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1 備忘録

1.1 テンプレート

```
1  #include <iostream>
2  #include <algorithm>
3  #include <iomanip>
4  #include <map>
5  #include <set>
6  #include <queue>
7  #include <stack>
8  #include <numeric>
9  #include <bitset>
10 #include <cmath>
11
12 static const int MOD = 1000000007;
13 using ll = long long;
14 using u32 = uint32_t;
15 using namespace std;
16
17 template<class T> constexpr T INF = ::numeric_limits<T>::max()/32*15+208;
18
19 int main() {
20
21     return 0;
22 }
```

1.2 makev chmax chmin

```
1  template <class T, class U>
2  vector<T> make_v(U size, const T& init){ return vector<T>(static_cast<size_t>(size), init); }
3
4  template<class... Ts, class U>
5  auto make_v(U size, Ts... rest) { return
6  ↪ vector<decltype(make_v(rest...))>(static_cast<size_t>(size), make_v(rest...)); }
7
8  template<class T> void chmin(T &a, const T &b){ a = (a < b ? a : b); }
9  template<class T> void chmax(T &a, const T &b){ a = (a > b ? a : b); }
```

1.3 unique

```
1  sort(v.begin(), v.end());
2  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。

```
1  for i in {A..H}; do cp main.cpp $i.cpp; done
2  for i in {A..H}; do echo -e "add_executable($i.exe $i.cpp)" >> CMakeLists.txt; done
3
4  add_compiler_options(-Wall -Wextra -Wshadow -D_GLIBCXX_DEBUG -ftrapv)
```

1.5 構文解析

```
1  using state = string::const_iterator;
2
3  int num(state &cur);
4  int factor(state &cur);
5  int muldiv(state &cur);
6  int addsub(state &cur);
7  int expr(state &cur);
8
9  int factor(state &cur) {
10     if(isdigit(*cur)) return num(cur);
11     cur++;
12     int ans = addsub(cur);
13     cur++;
14     return ans;
15 }
16
17 int num(state &cur) {
18     int ans = *cur - '0';
19     while(isdigit(++cur)) ans = ans*10 + (*cur - '0');
20     return ans;
21 }
22
23 int muldiv(state &cur) {
24     int ans = factor(cur);
25     while(true) {
26         if(*cur == '*') {
27             cur++;
28             ans *= factor(cur);
29         } else if(*cur == '/') {
30             cur++;
31             ans /= factor(cur);
32         } else break;
33     }
34     return ans;
35 }
36
37 int addsub(state &cur) {
38     int ans = muldiv(cur);
39     while(true) {
40         if(*cur == '+') {
41             cur++;
42             ans += muldiv(cur);
43         } else if(*cur == '-') {
44             cur++;
45             ans -= muldiv(cur);
46         } else break;
47     }
48     return ans;
49 }
50
51 int expr(state &cur) {
52     return addsub(cur);
53 }
```

2 使いそうなライブラリ

2.1 繰り返し二乗法

```
1  template <class T>
2  T pow_ (T x, T n, T M){
3      uint64_t u = 1, xx = x;
4      while (n > 0){
5          if (n&1) u = u * xx % M;
6          xx = xx * xx % M;
7          n >>= 1;
8      }
9      return static_cast<T>(u);
10 };
```

2.2 約数列挙

```
1  template<class T>
2  vector<T> divisor(T n){
3      vector<T> ret;
4      for(T i = 1; i * i <= n; i++) {
5          if(n % i == 0) {
6              ret.push_back(i);
7              if(i * i != n) ret.push_back(n / i);
8          }
9      }
10     sort(begin(ret), end(ret));
11     return ret;
12 }
```

2.3 素数列挙・素因数分解

```
1  vector<int> get_prime(int n){
2      if(n <= 1) return vector<int>();
3      vector<bool> is_prime(n+1, true);
4      vector<int> prime;
5      is_prime[0] = is_prime[1] = 0;
6      for (int i = 2; i <= n; ++i) {
7          if(is_prime[i]) prime.emplace_back(i);
8          for (auto &&j : prime){
9              if(i*j > n) break;
10             is_prime[i*j] = false;
11             if(i % j == 0) break;
12         }
13     }
14     return prime;
15 }
16 const auto primes = get_prime(65535);
17
18 template<class T>
19 vector<T> prime_factor(T n){
20     vector<T> res;
21     for (auto &&i : primes) {
22         while (n % i == 0){
23             res.emplace_back(i);
24             n /= i;
25         }
26     }
27     if(n != 1) res.emplace_back(n);
28     return res;
29 }
```

2.4 ダイクストラ法

```
1  template <typename T>
2  struct edge {
3      int from, to; T cost;
4      edge(int to, T cost) : from(-1), to(to), cost(cost) {}
5      edge(int from, int to, T cost) : from(from), to(to), cost(cost) {}
6  };
7
8  template <typename T>
9  vector<T> dijkstra(int s, vector<vector<edge<T>>> &G) {
10     size_t n=G.size();
11     vector<T> d(n, INF<T>);
12     priority_queue<pair<T, int>, vector<pair<T, int>>, greater<>> Q;
13     d[s]=0;
14     Q.emplace(0,s);
15     while(!Q.empty()){
16         T cost; int i;
17         tie(cost, i) = Q.top(); Q.pop();
18         if(d[i] < cost) continue;
19         for (auto &&e : G[i]) {
20             auto cost2 = cost + e.cost;
21             if(d[e.to] <= cost2) continue;
22             d[e.to] = cost2;
23             Q.emplace(d[e.to], e.to);
24         }
25     }
26     return d;
27 }
```

2.5 kruskal 法 (最小全域木)

```
1  template <typename T>
2  struct edge {
3      int from, to;
4      T cost;
5
6      edge(int to, T cost) : from(-1), to(to), cost(cost) {}
7      edge(int from, int to, T cost) : from(from), to(to), cost(cost) {}
8
9      explicit operator int() const {return to;}
10 };
11
12 class UnionFind {
13     vector<int> uni;
14     int n;
15 public:
16     explicit UnionFind(int n) : uni(static_cast<u32>(n), -1) , n(n) {};
17
18     int root(int a){
19         if (uni[a] < 0) return a;
20         else return (uni[a] = root(uni[a]));
21     }
22
23     bool unite(int a, int b) {
24         a = root(a);
25         b = root(b);
26         if(a == b) return false;
27         if(uni[a] > uni[b]) swap(a, b);
28         uni[a] += uni[b];
29         uni[b] = a;
30         return true;
31     }
32 };
33
34 template< typename T >
35 T kruskal(vector<edge<T>> &G, int V)
36 {
```

