
    a.resize(1<<n); b.resize(1<<n);
    for(int i=0; i<n; ++i) for(int mask=0; mask<(1<<n); ++mask)
        if(!(mask & (1<<i))) {a[mask+(1<<i)]+=a[mask]; a[mask+(1<<i)]%=p;}
    for(int i=0; i<n; ++i) for(int mask=0; mask<(1<<n); ++mask)
        if(!(mask & (1<<i))) {b[mask+(1<<i)]+=b[mask]; b[mask+(1<<i)]%=p;}
    vector<int> c(1<<n, 0);
    for(int mask=0; mask<(1<<n); ++mask) {c[mask]=a[mask]*b[mask]; c[mask]%=p;}
    for(int i=0; i<n; ++i) for(int mask=0; mask<(1<<n); ++mask)
        if(mask & (1<<i)) {c[mask]-=c[mask-(1<<i)]}; c[mask]%=p;}
    return c;
}
vector<int> bxor(vector<int> a, vector<int> b)
{
    assert(p%2==1); int inv2=(p+1)/2;
    int n=0; while((1<<n)<a.size()) ++n;
    a.resize(1<<n); b.resize(1<<n);
    for(int i=0; i<n; ++i) for(int mask=0; mask<(1<<n); ++mask)
        if(!(mask & (1<<i))) {int u=a[mask], v=b[mask+(1<<i)]; a[mask+(1<<i)]=(u+v)%p; a[mask]=(u-v)%p;}
    for(int i=0; i<n; ++i) for(int mask=0; mask<(1<<n); ++mask)
        if(!(mask & (1<<i))) {int u=b[mask], v=b[mask+(1<<i)]; b[mask+(1<<i)]=(u+v)%p; b[mask]=(u-v)%p;}
    vector<int> c(1<<n, 0);
    for(int mask=0; mask<(1<<n); ++mask) {c[mask]=a[mask]*b[mask]; c[mask]%=p;}
    for(int i=0; i<n; ++i) for(int mask=0; mask<(1<<n); ++mask)
        if(!(mask & (1<<i))) {int u=c[mask], v=c[mask+(1<<i)]; c[mask+(1<<i)]=(v-u)*inv2%p; c[mask]=(u+v)*inv2%p;}
    return c;
}
//bd06c6
```

4.2 FFT & co

```
typedef long long ll;
const int p=998244353;
int po(int a, int b) {if(b==0) return 1; if(b==1) return a; if(b%2==0) {int u=po(a, b/2); return (u*1LL*u)%p;} else {int u=po(a, b-1); return (a*1LL*u)%p;}}
int inv(int x) {return po(x, p-2);}
template<int M, int K, int G> struct Fft {
    // 1, 1/4, 1/8, 3/8, 1/16, 5/16, 3/16, 7/16, ...
    int g[1<<(K-1)];
    Fft() : g() { //if t1 constexpr...
        static_assert(K >= 2, "Fft: K >= 2 must hold");
        g[0] = 1;
        g[1<<(K-2)] = G;
    }
};
```

```
for (int l = 1 << (K - 2); l >= 2; l >= 1) {
    g[l >> 1] = (g[l] * 1LL * g[l]) % M;
}
assert((g[1]*1LL * g[1]) % M == M - 1);
for (int l = 2; l <= 1 << (K - 2); l <= 1) {
    for (int i = 1; i < l; ++i) {
        g[l + i] = (g[l] * 1LL * g[i]) % M;
    }
}
}

void fft(vector<int> &x) const {
    const int n = x.size();
    assert(n <= 1 << K);
    for (int h = __builtin_ctz(n); h--;) {
        const int l = (1 << h);
        for (int i = 0; i < n >> (h+1); ++i) {
            for (int j = i << (h+1); j < ((i << 1) + 1) << h; ++j) {
                const int t = (g[i] * 1LL * x[j | l]) % M;
                x[j | l] = x[j] - t;
                if (x[j | l] < 0) x[j | l] += M;
                x[j] += t;
                if (x[j] >= M) x[j] -= M;
            }
        }
    }
    for (int i = 0, j = 0; i < n; ++i) {
        if (i < j) std::swap(x[i], x[j]);
        for (int l = n; (l >= 1) && !((j ^ l) & 1); )
            {}
    }
}

vector<int> convolution(vector<int> a, vector<int> b)
{
    const {
        if(a.empty() || b.empty()) return {};
        for(int& x:a) {x%=p; if(x>=p) x-=p; if(x<0) x+=p;}
        for(int& x:b) {x%=p; if(x>=p) x-=p; if(x<0) x+=p;}
        const int na = a.size(), nb = b.size();
        int n, invN = 1;
        for (n = 1; n < na + nb - 1; n <= 1) invN = ((invN & 1) ? (invN + M) : invN) >> 1;
        vector<int> x(n, 0), y(n, 0);
        std::copy(a.begin(), a.end(), x.begin());
        std::copy(b.begin(), b.end(), y.begin());
        fft(x);
        fft(y);
        for (int i = 0; i < n; ++i) x[i] = (((static_cast<long long>(x[i]) * y[i]) % M) * invN) % M;
        std::reverse(x.begin() + 1, x.end());
        fft(x);
        x.resize(na + nb - 1);
        return x;
    }
};
Fft<998244353, 23, 31> muls;

vector<int> form(vector<int> v, int n)
{
    while(v.size()<n) v.push_back(0);
    while(v.size()>n) v.pop_back();
    return v;
}

vector<int> operator *(vector<int> v1, vector<int> v2)
{
    return muls.convolution(v1, v2);
}

vector<int> operator +(vector<int> v1, vector<int> v2)
{
    while(v2.size()<v1.size()) v2.push_back(0); while(v1.size()<v2.size()) v1.push_back(0);
    for(int i=0; i<v1.size(); ++i) {v1[i]+=v2[i]; if(v1[i]>=p) v1[i]-=p; else if(v1[i]<0) v1[i]+=p;}
    return v1;
}

vector<int> operator -(vector<int> v1, vector<int> v2)
{
    int sz=max(v1.size(), v2.size()); while(v1.size()<sz) v1.push_back(0); while(v2.size()<sz) v2.push_back(0);
    for(int i=0; i<sz; ++i) {v1[i]-=v2[i]; if(v1[i]<0) v1[i]+=p;}
}
```

```

    ]+=p; else if(v1[i]>=p) v1[i]-=p;} return v1;
}
vector<int> trmi(vector<int> v)
{
    for(int i=1;i<v.size();i+=2) {if(v[i]>0) v[i]=p-v[i]
    ]; else v[i]=(-v[i]);}
    return v;
}
vector<int> deriv(vector<int> v)
{
    if(v.empty()) return{};
    vector<int> ans(v.size()-1);
    for(int i=1;i<v.size();++i) ans[i-1]=(v[i]*1LL*i)%p;
    return ans;
}
vector<int> integ(vector<int> v)
{
    vector<int> ans(v.size()+1);ans[0]=0;
    for(int i=1;i<v.size();++i) ans[i-1]=(v[i]*1LL*i)%p;
    return ans;
}
vector<int> mul(vector<vector<int> > v)
{
    if(v.size()==1) return v[0];
    vector<vector<int> > v1,v2;for(int i=0;i<v.size()
    /2;++i) v1.push_back(v[i]); for(int i=v.size()/2;i
    <v.size();++i) v2.push_back(v[i]);
    return muls.convolution(mul(v1),mul(v2));
}
vector<int> invl(vector<int> v,int n)
{
    assert(v[0]!=0);
    int sz=1;v=form(v,n);vector<int> a={inv(v[0])};
    while(sz<n)
    {
        vector<int> vsz;for(int i=0;i<min(n,2*sz);++i) vsz
        .push_back(v[i]);
        vector<int> b=((vector<int>) {1})-muls.convolution
        (a,vsz);
        for(int i=0;i<sz;++i) assert(b[i]==0);
        b.erase(b.begin(),b.begin()+sz);
        vector<int> c=muls.convolution(b,a);
        for(int i=0;i<sz;++i) a.push_back(c[i]);
        sz*=2;
    }
    return form(a,n);
}
//285dcc

```

4.3 Быстрое FFT

- Solution based on <https://codeforces.com/blog/entry/117947>
- Iterative and in-place version.
- Uses signed montgomery
- Optimized to minimize memory usage

```

const int MOD = 998244353;
const long long MOD2 = (long long) MOD * MOD;
const int root = 3;
const int alim = 64; // Bound for using O(n^2)
                        polynomial mult

int modpow(int b, int e) {
    int ans = 1;
    for (; e; b = (long long) b * b % MOD, e /= 2)
        if (e & 1) ans = (long long) ans * b % MOD;
    return ans;
}

const int MODinv = 2 - MOD; // pow(-MOD, -1, 2**32)
inline int m_reduce(long long x) {
    int m = x * MODinv;
    return (x>>32) - (((long long) m * MOD) >> 32);
}

const int r2 = modpow(2, 64);
inline int m_transform(int x) {

```

```

    return m_reduce((long long)x * r2);
}

inline int m_add(int x, int y) {
    int z = x + y;
    return z < 0 ? z + MOD : z - MOD;
}

inline int m_sub(int x, int y) {
    int z = x - y;
    return z < 0 ? z + MOD : z - MOD;
}

inline int m_mult(int x, int y) {
    return m_reduce((long long) x * y);
}

vector<int> rt = {1};
vector<int> transformed_rt;
vector<int> transformed_rt2;

template<int a>
void transform(vector<int> &P) {
    int m = P.size();
    int n = m / a;

    int size = rt.size();
    while (2 * size < n) {
        rt.resize(n / 2);
        int r = modpow(root, MOD / (4 * size));
        for (int i = 0; i < size; ++i)
            rt[i + size] = (long long) r * rt[i] % MOD
        ;
        size *= 2;
    }

