

ICPC Notebook

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template

hash.sh

使い方: sh hash.sh -> コピペ -> Ctrl + D
コメント・空白・改行を削除して md5 でハッシュする
g++ -dD -E -P -fpreprocessed - | tr -d '[:space:]' | md5sum | cut -c-6

settings.sh

Clion の設定
Settings → Build → CMake → Reload CMake Project
add_compile_options(-D_GLIBCXX_DEBUG)
Caps Lock を Ctrl に変更
setxkbmap -option ctrl:nocaps

template.hpp

md5: 015ba5

#include <bits/stdc++.h>
using namespace std;
using ll = long long;
const ll INF = LLONG_MAX / 4;
#define all(a) begin(a), end(a)
bool chmin(auto& a, auto b) { return a > b ? a = b, 1 : 0; }
bool chmax(auto& a, auto b) { return a < b ? a = b, 1 : 0; }

int main() {
cin.tie(0)->sync_with_stdio(0);
// your code here...
}

data-structure

2dBIT.hpp

md5: a0e12e

template<typename T> struct BinaryIndexedTree2D {
int H, W;
vector<vector<T>> bit;

BinaryIndexedTree2D(int H, int W) : H(H), W(W), bit(H + 3, vector<T>(W + 3, 0)) {}
void add(int x, int y, T w) {
if(x < 0 || x >= H || y < 0 || y >= W) return;
for(int a = (++y, ++x); a <= H; a += a & -a) {
for(int b = y; b <= W; b += b & -b) { bit[a][b] += w;
}
}
}

void imos(int x1, int y1, int x2, int y2, T w) {
add(x1, y1, w);
add(x2, y2, w);
add(x1, y2, -w);
add(x2, y1, -w);
}

T sum(int x, int y) {
if(x < 0 || x >= H || y < 0 || y >= W) return 0;
if(x >= H) x = H - 1;
if(y >= W) y = W - 1;
T ret = 0;
for(int a = (++y, ++x); a > 0; a -= a & -a) {
for(int b = y; b > 0; b -= b & -b) { ret += bit[a][b];
}
}
return ret;
}

T sum(int x1, int y1, int x2, int y2) {
return sum(x2, y2) - sum(x1 - 1, y2) - sum(x2, y1 - 1) + sum(x1 - 1, y1 - 1);
}
};

BIT.hpp

md5: 4dd117

binary_trie.hpp

md5: af8046

```
struct BIT {
    vector<ll> a;
    BIT(ll n) : a(n + 1) {}
    void add(ll i, ll x) { // A[i] += x
        i++;
        while(i < size(a)) {
            a[i] += x;
            i += i & -i;
        }
    }
    ll sum(ll r) {
        ll s = 0;
        while(r) {
            s += a[r];
            r -= r & -r;
        }
        return s;
    }
    ll sum(ll l, ll r) { // sum of A[l, r)
        return sum(r) - sum(l);
    }
};
```

FastSet.hpp

md5: 5c5532

```
// using u64 = uint64_t;
const u64 B = 64;
struct FastSet {
    u64 n;
    vector<vector<u64>> a;
    FastSet(u64 n_) : n(n_) {
        do a.emplace_back(n_ = (n_ + B - 1) / B);
        while(n_ > 1);
    }
    // bool operator[](ll i) const { return a[0][i / B] >> (i % B) & 1; }
    void set(ll i) {
        for(auto& v : a) {
            v[i / B] |= 1ULL << (i % B);
            i /= B;
        }
    }
    void reset(ll i) {
        for(auto& v : a) {
            v[i / B] &= ~(1ULL << (i % B));
            if(v[i / B]) break;
            i /= B;
        }
    }
    ll next(ll i) { // i を超える最小の要素
        for(int h = 0; h < size(a); h++) {
            i++;
            if(i / B >= size(a[h])) break;
            u64 d = a[h][i / B] >> (i % B);
            if(d) {
                i += countr_zero(d);
                while(h--) i = i * B + countr_zero(a[h][i]);
                return i;
            }
            i /= B;
        }
        return n;
    }
    ll prev(ll i) { // i より小さい最大の要素
        for(int h = 0; h < size(a); h++) {
            i--;
            if(i < 0) break;
            u64 d = a[h][i / B] << (~i % B);
            if(d) {
                i -= countl_zero(d);
                while(h--) i = i * B + __lg(a[h][i]);
                return i;
            }
            i /= B;
        }
        return -1;
    }
};
```

```
// base: b75bb1
template<typename T, int MAX_LOG = 32> struct BinaryTrie {
    struct Node {
        array<int, 2> next;
        int common;
        T lazy;
        Node() : next{-1, -1}, common(), lazy() {}
    };
    vector<Node> nodes;
    BinaryTrie() { nodes.push_back(Node()); }
    void apply_xor(T val) { nodes[0].lazy ^= val; }
    void push(int cur, int b) {
        if((nodes[cur].lazy >> b) & 1) swap(nodes[cur].next[0], nodes[cur].next[1]);
        for(int i = 0; i < 2; i++) {
            if(nodes[cur].next[i] == -1)
                nodes[nodes[cur].next[i]].lazy ^= nodes[cur].lazy;
            nodes[cur].lazy = 0;
        }
    }
    void add(T val, int cur = 0, int b = MAX_LOG - 1) {
        nodes[cur].common++;
        if(b == -1) return;
        push(cur, b);
        int nxt = (val >> (T)b) & (T)1;
        if(nodes[cur].next[nxt] == -1) {
            nodes[cur].next[nxt] = size(nodes);
            nodes.push_back(Node());
        }
        add(val, nodes[cur].next[nxt], b - 1);
    }

    void erase(T val, int cur = 0, int b = MAX_LOG - 1) {
        nodes[cur].common--;
        if(b == -1) return;
        push(cur, b);
        erase(val, nodes[cur].next[(val >> b) & 1], b - 1);
    }

    T min_element(T val = 0, int cur = 0, int b = MAX_LOG - 1) {
        if(b == -1) return 0;
        push(cur, b);
        T nxt = (val >> b) & 1;
        int ind = nodes[cur].next[nxt];
        if(ind == -1 || nodes[ind].common == 0) nxt ^= 1;
        return min_element(val, nodes[cur].next[nxt], b - 1) | (nxt << b);
    } // ddf699

    T max_element(T val = 0, int cur = 0, int b = MAX_LOG - 1) {
        return min_element(~val); } // 5e1a86

    int lower_bound_rank(T val, int cur = 0, int b = MAX_LOG - 1) {
        if(cur == -1 || b == -1) return 0;
        push(cur, b);
        T nxt = (val >> b) & 1;
        int ret = lower_bound_rank(val, nodes[cur].next[nxt], b - 1);
        if(nxt == 1 && nodes[cur].next[0] != -1) { ret += nodes[nodes[cur].next[0]].common; }
        return ret;
    } // 05b14c

    int upper_bound_rank(T val) { return lower_bound_rank(val + 1); } // 70e301

    T kth_smallest(int k, int cur = 0, int b = MAX_LOG - 1) {
        if(b == -1) return 0;
        int lower_ind = nodes[cur].next[0];
        int lower_cnt = 0;
        if(lower_ind != -1) lower_cnt = nodes[lower_ind].common;
        if(k < lower_cnt) return kth_smallest(k, nodes[cur].next[0], b - 1);
        return kth_smallest(k - lower_cnt, nodes[cur].next[1], b - 1) | (T(1) << b);
    } // b85845

    T kth_largest(int k) { return kth_smallest(nodes[0].common -
```

```
k); } // 1df41b
```

```
int count(T val) {
    int cur = 0;
    for(int b = MAX_LOG - 1; b >= 0; b--) {
        push(cur, b);
        cur = nodes[cur].next[(val >> b) & 1];
        if(cur == -1) return 0;
    }
    return nodes[cur].common;
} // 2a3342

int count() { return nodes[0].common; } // 210f0e
};
```

disjoint_sparse_table.hpp

md5: 3df31b

```
template<typename SG> struct disjoint_sparse_table {
    using S = typename SG::S;
    vector<vector<S>> st;
    vector<int> lg;

    disjoint_sparse_table(const vector<S>& v) {
        int b = 0;
        while((1 << b) <= size(v)) b++;
        st.assign(b, vector<S>(size(v)));
        for(int i = 0; i < size(v); i++) st[0][i] = v[i];
        for(int i = 1; i < b; i++) {
            int shift = 1 << i;
            for(int j = 0; j < size(v); j += shift << 1) {
                int t = min(j + shift, (int)size(v));
                st[i][t - 1] = v[t - 1];
                for(int k = t - 2; k >= j; k--) st[i][k] =
SG::op(v[k], st[i][k + 1]);
                if(size(v) <= t) break;
                st[i][t] = v[t];
                for(int k = t + 1; k < min((int)size(v), t +
shift); k++) st[i][k] = SG::op(st[i][k - 1], v[k]);
            }
            lg.resize(1 << b);
            for(int i = 2; i < size(lg); i++) lg[i] = lg[i >> 1] + 1;
        }
        S prod(int l, int r) {
            if(l >= --r) return st[0][l];
            int b = lg[l ^ r];
            return SG::op(st[b][l], st[b][r]);
        }
    };
};
```

dsu.hpp

md5: b55e78

```
// base: d569f4
struct dsu {
    private:
        int _n;
        vector<int> p;

    public:
        dsu() : _n(0) {}
        explicit dsu(int n) : _n(n), p(n, -1) {}

        int merge(int a, int b) {
            // assert(0 <= a && a < _n);
            // assert(0 <= b && b < _n);
            int x = leader(a), y = leader(b);
            if(x == y) return x;
            if(-p[x] < -p[y]) swap(x, y);
            p[x] += p[y];
            p[y] = x;
            return x;
        }

        bool same(int a, int b) {
            // assert(0 <= a && a < _n);
            // assert(0 <= b && b < _n);
            return leader(a) == leader(b);
        }

        int leader(int a) {
            // assert(0 <= a && a < _n);
            if(p[a] < 0) return a;

