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1 Basic

1.1 .vimrc

```
syntax on
se ru nu ai
se ts=4 sts=4 sw=4 st=4 expandtab smarttab
inoremap {<ENTER> {}<LEFT><ENTER><ENTER><UP><TAB>
```

1.2 Default code

```
#pragma GCC optimize("Ofast", "no-stack-protector", "
    unroll-loops")
#pragma GCC optimize("no-stack-protector")
#pragma GCC target("sse,sse2,sse3,ssse3,sse4,sse4.2,
    popcnt,abm,mmx,avx,tune=native")
#pragma GCC diagnostic ignored "-W"

mt19937 rng(chrono::steady_clock::now().
    time_since_epoch().count());
int randint(int lb, int ub)
{ return uniform_int_distribution<int>(lb, ub)(rng); }

struct KeyHasher {
  size_t operator()(const Key& k) const {
    return k.first + k.second * 100000;
  }
};
typedef unordered_map<Key,int,KeyHasher> map_t;

/*
int __builtin_clz (unsigned int x):
Returns the number of leading 0-bits in x, starting at
    the most significant bit position. If x is 0, the
    result is undefined.

Built-in Function: int __builtin_popcount (unsigned int
     x):
Returns the number of 1-bits in x.
*/

/*increase stack*/
const int size = 256 << 20;
register long rsp asm("rsp");
char *p = (char*)malloc(size) + size, *bak = (char*)rsp
    ;
__asm__("movq %0, %%rsp\n"::"r"(p));
// main
__asm__("movq %0, %%rsp\n"::"r"(bak));

/*
(i, factor number of i)
10080      72,   50400      108
110880     144,  221760     168
332640     192,  498960     200
554400     216,  665280     224
720720     240,  1081080    256
2162160    320,  3603600    360
4324320    384,  6486480    400
7207200    432,  8648640    448
10810800   480,  21621600   576
32432400   600,  43243200   672
61261200   720,  73513440   768
110270160  800,  245044800  1008
367567200  1152, 551350800  1200
698377680  1280, 735134400  1344
1102701600 1440, 1396755360 1536
*/
```

1.3 FasterIO

```
static inline char getRawChar() {
    static char buf[1 << 16], *p = buf, *end = buf;
    if (p == end) {
        if ((end = buf + fread_unlocked(buf, 1, 1 <<
            16, stdin)) == buf) return '\0';
```

```
        p = buf;
    }
    return *p++;
}
while (c = getRawChar() && (unsigned)(c - '0') > 10U) n
     = n * 10 + (c - '0');
```

1.4 Rope

```
#include <ext/rope>
using namespace __gnu_cxx;

rope<int> *p[N],*sz[N];  //use merge by size
int pp[N],szz[N];

int ret = p[ver]->at(x);
p[ver]->replace(x,ret);
p[0] = new rope<int>(pp,pp+n+1);
```

1.5 Black magic

```
#include <bits/stdc++.h>
#include <ext/pb_ds/assoc_container.hpp>
#include <ext/pb_ds/priority_queue.hpp>
#include <ext/rope>
using namespace __gnu_pbds;
using namespace __gnu_cxx;
using namespace std;

__gnu_pbds::priority_queue<int> pq;
__gnu_pbds::priority_queue<int>::point_iterator idx
    [10];
idx[0] = pq.push(1);

typedef tree<int,null_type,less<int>,rb_tree_tag,
    tree_order_statistics_node_update> TREE;
TREE name;
*name.find_by_order(0);
name.order_of_key(1);
name.insert(2);
name.delete(3);
name.split(v, b); /// value < v of a split to b
name.join(another TREE);
```

1.6 Lawfung

- Pick's theorem
  $A = i + \frac{b}{2} - 1$
- Laplacian matrix
  $L = D - A$
- Extended Catalan number
  $\frac{1}{(k-1)n+1}\binom{kn}{n}$
- Derangement $D_n = (n-1)(D_{n-1} + D_{n-2})$
- Möbius
  $\sum_{i|n} \mu(i) = [n = 1]$ $\sum_{i|n} \phi(i) = n$
- Inversion formula
  $f(n) = \sum_{i=0}^{n} \binom{n}{i} g(i)$ $g(n) = \sum_{i=0}^{n} (-1)^{n-i}\binom{n}{i} f(i)$
  $f(n) = \sum_{d|n} g(d)$ $g(n) = \sum_{d|n} \mu(\frac{n}{d}) f(d)$
- Sum of powers
  $\sum_{k=1}^{n} k^m = \frac{1}{m+1}\sum_{k=0}^{m}\binom{m+1}{k}$ B_k^+ n^{m+1-k}
  $\sum_{j=0}^{m}\binom{m+1}{j} B_j^- = 0$
  note : $B_1^+ = -B_1^-$ $B_i^+ = B_i^-$
- Cipolla's algorithm
  $\left(\frac{u}{p}\right) = u^{\frac{p-1}{2}}$
  1. $\left(\frac{a^2-n}{p}\right) = -1$
  2. $x = (a + \sqrt{a^2 - n})^{\frac{p+1}{2}}$
- High order residue
  $[d^{\frac{p-1}{(n,p-1)}} \equiv 1]$
- Packing and Covering
  $|MaximumIndependentSet| + |MinimumVertexCover| = |V|$
- Kőnig's theorem
  $|maximummatching| = |minimumvertexcover|$
- Dilworth's theorem
  $width = |largestantichain| = |smallestchaindecomposition|$
- Mirsky's theorem
  $height = |longestchain| = |smallestantichaindecomposition| = |minimumanticliquepartition|$
- Triangle center
  - $G : (1,)$
  - $O : (a^2(b^2 + c^2 - a^2),) = (sin2A,)$
  - $I : (a,) = (sinA)$
  - $E : (-a, b, c) = (-sinA, sinB, sinC)$
  - $H : (\frac{1}{b^2+c^2-a^2},) = (tanA,)$

1.7 Check

```
for i in $(seq 1 10000);
do
    ./gen > input
    ./ac < input > out_ac
    ./wa < input > out_wa
    diff out_ac out_wa || break
done
```

2 Data Structure

2.1 Disjoint set

```
struct DJS{
    int p[N], rk[N];
    vector<pair<int*,int>> memo;
    vector<size_t> stk;
    void save(){
        stk.push_back(memo.size());
    }
    void undo(){
        while(memo.size() > stk.back()){
            *memo.back().first = memo.back().second;
            memo.pop_back();
        }
        stk.pop_back();
    }
    void assign(int *x, int v){
        memo.push_back({x, *x});
        *x=v;
    }
    //assign(&a, b); //a = b
} djs;
```

2.2 Persistent treap

```
#include <bits/stdc++.h>
using namespace std;

struct Treap {
    static Treap mem[P];
    Treap *lc,*rc;
    char c; int sz;
    Treap(){}
    Treap(char _c) : lc(NULL),rc(NULL),sz(1),c(_c){}
```

```
} Treap::mem[P], *ptr=Treap::mem ;
int Sz(Treap* t) {
    return t?t->sz:0;
}
void pull(Treap* t) {
    if (!t) return;
    t->sz = Sz(t->lc) + Sz(t->rc) + 1;
}
Treap* merge(Treap* a,Treap* b) {
    if (!a || !b) return a?a:b;
    Treap* ret;
    if (myRnd() % (Sz(a) + Sz(b)) < Sz(a)) {
        ret = new (ptr++) Treap(*a);
        ret->rc = merge(a->rc,b);
    }
    else {
        ret = new(ptr++) Treap(*b);
        ret->lc=merge(a,b->lc);
    }
    pull(ret);
    return ret;
}
void split(Treap* t,int k,Treap* &a,Treap* &b) {
    if (!t) a=b=NULL;
    else if (Sz(t->lc) + 1 <= k) {
        a = new(ptr++) Treap(*t);
        split(t->rc,k-Sz(t->lc)-1,a->rc,b);
        pull(a);
    }
    else {
        b=new(ptr++) Treap(*t);
        split(t->lc,k,a,b->lc);
        pull(b);
    }
}
int d;
char buf[M];
Treap* ver[N];

ptr = Treap::mem;
v_cnt++;
ver[v_cnt] = ver[v_cnt-1];
split(ver[v_cnt],p,tl,tr);
tl = merge(tl,new(ptr++)Treap(buf[j]));
```

3 Flow

3.1 ISAP with bound

```
/*
Maximum density subgraph ( \sum W_e + \sum W_v ) / |V|
Binary search on answer:
For a fixed D, construct a Max flow model as follow:
Let S be Sum of all weight( or inf)
1. from source to each node with cap = S
2. For each (u,v,w) in E, (u->v,cap=w), (v->u,cap=w)
3. For each node v, from v to sink with cap = S + 2 * D
     - deg[v] - 2 * (W of v)
where deg[v] = \sum weight of edge associated with v
If maxflow < S * |V|, D is an answer.
Requiring subgraph: all vertex can be reached from
    source with
edge whose cap > 0.
*/

//Be careful that it's zero base !!!!!!!!
#include <bits/stdc++.h>
using namespace std;
typedef long long ll;
#define SZ(x) ((int)(x).size())
#define eb emplace_back
const ll INF = 0x3f3f3f3f3f3f3f3f;

const ll N = 5e2 + 5;
struct isap{
  struct edge{
    int t, r;
    ll c;
    edge(int _t, int _r, ll _c) : t(_t), r(_r), c(_c)
        {}
  };
  int n, S, T;
  vector<edge> adj[N];
    int dis[N], gap[N], ok;
  isap(int _n, int _s, int _t) : n(_n), S(_s), T(_t) {
    for(int i = 0; i < n + 2; ++ i) adj[i].clear();
  }
  void add(int u, int v, ll c){
    adj[u].eb(  v, adj[v].size(), c  );
    adj[v].eb(  u, adj[u].size() - 1, 0  );
  }
  ll dfs(int now, ll f){
    if(now == T)  return f;
    int mi = n;
    for(edge &e : adj[now]){
      if(e.c){
        ll x;
        if( dis[now] == dis[e.t] + 1 && (x = dfs(e.t,
            min(f, e.c))) ){
          e.c -= x;
          adj[e.t][e.r].c += x;
          return x;
        }
        mi = min(mi, dis[e.t]);
      }
    }
    if( --gap[dis[now]] == 0) ok = 0;
    dis[now] = mi + 1;
    gap[ dis[now] ]++;
    return 0;
  }
  ll flow(){
        memset(dis, 0, n * 4);
    memset(gap, 0, n * 4);
        gap[0] = n;
    ok = 1;
    ll r = 0;
    while(dis[S] < n && ok) r += dfs(S, INF);
    return r;
  }
    // below for bounded only
    ll D[N];
    void bounded_init() {
        memset(D, 0, n * 8);
    }
    void add2(int u, int v, ll b, ll c) {
        add(u, v, c - b);
        D[u] -= b;
        D[v] += b;
    }
    ll bounded_flow() {
        int SS = n, TT = n + 1;
        ll base = 0;
        for(int i = 0; i < n; ++ i) {
            if (D[i] > 0) base += D[i];
            if (D[i] > 0) add(SS, i, D[i]);
            if (D[i] < 0) add(i ,TT, -D[i]);
        }
        add(T, S, INF);
        int tmps = S, tmpt = T;
        n += 2; S = SS, T = TT;
        ll f = flow();
        n -= 2; S = tmps; T = tmpt;
        return f == base ? flow() : -1LL;
    }
};
int main(){}
```

3.2 Min Cost Max Flow

```
const ll N = 5e2 + 5;
struct MCFlow{
  struct edge{
    int t, r;
    ll cap, cos;
    edge(int _t, int _r, ll _cp, ll _co) : t(_t), r(_r)
        , cap(_cp), cos(_co){}
  };
```

```
  int n, S, T;
  vector<edge> adj[N];
  MCFlow(int _n,int _s,int _t) : n(_n), S(_s), T(_t) {
    for(int i = 0; i < n; ++ i)
      adj[i].clear();
  }
  void add(int s, int t, ll cap, ll cos){
    adj[s].eb(t, SZ(adj[t])  , cap, cos);
    adj[t].eb(s, SZ(adj[s])-1, 0  , -cos);
  }
  pll flow(){
    ll tc = 0, tf = 0, dis[N];
    int inq[N], pre[N], prE[N];
    while(1){
      memset(dis, INF, n * 8);
      memset(inq, 0  , n * 4);
      queue<int> qu;
      qu.push(S);
      inq[S] = 1;
      dis[S] = 0;
      while(SZ(qu)){
        int now = qu.front();
        qu.pop();
        inq[now] = 0;
        for(int i = 0; i < SZ(adj[now]); ++i){
          auto e = adj[now][i];
          if(e.cap && dis[now] + e.cos < dis[e.t]){
            dis[e.t] = dis[now] + e.cos;
            pre[e.t] = now;
            prE[e.t] = i;
            if(!inq[e.t]){
              qu.push(e.t);
              inq[e.t] = 1;
            }
          }
        }
      }
      if(dis[T] == INF) break;
      ll mi = INF;
      for(int now = T; now != S; now = pre[now])
        mi = min(mi, adj[pre[now]][prE[now]].cap);
      for(int now = T; now != S; now = pre[now]){
        adj[pre[now]][prE[now] ]            .cap-=mi;
        adj[now][adj[pre[now]][prE[now]].r ].cap+=mi;
      }
      tc += mi * dis[T];
      tf += mi;
    }
    return pll(tf, tc);
  }
};
```

3.3 Global Min Cut

```
struct SW {
    //find global min cut in O(V^3)
    //points are ZERO-BASE!!!
    static const int N = 506;
    int adj[N][N],wei[N],n;
    bool vis[N],del[N];
    void init(int _n) {
        n = _n;
        memset(adj,0,sizeof(adj));
        memset(del,0,sizeof(del));
    }
    void add_edge(int x,int y,int w) {
        adj[x][y] += w;
        adj[y][x] += w;
    }
    void search(int &s,int &t) {
        memset(wei,0,sizeof(wei));
        memset(vis,0,sizeof(vis));
        s = t = -1;
        while (true) {
            int mx=-1, mx_id=0;
            for (int i=0;i<n;++i) {
                if (!del[i] && !vis[i] && mx<wei[i]) {
                    mx_id = i;
                    mx = wei[i];
                }
            }
            if (mx == -1) break;
            vis[mx_id] = true;
            s = t; t = mx_id;
            for (int i = 0; i < n; ++i) {
                if (!vis[i] && !del[i]) {
                    wei[i] += adj[mx_id][i];
                }
            }
        }
    }
    int solve() {
        int ret = 2147483647; //INF
        for (int i = 0; i < n - 1; ++i) {
            int x, y;
            search(x, y);
            ret = min(ret, wei[y]);
            del[y] = true;
            for (int i = 0;i < n; ++i) {
                adj[x][i] += adj[y][i];
                adj[i][x] += adj[y][i];
            }
        }
        return ret;
    }
} SW;
```

3.4 Gomory Hu Tree

```
def cut(G,s,t) :
  return minimum s-t cut in G

def gomory_hu(G):
  T = {}
  P = [1] * |V(G)|
  for s in [2,n] :
    t = p[s]
    C = cut(G,s,t)
    add(s,t,w(C)) to c
    for i in [s+1,n] :
      if p[i] == t and s-i path exists in G\C :
        p[i] = s
  return T;
```

