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1 Basic

1.1 Default code

```

#include<bits/stdc++.h>
#define int long long
#define mod 1000000007
#define endl '\n'
#define pii pair<int,int>
using namespace std;

signed main(){
    ios::sync_with_stdio(0),cin.tie(0);
}
```

1.2 Linux 對拍

```

set -e
for ((i=0;i<300;i++))
do
    echo "$i"
    python gen.py > input
    ./ac < input > ac.out
    ./wa < input > wa.out
    diff ac.out wa.out || break
done
```

1.3 Windows 對拍

```

@echo off
:loop
    echo %%x
    python gen.py > input
    ./ac.exe < input > ac.out
    ./wa.exe < input > wa.out
    fc ac.out wa.out
    if not errorlevel 1 goto loop
```

1.4 builtin 函數

```

// 右邊第一個 1 的位置
int __builtin_ffs(unsigned int);
int __builtin_ffsl(unsigned long);
int __builtin_ffsll(unsigned long long);
// 左邊第一個 1 之前 0 的數量
int __builtin_clz(unsigned int);
int __builtin_clzl(unsigned long);
int __builtin_clzll(unsigned long long);
// 右邊第一個 1 之後 0 的數量
int __builtin_ctz(unsigned int);
int __builtin_ctzl(unsigned long);
int __builtin_ctzll(unsigned long long);
// 1 的數量
int __builtin_popcount(unsigned int);
int __builtin_popcountl(unsigned long);
int __builtin_popcountll(unsigned long long);
// 1 的數量 mod 2
int __builtin_parity(unsigned int);
int __builtin_parityl(unsigned long);
int __builtin_parityll(unsigned long long);
// 二進制表示數字
int a = 0b101101;
```

1.5 輸入輸出

```

// 開讀檔
fopen("input_file_name","r",stdin);
fopen("output_file_name","w",stdout);
```

1.6 Python 輸入輸出

```

a = list(map(int,input().split()))

# 開讀檔
import sys, os.path
if(os.path.exists('input_file.txt')):
    sys.stdin = open("input_file.txt","r")
    sys.stdout = open("output_file.txt","w")
```

2 Data Structure

2.1 Link-Cut Tree

```

struct Splay {
    static Splay nil, mem[MEM], *pmem;
    Splay *ch[2], *f;
    int val, rev, size;
    Splay (int _val=-1) : val(_val), rev(0), size(1)
    { f = ch[0] = ch[1] = &nil; }
    bool isr()
    { return f->ch[0] != this && f->ch[1] != this; }
    int dir()
    { return f->ch[0] == this ? 0 : 1; }
    void setCh(Splay *c, int d){
        ch[d] = c;
        if (c != &nil) c->f = this;
        pull();
    }
    void push(){
        if( !rev ) return;
        swap(ch[0], ch[1]);
        if (ch[0] != &nil) ch[0]->rev ^= 1;
        if (ch[1] != &nil) ch[1]->rev ^= 1;
        rev=0;
    }
    void pull(){
        size = ch[0]->size + ch[1]->size + 1;
        if (ch[0] != &nil) ch[0]->f = this;
        if (ch[1] != &nil) ch[1]->f = this;
    }
} Splay::nil, Splay::mem[MEM], *Splay::pmem = Splay::
mem;
Splay *nil = &Splay::nil;
void rotate(Splay *x){
    Splay *p = x->f;
    int d = x->dir();
    if (!p->isr()) p->f->setCh(x, p->dir());
    else x->f = p->f;
    p->setCh(x->ch[!d], d);
    x->setCh(p, !d);
    p->pull(); x->pull();
}
vector<Splay*> splayVec;
void splay(Splay *x){
    splayVec.clear();
    for (Splay *q=x;; q=q->f){
        splayVec.push_back(q);
        if (q->isr()) break;
    }
    reverse(begin(splayVec), end(splayVec));
    for (auto it : splayVec) it->push();
    while (!x->isr()) {
        if (x->f->isr()) rotate(x);
        else if (x->dir()==x->f->dir())
            rotate(x->f), rotate(x);
        else rotate(x), rotate(x);
    }
}
int id(Splay *x) { return x - Splay::mem + 1; }
Splay* access(Splay *x){
    Splay *q = nil;
    for (;x!=nil;x=x->f){
        splay(x);
        x->setCh(q, 1);
        q = x;
    }
    return q;
}
void chroot(Splay *x){
    access(x);
    splay(x);
    x->rev ^= 1;
    x->push(); x->pull();
}
void link(Splay *x, Splay *y){
    access(x);
    splay(x);
    chroot(y);
    x->setCh(y, 1);
}
void cut_p(Splay *y) {

```

```

    access(y);
    splay(y);
    y->push();
    y->ch[0] = y->ch[0]->f = nil;
}
void cut(Splay *x, Splay *y){
    chroot(x);
    cut_p(y);
}
Splay* get_root(Splay *x) {
    access(x);
    splay(x);
    for(; x->ch[0] != nil; x = x->ch[0])
        x->push();
    splay(x);
    return x;
}
bool conn(Splay *x, Splay *y) {
    x = get_root(x);
    y = get_root(y);
    return x == y;
}
Splay* lca(Splay *x, Splay *y) {
    access(x);
    access(y);
    splay(x);
    if (x->f == nil) return x;
    else return x->f;
}
}

```

2.2 持久化線段樹

```

struct Seg{
    struct Node{
        int v;
        Node* l,*r;
    };
    vector<Node*> version;
    Node* build(int l,int r){
        Node* node=new Node;
        if(l==r){
            node->v=l;
            return node;
        }
        int mid=(l+r)/2;
        node->l=build(l,mid);
        node->r=build(mid+1,r);
        return node;
    }
    int query(Node* cur,int l,int r,int x){
        if(l==r){
            return cur->v;
        }
        int mid=(l+r)/2;
        if(x<=mid) return query(cur->l,l,mid,x);
        else return query(cur->r,mid+1,r,x);
    }
    Node* update(Node* cur,int l,int r,int x,int y){
        Node* node=new Node;
        if(l==r){
            node->v=y;
            return node;
        }
        int mid=(l+r)/2;
        if(x<=mid){
            node->l=update(cur->l,l,mid,x,y);
            node->r=cur->r;
        }
        else{
            node->l=cur->l;
            node->r=update(cur->r,mid+1,r,x,y);
        }
        return node;
    }
};

```

2.3 Treap

```

mt19937 gen(chrono::steady_clock::now().
    time_since_epoch().count()); // C++ randomizer
struct Node {
    int k, p, sz = 1;

```

```

Node *l = 0, *r = 0;
bool tag = 0;
Node(int kk) {
    k = kk;
    p = gen();
}
};
Node *root = 0;
int size(Node *x) {return x ? x->sz : 0;}
void push(Node *x) {
    if(x->tag) {
        if(x->l) x->l->tag ^= true;
        if(x->r) x->r->tag ^= true;
        x->tag = false;
    }
}
void pull(Node* x) {
    x->sz = size(x->l) + size(x->r) + 1;
}
Node* merge(Node *a, Node *b) {
    if(!a || !b) return a ? b;
    if(a->p > b->p) {
        push(a);
        a->r = merge(a->r, b);
        pull(a);
        return a;
    }
    else{
        push(b);
        b->l = merge(a, b->l);
        pull(b);
        return b;
    }
}
void splitKey(Node* x, int k, Node *&a, Node *&b) {
    if(!x) {a = b = 0; return;}
    push(x);
    if(x->k <= k) {
        a = x;
        splitKey(a->r, k, a->r, b);
        pull(a);
    }
    else{
        b = x;
        splitKey(b->l, k, a, b->l);
        pull(b);
    }
}
void splitKth(Node *x, int k, Node *&a, Node *&b) {
    if(!x) {a = b = 0; return;}
    push(x);
    if(size(x->l) < k) {
        a = x;
        splitKth(a->r, k - size(x->l) - 1, a->r, b);
        pull(a);
    }
    else{
        b = x;
        splitKth(b->l, k, a, b->l);
        pull(b);
    }
}
void insert(int id) {
    Node *l, *r;
    splitKey(root, id, l, r);
    Node *m = new Node(id);
    root = merge(l, merge(m, r));
}
void erase(int x) {
    Node *a, *b, *c;
    splitKey(root, x, b, c);
    splitKey(b, x - 1, a, b);
    root = merge(a, c);
}

```

2.4 線段樹

```

struct Seg{
    vector<int> seg,tag;
    #define cl (i<<1)+1
    #define cr (i<<1)+2
    void push(int i,int l,int r){

