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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));

/*
# Pick's theorem
$A=i+\frac{b}{2}-1$

# Laplacian matrix
$L = D - A$

# Extended Catalan number
$\frac{1}{(k-1)n+1} \{kn \choose n\}$
*/

```

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

$$\frac{1}{(k-1)n+1} \binom{kn}{n}$$

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;

int myRnd() {
    return 10000*(rand()%10000) + (rand()%10000);
}

struct Treap {
    static Treap mem[MAX_P];
    Treap *lc, *rc;
    char c; int sz;
    Treap(){
        Treap(_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

```

#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 + sqrtl(bb*bb-4*aa*cc))/(2*aa);
        D sin2 = (-bb - sqrtl(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+sqrtl(bbb*bbb-4*aaa*ccc))/(aaa*2);
        D cos2=(-bbb-sqrtl(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[i].FI) ) < 0;
        return ata[i] < ata[j];
    });
    vector<Line> fin;
    for( int i=0; i<sz; i++)
        if (!i or fabs(ata[ord[i]] - ata[ord[i-1]]) > eps)
            fin.pb(lines[ord[i]]);
    deque<Line> dq;
    for( int i=0; i<(int)(fin.size()); i++) {
        while((int)(dq.size()) >= 2 and
            not isin(fin[i], dq[(int)(dq.size())-2],
                dq[(int)(dq.size())-1]))
            dq.pop_back();
        while((int)(dq.size()) >= 2 and
            not isin(fin[i], dq[0], dq[1]))
            dq.pop_front();
        dq.push_back(fin[i]);
    }
    while( (int)(dq.size()) >= 3 and
        not isin(dq[0], dq[(int)(dq.size())-2],
            dq[(int)(dq.size())-1]))
        dq.pop_back();
    while( (int)(dq.size()) >= 3 and
        not isin(dq[(int)(dq.size())-1], dq[0], dq[1]))
        dq.pop_front();
    vector<Line> res(dq.begin(),dq.end());
    return res;
}

```

4.3 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 3^T + V^2 2^T)
struct SteinerTree{
#define V 33
#define T 8
#define INF 1023456789
    int n, dst[V][V], dp[1<<T][V], tdst[V];
    void init( int _n ){
        n = _n;
        for( int i = 0 ; i < n ; i ++ ){
            for( int j = 0 ; j < n ; j ++ )
                dst[ i ][ j ] = INF;
            dst[ i ][ i ] = 0;
        }
    }
    void add_edge( int ui , int vi , int wi ){
        dst[ ui ][ vi ] = min( dst[ ui ][ vi ] , wi );
        dst[ vi ][ ui ] = min( dst[ vi ][ ui ] , wi );
    }
    void shortest_path(){
        for( int k = 0 ; k < n ; k ++ )
            for( int i = 0 ; i < n ; i ++ )
                for( int j = 0 ; j < n ; j ++ )
                    dst[ i ][ j ] = min( dst[ i ][ j ],
                        dst[ i ][ k ] + dst[ k ][ j ] );
    }
    int solve( const vector<int>& ter ){
        int t = (int)ter.size();
        for( int i = 0 ; i < ( 1 << t ) ; i ++ )
            for( int j = 0 ; j < n ; j ++ )
                dp[ i ][ j ] = INF;
        for( int i = 0 ; i < n ; i ++ )
            dp[ 0 ][ i ] = 0;
        for( int msk = 1 ; msk < ( 1 << t ) ; msk ++ ){
            if( msk == ( msk & (-msk) ) ){
                int who = __lg( msk );
                for( int i = 0 ; i < n ; i ++ )
                    dp[ msk ][ i ] = dst[ ter[ who ] ][ i ];
                continue;
            }
            for( int i = 0 ; i < n ; i ++ )
                for( int submsk = ( msk - 1 ) & msk ; submsk = ( submsk - 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^tmp).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 * b2.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-->1) {
        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 mul(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 = mul(ret, now, mod);
        now = mul(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-->1) {
        ret = mul(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; i<N; i++) {
 if (!prime[i]) {
 for (LL j=i*1LL*i; j<N; 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 Debruijn

```

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; SIGMA > c; 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; SIGMA > c; 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; i < n; 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 Book

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

```



```

    }
    if(b[now].tag != 0) ans.A += ans.B * b[now].tag
    , ans.B = 0;
    return ans;
}
}
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
                )), 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 Sigma Problem

```

//problem->for(int i = 1; i <= n; i++) ans += pow(i, k);
#define int long long
#define MAX 2020
#define INF 0x3f3f3f3f
#define mod 1000000007LL
int b[MAX], c[MAX][MAX], ni[MAX];
int ppow(int a, int k){
    if(k == 0) return 1;
    if(k % 2 == 0) return ppow(a * a % mod, k >> 1);
    if(k % 2 == 1) return ppow(a * a % mod, k >> 1) * a % mod;
}

```

```

}
void solveinit(){
    REP(i, 0, MAX){
        REP(j, 0, i + 1){
            if(j == 0 || j == i) c[i][j] = 1;
            else c[i][j] = (c[i - 1][j] + c[i - 1][j - 1]) % mod;
        }
    }
    REP(i, 1, MAX) ni[i] = ppow(i, mod - 2);
    b[0] = 1;
    REP(i, 1, MAX){
        REP(j, 0, i) b[i] = (b[i] + c[i + 1][j] * b[j]) % mod;
        b[i] = b[i] * ni[i + 1] % mod;
        b[i] = mod - b[i];
    }
}
int t, n, k;
int32_t main(){
    solveinit();
    cin >> t;
    REP(times, 0, t){
        cin >> n >> k;
        n %= mod;
        int ans = 0, np = 1;
        REP(i, 1, k + 2){
            np = np * (n + 1) % mod;
            ans = (ans + c[k + 1][i] * np % mod * b[k + 1 - i] % mod) % mod;
        }
        ans = (ans * ni[k + 1]) % mod;
        cout << ans << endl;
    }
    return 0;
}

```

8.15 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 {

```

8.16 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;
}

```

8.17 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;
}

```