```

```
int x = a;
while(p[x] >= 0) x = p[x];
while(p[a] >= 0) {
    int t = p[a];
    p[a] = x;
    a = t;
}
return x;
}
```

```
int size(int a) {
    // assert(0 <= a && a < _n);
    return -p[leader(a)];
} // 818fe7
```

```
vector<vector<int>> groups() {
    vector<int> leader_buf(_n), group_size(_n);
    for(int i = 0; i < _n; i++) {
        leader_buf[i] = leader(i);
        group_size[leader_buf[i]]++;
    }
    vector<vector<int>> result(_n);
    for(int i = 0; i < _n; i++)
result[i].reserve(group_size[i]);
    for(int i = 0; i < _n; i++)
result[leader_buf[i]].push_back(i);
    result.erase(remove_if(result.begin(), result.end(), [&
(const vector<int>& v) { return v.empty(); }]),
        result.end());
    return result;
} // bf3a1e
};
```

lazy_segtree.hpp

md5: c86cef

```
// base: 918715
unsigned int bit_ceil(unsigned int n) {
    unsigned int x = 1;
    while(x < (unsigned int)(n)) x *= 2;
    return x;
}

int countr_zero(unsigned int n) { return __builtin_ctz(n); }
constexpr int countr_zero_constexpr(unsigned int n) {
    int x = 0;
    while(!(n & (1 << x))) x++;
    return x;
}

template<class S, S (*op)(S, S), S (*e)(), class F, S
(*mapping)(F, S), F (*composition)(F, F), F (*id)()>
struct lazy_segtree {
    public:
        lazy_segtree() : lazy_segtree(0) {}
        explicit lazy_segtree(int n) : lazy_segtree(vector<S>(n,
e())) {}
        explicit lazy_segtree(const vector<S>& v) :
_n(int(v.size())) {
            size = (int)bit_ceil((unsigned int)(_n));
            log = countr_zero((unsigned int)size);
            d = vector<S>(2 * size, e());
            lz = vector<F>(size, id());
            for(int i = 0; i < _n; i++) d[size + i] = v[i];
            for(int i = size - 1; i >= 1; i--) { update(i); }
        }

        void set(int p, S x) {
            // assert(0 <= p && p < _n);
            p += size;
            for(int i = log; i >= 1; i--) push(p >> i);
            d[p] = x;
            for(int i = 1; i <= log; i++) update(p >> i);
        }

        S get(int p) {
            // assert(0 <= p && p < _n);
            p += size;
            for(int i = log; i >= 1; i--) push(p >> i);
            return d[p];
        }

        S prod(int l, int r) {
            // assert(0 <= l && l <= r && r <= _n);
            if(l == r) return e();

```

```

    l += size;
    r += size;

    for(int i = log; i >= 1; i--) {
        if(((l >> i) << i) != l) push(l >> i);
        if(((r >> i) << i) != r) push((r - 1) >> i);
    }

    S sm1 = e(), smr = e();
    while(l < r) {
        if(l & 1) sm1 = op(sm1, d[l++]);
        if(r & 1) smr = op(d[--r], smr);
        l >>= 1;
        r >>= 1;
    }

    return op(sm1, smr);
}

void apply(int l, int r, F f) {
    assert(0 <= l && l <= r && r <= _n);
    if(l == r) return;

    l += size;
    r += size;

    for(int i = log; i >= 1; i--) {
        if(((l >> i) << i) != l) push(l >> i);
        if(((r >> i) << i) != r) push((r - 1) >> i);
    }

    {
        int l2 = l, r2 = r;
        while(l < r) {
            if(l & 1) all_apply(l++, f);
            if(r & 1) all_apply(--r, f);
            l >>= 1;
            r >>= 1;
        }
        l = l2;
        r = r2;
    }

    for(int i = 1; i <= log; i++) {
        if(((l >> i) << i) != l) update(l >> i);
        if(((r >> i) << i) != r) update((r - 1) >> i);
    }
}

template<class G> int max_right(int l, G g) {
    // assert(0 <= l && l <= _n);
    // assert(g(e()));
    if(l == _n) return _n;
    l += size;
    for(int i = log; i >= 1; i--) push(l >> i);
    S sm = e();
    do {
        while(l % 2 == 0) l >>= 1;
        if(!g(op(sm, d[l]))) {
            while(l < size) {
                push(l);
                l = (2 * l);
                if(g(op(sm, d[l]))) {
                    sm = op(sm, d[l]);
                    l++;
                }
            }
            return l - size;
        }
        sm = op(sm, d[l]);
        l++;
    } while((l & -l) != l);
    return _n;
} // d93691

template<class G> int min_left(int r, G g) {
    // assert(0 <= r && r <= _n);
    // assert(g(e()));
    if(r == 0) return 0;
    r += size;
    for(int i = log; i >= 1; i--) push((r - 1) >> i);
    S sm = e();

```

```

    do {
        r--;
        while(r > 1 && (r % 2)) r >>= 1;
        if(!g(op(d[r], sm))) {
            while(r < size) {
                push(r);
                r = (2 * r + 1);
                if(g(op(d[r], sm))) {
                    sm = op(d[r], sm);
                    r--;
                }
            }
            return r + 1 - size;
        }
        sm = op(d[r], sm);
    } while((r & -r) != r);
    return 0;
} // c9a7eb

private:
int _n, size, log;
vector<S> d;
vector<F> lz;

void update(int k) { d[k] = op(d[2 * k], d[2 * k + 1]); }
void all_apply(int k, F f) {
    d[k] = mapping(f, d[k]);
    if(k < size) lz[k] = composition(f, lz[k]);
}
void push(int k) {
    all_apply(2 * k, lz[k]);
    all_apply(2 * k + 1, lz[k]);
    lz[k] = id();
}
};

```

potential_dsu.hpp

md5: b2e5eb

```

// base: 650ffa
template<typename Abel> struct potential_dsu {
    using T = typename Abel::T;
    int tCount;
    vector<int> p, rank;
    vector<T> potential;
    int N;
    potential_dsu(int size) {
        N = size;
        p.resize(N, -1);
        rank.resize(N, 0);
        potential.resize(N, Abel::e());
        tCount = N;
    }

    bool same(int x, int y) { return leader(x) == leader(y); }

    // w[y] - w[x] = w
    void merge(int x, int y, T w) {
        w = Abel::op(w, get_potential(x));
        w = Abel::op(w, Abel::inv(get_potential(y)));
        link(leader(x), leader(y), w);
    }

    int leader(int x) {
        if(p[x] < 0) return x;
        int l = leader(p[x]);
        potential[x] = Abel::op(potential[x], potential[p[x]]);
        return p[x] = l;
    }

    T get_potential(int x) {
        leader(x);
        return potential[x];
    }

    // w[y] - w[x]
    T diff(int x, int y) { return Abel::op(get_potential(y),
        Abel::inv(get_potential(x))); }

    int count() { return tCount; } // 154012

    int size(int a) {
        // assert(0 <= a && a < _n);
    }
};

```

```

    return -p[leader(a)];
} // 818fe7

vector<vector<int>> groups() {
    vector<int> leader_buf(N), group_size(N);
    for(int i = 0; i < N; i++) {
        leader_buf[i] = leader(i);
        group_size[leader_buf[i]]++;
    }
    vector<vector<int>> result(N);
    for(int i = 0; i < N; i++)
result[i].reserve(group_size[i]);
    for(int i = 0; i < N; i++)
result[leader_buf[i]].push_back(i);
    result.erase(remove_if(result.begin(), result.end(), [&
(const vector<int>& v) { return v.empty(); }]),
        result.end());
    return result;
} // 92d7ce

private:
void link(int x, int y, T w) {
    if(x == y) return;
    tCount--;
    if(rank[x] < rank[y]) {
        swap(x, y);
        w = Abel::inv(w);
    }
    p[x] += p[y];
    p[y] = x;
    if(rank[x] == rank[y]) rank[x]++;
    tCount--;
    potential[y] = w;
}
};

/*
struct Abel {
    using T = int;
    static T e() { return 0; }
    static T op(T a, T b) { return a + b; }
    static T inv(T a) { return -a; }
};

potential_dsu<Abel> dsu(N);
*/

```

range_set.hpp

md5: 1bc645

```

template<bool margeAdjacent = true> struct range_set : public
map<ll, ll> {
    auto get(ll p) const {
        auto it = upper_bound(p);
        if(it == begin() || (--it)->second < p) return end();
        return it;
    }

    void insert(ll l, ll r) {
        auto itl = upper_bound(l), itr = upper_bound(r +
margeAdjacent);
        if(itl != begin()) {
            if((--itl)->second < l - margeAdjacent) ++itl;
        }
        if(itl != itr) {
            l = min(l, itl->first);
            r = max(r, prev(itr)->second);
            erase(itl, itr);
        }
        (*this)[l] = r;
    }

    void remove(ll l, ll r) {
        auto itl = upper_bound(l), itr = upper_bound(r);
        if(itl != begin())
            if((--itl)->second < l) ++itl;
        if(itl == itr) return;
        int tl = min(l, itl->first), tr = max(r, prev(itr)-
>second);
        erase(itl, itr);
        if(tl < l) (*this)[tl] = l - 1;
        if(r < tr) (*this)[r + 1] = tr;
    }
}