    // For montgomery
    for (int i = transformed_rt.size(); i < rt.size();
    ++i) {
        transformed_rt.resize(rt.size());
        transformed_rt[i] = m_transform(rt[i]);
        transformed_rt2.resize(rt.size());
        transformed_rt2[i] = (unsigned int) MODinv *
        transformed_rt[i];
    }

    int k = n;
    while (k >= 4) k /= 4;

    if (k == 2) {
        int step = n * a;
        int half_step = step / 2;
        for (int j1 = 0; j1 < half_step; ++j1) {
            int j2 = j1 + half_step;

            int diff = m_sub(P[j1], P[j2]);
            P[j1] = m_add(P[j1], P[j2]);
            P[j2] = diff;
        }
        k = n/2;
    } else {
        k = n;
    }

    for (; k > 1; k /= 4) {
        for (int i = 0; i < n/k; ++i) {
            int step = k * a;
            int half_step = step / 2;
            int quarter_step = half_step / 2;

            int R20 = transformed_rt2[2 * i];
            int RR0 = transformed_rt[2 * i];

            int R21 = transformed_rt2[2 * i + 1];
            int RR1 = transformed_rt[2 * i + 1];

            int R2 = transformed_rt2[i];
            int RR = transformed_rt[i];

            int j1 = i * step;

```



```

    int j2 = j1 + quarter_step;
    int j3 = j2 + quarter_step;
    int j4 = j3 + quarter_step;

    for (int j = 0; j < quarter_step; ++j, ++j1, ++j2, ++j3, ++j4) {
        int z0;
        {
            int z = P[j3];
            int m = (unsigned int) R2 * z;
            z0 = ((long long) z * RR - (long long) m * MOD) >> 32;
        }

        int z1;
        {
            int z = P[j4];
            int m = (unsigned int) R2 * z;
            z1 = ((long long) z * RR - (long long) m * MOD) >> 32;
        }

        int sum0 = m_add(P[j1], z0);
        int diff0 = m_sub(P[j1], z0);
        int sum1 = P[j2] + z1;
        int diff1 = P[j2] - z1;

        // [sum0, sum1, diff0, diff1]

        int zz0;
        {
            int z = sum1;
            int m = (unsigned int) R20 * z;
            zz0 = ((long long) z * RR0 - (long long) m * MOD) >> 32;
        }

        int zz1;
        {
            int z = diff1;
            int m = (unsigned int) R21 * z;
            zz1 = ((long long) z * RR1 - (long long) m * MOD) >> 32;
        }

        P[j1] = m_add(sum0, zz0);
        P[j2] = m_sub(sum0, zz0);
        P[j3] = m_add(diff0, zz1);
        P[j4] = m_sub(diff0, zz1);
    }
}

for (int i = 0; i < m; ++i)
    if (P[i] < 0) P[i] += MOD;
}

template<int a>
void inverse_transform(vector<int> &P) {
    int m = P.size();
    int n = m / a;
    int n_inv = m_transform(modpow(n, MOD - 2));

    vector<int> rev(n);
    for (int i = 1; i < n; ++i) {
        rev[i] = rev[i / 2] / 2 + (i & 1) * n / 2;
    }

    // P = [p * n_inv for p in P]
    for (int i = 0; i < m; ++i)
        P[i] = m_mult(n_inv, P[i]);

    // P = [P[a * rev[i] // a] + (i % a)] for i in range(m)]
    for (int i = 1; i < n; ++i)
        if (i < rev[i])
            swap_ranges(P.begin() + a * i, P.begin() + a * i + a, P.begin() + a * rev[i]);

    // P = [P[-a * (i // a) + (i % a)] for i in range(

```

```

m)]
for (int i = 1; i < n/2; ++i)
    swap_ranges(P.begin() + a * i, P.begin() + a * i + a, P.begin() + a * (n - i));

transform<a>(P);

// P = [P[a * rev[i] // a] + (i % a)] for i in range(m)]
for (int i = 1; i < n; ++i)
    if (i < rev[i])
        swap_ranges(P.begin() + a * i, P.begin() + a * i + a, P.begin() + a * rev[i]);
}

template<int a>
void fast_polymult_mod(vector<int> &P, vector<int> &Q)
{
    int m = P.size();
    int n = m / a;

    transform<a>(P);
    transform<a>(Q);

    vector<int> &PQ = P;
    for (int i = 0; i < n; ++i) {
        vector<unsigned long long> res(2 * a);
        for (int j = 0; j < a; ++j) {
            if (j >= 10 && j % 9 == 8)
                for (int k = j; k < j + a - 10; ++k)
                    res[k] -= (res[k] >> 63) * 9 * MOD2;
            for (int k = 0; k < a; ++k)
                res[j + k] += (long long) P[i * a + j] * Q[i * a + k];
        }

        int c = rt[i/2];
        if (i & 1) c = MOD - c;
        for (int j = 0; j < a; ++j)
            PQ[i * a + j] = (res[j] + c * (res[j] + a) % MOD) % MOD;
    }

    inverse_transform<a>(PQ);
}

template <size_t... N>
void work(std::index_sequence<N...>, int x, std::vector<int>& a, std::vector<int>& b) {
    static void (*ptrs[]) (std::vector<int>&, std::vector<int>&) = {&fast_polymult_mod<N+1>...};
    ptrs[x - 1](a, b);
}

void fast_polymult(vector<int> &P, vector<int> &Q) {
    int m1 = P.size();
    int m2 = Q.size();
    int res_len = m1 + m2 - 1;

    int b = 1;
    while ((alim << b) < res_len) ++b;
    int a = ((res_len - 1) >> b) + 1;
    int m = a << b;

    P.resize(m);
    Q.resize(m);

    // Call fast_polymult_mod<a>(P, Q);
    work(std::make_index_sequence<alim>{}, a, P, Q);

    P.resize(res_len);
}
//239b3e

```

4.4 FFT в double'ax

```

using cd = complex<double>;
const double PI = acos(-1);

```

```

void fft(vector<cd> & a, bool invert) {
    int n = a.size();

    for (int i = 1, j = 0; i < n; i++) {
        int bit = n >> 1;
        for (; j & bit; bit >>= 1)
            j ^= bit;
        j ^= bit;

        if (i < j)
            swap(a[i], a[j]);
    }

    for (int len = 2; len <= n; len <= 1) {
        double ang = 2 * PI / len * (invert ? -1 : 1);
        cd wlen(cos(ang), sin(ang));
        for (int i = 0; i < n; i += len) {
            cd w(1);
            for (int j = 0; j < len / 2; j++) {
                cd u = a[i+j], v = a[i+j+len/2] * w;
                a[i+j] = u + v;
                a[i+j+len/2] = u - v;
                w *= wlen;
            }
        }
    }

    if (invert) {
        for (cd & x : a)
            x /= n;
    }
}

vector<int> multiply(vector<int> const& a, vector<int>
    const& b) {
    vector<cd> fa(a.begin(), a.end()), fb(b.begin(), b.
        end());
    int n = 1;
    while (n < a.size() + b.size())
        n <= 1;
    fa.resize(n);
    fb.resize(n);

    fft(fa, false);
    fft(fb, false);
    for (int i = 0; i < n; i++)
        fa[i] *= fb[i];
    fft(fa, true);

    vector<int> result(n);
    for (int i = 0; i < n; i++)
        result[i] = round(fa[i].real());
    while(!result.empty() && !result.back()) result.
        pop_back();
    return result;
}
//35d9d0

```

5 Структуры данных

5.1 Дерево Фенвика

```

int fe[maxn];
void pl(int pos, int val) {while(pos<maxn) {fe[pos]+=
    val;pos|= (pos+1);}}
int get(int pos) {int ans=0;while(pos>=0) {ans+=fe[pos
    ];pos&=(pos+1);--pos;} return ans;} /// [0,pos] -
    vkluchitelno!!!
int get(int l, int r) {return get(r-1)-get(l-1);} ///
    sum of [l,r)

//2991a1

```

5.2 Дерево отрезков в точке

```

template<typename T, typename U>
struct SegmentTree {
    int h, n;
    T neutral;
    U unite;

```

```

vector<T> data;

```

```

template<typename I>
SegmentTree(int sz, T neutral, U unite, I init) :
    h(__lg(sz) + 1), n(1 << h), neutral(neutral),
    unite(unite), data(2 * n) {
    for (int i = 0; i < sz; ++i) data[i + n] =
        init(i);
    for (int i = n - 1; i > 0; --i) data[i] =
        unite(data[2 * i], data[2 * i + 1]);
}

SegmentTree(int sz, T neutral, U unite) : h(__lg(
    sz) + 1), n(1 << h), neutral(neutral), unite(unite
    ), data(2 * n, neutral) {}

void set(int i, T x) {
    data[i + n] = x;
    for (i /= 2; i > 0; i /= 2) data[i] = unite(
        data[2 * i], data[2 * i + 1]);
}

