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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"

#include <bits/stdc++.h>
mt19937 rng(0x5EED);
int randint(int lb, int ub)
{ return uniform_int_distribution<int>(lb, ub)(rng); }

#define SECS (clock() / CLOCKS_PER_SEC)

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

$$\sum_{i|n} \mu(i) = [n=1] \quad \sum_{i|n} \phi(i) = n$$

- Binomial inversion formula

$$f(n) = \sum_{i=0}^n \binom{n}{i} g(i) \quad g(n) = \sum_{i=0}^n (-1)^{n-i} \binom{n}{i} f(i)$$

- Sum of powers

$$\sum_{k=1}^n k^m = \frac{1}{m+1} \sum_{k=0}^m \binom{m+1}{k} B_k^+ n^{m+1-k}$$

$$\sum_{j=0}^m \binom{m+1}{j} B_j^- = 0$$

$$\text{note : } B_1^+ = -B_1^- \quad B_i^+ = B_i^-$$

1.7 check

```
for ((i=0; i<100;i++))
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], sz, 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;
    }
    void init(int n){
        for(int i=1; i<=n; i++){
            p[i]=i; rk[i]=0;
        }
        sz=n; memo.clear(); stk.clear();
    }
    int f(int x){
        return x == p[x] ? x : f(p[x]);
    }
    void uni(int a, int b){
        int aa=f(a); int bb=f(b);
        if(aa == bb) return;
        assign(&sz, sz-1);
        if(rk[aa] > rk[bb]) swap(aa, bb);
        assign(&p[aa], bb);
        assign(&rk[bb], max(rk[bb], rk[aa]+1));
    }
} djs;
```

2.2 Persistent treap

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

const int MAX_N = 1e5 + 6;
const int MAX_M = 1e6 + 6;
const int MAX_P = 3e7;

struct Treap {
```

```

static Treap mem[MAX_P];
Treap *lc,*rc;
char c; int sz;
Treap(){}
Treap(char _c) : lc(NULL),rc(NULL),sz(1),c(_c){}
} Treap::mem[MAX_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[MAX_M];
Treap* ver[MAX_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]));

```

2.3 Link Cut Tree

```

struct SplayNode {
    static SplayNode HOLE;
    SplayNode *ch[2], *par;
    bool rev;
    SplayNode(): par(&HOLE), rev(false) { ch[0] = ch[1] = &HOLE; }
    bool isRoot() {
        return (par->ch[0] != this && par->ch[1] != this);
    }
    void push() {
        if (rev) {
            if (ch[0]) ch[0]->rev ^= 1;
            if (ch[1]) ch[1]->rev ^= 1;
            swap(ch[0], ch[1]);
            rev ^= 1;
        }
    }
    void pushFromRoot() {
        if (!isRoot()) par->pushFromRoot();
        push();
    }
    void pull() {
        if (ch[0]) ch[0]->d = d + ch[0]->parLen;
        if (ch[1]) ch[1]->d = d + ch[1]->parLen;
    }
    void rotate() {
        SplayNode *p = par, *gp = p->par;
        bool dir = (p->ch[1] == this);

```