```

```

bool same(ll p, ll q) {
    auto it = get(p);
    return it != end() && it->first <= q && q <= it->second;
}
};

```

range_tree.hpp

md5: 7f74d5

```

template<class K, class M> struct range_tree {
    using S = typename M::S;
    using D = typename M::D;

private:
    vector<pair<K, K>> ps;
    vector<K> xs;
    vector<vector<K>> ys;
    vector<D> ds;
    int n;
    int id(K x) const { return lower_bound(all(xs), x) -
xs.begin(); }

    int id(int k, K y) const { return lower_bound(all(ys[k]), y)
- ys[k].begin(); }

public:
    void add(K x, K y) { ps.emplace_back(x, y); }
    void build() {
        sort(ps.begin(), ps.end());
        ps.erase(unique(all(ps)), ps.end());
        n = size(ps);
        xs.reserve(n);
        for(auto& [x, _] : ps) xs.push_back(x);
        ys.resize(2 * n);
        ds.resize(2 * n, M::init(0));
        for(int i = 0; i < n; i++) {
            ys[i + n] = {ps[i].second};
            ds[i + n] = M::init(1);
        }
        for(int i = n - 1; i > 0; i--) {
            ys[i].resize(size(ys[i << 1]) + size(ys[(i << 1] |
1)));
            merge(all(ys[i << 1]), all(ys[(i << 1] | 1)),
ys[i].begin());
            ys[i].erase(unique(all(ys[i])), ys[i].end());
            ds[i] = M::init(size(ys[i]));
        }
    }

    void apply(K x, K y, S a) {
        int k = lower_bound(all(ps), make_pair(x, y)) -
ps.begin() + n;
        while(k > 0) {
            M::apply(ds[k], id(k, y), a);
            k >>= 1;
        }
    }

    S prod(K x1, K y1, K x2, K y2) {
        int a = id(x1), b = id(x2);
        a += n;
        b += n;
        S l = M::e(), r = M::e();
        while(a < b) {
            if(a & 1) {
                l = M::op(l, M::prod(ds[a], id(a, y1), id(a, y2)));
                ++a;
            }
            if(b & 1) {
                --b;
                r = M::op(M::prod(ds[b], id(b, y1), id(b, y2)), r);
            }
            a >>= 1;
            b >>= 1;
        }
        return M::op(l, r);
    }
};

/* 使い方

// モノイド
struct M {

```

```
using S = ll; // データ(モノイド)の型
using D = BIT; // ノードに持たせるデータ構造の型
static S op(S a, S b) { return a + b; } // Sの二項演算
static S e() { return 0; } // Sの単位元
static D init(int n) { return BIT(n); } // Dを長さnで初期化する関数
static void apply(D& bit, int k, const S& v) { bit.add(k, v); } // Dのk番目にvを適用する関数
static S prod(D& bit, int l, int r) { return bit.sum(l, r); } // Dの[l, r) に対するクエリを行う関数
};

rt.add(x, y): 座標 (x, y) を追加
rt.build(): クエリを受け付ける準備をする
rt.apply(x, y, a): 座標 (x, y) に a を適用
rt.prod(x1, y1, x2, y2): 座標 x \in [x1, x2), y \in [y1, y2) の領域にクエリを行う
*/
```

segtree.hpp

md5: d32488

```
// base: bafcf8
unsigned int bit_ceil(unsigned int n) {
    unsigned int x = 1;
    while(x < (unsigned int)(n)) x *= 2;
    return x;
}
int countr_zero(unsigned int n) { return __builtin_ctz(n); }
constexpr int countr_zero_constexpr(unsigned int n) {
    int x = 0;
    while(!(n & (1 << x))) x++;
    return x;
}
template<class S, S (*op)(S, S), S (*e)()> struct segtree {
public:
    segtree() : segtree(0) {}
    explicit segtree(int n) : segtree(vector<S>(n, e())) {}
    explicit segtree(const vector<S>& v) : _n(int(v.size())) {
        size = (int)bit_ceil((unsigned int)(n));
        log = countr_zero((unsigned int)size);
        d = vector<S>(2 * size, e());
        for(int i = 0; i < _n; i++) d[size + i] = v[i];
        for(int i = size - 1; i >= 1; i--) { update(i); }
    }

    void set(int p, S x) {
        // assert(0 <= p && p < _n);
        p += size;
        d[p] = x;
        for(int i = 1; i <= log; i++) update(p >> i);
    }

    S get(int p) const {
        // assert(0 <= p && p < _n);
        return d[p + size];
    }

    S prod(int l, int r) const {
        // assert(0 <= l && l <= r && r <= _n);
        S sm_l = e(), sm_r = e();
        l += size;
        r += size;

        while(l < r) {
            if(l & 1) sm_l = op(sm_l, d[l++]);
            if(r & 1) sm_r = op(d[--r], sm_r);
            l >>= 1;
            r >>= 1;
        }
        return op(sm_l, sm_r);
    }

    S all_prod() const { return d[1]; }

    template<class F> int max_right(int l, F f) {
        // assert(0 <= l && l <= _n);
        // assert(f(e()));
        if(l == _n) return _n;
        l += size;
        S sm = e();
```

```
do {
    while(l % 2 == 0) l >>= 1;
    if(!f(op(sm, d[l]))) {
        while(l < size) {
            l = (2 * l);
            if(f(op(sm, d[l]))) {
                sm = op(sm, d[l]);
                l++;
            }
        }
        return l - size;
    }
    sm = op(sm, d[l]);
    l++;
} while((l & -l) != l);
return _n;
} // faa03f

template<class F> int min_left(int r, F f) {
    // assert(0 <= r && r <= _n);
    // assert(f(e()));
    if(r == 0) return 0;
    r += size;
    S sm = e();
    do {
        r--;
        while(r > 1 && (r % 2)) r >>= 1;
        if(!f(op(d[r], sm))) {
            while(r < size) {
                r = (2 * r + 1);
                if(f(op(d[r], sm))) {
                    sm = op(d[r], sm);
                    r--;
                }
            }
            return r + 1 - size;
        }
        sm = op(d[r], sm);
    } while((r & -r) != r);
    return 0;
} // efa466

private:
int _n, size, log;
vector<S> d;

    void update(int k) { d[k] = op(d[2 * k], d[2 * k + 1]); }
};
```

sparse_table.hpp

md5: f3812e

```
template<typename T, auto op> struct sparse_table {
    vector<vector<T>> st;
    vector<int> lg;

    sparse_table(const vector<T>& v) {
        int b = 0;
        while((1 << b) <= v.size()) b++;
        st.assign(b, vector<T>(1 << b));
        for(int i = 0; i < size(v); i++) { st[0][i] = v[i]; }
        for(int i = 1; i < b; i++) {
            for(int j = 0; j + (1 << i) <= (1 << b); j++) st[i][j]
= op(st[i - 1][j], st[i - 1][j + (1 << (i - 1))]);
        }
        lg.resize(v.size() + 1);
        for(int i = 2; i < size(lg); i++) lg[i] = lg[i >> 1] + 1;
    }

    inline T prod(int l, int r) {
        int b = lg[r - l];
        return op(st[b][l], st[b][r - (1 << b)]);
    }
};
```

undo_dsus.hpp

md5: f5d93b

```
// base: edf246
struct undo_dsus {
private:
    int _n;
    vector<int> p;
```

```
public:
undo_dsu() : _n(0) {}
explicit undo_dsu(int n) : _n(n), p(n, -1) {}

int merge(int a, int b) {
    // assert(0 <= a && a < _n);
    // assert(0 <= b && b < _n);
    int x = leader(a), y = leader(b);
    if(x == y) {
        history.emplace(x, p[x]);
        history.emplace(y, p[y]);
        return x;
    }
    if(-p[x] < -p[y]) swap(x, y);
    history.emplace(x, p[x]);
    history.emplace(y, p[y]);
    p[x] += p[y];
    p[y] = x;
    return x;
}

bool same(int a, int b) {
    // assert(0 <= a && a < _n);
    // assert(0 <= b && b < _n);
    return leader(a) == leader(b);
}

int leader(int a) {
    // assert(0 <= a && a < _n);
    while(p[a] >= 0) a = p[a];
    return a;
}

void undo() {
    p[history.top().first] = history.top().second;
    history.pop();
    p[history.top().first] = history.top().second;
    history.pop();
}

int snapshot() { return history.size(); }

void rollback(int snapshot = 0) {
    while(history.size() > snapshot) undo();
}

int size(int a) {
    // assert(0 <= a && a < _n);
    return -p[leader(a)];
} // 818fe7
};
```

math

BinaryGCD.hpp

md5: f3ab31

```
u64 ctz(u64 x) { return countr_zero(x); }
u64 binary_gcd(u64 x, u64 y) {
    if(!x || !y) return x | y;
    u64 n = ctz(x), m = ctz(y);
    x >>= n, y >>= m;
    while(x != y) {
        if(x > y) x = (x - y) >> ctz(x - y);
        else y = (y - x) >> ctz(y - x);
    }
    return x << min(n, m);
}
```