T get(int l, int r) {
    T leftRes = neutral, rightRes = neutral;
    for (l += n, r += n; l < r; l /= 2, r /= 2) {
        if (l & 1) leftRes = unite(leftRes, data[l
            ++]);
        if (r & 1) rightRes = unite(data[--r],
            rightRes);
    }
    return unite(leftRes, rightRes);
}

int left(int i) {
    int lvl = __lg(i);
    return (i & ((1 << lvl) - 1)) * (1 << (h - lvl
        ));
}

int right(int i) {
    int lvl = __lg(i);
    return ((i & ((1 << lvl) - 1)) + 1) * (1 << (h
        - lvl));
}

// l \in [0; n) && ok(get(l, l), l);
// returns last r: ok(get(l, r), r)
template<typename C>
int lastTrue(int l, C ok) {
    T cur = neutral;
    l += n;
    do {
        l >>= __builtin_ctz(l);
        T with1 = unite(cur, data[l]);
        if (ok(with1, right(l))) {
            cur = with1;
            ++l;
        } else {
            while (l < n) {
                T with2 = unite(cur, data[2 * l]);
                if (ok(with2, right(2 * l))) {
                    cur = with2;
                    l = 2 * l + 1;
                } else {
                    l = 2 * l;
                }
            }
            return l - n;
        }
    } while (l & (l - 1));
    return n;
}

// r \in [0; n) && ok(get(r, r), r);
// returns first l: ok(get(l, r), l)
template<typename C>
int firstTrue(int r, C ok) {
    T cur = neutral;
    r += n;
    while (r & (r - 1)) {
        r >>= __builtin_ctz(r);
        T with1 = unite(data[--r], cur);

```



```

        if (ok(with1, left(r))) {
            cur = with1;
        } else {
            while (r < n) {
                T with2 = unite(data[2 * r + 1],
                                cur);
                if (ok(with2, left(2 * r + 1))) {
                    cur = with2;
                    r = 2 * r;
                } else {
                    r = 2 * r + 1;
                }
            }
            return r - n + 1;
        }
    }
    return 0;
}

void example () {
    // max
    SegmentTree<int> segtree(n, -(int)1e18, [] (int x,
        int y) { return max(x, y); });

    // sum
    SegmentTree<int> ones(n, 0LL, [] (int x, int y) {
        return x + y; });

    auto left_zero = [&](int r) { // nearest zero
        strictly to the left
        return ones.firstTrue(r, [r](int sum, int l){
            return r - l == sum; }) - 1;
    };
    auto right_zero = [&](int l) { // nearest zero
        strictly to the right
        return ones.lastTrue(l + 1, [l](int sum, int r){
            return r - (l + 1) == sum; });
    };
}

//358fb0

```

5.3 Массовое дерево отрезков

```

#ifdef LOCAL
int __lg(int x) { return 63 - __builtin_clzll(x); }
#endif

template<typename Data, typename Mod, typename
    UniteData, typename UniteMod, typename Apply>
struct MassSegmentTree {
    int h, n;
    Data zd;
    Mod zm;
    vector<Data> data;
    vector<Mod> mod;

    UniteData ud; // Data (Data, Data)
    UniteMod um; // Mod (Mod, Mod);
    Apply a; // Data (Data, Mod, int); last argument is
        the length of current segment (could be used for
        range += and sum counting, for instance)

    template<typename I>
    MassSegmentTree(int sz, Data zd, Mod zm, UniteData
        ud, UniteMod um, Apply a, I init) : h(__lg(sz > 1
        ? sz - 1 : 1) + 1), n(1 << h), zm(zm), zd(zd),
        data(2 * n, zd), mod(n, zm), ud(ud), um(um), a(a)
        {
            for (int i = 0; i < sz; ++i) data[i + n] = init(i)
            ;
            for (int i = n - 1; i > 0; --i) data[i] = ud(data
                [2 * i], data[2 * i + 1]);
        }

    MassSegmentTree(int sz, Data zd, Mod zm, UniteData
        ud, UniteMod um, Apply a) : h(__lg(sz > 1 ? sz - 1
        : 1) + 1), n(1 << h), zm(zm), zd(zd), data(2 * n,
        zd), mod(n, zm), ud(ud), um(um), a(a) {}
}

```

```

void push(int i) {
    if (mod[i] == zm) return;
    apply(2 * i, mod[i]);
    apply(2 * i + 1, mod[i]);
    mod[i] = zm;
}

// is used only for apply
int length(int i) { return 1 << (h - __lg(i)); }

// used only for descent
int left(int i) {
    int lvl = __lg(i);
    return (i & ((1 << lvl) - 1)) * (1 << (h - lvl));
}

// used only for descent
int right(int i) {
    int lvl = __lg(i);
    return ((i & ((1 << lvl) - 1)) + 1) * (1 << (h -
        lvl));
}

template<typename S>
void apply(int i, S x) {
    data[i] = a(data[i], x, length(i));
    if (i < n) mod[i] = um(mod[i], x);
}

void update(int i) {
    if (mod[i] != zm) return;
    data[i] = ud(data[2 * i], data[2 * i + 1]);
}

template<typename S>
void update(int l, int r, S x) { // [l; r)
    l += n, r += n;
    for (int shift = h; shift > 0; --shift) {
        push(l >> shift);
        push((r - 1) >> shift);
    }
    for (int lf = l, rg = r; lf < rg; lf /= 2, rg /=
        2) {
        if (lf & 1) apply(lf++, x);
        if (rg & 1) apply(--rg, x);
    }
    for (int shift = 1; shift <= h; ++shift) {
        update(l >> shift);
        update((r - 1) >> shift);
    }
}

Data get(int l, int r) { // [l; r)
    l += n, r += n;
    for (int shift = h; shift > 0; --shift) {
        push(l >> shift);
        push((r - 1) >> shift);
    }
    Data leftRes = zd, rightRes = zd;
    for (; l < r; l /= 2, r /= 2) {
        if (l & 1) leftRes = ud(leftRes, data[l++]);
        if (r & 1) rightRes = ud(data[--r], rightRes);
    }
    return ud(leftRes, rightRes);
}

// l \in [0; n) && ok(get(l, l), l);
// returns last r: ok(get(l, r), r)
template<typename C>
int lastTrue(int l, C ok) {
    l += n;
    for (int shift = h; shift > 0; --shift) push(l >>
        shift);
    Data cur = zd;
    do {
        l >>= __builtin_ctz(l);
        Data with1;
        with1 = ud(cur, data[l]);
        if (ok(with1, right(l))) {
            cur = with1;

```

```

    ++l;
} else {
    while (l < n) {
        push(l);
        Data with2;
        with2 = ud(cur, data[2 * l]);
        if (ok(with2, right(2 * l))) {
            cur = with2;
            l = 2 * l + 1;
        } else {
            l = 2 * l;
        }
    }
    return l - n;
} while (l & (l - 1));
return n;
}

// r \in [0; n) && ok(get(r, r), r);
// returns first l: ok(get(l, r), l)
template<typename C>
int firstTrue(int r, C ok) {
    r += n;
    for (int shift = h; shift > 0; --shift) push((r - 1) >> shift);
    Data cur = zd;
    while (r & (r - 1)) {
        r >>= __builtin_ctz(r);
        Data with1;
        with1 = ud(data[--r], cur);
        if (ok(with1, left(r))) {
            cur = with1;
        } else {
            while (r < n) {
                push(r);
                Data with2;
                with2 = ud(data[2 * r + 1], cur);
                if (ok(with2, left(2 * r + 1))) {
                    cur = with2;
                    r = 2 * r;
                } else {
                    r = 2 * r + 1;
                }
            }
            return r - n + 1;
        }
    }
    return 0;
}

void example () {
    // max and +=
    MassSegmentTree segtree(n, 0LL, 0LL,
    [](int x, int y) { return max(x, y); },
    [](int x, int y) { return x + y; },
    [](int x, int y, int len) { return x + y; });

    // sum and +=
    MassSegmentTree segtree(n, 0LL, 0LL,
    [](int x, int y) { return x + y; },
    [](int x, int y) { return x + y; },
    [](int x, int y, int len) { return x + y * len; });

    // sum and assignment
    MassSegmentTree segtree(n, 0LL, -1LL,
    [](int x, int y) { return x + y; },
    [](int x, int y) { return y; },
    [](int x, int y, int len) { return y * len; });
}

//0a439e

```

5.4 Битовый бор

```

template<unsigned int sz, typename T=int>
struct binarytrie{
    using Bit=typename conditional<sz<=32,unsigned int,
    unsigned long long>::type;
    struct node{

```