```

```

        if(tag[i]!=0){
            seg[i]+=tag[i]; // update by tag
            if(l!=r){
                tag[cl]+=tag[i]; // push
                tag[cr]+=tag[i]; // push
            }
            tag[i]=0;
        }
    }
}
void pull(int i,int l,int r){
    int mid=(l+r)>>1;
    push(cl,l,mid);push(cr,mid+1,r);
    seg[i]=max(seg[cl],seg[cr]); // pull
}
void build(int i,int l,int r,vector<int>&arr){
    if(l==r){
        seg[i]=arr[l]; // set value
        return;
    }
    int mid=(l+r)>>1;
    build(cl,l,mid,arr);
    build(cr,mid+1,r,arr);
    pull(i,l,r);
}
Seg(vector<int>& arr){
    seg.resize(arr.size()*4);
    tag.resize(arr.size()*4);
    build(0,0,arr.size()-1,arr);
}
void update(int i,int l,int r,int nl,int nr,int x){
    push(i,l,r);
    if(nl<=l&&r<=nr){
        tag[i]+=x;
        return;
    }
    int mid=(l+r)>>1;
    if(nl<=mid) update(cl,l,mid,nl,nr,x);
    if(nr>mid) update(cr,mid+1,r,nl,nr,x);
    pull(i,l,r);
}
int query(int i,int l,int r,int nl,int nr){
    push(i,l,r);
    if(nl<=l&&r<=nr){
        return seg[i];
    }
    int mid=(l+r)>>1;
    int ans=0;
    if(nl<=mid) ans=max(ans,query(cl,l,mid,nl,nr));
    if(nr>mid) ans=max(ans,query(cr,mid+1,r,nl,nr));
    return ans;
}
};

```

3 Flow

3.1 Dinic

```

const int inf = 1e8;
struct Dinic{
    #define SZ(x) (int)(x.size())
    struct Edge{
        int v,f,re;
    };
    vector<vector<Edge>> E;
    vector<int> level;
    int n,s,t;
    Dinic(int nn,int ss,int tt){
        n=nn;s=ss;t=tt;
        E.resize(n);
        level.resize(n);
    }
    void addEdge(int u,int v,int w){
        E[u].push_back({v,w,SZ(E[v])});
        E[v].push_back({u,0,SZ(E[u])-1});
    }
    bool bfs(){
        level.assign(n,0);
        queue<int> q;
        q.push(s);
        level[s]=1;
        while(q.size()){

```

```

    int u=q.front();q.pop();
    for(auto&it:E[u]){
        int v=it.v;
        if(it.f>0 && !level[v]){
            level[v]=level[u]+1;
            q.push(v);
        }
    }
    return level[t];
}
int dfs(int u,int nf){
    if(u==t)return nf;
    int ret=0;
    for(auto&it:E[u]){
        int v=it.v;
        if(it.f>0&&level[v]==level[u]+1){
            int tem = dfs(v,min(nf,it.f));
            ret+=tem;nf-=tem;
            it.f-=tem;E[v][it.re].f+=tem;
            if(!nf)return ret;
        }
    }
    if(!ret)level[u]=0;
    return ret;
}
int flow(){
    int ret=0;
    while(bfs()) ret+=dfs(s,inf);
    return ret;
}
};

```

3.2 匈牙利

```

#define NIL -1
#define INF 100000000
int n,matched;
int cost[MAXN][MAXN];
bool sets[MAXN]; // whether x is in set S
bool sett[MAXN]; // whether y is in set T
int xlabel[MAXN],ylabel[MAXN];
int xy[MAXN],yx[MAXN]; // matched with whom
int slack[MAXN]; // given y: min{xlabel[x]+ylabel[y]-cost[x][y]} | x not in S
int prev[MAXN]; // for augmenting matching
inline void relabel() {
    int i,delta=INF;
    for(i=0;i<n;i++) if(!sett[i]) delta=min(slack[i],delta);
    for(i=0;i<n;i++) if(sets[i]) xlabel[i]-=delta;
    for(i=0;i<n;i++) {
        if(sett[i]) ylabel[i]+=delta;
        else slack[i]-=delta;
    }
}
inline void add_sets(int x) {
    int i;
    sets[x]=1;
    for(i=0;i<n;i++) {
        if(xlabel[x]+ylabel[i]-cost[x][i]<slack[i]) {
            slack[i]=xlabel[x]+ylabel[i]-cost[x][i];
            prev[i]=x;
        }
    }
}
inline void augment(int final) {
    int x=prev[final],y=final,tmp;
    matched++;
    while(1) {
        tmp=xy[x]; xy[x]=y; yx[y]=x; y=tmp;
        if(y==NIL) return;
        x=prev[y];
    }
}
inline void phase() {
    int i,y,root;
    for(i=0;i<n;i++) { sets[i]=sett[i]=0; slack[i]=INF; }
    for(root=0;root<n&&xy[root]!=NIL;root++);
    add_sets(root);
    while(1) {
        relabel();

```

```

        for(y=0;y<n;y++) if(!sett[y]&&slack[y]==0) break;
        if(yx[y]==NIL) { augment(y); return; }
        else { add_sets(yx[y]); sett[y]=1; }
    }
}
inline int hungarian() {
    int i,j,c=0;
    for(i=0;i<n;i++) {
        xy[i]=yx[i]=NIL;
        xlabel[i]=ylabel[i]=0;
        for(j=0;j<n;j++) xlabel[i]=max(cost[i][j],xlabel[i]);
    }
    for(i=0;i<n;i++) phase();
    for(i=0;i<n;i++) c+=cost[i][xy[i]];
    return c;
}

```

3.3 KM

```

struct KM{ // max weight, for min negate the weights
    int n, mx[MAXN], my[MAXN], pa[MAXN];
    ll g[MAXN][MAXN], lx[MAXN], ly[MAXN], sy[MAXN];
    bool vx[MAXN], vy[MAXN];
    void init(int _n) { // 1-based
        n = _n;
        for(int i=1; i<=n; i++) fill(g[i], g[i]+n+1, 0);
    }
    void addEdge(int x, int y, ll w) {g[x][y] = w;}
    void augment(int y) {
        for(int x, z; y; y = z)
            x=pa[y], z=mx[x], my[y]=x, mx[x]=y;
    }
    void bfs(int st) {
        for(int i=1; i<=n; ++i) sy[i]=INF, vx[i]=vy[i]=0;
        queue<int> q; q.push(st);
        for(;;) {
            while(q.size()) {
                int x=q.front(); q.pop(); vx[x]=1;
                for(int y=1; y<=n; ++y) if(!vy[y]){
                    ll t = lx[x]+ly[y]-g[x][y];
                    if(t==0){
                        pa[y]=x;
                        if(!my[y]){augment(y);return;}
                        vy[y]=1, q.push(my[y]);
                    }else if(sy[y]>t) pa[y]=x,sy[y]=t;
                }
            }
            ll cut = INF;
            for(int y=1; y<=n; ++y)
                if(!vy[y]&&cut>sy[y]) cut=sy[y];
            for(int j=1; j<=n; ++j){
                if(vx[j]) lx[j] -= cut;
                if(vy[j]) ly[j] += cut;
                else sy[j] -= cut;
            }
            for(int y=1; y<=n; ++y) if(!vy[y]&&sy[y]==0){
                if(!my[y]){augment(y);return;}
                vy[y]=1, q.push(my[y]);
            }
        }
    }
    ll solve(){
        fill(mx, mx+n+1, 0); fill(my, my+n+1, 0);
        fill(ly, ly+n+1, 0); fill(lx, lx+n+1, -INF);
        for(int x=1; x<=n; ++x) for(int y=1; y<=n; ++y)
            lx[x] = max(lx[x], g[x][y]);
        for(int x=1; x<=n; ++x) bfs(x);
        ll ans = 0;
        for(int y=1; y<=n; ++y) ans += g[my[y]][y];
        return ans;
    }
} graph;

```

3.4 MCMF

```

struct MCMF {
    #define SZ(x) (int)(x.size())
    struct Edge {
        int v, f, re, c;
    };
    vector<vector<Edge>> E;
    vector<int> dis, x, y;
    int n, s, t;
    MCMF(int nn, int ss, int tt) {
        n = nn; s = ss; t = tt;