4 Geometry

4.1 Circle

```
//Note that this code will crash if circle A and B are
    the same
typedef pair<double, double> pdd;
pdd rtcw(pdd p){return pdd(p.Y, -p.X); }
vector<pdd> circlesintersect(pdd A, pdd B, double r1,
    double r2){
    vector<pdd> ret;
    double d = dis(A, B);
    if(d > r1 + r2 || d + min(r1, r2) < max(r1, r2))
        return ret;
    double x = (d * d + r1 * r1 - r2 * r2) / (2 * d);
    double y = sqrt(r1 * r1 - x * x);
    pdd v = (B - A) / d;
    ret.eb(A + v * x + rtcw(v) * y);
    if(y > 0)
        ret.eb(A + v * x - rtcw(v) * y);
    return ret;
}
```

4.2 Half Plane Intersection

```
Pt interPnt( Line l1, Line l2, bool &res ){
    Pt p1, p2, q1, q2;
    tie(p1, p2) = l1; tie(q1, q2) = l2;
    double f1 = (p2 - p1) ^ (q1 - p1);
    double f2 = (p2 - p1) ^ (p1 - q2);
```

```
    double f = (f1 + f2);
    if( fabs(f) < eps){ res=0; return {0, 0}; }
    res = true;
    return q1 * (f2 / f) + q2 * (f1 / f);
}
bool isin( Line l0, Line l1, Line l2 ){
    // Check inter(l1, l2) in l0
    bool res; Pt p = interPnt(l1, l2, res);
    return ( (l0.SE - l0.FI) ^ (p - l0.FI) ) > eps;
}
/* If no solution, check: 1. ret.size() < 3
 * Or more precisely, 2. interPnt(ret[0], ret[1])
 * in all the lines. (use (l.S - l.F) ^ (p - l.F) > 0
 */
/* --^-- Line.FI --^-- Line.SE --^-- */
vector<Line> halfPlaneInter( vector<Line> lines ){
    int sz = lines.size();
    vector<double> ata(sz), ord(sz);
    for( int i=0; i<sz; i++) {
        ord[i] = i;
        Pt d = lines[i].SE - lines[i].FI;
        ata[i] = atan2(d.Y, d.X);
    }
    sort( ord.begin(), ord.end(), [&](int i, int j) {
            if( fabs(ata[i] - ata[j]) < eps )
            return ( (lines[i].SE - lines[i].FI) ^
                    (lines[j].SE - lines[i].FI) ) < 0;
            return ata[i] < ata[j];
            });
    vector<Line> fin;
    for (int i=0; i<sz; i++)
        if (!i or fabs(ata[ord[i]] - ata[ord[i-1]]) >
            eps)
            fin.PB(lines[ord[i]]);
    deque<Line> dq;
    for (int i=0; i<(int)(fin.size()); i++) {
        while((int)(dq.size()) >= 2 and
                not isin(fin[i], dq[(int)(dq.size())
                    -2],
                    dq[(int)(dq.size())-1]))
            dq.pop_back();
        while((int)(dq.size()) >= 2 and
                not isin(fin[i], dq[0], dq[1]))
            dq.pop_front();
        dq.push_back(fin[i]);
    }
    while( (int)(dq.size()) >= 3 and
            not isin(dq[0], dq[(int)(dq.size())-2],
                dq[(int)(dq.size())-1]))
        dq.pop_back();
    while( (int)(dq.size()) >= 3 and
            not isin(dq[(int)(dq.size())-1], dq[0], dq
                [1]))
        dq.pop_front();
    vector<Line> res(dq.begin(),dq.end());
    return res;
}
```

4.3 Convex Hull 3D

```
#define SIZE(X) (int(X.size()))
#define PI 3.14159265358979323846264338327950288
struct Pt{
    Pt cross(const Pt &p) const
    { return Pt(y * p.z - z * p.y, z * p.x - x * p.z, x
        * p.y - y * p.x); }
} info[N];
int mark[N][N],n, cnt;;
double mix(const Pt &a, const Pt &b, const Pt &c)
{ return a * (b ^ c); }
double area(int a, int b, int c)
{ return norm((info[b] - info[a]) ^ (info[c] - info[a])
    ); }
double volume(int a, int b, int c, int d)
{ return mix(info[b] - info[a], info[c] - info[a], info
    [d] - info[a]); }
struct Face{
    int a, b, c; Face(){}
    Face(int a, int b, int c): a(a), b(b), c(c) {}
    int &operator [](int k)
    { if (k == 0) return a; if (k == 1) return b;
        return c; }
};
vector<Face> face;
void insert(int a, int b, int c)
{ face.push_back(Face(a, b, c)); }
void add(int v) {
    vector <Face> tmp; int a, b, c; cnt++;
    for (int i = 0; i < SIZE(face); i++) {
        a = face[i][0]; b = face[i][1]; c = face[i][2];
        if(Sign(volume(v, a, b, c)) < 0)
            mark[a][b] = mark[b][a] = mark[b][c] = mark
                [c][b] = mark[c][a] = mark[a][c] = cnt;
        else tmp.push_back(face[i]);
    } face = tmp;
    for (int i = 0; i < SIZE(tmp); i++) {
        a = face[i][0]; b = face[i][1]; c = face[i][2];
        if (mark[a][b] == cnt) insert(b, a, v);
        if (mark[b][c] == cnt) insert(c, b, v);
        if (mark[c][a] == cnt) insert(a, c, v);
    }}
int Find(){
    for (int i = 2; i < n; i++) {
        Pt ndir = (info[0] - info[i]) ^ (info[1] - info
            [i]);
        if (ndir == Pt()) continue; swap(info[i], info
            [2]);
        for (int j = i + 1; j < n; j++) if (Sign(volume
            (0, 1, 2, j)) != 0) {
            swap(info[j], info[3]); insert(0, 1, 2);
                insert(0, 2, 1); return 1;
        } } return 0; }
int main() {
    for (; scanf("%d", &n) == 1; ) {
        for (int i = 0; i < n; i++) info[i].Input();
        sort(info, info + n); n = unique(info, info + n
            ) - info;
        face.clear(); random_shuffle(info, info + n);
        if (Find()) { memset(mark, 0, sizeof(mark));
            cnt = 0;
            for (int i = 3; i < n; i++) add(i); vector<
                Pt> Ndir;
            for (int i = 0; i < SIZE(face); ++i) {
                Pt p = (info[face[i][0]] - info[face[i
                    ][1]]) ^
                    (info[face[i][2]] - info[face[i
                        ][1]]);
                p = p / norm( p ); Ndir.push_back(p);
            } sort(Ndir.begin(), Ndir.end());
            int ans = unique(Ndir.begin(), Ndir.end())
                - Ndir.begin();
            printf("%d\n", ans);
        } else printf("1\n");
    } }
double calcDist(const Pt &p, int a, int b, int c)
{ return fabs(mix(info[a] - p, info[b] - p, info[c] - p
    ) / area(a, b, c)); }
//compute the minimal distance of center of any faces
double findDist() { //compute center of mass
    double totalWeight = 0; Pt center(.0, .0, .0);
    Pt first = info[face[0][0]];
    for (int i = 0; i < SIZE(face); ++i) {
        Pt p = (info[face[i][0]]+info[face[i][1]]+info[
            face[i][2]]+first)*.25;
        double weight = mix(info[face[i][0]] - first,
            info[face[i][1]]
                - first, info[face[i][2]] - first);
        totalWeight += weight; center = center + p *
            weight;
    } center = center / totalWeight;
    double res = 1e100; //compute distance
    for (int i = 0; i < SIZE(face); ++i)
        res = min(res, calcDist(center, face[i][0],
            face[i][1], face[i][2]));
    return res; }
```

4.4 Convex Hull

```
/* Given a convexhull, answer querys in O(\lg N)
```

```
   CH should not contain identical points, the area
       should
   be > 0, min pair(x, y) should be listed first */
double det( const Pt& p1 , const Pt& p2 )
{ return p1.X * p2.Y - p1.Y * p2.X; }
struct Conv{
    int n;
    vector<Pt> a;
    vector<Pt> upper, lower;
    Conv(vector<Pt> _a) : a(_a){
        n = a.size();
        int ptr = 0;
        for(int i=1; i<n; ++i) if (a[ptr] < a[i]) ptr =
            i;
        for(int i=0; i<=ptr; ++i) lower.push_back(a[i])
            ;
        for(int i=ptr; i<n; ++i) upper.push_back(a[i]);
        upper.push_back(a[0]);
    }
    int sign( LL x ){ // fixed when changed to double
        return x < 0 ? -1 : x > 0; }
    pair<LL,int> get_tang(vector<Pt> &conv, Pt vec){
        int l = 0, r = (int)conv.size() - 2;
        for( ; l + 1 < r; ){
            int mid = (l + r) / 2;
            if(sign(det(conv[mid+1]-conv[mid],vec))>0)r
                =mid;
            else l = mid;
        }
        return max(make_pair(det(vec, conv[r]), r),
                make_pair(det(vec, conv[0]), 0));
    }
    void upd_tang(const Pt &p, int id, int &i0, int &i1
        ){
        if(det(a[i0] - p, a[id] - p) > 0) i0 = id;
        if(det(a[i1] - p, a[id] - p) < 0) i1 = id;
    }
    void bi_search(int l, int r, Pt p, int &i0, int &i1
        ){
        if(l == r) return;
        upd_tang(p, l % n, i0, i1);
        int sl=sign(det(a[l % n] - p, a[(l + 1) % n] -
            p));
        for( ; l + 1 < r; ) {
            int mid = (l + r) / 2;
            int smid=sign(det(a[mid%n]-p, a[(mid+1)%n]-
                p));
            if (smid == sl) l = mid;
            else r = mid;
        }
        upd_tang(p, r % n, i0, i1);
    }
    int bi_search(Pt u, Pt v, int l, int r) {
        int sl = sign(det(v - u, a[l % n] - u));
        for( ; l + 1 < r; ) {
            int mid = (l + r) / 2;
            int smid = sign(det(v - u, a[mid % n] - u))
                ;
            if (smid == sl) l = mid;
            else r = mid;
        }
        return l % n;
    }
    // 1. whether a given point is inside the CH
    bool contain(Pt p) {
        if (p.X < lower[0].X || p.X > lower.back().X)
            return 0;
        int id = lower_bound(lower.begin(), lower.end()
            , Pt(p.X, -INF)) - lower.begin();
        if (lower[id].X == p.X) {
            if (lower[id].Y > p.Y) return 0;
        }else if(det(lower[id-1]-p,lower[id]-p)<0)
            return 0;
        id = lower_bound(upper.begin(), upper.end(), Pt
            (p.X, INF), greater<Pt>()) - upper.begin();
        if (upper[id].X == p.X) {
            if (upper[id].Y < p.Y) return 0;
        }else if(det(upper[id-1]-p,upper[id]-p)<0)
            return 0;
        return 1;
    }
    // 2. Find 2 tang pts on CH of a given outside
        point
    // return true with i0, i1 as index of tangent
        points
    // return false if inside CH
    bool get_tang(Pt p, int &i0, int &i1) {
        if (contain(p)) return false;
        i0 = i1 = 0;
        int id = lower_bound(lower.begin(), lower.end()
            , p) - lower.begin();
        bi_search(0, id, p, i0, i1);
        bi_search(id, (int)lower.size(), p, i0, i1);
        id = lower_bound(upper.begin(), upper.end(), p,
             greater<Pt>()) - upper.begin();
        bi_search((int)lower.size() - 1, (int)lower.
            size() - 1 + id, p, i0, i1);
        bi_search((int)lower.size() - 1 + id, (int)
            lower.size() - 1 + (int)upper.size(), p, i0
            , i1);
        return true;
    }
    // 3. Find tangent points of a given vector
    // ret the idx of vertex has max cross value with
        vec
    int get_tang(Pt vec){
        pair<LL, int> ret = get_tang(upper, vec);
        ret.second = (ret.second+(int)lower.size()-1)%n
            ;
        ret = max(ret, get_tang(lower, vec));
        return ret.second;
    }
    // 4. Find intersection point of a given line
    // return 1 and intersection is on edge (i, next(i)
        )
    // return 0 if no strictly intersection
    bool get_intersection(Pt u, Pt v, int &i0, int &i1)
        {
        int p0 = get_tang(u - v), p1 = get_tang(v - u);
        if(sign(det(v-u,a[p0]-u))*sign(det(v-u,a[p1]-u)
            )<0){
            if (p0 > p1) swap(p0, p1);
            i0 = bi_search(u, v, p0, p1);
            i1 = bi_search(u, v, p1, p0 + n);
            return 1;
        }
        return 0;
    }
};
```

4.5 Polar Angle Sort

```
bool cmp(vec a,vec b){
  if((a.Y>0||(a.Y==0&&a.X>0))&&(b.Y<0||(b.Y==0&&b.X<0))
      )
    return 1;
  if((b.Y>0||(b.Y==0&&b.X>0))&&(a.Y<0||(a.Y==0&&a.X<0))
      )
    return 0;
  return (a^b)>0;
}
```

4.6 Circle and Polygon intersection

```
struct Circle_and_Segment_Intersection {
    const ld eps = 1e-9;
    vector<pdd> solve(pdd p1, pdd p2, pdd cen, ld r) {
        //please notice that p1 != p2
        //condiser p = p2 + (p1 - p2) * t, 0 <= t <= 1
        vector<pdd> ret;
        p1 = p1 - cen; p2 = p2 - cen;
        ld a = (p1 - p2) * (p1 - p2);
        ld b = 2 * (p2 * (p1 - p2));
        ld c = p2 * p2 - r * r;
        ld bb4ac = b * b - 4 * a * c;
        if (bb4ac < -eps) return ret; //no intersection
        vector<ld> ts;
        if ( (bb4ac) <= eps) {
            ts.push_back(-b / 2 / a);
```

```
        }
        else {
            ts.push_back( (-b + sqrt(bb4ac)) / (a * 2)
                );
            ts.push_back( (-b - sqrt(bb4ac)) / (a * 2)
                );
        }
        sort(ts.begin(), ts.end());
        for (ld t: ts) {
            if (-eps <= t && t <= 1 + eps) {
                t = max(t, 0.0);
                t = min(t, 1.0);
                pdd pt = p2 + t * (p1 - p2);
                pt = pt + cen;
                ret.push_back(pt);
            }
        }
        return ret;
    }
} solver;

double f(ld a, ld b) {
    ld ret = b - a;
    while (ret <= -pi - eps) ret += 2 * pi;
    while (ret >= pi + eps) ret -= 2 * pi;
    return ret;
}

ld solve_small(pdd cen, ld r, pdd p1, pdd p2) {
    p1 = p1 - cen, p2 = p2 - cen;
    cen = {0, 0};
    vector<pdd> inter = solver.solve(p1, p2, cen, r);
    ld ret = 0.0;
    if ((int)inter.size() == 0) {
        if (in_cir(cen, r, p1)) {
            ret = (p1 ^ p2) / 2;
        }
        else {
            ret = (r * r * f(atan2(p1.Y, p1.X), atan2(
                p2.Y, p2.X))) / 2 ;
        }
    }
    else if ( (int)inter.size() == 1) {
        if (!in_cir(cen, r, p1) && !in_cir(cen, r, p2))
             {
            //outside cut
            ret = (r * r * f(atan2(p1.Y, p1.X), atan2(
                p2.Y, p2.X))) / 2;
        }
        else if (!in_cir(cen, r, p1)) {
            pdd _p1 = inter[0];
            ret +=  ((_p1 ^ p2) / 2);
            ret +=  (r * r * f(atan2(p1.Y, p1.X), atan2
                (_p1.Y, _p1.X))) / 2;
        }
        else if (!in_cir(cen, r, p2)) {
            pdd _p2 = inter[0];
            ret +=  ((p1 ^ _p2) / 2);
            ret +=  (r * r * f(atan2(_p2.Y, _p2.X),
                atan2(p2.Y, p2.X))) / 2;
        }
    }
    else if ( (int)inter.size() == 2) {
        pdd _p2 = inter[0], _p1 = inter[1];
        ret +=  ((_p1 ^ _p2) / 2);
        ret +=  (r * r * f(atan2(_p2.Y, _p2.X), atan2(
            p2.Y, p2.X))) / 2;
        ret +=  (r * r * f(atan2(p1.Y, p1.X), atan2(_p1
            .Y, _p1.X))) / 2;
    }
    return ret;
}

ld solve(pdd cen, ld r, vector<pdd> pts) {
    ld ret = 0;
    for (int i = 0; i < (int)pts.size(); ++i) {
        ret += solve_small(cen, r, pts[i], pts[(i + 1)
            % int(pts.size())]);
    }
    ret = max(ret, -ret);
    return ret;
}
```