```

37     sort(begin(G), end(G), [](const edge< T > &a, const edge< T > &b) { return (a.cost <
    ↪ b.cost); });
38     UnionFind tree(V);
39     T ret = 0;
40     for(auto &e : G) {
41         if(tree.unite(e.from, e.to)) ret += e.cost;
42     }
43     return (ret);
44 }

```

2.6 Union-Find

```

1  class UnionFind {
2      int n;
3      vector<int> uni;
4  public:
5      explicit UnionFind(int n) : uni(static_cast<u32>(n), -1) , n(n){};
6
7      int root(int a){
8          if (uni[a] < 0) return a;
9          else return (uni[a] = root(uni[a]));
10     }
11
12     bool unite(int a, int b) {
13         a = root(a);
14         b = root(b);
15         if(a == b) return false;
16         if(uni[a] > uni[b]) swap(a, b);
17         uni[a] += uni[b];
18         uni[b] = a;
19         return true;
20     }
21
22     int size(int i){ return -uni[root(i)]; }
23     bool same(int a, int b) { return root(a) == root(b); }
24 };

```

2.7 正方向列

```

1  template<class T, size_t SIZE>
2  struct SquareMatrix {
3      using ar = array<T, SIZE>;
4      using mat = array<ar, SIZE>;
5      mat A;
6      SquareMatrix() = default;
7      static SquareMatrix I(T e){
8          SquareMatrix X;
9          for (int i = 0; i < SIZE; ++i) {
10             X[i][i] = e;
11         }
12         return X;
13     }
14
15     inline const ar &operator[](int k) const{ return (A.at(k)); }
16     inline ar &operator[](int k) { return (A.at(k)); }
17     SquareMatrix &operator+= (const SquareMatrix &B){
18         for (int i = 0; i < SIZE; ++i) {
19             for (int j = 0; j < SIZE; ++j) {
20                 (*this)[i][j] += B[i][j];
21             }
22         }
23         return (*this);
24     }
25
26     SquareMatrix &operator-= (const SquareMatrix &B){
27         for (int i = 0; i < SIZE; ++i) {

```

```

28         for (int j = 0; j < SIZE; ++j) {
29             (*this)[i][j] -= B[i][j];
30         }
31     }
32     return (*this);
33 }
34
35 SquareMatrix &operator*=(const SquareMatrix &B) {
36     SquareMatrix C;
37     for (int i = 0; i < SIZE; ++i) {
38         for (int j = 0; j < SIZE; ++j) {
39             for (int k = 0; k < SIZE; ++k) {
40                 C[i][j] += ((*this)[i][k] * B[k][j]);
41             }
42         }
43     }
44     A.swap(C.A);
45     return (*this);
46 }
47
48 SquareMatrix pow(ll n) const {
49     SquareMatrix a = (*this), res = I(T(1));
50     while(n > 0){
51         if(n & 1) res *= a;
52         a *= a;
53         n >>= 1;
54     }
55     return res;
56 }
57 SquareMatrix operator+(const SquareMatrix &B) const {return SquareMatrix(*this) += B;}
58 SquareMatrix operator-(const SquareMatrix &B) const {return SquareMatrix(*this) -= B;}
59 SquareMatrix operator*(const SquareMatrix &B) const {return SquareMatrix(*this) *= B;}
60 };

```

2.8 Dinic 法 (最大流)

```

1  template<class T>
2  class Dinic {
3      struct edge {
4          int to{}, rev{};
5          T cap;
6          edge() = default;
7          edge(int to, T cap, int rev):to(to), cap(cap), rev(rev) {}
8      };
9      int n{};
10     vector<vector<edge>> G;
11     vector<int> level, iter;
12 public:
13     Dinic() = default;
14     explicit Dinic(int sz): n(sz), G(n), level(n), iter(n){}
15     void add_edge(int from, int to, T cap, bool directed){
16         G[from].emplace_back(to, cap, G[to].size());
17         G[to].emplace_back(from, directed?0:cap, G[from].size()-1);
18     }
19
20     void bfs(int s){
21         fill(level.begin(), level.end(), -1);
22         queue<int> Q;
23         level[s] = 0;
24         Q.emplace(s);
25         while(!Q.empty()){
26             int v = Q.front(); Q.pop();
27             for (auto &e : G[v]) {
28                 if(e.cap > 0 && level[e.to] < 0){
29                     level[e.to] = level[v]+1;
30                     Q.emplace(e.to);
31                 }
32             }

```

```

33     }
34 }
35
36 T dfs(int v, int t, T f){
37     if(v == t) return f;
38     for (int &i = iter[v]; i < G[v].size(); ++i) {
39         edge &e = G[v][i];
40         if(e.cap > 0 && level[v] < level[e.to]){
41             T d = dfs(e.to, t, min(f, e.cap));
42             if(d > 0){
43                 e.cap -= d;
44                 G[e.to][e.rev].cap += d;
45                 return d;
46             }
47         }
48     }
49     return 0;
50 }
51
52 T flow(int s, int t, T lim = INF<T>){
53     T fl = 0;
54     while(true){
55         bfs(s);
56         if(level[t] < 0 || lim == 0) return fl;
57         fill(iter.begin(), iter.end(), 0);
58         T f;
59         while((f=dfs(s,t, lim))>0){
60             fl += f;
61             lim -= f;
62         }
63     }
64 }
65
66 bool back_edge(int s, int t, int from, int to){
67     for (auto &&e : G[from]) {
68         if(e.to == to) {
69             if(e.cap == 0 && flow(from, to, 1) == 0){
70                 flow(from, s, 1);
71                 flow(t, to, 1);
72                 return true;
73             }
74         }
75     }
76     return false;
77 }
78 };

```

2.9 幾何ライブラリ

