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1 備忘録

1.1 テンプレート

```
#[[#include]]# <iostream>
#[[#include]]# <algorithm>
#[[#include]]# <iomanip>
#[[#include]]# <map>
#[[#include]]# <set>
#[[#include]]# <queue>
#[[#include]]# <stack>
#[[#include]]# <numeric>
#[[#include]]# <bitset>
#[[#include]]# <cmath>

static const int MOD = 1000000007;
using ll = long long;
using u32 = uint32_t;
using namespace std;

template<class T> constexpr T INF = ::numeric_limits<T>::max()/32*15+208;

int main() {

    return 0;
}
```

1.2 makev chmax chmin

```
template <class T, class U>
vector<T> make_v(U size, const T& init){ return vector<T>(static_cast<size_t>(size), init); }

template<class... Ts, class U>
auto make_v(U size, Ts... rest) { return
↪  vector<decltype(make_v(rest...))>(static_cast<size_t>(size), make_v(rest...)); }

template<class T> void chmin(T &a, const T &b){ a = (a < b ? a : b); }
template<class T> void chmax(T &a, const T &b){ a = (a > b ? a : b); }
```

1.3 unique

```
sort(v.begin(), v.end());
v.erase(unique(v.begin(), v.end()), v.end());
```

1.4 ファイルを作成する

テンプレートを書いたら、bash を開いて、以下のコマンドを打つ。

```
for i in {A..H}; do cp main.cpp $i.cpp; done
for i in {A..H}; do echo -e "add_executable($i.exe $i.cpp)" >> CMakeLists.txt; done
```

```
add_compiler_options(-Wall -Wextra -Wshadow -D_GLIBCXX_DEBUG -ftrapv)
```

1.5 構文解析

```
using state = string::const_iterator;

int num(state &cur);
int factor(state &cur);
int muldiv(state &cur);
int addsub(state &cur);
int expr(state &cur);

int factor(state &cur) {
    if(isdigit(*cur)) return num(cur);
    cur++;
    int ans = addsub(cur);
    cur++;
    return ans;
}

int num(state &cur) {
    int ans = *cur -'0';
    while(isdigit(*++cur)) ans = ans*10 + (*cur-'0');
    return ans;
}

int muldiv(state &cur) {
    int ans = factor(cur);
    while(true){
        if(*cur == '*'){
            cur++;
            ans *= factor(cur);
        }else if(*cur == '/'){
            cur++;
            ans /= factor(cur);
        }else break;
    }
    return ans;
}

int addsub(state &cur){
    int ans = muldiv(cur);
    while(true){
        if(*cur == '+'){
            cur++;
            ans += muldiv(cur);
        }else if(*cur == '-'){
            cur++;
            ans -= muldiv(cur);
        }else break;
    }
    return ans;
}

int expr(state &cur){
    return addsub(cur);
}
```

2　使いそうなライブラリ

2.1　繰り返し二乗法

```
template <class T>
T pow_ (T x, T n, T M){
    uint64_t u = 1, xx = x;
    while (n > 0){
        if (n&1) u = u * xx % M;
        xx = xx * xx % M;
        n >>= 1;
    }
    return static_cast<T>(u);
};
```

2.2　約数列挙

```
template<class T>
vector<T> divisor(T n){
    vector<T> ret;
    for(T i = 1; i * i <= n; i++) {
        if(n % i == 0) {
            ret.push_back(i);
            if(i * i != n) ret.push_back(n / i);
        }
    }
    sort(begin(ret), end(ret));
    return(ret);
}
```

2.3　素数列挙・素因数分解

```
vector<int> get_prime(int n){
    if(n <= 1) return vector<int>();
    vector<bool> is_prime(n+1, true);
    vector<int> prime;
    is_prime[0] = is_prime[1] = 0;
    for (int i = 2; i <= n; ++i) {
        if(is_prime[i]) prime.emplace_back(i);
        for (auto &&j : prime){
            if(i*j > n) break;
            is_prime[i*j] = false;
            if(i % j == 0) break;
        }
    }
    return prime;
}
const auto primes = get_prime(65535);

template<class T>
vector<T> prime_factor(T n){
    vector<T> res;
    for (auto &&i : primes) {
        while (n % i == 0){
            res.emplace_back(i);
            n /= i;
        }
    }
    if(n != 1) res.emplace_back(n);
    return res;
}
```

2.4 ダイクストラ法

```
template <typename T>
struct edge {
    int from, to; T cost;
    edge(int to, T cost) : from(-1), to(to), cost(cost) {}
    edge(int from, int to, T cost) : from(from), to(to), cost(cost) {}
};

template <typename T>
vector<T> dijkstra(int s,vector<vector<edge<T>>> &G){
    size_t n=G.size();
    vector<T> d(n, INF<T>);
    priority_queue<pair<T, int>,vector<pair<T, int>>,greater<>> Q;
    d[s]=0;
    Q.emplace(0,s);
    while(!Q.empty()){
        T cost; int i;
        tie(cost, i) = Q.top(); Q.pop();
        if(d[i] < cost) continue;
        for (auto &&e : G[i]) {
            auto cost2 = cost + e.cost;
            if(d[e.to] <= cost2) continue;
            d[e.to] = cost2;
            Q.emplace(d[e.to], e.to);
        }
    }
    return d;
}
```

2.5 kruskal 法 (最小全域木)

```
template <typename T>
struct edge {
    int from, to;
    T cost;

    edge(int to, T cost) : from(-1), to(to), cost(cost) {}
    edge(int from, int to, T cost) : from(from), to(to), cost(cost) {}

    explicit operator int() const {return to;}
};

class UnionFind {
    vector<int> uni;
    int n;
public:
    explicit UnionFind(int n) : uni(static_cast<u32>(n), -1) , n(n){};

    int root(int a){
        if (uni[a] < 0) return a;
        else return (uni[a] = root(uni[a]));
    }

    bool unite(int a, int b) {
        a = root(a);
        b = root(b);
        if(a == b) return false;
        if(uni[a] > uni[b]) swap(a, b);
        uni[a] += uni[b];
        uni[b] = a;
        return true;
    }
};

template< typename T >
T kruskal(vector<edge<T>> &G, int V)
{
```

```
    sort(begin(G), end(G), [](const edge< T > &a, const edge< T > &b) { return (a.cost <
    ↪ b.cost); });
    UnionFind tree(V);
    T ret = 0;
    for(auto &e : G) {
        if(tree.unite(e.from, e.to)) ret += e.cost;
    }
    return (ret);
}
```