```

        T cnt;
        array<int, 2>nxt;
        node():cnt(0),nxt({-1,-1}){}
    };
    vector<node>v;
    binarytrie(){v.emplace_back();}
    void insert(Bit x){add(x,1);}
    void erase(Bit x){add(x,-1);}
    void add(Bit x,T k)
    {
        assert(0<=x&&(x>>sz)==0);
        int p=0;
        v[p].cnt+=k;
        for(int i=sz;i--;)
        {
            int j=x>>i&1;
            if(v[p].nxt[j]==-1)
            {
                v[p].nxt[j]=v.size();
                v.emplace_back();
            }
            p=v[p].nxt[j];
            v[p].cnt+=k;
        }
    }
    T count(Bit x, Bit xor_val=0) const // [0, x)
    {
        assert(0<=xor_val&&(xor_val>>sz)==0);
        if(x<0) return 0;
        else if(x>>sz) return v[0].cnt;
        T ret=0;
        int p=0;
        for(int i=sz;i--;)
        {
            int j=x>>i&1, k=xor_val>>i&1;
            if(j==0) p=v[p].nxt[k];
            else
            {
                if(v[p].nxt[k]>=0) ret+=v[v[p].nxt[k]].cnt;
                p=v[p].nxt[!k];
            }
            if(p==-1) break;
        }
        return ret;
    }
    Bit max(Bit xor_val=0) const
    {
        assert(0<=xor_val&&(xor_val>>sz)==0);
        int p=0;
        Bit ret=0;
        if(v[p].cnt==0) return ret;
        for(int i=sz;i--;)
        {
            ret<=1;
            int k=xor_val>>i&1;
            if(v[p].nxt[!k]>=0&&v[v[p].nxt[!k]].cnt>0)
            {
                p=v[p].nxt[!k];
                ret|=1;
            }
            else p=v[p].nxt[k];
        }
        return ret;
    }
    Bit min(Bit xor_val=0) const
    {
        assert(0<=xor_val&&(xor_val>>sz)==0);
        int p=0;
        Bit ret=0;
        for(int i=sz;i--;)
        {
            ret<=1;
            int k=xor_val>>i&1;
            if(v[p].nxt[k]>=0&&v[v[p].nxt[k]].cnt>0) p=v[p].
            nxt[k];
            else
            {
                p=v[p].nxt[!k];
                ret|=1;
            }
        }
    }

```

```

    }
    return ret;
}
Bit find_by_order(T ord, Bit xor_val=0) const
{
    assert(0<=xor_val&&(xor_val>>sz)==0);
    assert(0<=ord&&ord<v[0].cnt);
    int p=0;
    Bit ret=0;
    for(int i=sz;i--;)
    {
        ret<=1;
        int k=xor_val>>i&1;
        if(v[p].nxt[k]>=0)
        {
            if(ord>=v[v[p].nxt[k]].cnt)
            {
                ord=v[v[p].nxt[k]].cnt;
                p=v[p].nxt[!k];
                ret|=1;
            }
            else p=v[p].nxt[k];
        }
        else
        {
            p=v[p].nxt[!k];
            ret|=1;
        }
    }
    return ret;
}
T order_of_key(Bit x, Bit xor_val=0) const {return
    count(x, xor_val);}
};
binarytrie<32>bt;

```

//0b3855

5.5 Ordered set

```

#include <ext/pb_ds/assoc_container.hpp>
#include <ext/pb_ds/tree_policy.hpp>

```

```

using namespace __gnu_pbds;
using namespace std;

```

```

using ordered_set = tree<int, null_type, less<>,
    rb_tree_tag, tree_order_statistics_node_update>;
//f589b9

```

5.6 Convex hull trick

```

int div_up(int a, int b) { return a/b+((a^b)>0&&a%b);
} // divide a by b rounded up
const int LQ = ..., RQ = ...; //leftmost query,
    rightmost query
int in(ii L, int x) {
    return L.x * x + L.y;
}
struct Hull {
    vector <pair <int, int> > lines;
    vector <int> borders;
    void push(ii L) {
        while (lines.size() && in(L, borders.back()) < in(
            lines.back(), borders.back())) {
            lines.pop_back();
            borders.pop_back();
        }
        if (lines.empty()) {
            lines = {L};
            borders = {LQ};
        }
        else if (lines.back().x > L.x) {
            int x = div_up(L.y - lines.back().y, lines.
                back().x - L.x);
            if (x <= RQ) {
                lines.app(L);
                borders.app(x);
            }
        }
    }
}

```

```

}
Hull (){}
Hull (vector <ii> a) {
    auto comp = [&] (ii u, ii v) {
        return u.x > v.x || (u.x == v.x && u.y < v.y);
    };
    sort(all(a), comp);
    for (auto L : a) {
        push(L);
    }
}
int get(int x) {
    int pos = upper_bound(all(borders), x) - borders.
        begin();
    assert(pos>0);
    pos--;
    return in(lines[pos], x);
}
};
//04555a

```

5.7 Центроиды

```

vector<int> sz(n), lvl(n, -1);
auto dfs = [&](auto dfs, int cur, int prev) -> int {
    if (lvl[cur] != -1) return 0;
    sz[cur] = 1;
    for (auto [nxt, w] : g[cur]) {
        if (nxt != prev) sz[cur] += dfs(dfs, nxt, cur);
    }
    return sz[cur];
};
auto find = [&](auto find, int cur, int prev, int tot)
    -> int {
    int bch = -1, bsz = 0;
    for (auto [nxt, w] : g[cur]) {
        if (nxt == prev || lvl[nxt] != -1) continue;
        if (sz[nxt] > bsz) {
            bch = nxt;
            bsz = sz[nxt];
        }
    }
    if (bsz + bsz <= tot) return cur;
    return find(find, bch, cur, tot);
};
dfs(dfs, 0, 0);
auto c = find(find, 0, 0, sz[0]);
vector<pair<int, int>> stack{{c, 0}};
while (!stack.empty()) {
    auto [centroid, l] = stack.back();
    stack.pop_back();
    lvl[centroid] = 1;
    for (auto [nxt, w] : g[centroid]) {
        if (lvl[nxt] != -1) continue;
        dfs(dfs, nxt, centroid);
        int new_centroid = find(find, nxt, centroid,
            sz[nxt]);
        stack.push_back({new_centroid, lvl[centroid] +
            1});
    }
}
//0e1e52

```

5.8 Дерево Ли Чао

```

struct Line{
    int a, b;
    Line(){}
    Line (int a, int b) : a(a), b(b) {}
    int get(int x) { return a + b * x; }
};

struct Lichao {
    int n;
    vector <int> x;
    vector <Line> t;
    Lichao(){}
}

```

```

Lichao (int n, vector<int> x) : n(n), t(n << 2,
Line(Inf, 0)), x(x) {}

void put(int v, int l, int r, Line L) {
    if (l + 1 == r) {
        if (L.get(x[l]) < t[v].get(x[l])) {
            t[v] = L;
        }
        return;
    }
    int m = (l + r) / 2;
    if (L.get(x[m]) < t[v].get(x[m])) {
        swap(L, t[v]);
    }
    if (L.b > t[v].b) {
        put(2 * v + 1, l, m, L);
    }
    else {
        put(2 * v + 2, m, r, L);
    }
}

int get(int v, int l, int r, int i) {
    if (l + 1 == r) {
        return t[v].get(x[l]);
    }
    int m = (l + r) / 2;
    int ans = t[v].get(x[i]);
    if (i < m) {
        ans = min(ans, get(2 * v + 1, l, m, i));
    } else {
        ans = min(ans, get(2 * v + 2, m, r, i));
    }
    return ans;
}

void put(Line L) {
    put(0, 0, n, L);
}

int get(int i) {
    return get(0, 0, n, i);
}
};

```

//99f5fa

5.9 Min-Kinetic Segment Tree

I guess the source is <https://koosaga.com/307>

```

using lint = long long;
const lint inf = 4e18;
const int MAXT = 4100000;
using pi = array<lint, 2>;

struct line {
    lint A, B;
    int idx;

    lint eval(lint x) { return A * x + B; }

    // returns the x-intercept of intersection "
    strictly" larger than T
    lint cross_after(line &x, lint T) {
        if (x.A == A) {
            return inf;
        }
        lint up = x.B - B;
        lint dn = A - x.A;
        if (dn < 0) {
            dn *= -1;
            up *= -1;
        }
        lint incept = (up <= 0 ? -((-up) / dn) : (up +
dn - 1) / dn);
        if (incept > T)
            return incept;
        return inf;
    }
};

```

```

struct kst { // min kinetic segment tree
    line tree[MAXT];
    lint melt[MAXT], T;
    pi lazy[MAXT];
    int n;

    bool cmp(line &a, line &b) {
        lint l = a.eval(T), r = b.eval(T);
        if (l != r)
            return l > r;
        return a.A > b.A;
    }

    void pull(int p) {
        tree[p] = cmp(tree[2 * p], tree[2 * p + 1]) ?
tree[2 * p + 1] : tree[2 * p];
        melt[p] = min({melt[2 * p], melt[2 * p + 1],
tree[2 * p].cross_after(tree[2 * p + 1], 0)});
    }

    void init(int s, int e, int p, vector<line> &l) {
        if (s == e) {
            tree[p] = l[s];
            melt[p] = inf;
            lazy[p] = {0, 0};
            return;
        }
        lazy[p] = {0, 0};
        int m = (s + e) / 2;
        init(s, m, 2 * p, l);
        init(m + 1, e, 2 * p + 1, l);
        pull(p);
    }

    void lazydown(int p) {
        for (int i = 2 * p; i < 2 * p + 2; i++) {
            lazy[i][0] += lazy[p][0];
            lazy[i][1] += lazy[p][1];
            tree[i].B += lazy[p][0] * tree[i].A + lazy
[p][1];
            melt[i] -= lazy[p][0];
        }
        lazy[p][0] = lazy[p][1] = 0;
    }

    void propagate(int p) {
        if (melt[p] > 0)
            return;
        lazydown(p);
        propagate(2 * p);
        propagate(2 * p + 1);
        pull(p);
    }

    lint query(int s, int e, int ps, int pe, int p =
1) {
        if (e < ps || pe < s)
            return inf;
        if (s <= ps && pe <= e)
            return tree[p].eval(0);
        int pm = (ps + pe) / 2;
        lazydown(p);
        return min(query(s, e, ps, pm, 2 * p), query(s
, e, pm + 1, pe, 2 * p + 1));
    }

    void heaten(int s, int e, int ps, int pe, int p,
lint v) {
        if (e < ps || pe < s)
            return;
        if (s <= ps && pe <= e) {
            lazy[p][0] += v;
            tree[p].B += v * tree[p].A;
            melt[p] -= v;
            propagate(p);
            return;
        }
        lazydown(p);
        int pm = (ps + pe) / 2;
        heaten(s, e, ps, pm, 2 * p, v);
    }
};

```