```

        par = gp;
        if (!p->isRoot()) gp->ch[gp->ch[1] == p] = this;
        p->ch[dir] = ch[dir ^ 1];
        p->ch[dir]->par = p;
        p->par = this;
        ch[dir ^ 1] = p;
        p->pull(), pull();
    }
    void splay() {
        pushFromRoot();
        while (!isRoot()) {
            if (!par->isRoot()) {
                SplayNode *gp = par->par;
                if ((gp->ch[0] == par) == (par->ch[0] == this))
                    rotate();
                else par->rotate();
            }
            rotate();
        }
    }
} SplayNode::HOLE;
namespace LCT {
    SplayNode *access(SplayNode *x) {
        SplayNode *last = &SplayNode::HOLE;
        while (x != &SplayNode::HOLE) {
            x->splay();
            x->ch[1] = last;
            x->pull();
            last = x;
            x = x->par;
        }
        return last;
    }
    void makeRoot(SplayNode *x) {
        access(x);
        x->splay();
        x->rev ^= 1;
    }
    void link(SplayNode *x, SplayNode *y) {
        makeRoot(x);
        x->par = y;
    }
    void cut(SplayNode *x, SplayNode *y) {
        makeRoot(x);
        access(y);
        y->splay();
        y->ch[0] = &SplayNode::HOLE;
        x->par = &SplayNode::HOLE;
    }
    void cutParent(SplayNode *x) {
        access(x);
        x->splay();
        x->ch[0]->par = &SplayNode::HOLE;
        x->ch[0] = &SplayNode::HOLE;
    }
    SplayNode *findRoot(SplayNode *x) {
        x = access(x);
        while (x->ch[0] != &SplayNode::HOLE) x = x->ch[0];
        x->splay();
        return x;
    }
    SplayNode *query(SplayNode *x, SplayNode *y) {
        makeRoot(x);
        return access(y);
    }
    SplayNode *queryLca(SplayNode *x, SplayNode *y) {
        access(x);
        auto lca = access(y);
        x->splay();
        return lca->data + lca->ch[1]->sum + (x == lca ? 0 : x->sum);
    }
    void modify(SplayNode *x, int data) {
        x->splay();
        x->data = data;
        x->pull();
    }
}

```

3 Flow

3.1 Flow with lower 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.

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

#define SZ(x) ((int)(x).size())

struct Flow {
    static const int N = 8006;
    struct Edge {
        int to, cap, rev;
        Edge(int _to, int _cap, int _rev): to(_to), cap(
            _cap), rev(_rev){}
    };
    vector<Edge> G[N];
    int d[N];
    int S, T, s, t;
    int n;
    int nows, nowt;
    void init(int _n, int _s, int _t) {
        //vertex are numbered from 0 to n, and s and t
        //the source/sink in the original graph
        S = _n+1, T = _n+2;
        s = _s, t = _t;
        n = _n;
        for (int i=0; n+3>=i; i++){
            G[i].clear();
            d[i] = 0;
        }
    }
    void add_edge(int from, int to, int low, int upp) {
        G[from].push_back(Edge(to, upp-low, SZ(G[to])));
        G[to].push_back(Edge(from, 0, SZ(G[from])-1));
        d[from] -= low;
        d[to] += low;
    }
    void add_edge(int from, int to, int cap) {
        G[from].push_back(Edge(to, cap, SZ(G[to])));
        G[to].push_back(Edge(from, 0, SZ(G[from])-1));
    }
    int iter[N], level[N];
    void BFS() {
        memset(level, -1, sizeof(level)); level[nows] =
            1;
        queue<int> que; que.push(nows);
        while (!que.empty()) {
            int t=que.front(); que.pop();
            for (Edge e:G[t]) {
                if (e.cap > 0 && level[e.to] == -1) {
                    level[e.to] = level[t]+1;
                    que.push(e.to);
                }
            }
        }
    }
    int dfs(int now, int flow) {
        if (now == nowt) return flow;
        for (int &i=iter[now]; SZ(G[now])>i; i++) {
            Edge &e = G[now][i];

```

```

                if (e.cap > 0 && level[e.to] == level[now
                    ]+1) {
                    int ret = dfs(e.to, min(flow, e.cap));
                    if (ret > 0) {
                        e.cap -= ret; G[e.to][e.rev].cap +=
                            ret;
                        return ret;
                    }
                }
            }
            return 0;
        }
    }
    int flow() {
        int ret = 0;
        while (true) {
            BFS();
            if (level[nowt] == -1) break;
            memset(iter, 0, sizeof(iter));
            int tmp;
            while ((tmp = dfs(nows, 1000000007)) > 0) {
                ret += tmp;
            }
            return ret;
        }
    }
    int get_ans() {
        nows = S, nowt = T;
        int base=0;
        for (int i=0; n>=i; i++) {
            if (d[i] > 0) base += d[i];
            if (d[i] > 0) add_edge(S, i, d[i]);
            if (d[i] < 0) add_edge(i, T, -d[i]);
        }
        add_edge(t, s, 0, 1000000007);
        if (flow() != base) return -1; //invalid flow
        nows = s, nowt = t;
        return flow();
    }
} flow;

```

3.2 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;

```

3.3 Gomory Hu Tree