```

```

    E.resize(n);
    x.resize(n);
    y.resize(n);
}
void addEdge(int u, int v, int w, int c) {
    E[u].push_back({v, w, SZ(E[v]), c});
    E[v].push_back({u, 0, SZ(E[u]) - 1, -c});
}
bool spfa() {
    dis.assign(n, 0x3f3f3f3f);
    x.assign(n, -1);
    y.assign(n, -1);
    vector<bool> inq(n, false);
    queue<int> q;
    q.push(s);
    inq[s] = true;
    dis[s] = 0;
    while(q.size()) {
        int u = q.front(); q.pop();
        inq[u] = false;
        for(int i = 0; i < E[u].size(); i++) {
            auto& it = E[u][i];
            int v = it.v;
            if(it.f > 0 && dis[v] > dis[u] + it.c) {
                dis[v] = dis[u] + it.c;
                x[v] = u;
                y[v] = i;
                if(!inq[v]) {
                    q.push(v);
                    inq[v] = true;
                }
            }
        }
    }
    return x[t] != -1;
}
pii solve() {
    int mf = 0, mc = 0;
    while(spfa()) {
        int nf = 0x3f3f3f3f;
        for(int i = t; i != s; i = x[i]) {
            nf = min(nf, E[x[i]][y[i]].f);
        }
        for(int i = t; i != s; i = x[i]) {
            auto& it = E[x[i]][y[i]];
            it.f -= nf;
            E[it.v][it.re].f += nf;
        }
        mf += nf;
        mc += nf * dis[t];
    }
    return {mf, mc};
}
};

```

4 幾何

4.1 宣告

```

typedef long double ld;
const ld eps = 1e-10;
#define sign(x) ((x) > eps) - ((x) < -eps)
#define sq(p) ((p)*(p))
#define len(p) (sqrt(sq(p)))
#define r90(p) Pt(-(p).y, (p).x)

struct Pt {
    ld x, y;
    Pt(ld x = 0, ld y = 0) : x(x), y(y) {}
    Pt operator + (const Pt &a) const {
        return Pt(x + a.x, y + a.y);
    }
    Pt operator - (const Pt &a) const {
        return Pt(x - a.x, y - a.y);
    }
    Pt operator * (const ld &a) const {
        return Pt(x * a, y * a);
    }
    Pt operator / (const ld &a) const {
        return Pt(x / a, y / a);
    }
    ld operator * (const Pt &a) const {
        return x * a.x + y * a.y;
    }
    ld operator ^ (const Pt &a) const {
        return x * a.y - y * a.x;
    }
}

```

```

bool operator < (const Pt &a) const {
    return sign(x - a.x) < 0 || sign(x - a.x) == 0 &&
        sign(y - a.y) < 0;
}
bool operator == (const Pt &a) const {
    return sign(x - a.x) == 0 && sign(y - a.y) == 0;
}

```

```

struct Line {
    Pt s, e, v; // start, end, end-start
    ld rad;
    Line(Pt s = Pt(), Pt e = Pt())
        : s(s), e(e), v(e - s), rad(atan2(v.y, v.x)) {}
    bool operator < (const Line &l) const {
        return rad < l.rad;
    }
};

```

```

struct Circle {
    Pt o; ld r2;
    Circle(Pt o = Pt(), ld r = 0) : o(o), r2(sq(r)) {}
    Circle(const Pt &p1, const Pt &p2)
        : o((p1 + p2) / 2), r2(sq(p1 - p2) / 4.0) {}
    Circle(const Pt &p1, const Pt &p2, const Pt &p3) {
        Pt va = r90(p1 - p2), vb = r90(p1 - p3);
        if (sign(va ^ vb) == 0) {
            *this = Circle(p1, p2);
            Circle t(p1, p3);
            if (r2 < t.r2) *this = t;
            t = Circle(p2, p3);
            if (r2 < t.r2) *this = t;
        }
        else {
            Pt p12 = (p1 + p2) / 2, p13 = (p1 + p3) / 2;
            ld t = ((p13 - p12) * (p1 - p3)) / (va ^ vb);
            o = p12 + va*t;
            r2 = sq(o - p1);
        }
    }
    bool contain(const Pt &a) {
        return sign(sq(a - o) - r2) <= 0;
    }
};

```

4.2 矩形面積

```

struct AreaofRectangles {
#define cl(x) (x<<1)
#define cr(x) (x<<1|1)
    ll n, id, sid;
    pair<ll, ll> tree[MXN<<3]; // count, area
    vector<ll> ind;
    tuple<ll, ll, ll, ll> scan[MXN<<1];
    void pull(int i, int l, int r) {
        if(tree[i].first) tree[i].second = ind[r+1] - ind[l];
        else if(l != r) {
            int mid = (l+r)>>1;
            tree[i].second = tree[cl(i)].second + tree[cr(i)].second;
        }
        else tree[i].second = 0;
    }
    void upd(int i, int l, int r, int ql, int qr, int v) {
        if(ql <= l && r <= qr) {
            tree[i].first += v;
            pull(i, l, r); return;
        }
        int mid = (l+r) >> 1;
        if(ql <= mid) upd(cl(i), l, mid, ql, qr, v);
        if(qr > mid) upd(cr(i), mid+1, r, ql, qr, v);
        pull(i, l, r);
    }
    void init(int _n) {
        n = _n; id = sid = 0;
        ind.clear(); ind.resize(n<<1);
        fill(tree, tree+(n<<2), make_pair(0, 0));
    }
    void addRectangle(int lx, int ly, int rx, int ry) {
        ind[id++] = lx; ind[id++] = rx;
        scan[sid++] = make_tuple(ly, 1, lx, rx);
        scan[sid++] = make_tuple(ry, -1, lx, rx);
    }
    ll solve() {
        sort(ind.begin(), ind.end());
    }
}

```

```

    ind.resize(unique(ind.begin(), ind.end()) - ind
        .begin());
    sort(scan, scan + sid);
    ll area = 0, pre = get<0>(scan[0]);
    for(int i = 0; i < sid; i++){
        auto [x, v, l, r] = scan[i];
        area += tree[1].second * (x-pre);
        upd(1, 0, ind.size()-1, lower_bound(ind.
            begin(), ind.end(), l)-ind.begin(),
            lower_bound(ind.begin(), ind.end(), r)-
            ind.begin()-1, v);
        pre = x;
    }
    return area;
} }rect;

```

4.3 最近點對

```

#include<bits/stdc++.h>
#define int long long
using namespace std;
using ld = long double;
const int mod = 1e9+7;
struct pt{
    int x,y;
    int id;
    ld dis(const pt& rhs){
        return sqrt((x-rhs.x)*(x-rhs.x)+(y-rhs.y)*(y-
            rhs.y));
    }
};
signed main(){
    int n;
    cin>>n;
    vector<pt> a(n);
    for(int i=0;i<n;i++){
        cin>>a[i].x>>a[i].y;
        a[i].id=i;
    }
    ld ans = 1e19;
    sort(a.begin(),a.end(),[](const pt&a,const pt&b){
        if(a.x==b.y)return a.y<b.y;
        return a.x<b.x;
    });
    pt ans2;
    function<void(int,int)> dnq = [&](int l,int r){
        if(r-l<4){
            for(int i=l;i<=r;i++){
                for(int j=i+1;j<=r;j++){
                    ld temans = a[i].dis(a[j]);
                    if(temans<ans){
                        ans=temans;
                        ans2 = {a[i].id,a[j].id};
                    }
                }
            }
            sort(a.begin()+l,a.begin()+r+1,[](const pt&
                a,const pt&b){return a.y<b.y;});
            return;
        }
        int mid = (l+r)/2;
        int midx = a[mid].x;
        dnq(l,mid);dnq(mid+1,r);
        inplace_merge(a.begin()+l,a.begin()+mid+1,a.
            begin()+r+1,[](const pt&a,const pt&b){
                return a.y<b.y;});
        vector<int> c;c.reserve(r-l+1);
        for(int i=l;i<=r;i++){
            if(abs(a[i].x-midx)<ans){
                for(int j=c.size()-1;j>=0&&a[i].y-a[c[j]
                    ]>ans;j--){
                    ld temans = a[i].dis(a[c[j]]);
                    if(temans<ans){
                        ans=temans;
                        ans2 = {a[i].id,a[c[j]].id
                            };
                    }
                }
            }
        }
        c.push_back(i);
    }
}

```

```

};
dnq(0,n-1);
cout<<min(ans2.x,ans2.y)<<' '<<max(ans2.x,ans2.y)<<
    ' '<<fixed<<setprecision(6)<<ans<<'\n';
}