```

        heaten(s, e, pm + 1, pe, 2 * p + 1, v);
        pull(p);
    }

void add(int s, int e, int ps, int pe, int p, lint
v) {
    if (e < ps || pe < s)
        return;
    if (s <= ps && pe <= e) {
        lazy[p][1] += v;
        tree[p].B += v;
        return;
    }
    lazydown(p);
    int pm = (ps + pe) / 2;
    add(s, e, ps, pm, 2 * p, v);
    add(s, e, pm + 1, pe, 2 * p + 1, v);
    pull(p);
}

void init(vector<line> &l, lint _T) {
    n = l.size();
    T = _T;
    init(0, n - 1, 1, 1);
}
};
//66f9a9

```

6 Строковые алгоритмы

6.1 Префикс-функция

```

vector<int> prefix_function(string s) {
    vector<int> p(s.size());
    for (int i = 1; i < s.size(); ++i) {
        p[i] = p[i - 1];
        while (p[i] && s[p[i]] != s[i]) p[i] = p[p[i] - 1];
        p[i] += s[i] == s[p[i]];
    }
    return p;
}
//c33adc

```

6.2 Z-функция

```

vector<int> z_function (string s) { // z[i] - lcp of s
    and s[i:]
    int n = (int) s.length();
    vector<int> z (n);
    for (int i=1, l=0, r=0; i<n; ++i) {
        if (i <= r)
            z[i] = min (r-i+1, z[i-l]);
        while (i+z[i] < n && s[z[i]] == s[i+z[i]])
            ++z[i];
        if (i+z[i]-1 > r)
            l = i, r = i+z[i]-1;
    }
    return z;
}
//85d656

```

6.3 Алгоритм Манакера

```

vector<int> manacher_odd(const string &s) {
    vector<int> man(s.size(), 0);
    int l = 0, r = 0;
    int n = s.size();
    for (int i = 1; i < n; i++) {
        if (i <= r) {
            man[i] = min(r - i, man[l + r - i]);
        }
        while (i + man[i] + 1 < n && i - man[i] - 1 >= 0
            && s[i + man[i] + 1] == s[i - man[i] - 1]) {
            man[i]++;
        }
        if (i + man[i] > r) {
            l = i - man[i];
            r = i + man[i];
        }
    }
}

```

```

    }
}
return man;
}
// abacaba : (0 1 0 3 0 1 0)
// abbaa : (0 0 0 0 0)

vector<int> manacher_even(const string &s) {
    assert(s.size());
    string t;
    for (int i = 0; i + 1 < s.size(); ++i) {
        t += s[i];
        t += '#';
    }
    t += s.back();
    auto odd = manacher_odd(t);
    vector<int> ans;
    for (int i = 1; i < odd.size(); i += 2) {
        ans.push_back((odd[i]+1)/2);
    }
    return ans;
}
// abacaba : (0 0 0 0 0 0)
// abbaa : (0 2 0 1)

auto pal = [&] (int i, int from, int len) {
    if (len == 0) {
        return true;
    }
    int m = len/2;
    if (len & 1) {
        return o[i][from + m] >= m;
    }
    else {
        return e[i][from + m - 1] >= m;
    }
};
//d74301

6.4 Суфмассив
Переработанный китайский суфмассив

const int inf = 1e9;
struct rmq {
    int n;
    vector<int> a;
    void build(const vector<int> &x) {
        assert(x.size() == n);
        for (int i = 0; i < n; ++i) a[n + i] = x[i];
        for (int i = n - 1; i > 0; --i) a[i] = min(a[2 * i
], a[2 * i + 1]);
    }
    rmq(int n) : n(n), a(2 * n, inf) {}
    void put(int i, int x) {
        a[i + n] = min(a[i + n], x);
        for (i = (i + n) / 2; i > 0; i /= 2) {
            a[i] = min(a[i * 2], a[i * 2 + 1]);
        }
    }
    int getMin(int l, int r) { //[l;r)
        assert(l < r);
        int res = inf;
        for (l += n, r += n; l < r; l /= 2, r /= 2) {
            if (l & 1) res = min(res, a[l++]);
            if (r & 1) res = min(res, a[--r]);
        }
        return res;
    }
};

template <typename T>
vector<int> SA(const T &a) {
    int m = *max_element(all(a)) + 1, n = a.size();
    vector<int> sa(n), nsa(n), pre(max(n, m)), x(a.
begin(), a.end()), y(n);
    for (int e : x) pre[e]++;
    for (int i = 1; i < m; ++i) pre[i] += pre[i - 1];
    for (int i = 0; i < n; ++i) sa[--pre[x[i]]] = i;
    int dif = 1;
}

```

```

y[sa.front()]=0;
for (int i = 1; i < n; ++i) {
    dif += x[sa[i]]!=x[sa[i-1]];
    y[sa[i]] = dif - 1;
}
x = y;
for (int h = 1; dif < n; h *= 2) {
    fill(all(pre), 0);
    for (int e : x) pre[e]++;
    for (int i = 1; i < dif; ++i) pre[i] += pre[i
- 1];
    for (int t = n; t--; ) {
        int i = sa[t];
        if (i>=h) {
            nsa[--pre[x[i-h]]]=i-h;
        }
        else if (i + 1 != h) {
            nsa[--pre[x[i-h+n+1]]]=i-h+n+1;
        }
    }
    nsa[--pre[x[n - h]]]=n-h;
    sa = nsa;
    auto getr = [&] (int i) {
        if (i + h < n) {
            return x[i + h];
        }
        else {
            return x[i + h - n - 1];
        }
    };
    dif = 1;
    y[sa.front()]=0;
    for (int i = 1; i < n; ++i) {
        if (x[sa[i]]!=x[sa[i-1]] || sa[i-1]+h==n)
        {
            dif++;
        }
        else {
            dif += getr(sa[i]) != getr(sa[i-1]);
        }
        y[sa[i]]=dif-1;
    }
    x = y;
}
return sa;
}

template <typename T>
struct suar {
    vector <int> sa, lcp, pos; rmq t;
    suar (const T &a) : t((int)a.size() - 1) {
        sa = SA(a);
        int n = (int)a.size(), k = 0;
        lcp.resize(n - 1);
        pos.resize(n);
        for (int i = 0; i < n; ++i) pos[sa[i]] = i;
        for (int i = 0; i < n; ++i) {
            if (pos[i]+1<n) {
                int j = sa[pos[i]+1];
                while (i+k<n&&j+k<n&&a[i+k]==a[j+k])k
                ++;
                lcp[pos[i]]=k;
            }
            if (k) {
                k--;
            }
        }
        t.build(lcp);
    }
    int getLcp(int i, int j) {
        i = pos[i]; j = pos[j];
        if (j < i) {
            swap(i, j);
        }
        if (i == j) {
            return inf;
        }
        else {
            return t.getMin(i, j);
        }
    }
};

```

```

    }
};

//6327c9

6.5 Алгоритм Ахо — Корасик
6.6 Алгоритм Ахо Корасик

struct node{
    int next[alpha] = {}, link[alpha] = {};
    int suf = 0;
    ll visited = 0, ans = 0;
    vector<int> term;
    node() {}
};

vector<node> mem;

int get_next(int nd, char c) {
    if (!mem[nd].next[c - a]) { mem[nd].next[c - a] =
        mem.size(); mem.emplace_back(); }
    return mem[nd].next[c - a];
}

void find(string s, vector<string> t) {
    mem.reserve(1e6 + 100);mem.clear();
    mem.emplace_back();mem.emplace_back();
    // 0th element is nullptr, 1st is the root
    int q = t.size();
    for (int j = 0; j < q; ++j) {
        int cur = 1;
        for (char c : ts[j]) cur = get_next(cur, c);
        mem[cur].term.push_back(j);
    }
    vector<int> bfs_order;
    queue<int> bfs;
    {
        node &root = mem[1];
        root.suf = 1;
        for (char c = a; c < a + alpha; ++c) {
            root.link[c - a] = (root.next[c - a] ? root.
            next[c - a] : 1);
        }
        bfs.push(1);
    }
    while (!bfs.empty()) {
        int cur_idx = bfs.front();
        bfs.pop();
        node &cur = mem[cur_idx];
        bfs_order.push_back(cur_idx);
        for (char c = a; c < a + alpha; ++c) {
            int nxt_idx = cur.next[c - a];
            if (!nxt_idx) continue;
            node &nxt = mem[nxt_idx];
            nxt.suf = (cur_idx == 1 ? 1 : mem[cur.suf].link[
            c - a]);
            for (char c = a; c < a + alpha; ++c) {
                nxt.link[c - a] = (nxt.next[c - a] ? nxt.next[
                c - a] : mem[nxt.suf].link[c - a]);
            }
            bfs.push(nxt_idx);
        }
    }
    // do something
}
//23bad7

```

6.7 Дерево палиндромов

6.8 Дерево палиндромов