4.7 Line Intersection

```
int intersect(PII a , PII b , PII c , PII d){
    if(max(a.F , b.F) < min(c.F , d.F)) return 0;
    if(max(c.F , d.F) < min(a.F , b.F)) return 0;
    if(max(a.S , b.S) < min(c.S , d.S)) return 0;
    if(max(c.S , d.S) < min(a.S , b.S)) return 0;
    if(cross(b - a , c - a) * cross(b - a , d - a) ==
        1) return 0;
    if(cross(d - c , a - c) * cross(d - c , b - c) ==
        1) return 0;
    return 1;
}
```

4.8 Line Intersection Point

```
pdd intersect(pdd p1, pdd p2, pdd q1, pdd q2) {
    //make sure that p1p2 is not parallel to q1q2
    return p1 + ((q1 - p1) ^ (q2 - q1)) / ((p2 - p1) ^
        (q2 - q1)) * (p2 - p1);
}
```

4.9 Rotating Calipers

```
#define NXT(x) ((x + 1) % m)
int main () {
    vector<pii> v; // v is the input points
    sort(v.begin(), v.end());
    vector<pii> up, down;
    for (pii p: v) {
        while (SZ(down) >= 2 && sgn((p - down[SZ(down)
            - 2]) ^ (p - down.back())) >= 0) {
            down.pop_back();
        }
        down.push_back(p);
    }
    reverse(v.begin(), v.end());
    for (pii p: v) {
        while (SZ(up) >= 2 && sgn((p - up[SZ(up) - 2])
            ^ (p - up.back())) >= 0) {
            up.pop_back();
        }
        up.push_back(p);
    }
    vector<pii> all;
    for (pii p: down) { all.push_back(p); }  all.
        pop_back();
    for (pii p: up) { all.push_back(p); }
    all.pop_back();
    int m = all.size();
    int ptr = (int)down.size() - 1;
    for (int i = 0; i < m; ++i) {
        while (((all[NXT(ptr)] - all[ptr]) ^ (all[NXT(i
            )] - all[i])) > 0) {
            ptr = NXT(ptr);
        }
    }
}
```

5 Graph

5.1 Biconnected Component

```
int low[N],dfn[N];
bool vis[N];
int cnt[N], e[N], x[N], y[N];
int stamp, bcc_no = 0;

vector<int> G[N], bcc[N];
stack<int> sta;

void dfs(int now,int par) {
    vis[now] = true;
    dfn[now] = low[now] = (++stamp);
```

```
    for (int i:G[now]) {
        int to= ( e[i] ^ now );
        if (to == par) continue;
        if (!vis[to]) {
            sta.push(i); dfs(to,now);
            low[now] = min(low[now],low[to]);
            if (low[to] >= dfn[now]) {
                ++bcc_no; int p;
                do {
                    p = sta.top(); sta.pop();
                    bcc[bcc_no].push_back(p);
                } while (p != i);
            }
        }
        else if (dfn[to] < dfn[now]) {
            sta.push(i);
            low[now] = min(low[now],dfn[to]);
        }
    }
}
```

5.2 General graph macthing

```
const int N = 100006, E = (2e5) * 2;
struct Graph{
    //1-index
    int to[E],bro[E],head[N],e;
    int lnk[N],vis[N],stp,n;
    int per[N];
    void init( int _n ){
        //remember to set every array to 0
        stp = 0; e = 1; n = _n;
        for( int i = 1 ; i <= n ; i ++ )
            head[i] = lnk[i] = vis[i] = 0, per[i] = i;
        //random_shuffle(per+1, per+n+1);
    }
    void add_edge(int u,int v){
        u=per[u], v=per[v];
        to[e]=v,bro[e]=head[u],head[u]=e++;
        to[e]=u,bro[e]=head[v],head[v]=e++;
    }
    bool dfs(int x){
        vis[x]=stp;
        for(int i=head[x];i;i=bro[i]){
            int v=to[i];
            if(!lnk[v]){
                lnk[x]=v,lnk[v]=x;
                return true;
            }else if(vis[lnk[v]]<stp){
                int w=lnk[v];
                lnk[x]=v,lnk[v]=x,lnk[w]=0;
                if(dfs(w)){
                    return true;
                }
                lnk[w]=v,lnk[v]=w,lnk[x]=0;
            }
        }
        return false;
    }
    int solve(){
        int ans = 0;
        for(int i=1;i<=n;i++)
            if(!lnk[i]){
                stp++; ans += dfs(i);
            }
        return ans;
    }
} graph;
```

5.3 KM

```
const int INF = 0x3f3f3f3f;
const int maxn = 610;

int n, w[maxn][maxn], lx[maxn], ly[maxn], slk[maxn];
int s[maxn], t[maxn], good[maxn];

int match(int now) {
    s[now] = 1;
    for (int to = 1; to <= n; to ++) {
        if(t[to]) continue;
        if(lx[now] + ly[to] == w[now][to]) {
            t[to] = 1;
            if(good[to] == 0 || match(good[to]))
                return good[to] = now, 1;
        }
        else slk[to] = min(slk[to], lx[now] + ly[to] -
            w[now][to]);
    }
    return 0;
}
void update() {
    int val = INF;
    for (int i = 1; i <= n; i ++)
        if(t[i] == 0) val = min(val, slk[i]);
    for (int i = 1; i <= n; i ++) {
        if(s[i]) lx[i] -= val;
        if(t[i]) ly[i] += val;
    }
}
void run_km() {
    for (int i = 1; i <= n; i ++) {
        lx[i] = w[i][1];
        for (int j = 1; j <= n; j ++)
            lx[i] = max(lx[i], w[i][j]);
    }
    for (int i = 1; i <= n; i ++)
        ly[i] = 0, good[i] = 0;
    for (int i = 1; i <= n; i ++) {
        for (int j = 1; j <= n; j ++) slk[j] = INF;
        while(1) {
            for (int j = 1; j <= n; j ++)
                s[j] = t[j] = 0;
            if(match(i)) break;
            else update();
        }
    }
}
/* how_to_use:
1. put edge in w[i][j]
2. run_km
3. match: (good[i], i)
*/
```

5.4 Maximum Weighted Matching(General Graph)

```
struct WeightGraph {
    static const int INF = INT_MAX;
    static const int N = 514;
    struct edge{
        int u,v,w; edge(){}
        edge(int ui,int vi,int wi)
            :u(ui),v(vi),w(wi){}
    };
    int n,n_x;
    edge g[N*2][N*2];
    int lab[N*2];
    int match[N*2],slack[N*2],st[N*2],pa[N*2];
    int flo_from[N*2][N+1],S[N*2],vis[N*2];
    vector<int> flo[N*2];
    queue<int> q;
    int e_delta(const edge &e){
        return lab[e.u]+lab[e.v]-g[e.u][e.v].w*2;
    }
    void update_slack(int u,int x){
        if(!slack[x]||e_delta(g[u][x])<e_delta(g[slack[
            x]][x]))slack[x]=u;
    }
    void set_slack(int x){
        slack[x]=0;
        for(int u=1;u<=n;++u)
            if(g[u][x].w>0&&st[u]!=x&&S[st[u]]==0)
                update_slack(u,x);
    }
    void q_push(int x){
        if(x<=n)q.push(x);
```

```
        else for(size_t i=0;i<flo[x].size();i++)
            q_push(flo[x][i]);
    }
    void set_st(int x,int b){
        st[x]=b;
        if(x>n)for(size_t i=0;i<flo[x].size();++i)
            set_st(flo[x][i],b);
    }
    int get_pr(int b,int xr){
        int pr=find(flo[b].begin(),flo[b].end(),xr)-flo
            [b].begin();
        if(pr%2==1){
            reverse(flo[b].begin()+1,flo[b].end());
            return (int)flo[b].size()-pr;
        }else return pr;
    }
    void set_match(int u,int v){
        match[u]=g[u][v].v;
        if(u<=n) return;
        edge e=g[u][v];
        int xr=flo_from[u][e.u],pr=get_pr(u,xr);
        for(int i=0;i<pr;++i)set_match(flo[u][i],flo[u
            ][i^1]);
        set_match(xr,v);
        rotate(flo[u].begin(),flo[u].begin()+pr,flo[u].
            end());
    }
    void augment(int u,int v){
        for(;;){
            int xnv=st[match[u]];
            set_match(u,v);
            if(!xnv)return;
            set_match(xnv,st[pa[xnv]]);
            u=st[pa[xnv]],v=xnv;
        }
    }
    int get_lca(int u,int v){
        static int t=0;
        for(++t;u||v;swap(u,v)){
            if(u==0)continue;
            if(vis[u]==t)return u;
            vis[u]=t;
            u=st[match[u]];
            if(u)u=st[pa[u]];
        }
        return 0;
    }
    void add_blossom(int u,int lca,int v){
        int b=n+1;
        while(b<=n_x&&st[b])++b;
        if(b>n_x)++n_x;
        lab[b]=0,S[b]=0;
        match[b]=match[lca];
        flo[b].clear();
        flo[b].push_back(lca);
        for(int x=u,y;x!=lca;x=st[pa[y]])
            flo[b].push_back(x),flo[b].push_back(y=st[
                match[x]]),q_push(y);
        reverse(flo[b].begin()+1,flo[b].end());
        for(int x=v,y;x!=lca;x=st[pa[y]])
            flo[b].push_back(x),flo[b].push_back(y=st[
                match[x]]),q_push(y);
        set_st(b,b);
        for(int x=1;x<=n_x;++x)g[b][x].w=g[x][b].w=0;
        for(int x=1;x<=n;++x)flo_from[b][x]=0;
        for(size_t i=0;i<flo[b].size();++i){
            int xs=flo[b][i];
            for(int x=1;x<=n_x;++x)
                if(g[b][x].w==0||e_delta(g[xs][x])<
                    e_delta(g[b][x]))
                    g[b][x]=g[xs][x],g[x][b]=g[x][xs];
            for(int x=1;x<=n;++x)
                if(flo_from[xs][x])flo_from[b][x]=xs;
        }
        set_slack(b);
    }
    void expand_blossom(int b){
        for(size_t i=0;i<flo[b].size();++i)
            set_st(flo[b][i],flo[b][i]);
        int xr=flo_from[b][g[b][pa[b]].u],pr=get_pr(b,
            xr);
        for(int i=0;i<pr;i+=2){
            int xs=flo[b][i],xns=flo[b][i+1];
            pa[xs]=g[xns][xs].u;
            S[xs]=1,S[xns]=0;
            slack[xs]=0,set_slack(xns);
            q_push(xns);
        }
        S[xr]=1,pa[xr]=pa[b];
        for(size_t i=pr+1;i<flo[b].size();++i){
            int xs=flo[b][i];
            S[xs]=-1,set_slack(xs);
        }
        st[b]=0;
    }
    bool on_found_edge(const edge &e){
        int u=st[e.u],v=st[e.v];
        if(S[v]==-1){
            pa[v]=e.u,S[v]=1;
            int nu=st[match[v]];
            slack[v]=slack[nu]=0;
            S[nu]=0,q_push(nu);
        }else if(S[v]==0){
            int lca=get_lca(u,v);
            if(!lca)return augment(u,v),augment(v,u),
                true;
            else add_blossom(u,lca,v);
        }
        return false;
    }
    bool matching(){
        memset(S+1,-1,sizeof(int)*n_x);
        memset(slack+1,0,sizeof(int)*n_x);
        q=queue<int>();
        for(int x=1;x<=n_x;++x)
            if(st[x]==x&&!match[x])pa[x]=0,S[x]=0,
                q_push(x);
        if(q.empty())return false;
        for(;;){
            while(q.size()){
                int u=q.front();q.pop();
                if(S[st[u]]==1)continue;
                for(int v=1;v<=n;++v)
                    if(g[u][v].w>0&&st[u]!=st[v]){
                        if(e_delta(g[u][v])==0){
                            if(on_found_edge(g[u][v]))
                                return true;
                        }else update_slack(u,st[v]);
                    }
            }
            int d=INF;
            for(int b=n+1;b<=n_x;++b)
                if(st[b]==b&&S[b]==1)d=min(d,lab[b]/2);
            for(int x=1;x<=n_x;++x)
                if(st[x]==x&&slack[x]){
                    if(S[x]==-1)d=min(d,e_delta(g[slack
                        [x]][x]));
                    else if(S[x]==0)d=min(d,e_delta(g[
                        slack[x]][x])/2);
                }
            for(int u=1;u<=n;++u){
                if(S[st[u]]==0){
                    if(lab[u]<=d)return 0;
                    lab[u]-=d;
                }else if(S[st[u]]==1)lab[u]+=d;
            }
            for(int b=n+1;b<=n_x;++b)
                if(st[b]==b){
                    if(S[st[b]]==0)lab[b]+=d*2;
                    else if(S[st[b]]==1)lab[b]-=d*2;
                }
            q=queue<int>();
            for(int x=1;x<=n_x;++x)
                if(st[x]==x&&slack[x]&&st[slack[x]]!=x
                    &&e_delta(g[slack[x]][x])==0)
                    if(on_found_edge(g[slack[x]][x]))
                        return true;
            for(int b=n+1;b<=n_x;++b)
                if(st[b]==b&&S[b]==1&&lab[b]==0)
                    expand_blossom(b);
        }
        return false;
    }
    pair<long long,int> solve(){
```

```
        memset(match+1,0,sizeof(int)*n);
        n_x=n;
        int n_matches=0;
        long long tot_weight=0;
        for(int u=0;u<=n;++u)st[u]=u,flo[u].clear();
        int w_max=0;
        for(int u=1;u<=n;++u)
            for(int v=1;v<=n;++v){
                flo_from[u][v]=(u==v?u:0);
                w_max=max(w_max,g[u][v].w);
            }
        for(int u=1;u<=n;++u)lab[u]=w_max;
        while(matching())++n_matches;
        for(int u=1;u<=n;++u)
            if(match[u]&&match[u]<u)
                tot_weight+=g[u][match[u]].w;
        return make_pair(tot_weight,n_matches);
    }
    void add_edge( int ui , int vi , int wi ){
        g[ui][vi].w = g[vi][ui].w = wi;
    }
    void init( int _n ){
        n = _n;
        for(int u=1;u<=n;++u)
            for(int v=1;v<=n;++v)
                g[u][v]=edge(u,v,0);
    }
} graph;
```