```

1  using real = double;
2  static constexpr real EPS = 1e-10;
3  struct Point {
4      real x, y;
5      Point& operator+=(const Point a) { x += a.x; y += a.y; return *this; }
6      Point& operator-=(const Point a) { x -= a.x; y -= a.y; return *this; }
7      Point& operator*=(const real k) { x *= k; y *= k; return *this; }
8      Point& operator/=(const real k) { x /= k; y /= k; return *this; }
9      Point operator+(const Point a) const {return Point(*this) += a; }
10     Point operator-(const Point a) const {return Point(*this) -= a; }
11     Point operator*(const real k) const {return Point(*this) *= k; }
12     Point operator/(const real k) const {return Point(*this) /= k; }
13     bool operator<(const Point &a) const { return (x != a.x ? x < a.x : y < a.y); }
14     explicit Point(real a = 0, real b = 0) : x(a), y(b) {};
15 };
16
17 bool sorty(Point a, Point b){
18     return (a.y != b.y ? a.y < b.y : a.x < b.x);
19 }

```



```

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);

```

```

89     real d = abs(c1.c-c2.c);
90     real r = c1.r + c2.r;
91     if(fabs(d-r) < EPS) return CIRCUMSCRIBED;
92     if(d > r) return SEPARATE;
93     if(fabs(d+c2.r-c1.r) < EPS) return INSCRIBE;
94     if(d+c2.r < c1.r) return CONTAIN;
95     return INTERSECT;
96 }
97
98 real distance(Line l, Point c){
99     return abs(cross(l.b-l.a, c-l.a)/abs(l.b-l.a));
100 }
101
102
103 real distance(Segment s, Point c){
104     if(dot(s.b-s.a, c-s.a) < EPS) return abs(c-s.a);
105     if(dot(s.a-s.b, c-s.b) < EPS) return abs(c-s.b);
106     return abs(cross(s.b-s.a, c-s.a)) / abs(s.a-s.b);
107 }
108
109 real distance(Segment s, Segment t){
110     if(intersect(s, t)) return 0.0;
111     return min({distance(s, t.a), distance(s, t.b),
112                distance(t, s.a), distance(t, s.b)});
113 }
114
115
116 Point project(Line l, Point p){
117     Point Q = l.b-l.a;
118     return l.a + Q*(dot(p-l.a, Q) / dot(Q, Q));
119 }
120
121
122 Point project(Segment s, Point p){
123     Point Q = s.b-s.a;
124     return s.a + Q*(dot(p-s.a, Q) / dot(Q, Q));
125 }
126
127 Point refrect(Segment s, Point p){
128     Point Q = project(s, p);
129     return Q*2-p;
130 }
131
132 bool isOrthogonal(Segment s, Segment t){
133     return fabs(dot(s.b-s.a, t.b-t.a)) < EPS;
134 }
135
136 bool isparallel(Segment s, Segment t){
137     return fabs(cross(s.b-s.a, t.b-t.a)) < EPS;
138 }
139
140
141 Point crossPoint(Segment s, Segment t){
142     real d1 = cross(s.b-s.a, t.b-t.a);
143     real d2 = cross(s.b-s.a, s.b-t.a);
144     if(fabs(d1) < EPS && fabs(d2) < EPS) return t.a;
145     return t.a+(t.b-t.a)*d2/d1;
146 }
147
148 Point crossPoint(Line s, Line t){
149     real d1 = cross(s.b-s.a, t.b-t.a);
150     real d2 = cross(s.b-s.a, s.b-t.a);
151     if(fabs(d1) < EPS && fabs(d2) < EPS) return t.a;
152     return t.a+(t.b-t.a)*d2/d1;
153 }
154
155 Polygon crossPoint(Circle c, Line l){
156     Point p = project(l, c.c), q = (l.b-l.a)/abs(l.b-l.a);
157     if(abs(distance(l, c.c)-c.r) < EPS){

```

```

158     return {p};
159 }
160 double k = sqrt(c.r*c.r-dot(p-c.c, p-c.c));
161 return {p-q*k, p+q*k};
162 }
163
164 Polygon crossPoint(Circle c, Segment s){
165     auto tmp = crossPoint(c, Line(s.a, s.b));
166     Polygon ret;
167     for (auto &i : tmp) {
168         if(distance(s, i) < EPS) ret.emplace_back(i);
169     }
170     return ret;
171 }
172
173
174 Polygon crossPoint(Circle c1, Circle c2){
175     double d = abs(c1.c-c2.c);
176     double a = acos((c1.r*c1.r+d*d-c2.r*c2.r)/(2*c1.r*d));
177     double t = arg(c2.c-c1.c);
178     return {c1.c+polar(c1.r, t+a), c1.c+polar(c1.r, t-a)};
179 }
180
181 Polygon tangent(Circle c1, Point p){
182     Circle c2 = Circle(p, sqrt(dot(c1.c-p, c1.c-p)-c1.r*c1.r));
183     return crossPoint(c1, c2);
184 }
185 vector<Line> tangent(Circle c1, Circle c2){
186     vector<Line> ret;
187     if(c1.r < c2.r) swap(c1, c2);
188     double k = dot(c1.c-c2.c, c1.c-c2.c);
189     if(abs(k) < EPS) return {};
190     Point u = (c2.c-c1.c)/sqrt(k);
191     Point v(-u.y, u.x);
192     for (auto &i : {-1, 1}) {
193         double h = (c1.r+i*c2.r)/sqrt(k);
194         if(abs(h*h-1) < EPS){
195             ret.emplace_back(c1.c+u*c1.r, c1.c+(u+v)*c1.r);
196         }else if(h*h < 1){
197             Point u2 = u*h, v2 = v*sqrt(1-h*h);
198             ret.emplace_back(c1.c+(u2+v2)*c1.r, c2.c-(u2+v2)*c2.r*i);
199             ret.emplace_back(c1.c+(u2-v2)*c1.r, c2.c-(u2-v2)*c2.r*i);
200         }
201     }
202     return ret;
203 }
204
205 real area(Polygon v){
206     if(v.size() < 3) return 0.0;
207     real ans = 0.0;
208     for (int i = 0; i < v.size(); ++i) {
209         ans += cross(v[i], v[(i+1)%v.size()]);
210     }
211     return ans/2;
212 }
213
214 real area(Circle c, Polygon &v){
215     int n = v.size();
216     real ans = 0.0;
217     Polygon u;
218     for (int i = 0; i < n; ++i) {
219         u.emplace_back(v[i]);
220         auto q = crossPoint(c, Segment(v[i], v[(i+1)%n]));
221         for (auto &j : q) {
222             u.emplace_back(j);
223         }
224     }
225     for (int i = 0; i < u.size(); ++i) {
226         Point A = u[i]-c.c, B = u[(i+1)%u.size()]-c.c;

```