2.6 Union-Find

```
class UnionFind {
    int n;
    vector<int> uni;
public:
    explicit UnionFind(int n) : uni(static_cast<u32>(n), -1) , n(n){};

    int root(int a){
        if (uni[a] < 0) return a;
        else return (uni[a] = root(uni[a]));
    }

    bool unite(int a, int b) {
        a = root(a);
        b = root(b);
        if(a == b) return false;
        if(uni[a] > uni[b]) swap(a, b);
        uni[a] += uni[b];
        uni[b] = a;
        return true;
    }

    int size(int i){ return -uni[root(i)]; }
    bool same(int a, int b) { return root(a) == root(b); }
};
```

2.7 正方行列

```
template<class T, size_t SIZE>
struct SquareMatrix {
    using ar = array<T, SIZE>;
    using mat = array<ar, SIZE>;
    mat A;
    SquareMatrix() = default;
    static SquareMatrix I(T e){
        SquareMatrix X;
        for (int i = 0; i < SIZE; ++i) {
            X[i][i] = e;
        }
        return X;
    }

    inline const ar &operator[](int k) const{ return (A.at(k)); }
    inline ar &operator[](int k) { return (A.at(k)); }
    SquareMatrix &operator+= (const SquareMatrix &B){
        for (int i = 0; i < SIZE; ++i) {
            for (int j = 0; j < SIZE; ++j) {
                (*this)[i][j] += B[i][j];
            }
        }
        return (*this);
    }

    SquareMatrix &operator-= (const SquareMatrix &B){
        for (int i = 0; i < SIZE; ++i) {
```

```
            for (int j = 0; j < SIZE; ++j) {
                (*this)[i][j] -= B[i][j];
            }
        }
        return (*this);
    }

    SquareMatrix &operator*=(const SquareMatrix &B) {
        SquareMatrix C;
        for (int i = 0; i < SIZE; ++i) {
            for (int j = 0; j < SIZE; ++j) {
                for (int k = 0; k < SIZE; ++k) {
                    C[i][j] += ((*this)[i][k] * B[k][j]);
                }
            }
        }
        A.swap(C.A);
        return (*this);
    }

    SquareMatrix pow(ll n) const {
        SquareMatrix a = (*this), res = I(T(1));
        while(n > 0){
            if(n & 1) res *= a;
            a *= a;
            n >>= 1;
        }
        return res;
    }
    SquareMatrix operator+(const SquareMatrix &B) const {return SquareMatrix(*this) += B;}
    SquareMatrix operator-(const SquareMatrix &B) const {return SquareMatrix(*this) -= B;}
    SquareMatrix operator*(const SquareMatrix &B) const {return SquareMatrix(*this) *= B;}
};
```

2.8 Dinic 法 (最大流)

```
template<class T>
class Dinic {
    struct edge {
        int to{}, rev{};
        T cap;
        edge() = default;
        edge(int to, T cap, int rev):to(to), cap(cap), rev(rev) {}
    };
    int n{};
    vector<vector<edge>> G;
    vector<int> level, iter;
public:
    Dinic() = default;
    explicit Dinic(int sz): n(sz), G(n), level(n), iter(n){}
    void add_edge(int from, int to, T cap, bool directed){
        G[from].emplace_back(to, cap, G[to].size());
        G[to].emplace_back(from, directed?0:cap, G[from].size()-1);
    }

    void bfs(int s){
        fill(level.begin(), level.end(), -1);
        queue<int> Q;
        level[s] = 0;
        Q.emplace(s);
        while(!Q.empty()){
            int v = Q.front(); Q.pop();
            for (auto &&e : G[v]) {
                if(e.cap > 0 && level[e.to] < 0){
                    level[e.to] = level[v]+1;
                    Q.emplace(e.to);
                }
            }
```

```
        }
    }

    T dfs(int v, int t, T f){
        if(v == t) return f;
        for (int &i = iter[v]; i < G[v].size(); ++i) {
            edge &e = G[v][i];
            if(e.cap > 0 && level[v] < level[e.to]){
                T d = dfs(e.to, t, min(f, e.cap));
                if(d > 0){
                    e.cap -= d;
                    G[e.to][e.rev].cap += d;
                    return d;
                }
            }
        }
        return 0;
    }

    T flow(int s, int t, T lim = INF<T>){
        T fl = 0;
        while(true){
            bfs(s);
            if(level[t] < 0 || lim == 0) return fl;
            fill(iter.begin(), iter.end(), 0);
            T f;
            while((f=dfs(s,t, lim))>0){
                fl += f;
                lim -= f;
            }
        }
    }

    bool back_edge(int s, int t, int from, int to){
        for (auto &&e : G[from]) {
            if(e.to == to) {
                if(e.cap == 0 && flow(from, to, 1) == 0){
                    flow(from, s, 1);
                    flow(t, to, 1);
                    return true;
                }
            }
        }
        return false;
    }
};
```