```

4.4 凸包

```

double cross(Pt o, Pt a, Pt b){
    return (a-o) ^ (b-o);
}
vector<Pt> convex_hull(vector<Pt> pt){
    sort(pt.begin(),pt.end());
    int top=0;
    vector<Pt> stk(2*pt.size());
    for (int i=0; i<(int)pt.size(); i++){
        while (top >= 2 && cross(stk[top-2],stk[top-1],pt[i]
            ]) <= 0)
            top--;
        stk[top++] = pt[i];
    }
    for (int i=pt.size()-2, t=top+1; i>=0; i--){
        while (top >= t && cross(stk[top-2],stk[top-1],pt[i]
            ]) <= 0)
            top--;
        stk[top++] = pt[i];
    }
    stk.resize(top-1);
    return stk;
}

```

4.5 兩直線交點

```

pair<int, Pt> L_intersect(const Line &a, const Line &b)
{
    ld f1 = a.v ^ (b.s - a.s), f2 = a.v ^ (a.s - b.e), f;
    if(sign(f = f1 + f2) == 0)
        return sign(f1) ? {0, a.s} : {2, a.s};
    return {1, b.s * (f2 / f) + b.e * (f1 / f)};
}

```

4.6 兩線段交點

```

inline int ori(const Pt &o, const Pt &a, const Pt &b) {
    return sign((a - o) ^ (b - o)); }
// 0:out, 1:ontop, 2:in
inline int btw(const Pt &a, const Pt &b, const Pt &c) {
    if (ori(a, b, c)) return 0;
    int s = sign((c - a) * (c - b));
    return (s < 0) + (s <= 0); }
// 0:no, 1:1pt(parallel), -1:1pt, 2:inf pt
int banana(const Pt &p1, const Pt &p2,
    const Pt &p3, const Pt &p4) {
    int a123 = ori(p1, p2, p3);
    int a124 = ori(p1, p2, p4);
    int a341 = ori(p3, p4, p1);
    int a342 = ori(p3, p4, p2);
    if (a123 == 0 && a124 == 0) {
        return btw(p1, p2, p3) + btw(p1, p2, p4) +
            btw(p3, p4, p1) + btw(p3, p4, p2) >> 1;
    }
    return -(a123 * a124 <= 0 && a341 * a342 <= 0);
}
pair<int, Pt> S_intersect(const Pt &p1, const Pt &p2,
    const Pt &p3, const Pt &p4) {
    int b = banana(p1, p2, p3, p4);
    if (b != -1) return {b, btw(p1, p2, p3) ? p3 : p4};
    ld a123 = (p2 - p1) ^ (p3 - p1);
    ld a124 = (p2 - p1) ^ (p4 - p1);
    return {1, (p4 * a123 - p3 * a124) / (a123 - a124)
        };
}

```

4.7 李超線段樹

```

struct LiChao_min{
    struct line{
        ll m,c;
        line(ll _m=0,ll _c=0){ m=_m; c=_c; }
        ll eval(ll x){ return m*x+c; } // overflow
    };
    struct node{

```



```

    node *l,*r; line f;
    node(line v){ f=v; l=r=NULL; }
};
typedef node* pnode;
pnode root; ll sz,ql,q,r;
#define mid ((l+r)>>1)
void insert(line v,ll l,ll r,pnode &nd){
    /* if(!(ql<=l&&r<=qr)){
        if(!nd) nd=new node(line(0,INF));
        if(ql<=mid) insert(v,l,mid,nd->l);
        if(qr>mid) insert(v,mid+1,r,nd->r);
        return;
    } used for adding segment */
    if(!nd) nd=new node(v); return; }
    ll trl=nd->f.eval(l),trr=nd->f.eval(r);
    ll vl=v.eval(l),vr=v.eval(r);
    if(trl<=vl&&trr<=vr) return;
    if(trl>vl&&trr>vr) { nd->f=v; return; }
    if(trl>vl) swap(nd->f,v);
    if(nd->f.eval(mid)<v.eval(mid))
        insert(v,mid+1,r,nd->r);
    else swap(nd->f,v),insert(v,l,mid,nd->l);
}
ll query(ll x,ll l,ll r,pnode &nd){
    if(!nd) return INF;
    if(l==r) return nd->f.eval(x);
    if(mid>=x)
        return min(nd->f.eval(x),query(x,l,mid,nd->l));
    return min(nd->f.eval(x),query(x,mid+1,r,nd->r));
}
/* -sz<=ll query_x<=sz */
void init(ll _sz){ sz=_sz+1; root=NULL; }
void add_line(ll m,ll c,ll l=-INF,ll r=INF){
    line v(m,c); ql=l; qr=r; insert(v,-sz,sz,root);
}
ll query(ll x) { return query(x,-sz,sz,root); }
};

```

4.8 最小包覆圓

```

// remember to shuffle!!!
Circle encircle(const vector<Pt> &pts) {
    Circle ans(Pt(), 0);
    for (int i = 0; i < pts.size(); ++i) {
        if (ans.contains(pts[i])) continue;
        ans = {pts[i], 0};
        for (int j = 0; j < i; ++j) {
            if (ans.contains(pts[j])) continue;
            ans = {pts[i], pts[j]};
            for (int k = 0; k < j; ++k) {
                if (ans.contains(pts[k])) continue;
                ans = {pts[i], pts[j], pts[k]}; } } }
    return ans;
}

```

4.9 最小包覆球

```

// Pt : { x , y , z }
#define N 202020
int n, nouter; Pt pt[ N ], outer[4], res;
double radius,tmp;
void ball() {
    Pt q[3]; double m[3][3], sol[3], L[3], det;
    int i,j; res.x = res.y = res.z = radius = 0;
    switch ( nouter ) {
        case 1: res=outer[0]; break;
        case 2: res=(outer[0]+outer[1])/2; radius=norm2(res, outer[0]); break;
        case 3:
            for (i=0; i<2; ++i) q[i]=outer[i+1]-outer[0];
            for (i=0; i<2; ++i) for(j=0; j<2; ++j) m[i][j]=(q[i] * q[j])*2;
            for (i=0; i<2; ++i) sol[i]=(q[i] * q[i]);
            if (fabs(det=m[0][0]*m[1][1]-m[0][1]*m[1][0])<eps)
                return;
            L[0]=(sol[0]*m[1][1]-sol[1]*m[0][1])/det;
            L[1]=(sol[1]*m[0][0]-sol[0]*m[1][0])/det;
            res=outer[0]+q[0]*L[0]+q[1]*L[1];
            radius=norm2(res, outer[0]);
            break;
        case 4:

```

```

            for (i=0; i<3; ++i) q[i]=outer[i+1]-outer[0], sol[i]=(q[i] * q[i]);
            for (i=0; i<3; ++i) for(j=0; j<3; ++j) m[i][j]=(q[i] * q[j])*2;
            det= m[0][0]*m[1][1]*m[2][2]
                + m[0][1]*m[1][2]*m[2][0]
                + m[0][2]*m[1][0]*m[2][1]
                - m[0][2]*m[1][1]*m[2][0]
                - m[0][1]*m[1][0]*m[2][2]
                - m[0][0]*m[1][2]*m[2][1];
            if ( fabs(det)<eps ) return;
            for (j=0; j<3; ++j) {
                for (i=0; i<3; ++i) m[i][j]=sol[i];
                L[j]=( m[0][0]*m[1][1]*m[2][2]
                    + m[0][1]*m[1][2]*m[2][0]
                    + m[0][2]*m[1][0]*m[2][1]
                    - m[0][2]*m[1][1]*m[2][0]
                    - m[0][1]*m[1][0]*m[2][2]
                    - m[0][0]*m[1][2]*m[2][1]
                    ) / det;
                for (i=0; i<3; ++i) m[i][j]=(q[i] * q[j])*2;
            } res=outer[0];
            for (i=0; i<3; ++i) res = res + q[i] * L[i];
            radius=norm2(res, outer[0]);
        }
    }
    void minball(int n){ ball();
        if( nouter < 4 ) for( int i = 0 ; i < n ; i ++ )
            if( norm2(res, pt[i]) - radius > eps ){
                outer[ nouter ++ ] = pt[ i ]; minball(i); --
                nouter;
            } if(i>0){ Pt Tt = pt[i];
                memmove(&pt[1], &pt[0], sizeof(Pt)*i); pt[0]=Tt;
            }
    }
    double solve(){
        // n points in pt
        random_shuffle(pt, pt+n); radius=-1;
        for(int i=0;i<n;i++) if(norm2(res,pt[i])-radius>eps)
            nouter=1, outer[0]=pt[i], minball(i);
        return sqrt(radius);
    }
}