```

227         if(abs(A) >= c.r+EPS || abs(B) >= c.r+EPS){
228             Point C = polar(1, arg(B)-arg(A));
229             ans += c.r*c.r*arg(C)/2;
230         }else {
231             ans += cross(A, B)/2;
232         }
233     }
234     return ans;
235 }
236
237 Polygon convex_hull(Polygon v){
238     int n = v.size();
239     sort(v.begin(),v.end(), sorty);
240     int k = 0;
241     Polygon ret(n*2);
242     for (int i = 0; i < n; ++i) {
243         while(k > 1 && cross(ret[k-1]-ret[k-2], v[i]-ret[k-1]) < 0) k--;
244         ret[k++] = v[i];
245     }
246     for(int i = n-2, t=k; i >= 0; i--){
247         while(k > t && cross(ret[k-1]-ret[k-2], v[i]-ret[k-1]) < 0) k--;
248         ret[k++] = v[i];
249     }
250     ret.resize(k-1);
251     return ret;
252 }
253
254 bool isconvex(Polygon v){
255     int n = v.size();
256     for (int i = 0; i < n; ++i) {
257         if(ccw(v[(i+n-1)%n], v[i], v[(i+1)%n]) == CLOCKWISE) return false;
258     }
259     return true;
260 }
261
262 int contains(Polygon v, Point p){
263     int n = v.size();
264     bool x = false;
265     static constexpr int IN = 2;
266     static constexpr int ON = 1;
267     static constexpr int OUT = 0;
268     for (int i = 0; i < n; ++i) {
269         Point a = v[i]-p, b = v[(i+1)%n]-p;
270         if(fabs(cross(a, b)) < EPS && dot(a, b) < EPS) return ON;
271         if(a.y > b.y) swap(a, b);
272         if(a.y < EPS && EPS < b.y && cross(a, b) > EPS) x = !x;
273     }
274     return (x?IN:OUT);
275 }
276
277 real diameter(Polygon v){
278     int n = v.size();
279     if(n == 2) return abs(v[0]-v[1]);
280     int i = 0, j = 0;
281     for (int k = 0; k < n; ++k) {
282         if(v[i] < v[k]) i = k;
283         if(!(v[j] < v[k])) j = k;
284     }
285     real ret = 0;
286     int si = i, sj = j;
287     while(i != sj || j != si){
288         ret = max(ret, abs(v[i]-v[j]));
289         if(cross(v[(i+1)%n]-v[i], v[(j+1)%n]-v[j]) < 0.0) i = (i+1)%n;
290         else j = (j+1)%n;
291     }
292     return ret;
293 }
294
295 Polygon convexCut(Polygon v, Line l){

```

```

296 Polygon q;
297 int n = v.size();
298 for (int i = 0; i < n; ++i) {
299     Point a = v[i], b = v[(i+1)%n];
300     if(ccw(l.a, l.b, a) != -1) q.push_back(a);
301     if(ccw(l.a, l.b, a)*ccw(l.a, l.b, b) < 0){
302         q.push_back(crossPoint(Line(a, b), l));
303     }
304 }
305 return q;
306 }
307
308 real closest_pair(Polygon &v, int l = 0, int r = -1){
309     if(! (~r)){
310         r = v.size();
311         sort(v.begin(), v.end());
312     }
313     if(r - l < 2) {
314         return abs(v.front() - v.back());
315     }
316     int mid = (l+r)/2;
317     real p = v[mid].x;
318     real d = min(closest_pair(v, l, mid), closest_pair(v, mid, r));
319     inplace_merge(v.begin()+l, v.begin()+mid, v.begin()+r, sorty);
320     Polygon u;
321     for (int i = l; i < r; ++i) {
322         if(fabs(v[i].x-p) >= d) continue;
323         for (int j = 0; j < u.size(); ++j) {
324             real dy = v[i].y - next(u.rbegin(), j) ->y;
325             if(dy >= d) break;
326             d = min(d, abs(v[i] - *next(u.rbegin(), j)));
327         }
328         u.emplace_back(v[i]);
329     }
330     return d;
331 }

```

2.10 木上の非再帰 dfs

```

1 deque<int> Q;
2 stack<int> s;
3 int cnt = 0;
4 vector<int> visited(n, 0), num(n);
5 s.emplace(0);
6 while(!s.empty()){
7     int a = s.top(); s.pop();
8     visited[a]++;
9     num[a] = cnt++;
10    Q.emplace_front(a);
11    for (auto &&i : v[a]) {
12        if(!visited[i]) s.emplace(i);
13    }
14 }

```

3 まあまあ使いそうなライブラリ

3.1 階乗ライブラリ

```

1 template <class T>
2 T pow_ (T x, T n, T M){
3     uint64_t u = 1, xx = x;
4     while (n > 0){
5         if (n&1) u = u * xx % M;
6         xx = xx * xx % M;
7         n >>= 1;
8     }

```

```

9     return static_cast<T>(u);
10 };
11
12 template <class T> class Factorial {
13     T mod;
14     vector<uint64_t> facts, factinv;
15
16 public:
17     Factorial(int n, T mod) : facts(static_cast<u32>(n+1)), factinv(static_cast<u32>(n+1)),
18         ↪ mod(mod) {
19         facts[0] = 1;
20         for (int i = 1; i < n+1; ++i) facts[i] = facts[i-1]*i % mod;
21         factinv[n] = pow_(facts[n], static_cast<uint64_t>(mod - 2),
22             ↪ static_cast<uint64_t>(mod));
23         for (int i = n-1; i >= 0; --i) factinv[i] = factinv[i+1] * (i+1) % mod;
24     }
25
26     T fact(int k) const {
27         if(k >= 0) return static_cast<T>(facts[k]);
28         else return static_cast<T>(factinv[-k]);
29     }
30
31     T operator[] (const int &k) const {
32         if(k >= 0) return static_cast<T>(facts[k]);
33         else return static_cast<T>(factinv[-k]);
34     }
35
36     T C(int p, int q) const {
37         if(q < 0 || p < q) return 0;
38         return static_cast<T>(facts[p] * factinv[q] % mod * factinv[p-q] % mod);
39     }
40
41     T P(int p, int q) const {
42         if(q < 0 || p < q) return 0;
43         return static_cast<T>((facts[p] * factinv[p-q]) % mod);
44     }
45
46     T H(int p, int q) const {
47         if(p < 0 || q < 0) return 0;
48         return static_cast<T>(q == 0 ? 1 : C(p+q-1, q));
49     }
50 };

```

3.2 Binary Indexed Tree (Fenwick Tree)