ExtGCD.hpp

md5: c3fa9b

```
// returns gcd(a, b) and assign x, y to integers
// s.t. ax + by = gcd(a, b) and |x| + |y| is minimized
ll extgcd(ll a, ll b, ll& x, ll& y) {
    // assert(a >= 0 && b >= 0);
    if(!b) return x = 1, y = 0, a;
    ll d = extgcd(b, a % b, y, x);
    y -= a / b * x;
    return d;
}
```

crt.hpp

md5: 338cb4

```
// mが互いに素になるように前処理
// lcm(m) % MODを返す
// crtの解がなければ-1を返す
ll pre_garner(vector<ll>& b, vector<ll>& m, ll MOD) {
    ll res = 1;
    for(int i = 0; i < (int)b.size(); i++) {
        for(int j = 0; j < i; j++) {
            ll g = gcd(m[i], m[j]);
            if((b[i] - b[j]) % g != 0) return -1;
            m[i] /= g;
            m[j] /= g;
            ll gi = gcd(m[i], g);
            ll gj = g / gi;
            do {
                g = gcd(gi, gj);
                gi *= g;
                gj /= g;
            } while(g != 1);
            m[i] *= gi;
            m[j] *= gj;
            b[i] %= m[i];
            b[j] %= m[j];
        }
    }
    for(int i = 0; i < size(b); i++) (res *= m[i]) %= MOD;
    return res;
}

// m が互いに素であることが保証されている場合
// b[i] = x (mod m[i]) となる最小の x \le 0 を求める
ll garner(vector<ll> b, vector<ll> m, ll MOD) {
    m.push_back(MOD);
    vector<ll> coeffs(size(m), 1);
    vector<ll> constants(size(m), 0);
    for(int k = 0; k < size(b); k++) {
        ll t = ((b[k] - constants[k]) * modinv(coeffs[k], m[k]))
% m[k];
        if(t < 0) t += m[k];
        for(int i = k + 1; i < size(m); i++) {
            (constants[i] += t * coeffs[i]) %= m[i];
            (coeffs[i] *= m[k]) %= m[i];
        }
    }
    return constants.back();
}
```

eratos.hpp

md5: 0de96f

```
void eratos(int n, vector<bool>& isprime) {
    isprime = vector<bool>(n + 1, true);
    isprime[0] = false;
    isprime[1] = false;
    int last = ((int)sqrt(n)) + 1;
    for(int i = 2; i < last; i++) {
        if(isprime[i]) {
            int j = i + i;
            while(j <= n) {
                isprime[j] = false;
                j += i;
            }
        }
    }
}
```

factorize.hpp

md5: 8e6dd4

```
// \sqrt(n)の素因数分解 a01341
map<ll, int> prime_factor(ll n) {
    map<ll, int> ret;
    for(ll i = 2; i * i <= n; i++) {
        while(n % i == 0) {
            ret[i]++;
            n /= i;
        }
    }
    if(n != 1) ret[n] = 1;
    return ret;
}
```



```
// 線形篩 1f4de3
vector<int> preprocess(int n) {
    n++;
    vector<int> res(n);
    std::iota(res.begin(), res.end(), 0);
    for(int i = 2; i * i < n; ++i) {
        if(res[i] < i) continue;
        for(int j = i * i; j < n; j += i)
            if(res[j] == j) res[j] = i;
    }
    return res;
}

map<int, int> prime_factor(int n, const vector<int>& lp) {
    map<int, int> ret;
    while(n > 1) {
        ret[lp[n]]++;
        n /= lp[n];
    }
    return ret;
}
```

floor_sum.hpp

md5: 0f7242

```
ll floor_sum(const ll& n, const ll& m, ll a, ll b) {
    ll ret = 0;
    if(a >= m) ret += (n - 1) * n * (a / m) / 2, a %= m;
    if(b >= m) ret += n * (b / m), b %= m;
    ll y = (a * n + b) / m;
    if(y == 0) return ret;
    ll x = y * m - b;
    ret += (n - (x + a - 1) / a) * y;
    ret += floor_sum(y, a, m, (a - x % a) % a);
    return ret;
}
```

modinv.hpp

md5: a0de19

```
ll modinv(ll a, ll MOD) {
    ll b = MOD, u = 1, v = 0;
    while(b) {
        ll t = a / b;
        a -= t * b;
        swap(a, b);
        u -= t * v;
        swap(u, v);
    }
    u %= MOD;
    if(u < 0) u += MOD;
    return u;
}
```

modpow.hpp

md5: 6b940c

```
ll modpow(ll a, ll n, ll MOD) {
    using T = __int128_t;
    // using T = ll;
    T res = 1;
    T mul = a;
    mul %= MOD;
    if(n < 0) {
        n = -n;
        mul = modinv(mul, MOD);
    }
    while(n > 0) {
        if(n & 1) res = (res * mul) % MOD;
        mul = (mul * mul) % MOD;
        n >>= 1;
    }
    return ll(res);
}
```

primality.hpp

md5: d6eb6a

```
bool is_prime(ll N) {
    if(N == 2) return true;
    if(N == 1 || N % 2 == 0) return false;
    ll s = 0;
    ll d = N - 1;
    while(d % 2 == 0) {
        s++;
    }
```

```
        d /= 2;
    }
    vector<ll> tests = {2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31, 37};
    for(auto a : tests) {
        if(a == N) continue;
        ll X = modpow(a, d, N);
        int r = 0;
        if(X == 1) { continue; }
        while(X != N - 1) {
            X = modpow(X, 2, N);
            r++;
            if(X == 1 || r == s) return false;
        }
    }
    return true;
}
```

rho.hpp

md5: 820144

```
ll find_prime_factor(ll N) {
    using i128 = __int128_t;
    if(N % 2 == 0) { return 2; }
    int b = int(sqrt(sqrt(sqrt(N)))) + 1;
    for(ll c = 1; c < N; c++) {
        auto f = [&](ll a) -> ll { return modpow(a, 2, N) + c; };
        ll y = 6;
        ll g = 1;
        i128 q = 1;
        int r = 1;
        int k = 0;
        ll ys = 0;
        ll x = 0;
        while(g == 1) {
            x = y;
            while(k < 3 * r / 4) {
                y = f(y);
                k++;
            }
            while(k < r && g == 1) {
                ys = y;
                for(ll i = 0; i < min(b, r - k); i++) {
                    y = f(y);
                    q *= abs(x - y);
                    q %= N;
                }
                g = gcd(ll(q), N);
                k += b;
            }
            k = r;
            r *= 2;
        }
        if(g == N) {
            g = 1;
            y = ys;
            while(g == 1) {
                y = f(y);
                g = gcd(abs(x - y), N);
            }
        }
        if(g == N) { continue; }
        if(is_prime(g)) { return g; }
        if(is_prime(N / g)) { return N / g; }
        return find_prime_factor(g);
    }
    assert(false);
}

map<ll, int> factorize(ll N) {
    map<ll, int> ret;
    while(!is_prime(N) && N > 1) {
        ll p = find_prime_factor(N);
        int s = 0;
        while(N % p == 0) {
            N /= p;
            s++;
        }
        ret[p] = s;
    }
    if(N > 1) { ret[N] = 1; }
```



```
    return ret;
}
```

modint

BarrettReduction.hpp

md5: 2ca7f3

```
// using u64 = uint64_t;
struct Barrett { // mod < 2^32
    u64 m, im;
    Barrett(u64 mod) : m(mod), im((-1ULL / m + 1) {}) {
        // input: a * b < 2^64, output: a * b % mod
        u64 mul(u64 a, u64 b) const {
            a *= b;
            u64 x = ((__uint128_t)a * im) >> 64;
            a -= x * m;
            if((__ll)a < 0) a += m;
            return a;
        }
    };
};
```

modint.hpp

md5: 81b530

```
const ll mod = 998244353;
struct mm {
    ll x;
    mm(ll x_ = 0) : x(x_ % mod) {
        if(x < 0) x += mod;
    }
    friend mm operator+(mm a, mm b) { return a.x + b.x; }
    friend mm operator-(mm a, mm b) { return a.x - b.x; }
    friend mm operator*(mm a, mm b) { return a.x * b.x; }
    friend mm operator/(mm a, mm b) { return a * b.inv(); }
    // 4行コピー Alt + Shift + クリックで複数カーソル
    friend mm& operator+=(mm& a, mm b) { return a = a.x + b.x; }
    friend mm& operator-=(mm& a, mm b) { return a = a.x - b.x; }
    friend mm& operator*=(mm& a, mm b) { return a = a.x * b.x; }
    friend mm& operator/=(mm& a, mm b) { return a = a * b.inv(); }
}

mm inv() const { return pow(mod - 2); }
mm pow(ll b) const {
    mm a = *this, c = 1;
    while(b) {
        if(b & 1) c *= a;
        a *= a;
        b >>= 1;
    }
    return c;
}
};
```

FPS

FFT.hpp

md5: 6e60c3

```
// {998244353, 3}, {1811939329, 13}, {2013265921, 31}
mm g = 3; // 原始根
void fft(vector<mm>& a) {
    ll n = size(a), lg = __lg(n);
    assert((1 << lg) == n);
    vector<mm> b(n);
    for(int l = 1; l <= lg; l++) {
        ll w = n >> l;
        mm s = 1, r = g.pow(mod >> l);
        for(ll u = 0; u < n / 2; u += w) {
            for(int d = 0; d < w; d++) {
                mm x = a[u << 1 | d], y = a[u << 1 | w | d] * s;
                b[u | d] = x + y;
                b[n >> 1 | u | d] = x - y;
            }
            s *= r;
        }
        swap(a, b);
    }
}

vector<mm> conv(vector<mm> a, vector<mm> b) {
    if(a.empty() || b.empty()) return {};
    size_t s = size(a) + size(b) - 1, n = bit_ceil(s);
    // if(min(sz(a), sz(b)) <= 60) 愚直に掛け算
    a.resize(n);
}
```

```
    b.resize(n);
    fft(a);
    fft(b);
    mm inv = mm(n).inv();
    for(int i = 0; i < n; i++) a[i] *= b[i] * inv;
    reverse(1 + all(a));
    fft(a);
    a.resize(s);
    return a;
}
```

