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Contest (1)

template.cpp25 lines

```
#include <bits/stdc++.h>

#include <ext/pb_ds/assoc_container.hpp>
#include <ext/pb_ds/tree_policy.hpp>
using namespace std;
using namespace __gnu_pbds;

template <class T>
using ordered_set = tree<T, null_type, less<T>, rb_tree_tag,
    tree_order_statistics_node_update>;

#define int long long int
#define pb push_back
#define pi pair<int, int>
#define pli pair<pi, int>
#define fir first
#define sec second
#define MAXN 1000006
#define mod 998244353

signed main() {
    ios_base::sync_with_stdio(false);
    cin.tie(NULL);
    mt19937_64 rng(chrono::steady_clock::now().time_since_epoch()
        .count());
    return 0;
}
```

runner.py44 lines

```
import os
import subprocess

naive = "brute.cpp" # path to naive code
code = "d.cpp" # path to your code
generator = "g.cpp" # path to test generator

def compile_codes():
    os.system('g++ ' + generator + ' -o generator -O2')
    os.system('g++ ' + naive + ' -o naive -O2')
    os.system('g++ ' + code + ' -o code -O2')

def generate_case():
    os.system('./generator > in');
```

def get_naive_output():

1

```
    output = os.popen('./naive <in').read()
    return output

1
def get_code_output():
    # se tiver um runtime error, vai parar
2
    xalala = subprocess.run('./code <in', shell=True, text=True
        , capture_output=True, check=True)
    return xalala.stdout

5
def main():
    compile_codes()

    while True:
        generate_case()
        naive_output = get_naive_output()
        code_output = get_code_output()

        if naive_output == code_output:
            print('ACCEPTED')
        else :
            print('FAILED\n')
            print('ANSWER:')
            print(naive_output)
            print('\nCODE OUTPUT:')
            print(code_output)
            break

if __name__ == '__main__':
    main()
```

int128.cpp22 lines

```
__int128 read() {
    __int128 x = 0, f = 1;
    char ch = getchar();
    while (ch < '0' || ch > '9') {
        if (ch == '-') f = -1;
        ch = getchar();
    }
    while (ch >= '0' && ch <= '9') {
        x = x * 10 + ch - '0';
        ch = getchar();
    }
    return x * f;
}

void print(__int128 x) {
    if (x < 0) {
        cout << "-";
        x = -x;
    }
    if (x > 9) print(x / 10);
    char at = (x % 10) + '0';
    cout << at;
}
```

pragma.cpp5 lines

```
#include <iostream>
using namespace std;
#pragma GCC target("avx2")
#pragma GCC optimize("O3")
#pragma GCC optimize("unroll-loops")
```

Mathematics (2)

modint.cpp78 lines

```
struct modint {
    int val;
    modint(int v = 0) { val = v % mod; }
    int pow(int y) {
        modint x = val;
        modint z = 1;
        while (y) {
            if (y & 1) z *= x;
            x *= x;
            y >>= 1;
        }
        return z.val;
    }
    int inv() { return pow(mod - 2); }
    void operator=(int o) { val = o % mod; }
    void operator=(modint o) { val = o.val % mod; }
    void operator+=(modint o) { *this = *this + o; }
    void operator-=(modint o) { *this = *this - o; }
    void operator*=(modint o) { *this = *this * o; }
    void operator/=(modint o) { *this = *this / o; }
    bool operator==(modint o) { return val == o.val; }
    bool operator!=(modint o) { return val != o.val; }
    int operator*(modint o) { return ((val * o.val) % mod); }
    int operator/(modint o) { return (val * o.inv()) % mod; }
    int operator+(modint o) { return (val + o.val) % mod; }
    int operator-(modint o) { return (val - o.val + mod) % mod; }
};

modint f[MAXN];
modint inv[MAXN];
modint invfat[MAXN];
void calc() {
    f[0] = 1;
    for (int i = 1; i < MAXN; i++) {
        f[i] = f[i - 1] * i;
    }
    inv[1] = 1;
    for (int i = 2; i < MAXN; ++i) {
        int val = mod / i;
        val = (inv[mod % i] * val) % mod;
        val = mod - val;
        inv[i] = val;
    }
    invfat[0] = 1;
    invfat[MAXN - 1] = modint(f[MAXN - 1]).inv();
    for (int i = MAXN - 2; i >= 1; i--) {
        invfat[i] = invfat[i + 1] * (i + 1);
    }
}

modint ncr(int n, int k) // combinacao
{
    modint ans = f[n] * invfat[k];
    ans *= invfat[n - k];
    return ans;
}

modint arr(int n, int k) // arranjo
{
    modint ans = f[n] * invfat[n - k];
    return ans;
}

modint ncr(int n, int k) {
    // calcular combinacao para n grande
    // nesse problema n <= 10^12
    // em O(k)
    modint num = 1;
    modint den = 1;
    for (int i = 0; i < k; i++) {
        num = num * modint(n - i);
```

```
        den = den * modint(i + 1);
    }
    modint ans = num / den;
    return ans;
}
modint stars_andBars(int n, int k) {
    // para pares de inteiros n e k
    // encontre a quantidade de k-tuplas com soma == n
    // x1 + x2 + ... + xk = n
    return ncr(n + k - 1, k - 1);
}
```

divisiontrick.cpp5 lines

```
for (int l = 1, r; l <= n; l = r + 1) {
    // todos os numeros i no intervalo [l, r] possuem (n / i) ==
    // x
    r = n / (n / l);
    int x = (n / l);
}
```

crivo.cpp23 lines

```
bitset<MAXN> prime;
vector<int> nxt(MAXN);
vector<int> factors;
void crivo() {
    prime.set();
    prime[0] = false, prime[1] = false;
    for (int i = 2; i < MAXN; i++) {
        if (prime[i]) {
            nxt[i] = i;
            for (int j = 2; j * i < MAXN; j++) {
                prime[j * i] = false;
                nxt[j * i] = i;
            }
        }
    }
}
void fact(int n) {
    factors.clear();
    while (n > 1) {
        factors.pb(nxt[n]);
        n = n / nxt[n];
    }
}
```

gaussianelimination.cpp33 lines

```
#define EPS 1e-9
vector<double> ans;
int gauss(vector<vector<double>> a) {
    int n = a.size(), m = a[0].size() - 1, ret = 1;
    ans.assign(m, 0);
    vector<int> where(m, -1);
    for (int col = 0, row = 0; col < m && row < n; col++, row++)
    {
        int sel = row;
        for (int i = row; i < n; i++)
            if (abs(a[i][col]) > abs(a[sel][col])) sel = i;
        if (abs(a[sel][col]) < EPS) continue;
        for (int i = col; i <= m; i++) swap(a[sel][i], a[row][i]);
        where[col] = row;
        for (int i = 0; i < n; i++) {
            if (i != row) {
                double c = a[i][col] / a[row][col];
                for (int j = col; j <= m; j++) a[i][j] -= a[row][j] * c;
            }
        }
    }
}
```

```
    }
}
for (int i = 0; i < m; i++) {
    if (where[i] != -1)
        ans[i] = (a[where[i]][m] / a[where[i]][i]);
    else
        ret = 2;
}
for (int i = 0; i < n; i++) {
    double sum = 0;
    for (int j = 0; j < m; j++) sum += (ans[j] * a[i][j]);
    if (abs(sum - a[i][m]) > EPS) ret = 0;
}
return ret; // 0 = nao existe solucao, 1 = existe uma
           // solucao, 2 = existem multiplas solucoes
}
```

gaussianbitset.cpp31 lines

```
bitset<MAXN> ans;
int gauss(vector<bitset<MAXN>>& a) {
    ans.reset();
    int n = a.size(), m = a[0].size() - 1, ret = 1;
    vector<int> where(m, -1);
    for (int col = 0, row = 0; col < m && row < n; col++) {
        for (int i = row; i < n; i++) {
            if (a[i][col]) {
                swap(a[i], a[row]);
                break;
            }
        }
        if (!a[row][col]) continue;
        where[col] = row;
        for (int i = 0; i < n; i++)
            if (i != row && a[i][col]) a[i] ^= a[row];
        ++row;
    }
    for (int i = 0; i < m; i++) {
        if (where[i] != -1)
            ans[i] = (a[where[i]][m] / a[where[i]][i]);
        else
            ret = 2;
    }
    for (int i = 0; i < n; i++) {
        double sum = 0;
        for (int j = 0; j < m; j++) sum += (ans[j] * a[i][j]);
        if (abs(sum - a[i][m]) > EPS) ret = 0;
    }
    return ret;
}
```

Data structures (3)

segtree.cpp25 lines

```
struct segtree {
    int n;
    vector<int> seg;
    int neutral() { return 0; }
    int merge(int a, int b) { return a + b; }
    void build(vector<int> &v) {
        n = 1;
        while (n < v.size()) n <= 1;
        seg.assign(n <= 1, neutral());
        for (int i = 0; i < v.size(); i++) seg[i + n] = v[i];
        for (int i = n - 1; i; i--) seg[i] = merge(seg[i <= 1], seg
            [(i <= 1) | 1]);
    }
}
```

```
void upd(int i, int value) {
    seg[i += n] += value;
    for (i >= 1; i; i >= 1) seg[i] = merge(seg[i <= 1], seg[(
        i <= 1) | 1]);
}
int qry(int l, int r) {
    int ans1 = neutral(), ansr = neutral();
    for (i >= 1; i; i >= 1) {
        for (l += n, r += n + 1; l < r; l >= 1, r >= 1) {
            if (l & 1) ans1 = merge(ans1, seg[l++]);
            if (r & 1) ansr = merge(seg[--r], ansr);
        }
        return merge(ans1, ansr);
    }
};
```

segtreelazy.cpp53 lines

```
struct segtree {
    int n;
    vector<int> v;
    vector<int> seg;
    vector<int> lazy;
    segtree(int sz) {
        n = sz;
        seg.assign(4 * n, 0);
        lazy.assign(4 * n, 0);
    }
    int single(int x) { return x; }
    int neutral() { return 0; }
    int merge(int a, int b) { return a + b; }
    void add(int i, int l, int r, int diff) {
        seg[i] += (r - l + 1) * diff;
        if (l != r) {
            lazy[i <= 1] += diff;
            lazy[(i <= 1) | 1] += diff;
        }
        lazy[i] = 0;
    }
    void update(int i, int l, int r, int ql, int qr, int diff) {
        if (lazy[i]) add(i, l, r, lazy[i]);
        if (l > r || l > qr || r < ql) return;
        if (l >= ql && r <= qr) {
            add(i, l, r, diff);
            return;
        }
        int mid = (l + r) >> 1;
        update(i <= 1, l, mid, ql, qr, diff);
        update((i <= 1) | 1, mid + 1, r, ql, qr, diff);
        seg[i] = merge(seg[i <= 1], seg[(i <= 1) | 1]);
    }
    int query(int l, int r, int ql, int qr, int i) {
        if (lazy[i]) add(i, l, r, lazy[i]);
        if (l > r || l > qr || r < ql) return neutral();
        if (l >= ql && r <= qr) return seg[i];
        int mid = (l + r) >> 1;
        return merge(query(l, mid, ql, qr, i <= 1), query(mid + 1,
            r, ql, qr, (i <= 1) | 1));
    }
    void build(int l, int r, int i) {
        if (l == r) {
            seg[i] = single(v[l]);
            return;
        }
        int mid = (l + r) >> 1;
        build(l, mid, i <= 1);
        build(mid + 1, r, (i <= 1) | 1);
        seg[i] = merge(seg[i <= 1], seg[(i <= 1) | 1]);
    }
    int qry(int l, int r) { return query(0, n - 1, l, r, 1); }
```

```

    void upd(int l, int r, int x) { update(l, 0, n - 1, l, r, x);
    }
};