```

1 template<class T>
2 class BIT {
3     vector<T> bit;
4 public:
5     BIT(int n): bit(vector<T>(n+1, 0)){}
6
7     T sum(int k){
8         T ret = 0;
9         for (++k; k > 0; k -= (k & -k)) ret += bit[k];
10        return ret;
11    }
12
13    void add(int k, T x){
14        for (++k; k < bit.size(); k += (k & -k)) bit[k] += x;
15    }
16 };

```

3.3 Segment Tree

```

1 template <class M>
2 struct SegmentTree{

```

```

3  using T = typename M::T;
4  int sz;
5  vector<T> seg;
6  explicit SegmentTree(int n) {
7      sz = 1;
8      while(sz < n) sz <= 1;
9      seg.assign(2*sz, M::e());
10 }
11
12 void set(int k, const T &x){ seg[k + sz] = x; }
13
14 void build(){
15     for (int i = sz-1; i > 0; --i) seg[i] = M::f(seg[2*i], seg[2*i+1]);
16 }
17
18 void update(int k, const T &x){
19     k += sz;
20     seg[k] = x;
21     while (k >= 1) seg[k] = M::f(seg[2*k], seg[2*k+1]);
22 }
23
24 T query(int a, int b){
25     T l = M::e(), r = M::e();
26     for(a += sz, b += sz; a < b; a >= 1, b >= 1){
27         if(a & 1) l = M::f(l, seg[a++]);
28         if(b & 1) r = M::f(seg[--b], r);
29     }
30     return M::f(l, r);
31 }
32
33 T operator[](const int &k) const { return seg[k + sz]; }
34 };
35
36
37 struct Monoid{
38     using T = int;
39     static T f(T a, T b) { return min(a, b); }
40     static T e() { return INF<int>; }
41 };

```

3.4 遅延伝播 Segment Tree

```

1  template <class M>
2  struct LazySegmentTree{
3      using T = typename M::T;
4      using L = typename M::L;
5      int sz, height{};
6      vector<T> seg; vector<L> lazy;
7      explicit LazySegmentTree(int n) {
8          sz = 1; while(sz < n) sz <= 1, height++;
9          seg.assign(2*sz, M::e());
10         lazy.assign(2*sz, M::l());
11     }
12
13     void set(int k, const T &x){
14         seg[k + sz] = x;
15     }
16
17     void build(){
18         for (int i = sz-1; i > 0; --i) seg[i] = M::f(seg[i<<1], seg[(i<<1)|1]);
19     }
20
21     T reflect(int k){ return lazy[k] == M::l() ? seg[k] : M::g(seg[k], lazy[k]); }
22
23     void eval(int k){
24         if(lazy[k] == M::l()) return;
25         lazy[(k<<1)|0] = M::h(lazy[(k<<1)|0], lazy[k]);
26         lazy[(k<<1)|1] = M::h(lazy[(k<<1)|1], lazy[k]);

```

```

27     seg[k] = reflect(k);
28     lazy[k] = M::l();
29 }
30 void thrust(int k){ for (int i = height; i; --i) eval(k>>i); }
31 void recalc(int k) { while(k >= 1) seg[k] = M::f(reflect((k<<1)|0), reflect((k<<1)|1)); }
32 void update(int a, int b, const L &x){
33     thrust(a += sz); thrust(b += sz-1);
34     for (int l = a, r = b+1; l < r; l >>=1, r >>= 1) {
35         if(l&1) lazy[l] = M::h(lazy[l], x), l++;
36         if(r&1) --r, lazy[r] = M::h(lazy[r], x);
37     }
38     recalc(a);
39     recalc(b);
40 }
41
42 T query(int a, int b){ // [l, r)
43     thrust(a += sz);
44     thrust(b += sz-1);
45     T ll = M::e(), rr = M::e();
46     for(int l = a, r = b+1; l < r; l >>=1, r >>=1) {
47         if (l & 1) ll = M::f(ll, reflect(l++));
48         if (r & 1) rr = M::f(reflect(--r), rr);
49     }
50     return M::f(ll, rr);
51 }
52 };
53
54 struct Monoid{
55     using T = ll;
56     using L = ll;
57     static T f(T a, T b) { return min(a, b); }
58     static T g(T a, L b) {
59         if(b == e()) return a; else return b;
60     }
61     static L h(L a, L b) {
62         if(b == e()) return a; else return b;
63     }
64     static T e() { return 0; }
65     static L l() { return 0; }
66 };

```

3.5 modint(固定MOD)

```

1  template<ll M = 1000000007>
2  struct modint{
3      ll val;
4      modint(): val(0){}
5      template<typename T>
6      explicit modint(T t){val = t%M; if(val < 0) val += M;}
7
8      modint pow(ll k){
9          modint res(1), x(val);
10         while(k){
11             if(k&1) res *= x;
12             x *= x;
13             k >>= 1;
14         }
15         return res;
16     }
17     template<typename T>
18     modint& operator=(T a){ val = a%M; if(val < 0) val += M; return *this; }
19     modint inv() {return pow(M-2);}
20     modint& operator+=(modint a){ val += a.val; if(val >= M) val -= M; return *this;}
21     modint& operator-=(modint a){ val += M-a.val; if(val >= M) val -= M; return *this;}
22     modint& operator*=(modint a){ val = 1LL*val*a.val%M; return *this;}
23     modint& operator/=(modint a){ return (*this) *= a.inv();}
24     modint operator+(modint a) const {return modint(val) +=a;}
25     modint operator-(modint a) const {return modint(val) -=a;}

```