```

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

def gomory_hu(G):
    T = {}
    P = [1] * IV(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

```

#include <bits/stdc++.h>
using namespace std;
//REMEMBER TO ROTATE AN ANGLE!!!
typedef double D; //maybe long double
typedef pair<D,D> pdd;
const D eps = 1e-9;

struct Circle {
    D x,y,r; pdd cen;
    Circle(){}
    Circle(D _x,D _y,D _r) : x(_x),y(_y),r(_r),cen(
        make_pair(_x,_y)){}
};

struct Cir_inter_type {
    int type;
    vector<pdd> pts;
    Cir_inter_type(){}
    Cir_inter_type(int _type,vector<pdd> _pts) : type(
        _type),pts(_pts){}
};

D get_dis(pdd a,pdd b) {
    return sqrt(pow(a.F-b.F,2) + pow(a.S-b.S,2));
}

bool eq(D a,D b) {
    return fabs(a-b) <= eps;
}

bool les(D a,D b) {
    return !eq(a,b) && a<b;
}

bool leq(D a,D b) {
    return les(a,b) || eq(a,b);
}

Cir_inter_type circle_inter(Circle a, Circle b) {
    Cir_inter_type ret;
    D dis=get_dis(a.cen,b.cen);
    if (eq(a.r+b.r,dis)) {
        //outside cut --> type 1
        D x=a.x + (b.x-a.x)*(a.r)/(a.r + b.r);

```

```

        D y=a.y + (b.y-a.y)*(a.r)/(a.r + b.r);
        vector<pdd> pts;
        pts.push_back(make_pair(x,y));
        ret = Cir_inter_type(1,pts);
    }
    else if (eq( max(a.r,b.r),min(a.r,b.r) + dis )) {
        //inside cut --> type 2
        if (a.r < b.r) swap(a,b);
        D x=a.x + (b.x - a.x)*a.r/(a.r - b.r);
        D y=a.y + (b.y - a.y)*a.r/(a.r - b.r);
        vector<pdd> pts;
        pts.push_back(make_pair(x,y));
        ret = Cir_inter_type(2,pts);
    }
    else if (les(a.r+b.r,dis)) {
        //no intersection --> type 3
        vector<pdd> pts;
        ret = Cir_inter_type(3,pts);
    }
    else if (les(min(a.r,b.r)+dis,max(a.r,b.r))) {
        //fully inside
        //if a is fully contain b, return type 4
        //if b is fully contain a, return type 5
        vector<pdd> pts;
        if (les(b.r,a.r)) {
            ret = Cir_inter_type(4,pts);
        }
        else if (les(a.r,b.r)) {
            ret = Cir_inter_type(5,pts);
        }
    }
    else if (les(dis,a.r + b.r)) {
        //two intersections --> type 6
        D c1=2*(b.x-a.x)*b.r;
        D c2=2*(b.y-a.y)*b.r;
        D c3=a.r*a.r-b.r*b.r-(b.x-a.x)*(b.x-a.x)-(b.y-a
            .y)*(b.y-a.y);
        D aa = c1*c1 + c2*c2;
        D bb = -2*c2*c3;
        D cc = c3*c3 - c1*c1;
        D sin1 = (-bb + sqrt(bb*bb-4*aa*cc))/(2*aa);
        D sin2 = (-bb - sqrt(bb*bb-4*aa*cc))/(2*aa);
        D aaa = c1*c1 + c2*c2;
        D bbb = -2*c1*c3;
        D ccc = c3*c3 - c2*c2;
        D cos1=(-bbb+sqrt(bbb*bbb-4*aaa*ccc))/(aaa*2);
        D cos2=(-bbb-sqrt(bbb*bbb-4*aaa*ccc))/(aaa*2);
        vector<pdd> pts;
        if (eq(sin1*sin1 + cos1*cos1,1.)) {
            pts.push_back(make_pair(b.x + b.r*cos1,b.y
                + b.r*(sin1)));
            pts.push_back(make_pair(b.x + b.r*cos2,b.y
                + b.r*(sin2)));
        }
        else {
            pts.push_back(make_pair(b.x + b.r*cos1,b.y
                + b.r*(sin2)));
            pts.push_back(make_pair(b.x + b.r*cos2,b.y
                + b.r*(sin1)));
        }
        ret = Cir_inter_type(6,pts);
    }
    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[j].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 Poly Union