```

4.10 旋轉卡尺

```

int FarthestPair(vector<Pt>& arr){
    int ret=0;
    for(int i = 0, j = i+1; i<arr.size(); i++){
        while(distance(arr[i], arr[j]) < distance(arr[i], arr[(j+1)%arr.size()])){
            j = (j+1) % arr.size();
        }
        ret = max(ret, distance(arr[i],arr[j]));
    }
    return ret;
}

```

4.11 Circle Cover

```

#define N 1021
#define D long double
struct CircleCover{
    int C; Circ c[ N ]; //填入C(圓數量),c(圓陣列)
    bool g[ N ][ N ], overlap[ N ][ N ];
    // Area[i] : area covered by at least i circles
    D Area[ N ];
    void init( int _C ){ C = _C; }
    bool CCinter( Circ& a , Circ& b , Pt& p1 , Pt& p2 ){
        Pt o1 = a.O , o2 = b.O;
        D r1 = a.R , r2 = b.R;
        if( norm( o1 - o2 ) > r1 + r2 ) return false;
        if( norm( o1 - o2 ) < max(r1, r2) - min(r1, r2) )
            return true;
        D d2 = ( o1 - o2 ) * ( o1 - o2 );
        D d = sqrt(d2);
        if( d > r1 + r2 ) return false;
        Pt u=(o1+o2)*0.5 + (o1-o2)*((r2*r2-r1*r1)/(2*d2));
        D A=sqrt((r1+r2+d)*(r1-r2+d)*(r1+r2-d)*(-r1+r2+d));
        Pt v=Pt( o1.Y-o2.Y , -o1.X + o2.X ) * A / (2*d2);
        p1 = u + v; p2 = u - v;
        return true;
    }
} Teve {

```

```

Pt p; D ang; int add;
Teve() {}
Teve(Pt _a, D _b, int _c):p(_a), ang(_b), add(_c){}
bool operator<(const Teve &a)const
{return ang < a.ang;}
}eve[ N * 2 ];
// strict: x = 0, otherwise x = -1
bool disjuct( Circ& a, Circ& b, int x )
{return sign( norm( a.0 - b.0 ) - a.R - b.R ) > x;}
bool contain( Circ& a, Circ& b, int x )
{return sign( a.R - b.R - norm( a.0 - b.0 ) ) > x;}
bool contain(int i, int j){
/* c[j] is non-strictly in c[i]. */
return (sign(c[i].R - c[j].R) > 0 ||
(sign(c[i].R - c[j].R) == 0 && i < j) ) &&
contain(c[i], c[j], -1);
}
void solve(){
for( int i = 0 ; i <= C + 1 ; i ++ )
Area[ i ] = 0;
for( int i = 0 ; i < C ; i ++ )
for( int j = 0 ; j < C ; j ++ )
overlap[i][j] = contain(i, j);
for( int i = 0 ; i < C ; i ++ )
for( int j = 0 ; j < C ; j ++ )
g[i][j] = !(overlap[i][j] || overlap[j][i] ||
disjuct(c[i], c[j], -1));
for( int i = 0 ; i < C ; i ++ ){
int E = 0, cnt = 1;
for( int j = 0 ; j < C ; j ++ )
if( j != i && overlap[j][i] )
cnt ++;
for( int j = 0 ; j < C ; j ++ )
if( i != j && g[i][j] ){
Pt aa, bb;
CCinter(c[i], c[j], aa, bb);
D A=atan2(aa.Y - c[i].O.Y, aa.X - c[i].O.X);
D B=atan2(bb.Y - c[i].O.Y, bb.X - c[i].O.X);
eve[E ++] = Teve(bb, B, 1);
eve[E ++] = Teve(aa, A, -1);
if(B > A) cnt ++;
}
}
if( E == 0 ) Area[ cnt ] += pi * c[i].R * c[i].R;
else{
sort( eve , eve + E );
eve[E] = eve[0];
for( int j = 0 ; j < E ; j ++ ){
cnt += eve[j].add;
Area[cnt] += (eve[j].p ^ eve[j + 1].p) * 0.5;
D theta = eve[j + 1].ang - eve[j].ang;
if (theta < 0) theta += 2.0 * pi;
Area[cnt] +=
(theta - sin(theta)) * c[i].R*c[i].R * 0.5;
}}}}};

```

4.12 Convex Hull Trick

```

/* 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;
} };

```

4.13 Half Plane Intersection

```

// for point or line solution, change > to >=
bool onleft(Line L, Pt p) {
    return dcmp(L.v^(p-L.s)) > 0;
} // segment should add Counterclockwise
// assume that Lines intersect
vector<Pt> HPI(vector<Line>& L) {
    sort(L.begin(), L.end()); // sort by angle
    int n = L.size(), fir, las;
    Pt *p = new Pt[n];
    Line *q = new Line[n];
    q[fir=las=0] = L[0];
    for(int i = 1; i < n; i++) {
        while(fir < las && !onleft(L[i], p[las-1])) las--;
        while(fir < las && !onleft(L[i], p[fir])) fir++;
        q[++las] = L[i];
        if(dcmp(q[las].v^q[las-1].v) == 0) {
            las--;
            if(onleft(q[las], L[i].s)) q[las] = L[i];
        }
        if(fir < las) p[las-1] = LLIntersect(q[las-1], q[las]);
    }
    while(fir < las && !onleft(q[fir], p[las-1])) las--;
    if(las-fir <= 1) return {};
    p[las] = LLIntersect(q[las], q[fir]);
    int m = 0;
    vector<Pt> ans(las-fir+1);
    for(int i = fir; i <= las; i++) ans[m++] = p[i];
    return ans;
}

```

5 圖論

5.1 BCC

```

struct BCC {
    vector<vector<int>> g;
    vector<int> dfn, low;
    vector<vector<int>> bcc;
    vector<int> stk;
    int nbcc=0;
    int cur=1;
    BCC(int n){
        g.resize(n);
        dfn.resize(n,0);
        low.resize(n);
    }
    void addEdge(int u,int v){
        g[u].push_back(v);
        g[v].push_back(u);
    }
    void dfs(int x,int f){
        if(!g[x].size()){
            bcc.push_back({x});
            nbcc++;
            return;
        }
        dfn[x]=low[x]=cur++;
        stk.push_back(x);
        for(int y:g[x]){
            if(y==f)continue;
            if(dfn[y]){
                low[x]=min(low[x],dfn[y]);
            }
            else{
                dfs(y,x);
                low[x]=min(low[x],low[y]);
                if(low[y]>=dfn[x]){
                    bcc.push_back({});
                    int b;
                    do{
                        bcc[nbcc].push_back(b=stk.back());
                        stk.pop_back();
                    }while(b!=y);
                    bcc[nbcc++].push_back(x);
                }
            }
        }
    }
}

```

```

    }
}
void solve(){
    for(int i=0;i<g.size();i++){
        if(!dfn[i]){
            dfs(i,-1);
        }
    }
}
};

```

5.2 重心剖分

```

struct CentroidDecomposition {
    int n;
    vector<vector<int>> G, out;
    vector<int> sz, v;
    CentroidDecomposition(int _n) : n(_n), G(_n), out(_n), sz(_n), v(_n) {}
    int dfs(int x, int par){
        sz[x] = 1;
        for (auto &i : G[x]) {
            if(i == par || v[i]) continue;
            sz[x] += dfs(i, x);
        }
        return sz[x];
    }
    int search_centroid(int x, int p, const int mid){
        for (auto &i : G[x]) {
            if(i == p || v[i]) continue;
            if(sz[i] > mid) return search_centroid(i, x, mid);
        }
        return x;
    }
    void add_edge(int l, int r){
        G[l].PB(r); G[r].PB(l);
    }
    int get(int x){
        int centroid = search_centroid(x, -1, dfs(x, -1)/2);
        v[centroid] = true;
        for (auto &i : G[centroid]) {
            if(!v[i]) out[centroid].PB(get(i));
        }
        v[centroid] = false;
        return centroid;
    }
};

```

5.3 輕重鍊剖分

```

#define REP(i, s, e) for(int i = (s); i <= (e); i++)
#define REPD(i, s, e) for(int i = (s); i >= (e); i--)
const int MAXN = 100010;
const int LOG = 19;
struct HLD{
    int n;
    vector<int> g[MAXN];
    int sz[MAXN], dep[MAXN];
    int ts, tid[MAXN], tdi[MAXN], tl[MAXN], tr[MAXN];
    // ts : timestamp , useless after yutruli
    // tid[ u ] : pos. of node u in the seq.
    // tdi[ i ] : node at pos i of the seq.
    // tl , tr[ u ] : subtree interval in the seq. of node u
    int prt[MAXN][LOG], head[MAXN];
    // head[ u ] : head of the chain contains u
    void dfssz(int u, int p){
        dep[u] = dep[p] + 1;
        prt[u][0] = p; sz[u] = 1; head[u] = u;
        for(int& v:g[u]) if(v != p){
            dep[v] = dep[u] + 1;
            dfssz(v, u);
            sz[u] += sz[v];
        }
    }
    void dfshl(int u){
        ts++;
        tid[u] = tl[u] = tr[u] = ts;
        tdi[tid[u]] = u;
        sort(ALL(g[u]),