5.5 Minimum mean cycle

```
/* minimum mean cycle O(VE) */
struct MMC{
    struct Edge { int v,u; double c; };
    int n, m, prv[V][V], prve[V][V], vst[V];
    Edge e[E];
    vector<int> edgeID, cycle, rho;
    double d[V][V];
    void init( int _n )
    { n = _n; m = 0; }
    // WARNING: TYPE matters
    void addEdge( int vi , int ui , double ci )
    { e[ m ++ ] = { vi , ui , ci }; }
    void bellman_ford() {
        for(int i=0; i<n; i++) d[0][i]=0;
        for(int i=0; i<n; i++) {
            fill(d[i+1], d[i+1]+n, inf);
            for(int j=0; j<m; j++) {
                int v = e[j].v, u = e[j].u;
                if(d[i][v]<inf && d[i+1][u]>d[i][v]+e[j
                    ].c) {
                    d[i+1][u] = d[i][v]+e[j].c;
                    prv[i+1][u] = v;
                    prve[i+1][u] = j;
                }
            }
        }
    }
    double solve(){
        // returns inf if no cycle, mmc otherwise
        double mmc=inf;
        int st = -1;
        bellman_ford();
        for(int i=0; i<n; i++) {
            double avg=-inf;
            for(int k=0; k<n; k++) {
                if(d[n][i]<inf-eps) avg=max(avg,(d[n][i
                    ]-d[k][i])/(n-k));
                else avg=max(avg,inf);
            }
            if (avg < mmc) tie(mmc, st) = tie(avg, i);
        }
        FZ(vst); edgeID.clear(); cycle.clear(); rho.
            clear();
        for (int i=n; !vst[st]; st=prv[i--][st]) {
            vst[st]++;
            edgeID.PB(prve[i][st]);
            rho.PB(st);
        }
        while (vst[st] != 2) {
            int v = rho.back(); rho.pop_back();
            cycle.PB(v);
            vst[v]++;
        }
        reverse(ALL(edgeID));
        edgeID.resize(SZ(cycle));
        return mmc;
    }
} mmc;
```

5.6 Heavy-Light decomposition

```
int siz[MAX] , son[MAX] , dep[MAX] , ffa[MAX];
int top[MAX] , idx[MAX] , idpo = 0;
int n , m;
int e[MAX][3];
vector<int> v[MAX];
struct node{ int big , sml; } st[MAX * 4];
void init(){
    REP(i , 0 , MAX) v[i].clear();
    MEM(siz , 0) , MEM(son , 0) , MEM(dep , 0) , MEM(
        ffa , 0);
    MEM(top , 0) , MEM(idx , 0) , idpo = 0;
}
void DFS1(int now , int fa , int deep){
    siz[now] = 1;
    dep[now] = deep;
    ffa[now] = fa;
    int big = 0;
    REP(i , 0 , v[now].size()){
        int to = v[now][i];
        if(to != fa){
            DFS1(to , now , deep + 1);
            siz[now] += siz[to];
            if(siz[to] > big) big = siz[to] , son[now]
                = to;
        }
    }
}
void DFS2(int now , int fa , int root){
    top[now] = root;
    idx[now] = ++idpo;
    if(son[now] != 0) DFS2(son[now] , now , root);
    REP(i , 0 , v[now].size()){
        int to = v[now][i];
        if(to != fa && to != son[now]) DFS2(to , now ,
            to);
    }
}
void solveinit(){
    DFS1(1 , 0 , 0);
    DFS2(1 , 0 , 1);
    REP(i , 2 , n + 1){
        int a = e[i][0] , b = e[i][1] , c = e[i][2];
        if(dep[a] < dep[b]) swap(a , b);
        update(1 , 1 , n , idx[a] , c);
    }
}
void query(int a , int b){
    node ans;
    ans.big = -INF , ans.sml = INF;
    int t1 = top[a] , t2 = top[b];
    while(t1 != t2){
        if(dep[t1] < dep[t2]) swap(t1 , t2) , swap(a ,
            b);
        ans = pull(ans , query(1 , 1 , n , idx[t1] ,
            idx[a]));
        a = ffa[t1] , t1 = top[a];
    }
    if(dep[a] > dep[b]) swap(a , b);
    if(a != b) ans = pull(ans , query(1 , 1 , n , idx[
        son[a]] , idx[b]));
    return cout << ans.sml << " " << ans.big << endl ,
        void();
}
init();
REP(i , 2 , n + 1){
    int a , b , c; cin >> a >> b >> c;
    e[i][0] = a , e[i][1] = b , e[i][2] = c;
    v[a].pb(b); v[b].pb(a);
```

```
}
solveinit();
query(a , b);
```

5.7 Dynamic MST

```
/* Dynamic MST O( Q lg^2 Q )
 (qx[i], qy[i])->chg weight of edge No.qx[i] to qy[i]
 delete an edge: (i, \infty)
 add an edge: change from \infty to specific value
 */
const int SZ=M+3*MXQ;
int a[N],*tz;
int find(int xx){
  int root=xx; while(a[root]) root=a[root];
  int next; while((next=a[xx])){a[xx]=root; xx=next; }
  return root;
}
bool cmp(int aa,int bb){ return tz[aa]<tz[bb]; }
int kx[N],ky[N],kt, vd[N],id[M], app[M];
bool extra[M];
void solve(int *qx,int *qy,int Q,int n,int *x,int *y,
    int *z,int m1,long long ans){
  if(Q==1){
    for(int i=1;i<=n;i++) a[i]=0;
    z[ qx[0] ]=qy[0]; tz = z;
    for(int i=0;i<m1;i++) id[i]=i;
    sort(id,id+m1,cmp); int ri,rj;
    for(int i=0;i<m1;i++){
      ri=find(x[id[i]]); rj=find(y[id[i]]);
      if(ri!=rj){ ans+=z[id[i]]; a[ri]=rj; }
    }
    printf("%lld\n",ans);
    return;
  }
  int ri,rj;
  //contract
  kt=0;
  for(int i=1;i<=n;i++) a[i]=0;
  for(int i=0;i<Q;i++){
    ri=find(x[qx[i]]); rj=find(y[qx[i]]); if(ri!=rj) a[
        ri]=rj;
  }
  int tm=0;
  for(int i=0;i<m1;i++) extra[i]=true;
  for(int i=0;i<Q;i++) extra[ qx[i] ]=false;
  for(int i=0;i<m1;i++) if(extra[i]) id[tm++]=i;
  tz=z; sort(id,id+tm,cmp);
  for(int i=0;i<tm;i++){
    ri=find(x[id[i]]); rj=find(y[id[i]]);
    if(ri!=rj){
      a[ri]=rj; ans += z[id[i]];
      kx[kt]=x[id[i]]; ky[kt]=y[id[i]]; kt++;
    }
  }
  for(int i=1;i<=n;i++) a[i]=0;
  for(int i=0;i<kt;i++) a[ find(kx[i]) ]=find(ky[i]);
  int n2=0;
  for(int i=1;i<=n;i++) if(a[i]==0)
  vd[i]=++n2;
  for(int i=1;i<=n;i++) if(a[i])
  vd[i]=vd[find(i)];
  int m2=0, *Nx=x+m1, *Ny=y+m1, *Nz=z+m1;
  for(int i=0;i<m1;i++) app[i]=-1;
  for(int i=0;i<Q;i++) if(app[qx[i]]==-1){
    Nx[m2]=vd[ x[ qx[i] ] ]; Ny[m2]=vd[ y[ qx[i] ] ];
        Nz[m2]=z[ qx[i] ];
    app[qx[i]]=m2; m2++;
  }
  for(int i=0;i<Q;i++){ z[ qx[i] ]=qy[i]; qx[i]=app[qx[
      i]]; }
  for(int i=1;i<=n2;i++) a[i]=0;
  for(int i=0;i<tm;i++){
    ri=find(vd[ x[id[i]] ]);  rj=find(vd[ y[id[i]] ]);
    if(ri!=rj){
      a[ri]=rj; Nx[m2]=vd[ x[id[i]] ];
      Ny[m2]=vd[ y[id[i]] ]; Nz[m2]=z[id[i]]; m2++;
    }
  }
  int mid=Q/2;
  solve(qx,qy,mid,n2,Nx,Ny,Nz,m2,ans);
  solve(qx+mid,qy+mid,Q-mid,n2,Nx,Ny,Nz,m2,ans);
}
int x[SZ],y[SZ],z[SZ],qx[MXQ],qy[MXQ],n,m,Q;
void init(){
  scanf("%d%d",&n,&m);
  for(int i=0;i<m;i++) scanf("%d%d%d",x+i,y+i,z+i);
  scanf("%d",&Q);
  for(int i=0;i<Q;i++){ scanf("%d%d",qx+i,qy+i); qx[i
      ]--; }
}
void work(){ if(Q) solve(qx,qy,Q,n,x,y,z,m,0); }
int main(){init(); work(); }
```

5.8 Minimum Steiner Tree

```
// Minimum Steiner Tree
// O(V 3^T + V^2 2^T)
struct SteinerTree{
#define V 33
#define T 8
#define INF 1023456789
    int n , dst[V][V] , dp[1 << T][V] , tdst[V];
    void init( int _n ){
        n = _n;
        for( int i = 0 ; i < n ; i ++ ){
            for( int j = 0 ; j < n ; j ++ )
                dst[ i ][ j ] = INF;
            dst[ i ][ i ] = 0;
        }
    }
    void add_edge( int ui , int vi , int wi ){
        dst[ ui ][ vi ] = min( dst[ ui ][ vi ] , wi );
        dst[ vi ][ ui ] = min( dst[ vi ][ ui ] , wi );
    }
    void shortest_path(){
        for( int k = 0 ; k < n ; k ++ )
            for( int i = 0 ; i < n ; i ++ )
                for( int j = 0 ; j < n ; j ++ )
                    dst[ i ][ j ] = min( dst[ i ][ j ],
                            dst[ i ][ k ] + dst[ k ][ j
                                ] );
    }
    int solve( const vector<int>& ter ){
        int t = (int)ter.size();
        for( int i = 0 ; i < ( 1 << t ) ; i ++ )
            for( int j = 0 ; j < n ; j ++ )
                dp[ i ][ j ] = INF;
        for( int i = 0 ; i < n ; i ++ )
            dp[ 0 ][ i ] = 0;
        for( int msk = 1 ; msk < ( 1 << t ) ; msk ++ ){
            if( msk == ( msk & (-msk) ) ){
                int who = __lg( msk );
                for( int i = 0 ; i < n ; i ++ )
                    dp[ msk ][ i ] = dst[ ter[ who ] ][
                        i ];
                continue;
            }
            for( int i = 0 ; i < n ; i ++ )
                for( int submsk = ( msk - 1 ) & msk ;
                    submsk ;
                        submsk = ( submsk - 1 ) & msk )
                    dp[ msk ][ i ] = min( dp[ msk ][ i
                        ],
                            dp[ submsk ][ i ] +
                            dp[ msk ^ submsk ][ i ] );
            for( int i = 0 ; i < n ; i ++ ){
                tdst[ i ] = INF;
                for( int j = 0 ; j < n ; j ++ )
                    tdst[ i ] = min( tdst[ i ],
                            dp[ msk ][ j ] + dst[ j ][
                                i ] );
            }
            for( int i = 0 ; i < n ; i ++ )
                dp[ msk ][ i ] = tdst[ i ];
        }
        int ans = INF;
        for( int i = 0 ; i < n ; i ++ )
            ans = min( ans , dp[ ( 1 << t ) - 1 ][ i ]
                );
```

```
        return ans;
    }
} solver;
```

5.9 Maximum Clique

```
struct BKB{
    static const int MAX_N = 50;
    typedef bitset<MAX_N> bst;
    bst N[MAX_N];
    int n;
    ll wei[MAX_N], ans, cc;
    BKB(int _n = 0): n(_n), ans(0), cc(0){
        for(int i = 0; i < _n; ++ i)
            N[i].reset();
    }
    void add_edge(int a, int b) {
        N[a][b] = N[b][a] = 1;
    }
    void set_wei(int a, ll w) {
        wei[a] = w;
    }
    ll CNT(bst P) {
        //if vertices have no weight: return P.count();
        ll rt = 0;
        for(int i = P._Find_first(); i < n; i = P.
            _Find_next(i) )
            rt += wei[i];
        return rt;
    }
    void pro(bst P, ll cnt = 0) {
        if (!P.any()){
            if(cnt == ans)
                ++ cc;
            else if(cnt > ans) {
                ans = cnt;
                cc = 1;
            }
            return;
        }
        // "<" can be change to "<=" if we don't need
            to count
        if ( CNT(P) + cnt < ans)
            return;
        int u = P._Find_first();
        bst now = P & ~N[u];
        for (int i = now._Find_first(); i < n; i = now.
            _Find_next(i) ) {
            pro(P & N[i], cnt + wei[i]);
            P[i] = 0;
        }
        return;
    }
    pll solve() {
        bst tmp;
        tmp.reset();
        for(int i = 0; i < n; ++ i)
            tmp[i] = 1;
        pro(tmp);
        return pll(ans, cc);
    }
} ss(0);
```

5.10 Zhu Liu Algo

```
struct ZL{
  //1 base edge and vertex
    static const int N=556,M=2660, MM = M * 10,inf=1e9;
    //MM = M * log N
  struct bian{
      int u,v,w,use,id;
  }b[M],a[MM];
  int n,m=0,ans,pre[N],id[N],vis[N],root,In[N],h[N],len
      ,way[M];
  void init(int _n,int _root){
        for (int i = 0; i < MM; ++i) {
            a[i] = {0, 0, 0, 0, 0};
        }
    n=_n; m=0; b[0].w=1e9; root=_root;
  }
  void add(int u,int v,int w){
    b[++m]=(bian){u,v,w,0,m};
    a[m]=b[m];
  }
  int work(){
    len=m;
      for (;;){
        for (int i=1;i<=n;i++){pre[i]=0; In[i]=inf;
            id[i]=0; vis[i]=0; h[i]=0;}
        for (int i=1;i<=m;i++)
            if (b[i].u!=b[i].v&&b[i].w<In[b[i].v]){
                pre[b[i].v]=b[i].u; In[b[i].v]=b[i].w
                    ; h[b[i].v]=b[i].id;
            }
        for (int i=1;i<=n;i++) if (pre[i]==0&&i!=root
            ) return 0;
        int cnt=0; In[root]=0;
        for (int i=1;i<=n;i++){
            if (i!=root) a[h[i]].use++;
            int now=i; ans+=In[i];
            while (vis[now]==0&&now!=root){
                vis[now]=i; now=pre[now];
            }
            if (now!=root&&vis[now]==i){
                cnt++; int kk=now;
                while (1){
                    id[now]=cnt; now=pre[now];
                    if (now==kk) break;
                }
            }
        }
        if (cnt==0) return 1;
        for (int i=1;i<=n;i++) if (id[i]==0) id[i]=++
            cnt;
        for (int i=1;i<=m;i++){
            int k1=In[b[i].v]; int k2=b[i].v;
            b[i].u=id[b[i].u]; b[i].v=id[b[i].v];
            if (b[i].u!=b[i].v){
                b[i].w-=k1; a[++len].u=b[i].id; a[len
                    ].v=h[k2];
                b[i].id=len;
            }
        }
        n=cnt;
        root=id[root];
      }
      return 1;
  }
  int getway(){
    for (int i=1;i<=m;i++) way[i]=0;
    for (int i=len;i>m;i--){
      a[a[i].u].use+=a[i].use; a[a[i].v].use-=a[i].use;
    }
    for (int i=1;i<=m;i++) way[i]=a[i].use;
        int ret = 0;
        for (int i = 1; i <= m; ++i){
            if (way[i] == 1) {
                ret += a[i].w;
            }
        }
        return ret;
  }
} zl;
//if zl.work() == 0, then it is not connected
//otherwise, use zl.getway() to check bian is selected
    or not
```