```

#define eps 1e-8
class PY{ public:
    int n;
    Pt pt[5];
    Pt& operator[](const int x){ return pt[x]; }
    void input(){
        int i; n=4;
        for(i=0; i<n; i++) scanf("%lf%lf", &pt[i].x, &pt[i].y);
    }
    double getArea(){
        int i; double s=pt[n-1]^pt[0];
        for(i=0; i<n-1; i++) s+=pt[i]^pt[i+1];
        return s/2;
    }
};
PY py[500];
pair<double, int> c[5000];
inline double segP(Pt &p, Pt &p1, Pt &p2){
    if(SG(p1.x-p2.x)==0) return (p.y-p1.y)/(p2.y-p1.y);
    return (p.x-p1.x)/(p2.x-p1.x);
}
double polyUnion(int n){
    int i, j, ii, jj, ta, tb, r, d;
    double z, w, s, sum, tc, td;
    for(i=0; i<n; i++) py[i][py[i].n]=py[i][0];
    sum=0;
    for(i=0; i<n; i++){
        for(ii=0; ii<py[i].n; ii++){
            r=0;
            c[r++]=make_pair(0.0, 0);
            c[r++]=make_pair(1.0, 0);

```

```

for(j=0; j<n; j++){
    if(i==j) continue;
    for(jj=0; jj<py[j].n; jj++){
        ta=SG(tri(py[i][ii], py[i][ii+1], py[j][jj]));
        tb=SG(tri(py[i][ii], py[i][ii+1], py[j][jj+1]));
        if(ta==0 && tb==0){
            if((py[j][jj+1]-py[j][jj])*(py[i][ii+1]-py[i][ii])>0 && j<i){
                c[r++]=make_pair(segP(py[j][jj], py[i][ii],
                    py[i][ii+1]), 1);
                c[r++]=make_pair(segP(py[j][jj+1], py[i][ii],
                    py[i][ii+1]), -1);
            }
            else if(ta>0 && tb<0){
                tc=tri(py[j][jj], py[j][jj+1], py[i][ii]);
                td=tri(py[j][jj], py[j][jj+1], py[i][ii+1]);
                c[r++]=make_pair(tc/(tc-td), 1);
            }
            else if(ta<0 && tb>0){
                tc=tri(py[j][jj], py[j][jj+1], py[i][ii]);
                td=tri(py[j][jj], py[j][jj+1], py[i][ii+1]);
                c[r++]=make_pair(tc/(tc-td), -1);
            }
        }
    }
}
sort(c, c+r);
z=min(max(c[0].first, 0.0), 1.0);
d=c[0].second; s=0;
for(j=1; j<r; j++){
    w=min(max(c[j].first, 0.0), 1.0);
    if(!d) s+=w-z;
    d+=c[j].second; z=w;
}
sum+=(py[i][ii]^py[i][ii+1])*s;
}
}
return sum/2;
}
int main(){
    int n, i, j, k;
    double sum, ds;
    scanf("%d", &n); sum=0;
    for(i=0; i<n; i++){
        py[i].input();
        ds=py[i].getArea();
        if(ds<0){
            for(j=0, k=py[i].n-1; j<k; j++, k--) swap(py[i][j],
                py[i][k]);
            ds=-ds;
        }
        sum+=ds;
    }
    printf("%.9f\n", sum/polyUnion(n));
}

```

4.4 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; }

```

4.5 Convex Hull

```

/* Given a convexhull, answer queries 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;
}
};

```

5 Graph

5.1 Biconnected Component

```

#include <bits/stdc++.h>
using namespace std;
const int N = 800006;

int low[N],dfn[N];
bool vis[N];
int cnt[N];
int e[N],x[N],y[N];
int stamp;

vector<int> G[N];
vector<int> bcc[N];
int bcc_no = 0;
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 matching