```

fenwick.cpp

33 lines

```

struct fenw {
    int n;
    vector<int> bit;
    fenw() {}
    fenw(int sz) {
        n = sz;
        bit.assign(sz + 1, 0);
    }
    int qry(int r) // query de prefixo a[0] + a[1] + ... a[r]
    {
        int ret = 0;
        for (int i = r + 1; i > 0; i -= i & -i) ret += bit[i];
        return ret;
    }
    void upd(int r, int x) // a[r] += x
    {
        for (int i = r + 1; i <= n; i += i & -i) bit[i] += x;
    }
    int bs(int x) // retorna o maior indice i (i < n) tal que:
        qry(i) < x
    {
        int i = 0, k = 0;
        while (1 << (k + 1) <= n) k++;
        while (k >= 0) {
            int nxt_i = i + (1 << k);
            if (nxt_i <= n && bit[nxt_i] < x) {
                i = nxt_i;
                x -= bit[i];
            }
            k--;
        }
        return i - 1;
    }
};

```

treap.cpp

93 lines

```

struct treap {
    int data, priority;
    int sz, lazy2;
    bool lazy;
    treap *l, *r, *parent;
};

int size(treap *node) { return (!node) ? 0 : node->sz; }
void recalc(treap *node) {
    if (!node) return;
    node->sz = 1;
    node->parent = 0;
    if (node->l) node->sz += node->l->sz, node->l->parent = node;
    if (node->r) node->sz += node->r->sz, node->r->parent = node;
}

void lazy_propagation(treap *node) {
    if (node == NULL) return;
    if (node->lazy2) {
        if (node->l) node->l->lazy2 += node->lazy2;
        if (node->r) node->r->lazy2 += node->lazy2;
        node->data += node->lazy2;
        node->lazy2 = 0;
    }
    if (node->lazy) {
        swap(node->l, node->r);
        if (node->l) node->l->lazy = !node->l->lazy;
        if (node->r) node->r->lazy = !node->r->lazy;
    }
}

```

```

    node->lazy = 0;
}

void split(treap *t, treap *&l, treap *&r, int n) {
    if (!t) return void(l = r = 0);
    lazy_propagation(t);
    if (size(t->l) >= n)
        split(t->l, l, t->l, n), r = t;
    else
        split(t->r, t->r, r, n - size(t->l) - 1), l = t;
    recalc(t);
}

void merge(treap *t, treap *l, treap *r) {
    lazy_propagation(l);
    lazy_propagation(r);
    if (!l)
        t = r;
    else if (!r)
        t = l;
    else if (l->priority > r->priority)
        merge(l->r, l->r, r), t = l;
    else
        merge(r->l, l, r->l), t = r;
    recalc(t);
}

void troca(treap *&t, int l, int r, int ll, int rr) // sap de
    ranges
{
    treap *a0, *a1, *b0, *b1, *c0, *c1, *d0, *d1;
    split(t, a0, a1, l);
    split(a1, b0, b1, r - l + 1);
    ll -= (r + 1);
    rr -= (r + 1);
    split(b1, c0, c1, ll);
    split(c1, d0, d1, rr - ll + 1);
    merge(t, a0, d0);
    merge(t, t, c0);
    merge(t, t, b0);
    merge(t, t, d1);
}

void add(treap *&t, int l, int r) {
    treap *a0, *a1, *b0, *b1;
    split(t, a0, a1, l);
    split(a1, b0, b1, r - l + 1);
    b0->lazy ^= 1;
    b0->lazy2 += 1;
    merge(t, a0, b0);
    merge(t, t, b1);
}

void dfs(treap *t) {
    if (!t) return;
    lazy_propagation(t);
    dfs(t->l);
    solve(t->data);
    dfs(t->r);
}

treap *create_node(int data, int priority) {
    treap *ret = new treap;
    ret->data = data;
    ret->priority = priority;
    ret->l = 0;
    ret->r = 0;
    ret->sz = 1;
    ret->lazy = 0;
    ret->lazy2 = 0;
    ret->parent = 0;
    return ret;
}

```

colorupdate.cpp

74 lines

```

const int inf = 1e15;
struct color_upd {
#define left fir
#define right sec.fir
#define color sec.sec
    set<pii> ranges;
    vector<pii> erased;
    color_upd(int n) // inicialmente, todo mundo pintado com a
        cor inf
    {
        // nao usar cores negativas!!!!!!!
        ranges.insert({0, {n - 1, inf}});
    }
    int get(int i) {
        auto it = ranges.upper_bound({i, {1e18, 1e18}});
        if (it == ranges.begin()) return -1;
        it--;
        return ((*it)).color;
    }
    void del(int l, int r) // apaga o intervalo [l, r]
    {
        erased.clear();
        auto it = ranges.upper_bound({l, {0, 0}});
        if (it != ranges.begin()) {
            it--;
        }
        while (it != ranges.end()) {
            if ((*it)).left > r)
                break;
            else if ((*it)).right >= l)
                erased.push_back(*it);
            it++;
        }
        if (erased.size() > 0) {
            int sz = erased.size();
            auto it = ranges.lower_bound({erased[0].left, {0, 0}});
            auto it2 = ranges.lower_bound({erased[sz - 1].left, {0, 0}});
            pii ini = *it, fim = *it2;
            it2++;
            ranges.erase(it, it2);
            pii upd1 = {ini.left, {l - 1, ini.color}};
            pii upd2 = {r + 1, {fim.right, fim.color}};
            erased[0].left = max(erased[0].left, l);
            erased[sz - 1].right = min(erased[sz - 1].right, r);
            if (upd1.left <= upd1.right) ranges.insert(upd1);
            if (upd2.left <= upd2.right) ranges.insert(upd2);
        }
    }
    void add(int a, int b, int c) {
        auto it = ranges.lower_bound({a, {b, 0}});
        pii aa = {-1, {-1, -1}};
        pii bb = {-1, {-1, -1}};
        if (it != ranges.end()) {
            if ((*it).color == c && (*it).left == b + 1) {
                aa = *it;
                b = (*it).right;
            }
        }
        if (it != ranges.begin()) {
            it--;
            if ((*it).color == c && (*it).right == a - 1) {
                bb = *it;
                a = (*it).left;
            }
        }
        ranges.erase(aa);
    }
}

```

```
        ranges.erase(bb);
        ranges.insert({a, {b, c}}});
    }
    void upd(int a, int b, int c)    // pinta o intervalo [a, b]
        com a cor c
    {
        del(a, b);
        add(a, b, c);
    }
};
```

bit2d.cpp

51 lines

```
struct bit2d {
    vector<int> ord;
    vector<vector<int>>> t;
    vector<vector<int>>> coord;
    bit2d(vector<pi> &pts)    // recebe todos os pontos que vao ser
        inseridos pra construir, mas nao insere eles
    {
        sort(pts.begin(), pts.end());
        for (auto const &a : pts) {
            if (ord.empty() || a.fir != ord.back()) ord.pb(a.fir);
        }
        t.resize(ord.size() + 1);
        coord.resize(t.size());
        for (auto &a : pts) {
            swap(a.fir, a.sec);
        }
        sort(pts.begin(), pts.end());
        for (auto &a : pts) {
            swap(a.fir, a.sec);
            for (int on = upper_bound(ord.begin(), ord.end(), a.fir)
                - ord.begin(); on < t.size(); on += on & -on) {
                if (coord[on].empty() || coord[on].back() != a.sec)
                    coord[on].push_back(a.sec);
            }
        }
        for (int i = 0; i < t.size(); i++) t[i].assign(coord[i].
            size() + 1, 0);
    }
    void add(int x, int y, int v)    // v[a][b] += v
    {
        for (int xx = upper_bound(ord.begin(), ord.end(), x) - ord.
            begin(); xx < t.size(); xx += xx & -xx) {
            for (int yy = upper_bound(coord[xx].begin(), coord[xx].
                end(), y) - coord[xx].begin(); yy < t[xx].size();
                yy += yy & -yy)
                t[xx][yy] += v;
        }
    }
    int qry(int x, int y)    // soma de todos os v[a][b] com (a <=
        x && b <= y)
    {
        int ans = 0;
        for (int xx = upper_bound(ord.begin(), ord.end(), x) - ord.
            begin(); xx > 0; xx -= xx & -xx) {
            for (int yy = upper_bound(coord[xx].begin(), coord[xx].
                end(), y) - coord[xx].begin(); yy > 0; yy -= yy & -
                yy)
                ans += t[xx][yy];
        }
        return ans;
    }
    int qry2(int x1, int y1, int x2, int y2) {
        return qry(x2, y2) - qry(x2, y1 - 1) - qry(x1 - 1, y2) +
            qry(x1 - 1, y1 - 1);
    }
    void add2(int x1, int y1, int x2, int y2, int v) {
```

```
        add(x1, y1, v);
        add(x1, y2 + 1, -v);
        add(x2 + 1, y1, -v);
        add(x2 + 1, y2 + 1, v);
    }
};
```

mo.cpp

45 lines

```
namespace mo {
    struct query {
        int idx, l, r;
    };
    int block;
    vector<query> queries;
    vector<int> ans;
    // bool cmp(query &x, query &y){    essa funcao de ordenacao pode
        funcionar em caso de TLE
    //    int ablock = x.l / MAGIC, bblock = y.l / MAGIC;
    //    if (ablock != bblock) return ablock < bblock;
    //    if (ablock & 1) return x.r < y.r;
    //    return x.r > y.r;
    // }
    bool cmp(query &x, query &y) {
        if (x.l / block != y.l / block) return x.l / block < y.l /
            block;
        return x.r < y.r;
    }
    void run() {
        block = (int)sqrt(n);
        sort(queries.begin(), queries.end(), cmp);
        ans.resize(queries.size());
        int cl = 0, cr = -1, sum = 0;
        auto add = [&](int x) { sum += x; };
        auto rem = [&](int x) { sum -= x; };
        for (int i = 0; i < queries.size(); i++) {
            while (cl > queries[i].l) {
                cl--;
                add(v[cl]);
            }
            while (cr < queries[i].r) {
                cr++;
                add(v[cr]);
            }
            while (cl < queries[i].l) {
                rem(v[cl]);
                cl++;
            }
            while (cr > queries[i].r) {
                rem(v[cr]);
                cr--;
            }
            ans[queries[i].idx] = sum;
        }
    }
} // namespace mo
```

segtree2d.cpp

33 lines

```
struct segtree2d {
    int n, m;
    vector<vector<int>>> seg;
    int neutral() { return 0; }
    int merge(int a, int b) { return a + b; }
    segtree2d(int nn, int mm) {
        n = nn, m = mm;
        seg = vector<vector<int>>>(2 * n, vector<int>(2 * m, neutral
            ())),
    }
```

```
    int qry(int x1, int y1, int x2, int y2) {
        int ret = neutral();
        int y3 = y1 + m, y4 = y2 + m;
        for (x1 += n, x2 += n; x1 <= x2; ++x1 /= 2, --x2 /= 2) {
            for (y1 = y3, y2 = y4; y1 <= y2; ++y1 /= 2, --y2 /= 2) {
                if (x1 % 2 == 1 and y1 % 2 == 1) ret = merge(ret, seg[
                    x1][y1]);
                if (x1 % 2 == 1 and y2 % 2 == 0) ret = merge(ret, seg[
                    x1][y2]);
                if (x2 % 2 == 0 and y1 % 2 == 1) ret = merge(ret, seg[
                    x2][y1]);
                if (x2 % 2 == 0 and y2 % 2 == 0) ret = merge(ret, seg[
                    x2][y2]);
            }
        }
        return ret;
    }
    void upd(int x, int y, int val) {
        int y2 = y += m;
        for (x += n; x; x /= 2, y = y2) {
            if (x >= n)
                seg[x][y] = val;
            else
                seg[x][y] = merge(seg[2 * x][y], seg[2 * x + 1][y]);
            while (y /= 2) seg[x][y] = merge(seg[x][2 * y], seg[x][2
                * y + 1]);
        }
    }
};
```