```

struct palindromic{
    int n;
    vector<int> p, suf{0, 0}, len{-1, 0};
    vector<array<int, alpha>> to({}, {});
    int sz = 2;

    palindromic(const string &s) : n(s.size()), p(n + 1,
        1) {

```



```

suf.reserve(n);
len.reserve(n);
for (int i = 0; i < n; ++i) {
    auto check = [&](int l) { return i > 1 && s[i]
== s[i - 1 - 1]; };
    int par = p[i];
    while (!check(len[par])) par = suf[par];
    if (to[par][s[i] - a] {
        p[i + 1] = to[par][s[i] - a];
        continue;
    }
    p[i + 1] = sz++;
    to[par][s[i] - a] = p[i + 1];
    to.emplace_back();
    len.emplace_back(len[par] + 2);
    do {
        par = suf[par];
    } while (!check(len[par]));
    int link = to[par][s[i] - a];
    if (link == p[i + 1]) link = 1;
    suf.emplace_back(link);
}
};
//6aecca

```

7 Потoki

7.1 Алгоритм Диница

```

#define pb push_back
struct Dinic{
    struct edge{
        int to, flow, cap;
    };

    const static int N = 555; //count of vertices

    vector<edge> e;
    vector<int> g[N + 7];
    int dp[N + 7];
    int ptr[N + 7];

    void clear(){
        for (int i = 0; i < N + 7; i++) g[i].clear();
        e.clear();
    }

    void addEdge(int a, int b, int cap){
        g[a].pb(e.size());
        e.pb({b, 0, cap});
        g[b].pb(e.size());
        e.pb({a, 0, 0});
    }

    int minFlow, start, finish;

    bool bfs(){
        for (int i = 0; i < N; i++) dp[i] = -1;
        dp[start] = 0;
        vector<int> st;
        int uk = 0;
        st.pb(start);
        while(uk < st.size()){
            int v = st[uk++];
            for (int to : g[v]){
                auto ed = e[to];
                if (ed.cap - ed.flow >= minFlow && dp[ed.to] ==
-1){
                    dp[ed.to] = dp[v] + 1;
                    st.pb(ed.to);
                }
            }
        }
        return dp[finish] != -1;
    }

    int dfs(int v, int flow){
        if (v == finish) return flow;
        for (; ptr[v] < g[v].size(); ptr[v]++){

```

```

            int to = g[v][ptr[v]];
            edge ed = e[to];
            if (ed.cap - ed.flow >= minFlow && dp[ed.to] == dp
[v] + 1){
                int add = dfs(ed.to, min(flow, ed.cap - ed.flow)
);
                if (add){
                    e[to].flow += add;
                    e[to ^ 1].flow -= add;
                    return add;
                }
            }
        }
        return 0;
    }

    int dinic(int start, int finish){
        Dinic::start = start;
        Dinic::finish = finish;
        int flow = 0;
        for (minFlow = (1 << 30); minFlow; minFlow >>= 1){
            while(bfs()){
                for (int i = 0; i < N; i++) ptr[i] = 0;
                while(int now = dfs(start, (int)2e9 + 7)) flow
+= now;
            }
            return flow;
        }
    }
};
dinic;
//15c079

```

7.2 Mincost k-flow

```

struct edge {
    int next, capacity, cost, flow = 0;

    edge() = default;

    edge(int next, int capacity, int cost) : next(next),
        capacity(capacity), cost(cost) {}

    int rem() const { return capacity - flow; }

    int operator+=(int f) { return flow += f; }

    int operator-=(int f) { return flow -= f; }
};

auto addEdge = [&](auto from, auto next, auto capacity
, int cost) {
    g[from].push_back(e.size());
    e.emplace_back(next, capacity, cost);
    g[next].push_back(e.size());
    e.emplace_back(from, 0, -cost);
};

/* in case of undirected graph use this:
addEdge(u, v, capacity, cost);
addEdge(v, u, capacity, cost);
*/
vector<ll> phi(n, 0);
auto fordBellman = [&](int s, int t) {
    phi.assign(n, 0);
    for (int iter = 0; iter < n; ++iter) {
        bool changed = false;
        for (int u = 0; u < n; ++u) {
            for (auto index : g[u]) {
                auto edge = e[index];
                if (edge.rem() > 0 && phi[edge.next] > phi[u]
+ edge.cost) {
                    phi[edge.next] = phi[u] + edge.cost;
                    changed = true;
                }
            }
        }
        if (!changed) break;
    }
};

fordBellman(s, t);
// now shortest path using dijkstra with potentials
vector<ll> dist;
vector<int> from;

```

```

vector<bool> cnt;
auto dijkstra = [&](int s, int t) {
    dist.assign(n, 1e18);
    from.assign(n, -1);
    cnt.assign(n, false);
    dist[s] = 0;
    set <pair <int, int> > se;
    se.insert({0, s});
    while ((int)(se.size())) {
        int cur = se.begin()->y;
        se.erase(se.begin());
        cnt[cur] = true;
        for (int index : g[cur]) {
            auto &edge = e[index];
            if (edge.rem() == 0) continue;
            ll weight = edge.cost + phi[cur] - phi[edge.next];
            if (dist[edge.next] > dist[cur] + weight) {
                se.erase({dist[edge.next], edge.next});
                dist[edge.next] = dist[cur] + weight;
                se.insert({dist[edge.next], edge.next});
                from[edge.next] = cur;
            }
        }
    }
    if (dist[t] == (ll) 1e18) return -1LL;
    ll cost = 0;
    for (int p = t; p != s; p = from[p]) {
        for (auto index : g[from[p]]) {
            auto &edge = e[index];
            ll weight = edge.cost + phi[from[p]] - phi[edge.next];
            if (edge.rem() > 0 && edge.next == p && dist[edge.next] == dist[from[p]] + weight) {
                edge += 1;
                e[index ^ 1] -= 1;
                cost += edge.cost;
                break;
            }
        }
    }
    for (int i = 0; i < n; ++i) {
        phi[i] += dist[i];
    }
    return cost;
};
ll cost = 0;
for (int flow = 0; flow < k; ++flow) {
    ll a = dijkstra(s, t);
    if (a == -1) {
        cout << "-1\n";
        return;
    }
    cost += a;
}
// now recover answer
auto findPath = [&](int s, int t) {
    vector<int> ans;
    int cur = s;
    while (cur != t) {
        for (auto index : g[cur]) {
            auto &edge = e[index];
            if (edge.flow <= 0) continue;
            edge -= 1;
            e[index ^ 1] += 1;
            ans.push_back(index / 4);
        }
        // index / 4 because each edge has 4 copies
        cur = edge.next;
        break;
    }
    return ans;
};
for (int flow = 0; flow < k; ++flow) {
    auto p = findPath(s, t);
    cout << p.size() << ' ';
    for (int x : p) cout << x + 1 << ' ';
    cout << '\n';
}
//94b9cb

```

8 Гамильтоновы путь и цикл

<https://codeforces.com/blog/entry/90513>,
<https://codeforces.com/blog/entry/90743>.

8.1 Link-cut tree

```

namespace LCT {
    vector<vi> ch;
    vi fa, rev;
    void init(int n) {
        ch.resize(n + 1);
        fa.resize(n + 1);
        rev.resize(n + 1);
        for (int i = 0; i <= n; i++)
            ch[i].resize(2),
            ch[i][0] = ch[i][1] = fa[i] = rev[i] = 0;
    }
    bool isr(int a)
    {
        return !(ch[fa[a]][0] == a || ch[fa[a]][1] == a);
    }
    void pushdown(int a)
    {
        if (rev[a])
        {
            rev[ch[a][0]] ^= 1, rev[ch[a][1]] ^= 1;
            swap(ch[a][0], ch[a][1]);
            rev[a] = 0;
        }
    }
    void push(int a)
    {
        if (!isr(a)) push(fa[a]);
        pushdown(a);
    }
    void rotate(int a)
    {
        int f = fa[a], gf = fa[f];
        int tp = ch[f][1] == a;
        int son = ch[a][tp ^ 1];
        if (!isr(f))
            ch[gf][ch[gf][1] == f] = a;
        fa[a] = gf;

        ch[f][tp] = son;
        if (son) fa[son] = f;

        ch[a][tp ^ 1] = f, fa[f] = a;
    }
    void splay(int a)
    {
        push(a);
        while (!isr(a))
        {
            int f = fa[a], gf = fa[f];
            if (isr(f)) rotate(a);
            else
            {
                int t1 = ch[gf][1] == f, t2 = ch[f][1] == a;
                if (t1 == t2) rotate(f), rotate(a);
                else rotate(a), rotate(a);
            }
        }
    }
    void access(int a)
    {
        int pr = a;
        splay(a);
        ch[a][1] = 0;
        while (1)
        {
            if (!fa[a]) break;
            int u = fa[a];
            splay(u);
            ch[u][1] = a;
            a = u;
        }
    }
}

```

```

    splay(pr);
}
void makeroot(int a)
{
    access(a);
    rev[a] ^= 1;
}
void link(int a, int b)
{
    makeroot(a);
    fa[a] = b;
}
void cut(int a, int b)
{
    makeroot(a);
    access(b);
    fa[a] = 0, ch[b][0] = 0;
}
int fdr(int a)
{
    access(a);
    while(1)
    {
        pushdown(a);
        if (ch[a][0]) a = ch[a][0];
        else {
            splay(a);
            return a;
        }
    }
}
//647cca

```

8.2 Undirected case

```

#include <bits/stdc++.h>
using namespace std;
namespace hamil {
    template <typename T> bool chkmax(T &x, T y) {return
        x < y ? x = y, true : false;}
    template <typename T> bool chkmin(T &x, T y) {return
        x > y ? x = y, true : false;}
    #define vi vector<int>
    #define pb push_back
    #define mp make_pair
    #define pi pair<int, int>
    #define fi first
    #define se second
    #define ll long long
    using namespace LCT;
    vector<vi> used;
    unordered_set<int> caneg;
    void cut(int a, int b) {
        LCT::cut(a, b);
        for (int s = 0; s < 2; s++) {
            for (int i = 0; i < used[a].size(); i++)
                if (used[a][i] == b) {
                    used[a].erase(used[a].begin() + i);
                    break;
                }
            if (used[a].size() == 1) caneg.insert(a);
            swap(a, b);
        }
    }
    void link(int a, int b) {
        LCT::link(a, b);
        for (int s = 0; s < 2; s++) {
            used[a].pb(b);
            if (used[a].size() == 2) caneg.erase(a);
            swap(a, b);
        }
    }
    vi work(int n, vector<pi> eg, ll mx_ch = -1) {
        // mx_ch : max number of adding/replacing
        // default is (n + 100) * (n + 50)
        // n : number of vertices. 1-indexed.
        // eg: vector<pair<int, int>> storing all the
        // edges.
        // return a vector<int> consists of all
        // indices of vertices on the path. return empty list
    }
}

```

```

    if failed to find one.