6 Math

6.1 Big Integer

```
struct Bigint{
    static const int LEN = 60;
    static const int BIGMOD = 10000;
    int s;
    int vl, v[LEN];
```

```
//  vector<int> v;
Bigint() : s(1) { vl = 0; }
Bigint(long long a) {
    s = 1; vl = 0;
    if (a < 0) { s = -1; a = -a; }
    while (a) {
        push_back(a % BIGMOD);
        a /= BIGMOD;
    }
}
Bigint(string str) {
    s = 1; vl = 0;
    int stPos = 0, num = 0;
    if (!str.empty() && str[0] == '-') {
        stPos = 1;
        s = -1;
    }
    for (int i=SZ(str)-1, q=1; i>=stPos; i--) {
        num += (str[i] - '0') * q;
        if ((q *= 10) >= BIGMOD) {
            push_back(num);
            num = 0; q = 1;
        }
    }
    if (num) push_back(num);
    n();
}
int len() const {
    return vl;//return SZ(v);
}
bool empty() const { return len() == 0; }
void push_back(int x) {
    v[vl++] = x; //v.PB(x);
}
void pop_back() {
    vl--; //v.pop_back();
}
int back() const {
    return v[vl-1]; //return v.back();
}
void n() {
    while (!empty() && !back()) pop_back();
}
void resize(int nl) {
    vl = nl; //v.resize(nl);
    fill(v, v+vl, 0); //fill(ALL(v), 0);
}
void print() const {
    if (empty()) { putchar('0'); return; }
    if (s == -1) putchar('-');
    printf("%d", back());
    for (int i=len()-2; i>=0; i--) printf("%.4d",v[
        i]);
}
friend std::ostream& operator << (std::ostream& out
    , const Bigint &a) {
    if (a.empty()) { out << "0"; return out; }
    if (a.s == -1) out << "-";
    out << a.back();
    for (int i=a.len()-2; i>=0; i--) {
        char str[10];
        snprintf(str, 5, "%.4d", a.v[i]);
        out << str;
    }
    return out;
}
int cp3(const Bigint &b)const {
    if (s != b.s) return s - b.s;
    if (s == -1) return -(-*this).cp3(-b);
    if (len() != b.len()) return len()-b.len();//
        int
    for (int i=len()-1; i>=0; i--)
        if (v[i]!=b.v[i]) return v[i]-b.v[i];
    return 0;
}
bool operator<(const Bigint &b)const
{ return cp3(b)<0; }
bool operator<=(const Bigint &b)const
{ return cp3(b)<=0; }
bool operator==(const Bigint &b)const
{ return cp3(b)==0; }
bool operator!=(const Bigint &b)const
{ return cp3(b)!=0; }
bool operator>(const Bigint &b)const
{ return cp3(b)>0; }
bool operator>=(const Bigint &b)const
{ return cp3(b)>=0; }
Bigint operator - () const {
    Bigint r = (*this);
    r.s = -r.s;
    return r;
}
Bigint operator + (const Bigint &b) const {
    if (s == -1) return -(-(*this)+(-b));
    if (b.s == -1) return (*this)-(-b);
    Bigint r;
    int nl = max(len(), b.len());
    r.resize(nl + 1);
    for (int i=0; i<nl; i++) {
        if (i < len()) r.v[i] += v[i];
        if (i < b.len()) r.v[i] += b.v[i];
        if(r.v[i] >= BIGMOD) {
            r.v[i+1] += r.v[i] / BIGMOD;
            r.v[i] %= BIGMOD;
        }
    }
    r.n();
    return r;
}
Bigint operator - (const Bigint &b) const {
    if (s == -1) return -(-(*this)-(-b));
    if (b.s == -1) return (*this)+(-b);
    if ((*this) < b) return -(b-(*this));
    Bigint r;
    r.resize(len());
    for (int i=0; i<len(); i++) {
        r.v[i] += v[i];
        if (i < b.len()) r.v[i] -= b.v[i];
        if (r.v[i] < 0) {
            r.v[i] += BIGMOD;
            r.v[i+1]--;
        }
    }
    r.n();
    return r;
}
Bigint operator * (const Bigint &b) {
    Bigint r;
    r.resize(len() + b.len() + 1);
    r.s = s * b.s;
    for (int i=0; i<len(); i++) {
        for (int j=0; j<b.len(); j++) {
            r.v[i+j] += v[i] * b.v[j];
            if(r.v[i+j] >= BIGMOD) {
                r.v[i+j+1] += r.v[i+j] / BIGMOD;
                r.v[i+j] %= BIGMOD;
            }
        }
    }
    r.n();
    return r;
}
Bigint operator / (const Bigint &b) {
    Bigint r;
    r.resize(max(1, len()-b.len()+1));
    int oriS = s;
    Bigint b2 = b; // b2 = abs(b)
    s = b2.s = r.s = 1;
    for (int i=r.len()-1; i>=0; i--) {
        int d=0, u=BIGMOD-1;
        while(d<u) {
            int m = (d+u+1)>>1;
            r.v[i] = m;
            if((r*b2) > (*this)) u = m-1;
            else d = m;
        }
        r.v[i] = d;
    }
    s = oriS;
    r.s = s * b.s;
    r.n();
    return r;
}
Bigint operator % (const Bigint &b) {
```

```
        return (*this)-(*this)/b*b;
    }
};
```

6.2 FFT

```
#include <bits/stdc++.h>
using namespace std;

const int MAXN = 2*262144;
typedef long double ld;
typedef complex<ld> cplx;
const ld PI = acos(-1);
const cplx I(0,1);
cplx omega[MAXN+1];
void pre_fft() {
  for (int i=0;i<=MAXN;i++) {
    omega[i] = exp(i*2*PI/MAXN*I);
  }
}
void fft(int n,cplx a[],bool inv=false) {
  int basic=MAXN/n;
  int theta=basic;
  for (int m=n;m>=2;m>>=1) {
    int mh=m>>1;
    for (int i=0;i<mh;i++) {
      cplx w=omega[inv?MAXN-(i*theta%MAXN):i*theta%MAXN
          ];
      for (int j=i;j<n;j+=m) {
        int k=j+mh;
        cplx x=a[j]-a[k];
        a[j] += a[k];
        a[k] = w*x;
      }
    }
    theta = (theta*2)%MAXN;
  }
  int i=0;
  for (int j=1;j<n-1;j++) {
    for (int k=n>>1;k>(i^=k);k>>=1) ;
    if (j<i) swap(a[i],a[j]);
  }
  if (inv) {
    for (int i=0;i<n;i++) a[i]/=n;
  }
}
cplx a[MAXN],b[MAXN],c[MAXN];
//how to use :
/*
pre_fft();
fft(n,a);
fft(n,b);
for (int i=0;n>i;i++) {
  c[i] = a[i]*b[i];
}
fft(n,c,1);
*/
```

6.3 NTT

```
// Remember coefficient are mod P
/*
(mod,root)
(65537,3)
(23068673,3)
(998244353,3)
(1107296257,10)
(2013265921,31)
(2885681153,3)
*/
typedef long long ll;
const int maxn = 65536;

struct NTT{
    ll mod = 2013265921, root = 31;
    ll omega[maxn+1];
    void prentt() {
        ll x=fpow(root,(mod-1)/maxn);
        omega[0] = 1;
        for (int i=1;i<=maxn;++i) {
            omega[i] = omega[i-1] * x % mod;
        }
    }
    void real_init(ll _mod,ll _root) {
        mod = _mod;
        root = _root;
        prentt();
    }
    ll fpow(ll a,ll n) {
        (n += mod-1) %= mod - 1;
        ll r = 1;
        for (; n; n>>=1) {
            if (n&1) (r*=a)%=mod;
            (a*=a)%=mod;
        }
        return r;
    }
    void bitrev(vector<ll> &v,int n) {
        int z = __builtin_ctz(n)-1;
        for (int i=0;i<n;++i) {
            int x=0;
            for (int j=0;j<=z;++j) x ^= ((i>>j&1) << (z
                -j));
            if (x>i) swap(v[x],v[i]);
        }
    }
    void ntt(vector<ll> &v,int n) {
        bitrev(v,n);
        for (int s=2;s<=n;s<<=1) {
            int z = s>>1;
            for (int i=0;i<n;i+=s) {
                for (int k=0;k<z;++k) {
                    ll x = v[i+k+z] * omega[maxn/s * k]
                        % mod;
                    v[i+k+z] = (v[i+k] + mod - x)%mod;
                    (v[i+k] += x) %= mod;
                }
            }
        }
    }
    void intt(vector<ll> &v,int n) {
        ntt(v,n);
        reverse(v.begin()+1,v.end());
        ll inv = fpow(n,mod-2);
        for (int i=0;i<n;++i) {
            (v[i] *= inv) %= mod;
        }
    }
    vector<ll> conv(vector<ll> a,vector<ll> b) {
        int sz=1;
        while (sz < a.size() + b.size() - 1) sz <<= 1;
        vector<ll> c(sz);
        while (a.size() < sz) a.push_back(0);
        while (b.size() < sz) b.push_back(0);
        ntt(a,sz), ntt(b,sz);
        for (int i=0;i<sz;++i) c[i] = (a[i] * b[i]) %
            mod;
        intt(c,sz);
        while (c.size() && c.back() == 0) c.pop_back();
        return c;
    }
};
ll chinese(ll b1, ll m1, ll b2, ll m2) {
    ll a1 = bigpow(m2,m1-2,m1)*b1 % m1;
    ll a2 = bigpow(m1,m2-2,m2)*b2 % m2;
    ll ret= (a1*m2 + a2*m1)%(m1*m2);
    assert(ret%m1 == b1 && ret%m2 == b2);
    return ret;
}
```

6.4 FWT

```
void FWT(ll a[],int n){
    for(int d = 1 ;d < n; d <<= 1)  // d = half of
        block size
        for(int i = 0; i < n; i += d + d) // every
            block
```

```
            for(int j = i; j < i + d; j++){   //
                processing
                ll x = a[j], y = a[j + d];
                a[j] = x + y;   a[j + d] = x - y; //FWT
                    XOR
                a[j] = x + y; //FWT AND
                a[j + d] = y + x; //FWT OR
                a[j] = (x + y) / 2;   a[j + d] = (x - y
                    ) / 2; //IFWT XOR
                a[j] = x - y; //IFWT AND
                a[j + d] = y - x; //IFWT OR
            }
}
```

6.5 Gaussian Elimination

```
const int GAUSS_MOD = 100000007LL;
struct GAUSS{
    int n;
    vector<vector<int>> v;
    int ppow(int a , int k){
        if(k == 0) return 1;
        if(k % 2 == 0) return ppow(a * a % GAUSS_MOD ,
            k >> 1);
        if(k % 2 == 1) return ppow(a * a % GAUSS_MOD ,
            k >> 1) * a % GAUSS_MOD;
    }
    vector<int> solve(){
        vector<int> ans(n);
        REP(now , 0 , n){
            REP(i , now , n) if(v[now][now] == 0 && v[i
                ][now] != 0)
                swap(v[i] , v[now]); // det = -det;
            if(v[now][now] == 0) return ans;
            int inv = ppow(v[now][now] , GAUSS_MOD - 2)
                ;
            REP(i , 0 , n) if(i != now){
                int tmp = v[i][now] * inv % GAUSS_MOD;
                REP(j , now , n + 1) (v[i][j] +=
                    GAUSS_MOD - tmp * v[now][j] %
                    GAUSS_MOD) %= GAUSS_MOD;
            }
        }
        REP(i , 0 , n) ans[i] = v[i][n + 1] * ppow(v[i
            ][i] , GAUSS_MOD - 2) % GAUSS_MOD;
        return ans;
    }
    // gs.v.clear() , gs.v.resize(n , vector<int>(n + 1
        , 0));
} gs;
```

6.6 Miller Rabin

```
ll mul(ll a,ll b,ll mod) {
    //return a*b%mod;
    //calculate a*b % mod
    ll r=0;
    a%=mod; b%=mod;
    while (b) {
        if (b&1) r=(a+r>=mod?a+r-mod:a+r);
        a=(a+a>=mod?a+a-mod:a+a);
        b>>=1;
    }
    return r;
}
ll pow(ll a,ll n,ll mod) {
    if (n==0) return 1ll;
    else if (n==1) return a%mod;
    return mul( pow(mul(a,a,mod),n/2,mod),n%2?a:1,mod )
        ;
}
const bool PRIME = 1, COMPOSITE = 0;
bool miller_robin(ll n,ll a) {
    if (__gcd(a,n) == n) return PRIME;
    if (__gcd(a,n) != 1) return COMPOSITE;
    ll d=n-1,r=0,ret;
    while (d%2==0) {
        r++; d/=2;
    }
    ret = pow(a,d,n);
    if (ret==1 ||ret==n-1) return PRIME;
    while (r--) {
        ret = mul(ret,ret,n);
        if (ret==n-1) return PRIME;
    }
    return COMPOSITE;
}
bool isPrime(ll n) {
    //for int: 2,7,61
    ll as[7] =
        {2,325,9375,28178,450775,9780504,1795265022};
    for (int i=0;7>i;i++) {
        if (miller_robin(n,as[i]) == COMPOSITE) return
            COMPOSITE;
    }
    return PRIME;
}
```

6.7 Pollard Rho

```
ll a, c;
ll doo(ll x, ll n) {
    return addd( mull( a, mull(x, x, n), n ), c, n);
}
ll solve(ll n) {
    if (isPrime(n)) return n;
    if (!(n & 1)) return 2;
    a = myRnd() % n; if (!a) a=1;
    c = myRnd() % n;
    while (c == 0 || c == 2) c = myRnd()%n;
    ll start = myRnd()%n;
    ll s1 = doo(start, n), s2 = doo(s1, n);
    while (true) {
        if (s1 == s2) {
            start = myRnd() % n;
            //a=myRnd()+1;
            a = Rnd() % n; if (!a) a = 1;
            c = Rnd() % n; while (c == 0 || c == 2) c =
                myRnd() % n;
            s1 = doo(start, n), s2 = doo(s1, n);
            continue;
        }
        ll _ = gcd(abs(s1 - s2), n);
        if (_ != 1) {
            return min(solve(_), solve(n / _));
        }
        s1 = doo(s1, n); s2 = doo(s2, n); s2 = doo(s2,
            n);
    }
}
```