persistentseg.cpp

37 lines

```
struct node {
    int item, l, r;
    node() {}
    node(int l, int r, int item) : l(l), r(r), item(item) {}
};
int n, q;
vector<node> seg;
vector<int> roots;
void init() { seg.resize(1); }
int newleaf(int vv) {
    int p = seg.size();
    seg.pb(node(0, 0, vv));
    return p;
}
int newpar(int l, int r) {
    int p = seg.size();
    seg.pb(node(l, r, seg[l].item + seg[r].item));
    return p;
}
int upd(int i, int l, int r, int pos) {
    if (l == r) return newleaf(seg[i].item + 1);
    int mid = (l + r) >> 1;
    if (pos <= mid) return newpar(upd(seg[i].l, l, mid, pos), seg
        [i].r);
    return newpar(seg[i].l, upd(seg[i].r, mid + 1, r, pos));
}
int build(int l, int r) {
    if (l == r) return newleaf(0);
    int mid = (l + r) >> 1;
    return newpar(build(l, mid), build(mid + 1, r));
}
int qry(int vl, int vr, int l, int r, int k) {
    if (l == r) return l;
    int mid = (l + r) >> 1;
    int c = seg[seg[vr].l].item - seg[seg[vl].l].item;
    if (c >= k) return qry(seg[vl].l, seg[vr].l, l, mid, k);
    return qry(seg[vl].r, seg[vr].r, mid + 1, r, k - c);
}
```

```

}

rmq.cpp21 lines
struct rmq {
    int n;
    vector<vector<pi>> m;
    vector<int> log;
    rmq() {}
    rmq(vector<pi> &v) {
        n = v.size();
        log.resize(n + 1);
        log[1] = 0;
        for (int i = 2; i <= n; i++) log[i] = log[i / 2] + 1;
        int sz = log[n] + 2;
        m = vector<vector<pi>>(sz, vector<pi>(n + 1));
        for (int i = 0; i < n; i++) {
            m[0][i] = v[i];
        }
        for (int j = 1; j < sz; j++) {
            for (int i = 0; i + (1 << j) <= n; i++) m[j][i] = min(m[j - 1][i], m[j - 1][i + (1 << (j - 1))]);
        }
    }
    int qry(int a, int b) { return min(m[log[b - a + 1]][a], m[log[b - a + 1]][b - (1 << log[b - a + 1]) + 1]).second;
}
};
```

```

binarylifting.cpp23 lines
item st[MAXN][21];
for (int i = 0; i < n; i++) {
    st[i][0].nxt = min(i + 1, n - 1);
    st[i][0].sum = v[st[i][0].nxt];
}
for (int i = 1; i < 21; i++) {
    for (int v = 0; v < n; v++) {
        st[v][i].nxt = st[st[v][i - 1].nxt][i - 1].nxt;
        st[v][i].sum = st[v][i - 1].sum + st[st[v][i - 1].nxt][i - 1].sum;
    }
}
while (q--) {
    int l, r;
    cin >> l >> r;
    int ans = v[l], len = r - l;
    for (int i = 20; i >= 0; i--) {
        if (len & (1 << i)) {
            ans += st[l][i].sum;
            l = st[l][i].nxt;
        }
    }
    cout << ans << endl;
}
}
```

Graph (4)

```

floydwarshall.cpp21 lines
int dist[MAXN][MAXN];
void floyd_warshall() {
    for (int k = 0; k < n; k++) {
        for (int i = 0; i < n; i++) {
            for (int j = 0; j < n; j++) {
                dist[i][j] = min(dist[i][j], dist[i][k] + dist[k][j]);
            }
        }
    }
}
```

```

}
}
void initialize() {
    for (int i = 0; i < n; i++) {
        for (int j = 0; j < n; j++) {
            if (i == j) {
                dist[i][j] = 0;
            } else {
                dist[i][j] = INF;
            }
        }
    }
}
}
```

```

centroiddecomp.cpp68 lines
int n, k, resp;
vector<int> adj[MAXN];
vector<int> cnt;
namespace cd {
    int sz;
    vector<int> subtree_size;
    vector<bool> visited;
    void dfs(int s, int f) {
        sz++;
        subtree_size[s] = 1;
        for (auto const &v : adj[s]) {
            if (v != f && !visited[v]) {
                dfs(v, s);
                subtree_size[s] += subtree_size[v];
            }
        }
    }
    int get_centroid(int s, int f) {
        bool is_centroid = true;
        int heaviest_child = -1;
        for (auto const &v : adj[s]) {
            if (v != f && !visited[v]) {
                if (subtree_size[v] > sz / 2) is_centroid = false;
                if (heaviest_child == -1 || subtree_size[v] > subtree_size[heaviest_child]) heaviest_child = v;
            }
        }
        return (is_centroid && sz - subtree_size[s] <= sz / 2) ? s : get_centroid(heaviest_child, s);
    }
}
void dfs2(int s, int f, int d) {
    while (d >= cnt.size()) cnt.pb(0);
    cnt[d]++;
    for (auto const &v : adj[s]) {
        if (v != f && !visited[v]) dfs2(v, s, d + 1);
    }
}
void solve(int s) {
    vector<int> tot;
    for (auto const &v : adj[s]) {
        if (visited[v]) continue;
        cnt.clear();
        dfs2(v, s, 1);
        for (int i = 1; i < cnt.size(); i++) {
            if (k - i < tot.size() && k - i >= 1) resp += (cnt[i] * tot[k - i]);
        }
        for (int i = 1; i < cnt.size(); i++) {
            while (i >= tot.size()) tot.pb(0);
            tot[i] += cnt[i];
        }
    }
    if (k < tot.size()) resp += tot[k];
}
```

```

}
int decompose_tree(int s) {
    sz = 0;
    dfs(s, s);
    int cend_tree = get_centroid(s, s);
    visited[cend_tree] = true;
    solve(cend_tree);
    for (auto const &v : adj[cend_tree]) {
        if (!visited[v]) decompose_tree(v);
    }
    return cend_tree;
}
void init() {
    subtree_size.resize(n);
    visited.resize(n);
    decompose_tree(0);
}
} // namespace cd
```

```

dsu.cpp24 lines
struct dsu {
    int tot;
    vector<int> parent;
    vector<int> sz;
    dsu(int n) {
        parent.resize(n);
        sz.resize(n);
        tot = n;
        for (int i = 0; i < n; i++) {
            parent[i] = i;
            sz[i] = 1;
        }
    }
    int find_set(int i) { return parent[i] = (parent[i] == i) ? i : find_set(parent[i]); }
    void make_set(int x, int y) {
        x = find_set(x), y = find_set(y);
        if (x != y) {
            if (sz[x] > sz[y]) swap(x, y);
            parent[x] = y;
            sz[y] += sz[x];
            tot--;
        }
    }
};
```

```

dsubipartido.cpp41 lines
struct dsu {
    vector<pi> parent;
    vector<int> rank;
    vector<int> bipartite;
    dsu(int n) {
        parent.resize(n);
        rank.resize(n);
        bipartite.resize(n);
        for (int v = 0; v < n; v++) {
            parent[v] = {v, 0};
            rank[v] = 0;
            bipartite[v] = 1;
        }
    }
    dsu() {}
    pi find_set(int v) {
        if (v != parent[v].fir) {
            int parity = parent[v].sec;
            parent[v] = find_set(parent[v].fir);
            parent[v].sec ^= parity;
        }
    }
}
```

```

    }
    return parent[v];
}
void add_edge(int a, int b) {
    pi pa = find_set(a);
    a = pa.fir;
    int x = pa.sec;
    pi pb = find_set(b);
    b = pb.fir;
    int y = pb.sec;
    if (a == b) {
        if (x == y) bipartite[a] = 0;
    } else {
        if (rank[a] < rank[b]) swap(a, b);
        parent[b] = {a, x ^ y ^ 1};
        bipartite[a] ^= bipartite[b];
        if (rank[a] == rank[b]) rank[a]++;
    }
}
bool is_bipartite(int v) { return bipartite[find_set(v).fir];
}
};

```

cycledetection.cpp

26 lines

```

int n, m, idx;
vector<int> cycles[MAXN];
vector<int> adj[MAXN];
int color[MAXN];
int parent[MAXN];
int ans[MAXN];
void dfs(int u, int p) { // chama dfs a partir de qm tem cor 0
    if (color[u] == 2) return;
    if (color[u] == 1) {
        idx++;
        int curr = p;
        ans[curr] = idx;
        cycles[idx].pb(curr);
        while (curr != u) {
            curr = parent[curr];
            cycles[idx].pb(curr);
            ans[curr] = idx;
        }
        return;
    }
    parent[u] = p;
    color[u] = 1;
    for (auto const &v : adj[u])
        if (v != parent[u]) dfs(v, u);
    color[u] = 2;
}

```

blockcuttree.cpp

74 lines

```

struct block_cut_tree {
    // Se art[i] >= 1, i eh ponto de articulacao
    // tree - eh a propria block-cut tree
    // pos[i] responde a qual vertice da arvore vertice i
    // pertence
    vector<vector<int>> g, blocks, tree;
    vector<vector<pi>> edgblocks; // sao as arestas do bloco i
    stack<int> s;
    stack<pi> s2;
    vector<int> id, art, pos;

    block_cut_tree(vector<vector<int>> g_) : g(g_) {
        int n = g.size();
        id.resize(n, -1), art.resize(n), pos.resize(n);
        build();
    }
}

```

```

}
int dfs(int i, int &t, int p = -1) {
    int lo = id[i] = t++;
    s.push(i);
    if (p != -1) {
        s2.emplace(i, p);
    }
    for (int j : g[i]) {
        if (j != p and id[j] != -1) s2.emplace(i, j);
    }
    for (int j : g[i]) {
        if (j != p) {
            if (id[j] == -1) {
                int val = dfs(j, t, i);
                lo = min(lo, val);
                if (val >= id[i]) {
                    art[i]++;
                    blocks.emplace_back(1, i);
                    while (blocks.back().back() != j) {
                        blocks.back().pb(s.top());
                        s.pop();
                    }
                    edgblocks.emplace_back(1, s2.top());
                    s2.pop();
                    pi aux = {j, i};
                    while (edgblocks.back().back() != aux) {
                        edgblocks.back().pb(s2.top());
                        s2.pop();
                    }
                }
                // if (val > id[i]) aresta i-j eh ponte
            } else {
                lo = min(lo, id[j]);
            }
        }
    }
    if (p == -1 and art[i]) {
        art[i]--;
    }
    return lo;
}
void build() {
    int t = 0;
    for (int i = 0; i < g.size(); i++) {
        if (id[i] == -1) dfs(i, t, -1);
    }
    tree.resize(blocks.size());
    for (int i = 0; i < g.size(); i++) {
        if (art[i]) pos[i] = tree.size(), tree.emplace_back();
    }
    for (int i = 0; i < blocks.size(); i++) {
        for (int j : blocks[i]) {
            if (!art[j])
                pos[j] = i;
            else
                tree[i].pb(pos[j]), tree[pos[j]].pb(i);
        }
    }
}
};

```

bridges.cpp

21 lines

```

nt n, m, timer;
vector<pi> edges;
vector<bool> is_bridge;
vector<pi> adj[MAXN];
int tin[MAXN];
int low[MAXN]; // memset -1

```

```

bool vis[MAXN]; // memset -1
void dfs(int v, int p) { // chama de quem nao foi vis ainda
    vis[v] = true;
    tin[v] = timer, low[v] = timer++;
    for (auto const &u : adj[v]) {
        if (u.fir == p) continue;
        if (vis[u.fir]) {
            low[v] = min(low[v], tin[u.fir]);
            continue;
        }
        dfs(u.fir, v);
        low[v] = min(low[v], low[u.fir]);
        if (low[u.fir] > tin[v]) is_bridge[u.sec] = 1;
    }
}
}