    LCT::init(n);
    if (mx_ch == -1) mx_ch = 1ll * (n + 100) * (n
+ 50); //default
    used.resize(n + 1);
    caneg.clear();
    for (int i = 1; i <= n; i++) used[i].clear();

    vector<vi> edges(n + 1);
    for (auto v : eg)
        edges[v.fi].pb(v.se),
        edges[v.se].pb(v.fi);

    for (int i = 1; i <= n; i++)
        caneg.insert(i);

    mt19937 x(chrono::steady_clock::now().
time_since_epoch().count());
    int tot = 0;
    while (mx_ch >= 0) {
        // cout << tot << ' ' << mx_ch << endl;
        vector<pi> eg;
        for (auto v : caneg)
            for (auto s : edges[v])
                eg.pb(mp(v, s));

        shuffle(eg.begin(), eg.end(), x);
        if (eg.size() == 0) break;
        for (auto v : eg) {
            mx_ch--;
            int a = v.fi, b = v.se;
            if (used[a].size() < used[b].size())
                swap(a, b);
            if (used[b].size() >= 2) continue;
            if (x() & 1) continue;
            if (LCT::fdr(a) == LCT::fdr(b))
                continue;
            if (used[a].size() < 2 && used[b].size
() < 2)
                tot++;
            if (used[a].size() == 2) {
                int p = used[a][x() % 2];
                cut(a, p);
            }
            link(a, b);
        }
        if (tot == n - 1) {
            vi cur;
            for (int i = 1; i <= n; i++)
                if (used[i].size() <= 1) {
                    int pl = i, ls = 0;
                    while (pl) {
                        cur.pb(pl);
                        int flag = 0;
                        for (auto v : used[pl])
                            if (v != ls) {
                                ls = pl;
                                pl = v;
                                flag = 1;
                                break;
                            }
                        if (!flag) break;
                    }
                    break;
                }
            return cur;
        }
        //failed to find a path
        return vi();
    }
}
//c35638

```

8.3 Directed case

```

namespace hamil {
    template <typename T> bool chkmax(T &x, T y) {return
        x < y ? x = y, true : false;}
}

```

```

template <typename T> bool chkmin(T &x, T y){return
    x>y?x=y,true:false;}
#define vi vector<int>
#define pb push_back
#define mp make_pair
#define pi pair<int, int>
#define fi first
#define se second
#define ll long long
using namespace LCT;
vi out, in;
vi work(int n, vector<pi> eg, ll mx_ch = -1) {
    // mx_ch : max number of adding/replacing
    default is (n + 100) * (n + 50)
    // n : number of vertices. 1-indexed.
    // eg: vector<pair<int, int> > storing all the
    edges.
    // return a vector<int> consists of all
    indices of vertices on the path. return empty list
    if failed to find one.
    out.resize(n + 1), in.resize(n + 1);
    LCT::init(n);
    for (int i = 0; i <= n; i++) in[i] = out[i] =
0;
    if (mx_ch == -1) mx_ch = 1ll * (n + 100) * (n
+ 50); //default
    vector<vi> from(n + 1), to(n + 1);
    for (auto v : eg)
        from[v.fi].pb(v.se),
        to[v.se].pb(v.fi);
    unordered_set<int> canin, canout;
    for (int i = 1; i <= n; i++)
        canin.insert(i),
        canout.insert(i);
    mt19937 x(chrono::steady_clock::now().
time_since_epoch().count());
    int tot = 0;
    while (mx_ch >= 0) {
        // cout << tot << ' ' << mx_ch << endl;
        vector<pi> eg;
        for (auto v : canout)
            for (auto s : from[v])
                if (in[s] == 0) {
                    assert(canin.count(s));
                    continue;
                }
            else eg.pb(mp(v, s));
        for (auto v : canin)
            for (auto s : to[v])
                eg.pb(mp(s, v));
        shuffle(eg.begin(), eg.end(), x);
        if (eg.size() == 0) break;
        for (auto v : eg) {
            mx_ch--;
            if (in[v.se] && out[v.fi]) continue;
            if (LCT::fdr(v.fi) == LCT::fdr(v.se))
continue;
            if (in[v.se] || out[v.fi])
                if (x() & 1) continue;
            if (!in[v.se] && !out[v.fi])
                tot++;
            if (in[v.se]) {
                LCT::cut(in[v.se], v.se);
                canin.insert(v.se);
                canout.insert(in[v.se]);
                out[in[v.se]] = 0;
                in[v.se] = 0;
            }
            if (out[v.fi]) {
                LCT::cut(v.fi, out[v.fi]);
                canin.insert(out[v.fi]);
                canout.insert(v.fi);
                in[out[v.fi]] = 0;
                out[v.fi] = 0;
            }
            LCT::link(v.fi, v.se);
            canin.erase(v.se);
            canout.erase(v.fi);
            in[v.se] = v.fi;
            out[v.fi] = v.se;

```

```

        }
        if (tot == n - 1) {
            vi cur;
            for (int i = 1; i <= n; i++)
                if (!in[i]) {
                    int pl = i;
                    while (pl) {
                        cur.pb(pl),
                        pl = out[pl];
                    }
                    break;
                }
            return cur;
        }
    }
    //failed to find a path
    return vi();
}
//43ae60

```

9 Геометрия

9.1 Примитивы

```

struct Point {
    int x, y;
    Point(){}
    Point (int x_, int y_) {
        x = x_; y = y_;
    }
    Point operator + (Point p) {
        return Point(x+p.x,y+p.y);
    }
    Point operator - (Point p) {
        return Point(x - p.x, y - p.y);
    }
    int operator * (Point p) {
        return x * p.y - y * p.x;
    }
    int operator % (Point p) {
        return x * p.x + y * p.y;
    }
    bool operator < (Point v) {
        return (*this) * v > 0;
    }
    bool operator > (Point v) {
        return v < (*this);
    };
    bool operator <= (Point v) {
        return (*this) * v >= 0;
    }
};
bool line(Point a, Point b, Point c) {
    return (b-a)*(c-b)==0;
}
bool ord(Point a, Point p, Point b) {
    return (p - a)*(p - b)<0;
}
int hp(Point a) {
    if (a.y == 0) return a.x >= 0;
    return a.y > 0;
}
bool comp(Point a, Point b) {
    if (hp(a) != hp(b)) return hp(a) < hp(b);
    return a.x * b.y - a.y * b.x > 0;
}
//a48b68

```

9.2 Выпуклая оболочка

```

using pt = pair<int, int>;
#define x first
#define y second

int cross(pt p, pt q) {
    return p.x * q.y - p.y * q.x;
}

```

```

}
int scalar(pt p, pt q) {
    return p.x * q.x + p.y * q.y;
}
pt operator-(pt a, pt b) { return {a.x - b.x, a.y - b.y}; }
vector<pt> convex(vector<pt> a) {
    sort(all(a));
    if (a.size() == 2 && a[0] == a[1]) return {a[0]};
    if (a.size() <= 1) return a;
    vector<pt> h;
    for (int t = 0; t < 2; ++t) {
        int sz = h.size() - t;
        for (auto p: a) {
            while (h.size() >= sz + 2 && cross(p - h.
end()[-1], h.end()[-2] - h.end()[-1]) <= 0) h.
pop_back();
            h.push_back(p);
        }
        reverse(all(a));
    }
    return h; // h is circular: h.front() == h.back()
}
//110bb5

```

9.3 Точка внутри многоугольника

```

auto inT = [&] (Point a, Point b, Point c, Point p)
{
    a = a-p; b = b-p; c = c-p;
    return abs(a*b)+abs(b*c)+abs(c*a) == abs(a*b+b
*c+c*a);
};
auto inP = [&] (Point p) { //a must be in
counterclockwise order!
    int l = 1, r = n - 1;
    while (l < r - 1) {
        int m = (l + r) / 2;
        if ((a[m] - a[0]) < (p - a[0])) {
            l = m;
        }
        else {
            r = m;
        }
    }
    return inT(a[l], a[0], a[r], p);
};
//1cd0cf

```

9.4 Касательные