6.8 Meissel-Lehmer Algorithm

```
#define MEM1(a) memset( (a) , 0 , sizeof( (a) ) );
const int N = 320000 + 6;
const int C = 10005;
const int D = 306;
LL pi_form[N];
LL phi_form[C][D];
LL p2_form[C][D];
LL p[N];
bool prime[N];
void init() {
    MEM1(phi_form);
    MEM1(p2_form);
    prime[0] = prime[1] = 1;
    int id=1;
    for (int i=2;N>i;i++) {
        if (!prime[i]) {
            for (LL j=i*1LL*i;N>j;j+=i) prime[j] = 1;
            p[id++] = i;
        }
        pi_form[i] = pi_form[i-1] + (!prime[i]);
    }
}
LL pi(LL m);
```

```
LL p2(LL m,LL n) {
    //cout<<"p2 = "<<p2_form[m][n]<<endl;
    if (m<C && n<D && p2_form[m][n] != -1) return
        p2_form[m][n];
    if (p[n] == 0) return 0;
    LL ret = 0, tmp=sqrt(m);
    for (LL i=n+1;p[i] <= tmp;i++) ret += pi(m/p[i]) -
        pi(p[i]) + 1;
    if (m < C && n < D) p2_form[m][n] = ret;
    return ret;
}
LL phi2(LL m,LL n) {
    if (m < C && n < D && phi_form[m][n] != -1) return
        phi_form[m][n];
    if (!n) return m;
    if (p[n] >= m) return 1;
    if (m<C && n<D) return phi_form[m][n] =  phi2(m,n
        -1) - phi2(m/p[n],n-1);
    return phi2(m,n-1) - phi2(m/p[n],n-1);
}
LL pi(LL m) {
    if (m < N) return pi_form[m];
    else {
        LL n=ceil(cbrt(m));
        return phi2(m,n) + n - 1 - p2(m,n);
    }
}
//init(); cin >> n; cout << pi(n); (n <= 10^11)
```

6.9 De Brujin

```
int res[maxn], aux[maxn], a[maxn], sz;

void db(int t, int p, int n, int k) {
    if (sz >= tg) return;
    if (t > n) {
        if (n % p == 0) {
            for (int i = 1; i <= p && sz < tg; ++i) res
                [sz++] = aux[i];
        }
    } else {
        aux[t] = aux[t - p];
        db(t + 1, p, n, k);
        for (int i = aux[t - p] + 1; i < k; ++i) {
            aux[t] = i;
            db(t + 1, t, n, k);
        }
    }
}

int de_bruijn(int k, int n) {
    // return cyclic string of length k^n such that
        every string of length n using k character
        appears as a substring.
    if (k == 1) {
        res[0] = 0;
        return 1;
    }
    for (int i = 0; i < k * n; i++) aux[i] = 0;
    sz = 0;
    db(1, 1, n, k);
    return sz;
}
```

6.10 Simplex Algorithm

```
/*
maximize Cx under
Ax <=b
x >= 0
b >= 0
n variables
m constraints
A is m by n
*/
const int MAX = 45;
int n, m;
double arr[MAX][MAX];
bool pro(){
    double mi = 0;
    int x = 1;
    for(int i = 1; i <= n + m; i ++)    if(arr[0][i] <
        mi){
        mi = arr[0][i];
        x = i;
    }
    if(abs(mi) < eps)   return 0;   // sigma <= 0
    mi = INF;   // theta
    int y = 0;
    for(int i = 1; i <= m; i ++){
        if(arr[i][x] > eps && arr[i][n + m + 1] / arr[i
            ][x] < mi) {
                mi = arr[i][n + m + 1] / arr[i][x];
                y = i;
        }
    }
    assert(y);
    double weed = arr[y][x];
    for(int i = 1; i <= n + m + 1 ; ++ i)
        arr[y][i] /= weed;
    // now arr[y][n + m + 1] == theta
    for(int i = 0; i <= m; i ++){
        if(i == y)  continue;
        double f = arr[i][x];
        for(int j = 1; j <= m + n + 1; j ++)
            arr[i][j] -= f * arr[y][j];
    }
    return 1;
}
int main(){
    cin >> n;
    cin >> m;
    memset(arr, 0, sizeof arr);
    // input C
    for(int i = 1 ; i <= n; i++ ){
        cin >> arr[0][i];
        arr[0][i] = - arr[0][i];
    }
    for(int i = 1; i <= m; i++){
        // input A
        for(int j = 1; j <= n; j++)
            cin >> arr[i][j];
        arr[i][n + i] = 1;
        // input b
        cin >> arr[i][n + m + 1];
    }
    while(pro());
    cout << arr[0][n + m + 1] << "\n";
    return 0;
}
```

6.11 Cipolla's algorithm

```
struct Cipolla
{
    ll p, n, a, w;
    Cipolla(ll _p, ll _n) : p(_p), n(_n){
        n %= p;
        a = -1;
    }
    ll power(ll a, ll x) {
        if(x == 0)  return 1;
        return power(a * a % p, x >> 1) * (x & 1 ? a :
            1) % p;
    }
    inline int lgd(ll x) {
        return power(x, (p - 1) / 2);
    }
    ll rnd() {
        return ( ((ll)rand() << 28) + rand());
    }
    pll mul(pll a, pll b) {
        return pll( (a.F * b.F + a.S * b.S % p * w) % p
            ,
                    (a.F * b.S + a.S * b.F) % p );
    }
    pll power(pll ii, ll x) {
```

```
        if(x == 0)  return pll(1, 0);
        return mul(power(mul(ii, ii), x >> 1), (x & 1 ?
             ii : pll(1, 0)));
    }
    ll solve() {
        if(p == 2)
            return n & 1;
        if(lgd(n) == p - 1)    return -1;
        if(n == 0)  return 0;
        while(a = rnd() % p, lgd((a * a  - n + p)% p)
            == 1);
        w = (a * a - n + p) % p;
        pll ii = power(pll(a, 1), (p + 1) / 2);
        assert(ii.S == 0);
        return ii.F;
    }
};
```

6.12 FWT XOR with ternary

```
pii operator*(const pii &p1, const pii &p2) {
    return {subb(mull(p1.F, p2.F) - mull(p1.S, p2.S)),
            subb(addd(mull(p1.F, p2.S) + mull(p1.S, p2.
                F)) - mull(p1.S, p2.S))};
}
pii cal1(pii p) {
    return {subb(-p.S), subb(p.F - p.S)};
}
pii cal2(pii p) {
    return {subb(p.S - p.F), subb(-p.F)};
}
//C is the size of a
void DFT(vector<pii> &a) {
    for (int mid = 1; mid < C; mid *= 3) {
        for (int j = 0; j < C; j += mid * 3) {
            for (int k = 0; k < mid; ++k) {
                pii x = a[j + k], y = a[j + k + mid], z
                     = a[j + k + (mid << 1)];
                a[j + k] = x + y + z;
                a[j + k + mid] = x + cal1(y) + cal2(z);
                a[j + k + (mid << 1)] = x + cal2(y) +
                    cal1(z);
            }
        }
    }
}
const int invn = ppow(C, mod - 2);
void IDFT(vector<pii> &a) {
    for (int mid = 1; mid < C; mid *= 3) {
        for (int j = 0; j < C; j += mid * 3) {
            for (int k = 0; k < mid; ++k) {
                pii x = a[j + k], y = a[j + k + mid],
                    z = a[j + k + (mid << 1)];
                a[j + k] = x + y + z;
                a[j + k + mid] = x + cal2(y) + cal1(z);
                a[j + k + (mid << 1)] = x + cal1(y) +
                    cal2(z);
            }
        }
    }
    for (int i = 0; i < C; ++i) {
        a[i].F = mull(a[i].F, invn);
    }
}
void ff(vector<pii> &a, vector<pii> b) {
    DFT(a); DFT(b);
    for (int i = 0; i < C; ++i) {
        a[i] = a[i] * b[i];
    }
    IDFT(a);
}
```

7 String

7.1 string tools

```
const KMP_SIZE = ;
struct KMP{
    string s;
    int f[KMP_SIZE] , pos;
    void solve(){
        f[0] = pos = -1;
        REP(i , 1 , s.size()){
            while(pos != -1 && s[pos + 1] != s[i]) pos
                = f[pos];
            if(s[pos + 1] == s[i]) pos ++;
            f[i] = pos;
        }
    }
};
const int ZVALUE_SIZE = ;
struct Z_VALUE{
    string s;
    int l = 0 , r = 0 , z[ZVALUE_SIZE];
    void solve(){
        REP(i , 0 , s.size()){
            z[i] = max(min(z[i - l] , r - i) , 0LL);
            while(i + z[i] < s.size() && s[z[i]] == s[i
                 + z[i]]){
                l = i , r = i + z[i];
                z[i] ++;
            }
        }
    }
};
const int PALINDROME_MAX = 2 * ;
struct Palindrome{
    string s , ss; // ss = input
    int z[PALINDROME_MAX];
    void solve(){
        s.resize(ss.size() + ss.size() + 1 , '.');
        REP(i , 0 , ss.size()) s[i + i + 1] = ss[i];
        int l = 0 , r = 0;
        REP(i , 0 , s.size()){
            z[i] = max(min(z[l + l - i] , r - i) , 1);
            while(i - z[i] >= 0 && i + z[i] < s.size()
                && s[i - z[i]] == s[i + z[i]]){
                l = i , r = i + z[i];
                z[i] ++;
            }
        }
    }
};
```

7.2 Aho-Corasick algorithm

```
struct AC_Automata {
    static const int N = 2e4 + 6;
    static const int SIGMA = 26;
    int ch[N][SIGMA], val[N], sz;
    int last[N],fail[N];
    int que[N],qs,qe, cnt[N];
    void init() {
        sz = 1;
        memset(ch[0],0,sizeof(ch[0]));
        qs = qe  = 0;
        memset(cnt,0,sizeof(cnt)); memset(val,0,sizeof(
            val)); memset(last,0,sizeof(last));
    }
    int idx(char c) {
        return c-'a';
    }
    int insert(string s,int v) {
        int now=0;
        int n=s.size();
        for (int i = 0; i < n; ++i) {
            int c=idx(s[i]);
            if (!ch[now][c]) {
                memset(ch[sz],0,sizeof(ch[sz]));
                val[sz] = 0; ch[now][c] = sz++;
            }
            now = ch[now][c];
        }
        val[now] = v;
        return now;
    }
```

```
    void print(int j) {
        if (j) {
            //now we match string v[j]
            print(last[j]);  //may match multiple
                strings
        }
    }
    void getFail() {
        qs=0,qe=0; fail[0]=0;
        for (int c = 0; c < SIGMA; c++) {
            int now=ch[0][c];
            if (now) {
                fail[now] = 0;
                que[qe++] = now;
                last[now] = 0;
            }
        }
        while (qs != qe) {
            int t=que[qs++];
            for (int c = 0; c < SIGMA; c++) {
                int now=ch[t][c];
                if (!now) continue;
                que[qe++] = now;
                int v=fail[t];
                while (v && !ch[v][c]) v=fail[v];
                fail[now] = ch[v][c];
                last[now] = val[ fail[now] ]? fail[now
                    ]:last[ fail[now] ];
            }
        }
    }
    void Find(string s) {
        getFail();
        int n=s.size(), now=0;
        for (int i=0;n>i;i++) {
            int c=idx(s[i]);
            while (now && !ch[now][c]) now = fail[now];
            now = ch[now][c];
            cnt[now]++;
        }
        for (int i=qe-1;i>=0;i--) {
            cnt[ fail[que[i]] ] += cnt[ que[i] ];
        }
    }
    void AC_evolution() {
        for (qs=1;qs!=qe;) {
            int now=que[qs++];
            for (int i=0;SIGMA>i;i++) {
                if (ch[now][i] == 0) ch[now][i] = ch[
                    fail[now]][i];
            }
        }
    }
} ac;

const int N = 156;
string s[N];
int ed[N];

ac.init();
ac.insert(s[i],i);
ac.Find();
ac.cnt[ ac.insert(s[i],i) ];
```

7.3 Suffix array

```
const int SA_SIZE = ;
const int logn = 1 + ;
string s;
int sa[SA_SIZE] , rk[SA_SIZE] , lcp[SA_SIZE];
int tma[2][SA_SIZE] , c[SA_SIZE] , sp[SA_SIZE][logn];

int getsa(){
    -> update m = ? // how many char
    int *x = tma[0] , *y = tma[1] , n = s.size() , m =
        200;
    REP(i , 0 , m) c[i] = 0;
    REP(i , 0 , n) c[x[i] = s[i]] ++;
    REP(i , 1 , m) c[i] += c[i - 1];
    RREP(i , n - 1 , 0) sa[--c[x[i]]] = i;
    for(int k = 1 ; k <= n ; k <<= 1){
        REP(i , 0 , m) c[i] = 0;
        REP(i , 0 , n) c[x[i]] ++;
        REP(i , 1 , m) c[i] += c[i - 1];
        int p = 0;
        REP(i , n - k , n) y[p ++] = i;
        REP(i , 0 , n) if(sa[i] >= k) y[p ++] = sa[i] -
            k;
        RREP(i , n - 1 , 0) sa[--c[x[y[i]]]] = y[i];
        y[sa[0]] = p = 0;
        REP(i , 1 , n) {
            if( x[sa[i]] == x[sa[i - 1]] && sa[i] + k <
                n && sa[i - 1] + k < n &&
                x[sa[i] + k] == x[sa[i - 1] + k] );
            else p ++;
            y[sa[i]] = p;
        }
        swap(x , y);
        if(p + 1 == n) break;
        m = p + 1;
    }
}
void getlcp(){
    int tmp = 0 , n = s.size();
    REP(i , 0 , n) rk[sa[i]] = i;
    REP(i , 0 , n){
        if(rk[i] == 0) lcp[0] = 0;
        else {
            if(tmp) tmp --;
            int po = sa[rk[i] - 1];
            while(tmp + po < n && tmp + i < n && s[tmp
                + i] == s[tmp + po]) tmp ++;
            lcp[rk[i]] = tmp;
        }
    }
}
void getsp(){
    int n = s.size();
    REP(i , 0 , n) sp[rk[i]][0] = s.size() - i;
    REP(i , 1 , n) sp[i - 1][1] = lcp[i];
    REP(i , 2 , logn){
        REP(j , 0 , n){
            if(j + (1 << (i - 2)) >= s.size()) continue
                ;
            sp[j][i] = min(sp[j][i - 1] , sp[j + (1 <<
                (i - 2))][i - 1]);
        }
    }
}
int Query(int L , int R){
    int tmp = (L == R) ? 0 : 32 - __builtin_clz(R - L);
    if(tmp == 0) return sp[L][0];
    else return min(sp[L][tmp] , sp[R - (1 << (tmp - 1)
        )][tmp]);
}
int Find(string ss){
    int L = 0 , R = s.size() , now;
    while(R - L > 1){
        now = (L + R) / 2;
        if(s[sa[now]] == ss[0]) break;
        else if(s[sa[now]] > ss[0]) R = now;
        else if(s[sa[now]] < ss[0]) L = now;
    }
    if(s[sa[now]] != ss[0]) return 0;
    REP(i , 1 , ss.size()){
        int pre = now , ty = 0;
        if(sa[now] + i >= s.size()) L = now , ty = 0;
        else if(s[sa[now] + i] == ss[i]) continue;
        else if(s[sa[now] + i] > ss[i]) R = now , ty =
            1;
        else if(s[sa[now] + i] < ss[i]) L = now , ty =
            0;

        while(R - L > 1){
            now = (L + R) / 2;
            if(sa[now] + i >= s.size()){
                if(ty == 0) R = now;
                if(ty == 1) L = now;
            }
            else if(ty == 0 && Query(pre , now) < i) R
                = now;
```

```
            else if(ty == 1 && Query(now , pre) < i) L
                = now;
            else if(s[sa[now] + i] == ss[i]) break;
            else if(s[sa[now] + i] > ss[i]) R = now;
            else if(s[sa[now] + i] < ss[i]) L = now;
        }
        if(sa[now] + i >= s.size()) return 0;
        if(s[sa[now] + i] != ss[i]) return 0;
    }
    L = now , R = now;
    RREP(i , 19 , 0){
        if(R + (1 << i) >= s.size()) continue;
        else if(Query(L , R + (1 << i)) >= ss.size()) R
            += (1 << i);
    }
    RREP(i , 19 , 0){
        if(L - (1 << i) < 0) continue;
        else if(Query(L - (1 << i) , R) >= ss.size()) L
            -= (1 << i);
    }
    return R - L + 1;
}
/*
how to use :
1. cin >> s;
2. getsa() , getlcp() , getsp();
3. string ss;
4. cin >> ss;
5. cout << Find(ss) << endl;
*/
```