```

dinic.cpp

83 lines

```

#define INF 1e9
struct edge {
    int to, from, flow, capacity, id;
};
struct dinic {
    int n, src, sink;
    vector<vector<edge>> adj;
    vector<int> level;
    vector<int> ptr;

    dinic(int sz) {
        n = sz;
        adj.resize(n);
        level.resize(n);
        ptr.resize(n);
    }
    void add_edge(int a, int b, int c, int id) {
        adj[a].pb({b, (int)adj[b].size(), c, c, id});
        adj[b].pb({a, (int)adj[a].size() - 1, 0, 0, id});
    }
    bool bfs() {
        level.assign(n, -1);
        level[src] = 0;
        queue<int> q;
        q.push(src);
        while (!q.empty()) {
            int u = q.front();
            q.pop();
            for (auto at : adj[u]) {
                if (at.flow && level[at.to] == -1) {
                    q.push(at.to);
                    level[at.to] = level[u] + 1;
                }
            }
        }
        return level[sink] != -1;
    }
    int dfs(int u, int flow) {
        if (u == sink || flow == 0) return flow;
        for (int &p = ptr[u]; p < adj[u].size(); p++) {
            edge &at = adj[u][p];
            if (at.flow && level[u] == level[at.to] - 1) {
                int kappa = dfs(at.to, min(flow, at.flow));
                at.flow -= kappa;
                adj[at.to][at.from].flow += kappa;
                if (kappa != 0) return kappa;
            }
        }
        return 0;
    }
    int run() {

```

```

int max_flow = 0;
while (bfs()) {
    ptr.assign(n, 0);
    while (1) {
        int flow = dfs(src, INF);
        if (flow == 0) break;
        max_flow += flow;
    }
}
return max_flow;
}
vector<pii> cut_edges() // arestas do corte minimo
{
    bfs();
    vector<pii> ans;
    for (int i = 0; i < n; i++) {
        for (auto const &j : adj[i]) {
            if (level[i] != -1 && level[j.to] == -1 && j.capacity >
                0) ans.pb({j.capacity, {i, j.to}});
        }
    }
    return ans;
}
vector<int> flow_edges(int n, int m) // fluxo em cada aresta
, na ordem da entrada
{
    vector<int> ans(m);
    for (int i = 0; i < n; i++) {
        for (auto const &j : adj[i])
            if (!j.capacity) ans[j.id] = j.flow;
    }
    return ans;
}
};

```

hopcroftkarp.cpp

137 lines

```

#define INF 1e9
struct hopcroft_karp {
    vector<int> match;
    vector<int> dist;
    vector<vector<int>>> adj;
    int n, m, t;
    hopcroft_karp(int a, int b) {
        n = a, m = b;
        t = n + m + 1;
        match.assign(t, n + m);
        dist.assign(t, 0);
        adj.assign(t, vector<int>{});
    }
    void add_edge(int u, int v) {
        adj[u].pb(v);
        adj[v].pb(u);
    }
    bool bfs() {
        queue<int> q;
        for (int u = 0; u < n; u++) {
            if (match[u] == n + m)
                dist[u] = 0, q.push(u);
            else
                dist[u] = INF;
        }
        dist[n + m] = INF;
        while (!q.empty()) {
            int u = q.front();
            q.pop();
            if (dist[u] < dist[n + m]) {
                for (auto const &v : adj[u]) {
                    if (dist[match[v]] == INF) {

```

```

                        dist[match[v]] = dist[u] + 1;
                        q.push(match[v]);
                    }
                }
            }
        }
        return dist[n + m] < INF;
    }
    bool dfs(int u) {
        if (u < n + m) {
            for (auto const &v : adj[u]) {
                if (dist[match[v]] == dist[u] + 1 && dfs(match[v])) {
                    match[v] = u;
                    match[u] = v;
                    return true;
                }
            }
            dist[u] = INF;
            return false;
        }
        return true;
    }
    vector<pi> run() {
        int cnt = 0;
        while (bfs())
            for (int u = 0; u < n; u++)
                if (match[u] == n + m && dfs(u)) cnt++;
        vector<pi> ans;
        for (int v = n; v < n + m; v++)
            if (match[v] < n + m) ans.pb({match[v], v});
        return ans;
    }
    vector<int> mvc() // minimum vertex cover
    {
        vector<pi> ans = run();
        vector<bool> vis(n + m, 0);
        for (int i = 0; i < n; i++) {
            if (match[i] == n + m) {
                queue<int> q;
                q.push(i);
                while (!q.empty()) {
                    int x = q.front();
                    q.pop();
                    vis[x] = 1;
                    for (auto const &y : adj[x]) {
                        if (!vis[y]) {
                            vis[y] = 1;
                            q.push(match[y]);
                        }
                    }
                }
            }
        }
        vector<int> vc;
        for (int i = 0; i < n; i++) {
            if (!vis[i]) vc.pb(i);
        }
        for (int i = n; i < n + m; i++) {
            if (vis[i]) vc.pb(i);
        }
        return vc;
    }
    vector<pi> mec() // minimum edge cover
    {
        vector<pi> ans = run();
        for (int i = 0; i < n + m; i++) {
            if (match[i] == n + m && adj[i].size() > 0) {
                if (i < n)
                    ans.pb({i, adj[i][0]});

```

```

                        else
                            ans.pb({adj[i][0], i});
                    }
                }
            }
            return ans;
        }
    };
    // minimum path cover on dag
    // minimum set of paths such that each of the vertices belongs
    // to exactly one path
    vector<vector<int>>> mpc(int n, vector<pi> &e) {
        hopcroft_karp h(n, n);
        for (auto const &i : e) h.add_edge(i.fir, n + i.sec);
        vector<pi> mat = h.run();
        vector<int> prv(n, -1);
        vector<int> nxt(n, -1);
        for (int i = 0; i < mat.size(); i++) {
            nxt[mat[i].fir] = mat[i].sec - n;
            prv[mat[i].sec - n] = mat[i].fir;
        }
        vector<vector<int>>> ans;
        for (int i = 0; i < n; i++) {
            if (prv[i] == -1 && nxt[i] == -1) {
                ans.pb({i});
            } else if (prv[i] == -1) {
                vector<int> curr;
                int x = i;
                while (1) {
                    curr.pb(x);
                    if (nxt[x] == -1) break;
                    x = nxt[x];
                }
                ans.pb(curr);
            }
        }
        return ans;
    }
};

```

pushrelabel.cpp

93 lines

```

#define INF 1e9
struct edge {
    int dest, back, f, c, id;
};
struct push_relabel {
    int n;
    vector<vector<edge>>> g;
    vector<int> ec;
    vector<edge *> cur;
    vector<vector<int>>> hs;
    vector<int> H;
    push_relabel(int sz) : g(sz), ec(sz), cur(sz), hs(2 * sz), H(
        sz) { n = sz; }
    void add_edge(int s, int t, int cap, int rcap, int id) {
        if (s == t) return;
        g[s].pb({t, (int)g[t].size(), 0, cap, id});
        g[t].pb({s, (int)g[s].size() - 1, 0, rcap, -1});
    }
    void add_flow(edge &e, int f) {
        edge &back = g[e.dest][e.back];
        if (!ec[e.dest] && f) hs[H[e.dest]].push_back(e.dest);
        e.f += f;
        e.c -= f;
        ec[e.dest] += f;
        back.f -= f;
        back.c += f;
        ec[back.dest] -= f;
    }
    int calc(int s, int t) {

```



```

int v = g.size();
H[s] = v;
ec[t] = 1;
vector<int> co(2 * v);
co[0] = v - 1;
for (int i = 0; i < v; i++) cur[i] = g[i].data();
for (edge &e : g[s]) add_flow(e, e.c);
for (int hi = 0;;) {
    while (hs[hi].empty())
        if (!hi--) return -ec[s];
    int u = hs[hi].back();
    hs[hi].pop_back();
    while (ec[u] > 0) {
        if (cur[u] == g[u].data() + g[u].size()) {
            H[u] = INF;
            for (edge &e : g[u])
                if (e.c && H[u] > H[e.dest] + 1) H[u] = H[e.dest] + 1, cur[u] = &e;
            if (++co[H[u]], !--co[hi] && hi < v)
                for (int i = 0; i < v; i++)
                    if (hi < H[i] && H[i] < v) --co[H[i]], H[i] = v + 1;
            hi = H[u];
        } else if (cur[u]->c && H[u] == H[cur[u]->dest] + 1)
            add_flow(*cur[u], min(ec[u], cur[u]->c));
        else
            ++cur[u];
    }
}
}
vector<int> flow_edges(int m) // fluxo em cada aresta
{
    vector<int> ans(m);
    for (int i = 0; i < n; i++) {
        for (auto const &j : g[i]) {
            if (j.id != -1) ans[j.id] = j.f;
        }
    }
    return ans;
}
};

struct flow_with_demands {
    push_relabel pr;
    vector<int> in, out;
    int n;

    flow_with_demands(int sz) : n(sz), pr(sz + 2), in(sz), out(sz) {}
    void add_edge(int u, int v, int cap, int dem, int id) {
        pr.add_edge(u, v, cap - dem, 0, id);
        out[u] += dem, in[v] += dem;
    }
    int run(int s, int t) {
        pr.add_edge(t, s, INF, 0, -1);
        for (int i = 0; i < n; i++) {
            pr.add_edge(n, i, in[i], 0, -1);
            pr.add_edge(i, n + 1, out[i], 0, -1);
        }
        return pr.calc(n, n + 1);
    }
}
bool check() // todas as constraints foram satisfeitas?
{
    for (auto const &i : pr.g[n]) {
        if (i.c > 0) return 0;
    }
    return 1;
}
};

```

hld.cpp

65 lines

```

struct hld {
    int n, cur_pos;
    segtree seg;
    vector<vector<int>>> adj;
    vector<int> parent, depth, heavy, head, pos, sz;
    int dfs(int s) {
        int size = 1, max_c_size = 0;
        for (auto const &c : adj[s]) {
            if (c != parent[s]) {
                parent[c] = s;
                depth[c] = depth[s] + 1;
                int c_size = dfs(c);
                size += c_size;
                if (c_size > max_c_size) max_c_size = c_size, heavy[s] = c;
            }
        }
        return sz[s] = size;
    }
    void decompose(int s, int h) {
        head[s] = h;
        pos[s] = cur_pos++;
        if (heavy[s] != -1) decompose(heavy[s], h);
        for (int c : adj[s]) {
            if (c != parent[s] && c != heavy[s]) decompose(c, c);
        }
    }
    hld(vector<vector<int>>> &g) {
        n = g.size();
        adj = g;
        seg = segtree(n);
        parent.assign(n, -1);
        depth.assign(n, -1);
        heavy.assign(n, -1);
        head.assign(n, -1);
        pos.assign(n, -1);
        sz.assign(n, 1);
        cur_pos = 0;
        dfs(0);
        decompose(0, 0);
    }
    int query_path(int a, int b) {
        int res = 0;
        for (; head[a] != head[b]; b = parent[head[b]]) {
            if (depth[head[a]] > depth[head[b]]) swap(a, b);
            res += seg.query(0, n - 1, pos[head[b]], pos[b], 1);
        }
        if (depth[a] > depth[b]) swap(a, b);
        res += seg.query(0, n - 1, pos[a], pos[b], 1);
        return res;
    }
    void update_path(int a, int b, int x) {
        for (; head[a] != head[b]; b = parent[head[b]]) {
            if (depth[head[a]] > depth[head[b]]) swap(a, b);
            seg.update(1, 0, n - 1, pos[head[b]], pos[b], x);
        }
        if (depth[a] > depth[b]) swap(a, b);
        seg.update(1, 0, n - 1, pos[a], pos[b], x);
    }
    void update_subtree(int a, int x) { seg.update(1, 0, n - 1, pos[a], pos[a] + sz[a] - 1, x); }
    int query_subtree(int a) { return seg.query(0, n - 1, pos[a], pos[a] + sz[a] - 1, 1); }
    int lca(int a, int b) {
        if (pos[a] < pos[b]) swap(a, b);
        return (head[a] == head[b]) ? b : lca(parent[head[a]], b);
    }
}