```

const int N = 514, E = (2e5) * 2;
struct Graph{
    int to[E],bro[E],head[N],e;
    int lnk[N],vis[N],stp,n;
    void init( int _n ){
        stp = 0; e = 1; n = _n;
        for( int i = 1 ; i <= n ; i ++ )
            lnk[i] = vis[i] = 0;
    }
    void add_edge(int u,int 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 Tutte matrix

```

## Graph Matching (tutte) ##
#define MAX 400
#define P 1000000007
typedef long long i64;
int mat[MAX][MAX];
i64 tutte[MAX][MAX];
inline int randInt(int n) {
    return ((rand() << 15) ^ rand()) % n;
}
int matRank(i64 a[MAX][MAX], int n, i64 p) {
    int i, j, k, cnt = 0, cur;
    i64 t;
    for (i = 0; i < n; ++i) {
        for (j = i + 1; j < n; ++j) {
            while (a[j][i]) {
                for (t = a[i][i] / a[j][i], k = 0; k < n; ++k) {
                    a[i][k] = (a[i][k] - a[j][k] * t) % p;
                    swap(a[i][k], a[j][k]);
                }
            }
        }
        for (cur = 0, j = i; j < n; ++j) {
            if (a[i][j]) { cur = 1; }
        }
        cnt += cur;
    }
    return cnt;
}
int maxMatch(const int mat[MAX][MAX], int n) {
    int i, j;
    memset(tutte, 0, sizeof(tutte));
    for (i = 0; i < n; ++i) {
        for (j = i + 1; j < n; ++j) {
            if (mat[i][j]) { tutte[j][i] = -(tutte[i][j] =
                randInt(P)); }
        }
    }
    return matRank(tutte, n, P) >> 1;
}

```

5.4 KM

```

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

```



```

int match(int now){
    s[now] = 1;
    REP(to, 1, n + 1){
        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;
}
int update(){
    int val = INF;
    REP(i, 1, n + 1) if(t[i] == 0) val = min(val,
        slk[i]);
    REP(i, 1, n + 1){
        if(s[i]) lx[i] -= val;
        if(t[i]) ly[i] += val;
    }
}
void solve(){
    REP(i, 1, n + 1) REP(j, 1, n + 1)
        lx[i] = max(lx[i], w[i][j]);
    REP(i, 1, n + 1){
        MEM(slk, INF);
        while(1){
            MEM(s, 0), MEM(t, 0);
            if(match(i)) break;
            else update();
        }
    }
}

```

5.5 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;

```

5.6 Minimum Weighted Matching

```

struct Graph {
    // Minimum General Weighted Matching (Perfect Match)
    static const int MXN = 105;
    int n, edge[MXN][MXN];
    int match[MXN],dis[MXN],onstk[MXN];
    vector<int> stk;
    void init(int _n) {
        n = _n;
        for( int i = 0 ; i < n ; i ++ )
            for( int j = 0 ; j < n ; j ++ )
                edge[ i ][ j ] = 0;
    }
    void add_edge(int u, int v, int w)
    { edge[u][v] = edge[v][u] = w; }
    bool SPFA(int u){
        if (onstk[u]) return true;
        stk.PB(u);
        onstk[u] = 1;
        for (int v=0; v<n; v++){
            if (u != v && match[u] != v && !onstk[v]){
                int m = match[v];
                if (dis[m] > dis[u] - edge[v][m] + edge[u][v]){
                    dis[m] = dis[u] - edge[v][m] + edge[u][v];
                    onstk[v] = 1;
                    stk.PB(v);
                    if (SPFA(m)) return true;
                }
                stk.pop_back();
                onstk[v] = 0;
            }
        }
        onstk[u] = 0;
        stk.pop_back();
        return false;
    }
    int solve() {
        // find a match
        for (int i=0; i<n; i+=2){
            match[i] = i+1;
            match[i+1] = i;
        }
        while (true){
            int found = 0;
            for( int i = 0 ; i < n ; i ++ )
                onstk[ i ] = dis[ i ] = 0;
            for (int i=0; i<n; i++){
                stk.clear();
                if (!onstk[i] && SPFA(i)){
                    found = 1;
                    while (SZ(stk)>=2){
                        int u = stk.back(); stk.pop_back();
                        int v = stk.back(); stk.pop_back();
                        match[u] = v;
                        match[v] = u;
                    }
                }
            }
            if (!found) break;
        }
        int ret = 0;
        for (int i=0; i<n; i++)
            ret += edge[i][match[i]];
        ret /= 2;
        return ret;
    }
}

```

```

}
}graph;

```

5.7 Minimum mean cycle

```

/* minimum mean cycle O(VE) */
struct MMC{
#define E 101010
#define V 1021
#define inf 1e9
#define eps 1e-6
    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;

```

5.8 Heavy-Light decomposition

```

#define MAX 100900
#define ls (now << 1)
#define rs (now << 1 | 1)
#define mid (l + r >> 1)