```

```

    [&](int a, int b){return sz[a] > sz[b];});
    bool flag = 1;
    for(int& v:g[u]) if(v != prt[u][0]){
        if(flag) head[v] = head[u], flag = 0;
        dfshl(v);
        tr[u] = tr[v];
    }
}
inline int lca(int a, int b){
    if(dep[a] > dep[b]) swap(a, b);
    int diff = dep[b] - dep[a];
    REPD(k, LOG-1, 0) if(diff & (1<<k)){
        b = prt[b][k];
    }
    if(a == b) return a;
    REPD(k, LOG-1, 0) if(prt[a][k] != prt[b][k]){
        a = prt[a][k]; b = prt[b][k];
    }
    return prt[a][0];
}
void init( int _n ){
    n = _n; REP( i , 1 , n ) g[ i ].clear();
}
void addEdge( int u , int v ){
    g[ u ].push_back( v );
    g[ v ].push_back( u );
}
void yutruli(){ //build function
    dfssz(1, 0);
    ts = 0;
    dfshl(1);
    REP(k, 1, LOG-1) REP(i, 1, n)
        prt[i][k] = prt[prt[i][k-1]][k-1];
}
vector< PII > getPath( int u , int v ){
    vector< PII > res;
    while( tid[ u ] < tid[ head[ v ] ] ){
        res.push_back( PII(tid[ head[ v ] ] , tid[ v ] ) );
        v = prt[ head[ v ] ][ 0 ];
    }
    res.push_back( PII( tid[ u ] , tid[ v ] ) );
    reverse( ALL( res ) );
    return res;
}
/* res : list of intervals from u to v
 * u must be ancestor of v
 * usage :
 * vector< PII >& path = tree.getPath( u , v )
 * for( PII tp : path ) {
 *     int l , r;tie( l , r ) = tp;
 *     upd( l , r );
 *     uu = tree.tdi[ l ] , vv = tree.tdi[ r ];
 *     uu ~> vv is a heavy path on tree
 * }
 */
}
} tree;

```

5.4 歐拉路徑

```

#define FOR(i,a,b) for(int i=a;i<=b;i++)
int dfs_st[10000500],dfn=0;
int ans[10000500],cnt=0,num=0;
vector<int>G[10000500];
int cur[10000500];
int ind[10000500],out[10000500];
void dfs(int x){
    FOR(i,1,n)sort(G[i].begin(),G[i].end());
    dfs_st[++dfn]=x;
    memset(cur,-1,sizeof(cur));
    while(dfn>0){
        int u=dfs_st[dfn];
        int complete=1;
        for(int i=cur[u]+1;i<G[u].size();i++){
            int v=G[u][i];
            num++;
            dfs_st[++dfn]=v;
            cur[u]=i;
            complete=0;
            break;
        }
        if(complete)ans[++cnt]=u,dfn--;
    }
}

```

```

}
}
bool check(int &start){
    int l=0,r=0,mid=0;
    FOR(i,1,n){
        if(ind[i]==out[i]+1)l++;
        if(out[i]==ind[i]+1)r++,start=i;
        if(ind[i]==out[i])mid++;
    }
    if(l==1&&r==1&&mid==n-2)return true;
    l=1;
    FOR(i,1,n)if(ind[i]!=out[i])l=0;
    if(l){
        FOR(i,1,n)if(out[i]>0){
            start=i;
            break;
        }
        return true;
    }
    return false;
}
int main(){
    cin>>n>>m;
    FOR(i,1,m){
        int x,y;scanf("%d%d",&x,&y);
        G[x].push_back(y);
        ind[y]++,out[x]++;
    }
    int start=-1,ok=true;
    if(check(start)){
        dfs(start);
        if(num!=m){
            puts("What a shame!");
            return 0;
        }
        for(int i=cnt;i>=1;i--){
            printf("%d ",ans[i]);
            puts("");
        }
        else puts("What a shame!");
    }
}

```

5.5 極大團

```

#define N 80
struct MaxClique{ // 0-base
    typedef bitset<N> Int;
    Int lnk[N] , v[N];
    int n;
    void init(int _n){
        n = _n;
        for(int i = 0 ; i < n ; i ++){
            lnk[i].reset(); v[i].reset();
        }
    }
    void addEdge(int a , int b)
    { v[a][b] = v[b][a] = 1; }
    int ans , stk[N], id[N] , di[N] , deg[N];
    Int cans;
    void dfs(int elem_num, Int candi, Int ex){
        if(candi.none()&&ex.none()){
            cans.reset();
            for(int i = 0 ; i < elem_num ; i ++){
                cans[id[stk[i]]] = 1;
                ans = elem_num; // cans is a maximal clique
                return;
            }
            int pivot = (candilex)._Find_first();
            Int smaller_candi = candi & (~lnk[pivot]);
            while(smaller_candi.count()){
                int nxt = smaller_candi._Find_first();
                candi[nxt] = smaller_candi[nxt] = 0;
                ex[nxt] = 1;
                stk[elem_num] = nxt;
                dfs(elem_num+1,candi&lnk[nxt],ex&lnk[nxt]);
            }
        }
    }
    int solve(){
        for(int i = 0 ; i < n ; i ++){
            id[i] = i; deg[i] = v[i].count();
        }
        sort(id , id + n , [&](int id1, int id2){
            return deg[id1] > deg[id2]; });
        for(int i = 0 ; i < n ; i ++){
            di[id[i]] = i;
        }
    }
}

```

```

for(int i = 0 ; i < n ; i ++){
    for(int j = 0 ; j < n ; j ++){
        if(v[i][j]) lnk[di[i]][di[j]] = 1;
    }
    ans = 1; cans.reset(); cans[0] = 1;
    dfs(0, Int(string(n, '1')), 0);
    return ans;
} }solver;

```

5.6 最大團

```

#define N 111
struct MaxClique{ // 0-base
    typedef bitset<N> Int;
    Int linkto[N], v[N];
    int n;
    void init(int _n){
        n = _n;
        for(int i = 0 ; i < n ; i ++){
            linkto[i].reset(); v[i].reset();
        }
    }
    void addEdge(int a , int b)
    { v[a][b] = v[b][a] = 1; }
    int popcount(const Int& val)
    { return val.count(); }
    int lowbit(const Int& val)
    { return val._Find_first(); }
    int ans , stk[N];
    int id[N] , di[N] , deg[N];
    Int cans;
    void maxclique(int elem_num, Int candi){
        if(elem_num > ans){
            ans = elem_num; cans.reset();
            for(int i = 0 ; i < elem_num ; i ++){
                cans[id[stk[i]]] = 1;
            }
        }
        int potential = elem_num + popcount(candi);
        if(potential <= ans) return;
        int pivot = lowbit(candi);
        Int smaller_candi = candi & (~linkto[pivot]);
        while(smaller_candi.count() && potential > ans){
            int next = lowbit(smaller_candi);
            candi[next] = !candi[next];
            smaller_candi[next] = !smaller_candi[next];
            potential --;
            if(next == pivot || (smaller_candi & linkto[next]
                ).count()){
                stk[elem_num] = next;
                maxclique(elem_num + 1, candi & linkto[next]);
            }
        }
    }
    int solve(){
        for(int i = 0 ; i < n ; i ++){
            id[i] = i; deg[i] = v[i].count();
        }
        sort(id , id + n , [&](int id1, int id2){
            return deg[id1] > deg[id2]; });
        for(int i = 0 ; i < n ; i ++){
            di[id[i]] = i;
        }
        for(int i = 0 ; i < n ; i ++){
            for(int j = 0 ; j < n ; j ++){
                if(v[i][j]) lnkto[di[i]][di[j]] = 1;
            }
        }
        Int cand; cand.reset();
        for(int i = 0 ; i < n ; i ++){
            cand[i] = 1;
        }
        ans = 1;
        cans.reset(); cans[0] = 1;
        maxclique(0, cand);
        return ans;
    }
} }solver;