FFT_fast.hpp

md5: 33f77f

```
// modint を u32 にして加減算を真面目にやると速い
mm g = 3; // 原始根
void fft(vector<mm>& a) {
    ll n = size(a), lg = __lg(n);
    static auto z = [] {
        vector<mm> z(30);
        mm s = 1;
        for(int i = 2; i < 32; i++) {
            z[i - 2] = s * g.pow(mod >> i);
            s *= g.inv().pow(mod >> i);
        }
        return z;
    }();
    for(int l = 0; l < lg; l++) {
        ll w = 1 << (lg - l - 1);
        mm s = 1;
        for(int k = 0; k < (1 << l); k++) {
            ll o = k << (lg - l);
            for(ll i = o; i < o + w; i++) {
                mm x = a[i], y = a[i + w] * s;
                a[i] = x + y;
                a[i + w] = x - y;
            }
            s *= z[countr_zero<uint64_t>(~k)];
        }
    }
}

// コピー
void ifft(vector<mm>& a) {
    ll n = size(a), lg = __lg(n);
    static auto z = [] {
        vector<mm> z(30);
        mm s = 1;
        for(int i = 2; i < 32; i++) { // g を逆数に
            z[i - 2] = s * g.inv().pow(mod >> i);
            s *= g.pow(mod >> i);
        }
        return z;
    }();
    for(ll l = lg; l--;) { // 逆順に
        ll w = 1 << (lg - l - 1);
        mm s = 1;
        for(int k = 0; k < (1 << l); k++) {
            ll o = k << (lg - l);
            for(ll i = o; i < o + w; i++) {
                mm x = a[i], y = a[i + w]; // *s を下に移動
                a[i] = x + y;
                a[i + w] = (x - y) * s;
            }
            s *= z[countr_zero<uint64_t>(~k)];
        }
    }
}

vector<mm> conv(vector<mm> a, vector<mm> b) {
    if(a.empty() || b.empty()) return {};
    size_t s = size(a) + size(b) - 1, n = bit_ceil(s);
    // if(min(size(a), size(b)) <= 60) 愚直に掛け算
    a.resize(n);
    b.resize(n);
    fft(a);
    fft(b);
    mm inv = mm(n).inv();
    for(int i = 0; i < n; i++) a[i] *= b[i] * inv;
    ifft(a);
    a.resize(s);
    return a;
}
```

graph

low_link.hpp

md5: d5d2f7

```

struct LowLink {
public:
    vector<vector<int>> g;
    vector<int> ord, low;
    vector<int> articulation;
    vector<bool> visited;
    vector<pair<int, int>> bridge;

    void dfs(int cur, int pre, int& k) {
        visited[cur] = true;
        ord[cur] = low[cur] = k++;
        bool isArticulation = false;
        int cnt = 0;
        for(auto to : g[cur]) {
            if(!visited[to]) {
                cnt++;
                dfs(to, cur, k);
                chmin(low[cur], low[to]);
                if(pre != -1 && ord[cur] <= low[to]) isArticulation
= true;
                if(ord[cur] < low[to]) bridge.emplace_back(min(cur,
to), max(cur, to));
            } else if(to != pre) chmin(low[cur], ord[to]);
        }
        if(pre == -1 && cnt > 1) isArticulation = true;
        if(isArticulation) articulation.push_back(cur);
    }

    void build(const vector<vector<int>>& g) {
        int n = g.size();
        this->g = g;
        ord.assign(n, -1);
        low.assign(n, -1);
        visited.assign(n, false);
        int k = 0;
        for(int i = 0; i < n; i++)
            if(!visited[i]) dfs(i, -1, k);
    }
    LowLink(const vector<vector<int>>& g) { build(g); }

    vector<int>& getArticulations() { return articulation; }
    vector<pair<int, int>>& getBridges() { return bridge; }
    vector<int>& getOrd() { return ord; }
    vector<int>& getLowlink() { return low; }
};

```

max_flow.hpp

md5: a7f1d5

```

// base: 9927a4
template<class Cap> struct mf_graph {
public:
    mf_graph() : _n(0) {}
    mf_graph(int n) : _n(n), g(n) {}

    int add_edge(int from, int to, Cap cap) {
        // assert(0 <= from && from < _n);
        // assert(0 <= to && to < _n);
        // assert(0 <= cap);
        int m = size(pos);
        pos.push_back({from, size(g[from])});
        int from_id = size(g[from]);
        int to_id = size(g[to]);
        if(from == to) to_id++;
        g[from].push_back(_edge{to, to_id, cap});
        g[to].push_back(_edge{from, from_id, 0});
        return m;
    }

    Cap flow(int s, int t, Cap flow_limit =
numeric_limits<Cap>::max()) {
        // assert(0 <= s && s < _n);
        // assert(0 <= t && t < _n);
        // assert(s != t);

        vector<int> level(_n), iter(_n);
        queue<int> que;

```

```

        auto bfs = [&]() {
            fill(all(level), -1);
            level[s] = 0;
            while(!que.empty()) que.pop();
            que.push(s);
            while(!que.empty()) {
                int v = que.front();
                que.pop();
                for(auto e : g[v]) {
                    if(e.cap == 0 || level[e.to] >= 0) continue;
                    level[e.to] = level[v] + 1;
                    if(e.to == t) return;
                    que.push(e.to);
                }
            }
        };
        auto dfs = [&](auto self, int v, Cap up) {
            if(v == s) return up;
            Cap res = 0;
            int level_v = level[v];
            for(int& i = iter[v]; i < size(g[v]); i++) {
                _edge& e = g[v][i];
                if(level_v <= level[e.to] || g[e.to][e.rev].cap ==
0) continue;
                Cap d = self(self, e.to, min(up - res, g[e.to]
[e.rev].cap));
                if(d <= 0) continue;
                g[v][i].cap -= d;
                g[e.to][e.rev].cap += d;
                res += d;
                if(res == up) break;
            }
            return res;
        };

        Cap flow = 0;
        while(flow < flow_limit) {
            bfs();
            if(level[t] == -1) break;
            fill(all(iter), 0);
            while(flow < flow_limit) {
                Cap f = dfs(dfs, t, flow_limit - flow);
                if(!f) break;
                flow += f;
            }
        }
        return flow;
    }

    vector<bool> min_cut(int s) {
        vector<bool> visited(_n);
        queue<int> que;
        que.push(s);
        visited[s] = true;
        while(!que.empty()) {
            int v = que.front();
            que.pop();
            for(auto e : g[v]) {
                if(e.cap && !visited[e.to]) {
                    visited[e.to] = true;
                    que.push(e.to);
                }
            }
        }
        return visited;
    } // 8735cf

    struct edge {
        int from, to;
        Cap cap, flow;
    }; // 9fe107

    edge get_edge(int i) {
        int m = size(pos);
        // assert(0 <= i && i < m);
        auto _e = g[pos[i].first][pos[i].second];
        auto _re = g[_e.to][_e.rev];
        return edge{pos[i].first, _e.to, _e.cap + _re.cap,
_re.cap};
    } // ad4299

    vector<edge> edges() {

```

```

    int m = size(pos);
    vector<edge> result;
    for(int i = 0; i < m; i++) result.push_back(get_edge(i));
    return result;
} // 5948b8

void change_edge(int i, Cap new_cap, Cap new_flow) {
    int m = size(pos);
    // assert(0 <= i && i < m);
    // assert(0 <= new_flow && new_flow <= new_cap);
    auto& _e = g[pos[i].first][pos[i].second];
    auto& _re = g[_e.to][_e.rev];
    _e.cap = new_cap - new_flow;
    _re.cap = new_flow;
} // 558c35

private:
int _n;
struct _edge {
    int to, rev;
    Cap cap;
};
vector<pair<int, int>> pos;
vector<vector<_edge>> g;
};

```

min_cost_flow.hpp

md5: 17d51b

```

// base: 4e9f1c
template<class Cap, class Cost> struct mcf_graph {
public:
    mcf_graph() {}
    mcf_graph(int n) : _n(n), g(n) {}

    int add_edge(int from, int to, Cap cap, Cost cost) {
        // assert(0 <= from && from < _n);
        // assert(0 <= to && to < _n);
        int m = size(pos);
        pos.push_back({from, size(g[from])});
        int from_id = size(g[from]);
        int to_id = size(g[to]);
        if(from == to) to_id++;
        g[from].push_back(_edge{to, to_id, cap, cost});
        g[to].push_back(_edge{from, from_id, 0, -cost});
        return m;
    }

    pair<Cap, Cost> flow(int s, int t, Cap flow_limit =
numeric_limits<Cap>::max()) {
        return slope(s, t, flow_limit).back();
    }

    vector<pair<Cap, Cost>> slope(int s, int t, Cap flow_limit =
numeric_limits<Cap>::max()) {
        // assert(0 <= s && s < _n);
        // assert(0 <= t && t < _n);
        // assert(s != t);
        vector<Cost> dual(_n, 0), dist(_n);
        vector<int> pv(_n), pe(_n);
        vector<bool> vis(_n);
        auto dual_ref = [&]() {
            fill(all(dist), numeric_limits<Cost>::max());
            fill(all(pv), -1);
            fill(all(pe), -1);
            fill(all(vis), false);
            struct Q {
                Cost key;
                int to;
                bool operator<(const Q& r) const { return key >
r.key; }
            };
            priority_queue<Q> que;
            dist[s] = 0;
            que.push(Q{0, s});
            while(!que.empty()) {
                int v = que.top().to;
                que.pop();
                if(vis[v]) continue;
                vis[v] = true;
                if(v == t) break;
                for(int i = 0; i < size(g[v]); i++) {
                    auto e = g[v][i];
                    if(vis[e.to] || !e.cap) continue;