2.9 幾何ライブラリ

```
using real = double;
static constexpr real EPS = 1e-10;
struct Point {
    real x, y;
    Point& operator+=(const Point a) { x += a.x; y += a.y;  return *this; }
    Point& operator-=(const Point a) { x -= a.x; y -= a.y;  return *this; }
    Point& operator*=(const real k) { x *= k; y *= k;  return *this; }
    Point& operator/=(const real k) { x /= k; y /= k;  return *this; }
    Point operator+(const Point a) const {return Point(*this) += a; }
    Point operator-(const Point a) const {return Point(*this) -= a; }
    Point operator*(const real k) const {return Point(*this) *= k; }
    Point operator/(const real k) const {return Point(*this) /= k; }
    bool operator<(const Point &a) const { return (x != a.x ? x < a.x : y < a.y); }
    explicit Point(real a = 0, real b = 0) : x(a), y(b) {};
};

bool sorty(Point a, Point b){
    return (a.y != b.y ? a.y < b.y : a.x < b.x);
}
```

```
20
21  istream& operator>> (istream& s, Point& P){
22      s >> P.x >> P.y;
23      return s;
24  }
25
26  inline real dot(Point a, Point b){ return a.x*b.x + a.y*b.y; }
27  inline real cross(Point a, Point b){ return a.x*b.y - a.y*b.x; }
28  inline real abs(Point a){ return sqrt(dot(a, a)); }
29
30
31  real angle(Point A, Point B){
32      return acos(dot(A, B)/abs(A)/abs(B));
33  }
34
35
36
37  static constexpr int COUNTER_CLOCKWISE = 1;
38  static constexpr int CLOCKWISE = -1;
39  static constexpr int ONLINE_BACK = 2;
40  static constexpr int ONLINE_FRONT = -2;
41  static constexpr int ON_SEGMENT = 0;
42
43  int ccw(Point a, Point b, Point c){
44      b -= a; c -= a;
45      if(cross(b, c) > EPS) return COUNTER_CLOCKWISE;
46      if(cross(b, c) < -EPS) return CLOCKWISE;
47      if(dot(b, c) < 0) return ONLINE_BACK;
48      if(abs(b) < abs(c)) return ONLINE_FRONT;
49      return ON_SEGMENT;
50  }
51  struct Segment {
52      Point a, b;
53      Segment(Point x, Point y) : a(x), b(y) {};
54  };
55
56  struct Line {
57      Point a, b;
58      Line(Point x, Point y) : a(x), b(y) {};
59  };
60
61  struct Circle{
62      Point c; real r;
63      Circle(Point c, real r): c(c), r(r) {};
64  };
65
66  using Polygon = vector<Point>;
67
68  bool intersect(Segment s, Segment t){
69      return (ccw(s.a, s.b, t.a)*ccw(s.a, s.b, t.b) <= 0 &&
70              ccw(t.a, t.b, s.a)*ccw(t.a, t.b, s.b) <= 0);
71  }
72
73  Point polar(double r, double t){
74      return Point(r*cos(t), r*sin(t));
75  }
76
77  double arg(Point p){
78      return atan2(p.y, p.x);
79  }
80
81  static constexpr int CONTAIN = 0;
82  static constexpr int INSCRIBE = 1;
83  static constexpr int INTERSECT = 2;
84  static constexpr int CIRCUMSCRIBED = 3;
85  static constexpr int SEPARATE = 4;
86
87  int intersect(Circle c1, Circle c2){
88      if(c1.r < c2.r) swap(c1, c2);
```

```
    real d = abs(c1.c-c2.c);
    real r = c1.r + c2.r;
    if(fabs(d-r) < EPS) return CIRCUMSCRIBED;
    if(d > r) return SEPARATE;
    if(fabs(d+c2.r-c1.r) < EPS) return INSCRIBE;
    if(d+c2.r < c1.r) return CONTAIN;
    return INTERSECT;
}

real distance(Line l, Point c){
    return abs(cross(l.b-l.a, c-l.a)/abs(l.b-l.a));
}


real distance(Segment s, Point c){
    if(dot(s.b-s.a, c-s.a) < EPS) return abs(c-s.a);
    if(dot(s.a-s.b, c-s.b) < EPS) return abs(c-s.b);
    return abs(cross(s.b-s.a, c-s.a)) / abs(s.a-s.b);
}

real distance(Segment s, Segment t){
    if(intersect(s, t)) return 0.0;
    return min({distance(s, t.a), distance(s, t.b),
                distance(t, s.a), distance(t, s.b)});
}


Point project(Line l, Point p){
    Point Q = l.b-l.a;
    return l.a + Q*(dot(p-l.a, Q) / dot(Q, Q));
}


Point project(Segment s, Point p){
    Point Q = s.b-s.a;
    return s.a + Q*(dot(p-s.a, Q) / dot(Q, Q));
}

Point refrect(Segment s, Point p){
    Point Q = project(s, p);
    return Q*2-p;
}

bool isOrthogonal(Segment s, Segment t){
    return fabs(dot(s.b-s.a, t.b-t.a)) < EPS;
}

bool isparallel(Segment s, Segment t){
    return fabs(cross(s.b-s.a, t.b-t.a)) < EPS;
}


Point crossPoint(Segment s, Segment t){
    real d1 = cross(s.b-s.a, t.b-t.a);
    real d2 = cross(s.b-s.a, s.b-t.a);
    if(fabs(d1) < EPS && fabs(d2) < EPS) return t.a;
    return t.a+(t.b-t.a)*d2/d1;
}

Point crossPoint(Line s, Line t){
    real d1 = cross(s.b-s.a, t.b-t.a);
    real d2 = cross(s.b-s.a, s.b-t.a);
    if(fabs(d1) < EPS && fabs(d2) < EPS) return t.a;
    return t.a+(t.b-t.a)*d2/d1;
}

Polygon crossPoint(Circle c, Line l){
    Point p = project(l, c.c), q = (l.b-l.a)/abs(l.b-l.a);
    if(abs(distance(l, c.c)-c.r) < EPS){
```

```
        return {p};
    }
    double k = sqrt(c.r*c.r-dot(p-c.c, p-c.c));
    return {p-q*k, p+q*k};