```

26     modint operator*(modint a) const {return modint(val) *a;}
27     modint operator/(modint a) const {return modint(val) /a;}
28     modint operator-(){ return modint(-val);}
29     bool operator==(const modint a) const {return val == a.val;}
30     bool operator!=(const modint a) const {return val != a.val;}
31     bool operator<(const modint a) const {return val < a.val;}
32 };
33
34 using mint = modint<MOD>;

```

3.6 行列

```

1  template<class T>
2  struct matrix {
3      vector<vector<T>> A;
4      matrix() = default;
5      matrix(size_t n, size_t m) : A(n, vector<T>(m)) {}
6      explicit matrix(size_t n) : A(n, vector<T>(n)) {};
7      size_t height() const { return A.size(); }
8      size_t width() const { return A[0].size(); }
9
10     const vector<T> &operator [] (int k) const { return A[k]; }
11     vector<T> &operator[] (int k) { return A[k]; }
12
13     static matrix I(size_t n){
14         matrix mat(n);
15         for (int i = 0; i < n; ++i) mat[i][i] = 1;
16         return mat;
17     }
18
19     matrix &operator+= (const matrix &B){
20         size_t h = height(), w = width();
21         for (int i = 0; i < h; ++i) {
22             for (int j = 0; j < w; ++j) {
23                 (*this)[i][j] += B[i][j];
24             }
25         }
26     }
27
28     matrix &operator-= (const matrix &B){
29         size_t h = height(), w = width();
30         for (int i = 0; i < h; ++i) {
31             for (int j = 0; j < w; ++j) {
32                 (*this)[i][j] -= B[i][j];
33             }
34         }
35     }
36
37     matrix &operator*=(const matrix &B)
38     {
39         size_t n = height(), m = B.width(), p = width();
40         matrix C (n, m);
41         for (int i = 0; i < n; ++i) {
42             for (int j = 0; j < m; ++j) {
43                 for (int k = 0; k < p; ++k) {
44                     C[i][j] = (C[i][j] + (*this)[i][k] * B[k][j]);
45                 }
46             }
47         }
48         A.swap(C.A);
49         return (*this);
50     }
51
52     template <class U>
53     matrix &operator%=(const U &m){
54         for (int i = 0; i < height(); ++i) {
55             for (int j = 0; j < width(); ++j) {
56                 (*this)[i][j] %= m;

```

```

57         }
58     }
59 }
60
61 matrix pow(ll n) const {
62     matrix a = (*this), res = I(height());
63     while(n > 0){
64         if(n & 1) res *= a;
65         a *= a;
66         n >>= 1;
67     }
68     return res;
69 }
70 matrix operator+(const matrix &A) const {return matrix(*this) += A;}
71 matrix operator-(const matrix &A) const {return matrix(*this) -= A;}
72 matrix operator*(const matrix &A) const {return matrix(*this) *= A;}
73 template <class U>
74 matrix operator%(const U &m) const {return matrix(*this) %= m;}
75
76 };

```

4 あまり使わなさそうなライブラリ

4.1 中国剰余定理

```

1  template <class T>
2  T pow_(T x, T n, T M){
3      uint64_t u = 1, xx = x;
4      while (n > 0){
5          if (n&1) u = u * xx % M;
6          xx = xx * xx % M;
7          n >>= 1;
8      }
9      return static_cast<T>(u);
10 };
11
12
13 template<typename T>
14 T extgcd(T a, T b, T &x ,T &y){
15     for (T u = y = 1, v = x = 0; a; ) {
16         ll q = b/a;
17         swap(x -= q*u, u);
18         swap(y -= q*v, v);
19         swap(b -= q*a, a);
20     }
21     return b;
22 }
23
24 template<typename T>
25 T mod_inv(T x, T m){
26     T s, t;
27     extgcd(x, m, s, t);
28     return (m+s)% m;
29 }
30
31 pair<ll, ll> CRT(const vector<pair<ll, ll>> &a){
32     ll r = 0, M = 1;
33     for (int i = 0; i < a.size(); ++i) {
34         ll p, q;
35         ll d = extgcd(M, a[i].second, p, q);
36         if((a[i].first - r) % d != 0) return make_pair(0, -1);
37         ll tmp = (a[i].first - r) / d * p % (a[i].second / d);
38         r += M * tmp;
39         M *= a[i].second/d;
40     }
41     return make_pair((r+M) % M, M);
42 }

```

4.2 SparseTable

```
1  template <class F>
2  struct SparseTable {
3      using T = typename F::T;
4      vector<vector<T>> table;
5      vector<int> u;
6      SparseTable() = default;
7      explicit SparseTable(const vector<T> &v){ build(v); }
8
9      void build(const vector<T> &v){
10         int n = v.size(), m = 1;
11         while((1<<m) <= n) m++;
12         table.assign(m, vector<T>(n));
13         u.assign(n+1, 0);
14         for (int i = 2; i <= n; ++i) {
15             u[i] = u[i>>1] + 1;
16         }
17         for (int i = 0; i < n; ++i) {
18             table[0][i] = v[i];
19         }
20         for (int i = 1; i < m; ++i) {
21             int x = (1<<(i-1));
22             for (int j = 0; j < n; ++j) {
23                 table[i][j] = F::f(table[i-1][j], table[i-1][min(j+x, n-1)]);
24             }
25         }
26     }
27
28     T query(int a, int b){
29         int l = b-a;
30         return F::f(table[u[l]][a], table[u[l]][b-(1<<u[l])]);
31     }
32 }
```

4.3 拡張ユークリッドの互除法

```
1  template<typename T>
2  T extgcd(T a, T b, T &x, T &y){
3      for (T u = y = 1, v = x = 0; a; ) {
4          ll q = b/a;
5          swap(x -= q*u, u);
6          swap(y -= q*v, v);
7          swap(b -= q*a, a);
8      }
9      return b;
10 }
11
```

4.4 ベルマンフォード法

```
1  template <typename T>
2  struct edge {
3      int from, to;
4      T cost;
5
6      edge(int to, T cost) : from(-1), to(to), cost(cost) {}
7      edge(int from, int to, T cost) : from(from), to(to), cost(cost) {}
8
9      explicit operator int() const {return to;}
10 };
11
12 template <typename T>
13 vector<T> bellman_ford(int s, int V, vector<edge<T> > &G){
14     const T INF = numeric_limits<T>::max();
15     vector<T> d(V, INF);
16     d[s] = 0;
```