```

```

                    Cost cost = e.cost - dual[e.to] + dual[v];
                    if(chmin(dist[e.to], dist[v] + cost)) {
                        pv[e.to] = v;
                        pe[e.to] = i;
                        que.push(Q{dist[e.to], e.to});
                    }
                }
            }
            if(!vis[t]) return false;
            for(int v = 0; v < _n; v++)
                if(vis[v]) dual[v] -= dist[t] - dist[v];
            return true;
        };
        Cap flow = 0;
        Cap cost = 0, prev_cost_per_flow = -1;
        vector<pair<Cap, Cost>> result;
        result.push_back({flow, cost});
        while(flow < flow_limit) {
            if(!dual_ref()) break;
            Cap c = flow_limit - flow;
            for(int v = t; v != s; v = pv[v]) { c = min(c,
g[pv[v]][pe[v]].cap); }
            for(int v = t; v != s; v = pv[v]) {
                auto& e = g[pv[v]][pe[v]];
                e.cap -= c;
                g[v][e.rev].cap += c;
            }
            Cost d = -dual[s];
            flow += c;
            cost += c * d;
            if(prev_cost_per_flow == d) { result.pop_back(); }
            result.push_back({flow, cost});
            prev_cost_per_flow = d;
        }
        return result;
    }

    struct edge {
        int from, to;
        Cap cap, flow;
    }; // 9fe107

    edge get_edge(int i) {
        int m = size(pos);
        // assert(0 <= i && i < m);
        auto _e = g[pos[i].first][pos[i].second];
        auto _re = g[_e.to][_e.rev];
        return edge({pos[i].first, _e.to, _e.cap + _re.cap,
_re.cap});
    } // d7bd7e

    vector<edge> edges() {
        int m = size(pos);
        vector<edge> result;
        for(int i = 0; i < m; i++) result.push_back(get_edge(i));
        return result;
    } // 5948b8

    void change_edge(int i, Cap new_cap, Cap new_flow) {
        int m = size(pos);
        // assert(0 <= i && i < m);
        // assert(0 <= new_flow && new_flow <= new_cap);

        auto& _e = g[pos[i].first][pos[i].second];
        auto& _re = g[_e.to][_e.rev];
        _e.cap = new_cap - new_flow;
        _re.cap = new_flow;
    } // 558c35

private:
int _n;
struct _edge {
    int to, rev;
    Cap cap;
    Cost cost;
};

vector<pair<int, int>> pos;
vector<vector<_edge>> g;
};

```

scc.hppmd5: 9f5fd6

// base: 3085f6
struct scc_graph {
 public:
 explicit scc_graph(int _n = 0) : n(_n), G(_n), rG(_n),
 comp(_n, -1), visited(_n, 0) {}

 void add_edge(int from, int to) {
 // assert(0 <= from && from < n);
 // assert(0 <= to && to < n);
 G[from].push_back(to);
 rG[to].push_back(from);
 }

 vector<vector<int>> scc() {
 fill(all(visited), 0);
 fill(all(comp), -1);
 order.clear();
 for(int i = 0; i < n; i++)
 if(!visited[i]) dfs(i);
 comp_size = 0;
 for(int i = size(order) - 1; i >= 0; i--) {
 if(comp[order[i]] < 0) rdfs(order[i], comp_size++);
 }
 vector<vector<int>> v(comp_size);
 for(int i = 0; i < n; i++) v[comp[i]].push_back(i);
 return v;
 }

 vector<int> get_comp() { return comp; } // bdafc0

 vector<vector<int>> dag() {
 vector<vector<int>> res(comp_size);
 for(int i = 0; i < n; i++)
 for(auto j : G[i]) {
 if(comp[i] != comp[j])
 res[comp[i]].push_back(comp[j]);
 }
 for(int i = 0; i < comp_size; i++) {
 sort(all(res[i]));
 res[i].erase(unique(all(res[i])), res[i].end());
 }
 return res;
 } // 312650

 private:
 vector<vector<int>> G, rG;
 vector<int> order, comp;
 vector<bool> visited;
 int n, comp_size;

 void dfs(int v) {
 visited[v] = true;
 for(auto to : G[v])
 if(!visited[to]) dfs(to);
 order.push_back(v);
 }

 void rdfs(int v, int k) {
 comp[v] = k;
 for(auto to : rG[v]) {
 if(comp[to] < 0) rdfs(to, k);
 }
 }
};

topological_sort.hppmd5: 024d40

vector<int> topological_sort(vector<vector<int>>& g) {
 int n = g.size();
 vector<int> indeg(n);
 for(int i = 0; i < n; i++)
 for(int j : g[i]) indeg[j]++;
 vector<int> res;
 queue<int> q;
 for(int i = 0; i < n; i++)
 if(indeg[i] == 0) q.push(i);
 while(!q.empty()) {
 auto v = q.front();
 q.pop();

two_sat.hppmd5: 681721

res.push_back(v);
for(auto u : g[v]) {
 indeg[u]--;
 if(indeg[u] == 0) q.push(u);
}
}
return res;
}
};

struct two_sat {
 public:
 two_sat() : _n(0), scc(0) {}
 two_sat(int n) : _n(n), scc(2 * n), _answer(n) {}

 void add_clause(int i, bool f, int j, bool g) {
 // assert(0 <= i && i < _n);
 // assert(0 <= j && j < _n);
 scc.add_edge(2 * i + (f ? 0 : 1), 2 * j + (g ? 1 : 0));
 scc.add_edge(2 * j + (g ? 0 : 1), 2 * i + (f ? 1 : 0));
 }

 bool satisfiable() {
 scc.scc();
 auto comp = scc.get_comp();
 for(int i = 0; i < _n; i++) {
 if(comp[2 * i] == comp[2 * i + 1]) return false;
 _answer[i] = comp[2 * i] < comp[2 * i + 1];
 }
 return true;
 }

 vector<bool> answer() { return _answer; }

 private:
 int _n;
 vector<bool> _answer;
 scc_graph scc;
};

graph/tree

cartesian_tree.hppmd5: ac77a5

template<class T> struct cartesian_tree {
 int root;
 vector<int> par, left, right;

 cartesian_tree(const vector<T>& v) : root(0), par(size(v),
-1), left(size(v), -1), right(size(v), -1) {
 stack<int> st;
 int N = size(v);
 for(int i = 0; i < N; i++) {
 int prev = -1;
 while(!st.empty() && v[st.top()] > v[i]) {
 prev = st.top();
 st.pop();
 }
 if(prev != -1) par[prev] = i;
 if(!st.empty()) par[i] = st.top();
 st.push(i);
 }

 root = -1;
 for(int i = 0; i < N; i++) {
 if(par[i] == -1) root = i;
 else if(par[i] < i) right[par[i]] = i;
 else left[par[i]] = i;
 }
 }
};

hld.hppmd5: 10247f

class HLDcomposition {
 private:
 int V;
 vector<vector<int>> G;
 vector<int> stsize, parent, pathtop, in, out;
 int root;

```

void build_stsize(int u, int p) {
    stsize[u] = 1, parent[u] = p;
    for(auto&& v : G[u]) {
        if(v == p) {
            if(v == G[u].back()) break;
            else swap(v, G[u].back());
        }
        build_stsize(v, u);
        stsize[u] += stsize[v];
        if(stsize[v] > stsize[G[u][0]]) swap(v, G[u][0]);
    }
}

void build_path(int u, int p, int& tm) {
    in[u] = tm++;
    for(auto v : G[u]) {
        if(v == p) continue;
        pathtop[v] = (v == G[u][0] ? pathtop[u] : v);
        build_path(v, u, tm);
    }
    out[u] = tm;
}

public:
void add_edge(int u, int v) {
    G[u].push_back(v);
    G[v].push_back(u);
}

void build(int _root = 0) {
    root = _root;
    int tm = 0;
    build_stsize(root, -1);
    pathtop[root] = root;
    build_path(root, -1, tm);
}

inline int index(int a) { return in[a]; }

int lca(int a, int b) {
    int pa = pathtop[a], pb = pathtop[b];
    while(pa != pb) {
        if(in[pa] > in[pb]) {
            a = parent[pa], pa = pathtop[a];
        } else {
            b = parent[pb], pb = pathtop[b];
        }
    }
    if(in[a] > in[b]) swap(a, b);
    return a;
}

pair<int, int> subtree_query(int a) { return {in[a], out[a]}; }

vector<tuple<int, int, bool>> path_query(int from, int to) {
    int pf = pathtop[from], pt = pathtop[to];
    using T = tuple<int, int, bool>;
    deque<T> front, back;
    while(pf != pt) {
        if(in[pf] > in[pt]) {
            front.push_back({in[pf], in[from] + 1, true});
            from = parent[pf], pf = pathtop[from];
        } else {
            back.push_front({in[pt], in[to] + 1, false});
            to = parent[pt], pt = pathtop[to];
        }
    }
    if(in[from] > in[to]) front.push_back({in[to], in[from] + 1, true});
    else front.push_back({in[from], in[to] + 1, false});
    vector<T> ret;
    while(!front.empty()) {
        ret.push_back(front.front());
        front.pop_front();
    }
    while(!back.empty()) {
        ret.push_back(back.front());
        back.pop_front();
    }
    return ret;
}