```

};

hldedge.cpp

67 lines

```

namespace hld {
    int cur_pos;
    vector<int> parent, depth, heavy, head, pos, sz, up;
    int dfs(int s) {
        int size = 1, max_c_size = 0;
        for (auto const &c : adj[s]) {
            if (c.fir != parent[s]) {
                parent[c.fir] = s;
                depth[c.fir] = depth[s] + 1;
                int c_size = dfs(c.fir);
                size += c_size;
                if (c_size > max_c_size) max_c_size = c_size, heavy[s] = c.fir;
            }
        }
        return sz[s] = size;
    }
    void decompose(int s, int h) {
        head[s] = h;
        pos[s] = cur_pos++;
        seg::v[pos[s]] = up[s];
        for (auto const &c : adj[s]) {
            if (c.fir != parent[s] && c.fir == heavy[s]) {
                up[c.fir] = c.sec;
                decompose(heavy[s], h);
            }
        }
        for (auto const &c : adj[s]) {
            if (c.fir != parent[s] && c.fir != heavy[s]) {
                up[c.fir] = c.sec;
                decompose(c.fir, c.fir);
            }
        }
    }
    void init() {
        parent.assign(MAXN, -1);
        depth.assign(MAXN, -1);
        heavy.assign(MAXN, -1);
        head.assign(MAXN, -1);
        pos.assign(MAXN, -1);
        sz.assign(MAXN, 1);
        up.assign(MAXN, 0);
        cur_pos = 0;
        dfs(0);
        decompose(0, 0);
        seg::build(0, n - 1, 1);
    }
    int query_path(int a, int b) {
        int res = -1;
        for (; head[a] != head[b]; b = parent[head[b]]) {
            if (depth[head[a]] > depth[head[b]]) swap(a, b);
            res = max(res, seg::query(0, n - 1, pos[head[b]], pos[b], 1));
        }
        if (depth[a] > depth[b]) swap(a, b);
        res = max(res, seg::query(0, n - 1, pos[a] + 1, pos[b], 1));
        return res;
    }
    void update_path(int a, int b, int x) {
        for (; head[a] != head[b]; b = parent[head[b]]) {
            if (depth[head[a]] > depth[head[b]]) swap(a, b);
            seg::update(1, 0, n - 1, pos[head[b]], pos[b], x);
        }
        if (depth[a] > depth[b]) swap(a, b);
        seg::update(1, 0, n - 1, pos[a] + 1, pos[b], x);
    }
}

```

```
}
void update_subtree(int a, int x) { seg::update(1, 0, n - 1,
    pos[a] + 1, pos[a] + sz[a] - 1, x); }
int query_subtree(int a, int x) { return seg::query(0, n - 1,
    pos[a] + 1, pos[a] + sz[a] - 1, 1); }
} // namespace hld
```

strongorientation.cpp25 lines

```
// encontrar uma orientacao para as arestas tal que o numero
// minimo de scc eh o menor possivel
// numero minimo de scc = numero de componentes conexas +
// numero de pontes
int n, m, timer, comps, bridges;
vector<pi> edges;
vector<pi> adj[MAXN];
int tin[MAXN]; // memset -1
int low[MAXN]; // memset -1
bool vis[MAXN];
char orient[MAXN];
void find_bridges(int v) { // chama se tem tin == -1
    low[v] = timer, tin[v] = timer++;
    for (auto const &p : adj[v]) {
        if (vis[p.sec]) continue;
        vis[p.sec] = true;
        orient[p.sec] = (v == edges[p.sec].first) ? '>' : '<';
        if (tin[p.fir] == -1) {
            find_bridges(p.fir);
            low[v] = min(low[v], low[p.fir]);
            if (low[p.fir] > tin[v]) bridges++;
        } else {
            low[v] = min(low[v], low[p.fir]);
        }
    }
}
```

twosat.cpp74 lines

```
struct two_sat {
    int n;
    vector<vector<int>> g, gr; // gr is the reversed graph
    vector<int> comp, ord, ans; // comp[v]: ID of the SCC
    containing node v
    vector<bool> vis;
    two_sat() {}
    two_sat(int sz) {
        n = sz;
        g.assign(2 * n, vector<int>());
        gr.assign(2 * n, vector<int>());
        comp.resize(2 * n);
        vis.resize(2 * n);
        ans.resize(2 * n);
    }
    void add_edge(int u, int v) {
        g[u].push_back(v);
        gr[v].push_back(u);
    }
    // int x, bool val: if 'val' is true, we take the variable to
    // be x. Otherwise we take it to be x's complement (not x)
    void implies(int i, bool f, int j, bool g) // a -> b
    {
        add_edge(i + (f ? 0 : n), j + (g ? 0 : n));
        add_edge(j + (g ? n : 0), i + (f ? n : 0));
    }
    void add_clause_or(int i, bool f, int j, bool g) // At least
    // one of them is true
    {
        add_edge(i + (f ? n : 0), j + (g ? 0 : n));
    }
}
```

```
add_edge(j + (g ? n : 0), i + (f ? 0 : n));
void add_clause_xor(int i, bool f, int j, bool g) // only
// one of them is true
{
    add_clause_or(i, f, j, g);
    add_clause_or(i, !f, j, !g);
}
void add_clause_and(int i, bool f, int j, bool g) // both of
// them have the same value
{
    add_clause_xor(i, !f, j, g);
}
void set(int i, bool f) // Set a variable
{
    add_clause_or(i, f, i, f);
}
void top_sort(int u) {
    vis[u] = 1;
    for (auto const &v : g[u]) {
        if (!vis[v]) top_sort(v);
    }
    ord.push_back(u);
}
void scc(int u, int id) {
    vis[u] = 1;
    comp[u] = id;
    for (auto const &v : gr[u]) {
        if (!vis[v]) scc(v, id);
    }
}
bool solve() {
    fill(vis.begin(), vis.end(), 0);
    for (int i = 0; i < 2 * n; i++) {
        if (!vis[i]) top_sort(i);
    }
    fill(vis.begin(), vis.end(), 0);
    reverse(ord.begin(), ord.end());
    int id = 0;
    for (const auto &v : ord) {
        if (!vis[v]) scc(v, id++);
    }
    for (int i = 0; i < n; i++) {
        if (comp[i] == comp[i + n]) return 0;
        ans[i] = (comp[i] > comp[i + n]) ? 1 : 0;
    }
    return 1;
}
};
```

sack.cpp47 lines

```
vector<int> adj[MAXN];
vector<int> v[MAXN];
int c[MAXN];
int cnt[MAXN];
int sz[MAXN];
void dfs_sz(int x, int p) {
    sz[x] = 1;
    for (auto const &i : adj[x]) {
        if (i != p) {
            dfs_sz(i, x);
            sz[x] += sz[i];
        }
    }
}
void modify(int c, int val) { cnt[c] += val; }
void dfs(int x, int p, bool keep) {
    int best = -1, big_child = -1;
```

```
for (auto const &i : adj[x]) {
    if (i != p && sz[i] > best) {
        best = sz[i];
        big_child = i;
    }
}
for (auto const &i : adj[x]) {
    if (i != p && i != big_child) dfs(i, x, 0);
}
if (big_child != -1) {
    dfs(big_child, x, 1);
    swap(v[x], v[big_child]); // O(1)
}
v[x].pb(x);
modify(c[x], 1); // adiciona
for (auto const &i : adj[x]) {
    if (i != p && i != big_child) {
        for (auto const &j : v[i]) {
            v[x].pb(j);
            modify(c[j], 1); // adiciona
        }
    }
}
// a cor c aparece cnt[c] vezes na subtree de x
// dai vc pode fazer algo tendo essa informacao
// seja responder queries ou algo do tipo aqui
if (!keep) {
    for (auto const &i : v[x]) modify(c[i], -1); // remove
}
}
```

reroot.cpp23 lines

```
int n;
vector<int> adj[MAXN];
int sz[MAXN];
int dp[MAXN];
int dfs(int u, int v) {
    sz[u] = 1;
    for (auto const &i : adj[u]) {
        if (i != v) sz[u] += dfs(i, u);
    }
    return sz[u];
}
void reroot(int u, int v) {
    for (auto const &i : adj[u]) {
        if (i != v) {
            int a = sz[u], b = sz[i];
            dp[i] = dp[u];
            dp[i] -= sz[u], dp[i] -= sz[i];
            sz[u] -= sz[i], sz[i] = n;
            dp[i] += sz[u], dp[i] += sz[i];
            reroot(i, u);
            sz[u] = a, sz[i] = b;
        }
    }
}
```

hungarian.cpp45 lines

```
struct hungarian { // declarar algo como hungarian h(n), n de
// cada lado
    int n, inf;
    vector<vector<int>> a;
    vector<int> u, v, p, way;
    hungarian(int n_) : n(n_), u(n + 1), v(n + 1), p(n + 1), way(
    n + 1) {
        a = vector<vector<int>>(n, vector<int>(n));
        inf = numeric_limits<int>::max();
    }
}
```

```

void add_edge(int x, int y, int c) { a[x][y] = c; }
pair<int, vector<int>>> run() {
    for (int i = 1; i <= n; i++) {
        p[0] = i;
        int j0 = 0;
        vector<int> minv(n + 1, inf);
        vector<int> used(n + 1, 0);
        do {
            used[j0] = true;
            int i0 = p[j0], j1 = -1;
            int delta = inf;
            for (int j = 1; j <= n; j++) {
                if (!used[j]) {
                    int cur = a[i0 - 1][j - 1] - u[i0] - v[j];
                    if (cur < minv[j]) minv[j] = cur, way[j] = j0;
                    if (minv[j] < delta) delta = minv[j], j1 = j;
                }
            }
            for (int j = 0; j <= n; j++) {
                if (used[j])
                    u[p[j]] += delta, v[j] -= delta;
                else
                    minv[j] -= delta;
            }
            j0 = j1;
        } while (p[j0] != 0);
        do {
            int j1 = way[j0];
            p[j0] = p[j1];
            j0 = j1;
        } while (j0);
    }
    vector<int> ans(n);
    for (int j = 1; j <= n; j++) ans[p[j] - 1] = j - 1;
    return make_pair(-v[0], ans);
}
};

```

mincostmaxflow.cpp

64 lines

```

namespace mcf {
struct edge {
    int to, capacity, cost, res;
};
int source, destiny;
vector<edge> adj[MAXN];
vector<int> dist;
vector<int> parent;
vector<int> edge_index;
vector<bool> in_queue;
void add_edge(int a, int b, int c, int d) {
    adj[a].pb({b, c, d, (int)adj[b].size()});
    adj[b].pb({a, 0, -d, (int)adj[a].size() - 1});
}
bool dijkstra(int s) {
    dist.assign(MAXN, INF);
    parent.assign(MAXN, -1);
    edge_index.assign(MAXN, -1);
    in_queue.assign(MAXN, false);
    dist[s] = 0;
    queue<int> q;
    q.push(s);
    while (!q.empty()) {
        int u = q.front(), idx = 0;
        q.pop();
        in_queue[u] = false;
        for (auto const &v : adj[u]) {
            if (v.capacity && dist[v.to] > dist[u] + v.cost) {
                dist[v.to] = dist[u] + v.cost;

```

```

        parent[v.to] = u;
        edge_index[v.to] = idx;
        if (!in_queue[v.to]) {
            in_queue[v.to] = true;
            q.push(v.to);
        }
        idx++;
    }
    return dist[destiny] != INF;
}
int get_cost() {
    int flow = 0, cost = 0;
    while (dijkstra(source)) {
        int curr_flow = INF, curr = destiny;
        while (curr != source) {
            int p = parent[curr];
            curr_flow = min(curr_flow, adj[p][edge_index[curr]].capacity);
            curr = p;
        }
        flow += curr_flow;
        cost += curr_flow * dist[destiny];
        curr = destiny;
        while (curr != source) {
            int p = parent[curr];
            int res_idx = adj[p][edge_index[curr]].res;
            adj[p][edge_index[curr]].capacity -= curr_flow;
            adj[curr][res_idx].capacity += curr_flow;
            curr = p;
        }
    }
    return cost;
}
} // namespace mcf