```

5.7 SCC

```

struct Scc{
    vector<vector<int>>> g,rg;
    vector<int> scc;
    vector<bool> vis;
    vector<int> stk;
    int nsc=0;
    Scc(int n){
        g.resize(n);
        rg.resize(n);
        scc.resize(n);
        vis.resize(n);
    }
    void addEdge(int u,int v){

```

```

        g[u].push_back(v);
        rg[v].push_back(u);
    }
    void dfs1(int x){
        vis[x]=true;
        for(int y:g[x]){
            if(!vis[y])dfs1(y);
        }
        stk.push_back(x);
    }
    void dfs2(int x){
        vis[x]=true;
        scc[x]=nsc;
        for(int y:rg[x]){
            if(!vis[y])dfs2(y);
        }
    }
    void solve(){
        vis.assign(vis.size(),false);
        stk.clear();
        for(int i=0;i<vis.size();i++){
            if(!vis[i])dfs1(i);
        }
        reverse(stk.begin(),stk.end());
        vis.assign(n,false);
        for(int i:stk){
            if(!vis[i]){
                dfs2(i);
                nsc++;
            }
        }
    }
}
};

```

5.8 SPFA

```

#define MXN 200005
struct SPFA{
    int n;
    LL inq[MXN], len[MXN];
    vector<LL> dis;
    vector<pair<int, LL>> edge[MXN];
    void init(int _n){
        n = _n;
        dis.clear(); dis.resize(n, 1e18);
        for(int i = 0; i < n; i++){
            edge[i].clear();
            inq[i] = len[i] = 0;
        }
    }
    void addEdge(int u, int v, LL w){
        edge[u].push_back({v, w});
    }
    vector<LL> solve(int st = 0){
        deque<int> dq; //return {-1} if has negative cycle
        dq.push_back(st); //otherwise return dis from st
        inq[st] = 1; dis[st] = 0;
        while(!dq.empty()){
            int u = dq.front(); dq.pop_front();
            inq[u] = 0;
            for(auto [to, d] : edge[u]){
                if(dis[to] > d+dis[u]){
                    dis[to] = d+dis[u];
                    len[to] = len[u]+1;
                    if(len[to] > n) return {-1};
                    if(inq[to]) continue;
                    if(!dq.empty() && dis[dq.front()] > dis[to]){
                        dq.push_front(to) : dq.push_back(to);
                    }
                    inq[to] = 1;
                }
            }
        }
        return dis;
    }
} }spfa;

```

5.9 樹哈希

```

const ull mask = mt19937_64(time(nullptr))();
ull shift(ull x) {
    x ^= mask;
    x ^= x << 13;
    x ^= x >> 7;
    x ^= x << 17;
    x ^= mask;
    return x; }

```

```
void dfs(int u) { // edge[父] = {子}
    tree_hash[u] = 1;
    for (int v : edge[u]) {
        dfs(v);
        tree_hash[u] += shift(tree_hash[v]);
    }
}
```

5.10 差分約束

約束條件 $V_j - V_i \leq W$ addEdge(V_i, V_j, W) and run bellman-ford or spfa

6 數論

6.1 離散根號

```
int discrete_sqrt(int y, int p) { // find x s.t. x^2 = y (mod p)
    if (!y) return 0;
    if (p == 2) return (y & 1) == 1 ? 1 : -1;
    if (fpow(y, p - 1 >> 1, p) != 1) return -1;
    int Q = p - 1, S = 0;
    while (~Q & 1) { Q >>= 1; S++; }
    if (S == 1) return fpow(y, p + 1 >> 2, p);
    int z;
    while (1) {
        z = 1 + rand() % (p - 1);
        if (fpow(z, p - 1 >> 1, p) != 1) break;
    }
    int c = fpow(z, Q, p), R = fpow(y, Q + 1 >> 1, p);
    int t = fpow(y, Q, p), M = S, b, i;
    while (1) {
        if (t % p == 1) break;
        for (i = 1; i < M && fpow(t, 1LL << i, p) != 1; i++);
        b = fpow(c, 1LL << M - i - 1, p);
        R = R * b % p;
        c = fpow(b, 2, p);
        t = t * c % p; M = i;
    }
    return (R % p + p) % p;
}
```

6.2 離散對數

```
int BSGS(int start, int x, int y, int m) {
    unordered_map<int, int> mp;
    int big = 1, STEP = sqrt(m);
    for (int i = 0; i < STEP; i++) {
        mp[y] = i;
        y = y * x % m;
        big = big * x % m;
    }
    for (int step = 0; step < m + 10; step += STEP) {
        start = start * big % m;
        if (mp.count(start))
            return (step + STEP) - mp[start];
    }
    return -1;
}

int discrete_log(int x, int y, int m) { // find min k s
    .t. x^k = y (mod m)
    if (m == 1) return 0;
    int start = 1;
    for (int i = 0; i < 100; i++) {
        if (start == y) return i;
        start = start * x % m;
    }
    int pred = 100 + BSGS(start, x, y, m);
    if (fpow(x, pred, m) != y) return -1;
    return pred;
}
```

6.3 ex-crt

```
typedef __int128 ll;
void exgcd(ll a, ll b, ll &g, ll &x, ll &y) {
    if (b == 0) {
        g = a;
        x = 1;
        y = 0;
        return;
    }
    exgcd(b, a % b, g, y, x);
```

```
    y -= (a / b) * x;
}
bool flag = false;
ll a1, a2, n1, n2;
ll abs(ll x) {
    return x > 0 ? x : -x;
}
void china() {
    ll d = a2 - a1;
    ll g, x, y;
    exgcd(n1, n2, g, x, y);
    if (d % g == 0) {
        x = ((x * d / g) % (n2 / g) + (n2 / g)) % (n2 / g);
        a1 = x * n1 + a1;
        n1 = (n1 * n2) / g;
    }
    else
        flag = true;
}
int n;
long long as[100001]; // 算式答案 x
long long ns[100001]; // 模數 MOD
ll realchina() {
    a1 = as[0];
    n1 = ns[0];
    for (ll i = 1; i < n; i++) {
        a2 = as[i];
        n2 = ns[i];
        china();
        if (flag)
            return -1;
    }
    return a1;
}
int main() {
    cin >> n;
    flag = false;
    for (ll i = 0; i < n; i++)
        cin >> ns[i] >> as[i];
    cout << (long long)realchina() << endl;
}
```

6.4 ex-gcd

```
int exgcd(int a, int b, int& x, int& y) {
    if (b == 0) return x = 1, y = 0, a;
    int d = exgcd(b, a % b, y, x);
    y -= a / b * x;
    return d;
}
```

6.5 FFT

```
// const int MAXN = 262144;
// (must be 2^k)
// before any usage, run pre_fft() first
typedef long double ld;
typedef complex<ld> cplx; // real(), imag()
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);
}
// n must be 2^k
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 (i = 0; i < n; i++) a[i] /= n;
}
cplx arr[MAXN+1];
inline void mul(int _n, ll a[], int _m, ll b[], ll ans[]){
    int n=1, sum=_n+_m-1;
    while(n<sum)
        n<=1;
    for(int i=0; i<n; i++) {
        double x=(i<_n?a[i]:0), y=(i<_m?b[i]:0);
        arr[i]=complex<double>(x+y, x-y);
    }
    fft(n, arr);
    for(int i=0; i<n; i++)
        arr[i]=arr[i]*arr[i];
    fft(n, arr, true);
    for(int i=0; i<sum; i++)
        ans[i]=(long long int)(arr[i].real()/4+0.5);
}

```

6.6 高斯消去法

```

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;
// gs.v.clear(), gs.v.resize(n, vector<int>(n + 1, 0));

```

6.7 喬瑟夫問題

```

int josephus(int n, int m){ //n人每m次
    int ans = 0;
    for (int i=1; i<=n; ++i)
        ans = (ans + m) % i;
    return ans;
}

```

6.8 定理

- Lucas's Theorem :
For $n, m \in \mathbb{Z}^*$ and prime P , $C(m, n) \bmod P = \prod (C(m_i, n_i))$ where m_i is the i -th digit of m in base P .
- Stirling approximation :
$$n! \approx \sqrt{2\pi n} \left(\frac{n}{e}\right)^n e^{\frac{1}{12n}}$$
- Stirling Numbers(permutation $|P| = n$ with k cycles):
 $S(n, k) = \text{coefficient of } x^k \text{ in } \prod_{i=0}^{n-1} (x + i)$
- Stirling Numbers(Partition n elements into k non-empty set):
$$S(n, k) = \frac{1}{k!} \sum_{j=0}^k (-1)^{k-j} \binom{k}{j} j^n$$