```

```

HLDcomposition(int node_size)
    : V(node_size), G(V), stsize(V, 0), parent(V, -1),
  pathtop(V, -1), in(V, -1), out(V, -1) {}
};

```

rerooting.hpp

md5: 3bb537

```

// base: b7fc0f
template<class M, bool calc_contribution = false> struct
Rerooting {
    using S = typename M::S;
    using C = typename M::C;
    vector<S> dp, memo;
    vector<vector<pair<int, C>>> g;
    map<ll, S> hash;
    int N;

    Rerooting(int n) : N(n), g(n) {}

    void add_edge(int f, int t, const C& c) {
        g[f].emplace_back(t, c);
        g[t].emplace_back(f, c);
    }

    vector<S> build() {
        memo.resize(N, M::e());
        dp.resize(N, M::e());
        dfs(0, -1);
        reroot(0, M::e());
        return dp;
    }

private:
    void dfs(int cur, int pre = -1) {
        bool is_leaf = true;
        for(auto [to, c] : g[cur]) {
            if(to == pre) continue;
            is_leaf = false;
            dfs(to, cur);
            memo[cur] = M::merge(memo[cur], M::apply(memo[to], to,
cur, c));
        }
        if(is_leaf) { memo[cur] = M::leaf(); }
    }

    void reroot(int cur, const S val, int pre = -1) {
        vector<S> ds;
        ds.push_back(val);
        if(calc_contribution) {
            if(pre == -1) hash[cur * N + pre] = val;
        }
        for(auto [to, c] : g[cur]) {
            if(to == pre) continue;
            ds.push_back(M::apply(memo[to], to, cur, c));
            if(calc_contribution) { hash[cur * N + to] =
ds.back(); }
        }
        int n = size(ds);
        vector<S> l(n + 1, M::e()), r(n + 1, M::e());
        for(int i = 0; i < n; i++) l[i + 1] = M::merge(l[i],
ds[i]);
        for(int i = n - 1; i >= 0; i--) r[i] = M::merge(ds[i],
r[i + 1]);
        dp[cur] = r[0];
        int ind = 1;
        for(auto [to, c] : g[cur]) {
            if(to == pre) continue;
            S sub = M::merge(l[ind], r[ind + 1]);
            reroot(to, M::apply(sub, cur, to, c), cur);
            ind++;
        }
    }

public:
    S get_contribution(int p, int c) {
        if(hash.count(p * N + c)) return hash[p * N + c];
        return M::e();
    } // e6000f
};

/*

```

```
struct M {
    using S = pair<mm, int>; // DPの型
    using C = pair<mm, mm>; // 辺コストの型
    static S merge(S a, S b) { return {a.first + b.first,
a.second + b.second}; } // DPのマージ
    static S apply(S a, int from, int to, C b) { // DPの親への寄与
        return {(a.first + A[from]) * b.first + b.second *
(a.second + 1), a.second + 1};
    }
    static S e() { return {0, 0}; } // 単位元
    static S leaf() { return {0, 0}; } // 葉の値
};

Rerooting<M> reroot;
*/
```

flow

燃やす埋める.md

変形前の制約	変形後の制約
x が 0 のとき z 失う	(x, T, z)
x が 0 のとき z 得る	無条件で z 得る; (S, x, z)
x が 1 のとき z 失う	(S, x, z)
x が 1 のとき z 得る	無条件で z 得る; (x, T, z)
x, y, \dots がすべて 0 のとき z 得る	無条件で z 得る; $(S, w, z), (w, x, \infty), (w, y, \infty)$
x, y, \dots がすべて 1 のとき z 得る	無条件で z 得る; $(w, T, z), (x, w, \infty), (y, w, \infty)$

string

KMP.hppmd5: 298f79

```
// kmp[i] := max{ l ≤ i | s[:l] == s[(i+1)-l:i+1] }
// abacaba -> 0010123
auto KMP(string s) {
    vector<ll> p(size(s));
    for(int i = 1; i < size(s); i++) {
        ll g = p[i - 1];
        while(g && s[i] != s[g]) g = p[g - 1];
        p[i] = g + (s[i] == s[g]);
    }
    return p;
}
```

Manacher.hppmd5: 20c548

```
// 各位置での回文半径を求める
// aaabaaa -> 1214121
// 偶数長の回文を含めて直径を知るには、N+1 個の $ を挿入して 1 を引く
// $a$a$a$b$a$a$a$ -> 123432181234321
auto manacher(string s) {
    ll n = size(s), i = 0, j = 0;
    vector<ll> r(n);
    while(i < n) {
        while(i >= j && i + j < n && s[i - j] == s[i + j]) j++;
        r[i] = j;
        ll k = 1;
        while(i >= k && i + k < n && k + r[i - k] < j) {
            r[i + k] = r[i - k];
            k++;
        }
        i += k, j -= k;
    }
    return r;
}
```

RollingHash.hppmd5: 7403a8

```
// using u64 = uint64_t;
const u64 mod = INF;
```

```
u64 add(u64 a, u64 b) {
    a += b;
    if(a >= mod) a -= mod;
    return a;
}
u64 mul(u64 a, u64 b) {
    auto c = (__uint128_t)a * b;
    return add(c >> 61, c & mod);
}
random_device rnd;
const u64 r = ((u64)rnd() << 32 | rnd()) % mod;
struct RH {
    ll n;
    vector<u64> hs, pw;
    RH(string s) : n(size(s)), hs(n + 1), pw(n + 1, 1) {
        for(int i = 0; i < n; i++) {
            pw[i + 1] = mul(pw[i], r);
            hs[i + 1] = add(mul(hs[i], r), s[i]);
        }
    }
    u64 get(ll l, ll r) const { return add(hs[r], mod -
mul(hs[l], pw[r - l])); }
};
```

SuffixArray.hppmd5: cbf1dc

```
// returns pair{sa, lcp}
// sa 長さ n : s[sa[0]:] < s[sa[1]:] < ... < s[sa[n-1]:]
// lcp 長さ n-1 : lcp[i] = LCP(s[sa[i]:], s[sa[i+1]:])
auto SA(string s) {
    ll n = size(s) + 1, lim = 256;
    // assert(lim > ranges::max(s));
    vector<ll> sa(n), lcp(n), x(all(s) + 1), y(n), ws(max(n,
lim)), rk(n);
    iota(all(sa), 0);
    for(ll j = 0, p = 0; p < n; j = max(1LL, j * 2), lim = p) {
        p = j;
        iota(all(y), n - j);
        for(int i = 0; i < n; i++)
            if(sa[i] >= j) y[p++] = sa[i] - j;
        fill(all(ws), 0);
        for(int i = 0; i < n; i++) ws[x[i]]++;
        for(int i = 1; i < lim; i++) ws[i] += ws[i - 1];
        for(ll i = n; i--;) sa[--ws[x[y[i]]]] = y[i];
        swap(x, y);
        p = 1;
        x[sa[0]] = 0;
        for(int i = 1; i < n; i++) {
            ll a = sa[i - 1], b = sa[i];
            x[b] = (y[a] == y[b] && y[a + j] == y[b + j]) ? p - 1
: p++;
        }
    }
    for(int i = 1; i < n; i++) rk[sa[i]] = i;
    for(int i = 0, k = 0; i < n - 1; lcp[rk[i++]] = k) {
        if(k) k--;
        while(s[i + k] == s[sa[rk[i] - 1] + k]) k++;
    }
    sa.erase(begin(sa));
    lcp.erase(begin(lcp));
    return pair{sa, lcp};
}
```

Zalgorithm.hppmd5: 6388f3

```
// Z[i] := LCP(s, s[i:])
// abacaba -> 7010301
auto Z(string s) {
    ll n = size(s), l = -1, r = -1;
    vector<ll> z(n, n);
    for(int i = 1; i < n; i++) {
        ll& x = z[i] = i < r ? min(r - i, z[i - l]) : 0;
        while(i + x < n && s[i + x] == s[x]) x++;
        if(i + x > r) l = i, r = i + x;
    }
    return z;
}
```


aho_corasick.hpp

md5: f30f1f

// base: 822702

template<int char_size, int margin> struct AhoCorasick :
Trie<char_size + 1, margin> {
 using Trie<char_size + 1, margin>::Trie;

 const int FAIL = char_size;
 vector<int> correct;

 void build(bool heavy = true) {
 correct.resize(this->nodes.size());
 for(int i = 0; i < size(this->nodes); ++i) { correct[i] =
size(this->nodes[i].accept); }
 queue<int> que;
 for(int i = 0; i < char_size; ++i) {
 if(~this->nodes[0].nxt[i]) {
 this->nodes[this->nodes[0].nxt[i]].nxt[FAIL] = 0;
 que.emplace(this->nodes[0].nxt[i]);
 } else {
 this->nodes[0].nxt[i] = 0;
 }
 }
 while(!que.empty()) {
 auto& now = this->nodes[que.front()];
 int fail = now.nxt[FAIL];
 correct[que.front()] += correct[fail];
 que.pop();
 for(int i = 0; i < char_size; i++) {
 if(~now.nxt[i]) {
 this->nodes[now.nxt[i]].nxt[FAIL] = this->
nodes[fail].nxt[i];
 if(heavy) {
 auto& u = this->nodes[now.nxt[i]].accept;
 auto& v = this->nodes[this->
nodes[fail].nxt[i]].accept;
 vector<int> accept;
 set_union(all(u), all(v),
back_inserter(accept));
 u = accept;
 }
 que.emplace(now.nxt[i]);
 } else {
 now.nxt[i] = this->nodes[fail].nxt[i];
 }
 }
 }
 }

 vector<int> match(const char& c, int now = 0) {
 vector<int> res;
 now = this->nodes[now].nxt[c - margin];
 for(auto& v : this->nodes[now].accept) res.push_back(v);
 return res;
 } // 68ef6b

 unordered_map<int, int> match(const string& str, int now =
0) {
 unordered_map<int, int> res, visit_cnt;
 for(auto& c : str) {
 now = this->nodes[now].nxt[c - margin];
 visit_cnt[now]++;
 }
 for(auto& [now, cnt] : visit_cnt) {
 for(auto& v : this->nodes[now].accept) res[v] += cnt;
 }
 return res;
 } // 36fe6c

 pair<ll, int> move(const char& c, int now = 0) {
 now = this->nodes[now].nxt[c - margin];
 return {correct[now], now};
 } // 43ccad

 pair<ll, int> move(const string& str, int now = 0) {
 ll res = 0;
 for(auto& c : str) {
 auto [cnt, nxt] = move(c, now);
 res += cnt;
 now = nxt;
 }
 }
};

trie.hpp

md5: 09415e

return {res, now};
} // b1949a
};

template<int char_size> struct TrieNode {
 int nxt[char_size];
 int exist;
 vector<int> accept;