}

Polygon crossPoint(Circle c, Segment s){
    auto tmp = crossPoint(c, Line(s.a, s.b));
    Polygon ret;
    for (auto &&i : tmp) {
        if(distance(s, i) < EPS) ret.emplace_back(i);
    }
    return ret;
}


Polygon crossPoint(Circle c1, Circle c2){
    double d = abs(c1.c-c2.c);
    double a = acos((c1.r*c1.r+d*d-c2.r*c2.r)/(2*c1.r*d));
    double t = arg(c2.c-c1.c);
    return {c1.c+polar(c1.r, t+a), c1.c+polar(c1.r, t-a)};
}

Polygon tangent(Circle c1, Point p){
    Circle c2 = Circle(p, sqrt(dot(c1.c-p, c1.c-p)-c1.r*c1.r));
    return crossPoint(c1, c2);
}
vector<Line> tangent(Circle c1, Circle c2){
    vector<Line> ret;
    if(c1.r < c2.r) swap(c1, c2);
    double k = dot(c1.c-c2.c, c1.c-c2.c);
    if(abs(k) < EPS) return {};
    Point u = (c2.c-c1.c)/sqrt(k);
    Point v(-u.y, u.x);
    for (auto &&i : {-1, 1}) {
        double h = (c1.r+i*c2.r)/sqrt(k);
        if(abs(h*h-1) < EPS){
            ret.emplace_back(c1.c+u*c1.r, c1.c+(u+v)*c1.r);
        }else if(h*h < 1){
            Point u2 = u*h, v2 = v*sqrt(1-h*h);
            ret.emplace_back(c1.c+(u2+v2)*c1.r, c2.c-(u2+v2)*c2.r*i);
            ret.emplace_back(c1.c+(u2-v2)*c1.r, c2.c-(u2-v2)*c2.r*i);
        }
    }
    return ret;
}

real area(Polygon v){
    if(v.size() < 3) return 0.0;
    real ans = 0.0;
    for (int i = 0; i < v.size(); ++i) {
        ans += cross(v[i], v[(i+1)%v.size()]);
    }
    return ans/2;
}

real area(Circle c, Polygon &v){
    int n = v.size();
    real ans = 0.0;
    Polygon u;
    for (int i = 0; i < n; ++i) {
        u.emplace_back(v[i]);
        auto q = crossPoint(c, Segment(v[i], v[(i+1)%n]));
        for (auto &&j : q) {
            u.emplace_back(j);
        }
    }
    for (int i = 0; i < u.size(); ++i) {
        Point A = u[i]-c.c, B = u[(i+1)%u.size()]-c.c;
```

```
        if(abs(A) >= c.r+EPS || abs(B) >= c.r+EPS){
            Point C = polar(1, arg(B)-arg(A));
            ans += c.r*c.r*arg(C)/2;
        }else {
            ans += cross(A, B)/2;
        }
    }
    return ans;
}

Polygon convex_hull(Polygon v){
    int n = v.size();
    sort(v.begin(),v.end(), sorty);
    int k = 0;
    Polygon ret(n*2);
    for (int i = 0; i < n; ++i) {
        while(k > 1 && cross(ret[k-1]-ret[k-2], v[i]-ret[k-1]) < 0) k--;
        ret[k++] = v[i];
    }
    for(int i = n-2, t=k; i >= 0; i--){
        while(k > t && cross(ret[k-1]-ret[k-2], v[i]-ret[k-1]) < 0) k--;
        ret[k++] = v[i];
    }
    ret.resize(k-1);
    return ret;
}

bool isconvex(Polygon v){
    int n = v.size();
    for (int i = 0; i < n; ++i) {
        if(ccw(v[(i+n-1)%n], v[i], v[(i+1)%n]) == CLOCKWISE) return false;
    }
    return true;
}

int contains(Polygon v, Point p){
    int n = v.size();
    bool x = false;
    static constexpr int IN = 2;
    static constexpr int ON = 1;
    static constexpr int OUT = 0;
    for (int i = 0; i < n; ++i) {
        Point a = v[i]-p, b = v[(i+1)%n]-p;
        if(fabs(cross(a, b)) < EPS && dot(a, b) < EPS) return ON;
        if(a.y > b.y) swap(a, b);
        if(a.y < EPS && EPS < b.y && cross(a, b) > EPS) x = !x;
    }
    return (x?IN:OUT);
}

real diameter(Polygon v){
    int n = v.size();
    if(n == 2) return abs(v[0]-v[1]);
    int i = 0, j = 0;
    for (int k = 0; k < n; ++k) {
        if(v[i] < v[k]) i = k;
        if(!(v[j] < v[k])) j = k;
    }
    real ret = 0;
    int si = i, sj = j;
    while(i != sj || j != si){
        ret = max(ret, abs(v[i]-v[j]));
        if(cross(v[(i+1)%n]-v[i], v[(j+1)%n]-v[j]) < 0.0) i = (i+1)%n;
        else j = (j+1)%n;
    }
    return ret;
}

Polygon convexCut(Polygon v, Line l){
```

```
    Polygon q;
    int n = v.size();
    for (int i = 0; i < n; ++i) {
        Point a = v[i], b = v[(i+1)%n];
        if(ccw(l.a, l.b, a) != -1) q.push_back(a);
        if(ccw(l.a, l.b, a)*ccw(l.a, l.b, b) < 0){
            q.push_back(crossPoint(Line(a, b), l));
        }
    }
    return q;
}

real closest_pair(Polygon &v, int l = 0, int r = -1){
    if(!(~r)){
        r = v.size();
        sort(v.begin(),v.end());
    }
    if(r - l < 2) {
        return abs(v.front()-v.back());
    }
    int mid = (l+r)/2;
    real p = v[mid].x;
    real d = min(closest_pair(v, l, mid), closest_pair(v, mid, r));
    inplace_merge(v.begin()+l, v.begin()+mid, v.begin()+r, sorty);
    Polygon u;
    for (int i = l; i < r; ++i) {
        if(fabs(v[i].x-p) >= d) continue;
        for (int j = 0; j < u.size(); ++j) {
            real dy = v[i].y-next(u.rbegin(), j)->y;
            if(dy >= d) break;
            d = min(d, abs(v[i]-*next(u.rbegin(), j)));
        }
        u.emplace_back(v[i]);
    }
    return d;
}
```