```

17     for (int i = 0; i < V - 1; ++i) {
18         for (auto &&e : G) {
19             if (d[e.from] == INF) continue;
20             d[e.to] = min(d[e.to], d[e.from] + e.cost);
21         }
22     }
23     for (auto &&e : G) {
24         if (d[e.from] == INF) continue;
25         if (d[e.from] + e.cost < d[e.to]) return vector<T> ();
26     }
27     return d;
28 }

```

4.5 二部グラフの最大マッチング

```

1  class Bipartite_Matching {
2      vector<vector<int>>> G;
3      vector<int> match, used, alive;
4      int t;
5  public:
6      explicit Bipartite_Matching(int n): t(0), G(n), match(n, -1), used(n, 0), alive(n, -1){};
7
8      void connect(int a, int b){
9          G[a].emplace_back(b);
10         G[b].emplace_back(a);
11     }
12
13     bool dfs(int x){
14         used[x] = t;
15         for (auto &&i : G[x]) {
16             int w = match[i];
17             if (alive[i] == 0) continue;
18             if (w == -1 || (used[w] != t && dfs(w))) {
19                 match[x] = i;
20                 match[i] = x;
21                 return true;
22             }
23         }
24         return false;
25     }
26
27     int matching() {
28         int ans = 0;
29         for (int i = 0; i < G.size(); ++i) {
30             if (alive[i] == 0) continue;
31             if (match[i] == -1) {
32                 ++t;
33                 ans += dfs(i);
34             }
35         }
36         return ans;
37     }
38 };

```

4.6 最大独立集合

```

1  class IndependentSet {
2      int n;
3      vector<vector<int>>> G;
4      void dfs(int x, vector<bool> &visited, vector<bool> &gcan, vector<bool> &alive){
5          stack<int> s;
6          s.emplace(x);
7          while (!s.empty()) {
8              int y = s.top();
9              visited[y] = true;
10             gcan[y] = true;

```

```

11         s.pop();
12         for (auto &&i : G[y]) {
13             if(!visited[i] && alive[i]) s.emplace(i);
14         }
15     }
16 }
17
18 int ConnectedCase(vector<bool> can) {
19     int pMax = -1, pMin = -1, Max = -1, Min = n+1, num = 0;
20     for (int i = 0; i < n; ++i) {
21         if(!can[i]) continue;
22         ++num;
23         int tnum = 0;
24         for (auto &&j : G[i]) if(can[j]) ++tnum;
25         if(Max < tnum) Max = tnum, pMax = i;
26         if(Min > tnum) Min = tnum, pMin = i;
27     }
28     if(num == 1) return 1;
29     if(Max <= 2) {
30         if(Min == 1) return (num+1)/2;
31         else return num/2;
32     }
33     int ans = 0;
34     vector<bool> ncan = can;
35     if(Min < 2) {
36         ncan[pMin] = false;
37         for (auto &&i : G[pMin]) ncan[i] = false;
38         ans = max(ans, GeneralCase(ncan) + 1);
39     } else {
40         ncan[pMax] = false;
41         for (auto &&i : G[pMax]) ncan[i] = false;
42         int temp = GeneralCase(ncan);
43         ans = max(ans, temp+1);
44         ncan = can;
45         ncan[pMax] = false;
46         ans = max(ans, GeneralCase(ncan));
47     }
48     return ans;
49 }
50
51 int GeneralCase(vector<bool> alive) {
52     if(n <= 1) return n;
53     vector<bool> visited(n, 0);
54     int res = 0;
55     for (int i = 0; i < n; ++i) {
56         if(!visited[i] && alive[i]) {
57             vector<bool> gcan(n, false);
58             dfs(i, visited, gcan, alive);
59             res += ConnectedCase(gcan);
60         }
61     }
62     return res;
63 }
64 public:
65     explicit IndependentSet(int n): n(n), G(n) {}
66     void add_edge(int u, int v) {
67         G[u].emplace_back(v);
68         G[v].emplace_back(u);
69     }
70     int stable_set() {
71         vector<bool> alive(n, true);
72         return GeneralCase(alive);
73     }
74 };

```

4.7 最近共通祖先 (LCA)

```
1  template <class F>
2  struct SparseTable {
3      using T = typename F::T;
4      vector<vector<T>> table;
5      vector<int> u;
6      SparseTable() = default;
7      explicit SparseTable(const vector<T> &v){ build(v); }
8
9      void build(const vector<T> &v){
10         int n = v.size(), m = 1;
11         while((1<<m) <= n) m++;
12         table.assign(m, vector<T>(n));
13         u.assign(n+1, 0);
14         for (int i = 2; i <= n; ++i) {
15             u[i] = u[i>>1] + 1;
16         }
17         for (int i = 0; i < n; ++i) {
18             table[0][i] = v[i];
19         }
20         for (int i = 1; i < m; ++i) {
21             int x = (1<<(i-1));
22             for (int j = 0; j < n; ++j) {
23                 table[i][j] = F::f(table[i-1][j], table[i-1][min(j+x, n-1)]);
24             }
25         }
26     }
27
28     T query(int a, int b){
29         int l = b-a;
30         return F::f(table[u[l]][a], table[u[l]][b-(1<<u[l])]);
31     }
32 };
33
34
35 struct F {
36     using T = pair<int, int>;
37     static T f(T a, T b) { return min(a, b); }
38     static T e() { return T{INF<int>, -1}; }
39 };
40
41 class Graph {
42     SparseTable<F> table;
43     void dfs_euler(int v, int p, int d, int &k){
44         id[v] = k;
45         vs[k] = v;
46         depth[k++] = d;
47         for (auto &&u : G[v]) {
48             if(u != p){
49                 dfs_euler(u, v, d+1, k);
50                 vs[k] = v;
51                 depth[k++] = d;
52             }
53         }
54     }
55 public:
56     int n;
57     vector<vector<int>> G;
58     vector<int> vs, depth, id;
59     explicit Graph(int n) : n(n), G(n), vs(2*n-1), depth(2*n-1), id(n), table() {};
60     void add_edge(int a, int b){
61         G[a].emplace_back(b);
62         G[b].emplace_back(a);
63     }
64
65     void eulertour(int root) {
66         int k = 0;
67         dfs_euler(root, -1, 0, k);
```