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);

```

5.9 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(); }

```

5.10 Minimum Steiner Tree

```

// Minimum Steiner Tree
//  $O(V \cdot 3^T + V^2 \cdot 2^T)$ 
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 - 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;

```

5.11 Maximum Clique

```

struct maximum_clique {
static const int MAX_N = 81;
typedef bitset<MAX_N> bst;
bst N[MAX_N],empty;
int n,ans;
void init(int _n) {
//point from 0 ~ n-1
n=_n;
for (int i=0;MAX_N>i;i++) {
N[i] = empty;
}
}
void add_edge(int a,int b) {

```

```

    N[a][b] = N[b][a] = 1;
}
void sagiri(bst R, bst P, bst X) {
    if (P==empty && X==empty) {
        ans = max(ans, (int)R.count());
        return;
    }
    bst tmp=P[X];
    int u;
    if ((R[P[X]].count() <= ans) return;
    for (u=0; n>u; u++) {
        if (tmp[u]) break;
    }
    bst now = P&~N[u]; //P-N[u]
    for (int v=0; n>v; v++) {
        if (now[v]) {
            R[v] = true;
            sagiri(R, P&N[v], X&N[v]);
            R[v] = false; P[v] = false; X[v] = true;
        }
    }
}
int solve() {
    ans=0;
    bst R=empty, P, X=empty;
    P.flip();
    sagiri(R, P, X);
    return ans;
}
} solver;

```

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;
    fill(v, v+vl, 0);
    // v.resize(nl);
    // 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;
#define ld double
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=i;
            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;
}
};

```

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];
                //FWT
                //XOR
                a[j] = x + y;    a[j + d] = x - y;
                //AND
                a[j] = x + y;
                //OR
                a[j + d] = y + x;
                //IFWT
                //XOR
                a[j] = (x + y) / 2;    a[j + d] = (x - y
                    ) / 2;
                //AND
                a[j] = x - y;
                //OR
                a[j + d] = y - x;
            }
}

```

6.5 Gauss

```

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

```

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

typedef long long LL;

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-->0) {
        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

```

//const int G = (1LL<<31)-1;
LL mull(LL a,LL b,LL mod) {
    //if (a<G && b<G) return a*b%mod;
    LL ret = 0;
    LL now = a;
    while (b) {
        if (b&1) ret = addd(ret, now, mod);
        now = addd(now, now, mod);
        b >>= 1;
    }
    return ret;
}
LL ppow(LL a,LL n,LL mod) {
    LL ret = 1;
    LL now = a;
    while (n) {
        if (n&1) ret = mull(ret, now, mod);
        now = mull(now, now, mod);
        n >>= 1;
    }
    return ret;
}
LL gcd(LL a, LL b) {
    if (b==0) return a;
    else return gcd(b, a%b);
}
const bool PRIME = 1, COMPOSITE = 0;
bool miller_rabin(LL n, LL a) {
    if (gcd(n, a) == n) return PRIME;
    else if (gcd(n, a) != 1) return COMPOSITE;
    LL d = n - 1, r = 0;
    while (d % 2 == 0) {
        d >>= 1;
        ++r;
    }
    LL ret = ppow(a, d, n);
    if (ret == 1 || ret == n - 1) return PRIME;
    while (r-- > 0) {
        ret = mull(ret, ret, n);
        if (ret == n - 1) return PRIME;
    }
    return COMPOSITE;
}
bool isPrime(LL n) {
    LL as[7] = {2, 325, 9375, 28178, 450775, 9780504,
        1795265022};
    for (int i = 0; 7 > i; ++i) {
        if (miller_rabin(n, as[i]) == COMPOSITE) return
            COMPOSITE;
    }
    return PRIME;
}
const LL C = 2934852462451LL;
const LL D = 126871905557494LL;
LL rnd = 98134513458734897LL;
LL myRnd() {
    return rnd = (rnd + C) ^ D;
}
LL a, c;
LL doo(LL x, LL n) {
    return addd( mull( a, mull(x, x, n), n ), c, n);
}
#define aabs(x) (x) >= 0 ? (x):- (x)
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);
    LL s2 = doo(s1, n);
    while (true) {
        if (s1 == s2) {
            start = myRnd() % n;
            //a=myRnd()+1;