7.4 Lexicographically Smallest Rotation

```
string s;
const int N = 4000006;
int f[N];
void solve() {
    s = s + s;
    int n = (int)s.size();
    for (int i=0;i<n;++i) f[i] = -1;
    int k=0;
    for (int j=1;j<n;++j) {
        char sj = s[j];
        int i = f[j-k-1];
        while (i != -1 && sj != s[k+i+1]) {
            if (sj < s[k+i+1]) {
                k = j-i-1;
            }
            i = f[i];
        }
        if (sj != s[k+i+1]) {
            if (sj < s[k]) {
                k = j;
            }
            f[j-k] = -1;
        }
        else f[j-k] = i+1;
    }
    n>>=1;
    if (k >= n) k-= n;
    for (int i=k;i<k+n;++i) {
        cout << s[i];
    }
    cout << endl;
}
```

8 Boook

8.1 Block Tree

```
//Query on Tree 1, SPOJ

int t , n , m , N = 100;
vector<int> v[MAX] , g[MAX];
int pa[MAX] , dep[MAX] , val[MAX];
int siz[MAX] , id[MAX] , mm[MAX];
void init(){
    REP(i , 0 , n + 1) id[i] = 0;
    REP(i , 0 , n + 1) v[i].clear();
    REP(i , 0 , n + 1) g[i].clear();
}
void DFS(int now , int fa , int deep){
    pa[now] = fa , dep[now] = deep;
    if(id[now] == 0) siz[id[now] = now] = 1;
    for(auto to : v[now]){
        if(to == fa) continue;
        if(siz[id[now]] + 1 < N){
            g[now].pb(to);
            siz[id[to] = id[now]] ++;
        }
        DFS(to , now , deep + 1);
    }
}
void build(int now , int v){
    mm[now] = max(v , val[now]);
    for(auto to : g[now]){
        build(to , mm[now]);
    }
}
int query(int a , int b){
    int res = 0;
    while(a != b){
        if(id[a] == id[b]){
            if(dep[a] < dep[b]) swap(a , b);
            res = max(res , val[a]);
            a = pa[a];
        }
        else {
            if(dep[id[a]] < dep[id[b]]) swap(a , b);
            res = max(res , mm[a]);
            a = pa[id[a]];
        }
    }
    return res;
}
int x[MAX][3];
char c[MAX];
int32_t main(){
    scanf("%d" , &t);
    REP(times , 0 , t){
        scanf("%d" , &n);
        init();
        REP(i , 1 , n){
            REP(j , 0 , 3) scanf("%d" , &x[i][j]);
            v[x[i][0]].pb(x[i][1]);
            v[x[i][1]].pb(x[i][0]);
        }
        DFS(1 , 0 , 0);
        REP(i , 1 , n){
            if(dep[x[i][0]] > dep[x[i][1]]) val[x[i
                ][0]] = x[i][2];
            else val[x[i][1]] = x[i][2];
        }
        REP(i , 1 , n + 1){
            if(id[i] == i) build(i , -INF);
        }
        int q , w , tmp;
        while(scanf("%s",c) == 1){
            if(c[0] == 'D') break;
            scanf("%d%d" , &q , &w);
            if(c[0] == 'C'){
                if(dep[x[q][0]] > dep[x[q][1]]) val[x[q
                    ][0]] = w , tmp = x[q][0];
                else val[x[q][1]] = w , tmp = x[q][1];
                if(tmp == id[tmp]) build(tmp , -INF);
                else build(tmp , mm[pa[tmp]]);
            }
            else if(c[0] == 'Q'){
                printf("%d\n", query(q , w));
            }
        }
    }
    return 0;
}
```

8.2 Dancing Link

```
#define MAX 1050
#define INF 0x3f3f3f3f
struct DLX{
    int n , sz , s[MAX];
    int row[MAX * 100] , col[MAX * 100];
    int l[MAX * 100] , r[MAX * 100] , u[MAX * 100] , d[
        MAX * 100];
    int ans;
    void init(int n){
        this -> n = n;
        ans = INF;
        REP(i , 0 , n + 1){
            u[i] = d[i] = i;
            l[i] = i - 1;
            r[i] = i + 1;
        }
        r[n] = 0 , l[0] = n;
        sz = n + 1;
        MEM(s , 0);
    }
    void AddRow(int rr , vector<int> sol){
        int tmp = sz;
        for(auto to : sol){
            l[sz] = sz - 1;
            r[sz] = sz + 1;
            d[sz] = to;
            u[sz] = u[to];
            d[u[to]] = sz , u[to] = sz;
            row[sz] = rr , col[sz] = to;
            s[to] ++ , sz ++;
        }
        r[sz - 1] = tmp , l[tmp] = sz - 1;
    }
#define FOR(i , way , to) for(int i = way[to] ; i != to
     ; i = way[i])
    void remove(int c){
        l[r[c]] = l[c];
        r[l[c]] = r[c];
        FOR(i , d , c) FOR(j , r , i){
            u[d[j]] = u[j];
            d[u[j]] = d[j];
            --s[col[j]];
        }
    }
    int restore(int c){
        FOR(i , u , c) FOR(j , l , i){
            ++s[col[j]];
            u[d[j]] = j;
            d[u[j]] = j;
        }
        l[r[c]] = c;
        r[l[c]] = c;
    }
    void DFS(int floor){
        if(r[0] == 0){
            ans = min(ans , floor);
            return;
        }
        if(floor >= ans) return;
        int c = r[0];
        FOR(i , r , 0) if(s[i] < s[c]) c = i;
        remove(c);
        FOR(i , d , c){
            FOR(j , r , i) remove(col[j]);
            DFS(floor + 1);
            FOR(j , l , i) restore(col[j]);
        }
        restore(c);
    }
} solver;
int n , m;
int32_t main(){
    IOS;
    while(cin >> n >> m){
        solver.init(m);
        REP(i , 0 , n){
            int nn , in;
            cin >> nn;
            vector<int> sol;
            REP(j , 0 , nn) cin >> in , sol.pb(in);
            solver.AddRow(i , sol);
        }
        solver.DFS(0);
        if(solver.ans == INF) cout << "No" << endl;
        else cout << solver.ans << endl;
    }
    return 0;
}
```

8.3 Joseph Problem

```
int main() {
  long long  n, k, i, x = 0, y;
  scanf( "%I64d%I64d", &n, &k );
  for( i = 2; i <= k && i <= n; ++i ) x = ( x + k ) % i
      ;
  for( ; i <= n; ++i ) {
      y = ( i - x - 1 ) / k;
      if( i + y > n ) y = n - i;
      i += y;
      x = ( x + ( y + 1 ) % i * k ) % i;
  }
  printf( "%I64d\n", x + 1 );
  return 0;
}
```

8.4 Middle Speed Linear Recursion

```
#define MAX 100000
#define INF 0x3f3f3f3f
#define mod 10000
int n , k , x[MAX] , c[MAX];
vector<int> mul(vector<int> a , vector<int> b){
    vector<int> ans(n + n + 1);
    REP(i , 1 , n + 1) REP(j , 1 , n + 1)
        ans[i + j] = (ans[i + j] + (a[i] * b[j])) % mod
            ;
    RREP(i , n + n , n + 1){
        REP(j , 1 , n + 1) ans[i - j] = (ans[i - j] +
            ans[i] * c[j]) % mod;
        ans[i] = 0;
    }
    return ans;
}
vector<int> ppow(vector<int> a , int k){
    if(k == 1) return a;
    if(k % 2 == 0) return     ppow(mul(a , a) , k >> 1)
        ;
    if(k % 2 == 1) return mul(ppow(mul(a , a) , k >> 1)
         , a);
}
int main(){
    IOS;
    while(cin >> n && n){
        REP(i , 1 , n + 1) cin >> x[i];
        REP(i , 1 , n + 1) cin >> c[i];
        vector<int> v(n + n + 1);
        v[1] = 1;
        cin >> k , k ++;
        v = ppow(v , k);
        int ans = 0;
        REP(i , 1 , n + 1) ans = (ans + x[i] * v[i]) %
            mod;
        cout << ans << endl;
    }
    return 0;
}
```

8.5 Segment Max segment sum

```
int n , m , x[MAX];
class N{
public: int tag , sml , sum , none;
} b[MAX * 4];
void Pull(int now , int l , int r){
```

```
    if(l == r){
        if(b[now].tag){
            b[now].sum = b[now].tag;
            b[now].none = 0;
            b[now].sml = b[now].tag;
        }
        else{
            b[now].sum = 0;
            b[now].none = 1;
            b[now].sml = INF;
        }
    }
    else {
        b[now].sml = min(b[ls].sml , b[rs].sml);
        if(b[now].tag) b[now].sml = min(b[now].sml , b[
            now].tag);

        b[now].sum = b[ls].sum + b[rs].sum;
        b[now].none = b[ls].none + b[rs].none;
        if(b[now].tag) b[now].sum += b[now].tag * b[now
            ].none , b[now].none = 0;
    }
}
void take_tag(int now , int l , int r , int val){
    if(b[now].tag && b[now].tag < val) b[now].tag = 0;
    if(l != r && b[ls].sml < val) take_tag(ls , l , mid
         , val);
    if(l != r && b[rs].sml < val) take_tag(rs , mid + 1
         , r , val);
    Pull(now , l , r);
}
void Build(int now , int l , int r){
    b[now].none = 0;
    if(l == r) b[now].tag = b[now].sml = b[now].sum = x
        [l];
    else {
        Build(ls , l , mid) , Build(rs , mid + 1 , r);
        Pull(now , l , r);
    }
}
void update(int now , int l , int r , int ql , int qr ,
     int val){
    if(b[now].tag >= val) return ;
    if(ql <= l && r <= qr){
        take_tag(now , l , r , val);
        b[now].tag = val;
        Pull(now , l , r);
    }
    else{
        if(qr <= mid) update(ls , l , mid , ql , qr ,
            val);
        else if(mid + 1 <= ql) update(rs , mid + 1 , r
            , ql , qr , val);
        else update(ls , l , mid , ql , qr , val) ,
            update(rs , mid + 1 , r , ql , qr , val);
        Pull(now , l , r);
    }
}
PII query(int now , int l , int r , int ql , int qr){
    if(ql <= l && r <= qr) return mp(b[now].sum , b[now
        ].none);
    else {
        PII ans = mp(0 , 0);
        if(qr <= mid) ans = query(ls , l , mid , ql ,
            qr);
        else if(mid + 1 <= ql) ans = query(rs , mid + 1
             , r , ql , qr);
        else {
            PII a = query(ls , l , mid , ql , qr);
            PII b = query(rs , mid + 1 , r , ql , qr);
            ans = mp(a.A + b.A , a.B + b.B);
        }
        if(b[now].tag != 0) ans.A += ans.B * b[now].tag
             , ans.B = 0;
        return ans;
    }
}
REP(i , 1 , n + 1) cin >> x[i];
Build(1 , 1 , n);
update(1 , 1 , n , l , r , v);
cout << query(1 , 1 , n , l , r).A << endl;
```

8.6 Primitive root

```
#define int int_fast64_t
int n;
int ppow(int a , int k , int mod){
    if(k == 0) return 1;
    if(k % 2 == 0) return ppow(a * a % mod , k >> 1 ,
        mod);
    if(k % 2 == 1) return ppow(a * a % mod , k >> 1 ,
        mod) * a % mod;
}
int32_t main(){
    IOS;
    while(cin >> n){
        if(n == 2){
            cout << 1 << endl;
            continue;
        }
        vector<int> sol;
        int val = n - 1;
        REP(i , 2 , INF){
            if(i * i > val) break;
            else if(val % i == 0){
                sol.pb(i);
                while(val % i == 0) val /= i;
            }
        }
        if(val != 1) sol.pb(val);
        int ans;
        REP(i , 2 , INF){
            int ok = 1;
            for(auto to : sol){
                if(ppow(i , (n - 1) / to , n) == 1){
                    ok = 0;
                    break;
                }
            }
            if(ok){
                ans = i;
                break;
            }
        }
        cout << ans << endl;
    }
    return 0;
}
```

8.7 Chinese Remainder Theorem

```
#define INF 0x3f3f3f3f
void extgcd(ll a , ll b , ll &d , ll &x , ll &y){
    if(b == 0) d = a , x = 1 , y = 0;
    else extgcd(b , a % b , d , y , x) , y -= (a / b) *
         x;
}
ll n;
vector<ll> v , m;
int main(){
    while(cin >> n){
        v.clear() , m.clear();
        ll ans , mod , d , x , y;
        REP(i , 0 , n) cin >> mod >> ans , m.pb(mod) ,
            v.pb(ans);
        mod = m[0] , ans = v[0];
        REP(i , 1 , n){
            ll res = ((v[i] - ans) % m[i] + m[i]) % m[i
                ];
            extgcd(mod , m[i] , d , x , y);
            if(res % d != 0){ ans = -1; break; }

            res = (res / d * x % m[i] + m[i]) % m[i];
            ans = ans + res * mod;
            mod = mod * m[i] / d;
        }
        if(ans == -1) cout << ans << endl;
        else cout << ans % mod << endl;
    }
    return 0;
}
```