```

scc.cpp

54 lines

```

int n, m;
bool vis[MAXN];
int root[MAXN];
vector<int> order;
vector<int> roots;
vector<int> comp;
vector<vector<int>>> comps;
vector<int> adj[MAXN];
vector<int> adj_rev[MAXN];
vector<int> adj_scc[MAXN];
void dfs(int v) {
    vis[v] = true;
    for (auto const &u : adj[v])
        if (!vis[u]) dfs(u);
    order.pb(v);
}
void dfs2(int v) {
    comp.pb(v);
    vis[v] = true;
    for (auto const &u : adj_rev[v])
        if (!vis[u]) dfs2(u);
}
//...
cin >> n >> m;
for (int i = 0; i < m; i++) {
    int a, b;
    cin >> a >> b;
    adj[a].pb(b);
    adj_rev[b].pb(a);
}

```

```

for (int i = 0; i < n; i++) {
    if (!vis[i]) dfs(i);
}
reverse(order.begin(), order.end());
memset(vis, false, sizeof(vis));
for (auto const &v : order) {
    if (!vis[v]) {
        comp.clear();
        dfs2(v);
        comps.pb(comp);
        // making condensation graph
        int r = comp.back();
        for (auto const &u : comp) root[u] = r;
        roots.push_back(r);
    }
}
// making condensation graph
for (int v = 0; v < n; v++) {
    for (auto const &u : adj[v]) {
        int root_v = roots[v];
        int root_u = roots[u];
        if (root_u != root_v) adj_scc[root_v].pb(root_u);
    }
}
}

```

articulationpoints.cpp

23 lines

```

int n, m, timer;
vector<int> adj[MAXN];
bool is_cutpoint[MAXN];
int tin[MAXN]; // memset -1
int low[MAXN]; // memset -1
bool vis[MAXN];
void dfs(int v, int p) { // chama pros nao vis
    vis[v] = true;
    tin[v] = timer, low[v] = timer++;
    int childs = 0;
    for (auto const &u : adj[v]) {
        if (u == p) continue;
        if (vis[u]) {
            low[v] = min(low[v], tin[u]);
        } else {
            dfs(u, v);
            low[v] = min(low[v], low[u]);
            if (low[u] >= tin[v] && p != -1) is_cutpoint[v] = true;
            childs++;
        }
    }
    if (p == -1 && childs > 1) is_cutpoint[v] = true;
}

```

notes.md

98 lines

Bipartite Graph

A bipartite graph is a graph that does not contain any odd-length cycles.

Directed acyclic graph (DAG)

Is a directed graph with no directed cycles.

Independent Set

Is a set of vertices in a graph, no two of which are adjacent. That is, it is a set S of vertices such that for every two vertices in S , there is no edge connecting the two.

Clique

Is a subset of vertices of an undirected graph such that every two distinct vertices in the clique are adjacent.

Vertex Cover

Is a set of vertices that includes at least one endpoint of every edge of the graph.

Edge Cover

Is a set of edges such that every vertex of the graph is incident to at least one edge of the set.

Path Cover

Given a directed graph $G = (V, E)$, a path cover is a set of directed paths such that every vertex v belongs to at least one path.

Koning’s Theorem

In any bipartite graph, the number of edges in a maximum matching equals the number of vertices in a minimum vertex cover.

Properties

- Every tree is a bipartite graph.
- Any $N \times M$ grid is a bipartite graph.
- A set of vertices is a vertex cover if and only if its complement is an independent set.
- The number of vertices of a graph is equal to its minimum vertex cover number plus the size of a maximum independent set.
- In bipartite graphs, the size of the minimum edge cover is equal to the size of the maximum independent set
- In bipartite graphs, the size of the minimum edge cover plus the size of the minimum vertex cover is equal to the number of vertices.
- In bipartite graphs, maximum clique size is two.

Min-cut

The smallest total weight of the edges which if removed would disconnect the source from the sink.

Max-flow min-cut theorem

In a flow network, the maximum amount of flow passing from the source to the sink is equal to the total weight of the edges in a minimum cut.

Maximum flow with vertex capacities

In other words, the amount of flow passing through a vertex cannot exceed its capacity. To find the maximum flow, we can transform the problem into the maximum flow problem by expanding the network. Each vertex v is replaced by $v\text{-in}$ and $v\text{-out}$, where $v\text{-in}$ is connected by edges going into v and $v\text{-out}$ is connected to edges coming out from v . Then assign capacity $c(v)$ to the edge connecting $v\text{-in}$ and $v\text{-out}$.

Undirected edge-disjoint paths problem

We are given an undirected graph $G = (V, E)$ and two vertices s and t , and we have to find the maximum number of edge-disjoint $s\text{-}t$ paths in G .

Undirected vertex-disjoint paths problem

We are given an undirected graph $G = (V, E)$ and two vertices s and t , and we have to find the maximum number of vertex-disjoint (except for s and t) paths in G .

Menger’s theorem

The maximum number of edge-disjoint $s\text{-}t$ paths in an undirected graph is equal to the minimum number of edges in an $s\text{-}t$ cut-set.

Undirected vertex-disjoint paths solution

We can construct a network $N=(V,E)$ from G with vertex capacities, where the capacities of all vertices and all edges are 1. Then the value of the maximum flow is equal to the maximum number of independent paths from s to t .

Minimum vertex-disjoint path cover in directed acyclic graph (DAG)

Given a directed acyclic graph $G=(V, E)$, we are to find the minimum number of vertex-disjoint paths to cover each vertex in V . We can construct a bipartite graph G' from G . Each vertex v is replaced by $v\text{-in}$ and $v\text{-out}$, where $v\text{-in}$ is connected by edges going into v and $v\text{-out}$ is connected to edges coming out from v . Then it can be shown that G' has a matching M of size m if and only if G has a vertex-disjoint path cover C of containing m edges and $n\text{-}m$ paths.

Minimum general path cover in directed acyclic graph (DAG)

A general path cover is a path cover where a vertex can belong to more than one path. A minimum general path cover may be smaller than a minimum vertex-disjoint path cover. A minimum general path cover can be found almost like a minimum vertex-disjoint path cover. It suffices to add some new edges to the matching graph so that there is an edge a to b always when there is a path from a to b in the original graph.

Dilworths theorem and maximum antichain

An antichain is a set of nodes of a graph such that there is no path from any node to another node using the edges of the graph. Dilworths theorem states that in a directed acyclic graph, the size of a minimum general path cover equals the size of a maximum antichain.

Or in other words: For a DAG G that if has edges from vertex i to vertex j and vertex j to k , then it also has a edge from vertex i to vertex k , the size of a minimum path cover is equal to the size of a maximum independent set.

Maximum weighted antichain

In this problem, each vertex has a cost $a[i]$. The cost of an antichain is equal to the sum of the costs of the vertices present in it. We need to find the maximum cost of a antichain. We can construct the same bipartite of the maximum antichain problem from a dag G , these edges have an infinite capacity. We also need to create a source vertex and a sink, and we need to add edges source to $v\text{-in}$ with capacity $a[v]$ and $v\text{-out}$ to sink with capacity $a[v]$. The answer is equal to the sum of all $a[i]$ minus the maximum flow on this network.

Halls Theorem

Halls theorem can be used to find out whether a bipartite graph has a matching that contains all left or right nodes. Assume that we want to find a matching that contains all left nodes. Let X be any set of left nodes and let $f(X)$ be the set of their neighbors. According to Halls theorem, a matching that contains all left nodes exists exactly when for each X , the condition $|X| \leq |f(X)|$ holds.

Extra (Getting Confidence Trick)

<p>If you need to maximize a number $x = (a * b * c * \dots)$, then you can write it as $x = (e^{\log(a)} * e^{\log(b)} * e^{\log(c)} * \dots)$, and then the number is $x = e^{(\log(a) + \log(b) + \log(c) + \dots)}$, and the problem now becomes a problem of maximizing the sum of $(\log(a) + \log(b) + \log(c) + \dots)$.<p />

Use `exp()` and `log()` C++ functions :

Geometry (5)

convexhull.cpp47 lines

```
struct point {
    int x, y, id;
    point(int x, int y, int id) : x(x), y(y), id(id) {}
    point() {}
    point operator-(point const &o) const { return {x - o.x, y - o.y, -1}; }
    bool operator<(point const &o) const {
        if (x == o.x) return y < o.y;
        return x < o.x;
    }
    int operator^(point const &o) const { return x * o.y - y * o.x; }
};
int ccw(point const &a, point const &b, point const &x) {
    auto p = (b - a) ^ (x - a);
    return (p > 0) - (p < 0);
}
vector<point> convex_hull(vector<point> P) // sem colineares
{
    sort(P.begin(), P.end());
    vector<point> L, U;
    for (auto p : P) {
        while (L.size() >= 2 && ccw(L.end()[-2], L.end()[-1], p) == -1) L.pop_back();
        L.push_back(p);
    }
    reverse(P.begin(), P.end());
    for (auto p : P) {
        while (U.size() >= 2 && ccw(U.end()[-2], U.end()[-1], p) == -1) U.pop_back();
        U.push_back(p);
    }
    L.insert(L.end(), U.begin(), U.end() - 1);
    return L;
}
vector<point> convex_hull_no_collinears(vector<point> P) // com colineares
{
    sort(P.begin(), P.end());
    vector<point> L, U;
    for (auto p : P) {
```

```
while (L.size() >= 2 && ccw(L.end()[-2], L.end()[-1], p) <= 0) L.pop_back();
L.push_back(p);
}
reverse(P.begin(), P.end());
for (auto p : P) {
    while (U.size() >= 2 && ccw(U.end()[-2], U.end()[-1], p) <= 0) U.pop_back();
    U.push_back(p);
}
L.insert(L.end(), U.begin(), U.end() - 1);
return L;
}
```

linetrick.cpp13 lines

```
pi get_line(pi x, pi y) { // um jeito normalizado de
    representar a reta entre 2 pontos
    int xx = x.fir - y.fir;
    int yy = x.sec - y.sec;
    int g = __gcd(abs(xx), abs(yy));
    if (g != 0) {
        xx /= g, yy /= g;
    }
    if (xx < 0) {
        xx *= -1;
        yy *= -1;
    }
    return {xx, yy};
}
```

polygonarea.cpp19 lines

```
double area(vector<pi> fig) {
    double res = 0;
    for (unsigned i = 0; i < fig.size(); i++) {
        pi p = i ? fig[i - 1] : fig.back();
        pi q = fig[i];
        res += (p.fir - q.fir) * (p.sec + q.sec);
    }
    return fabs(res) / 2;
}
int cross(pi a, pi b) { return a.fir * b.sec - a.sec * b.fir; }
double area2(vector<pi> fig) {
    double res = 0;
    for (unsigned i = 0; i < fig.size(); i++) {
        pi p = i ? fig[i - 1] : fig.back();
        pi q = fig[i];
        res += cross(p, q);
    }
    return fabs(res) / 2;
}
```