```

68     }
69
70     void buildLCA(){
71         eulertour(0);
72         vector<pair<int, int>> v(2*n-1);
73         for (int i = 0; i < 2*n-1; ++i) {
74             v[i] = make_pair(depth[i], i);
75         }
76         table.build(v);
77     }
78
79     int LCA(int u, int v){
80         if(id[u] > id[v]) swap(u, v);
81         return table.query(id[u], id[v]+1).second;
82     }
83 };

```

4.8 Convex-Hull-Trick

```

1  template<class T>
2  class monotonic_CHT {
3      using P = pair<T, T>;
4      vector<P> lines;
5  public:
6      monotonic_CHT() {}
7
8      bool check(P l1, P l2, P l3){
9          if(l1 < l3) swap(l1, l3);
10         return (l3.second - l2.second)*(l2.first-l1.first)
11             >= (l2.second - l1.second)*(l3.first-l2.first);
12     }
13     void add(T a, T b){
14         P line(a, b);
15         while(lines.size() >= 2 && check(*(lines.end()-2), lines.back(), line))
16             ↪ lines.pop_back();
17         lines.emplace_back(line);
18     }
19     T f(int i, T x){
20         return lines[i].first * x + lines[i].second;
21     }
22
23     T f(P line, T x){
24         return line.first * x + line.second;
25     }
26
27     T get(T x){
28         static int head = 0;
29         while(lines.size()-head >= 2 && f(head, x) >= f(head+1, x)) ++head;
30         return f(head, x);
31     }
32 };

```

4.9 スライド最小値

```

1  template<class T, class F>
2  class sliding_window {
3      vector<T> v;
4      deque<T> Q;
5      F f;
6  public:
7      int l, r;
8      explicit sliding_window(vector<T> &v, F f) : v(v), f(f), l(0), r(0) {};
9      void set(vector<T> &u){
10         v = u;
11         Q.clear();

```

```

12     l = 0; r = 0;
13 }
14 void reset(){
15     Q.clear();
16     l = 0, r = 0;
17 }
18 void slideL(){
19     if(Q.front() == l++) Q.pop_front();
20 }
21 void slideR(){
22     while(!Q.empty() && !f(v[Q.back()], v[r])) Q.pop_back();
23     Q.push_back(r++);
24 }
25 T get_index() {
26     if(l == r) return 0;
27     return Q.front();
28 }
29 T value() {
30     if(l == r) return 0;
31     return v[Q.front()];
32 }
33 };

```

4.10 ポテンシャル付き Union-Find

```

1  template <class T>
2  class WeightedUnionFind {
3      vector<int> uni;
4      vector<T> weights;
5      int n;
6  public:
7      explicit WeightedUnionFind(int n, T SUM_UNITY = 0) :
8          uni(static_cast<u32>(n), -1), n(n), weights(n, SUM_UNITY){};
9
10     int root(int a) {
11         if (uni[a] < 0) return a;
12         else {
13             int r = root(uni[a]);
14             weights[a] += weights[uni[a]];
15             return (uni[a] = r);
16         }
17     }
18
19     bool unite(int a, int b, T w) {
20         w += weight(a); w -= weight(b);
21         a = root(a);
22         b = root(b);
23         if(a == b) return false;
24         if(uni[a] > uni[b]) swap(a, b), w = -w;
25         uni[a] += uni[b];
26         uni[b] = a;
27         weights[b] = w;
28         return true;
29     }
30
31     int size(int a){
32         return -uni[root(a)];
33     }
34
35     T weight(T a){
36         root(a);
37         return weights[a];
38     }
39     int diff(int x, int y){
40         return weight(y) - weight(x);
41     }
42 };

```


4.11 modint(実行時MOD)

```
1 struct modint {
2     static ll &mod(){
3         static ll mod_ = 0;
4         return mod_;
5     }
6
7     static void set_mod(const ll x) { mod() = x; }
8     static ll M() {return mod(); }
9
10    ll val;
11    modint(): val(0){}
12    template<typename T>
13    explicit modint(T t){val = t%M(); if(val < 0) val += M();}
14
15    modint pow(ll k){
16        modint res(1), x(val);
17        while(k){
18            if(k&1) res *= x;
19            x *= x;
20            k >>= 1;
21        }
22        return res;
23    }
24    template<typename T>
25    modint& operator=(T a){ val = a%M(); if(val < 0) val += M(); return *this; }
26    modint inv() {return pow(M()-2);}
27    modint& operator+=(modint a){ val += a.val; if(val >= M()) val -= M(); return *this;}
28    modint& operator-=(modint a){ val += M()-a.val; if(val >= M()) val -= M(); return *this;}
29    modint& operator*=(modint a){ val = val*a.val%M(); return *this;}
30    modint& operator/=(modint a){ return (*this) *= a.inv();}
31    modint operator+(modint a) const {return modint(val) +=a;}
32    modint operator-(modint a) const {return modint(val) -=a;}
33    modint operator*(modint a) const {return modint(val) *=a;}
34    modint operator/(modint a) const {return modint(val) /=a;}
35    modint operator-(){return modint(-val); }
36    bool operator==(const modint a) const {return val == a.val;}
37    bool operator!=(const modint a) const {return val != a.val;}
38    bool operator<(const modint a) const {return val < a.val;}
39 };
```

4.12 Xor-Shift

```
1 #include <chrono>
2 class xor_shift {
3     uint32_t x, y, z, w;
4 public:
5     xor_shift() :
6         ↪ x(static_cast<uint32_t>((chrono::system_clock::now().time_since_epoch().count()) & ((1LL
7         ↪ << 32)-1))),
8         y(1068246329), z(321908594), w(1234567890) {};
9
10    uint32_t urand(){
11        uint32_t t;
12        t = x ^ (x << 11);
13        x = y; y = z; z = w;
14        w = (w ^ (w >> 19)) ^ (t ^ (t >> 8));
15        return w;
16    };
17
18    int rand(int n){
19        if(n < 0) return -rand(-n);
20        uint32_t t = numeric_limits<uint32_t>::max() / (n+1) * (n+1);
21        uint32_t e = urand();
22        while(e >= t) e = urand();
23        return static_cast<int>(e%(n+1));
24    }
25 };
```

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