2.10 木上の非再帰 dfs

```
deque<int> Q;
stack<int> s;
int cnt = 0;
vector<int> visited(n, 0), num(n);
s.emplace(0);
while(!s.empty()){
    int a = s.top(); s.pop();
    visited[a]++;
    num[a] = cnt++;
    Q.emplace_front(a);
    for (auto &&i : v[a]) {
        if(!visited[i]) s.emplace(i);
    }
}
```

3 まあまあ使いそうなライブラリ

3.1 階乗ライブラリ

```
template <class T>
T pow_ (T x, T n, T M){
    uint64_t u = 1, xx = x;
    while (n > 0){
        if (n&1) u = u * xx % M;
        xx = xx * xx % M;
        n >>= 1;
    }
```

```
    return static_cast<T>(u);
};

template <class T> class Factorial {
    T mod;
    vector<uint64_t> facts, factinv;

public:
    Factorial(int n, T mod) : facts(static_cast<u32>(n+1)), factinv(static_cast<u32>(n+1)),
    ↪  mod(mod) {
        facts[0] = 1;
        for (int i = 1; i < n+1; ++i) facts[i] = facts[i-1]*i % mod;
        factinv[n] = pow_(facts[n], static_cast<uint64_t>(mod - 2),
        ↪  static_cast<uint64_t>(mod));
        for (int i = n-1; i >= 0; --i) factinv[i] = factinv[i+1] * (i+1) % mod;
    }

    T fact(int k) const {
        if(k >= 0) return static_cast<T>(facts[k]);
        else return static_cast<T>(factinv[-k]);
    }

    T operator[](const int &k) const {
        if(k >= 0) return static_cast<T>(facts[k]);
        else return static_cast<T>(factinv[-k]);
    }

    T C(int p, int q) const {
        if(q < 0 || p < q) return 0;
        return static_cast<T>(facts[p]*  factinv[q] % mod * factinv[p-q] % mod);
    }

    T P(int p, int q) const {
        if(q < 0 || p < q) return 0;
        return static_cast<T>((facts[p] * factinv[p-q]) % mod);
    }

    T H(int p, int q) const {
        if(p < 0 || q < 0) return 0;
        return static_cast<T>(q == 0 ? 1 : C(p+q-1, q));
    }
};
```

3.2 Binary Indexed Tree (Fenwick Tree)

```
template<class T>
class BIT {
    vector<T> bit;
public:
    BIT(int n): bit(vector<T>(n+1, 0)){}

    T sum(int k){
        T ret = 0;
        for (++k; k > 0; k -= (k & -k)) ret += bit[k];
        return ret;
    }

    void add(int k, T x){
        for (++k; k < bit.size(); k  += (k & -k)) bit[k] += x;
    }
};
```

3.3 Segment Tree

```
template <class M>
struct SegmentTree{
```

```
    using T = typename M::T;
    int sz;
    vector<T> seg;
    explicit SegmentTree(int n) {
        sz = 1;
        while(sz < n) sz <<= 1;
        seg.assign(2*sz, M::e());
    }

    void set(int k, const T &x){ seg[k + sz] = x; }

    void build(){
        for (int i = sz-1; i > 0; --i) seg[i] = M::f(seg[2*i], seg[2*i+1]);
    }

    void update(int k, const T &x){
        k += sz;
        seg[k] = x;
        while (k >>= 1) seg[k] = M::f(seg[2*k], seg[2*k+1]);
    }

    T query(int a, int b){
        T l = M::e(), r = M::e();
        for(a += sz, b += sz; a < b; a >>=1, b>>=1){
            if(a & 1) l = M::f(l, seg[a++]);
            if(b & 1) r = M::f(seg[--b], r);
        }
        return M::f(l, r);
    }

    T operator[](const int &k) const { return seg[k + sz]; }
};


struct Monoid{
    using T = int;
    static T f(T a, T b) { return min(a, b); }
    static T e() { return INF<int>; }
};
```

3.4 遅延伝播 Segment Tree

```
template <class M>
struct LazySegmentTree{
    using T = typename M::T;
    using L = typename M::L;
    int sz, height{};
    vector<T> seg; vector<L> lazy;
    explicit LazySegmentTree(int n) {
        sz = 1; while(sz < n) sz <<= 1, height++;
        seg.assign(2*sz, M::e());
        lazy.assign(2*sz, M::l());
    }

    void set(int k, const T &x){
        seg[k + sz] = x;
    }

    void build(){
        for (int i = sz-1; i > 0; --i) seg[i] = M::f(seg[i<<1], seg[(i<<1)|1]);
    }

    T reflect(int k){ return lazy[k] == M::l() ? seg[k] : M::g(seg[k], lazy[k]); }

    void eval(int k){
        if(lazy[k] == M::l()) return;
        lazy[(k<<1)|0] = M::h(lazy[(k<<1)|0], lazy[k]);
        lazy[(k<<1)|1] = M::h(lazy[(k<<1)|1], lazy[k]);
```

```
        seg[k] = reflect(k);
        lazy[k] = M::l();
    }
    void thrust(int k){ for (int i = height; i; --i) eval(k>>i); }
    void recalc(int k) { while(k >>= 1) seg[k] = M::f(reflect((k<<1)|0), reflect((k<<1)|1));}
    void update(int a, int b, const L &x){
        thrust(a += sz); thrust(b += sz-1);
        for (int l = a, r = b+1;l < r; l >>=1, r >>= 1) {
            if(l&1) lazy[l] = M::h(lazy[l], x), l++;
            if(r&1) --r, lazy[r] = M::h(lazy[r], x);
        }
        recalc(a);
        recalc(b);
    }

    T query(int a, int b){ // [l, r)
        thrust(a += sz);
        thrust(b += sz-1);
        T ll = M::e(), rr = M::e();
        for(int l = a, r = b+1; l < r; l >>=1, r>>=1) {
            if (l & 1) ll = M::f(ll, reflect(l++));
            if (r & 1) rr = M::f(reflect(--r), rr);
        }
        return M::f(ll, rr);
    }
};

struct Monoid{
    using T = ll;
    using L = ll;
    static T f(T a, T b) { return min(a, b); }
    static T g(T a, L b) {
        if(b == e()) return a; else return b;
    }
    static L h(L a, L b) {
        if(b == e()) return a; else return b;
    }
    static T e() { return 0; }
    static L l() { return 0; }
};
```