8.8 Stone merge

```
int n , x[MAX] , ans = 0;
vector<int> v;
int DFS(int now){
    int val = v[now] + v[now + 1];
    ans += val;
    v.erase(v.begin() + now);
    v.erase(v.begin() + now);
    int id = 0;
    RREP(i , now - 1 , 0) if(v[i] >= val) { id = i + 1;
         break; }
    v.insert(v.begin() + id , val);
    while(id >= 2 && v[id - 2] <= v[id]){
        int dis = v.size() - id;
        DFS(id - 2);
        id = v.size() - dis;
    }
}
int32_t main(){
    IOS;
    cin >> n;
    REP(i , 0 , n) cin >> x[i];
    REP(i , 0 , n){
        v.pb(x[i]);
        while(v.size() >= 3 && v[v.size() - 3] <= v[v.
            size() - 1])
            DFS(v.size() - 3);
    }
    while(v.size() > 1) DFS(v.size() - 2);
    cout << ans << endl;
    return 0;
}
```

8.9 Range modify and query BIT

```
int n , m , k;
int bit[4][MAX][MAX];
void update(int c[MAX][MAX] , int a , int b , int val){
    for(int i = a + 10 ; i < MAX ; i += i & -i)
        for(int j = b + 10 ; j < MAX ; j += j & -j)
            c[i][j] += val;
}
int update(int x , int y , int val){
    update(bit[0] , x , y , val);
    update(bit[1] , x , y , -val * x);
    update(bit[2] , x , y , -val * y);
    update(bit[3] , x , y , val * x * y);
}
void update(int a , int b , int x , int y , int val){
    update(a , b , val);
    update(a , y + 1 , -val);
    update(x + 1 , b , -val);
    update(x + 1 , y + 1 , val);
}
int query(int c[MAX][MAX] , int a , int b){
    int cnt = 0;
    for(int i = a + 10 ; i > 0 ; i -= i & -i)
        for(int j = b + 10 ; j > 0 ; j -= j & -j)
            cnt += c[i][j];
    return cnt;
}
int query(int x , int y){
    int cnt = 0;
    cnt += query(bit[0] , x , y) * (x + 1) * (y + 1);
    cnt += query(bit[1] , x , y) * (y + 1);
    cnt += query(bit[2] , x , y) * (x + 1);
    cnt += query(bit[3] , x , y);
    return cnt;
}
int query(int a , int b , int x , int y){
    int cnt = 0;
    cnt += query(a - 1 , b - 1);
    cnt -= query(a - 1 , y);
    cnt -= query(x , b - 1);
    cnt += query(x , y);
    return cnt;
}
int32_t main(){
    IOS;
    cin >> n >> m >> k;
    int tmp;
    REP(i , 1 , n + 1) REP(j , 1 , m + 1){
        cin >> tmp;
        update(i , j , i , j , tmp);
    }
    REP(i , 1 , k + 1){
        int a , b , x , y , val , add;
        cin >> a >> b >> x >> y >> val >> add;
        int sum = query(b , a , y , x);
        if(sum < val * (x - a + 1) * (y - b + 1)){
            update(b , a , y , x , add);
        }
    }
    REP(i , 1 , n + 1){
        REP(j , 1 , m + 1) cout << query(i , j , i , j)
            << " ";
        cout << endl;
    }
    return 0;
}
```

8.10 Manhattan Spanning Tree

```
#define edge pair<int , PII>
int n , sol[MAX];
PII x[MAX];
vector<edge> v;
class djs{
public:
    int x[MAX];
    void init(){ REP(i , 0 , MAX) x[i] = i; }
    int Find(int now){ return x[now] == now ? now : x[
        now] = Find(x[now]); }
    void Union(int a , int b){ x[Find(a)] = Find(b); }
    int operator[](int now){ return Find(now); }
} ds;
PII bit[MAX];
void update(int from , int val , int id){
    for(int i = from ; i < MAX ; i += i & -i)
        bit[i] = max(bit[i] , mp(val , id));
}
int query(int from){
    PII res = bit[from];
    for(int i = from ; i > 0 ; i -= i & -i)
        res = max(res , bit[i]);
    return res.B;
}
int cmp(int a , int b){
    return x[a] < x[b];
}
int DIS(int q , int w){
    return abs(x[q].A - x[w].A) + abs(x[q].B - x[w].B);
}
void BuildEdge(){
    vector<int> uni;
    REP(i , 0 , MAX) bit[i] = mp(-INF , -1);
    REP(i , 0 , n) sol[i] = i;
    REP(i , 0 , n) uni.pb(x[i].B - x[i].A);
    sort(ALL(uni));
    uni.resize(unique(ALL(uni)) - uni.begin());
    sort(sol , sol + n , cmp);
    REP(i , 0 , n){
        int now = sol[i];
        int tmp = x[sol[i]].B - x[sol[i]].A;
        int po = lower_bound(ALL(uni) , tmp) - uni.
            begin() + 1;
        int id = query(po);
        if(id >= 0) v.pb(mp(DIS(id , now) , mp(id , now
            )));
        update(po , x[now].A + x[now].B , now);
    }
}
void Build(){
    BuildEdge();
    REP(i , 0 , n) swap(x[i].A , x[i].B);
    BuildEdge();
    REP(i , 0 , n) x[i].A *= -1;
    BuildEdge();
```

```
    REP(i , 0 , n) swap(x[i].A , x[i].B);
    BuildEdge();
}
int solveKruskal(){
    ds.init();
    sort(ALL(v));
    int res = 0;
    REP(i , 0 , v.size()){
        int dis = v[i].A;
        PII tmp = v[i].B;
        if(ds[tmp.A] != ds[tmp.B]){
            ds.Union(tmp.A , tmp.B);
            res += dis;
        }
    }
    return res;
}
int32_t main(){
    IOS;
    cin >> n;
    REP(i , 0 , n) cin >> x[i].A >> x[i].B;
    Build();
    int ans = solveKruskal();
    cout << ans << endl;
    return 0;
}
```

8.11 Integer Split

```
int n , dp[MAX];
int32_t main(){
    dp[0] = 1;
    REP(i , 1 , MAX){
        REP(j , 1 , MAX){
            int tmp = j * (j * 3 - 1) / 2;
            if(tmp > i) break;
            else if(j % 2 == 1) dp[i] = (dp[i] + dp[i -
                 tmp]) % mod;
            else if(j % 2 == 0) dp[i] = (dp[i] - dp[i -
                 tmp] + mod) % mod;
        }
        REP(j , 1 , MAX){
            int tmp = j * (j * 3 + 1) / 2;
            if(tmp > i) break;
            else if(j % 2 == 1) dp[i] = (dp[i] + dp[i -
                 tmp]) % mod;
            else if(j % 2 == 0) dp[i] = (dp[i] - dp[i -
                 tmp] + mod) % mod;
        }
    }
    cin >> n;
    cout << dp[n] << endl;
    return 0;
}
```

8.12 K Cover Tree

```
int n , k , dp[MAX] , ans;
vector<int> v[MAX];
void DFS(int now , int fa){
    if(v[now].size() == 1 && v[now][0] == fa)
        return dp[now] = -1 , void();
    int sml = INF , big = -INF;
    for(auto to : v[now]) if(to != fa){
        DFS(to , now);
        sml = min(sml , dp[to]);
        big = max(big , dp[to]);
    }
    if(sml == -k) dp[now] = k , ans ++;
    else if(big - 1 >= abs(sml)) dp[now] = big - 1;
    else dp[now] = sml - 1;
}
int32_t main(){
    IOS;
    cin >> n >> k;
    REP(i , 2 , n + 1){
        int a , b; cin >> a >> b;
        v[a].pb(b); v[b].pb(a);
    }
    if(k == 0) cout << n << endl;
    else {
        DFS(0 , 0) , ans += dp[0] < 0;
        cout << ans << endl;
    }
    return 0;
}
```

8.13 M Segments' Maximum Sum

```
--------------------Greedy--------------------
int n , m , fr[MAX] , ba[MAX];
int v[MAX] , idx = 1;
set<PII> cc;
void erase(int id){
    if(id == 0) return;
    int f = fr[id] , b = ba[id];
    ba[fr[id]] = b , fr[ba[id]] = f;
    cc.erase(mp(abs(v[id]) , id));
}
int32_t main(){
    cin >> n >> m;
    int sum = 0 , pos = 0 , ans = 0;
    REP(i , 0 , n){
        int tmp; cin >> tmp;
        if(tmp == 0) continue;
        if((tmp >= 0 && sum >= 0) || (tmp <= 0 && sum
            <= 0)){
            sum += tmp;
        }
        else {
            if(sum > 0) ans += sum , pos ++;
            v[idx ++] = sum , sum = tmp;
        }
    }
    if(sum) v[idx ++] = sum;
    if(sum > 0) ans += sum , pos ++;
    REP(i , 0 , idx){
        fr[i + 1] = i;
        ba[i] = i + 1;
        if(i) cc.insert(mp(abs(v[i]) , i));
    } ba[idx - 1] = 0;
    while(pos > m){
        auto tmp = cc.begin();
        int val = (*tmp).A , id = (*tmp).B;
        cc.erase(tmp);
        if(v[id] < 0 && (fr[id] == 0 || ba[id] == 0))
            continue;
        if(v[id] == 0) continue;
        ans -= val , pos --;
        v[id] = v[fr[id]] + v[id] + v[ba[id]];
        cc.insert(mp(abs(v[id]) , id));
        erase(fr[id]) , erase(ba[id]);
    }
    cout << ans << endl;
    return 0;
}
--------------------Aliens--------------------
int n , k , x[MAX];
PII dp[MAX] , rd[MAX]; // max value , times , can be
    buy , times
int judge(int now){
    dp[1] = mp(0 , 0) , rd[1] = mp(-x[1] , 0);
    REP(i , 2 , n + 1){
        dp[i] = max(dp[i - 1] , mp(rd[i - 1].A + x[i] -
             now , rd[i - 1].B + 1));
        rd[i] = max(rd[i - 1] , mp(dp[i - 1].A - x[i]
                  , dp[i - 1].B));
    }
    return dp[n].B;
}
int32_t main(){
    IOS;
    cin >> n >> k;
    n ++;
    REP(i , 2 , n + 2) cin >> x[i];
    REP(i , 1 , n + 1) x[i] += x[i - 1];
    if(judge(0) <= k) cout << dp[n].A << endl;
    else {
```

```
        int l = 0 , r = 1000000000000LL;
        while(r - l > 1){
            int mid = l + ((r - l) >> 1) , res = judge(
                mid);
            if(res == k) return cout << dp[n].A + dp[n
                ].B * mid << endl , 0;
            else if(res < k) r = mid;
            else if(res > k) l = mid;
        }
        judge(l);
        cout << dp[n].A + k * l << endl;
    }
    return 0;
}
```

8.14 Minimum Enclosing Cycle

```
pdd arr[MAX], cen;
double r;
inline double dis(pdd a,pdd b){ return hypot(a.X-b.X,a.
    Y-b.Y);  }
int n,m;
inline double sq(double x){return x*x;}
pdd external(pdd p1,pdd p2,pdd p3){
  double a1=p1.X-p2.X,a2=p1.X-p3.X;
  double b1=p1.Y-p2.Y,b2=p1.Y-p3.Y;
  double c1=( sq(p1.X)-sq(p2.X)+sq(p1.Y)-sq(p2.Y) )/2;
  double c2=( sq(p1.X)-sq(p3.X)+sq(p1.Y)-sq(p3.Y) )/2;
  double dd=a1*b2-a2*b1;
  return pdd( (c1*b2-c2*b1)/dd , (a1*c2-a2*c1)/dd );
}
int main(){
  IOS
  srand(time(0));
  while(cin>>n>>m){
    if(n+m==0)  return 0;
    for(int i=0;i<m;i++){
      cin>>arr[i].X>>arr[i].Y;
    }
    random_shuffle(arr,arr+m);
    r=0;
    for(int i=0;i<m;i++){
      if(dis(cen,arr[i])>r){
        cen=arr[i]; r=0;
        for(int j=0;j<i;j++){
          if(dis(cen,arr[j])>r){
            cen=pdd( (arr[i].X+arr[j].X)/2 , (arr[i].Y+
                arr[j].Y)/2 );
            r=dis(cen,arr[j]);
            for(int k=0;k<j;k++){
              if(dis(cen,arr[k])>r){
                cen=external(arr[i],arr[j],arr[k]);
                r=dis(cen,arr[j]);
              }
            }
          }
        }
      }
    }
    cout<<stp<<r<< '\n';
  }
  return 0;
}
```

8.15 Rotating Sweep Line

```
PII p[MAX];
int n , idx[MAX] , pos[MAX];
long long wnt;
vector<PII> v;
inline PII operator + (PII x , PII y){ return mp(x.A +
    y.A , x.B + y.B); }
inline PII operator - (PII x , PII y){ return mp(x.A -
    y.A , x.B - y.B); }
inline long long cross(PII x , PII y){ return 1ll * x.A
     * y.B - 1ll * x.B * y.A; }
inline long long calcArea(PII x , PII y , PII z){
    long long val = abs(cross(y - x , z - x));
    return val;
}
inline int cmp1(PII x , PII y){
    x = p[x.B] - p[x.A];
    y = p[y.B] - p[y.A];
    return cross(x , y) > 0;
}
int32_t main(){
    cin >> n >> wnt , wnt += wnt;
    REP(i , 1 , n + 1) cin >> p[i].A >> p[i].B;
    sort(p + 1 , p + 1 + n);
    REP(i , 1 , n + 1) idx[i] = i , pos[i] = i;
    REP(i , 1 , n + 1) REP(j , i + 1 , n + 1) v.pb(mp(i
         , j));
    sort(ALL(v) , cmp1);
    for(auto line : v){
        int fr = pos[line.A] , ba = pos[line.B] , now;
        if(fr > ba) swap(fr , ba);
        now = fr;
        RREP(i , 10 , 0){
            int to = now - (1 << i);
            if(to >= 1 && calcArea(p[idx[fr]] , p[idx[
                ba]] , p[idx[to]]) <= wnt) now = to;
        }
        now = ba;
        RREP(i , 10 , 0){
            int to = now + (1 << i);
            if(to <= n && calcArea(p[idx[fr]] , p[idx[
                ba]] , p[idx[to]]) <= wnt) now = to;
        }
        swap(idx[fr] , idx[ba]) , swap(pos[line.A] ,
            pos[line.B]);
    }
    cout << "No" << endl;
    return 0;
}
```

8.16 Hilbert Curve

```
//soring Mo's with hilbert(L, R) can be faster!!!
ll hilbert(int n, int x, int y) {
    ll res = 0;
    for (int s = n / 2; s; s >>= 1) {
        int rx = (x & s) > 0;
        int ry = (y & s) > 0;
        res += s * 1ll * s * ((3 * rx) ^ ry);
        if (ry == 0) {
            if (rx == 1) {
                x = s - 1 - x;
                y = s - 1 - y;
            }
            swap(x, y);
        }
    }
    return res;
}
```

8.17 Next Permutation on binary

```
ll next_perm(ll v) {
    ll t = v | (v - 1);
    return (t + 1) | (((~t & -~t) - 1) >> (
        __builtin_ctz(v) + 1));
}
```

8.18 SOS DP

```
// 0 is 0, 1 can be 1 or 0
for (int i = 0; i < n; ++i)
    for (int j = 0; j < (1 << n); ++j)
        if ( j & (1 << i) )
            a[j] += a[ j ^ (1 << i) ];
```