Strings (6)

ahocorasick.cpp78 lines

```
namespace aho {
int go(int v, char ch);
const int K = 26; // tamanho do alfabeto
struct trie {
    char me; // char correspondente ao no atual
    int go[K]; // proximo vertice que eu devo ir
                estando em um estado (v, c)
    int down[K]; // proximo vertice da trie
    int is_leaf = 0; // se o vertice atual da trie eh uma
                    folha (fim de uma ou mais strings)
    int parent = -1; // no ancestral do no atual
}
```

```
int link = -1; // link de sufixo do no atual (outro no
                com o maior matching de sufixo)
int exit_link = -1; // folha mais proxima que pode ser
                alcancada a partir de v usando links de sufixo
trie(int p = -1, char ch = '$') : parent(p), me(ch) {
    fill(begin(go), end(go), -1);
    fill(begin(down), end(down), -1);
}
};
vector<trie> ac;
void init() // criar a raiz da trie
{
    ac.resize(1);
}
void add_string(string s) // adicionar string na trie
{
    int v = 0;
    for (auto const &ch : s) {
        int c = ch - 'a';
        if (ac[v].down[c] == -1) {
            ac[v].down[c] = ac.size();
            ac.emplace_back(v, ch);
        }
        v = ac[v].down[c];
    }
    ac[v].is_leaf++;
}
int get_link(int v) // pegar o suffix link saindo de v
{
    if (ac[v].link == -1) ac[v].link = (!v || !ac[v].parent) ? 0
        : go(get_link(ac[v].parent), ac[v].me);
    return ac[v].link;
}
int go(int v, char ch) // proximo estado saindo do estado(v,
                        ch)
{
    int c = ch - 'a';
    if (ac[v].go[c] == -1) {
        if (ac[v].down[c] != -1)
            ac[v].go[c] = ac[v].down[c];
        else
            ac[v].go[c] = (!v) ? 0 : go(get_link(v), ch);
    }
    return ac[v].go[c];
}
int get_exit_link(int v) // suffix link mais proximo de v que
                        seja uma folha
{
    if (ac[v].exit_link == -1) {
        int curr = get_link(v);
        if (!v || !curr)
            ac[v].exit_link = 0;
        else if (ac[curr].is_leaf)
            ac[v].exit_link = curr;
        else
            ac[v].exit_link = get_exit_link(curr);
    }
    return ac[v].exit_link;
}
int query(string s) // query O(n + ans)
{
    int ans = 0, curr = 0, at;
    for (auto const &i : s) {
        curr = go(curr, i);
        ans += ac[curr].is_leaf;
        at = get_exit_link(curr);
        while (at) {
            ans += ac[at].is_leaf;
            at = get_exit_link(at);
        }
    }
}
```

```
}
}
return ans;
}
// namespace aho
```

kmp.cpp27 lines

```
string s;
int n, m;
string a, b;
int c[MAXN][26];
vector<int> kmp(string &s) {
    int n = s.size();
    vector<int> p(n);
    for (int i = 1; i < n; i++) {
        int j = p[i - 1];
        while (j > 0 && s[i] != s[j]) j = p[j - 1];
        if (s[i] == s[j]) j++;
        p[i] = j;
    }
    return p;
}
void compute(string s) {
    s.pb('*');
    vector<int> p = kmp(s);
    for (int i = 0; i < s.size(); i++) {
        for (int cc = 0; cc < 26; cc++) {
            int j = i;
            while (j > 0 && 'a' + cc != s[j]) j = p[j - 1];
            if ('a' + cc == s[j]) j++;
            c[i][cc] = j;
        }
    }
}
```

manacher.cpp22 lines

```
vector<int> dl;
vector<int> d2;
void manacher(string s) {
    dl.resize(s.size());
    d2.resize(s.size());
    int l = 0, r = -1;
    for (int i = 0; i < s.size(); i++) {
        int k = (i > r) ? 1 : min(dl[l + r - i], r - i + 1);
        while (0 <= i - k && i + k < s.size() && s[i - k] == s[i +
            k]) k++;
        dl[i] = k;
        k = k - 1;
        if (i + k > r) l = i - k, r = i + k;
    }
    l = 0, r = -1;
    for (int i = 0; i < s.size(); i++) {
        int k = (i > r) ? 0 : min(d2[l + r - i + 1], r - i + 1);
        while (0 <= i - k - 1 && i + k < s.size() && s[i - k - 1]
            == s[i + k]) k++;
        d2[i] = k;
        k = k - 1;
        if (i + k > r) l = i - k - 1, r = i + k;
    }
}
```

minsuffix.cpp28 lines

```
int max_suffix(string s, bool mi = false) {
    s.push_back(*min_element(s.begin(), s.end()) - 1);
    int ans = 0;
    for (int i = 1; i < s.size(); i++) {
```

```
int j = 0;
while (ans + j < i and s[i + j] == s[ans + j]) j++;
if (s[i + j] > s[ans + j]) {
    if (!mi or i != s.size() - 2) ans = i;
} else if (j)
    i += j - 1;
}
return ans;
}
int min_suffix(string s) {
    for (auto &i : s) i *= -1;
    s.push_back(*max_element(s.begin(), s.end()) + 1);
    return max_suffix(s, true);
}
int max_cyclic_shift(string s) {
    int n = s.size();
    for (int i = 0; i < n; i++) s.pb(s[i]);
    return max_suffix(s);
}
int min_cyclic_shift(string s) {
    for (auto &i : s) i *= -1;
    return max_cyclic_shift(s);
}
// retorna a posicao de inicio menor/maior sufixo/shift de uma
string
```

hashing.cpp29 lines

```
const int MOD = (1ll << 61) - 1;
int P;
int mulmod(int a, int b) {
    const static int LOWER = (1ll << 30) - 1, GET31 = (1ll << 31)
        - 1;
    int l1 = a & LOWER, h1 = a >> 30, l2 = b & LOWER, h2 = b >>
        30;
    int m = l1 * h2 + l2 * h1, h = h1 * h2;
    int ans = l1 * l2 + (h >> 1) + ((h & 1) << 60) + (m >> 31) +
        ((m & GET31) << 30) + 1;
    ans = (ans & MOD) + (ans >> 61), ans = (ans & MOD) + (ans >>
        61);
    return ans - 1;
}
mt19937_64 rng(chrono::steady_clock::now().time_since_epoch().
    count());
int uniform(int l, int r) {
    uniform_int_distribution<int> uid(l, r);
    return uid(rng);
}
struct string_hashing {
    vector<int> h, p;
    string_hashing() {}
    string_hashing(string s) : h(s.size()), p(s.size()) {
        p[0] = 1, h[0] = s[0];
        for (int i = 1; i < s.size(); i++) p[i] = mulmod(p[i - 1],
            P), h[i] = (mulmod(h[i - 1], P) + s[i]) % MOD;
    }
    int get(int l, int r) {
        int hash = h[r] - (l ? mulmod(h[l - 1], p[r - l + 1]) : 0);
        return hash < 0 ? hash + MOD : hash;
    }
    int append(int h, int hb, int blen) { return (hb + mulmod(h,
        p[blen])) % MOD; }
};
// lembrar do P = uniform(256, MOD - 1);
```

suffixarray.cpp44 lines

```
vector<int> suffix_array(string s) {
    s += "$"; // menor do que todos os chars da string st
```

```
int n = s.size(), N = max(n + 1, 26011);
vector<int> sa(n), ra(n);
for (int i = 0; i < n; i++) {
    sa[i] = i, ra[i] = s[i];
}
for (int k = 0; k < n; k ? k *= 2 : k++) {
    vector<int> nsa(sa), nra(n), cnt(N);
    for (int i = 0; i < n; i++) {
        nsa[i] = (nsa[i] - k + n) % n;
        cnt[ra[i]]++;
    }
    for (int i = 1; i < N; i++) {
        cnt[i] += cnt[i - 1];
    }
    for (int i = n - 1; i > 0; i--) {
        sa[--cnt[ra[nsa[i]]]] = nsa[i];
    }
    for (int i = 1, r = 0; i < n; i++) {
        nra[sa[i]] = r += (ra[sa[i]] != ra[sa[i - 1]] || ra[(sa[i]
            ) + k] % n] != ra[(sa[i - 1] + k) % n]);
    }
    ra = nra;
    if (ra[sa[n - 1]] == n - 1) break;
}
return vector<int>(sa.begin() + 1, sa.end());
}
vector<int> kasai(string s, vector<int> sa) {
    int n = s.size(), k = 0;
    vector<int> ra(n), lcp(n);
    for (int i = 0; i < n; i++) {
        ra[sa[i]] = i;
    }
    for (int i = 0; i < n; i++, k -= !!k) {
        if (ra[i] == n - 1) {
            k = 0;
            continue;
        }
        int j = sa[ra[i] + 1];
        while (i + k < n and j + k < n and s[i + k] == s[j + k]) k
            ++;
        lcp[ra[i]] = k;
    }
    return lcp;
}
```

zfunction.cpp12 lines

```
vector<int> z_function(string &s) {
    int n = s.size();
    vector<int> z(n);
    z[0] = 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;
}
// z[i] = o tamanho de lcp(s, s.substr(i, n - i))
```

suffixautomaton.cpp90 lines

```
namespace sa {
    struct state {
        int len, suf_link;
        map<char, int> nxt;
    };
    vector<int> term;
    state st[2 * MAXN];
```

```
int dp[2 * MAXN];
int sz, last;
void init() {
    memset(dp, -1, sizeof(dp));
    st[0].len = 0;
    st[0].suf_link = -1;
    sz++;
    last = 0;
}
void get_link(int curr, int p, char c) {
    while (p != -1 && !st[p].nxt.count(c)) {
        st[p].nxt[c] = curr;
        p = st[p].suf_link;
    }
    if (p == -1) {
        st[curr].suf_link = 0;
        return;
    }
    int q = st[p].nxt[c];
    if (st[p].len + 1 == st[q].len) {
        st[curr].suf_link = q;
        return;
    }
    int clone = sz;
    sz++;
    st[clone].len = st[p].len + 1;
    st[clone].nxt = st[q].nxt;
    st[clone].suf_link = st[q].suf_link;
    while (p != -1 && st[p].nxt[c] == q) {
        st[p].nxt[c] = clone;
        p = st[p].suf_link;
    }
    st[q].suf_link = clone;
    st[curr].suf_link = clone;
}
void build(string &s) {
    for (auto const &c : s) {
        int curr = sz;
        sz++;
        st[curr].len = st[last].len + 1;
        get_link(curr, last, c);
        last = curr;
    }
    // achar os estados terminais
    // um estado terminal eh aquele que representa um sufixo da
        string s
    int p = last;
    while (p != -1) {
        term.pb(p);
        p = st[p].suf_link;
    }
}
void dfs2(int v) {
    if (dp[v] != -1) return;
    dp[v] = 1;
    for (auto const &u : st[v].nxt) {
        if (!u.sec) continue;
        dfs2(u.sec);
        dp[v] += dp[u.sec];
    }
}
void dfs(int v, int k, int &at, string &curr) {
    if (at == k) return;
    for (auto const &u : st[v].nxt) {
        if (!u.sec) continue;
        if (at + dp[u.sec] < k) {
            at += dp[u.sec];
            continue;
        }
    }
}
```

```
curr.pb(u.fir);
at++;
dfs(u.sec, k, at, curr);
if (at == k) return;
curr.pop_back();
}
}
void find_kth(int k) {
    int at = 0;
    string curr = "";
    dfs(0, k, at, curr);
    cout << curr << endl;
}
} // namespace sa
// chamar sa::init(); e sa::build(s);
```