3.5 modint(固定 MOD)

```
template<ll M = 1000000007>
struct modint{
    ll val;
    modint(): val(0){}
    template<typename T>
    explicit modint(T t){val = t%M; if(val < 0) val += M;}

    modint pow(ll k){
        modint res(1), x(val);
        while(k){
            if(k&1) res *= x;
            x *= x;
            k >>= 1;
        }
        return res;
    }
    template<typename T>
    modint& operator=(T a){ val = a%M; if(val < 0) val += M; return *this; }
    modint inv() {return pow(M-2);}
    modint& operator+=(modint a){ val += a.val; if(val >= M) val -= M; return *this;}
    modint& operator-=(modint a){ val += M-a.val; if(val >= M) val -= M; return *this;}
    modint& operator*=(modint a){ val = 1LL*val*a.val%M; return *this;}
    modint& operator/=(modint a){ return (*this) *= a.inv();}
    modint operator+(modint a) const {return modint(val) +=a;}
    modint operator-(modint a) const {return modint(val) -=a;}
```

```
    modint operator*(modint a) const {return modint(val) *=a;}
    modint operator/(modint a) const {return modint(val) /=a;}
    modint operator-(){ return modint(-val);}
    bool operator==(const modint a) const {return val == a.val;}
    bool operator!=(const modint a) const {return val != a.val;}
    bool operator<(const modint a) const {return val < a.val;}
};

using mint = modint<MOD>;
```

3.6 行列

```
template<class T>
struct matrix {
    vector<vector<T>> A;
    matrix() = default;
    matrix(size_t n, size_t m) : A(n, vector<T>(m)) {}
    explicit matrix(size_t n) : A(n, vector<T> (n)) {};
    size_t height() const { return (A.size()); }
    size_t width() const { return (A[0].size()); }

    const vector<T> &operator [] (int k) const { return A[k]; }
    vector<T> &operator[] (int k) { return A[k]; }

    static matrix I(size_t n){
        matrix mat(n);
        for (int i = 0; i < n; ++i) mat[i][i] = 1;
        return mat;
    }

    matrix &operator+= (const matrix &B){
        size_t h = height(), w = width();
        for (int i = 0; i < h; ++i) {
            for (int j = 0; j < w; ++j) {
                (*this)[i][j] += B[i][j];
            }
        }
    }

    matrix &operator-= (const matrix &B){
        size_t h = height(), w = width();
        for (int i = 0; i < h; ++i) {
            for (int j = 0; j < w; ++j) {
                (*this)[i][j] -= B[i][j];
            }
        }
    }

    matrix &operator*=(const matrix &B)
    {
        size_t n = height(), m = B.width(), p = width();
        matrix C (n, m);
        for (int i = 0; i < n; ++i) {
            for (int j = 0; j < m; ++j) {
                for (int k = 0; k < p; ++k) {
                    C[i][j] = (C[i][j] + (*this)[i][k] * B[k][j]);
                }
            }
        }
        A.swap(C.A);
        return (*this);
    }

    template <class U>
    matrix &operator%= (const U &m){
        for (int i = 0; i < height(); ++i) {
            for (int j = 0; j < width(); ++j) {
                (*this)[i][j] %= m;
```

```
            }
        }
    }

    matrix pow(ll n) const {
        matrix a = (*this), res = I(height());
        while(n > 0){
            if(n & 1) res *= a;
            a *= a;
            n >>= 1;
        }
        return res;
    }
    matrix operator+(const matrix &A) const {return matrix(*this) += A;}
    matrix operator-(const matrix &A) const {return matrix(*this) -= A;}
    matrix operator*(const matrix &A) const {return matrix(*this) *= A;}
    template <class U>
    matrix operator%(const U &m) const {return matrix(*this) %= m;}

};
```

4 あまり使わなさそうなライブラリ

4.1 中国剰余定理

```
template <class T>
T pow_ (T x, T n, T M){
    uint64_t u = 1, xx = x;
    while (n > 0){
        if (n&1) u = u * xx % M;
        xx = xx * xx % M;
        n >>= 1;
    }
    return static_cast<T>(u);
};


template<typename T>
T extgcd(T a, T b, T &x ,T &y){
    for (T u = y = 1, v = x = 0; a; ) {
        ll q = b/a;
        swap(x -= q*u, u);
        swap(y -= q*v, v);
        swap(b -= q*a, a);
    }
    return b;
}

template<typename T>
T mod_inv(T x, T m){
    T s, t;
    extgcd(x, m, s, t);
    return (m+s)% m;
}

pair<ll, ll> CRT(const vector<pair<ll, ll>> &a){
    ll r = 0, M = 1;
    for (int i = 0; i < a.size(); ++i) {
        ll p, q;
        ll d = extgcd(M, a[i].second, p, q);
        if((a[i].first - r )%d != 0) return make_pair(0, -1);
        ll tmp = (a[i].first - r) / d * p % (a[i].second / d);
        r += M * tmp;
        M *= a[i].second/d;
    }
    return make_pair((r+M) % M, M);
}
```

4.2 SparseTable

```
template <class F>
struct SparseTable {
    using T = typename F::T;
    vector<vector<T>> table;
    vector<int> u;
    SparseTable() = default;
    explicit SparseTable(const vector<T> &v){ build(v); }

    void build(const vector<T> &v){
        int n = v.size(), m = 1;
        while((1<<m) <= n) m++;
        table.assign(m, vector<T>(n));
        u.assign(n+1, 0);
        for (int i = 2; i <= n; ++i) {
            u[i] = u[i>>1] + 1;
        }
        for (int i = 0; i < n; ++i) {
            table[0][i] = v[i];
        }
        for (int i = 1; i < m; ++i) {
            int x = (1<<(i-1));
            for (int j = 0; j < n; ++j) {
                table[i][j] = F::f(table[i-1][j], table[i-1][min(j+x, n-1)]);
            }
        }
    }

    T query(int a, int b){
        int l = b-a;
        return F::f(table[u[l]][a], table[u[l]][b-(1<<u[l])]);
    }
}
```