```

```

        a = myRnd() % n;
        if (!a) a = 1;
        c = myRnd() % n;
        while (c == 0 || c == 2) c = myRnd() % n;
        s1 = doo(start, n);
        s2 = doo(s1, n);
        continue;
    }
    LL _ = gcd(aabs(s1 - s2), n);
    if (_ != 1) {
        return min(solve(_), solve(n / _));
    }
    s1 = doo(s1, n);
    s2 = doo(s2, n);
    s2 = doo(s2, n);
}
}
}

```

6.8 Pi

```

## Meissel-Lehmer ##
...cpp
#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) {
        //cout<<"pi = "<<m<<endl;
        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 Debrujin

```

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;
}

```

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 - 1] , 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

```

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

struct AC_Automata {
    static const int N = 2e4 + 6;
    static const int SIGMA = 26;
    int ch[N][SIGMA];
    int val[N];
    int sz;
    int last[N], fail[N];
    int que[N], qs, qe;
    int 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();
int 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, SP0J

#define MAX 10900
#define INF 0x3f3f3f3f

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 High 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

```

#define int long long
#define MAX 300900
#define INF 1000000000000000LL
#define ls (now << 1)
#define rs (now << 1 | 1)
#define mid ((l + r) >> 1)
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[no
            w].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;
    }
}
int32_t main(){
    IOS;
    cin >> n >> m;
    REP(i , 1 , n + 1) cin >> x[i];
    Build(1 , 1 , n);
    REP(i , 1 , m + 1){
        int ty , l , r , v;
        cin >> ty;
        if(ty == 1){
            cin >> l >> r >> v;
            update(1 , 1 , n , l , r , v);
        }
        if(ty == 2){
            cin >> l >> r;
            cout << query(1 , 1 , n , l , r).A << endl;
        }
    }
    return 0;
}

```

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 Same remainder Equation

```

#define INF 0x3f3f3f3f
void extgcd(long long a , long long b , long long &d ,
    long long &x , long long &y){
    if(b == 0) d = a , x = 1 , y = 0;
    else extgcd(b , a % b , d , y , x) , y -= (a / b) *
        x;
}
long long n;
vector<long long> v , m;
int main(){
    while(cin >> n){
        v.clear() , m.clear();
        long long 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){
            long long 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

```

#define int long long
#define MAX 50900

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

```

#define int long long
#define MAX 250
#define INF 0x3f3f3f3f
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>
#define MAX 50090
#define INF 0x3f3f3f3f

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

```

#define MAX 50900
#define mod 1000000007LL
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

```

#define MAX 100090
#define INF 0x3f3f3f3f
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 Maximum M Sum

```

-----Greedy-----
#define int long long
#define MAX 50900
#define INF 0x3f3f3f3f
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-----
#define int int_fast64_t
#define MAX 2000090
#define INF 0x3f3f3f3f
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 Range Color Online

```

#include <bits/stdc++.h>
using namespace std;
const int MAX_N = 1e5 + 6;
const int MAX_M = 3e5 + 6;
struct Node {
    int lc, rc;
    int val;
    void give_val(int _lc, int _rc, int _val) {
        lc = _lc; rc = _rc; val = _val;
    }
} node[530 * MAX_N];
int bit_root[MAX_N], root[MAX_N];
int node_cnt;
int getNode(int id) {
    int ret = ++node_cnt;
    node[ret] = node[id];
    return ret;
}
void pull(int id) {
    node[id].val = node[node[id].lc].val + node[node[id].
        rc].val;
}
void init(int id, int L, int R) {
    if (L == R) {
        node[id].give_val(0, 0, 0); return;
    }
    node[id].give_val(++node_cnt, ++node_cnt, 0);
    int mid = (L + R) >> 1;
    init(node[id].lc, L, mid);
    init(node[id].rc, mid + 1, R);
    return;
}
void modify(int old_id, int new_id, int L, int R, int pos,
    int val) {
    if (L == R) {
        node[new_id].val += val; return;
    }
    int mid = (L + R) >> 1;
    if (pos <= mid) {
        node[new_id].lc = getNode(node[old_id].lc);
        modify(node[old_id].lc, node[new_id].lc, L, mid, pos,
            val);
    }
    else {
        node[new_id].rc = getNode(node[old_id].rc);
        modify(node[old_id].rc, node[new_id].rc, mid + 1, R, pos,
            val);
    }
}