Various (7)

binarysearch.cpp26 lines

```
// busca ternaria para int, usando busca binaria:
int l = 0, r = 1e9;
while (l < r) {
    int mid = (l + r) >> 1;
    (calc(mid) < calc(mid + 1)) ? r = mid : l = mid + 1;
}
return calc(l);
// first element >= x
int lower(int l, int r, int x) // first element >= x
{
    while (l < r) {
        // int mid = l + (r - l) / 2; se tiver numero negativo
        int mid = (l + r) >> 1;
        (x <= k[mid]) ? r = mid : l = mid + 1;
    }
    return k[l];
}
// last element <= x
vector<int> k(MAXN);
int upper(int l, int r, int x) {
    while (l < r) {
        int mid = (l + r + 1) >> 1;
        (k[mid] <= x) ? l = mid : r = mid - 1;
    }
    return k[l];
}
```

ternarysearch.cpp12 lines

```
double eps = 1e-9;
while (r - l > eps) {
    double m1 = l + (r - l) / 3;
    double m2 = r - (r - l) / 3;
    double f1 = f(m1);
    double f2 = f(m2);
    if (f1 < f2)
        l = m1;
    else
        r = m2;
}
return f(l); // o maximo de f(l)
```

parallelbinarysearch.cpp37 lines

```
vector<pii> qry(q);
for (int i = 0; i < q; i++) {
    cin >> qry[i].sec.fir >> qry[i].sec.sec >> qry[i].fir;
    qry[i].sec.fir--, qry[i].sec.sec--;
```

```
}
vector<int> l(n);
vector<int> r(n);
vector<vector<int>> on(q);
for (int i = 0; i < n; i++) {
    l[i] = 0;
    r[i] = q;
}
while (l) {
    bool ok = 1;
    for (int i = 0; i < n; i++) {
        if (l[i] < r[i]) {
            ok = 0;
            int mid = (l[i] + r[i]) >> 1;
            on[mid].pb(i);
        }
    }
    if (ok) break;
    reset();
    for (int mid = 0; mid < q; mid++) {
        upd(qry[mid].sec.fir, qry[mid].sec.sec, qry[mid].fir);
        for (auto const &j : on[mid]) {
            int val = 0;
            for (auto const &k : adj[j]) {
                val += sum(k);
                if (val >= need[j]) break;
            }
            (val >= need[j]) ? r[j] = mid : l[j] = mid + 1;
        }
        on[mid].clear();
    }
}
// a resposta eh o l[i] para cada busca
```

alienstrick.cpp32 lines

```
pi solve(vector<int> &v, int lambda) {
    // associar um custo lambda para ser subtraido quando
    // realizamos uma operacao
    // dp[i] - melhor profit que tivemos considerando as i
    // primeiras posicoes
    // cnt[i] - quantas operacoes utilizamos para chegar no valor
    // de dp[i]
    vector<int> dp(n + 1);
    vector<int> cnt(n + 1);
    dp[0] = 0;
    cnt[0] = 0;
    for (int i = 1; i <= n; i++) {
        dp[i] = dp[i - 1];
        cnt[i] = cnt[i - 1];
        int id = i - 1;
        dp[i] += v[id];
        int lo = max(0ll, id - l + 1);
        int s = dp[lo] + (id - lo + 1) - lambda;
        if (s > dp[i]) {
            dp[i] = s;
            cnt[i] = cnt[lo] + 1;
        }
    }
    return {dp[n], cnt[n]};
}
int aliens_trick(vector<int> &v) {
    int l = 0, r = n;
    while (l < r) {
        int mid = (l + r) >> 1;
        pi ans = solve(v, mid);
        (ans.sec > k) ? l = mid + 1 : r = mid;
    }
    pi ans = solve(v, l);
```

```
return ans.fir + (l * k);
}

cht.cpp63 lines

struct line {
    mutable int m, b, p;
    bool operator<(const line &o) const {
        if (m != o.m) return m < o.m;
        return b < o.b;
    }
    bool operator<(const int x) const { return p < x; }
    int eval(int x) const { return m * x + b; }
    int inter(const line &o) const {
        int x = b - o.b, y = o.m - m;
        return (x / y) - ((x ^ y) < 0 && x % y);
    }
};

struct cht {
    int INF = 1e18;
    multiset<line, less<>> l;
    void add(int m, int b) {
        auto y = l.insert({m, b, INF});
        auto z = next(y);
        if (z != l.end() && y->m == z->m) {
            l.erase(y);
            return;
        }
        if (y != l.begin()) {
            auto x = prev(y);
            if (x->m == y->m) x = l.erase(x);
        }
        while (l) {
            if (z == l.end()) {
                y->p = INF;
                break;
            }
            y->p = y->inter(*z);
            if (y->p < z->p)
                break;
            else
                z = l.erase(z);
        }
        if (y == l.begin()) return;
        z = y;
        auto x = --y;
        while (l) {
            int ninter = x->inter(*z);
            if (ninter <= x->p)
                x->p = ninter;
            else {
                l.erase(z);
                break;
            }
            if (x == l.begin()) break;
            y = x;
            x--;
            if (x->p < y->p)
                break;
            else
                l.erase(y);
        }
    }
    int get(int x) {
        if (l.empty()) return 0;
        return l.lower_bound(x)->eval(x);
    }
};
```

expectedvaluedp.cpp26 lines

```
double dp[MAXN][MAXN][MAXN];
// sushi problem
double solve(int i, int j, int k) {
    if (!i && !j && !k) return dp[i][j][k] = 0;
    if (dp[i][j][k] != -1) return dp[i][j][k];
    /*
    It is well-known from statistics that for the geometric
    distribution
    (counting number of trials before a success, where each
    independent trial is probability p)
    the expected value is i / p
    */
    double p = ((double)(i + j + k) / n);
    double ret = 1 / p; // expected number of trials before a
    success
    if (i) {
        double prob = (double)i / (i + j + k); // probabilidade de
        ser um prato com um sushi
        ret += (solve(i - 1, j, k) * prob);
    }
    if (j) {
        double prob = (double)j / (i + j + k); // probabilidade de
        ser um prato com dois sushis
        ret += (solve(i + 1, j - 1, k) * prob);
    }
    if (k) {
        double prob = (double)k / (i + j + k); // probabilidade de
        ser um prato com tres sushis
        ret += (solve(i, j + 1, k - 1) * prob);
    }
    return dp[i][j][k] = ret;
}
```

kadane.cpp19 lines

```
int kadane(vector<int> v) {
    int n = v.size(), ans = 0, max_here = 0;
    for (int i = 0; i < n; i++) {
        max_here += v[i];
        if (ans < max_here) ans = max_here;
        if (max_here < 0) max_here = 0;
    }
    return ans;
}

int kadane_circular(vector<int> v) {
    int n = v.size(), max_kadane = kadane(v);
    int max_wrap = 0, i;
    for (i = 0; i < n; i++) {
        max_wrap += v[i];
        v[i] = -v[i];
    }
    max_wrap += kadane(v);
    return max(max_wrap, max_kadane);
}
```

divideandconquerdp.cpp16 lines

```
void compute(int l, int r, int optl, int optr, int i) {
    if (l > r) return;
    int mid = (l + r) >> 1;
    pair<int, int> ans = {1e18, -1}; // dp, k
    for (int q = optl; q <= min(mid, optr); q++) {
        if (q > 0)
            ans = min(ans, {dp[i - 1][q - 1] + cost(q, mid), q});
        else
            ans = min(ans, {cost(q, mid), q});
    }
    dp[i][mid] = ans.fir;
    compute(l, mid - 1, optl, ans.sec, i);
    compute(mid + 1, r, ans.sec, optr, i);
}

// dp[i][j] = min(dp[i - 1][k] + c(k, j)), para algum k <= j
// O(k * n * log(n))
```

sosdp.cpp20 lines

```
// nesse caso, f[x] eh a funcao que soma:
// todos os a[i], tal que, (x & i) == i)
for (int mask = 0; mask < (1 << m); mask++) {
    f[mask] = a[mask];
}
for (int i = 0; i < m; ++i) {
    for (int mask = 0; mask < (1 << m); mask++) {
        if (mask & (1 << i)) f[mask] += f[mask ^ (1 << i)];
    }
}

// nesse caso, f[x] eh a funcao que soma:
// todos os a[i], tal que, (x & i) == x)
for (int mask = 0; mask < (1 << m); mask++) {
    f[mask] = a[mask];
}
for (int i = 0; i < m; ++i) {
    for (int mask = 0; mask < (1 << m); mask++) {
        if (!(mask & (1 << i))) f[mask] += f[mask ^ (1 << i)];
    }
}
}
```

lis.cpp13 lines

```
int lis() {
    vector<int> q;
    for (int i = 0; i < v.size(); i++) {
        vector<int>::iterator it = lower_bound(q.begin(), q.end(),
        v[i]);
        if (it == q.end())
            q.pb(v[i]);
        else
            *it = v[i];
    }
    for (int i = 0; i < q.size(); i++) cout << q[i] << " ";
    cout << endl;
    return q.size();
}
```

largestsquareofones.cpp9 lines

```
int ans = 0;
for (int i = 0; i < n; i++) {
    for (int j = 0; j < n; j++) {
        dp[i][j] = v[i][j];
        if (i && j && dp[i][j]) dp[i][j] = min({dp[i][j - 1], dp[i
        - 1][j], dp[i - 1][j - 1]}) + 1;
        ans = max(ans, dp[i][j]);
    }
}
cout << ans * ans << endl;
```

steinertree.cpp16 lines

```
for (int i = 0; i <= 100; i++)
    for (int j = 0; j < (1 << 9); j++) dp[i][j] = 1e9;
for (int i = 0; i < k; i++)
    for (int j = 0; j < v.size(); j++) dp[j][1 << i] = d(cap[i],
    v[j]);
for (int mask = 2; mask < (1 << k); mask++) {
    for (int i = 0; i < v.size(); i++) {
        for (int mask2 = 1; mask2 < mask; mask2++) {
            if (!(mask & mask2) == mask2)) continue;
            int mask3 = mask ^ mask2;
            dp[i][mask] = min(dp[i][mask], dp[i][mask2] + dp[i][mask3
            ]);
        }
        for (int j = 0; j < v.size(); j++) dp[j][mask] = min(dp[j][
            mask], dp[i][mask] + d(v[i], v[j]));
    }
}
double ans = 1e9;
for (int i = 0; i <= 100; i++) ans = min(ans, dp[i][(1 << k) -
    1]);
```

subsetsum.cpp89 lines

```
// subset sum com bitset de tamanho variado
// with n <= 10^6
template <int len = 1>
int subset_sum(int n, int h) {
    if (n >= len) {
        return subset_sum<std::min(len * 2, (int)MAXN)>(n, h);
    }
    bitset<len> dp;
    dp[0] = 1;
    for (auto const &x : w) {
        dp = dp | (dp << x);
    }
    return dp._Find_next(max(0ll, h - 1)); // retorna o proximo
    bit setado apos a posicao passada como parametro
}

int solve(vector<int> &w, int tot, int h) {
    // tot -> soma de todos os elementos de w
    // h -> valor desejado
    // quero retornar o menor valor x >= h, tal que existe um
    subset com soma x em w
    if (!w.size()) return 0;
    sort(w.rbegin(), w.rend());
    if (w[0] * 2 >= tot) return w[0];
    int n = w.size();
    w.pb(0);
    vector<int> aux;
    int p = 0;
    for (int i = 1; i <= n; i++) {
        if (w[i] != w[i - 1]) {
            int cnt = i - p;
            int x = w[i - 1];
            int j = 1;
            while (j < cnt) {
                aux.pb(x * j);
                cnt -= j;
                j *= 2;
            }
            aux.pb(x * cnt);
            p = i;
        }
    }
    swap(aux, w);
    return subset_sum(tot, h);
}

int f[MAXN]; // f[i] -> quantos "itens" com valor i tem
bitset<MAXN> dp; // dp[i] = 1, se existe um subset com soma i
// garantir que a soma de todo mundo seja < MAXN
void subset_sum(vector<int> &v) {
    for (auto const &i : v) {
        f[i]++;
    }
    dp[0] = 1;
    for (int i = 1; i < MAXN; i++) {
        while (f[i] > 2) {
```



```
        f[i * 2]++;
        f[i] -= 2;
    }
    while (f[i]--) dp |= (dp << i);
}
}
/*
Given N non-negative integer weights w and a non-negative
target t,
computes the maximum S <= t such that S is the sum of some
subset of the weights.
O(N * max(w[i]))
*/
int knapsack(vector<int> w, int t) {
    int a = 0, b = 0;
    while (b < w.size() && a + w[b] <= t) {
        a += w[b++];
    }
    if (b == w.size()) {
        return a;
    }
    int m = *max_element(w.begin(), w.end());
    vector<int> u, v(2 * m, -1);
    v[a + m - t] = b;
    for (int i = b; i < w.size(); i++) {
        u = v;
        for (int x = 0; x < m; x++) {
            v[x + w[i]] = max(v[x + w[i]], u[x]);
        }
        for (int x = 2 * m; --x > m;) {
            for (int j = max(0ll, u[x]); j < v[x]; j++) v[x - w[j]] =
                max(v[x - w[j]], j);
        }
    }
    a = t;
    while (v[a + m - t] < 0) {
        a--;
    }
    return a;
}
```