4.3 拡張ユークリッドの互除法

```
template<typename T>
T extgcd(T a, T b, T &x ,T &y){
    for (T u = y = 1, v = x = 0; a; ) {
        ll q = b/a;
        swap(x -= q*u, u);
        swap(y -= q*v, v);
        swap(b -= q*a, a);
    }
    return b;
}

```

4.4 ベルマンフォード法

```
template <typename T>
struct edge {
    int from, to;
    T cost;

    edge(int to, T cost) : from(-1), to(to), cost(cost) {}
    edge(int from, int to, T cost) : from(from), to(to), cost(cost) {}

    explicit operator int() const {return to;}
};

template <typename T>
vector<T> bellman_ford(int s, int V,vector<edge<T> > &G){
    const T INF = numeric_limits<T>::max();
    vector<T> d(V, INF);
    d[s] = 0;
```

```
    for (int i = 0; i < V - 1; ++i) {
        for (auto &&e : G) {
            if (d[e.from] == INF) continue;
            d[e.to] = min(d[e.to], d[e.from] + e.cost);
        }
    }
    for (auto &&e : G) {
        if(d[e.from] == INF) continue;
        if(d[e.from] + e.cost < d[e.to]) return vector<T> ();
    }
    return d;
}
```

4.5 二部グラフの最大マッチング

```
class Bipartite_Matching {
    vector<vector<int>> G;
    vector<int> match, used, alive;
    int t;
public:
    explicit Bipartite_Matching(int n): t(0), G(n), match(n, -1), used(n, 0), alive(n, -1){};

    void connect(int a, int b){
        G[a].emplace_back(b);
        G[b].emplace_back(a);
    }

    bool dfs(int x){
        used[x] = t;
        for (auto &&i : G[x]) {
            int w = match[i];
            if(alive[i] == 0) continue;
            if(w == -1 || (used[w] != t && dfs(w))){
                match[x] = i;
                match[i] = x;
                return true;
            }
        }
        return false;
    }

    int matching() {
        int ans = 0;
        for (int i = 0; i < G.size(); ++i) {
            if(alive[i] == 0) continue;
            if(match[i] == -1) {
                ++t;
                ans += dfs(i);
            }
        }
        return ans;
    }
};
```

4.6 最大独立集合

```
class IndependentSet {
    int n;
    vector<vector<int>> G;
    void dfs(int x, vector<bool> &visited, vector<bool> &gcan, vector<bool> &alive){
        stack<int> s;
        s.emplace(x);
        while(!s.empty()){
            int y = s.top();
            visited[y] = true;
            gcan[y] = true;
```

```
            s.pop();
            for (auto &&i : G[y]) {
                if(!visited[i] && alive[i]) s.emplace(i);
            }
        }
    }

    int ConnectedCase(vector<bool> can) {
        int pMax = -1, pMin = -1, Max = -1, Min = n+1, num = 0;
        for (int i = 0; i < n; ++i) {
            if(!can[i]) continue;
            ++num;
            int tnum = 0;
            for (auto &&j : G[i]) if(can[j]) ++tnum;
            if(Max < tnum) Max = tnum, pMax = i;
            if(Min > tnum) Min = tnum, pMin = i;
        }
        if(num == 1) return 1;
        if(Max <= 2){
            if(Min == 1) return (num+1)/2;
            else return num/2;
        }
        int ans = 0;
        vector<bool> ncan = can;
        if(Min < 2){
            ncan[pMin] = false;
            for (auto &&i : G[pMin]) ncan[i] = false;
            ans = max(ans, GeneralCase(ncan) + 1);
        }else {
            ncan[pMax] = false;
            for (auto &&i : G[pMax]) ncan[i] = false;
            int temp = GeneralCase(ncan);
            ans = max(ans, temp+1);
            ncan = can;
            ncan[pMax] = false;
            ans = max(ans, GeneralCase(ncan));
        }
        return ans;
    }

    int GeneralCase(vector<bool> alive) {
        if(n <= 1) return n;
        vector<bool> visited(n, 0);
        int res = 0;
        for (int i = 0; i < n; ++i) {
            if(!visited[i] && alive[i]){
                vector<bool> gcan(n, false);
                dfs(i, visited, gcan, alive);
                res += ConnectedCase(gcan);
            }
        }
        return res;
    }
public:
    explicit IndependentSet(int n): n(n), G(n) {}
    void add_edge(int u, int v){
        G[u].emplace_back(v);
        G[v].emplace_back(u);
    }
    int stable_set() {
        vector<bool> alive(n, true);
        return GeneralCase(alive);
    }
};
```

4.7 最近共通祖先 (LCA)

```
template <class F>
struct SparseTable {
    using T = typename F::T;
    vector<vector<T>> table;
    vector<int> u;
    SparseTable() = default;
    explicit SparseTable(const vector<T> &v){ build(v); }

    void build(const vector<T> &v){
        int n = v.size(), m = 1;
        while((1<<m) <= n) m++;
        table.assign(m, vector<T>(n));
        u.assign(n+1, 0);
        for (int i = 2; i <= n; ++i) {
            u[i] = u[i>>1] + 1;
        }
        for (int i = 0; i < n; ++i) {
            table[0][i] = v[i];
        }
        for (int i = 1; i < m; ++i) {
            int x = (1<<(i-1));
            for (int j = 0; j < n; ++j) {
                table[i][j] = F::f(table[i-1][j], table[i-1][min(j+x, n-1)]);
            }
        }
    }

    T query(int a, int b){
        int l = b-a;
        return F::f(table[u[l]][a], table[u[l]][b-(1<<u[l])]);
    }
};


struct F {
    using T = pair<int, int>;
    static T f(T a, T b) { return min(a, b); }
    static T e() { return T{INF<int>, -1}; }
};

class Graph {
    SparseTable<F> table;
    void dfs_euler(int v, int p, int d, int &k){
        id[v] = k;
        vs[k] = v;
        depth[k++] = d;
        for (auto &&u : G[v]) {
            if(u != p){
                dfs_euler(u, v, d+1, k);
                vs[k] = v;
                depth[k++] = d;
            }
        }
    }
public:
    int n;
    vector<vector<int>> G;
    vector<int> vs, depth, id;
    explicit Graph(int n) : n(n), G(n), vs(2*n-1), depth(2*n-1), id(n), table() {};
    void add_edge(int a, int b){
        G[a].emplace_back(b);
        G[b].emplace_back(a);
    }

    void eulertour(int root) {
        int k = 0;
        dfs_euler(root, -1, 0, k);
```

```
    }

    void buildLCA(){
        eulertour(0);
        vector<pair<int, int>> v(2*n-1);
        for (int i = 0; i < 2*n-1; ++i) {
            v[i] = make_pair(depth[i], i);
        }
        table.build(v);
    }

    int LCA(int u, int v){
        if(id[u] > id[v]) swap(u, v);
        return table.query(id[u], id[v]+1).second;
    }
};
```