```

```

}
pull(new_id);
return;
}
int query(int id, int L, int R, int l, int r) {
    if (l <= L && R <= r) return node[id].val;
    int mid = (L + R) >> 1;
    if (mid + 1 > r) return query(node[id].lc, L, mid, l, r);
    else if (l > mid) return query(node[id].rc, mid + 1, R, l,
        r);
    return query(node[id].lc, L, mid, l, r) + query(node[id].
        rc, mid + 1, R, l, r);
}
set<int> st[MAX_M];
int last[MAX_N];
int s[MAX_N];
int n, q;
typedef long long LL;
void modify_bit(int L, int R, int pos, int val) {
    for (int i = L; n >= i; i += (i & (-i))) {
        modify(bit_root[i], bit_root[i], 1, n, pos, val);
    }
    if (R == n) return;
    for (int i = R + 1; n >= i; i += (i & (-i))) {
        modify(bit_root[i], bit_root[i], 1, n, pos, -val);
    }
}
int query_bit(int C, int L, int R) {
    int ret = 0;
    for (int i = C; i > 0; i -= (i & (-i))) {
        ret += query(bit_root[i], 1, n, L, R);
    }
    return ret;
}
int main () {
    int k, m;
    scanf("%d %d %d %d", &n, &q, &m, &k);
    node_cnt = 0; root[0] = ++node_cnt; init(root[0], 1, n)
        ;
    map<int, int> mp;
    for (int i = 1; n >= i; i++) {
        bit_root[i] = getNode(root[0]);
    }
    int id = 1;
    for (int i = 1; n >= i; i++) {
        int x; scanf("%d", &x);
        int ret = 0; auto iter = mp.find(x);
        if (iter == mp.end()) {
            mp.insert(make_pair(x, id));
            ret = id; id++;
        }
        else {
            ret = iter->second;
        }
        root[i] = getNode(root[i - 1]);
        if (last[ret] == 0) {
            modify(root[i - 1], root[i], 1, n, i, 1);
        }
        else {
            modify(root[i - 1], root[i], 1, n, i, 1);
            modify(root[i], root[i], 1, n, last[ret], -1);
        }
        last[ret] = i; st[ret].insert(i); s[i] = ret;
    }
    int pre_ans = 0;
    for (int i = 1; q >= i; i++) {
        int a, b, c;
        scanf("%d %d %d", &a, &b, &c);
        if (a == 0) {
            //one base !!! query(b, c)
            pre_ans = query(root[c], 1, n, b, c);
            pre_ans += query_bit(c, b, c);
            printf("%d\n", pre_ans);
        }
        else {
            //one base !!! a[b] = c
            c = (LL(pre_ans) * c % m) * k;
            if (mp[c] == s[b]) continue;
            int del = s[b]; auto iter = st[del].find(b);
            int ed = n + 1; ++iter;
            if (iter != st[del].end()) ed = *(iter);
            //b ~ ed - 1

```

```

    modify_bit(b,ed-1,b,-1);
    iter--;
    if (iter != st[del].begin()) {
        int start=*(--iter);
        modify_bit(b,ed-1,start,1);
    }
    st[del].erase(st[del].find(b));
    //finish delete

    //now let's add
    int ret=0;
    auto iter3=mp.find(c);
    if (iter3 == mp.end()) {
        mp.insert(make_pair(c,id));
        ret=id;
        id++;
    }
    else if (iter3->second == 0) {
        mp[c] = id;
        ret=id;
        id++;
    }
    else {
        ret=iter3->second;
    }
    auto iter4 = st[ret].insert(b).first;
    ed = n+1;
    ++iter4;
    if (iter4 != st[ret].end()) {
        ed = *(iter4);
    }
    --iter4;
    modify_bit(b,ed-1,b,1);
    if (iter4 != st[ret].begin()) {
        int start = *(--iter4);
        modify_bit(b,ed-1,start,-1);
    }
    s[b] = ret;
    st[ret].insert(b);
}
}
}

```

8.15 Minimum Enclosing Cycle

```

pdd arr[MAX];
pdd 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;
}

```

8.16 Triangle

```

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(){
    IOS;
    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;
}

```