```

auto max = [&] (auto cmp) {
    int k = 0;
    for (int lg = 18; lg >= 0; --lg) {
        int i = k + (1 << lg), j = k - (1 << lg);
        i = (i % n + n) % n;
        j = (j % n + n) % n;
        array<int, 3> ind{i, j, k};
        sort(all(ind), cmp);
        k = ind[2];
    }
    return k;
};
auto uppert = [&] (Point p) { //last vertex in
counterclockwise order about p
    auto cmp = [&] (int i, int j) {return (a[i] -
p) < (a[j] - p); };
    return max(cmp);
};
auto lowert = [&] (Point p) { //first vertex in
counterclockwise order about p
    auto cmp = [&] (int i, int j) {return (a[i] -
p) > (a[j] - p); };
    return max(cmp);
};
auto uppertinf = [&] (Point p) { //upper tangent
line parallel to vector p
    swap(p.x, p.y);
    p.x = -p.x;

```

```

    auto cmp = [&] (int i, int j) { return a[i] %
p < a[j] % p; };
    return max(cmp);
};
auto lowertinf = [&] (Point p) { //lower tangent
line parallel to vector p
    swap(p.x, p.y);
    p.x = -p.x;
    auto cmp = [&] (int i, int j) { return a[i] %
p > a[j] % p; };
    return max(cmp);
};

```

//90f89d

10 Цепные дроби

<https://cp-algorithms.com/algebra/continued-fractions.html>

10.1 Поиск нижней огибающей, сумма и минимум по модулю

```

int floor(int a, int b) {
    return a / b - ((a ^ b) < 0 && a % b);
}
vector<int> decompose(int p, int q) {
    vector<int> f;
    while (q != 0) {
        f.push_back(floor(p, q));
        p -= q * f.back();
        swap(p, q);
    }
    return f;
}

using matrix = array<int, 4>;

matrix operator*(matrix a, matrix b) {
    matrix c{0,0,0,0};
    for (int i = 0; i < 2; ++i) {
        for (int j = 0; j < 2; ++j) {
            for (int k = 0; k < 2; ++k) {
                c[2 * i + k] += a[2 * i + j] * b[2 * j + k];
            }
        }
    }
    return c;
}

#define x first
#define y second

// computes lower convex hull for 0 <= x <= N, 0 <= y
<= (ax + b) / c
vector<pair<int, int>> lower_convex_hull(int a, int b,
int c, int n) {
    matrix m = {1, 0, 0, 1};
    auto f = decompose(a, c);
    vector<pair<int, int>> conv{{1, 0}, {0, 1}};
    for (int x : f) {
        m = m * matrix{x, 1, 1, 0};
        conv.emplace_back(m[2], m[0]);
        if (m[2] > n) break; // there should be one (if
any) with .x > n
    }
    auto diff = [&] (int x, int y) {
        return c * y - a * x;
    };
    int x = 0, y = b / c;
    vector<pair<int, int>> res{{x, y}};
    int i;
    for (i = 2; i + 1 < conv.size(); i += 2) {
        while (diff(x + conv[i + 1].x, y + conv[i + 1].y)
<= b) {
            int t = 1 + (diff(x + conv[i - 1].x, y + conv[i
- 1].y) - b - 1) / abs(diff(conv[i].x, conv[i].y));
            auto [dx, dy] = tuple{conv[i - 1].x + t * conv[i
].x, conv[i - 1].y + t * conv[i].y};
            int k = (n - x) / dx;

```

```

    if (k == 0) break;
    if (diff(dx, dy)) k = min(k, (b - diff(x, y)) /
diff(dx, dy));
    x += k * dx, y += k * dy;
    res.push_back({x, y});
}
}
if (i >= conv.size()) i -= 2;
for (; i > 0; i -= 2) {
    auto [dx1, dy1] = conv[i];
    if (x + dx1 > n) continue;
    x += dx1, y += dy1;
    if (i + 1 < conv.size()) {
        auto [dx2, dy2] = conv[i + 1];
        int k = (n - x) / dx2;
        x += k * dx2;
        y += k * dy2;
    }
    res.emplace_back(x, y);
    int k = (n - x) / dx1;
    if (k == 0) continue;
    x += k * dx1;
    y += k * dy1;
    res.emplace_back(x, y);
}
return res;
}

// number of (x, y) under pq line such that p.x <= x <
q.x && 0 < y
int area(auto p, auto q) {
    int integers = gcd(q.x - p.x, q.y - p.y);
    return ((p.y + q.y - 1) * (q.x - p.x + 1) + integers
+ 1) / 2 - q.y;
}

// sum of (ax + b) / c for 0 <= x < n
int get_area(int a, int b, int c, int n) { // SUM (ax
+ b) / c for 0 <= x < n
    auto ch = lower_convex_hull(a, b, c, n + 1);
    int sum = 0;
    for (int i = 0; i + 1 < ch.size(); ++i) {
        sum += area(ch[i], ch[i + 1]);
    }
    return sum;
}

// min of (ax + b) % c for 0 <= x <= n
int get_min(int a, int b, int c, int n) {
    auto ch = lower_convex_hull(a, b, c, n);
    // in fact, here we need only the last point of the
    first half of the algo (that is going up)
    int mn = c;
    for (auto [x, y] : ch) mn = min(mn, (a * x + b) % c)
;
    return mn;
}
//87941e

```

10.2 Простая рекурсия

Число точек $(x, y) : 0 \leq x < n, 0 < y \leq (kx + b)/d$. То есть $\sum_{x=0}^{n-1} \lfloor \frac{kx+b}{d} \rfloor$.

```

int cnt (int n, int k, int b, int d)
{
    if (k == 0) return (b / d) * n;
    if (k >= d || b >= d) {
        return (k / d) * n * (n - 1) / 2 + (b / d) * n
+ cnt(n, k % d, b % d, d);
    }
    return cnt((k * n + b) / d, d, (k * n + b) % d, k)
;
}
//11a6a0

```

11 Разное

11.1 Компараторы

```

bool cmp1(int x, int y) { return x > y; }

struct cmp2{
    bool operator()(int x, int y) const { return x > y
; }
};

int32_t main() {
    set<int, decltype(cmp1)*> s1({1, 2, 3}, cmp1);
    for (int x : s1) cout << x << ' '; cout << '\n';
    set<int, cmp2> s2({4, 5, 6});
    for (int x : s2) cout << x << ' '; cout << '\n';
    auto cmp3 = [&](int x, int y) { return x > y; };
    set<int, decltype(cmp3)*> s3({7, 8, 9}, cmp3); //
second cmp3 could be omitted if cmp3 = [](...) {
... }
    for (int x : s3) cout << x << ' '; cout << '\n';

    vector<int> v{3, 2, 1};
    cout << lower_bound(all(v), 2, cmp1) - v.begin()
<< '\n';
    cout << lower_bound(all(v), 2, cmp2()) - v.begin()
<< '\n';
    cout << lower_bound(all(v), 2, cmp3) - v.begin()
<< '\n';
}

//21c6f2

```

11.2 Трюки от Сергея Копелиовича

11.2.1 Быстрый ввод

https://acm.math.spbu.ru/~sk1/algo/input-output/fread_writ

```

const int buf_size = 4096;

int getChar() {
    static char buf[buf_size];
    static int len = 0, pos = 0;
    if (pos == len)
        pos = 0, len = fread(buf, 1, buf_size, stdin);
    if (pos == len)
        return -1;
    return buf[pos++];
}

int readChar() {
    while (1) {
        int c = getChar();
        if (c > 32) return c;
    }
}

int readInt() {
    int s = 1, c = readChar(), x = 0;
    if (c == '-')
        s = -1, c = getChar();
    while (isdigit(c))
        x = x * 10 + c - '0', c = getChar();
    return s * x;
}

//dc0a77

```

<https://acm.math.spbu.ru/~sk1/algo/memory.cpp.html>

11.2.2 Быстрый аллокатор

```

const int MAX_MEM = 1e8;
int mpos = 0;
char mem[MAX_MEM];
inline void * operator new (size_t n) {
    assert((mpos += n) <= MAX_MEM);
    return (void *) (mem + mpos - n);
}
void operator delete (void *) noexcept { } // must
have!
void operator delete (void *, size_t) noexcept { } //
must have!

//8726b1

```


11.3 Флаги компиляции

```
-DLOCAL -Wall -Wextra -pedantic -Wshadow -Wformat=2
-Wfloat-equal -Wconversion -Wlogical-op -Wshift-
overflow=2 -Wduplicated-cond -Wcast-qual -Wcast-
align -D_GLIBCXX_DEBUG -D_GLIBCXX_DEBUG_PEDANTIC
-D_FORTIFY_SOURCE=2 -fsanitize=address -
fsanitize=undefined -fno-sanitize-recover -fstack-
protector -std=c++2a
```

11.3.1 Сеточка в vim

<https://codeforces.com/blog/entry/122540>

```
i|<esc>25A |<esc>
o+<esc>25A---+<esc>
Vky35Pdd
```

11.4 Что сделать на пробном туре

- Убедиться, что работают все IDE. Разобраться, как настраивать в них LOCAL.
- В системе ML — это ML или RE?
- Максимальный размер файла
- Можно посмотреть на время работы серверов позапуская Флойда — Варшалла
- Посмотреть, насколько быстр быстрый ввод

11.5 Хеш файла без комментариев

Хеш файла, игнорирующий переводы строк и комментарии:

```
$ cpp -dD -P -fpreprocessed "$filename" | tr -d '[:
space:]' | md5sum | cut -c-6
```