4.8 Convex-Hull-Trick

```
template<class T>
class monotonic_CHT {
    using P = pair<T, T>;
    vector<P> lines;
public:
    monotonic_CHT() {}

    bool check(P l1, P l2, P l3){
        if(l1 < l3) swap(l1, l3);
        return (l3.second - l2.second)*(l2.first-l1.first)
            >= (l2.second - l1.second)*(l3.first-l2.first);
    }
    void add(T a, T b){
        P line(a, b);
        while(lines.size() >= 2 && check(*(lines.end()-2), lines.back(), line))
        ↪  lines.pop_back();
        lines.emplace_back(line);
    }

    T f(int i, T x){
        return lines[i].first * x + lines[i].second;
    }

    T f(P line, T x){
        return line.first * x + line.second;
    }

    T get(T x){
        static int head = 0;
        while(lines.size()-head >= 2 && f(head, x) >= f(head+1, x)) ++head;
        return f(head, x);
    }
};
```

4.9 スライド最小値

```
template<class T, class F>
class sliding_window {
    vector<T> v;
    deque<T> Q;
    F f;
public:
    int l, r;
    explicit sliding_window(vector<T> &v, F f) : v(v), f(f), l(0), r(0) {};
    void set(vector<T> &u){
        v = u;
        Q.clear();
```

```
        l = 0; r = 0;
    }
    void reset(){
        Q.clear();
        l = 0, r = 0;
    }
    void slideL(){
        if(Q.front() == l++) Q.pop_front();
    }
    void slideR(){
        while(!Q.empty() && !f(v[Q.back()], v[r])) Q.pop_back();
        Q.push_back(r++);
    }
    T get_index()  {
        if(l == r) return 0;
        return Q.front();
    }
    T value()  {
        if(l == r) return 0;
        return v[Q.front()];
    }
};
```

4.10 ポテンシャル付き Union-Find

```
template <class T>
class WeightedUnionFind {
    vector<int> uni;
    vector<T> weights;
    int n;
public:
    explicit WeightedUnionFind(int n, T SUM_UNITY = 0) :
    uni(static_cast<u32>(n), -1) , n(n), weights(n,  SUM_UNITY){};

    int root(int a) {
        if (uni[a] < 0) return a;
        else {
            int r = root(uni[a]);
            weights[a] += weights[uni[a]];
            return (uni[a] = r);
        }
    }

    bool unite(int a, int b, T w) {
        w += weight(a); w -= weight(b);
        a = root(a);
        b = root(b);
        if(a == b) return false;
        if(uni[a] > uni[b]) swap(a, b), w = -w;
        uni[a] += uni[b];
        uni[b] = a;
        weights[b] = w;
        return true;
    }

    int size(int a){
        return -uni[root(a)];
    }

    T weight(T a){
        root(a);
        return weights[a];
    }
    int diff(int x, int y){
        return weight(y) - weight(x);
    }
};
```

4.11 modint(実行時 MOD)

```
struct modint {
    static ll &mod(){
        static ll mod_ = 0;
        return mod_;
    }

    static void set_mod(const ll x) { mod() = x; }
    static ll M() {return mod(); }

    ll val;
    modint(): val(0){}
    template<typename T>
    explicit modint(T t){val = t%M(); if(val < 0) val += M();}

    modint pow(ll k){
        modint res(1), x(val);
        while(k){
            if(k&1) res *= x;
            x *= x;
            k >>= 1;
        }
        return res;
    }
    template<typename T>
    modint& operator=(T a){ val = a%M(); if(val < 0) val += M(); return *this; }
    modint inv() {return pow(M()-2);}
    modint& operator+=(modint a){ val += a.val; if(val >= M()) val -= M(); return *this;}
    modint& operator-=(modint a){ val += M()-a.val; if(val >= M()) val -= M(); return *this;}
    modint& operator*=(modint a){ val = val*a.val%M(); return *this;}
    modint& operator/=(modint a){ return (*this) *= a.inv();}
    modint operator+(modint a) const {return modint(val) +=a;}
    modint operator-(modint a) const {return modint(val) -=a;}
    modint operator*(modint a) const {return modint(val) *=a;}
    modint operator/(modint a) const {return modint(val) /=a;}
    modint operator-(){return modint(-val); }
    bool operator==(const modint a) const {return val == a.val;}
    bool operator!=(const modint a) const {return val != a.val;}
    bool operator<(const modint a) const {return val < a.val;}
};
```

4.12 Xor-Shift

```
#include <chrono>
class xor_shift {
    uint32_t x, y, z, w;
public:
    xor_shift() :
    ↪ x(static_cast<uint32_t>((chrono::system_clock::now().time_since_epoch().count())&((1LL
    ↪ << 32)-1))),
    y(1068246329), z(321908594), w(1234567890) {};

    uint32_t urand(){
        uint32_t t;
        t = x ^ (x << 11);
        x = y; y = z; z = w;
        w = (w ^ (w >> 19)) ^ (t ^ (t >> 8));
        return w;
    };

    int rand(int n){
        if(n < 0) return -rand(-n);
        uint32_t t = numeric_limits<uint32_t>::max()/(n+1)*(n+1);
        uint32_t e = urand();
        while(e >= t) e = urand();
        return static_cast<int>(e%(n+1));
    }
```

```
23
24      int rand(int a, int b){
25          if(a > b) swap(a, b);
26          return a+rand(b-a);
27      }
28  };
```