 TrieNode() : exist(0) { memset(nxt, -1, sizeof(nxt)); }
};

template<int char_size, int margin> struct Trie {
 using Node = TrieNode<char_size>;

 vector<Node> nodes;
 int root;
 Trie() : root(0) { nodes.push_back(Node()); }

 void update_direct(int node, int id) {
nodes[node].accept.push_back(id); }

 void update_child(int node, int child, int id) {
++nodes[node].exist; }

 void add(const string& str, int str_index, int node_index,
int id) {
 if(str_index == size(str)) {
 update_direct(node_index, id);
 } else {
 const int c = str[str_index] - margin;
 if(nodes[node_index].nxt[c] == -1) {
 nodes[node_index].nxt[c] = size(nodes);
 nodes.push_back(Node());
 }
 add(str, str_index + 1, nodes[node_index].nxt[c], id);
 update_child(node_index, nodes[node_index].nxt[c],
id);
 }
 }

 void add(const string& str, int id = -1) {
 if(id == -1) id = nodes[0].exist;
 add(str, 0, 0, id);
 }

 void query(const string& str, const function<void(int)>& f,
int str_index, int node_index) {
 for(auto& idx : nodes[node_index].accept) f(idx);
 if(str_index == size(str)) {
 return;
 } else {
 const int c = str[str_index] - margin;
 if(nodes[node_index].nxt[c] == -1) return;
 query(str, f, str_index + 1,
nodes[node_index].nxt[c]);
 }
 }

 void query(const string& str, const function<void(int)>& f)
{ query(str, f, 0, 0); }

 int count() const { return nodes[0].exist; }
};

algorithm

md5: df858f

doubling.hpp

template<int L> struct Doubling {
 private:
 vector<vector<int>> V;

 public:
 Doubling(const vector<int>& v) {
 int N = size(v);
 V = vector<vector<int>>(L, vector<int>(N));
 for(int i = 0; i < N; i++) V[0][i] = v[i];
 for(int i = 0; i < L - 1; i++)


```
        for(int j = 0; j < N; j++) {
            if(V[i][j] != -1) V[i + 1][j] = V[i][V[i][j]];
        }
    }

    int jump(int from, ll k) {
        for(int cnt = 0; k > 0; k >>= 1, ++cnt) {
            if((k & 1) && from != -1) from = V[cnt][from];
        }
        return from;
    }
};
```

doubling_monoid.hpp

md5: 530e69

```
template<int L, class T, auto op, auto e> struct Doubling {
private:
    vector<vector<int>>> V;
    vector<vector<T>>> data;

public:
    Doubling(const vector<int>& to, const vector<T>& v) {
        int N = size(to);
        V = vector<vector<int>>>(L, vector<int>(N, -1));
        data = vector<vector<T>>>(L, vector<T>(N, e()));
        for(int i = 0; i < N; i++) {
            V[0][i] = to[i];
            data[0][i] = v[i];
        }

        for(int i = 0; i < L - 1; i++) {
            for(int j = 0; j < N; j++) {
                if(V[i][j] != -1) {
                    V[i + 1][j] = V[i][V[i][j]];
                    data[i + 1][j] = op(data[i][j], data[i][V[i]
[j]]);
                } else {
                    V[i + 1][j] = V[i][j];
                    data[i + 1][j] = data[i][j];
                }
            }
        }
    }

    pair<int, T> jump(int from, ll k) {
        T res = e();
        for(int cnt = 0; k > 0; k >>= 1, ++cnt) {
            if((k & 1) && from != -1) {
                res = op(res, data[cnt][from]);
                from = V[cnt][from];
            }
        }
        return {from, res};
    }
};
```

- geometry
- memo

Primes.md

素数の個数

n	10^2	10^3	10^4	10^5	10^6	10^7	10^8	10^9	10^{10}
$\pi(n)$	25	168	1229	9592	78498	664579	5.76e+6	5.08e+7	4.55e+8

高度合成数

$\leq n$	10^3	10^4	10^5	10^6	10^7		10^8		10^9	
x	840	7560	83160	720720	8648640		73513440		735134400	
$d^0(x)$	32	64	128	240	448		768		1344	
$\leq n$	10^{10}	10^{11}	10^{12}	10^{13}	10^{14}	10^{15}	10^{16}	10^{17}	10^{18}	
$d^0(x)$	2304	4032	6720	10752	17280	26880	41472	64512	103680	

素数階乗

n	2	3	5	7	11	13	17	19	23	29
$n\#$	2	6	30	210	2310	30030	510510	9.70e+6	2.23e+8	6.47e+9

階乗

$4!$	$5!$	$6!$	$7!$	$8!$	$9!$	$10!$	$11!$	$12!$	$13!$
24	120	720	5040	40320	362880	3.63e+6	3.99e+7	4.79e+8	6.23e+9

ext.cpp

md5: 64e006

```
#include <bits/stdc++.h>
#include <ext/pb_ds/assoc_container.hpp>
#include <ext/pb_ds/tree_policy.hpp>
#include <ext/pb_ds/priority_queue.hpp>
#include <ext/rope>

using namespace __gnu_pbds;
using namespace __gnu_cxx; // for ext/rope
using namespace std;

int main() {
    tree<int, null_type, less<int>, rb_tree_tag,
tree_order_statistics_node_update> tree;

    tree.insert(1); // 1
    tree.insert(10); // 1 10
    tree.insert(6); // 1 6 10
    tree.insert(7); // 1 6 7 10
    tree.insert(4); // 1 4 6 7 10
    tree.erase(6); // 1 4 7 10
    assert(tree.order_of_key(5) == 2); // 5未満の要素数
    assert(*tree.find_by_order(2) == 7); // 0-indexedで2番目の要素

    gp_hash_table<int, int> m;
    m[2] = 5;
    m[1] = 10;
    m[3] = 7;

    __gnu_pbds::priority_queue<int, greater<int>,
rc_binomial_heap_tag> pq;
    auto it = pq.push(1); // 1
    pq.push(10); // 1 10
    assert(pq.top() == 1);
    pq.modify(it, 20); // 10 20
    assert(pq.top() == 10);
    pq.erase_if([&](int x) { return x <= 10; }); // 20
    assert(pq.top() == 20);
    assert(pq.size() == 1);
    pq.erase(it); // empty
    assert(pq.empty());

    // access, insert, erase: O(log n)
    rope<int> v;
    v.insert(0, 1); // 1
    v.insert(0, 2); // 2 1
    v.insert(1, 3); // 2 3 1
    v.insert(2, 4); // 2 3 4 1
    v.erase(1, 2); // 2 1
    assert(v.size() == 2);
    assert(v[0] == 2);
    assert(v[1] == 1);

    return 0;
}
```

priority_queue.md

	push	pop	modify	erase
std::priority_queue	最悪 $\Theta(n)$,償却 $\Theta(\log(n))$	最悪 $\Theta(\log(n))$	最悪 $\Theta(n \log(n))$	$\Theta(n \log(n))$
pairing_heap_tag	$O(1)$	最悪 $\Theta(n)$,償却 $\Theta(\log n)$	最悪 $\Theta(n)$,償却 $\Theta(\log(n))$	最悪 $\Theta(n)$,償却 $O(\log(n))$

	push	pop	modify	erase
binary_heap_tag	最悪 $\Theta(n)$, 償却 $O(\log(n))$	最悪 $\Theta(n)$, 償却 $O(\log(n))$	$\Theta(n)$	$\Theta(n)$
binomial_heap_tag	最悪 $\Theta(n)$, 償却 $O(\log(n))$	$\Theta(\log(n))$	$\Theta(\log(n))$	$\Theta(\log(n))$
rc_binomial_heap_tag	$O(1)$	$\Theta(\log(n))$	$\Theta(\log(n))$	$\Theta(\log(n))$

	push	pop	modify	erase
thin_heap_tag	$O(1)$	最悪 $\Theta(n)$, 償却 $O(\log(n))$	最悪 $\Theta(\log(n))$,償却 $O(1)$ or 償却 $\Theta(\log n)$	最悪 $\Theta(n)$, 償却 $O(\log(n))$

joinは基本的に erase の最悪計算量に一致.pairing_heap_tagのみ高速で $O(1)$