- Pick's Theorem : $A = i + b/2 - 1$
 A : Area · i : grid number in the inner · b : grid number on the side
- Catalan number : $C_n = \binom{2n}{n} / (n+1)$
 $C_n^{n+m} - C_{n+1}^{n+m} = (m+n)! \frac{n-m+1}{n+1}$ for $n \geq m$
 $C_n = \frac{1}{n+1} \binom{2n}{n} = \frac{(2n)!}{(n+1)!n!}$
 $C_0 = 1$ and $C_{n+1} = 2 \binom{2n+1}{n+2} C_n$
 $C_0 = 1$ and $C_{n+1} = \sum_{i=0}^n C_i C_{n-i}$ for $n \geq 0$
- Euler Characteristic:
planar graph: $V - E + F - C = 1$
convex polyhedron: $V - E + F = 2$
 V, E, F, C : number of vertices, edges, faces(regions), and components
- Kirchhoff's theorem :
 $A_{ii} = \deg(i), A_{ij} = (i, j) \in E ? -1 : 0$, Deleting any one row, one column, and cal the $\det(A)$
- Polya' theorem (c is number of color · m is the number of cycle size):
 $(\sum_{i=1}^m c^{gcd(i, m)}) / m$
- Burnside lemma:
 $|X/G| = \frac{1}{|G|} \sum_{g \in G} |X^g|$
- 錯排公式: (n 個人中 · 每個人皆不再原來位置的組合數):
 $dp[0] = 1; dp[1] = 0;$
 $dp[i] = (i-1) * (dp[i-1] + dp[i-2]);$
- Bell 數 (有 n 個人, 把他們拆組的方法總數) :
 $B_0 = 1$
 $B_n = \sum_{k=0}^n s(n, k)$ (second - stirling)
 $B_{n+1} = \sum_{k=0}^n \binom{n}{k} B_k$
- Wilson's theorem :
 $(p-1)! \equiv -1 \pmod{p}$
- Fermat's little theorem :
 $a^p \equiv a \pmod{p}$
- Euler's totient function:
 $A^{B^C} \bmod p = \text{pow}(A, \text{pow}(B, C, p-1)) \bmod p$
- 歐拉函數降冪公式:
 $A^B \bmod C = A^{B \bmod \phi(C) + \phi(C)} \bmod C$
- 6 的倍數:
 $(a-1)^3 + (a+1)^3 + (-a)^3 + (-a)^3 = 6a$

6.9 Miller Rabin

```

// {2,7,61} for [1, 2^32)
int magic[] = {2, 325, 9375, 28178, 450775, 9780504, 1795265022};
bool witness(int a, int n, int u, int t) {
    if(!a) return false;
    int x = powm(a, u, n); // a, u using __int128 in `powm`
    for(int i = 0; i < t; i++) {
        int nx = (__int128)x * x % n;
        if(nx == 1 && x != 1 && x != n-1) return true;
        x = nx;
    }
    return x != 1;
}
bool miller_rabin(int n) {
    int s = 7;
    if(n < 2) return false;
    if(~n & 1) return n == 2;
    int u = n - 1, t = 0;
    while(~u & 1) u >>= 1, t++;
    while(s--) {
        int a = magic[s] % n;
        if(witness(a, n, u, t)) return false;
    }
    return true;
}

```

6.10 NTT

```
// Remember coefficient are mod P
/* p=a*2^n+1
n    2^n    p    a    root
16   65536   65537   1    3
20   1048576 7340033   7    3 */
// (must be 2^k)
template<LL P, LL root, int MAXN>
struct NTT{
    static LL bigmod(LL a, LL b) {
        LL res = 1;
        for (LL bs = a; b; b >>= 1, bs = (bs * bs) % P)
            if (b&1) res=(res*bs)%P;
        return res;
    }
    static LL inv(LL a, LL b) {
        if(a==1) return 1;
        return ((LL)(a-inv(b%a,a))*b+1)/a)%b;
    }
    LL omega[MAXN+1];
    NTT() {
        omega[0] = 1;
        LL r = bigmod(root, (P-1)/MAXN);
        for (int i=1; i<=MAXN; i++)
            omega[i] = (omega[i-1]*r)%P;
    }
    // n must be 2^k
    void tran(int n, LL a[], bool inv_ntt=false){
        int basic = MAXN / n, theta = basic;
        for (int m = n; m >= 2; m >>= 1) {
            int mh = m >> 1;
            for (int i = 0; i < mh; i++) {
                LL w = omega[i*theta*MAXN];
                for (int j = i; j < n; j += m) {
                    int k = j + mh;
                    LL x = a[j] - a[k];
                    if (x < 0) x += P;
                    a[j] += a[k];
                    if (a[j] > P) a[j] -= P;
                    a[k] = (w * x) % P;
                }
            }
            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_ntt) {
            LL ni = inv(n,P);
            reverse(a+1, a+n);
            for (i = 0; i < n; i++)
                a[i] = (a[i] * ni) % P;
        }
    }
};
const LL P=2013265921, root=31;
const int MAXN=4194304;
NTT<P, root, MAXN> ntt;
```

6.11 Pollard's Rho

```
// does not work when n is prime O(n^(1/4))
int mul(__int128 a, __int128 b, int m) { return (a % m)
    * (b % m) % m; }
int pollard_rho(int p) {
    int x, y, z, c, g, i, j;
    while (1) {
        y = x = rand() % p; c = rand() % p;
        i = 0, z = j = 1;
        while (++i) {
            x = (mul(x, x, p) + c) % p;
            z = mul(z, abs(y - x), p);
            if (x == y || !z) break;
            if (i % 127 == 0 || i == j) {
                g = __gcd(z, p);
                if (g > 1) return g;
                if (i == j) y = x, j <= 1;
            }
        }
    }
}
```

6.12 質數

```
/* 12721, 13331, 14341, 75577, 123457, 222557, 556679
* 999983, 1097774749, 1076767633, 100102021, 999997771
* 1001010013, 1000512343, 987654361, 999991231
* 999888733, 98789101, 987777733, 999991921, 1010101333
* 1010102101, 1000000000039, 100000000000037
* 2305843009213693951, 4611686018427387847
* 9223372036854775783, 18446744073709551557 */
int lpf[N], phi[N], mu[N];
bitset<N+1> np;
vector<int> primes;
void sieve() {
    np[0] = np[1] = phi[1] = mu[1] = 1;
    for (int i = 2; i < N; i++) {
        if (!np[i]) {
            primes.push_back(i);
            lpf[i] = i;
            phi[i] = i - 1;
            mu[i] = -1;
        }
        for (int p : primes) {
            int j = i * p;
            if (j >= N) break;
            np[j] = 1;
            lpf[j] = p;
            if (i % p == 0) {
                phi[j] = p * phi[i];
                mu[j] = 0;
                break;
            }
            phi[j] = phi[i] * phi[p];
            mu[j] = -mu[i];
        }
    }
}
```

6.13 phi

```
ll phi(ll n){ // 計算小於n的數中與n互質的有幾個
    ll res = n, a=n; // O(sqrt(N))
    for (ll i=2; i*i<=a; i++){
        if (a%i==0){
            res = res/i*(i-1);
            while (a%i==0) a/=i;
        }
    }
    if (a>1) res = res/a*(a-1);
    return res;
}
```

6.14 矩陣快速幂

```
LL len, mod;
vector<vector<LL>> operator*(vector<vector<LL>> x,
    vector<vector<LL>> y){
    vector<vector<LL>> ret(len, vector<LL>(len, 0));
    for (int i=0; i<len; i++){
        for (int j=0; j<len; j++){
            for (int k=0; k<len; k++){
                ret[i][j] = (ret[i][j] + x[i][k] * y[k][j]) %
                    mod;
            }
        }
    }
    return ret;
}
struct Martix_fast_pow{ //O(len^3 lg k)
    LL init(int _len, LL m=9223372036854775783LL){
        len=_len, mod=m;
    }
    // mfp.solve(k, {0, 1}, {1, 1}) k'th fib {值, 係數} // 0-base
    LL solve(LL n, vector<vector<LL>> poly){
        if (n<len) return poly[n][0];
        vector<vector<LL>> mar(len, vector<LL>(len, 0)), x
            (len, vector<LL>(len, 0));
        for (int i=0; i<len; i++) mar[i][i]=1;
        for (int i=0; i+1<len; i++) x[i][i+1]=1;
        for (int i=0; i<len; i++) x[len-1][i]=poly[i][1];
        while (n){
            if (n&1) mar=mar*x;
            n>>=1, x=x*x;
        }
        LL ans=0;
        for (int i=0; i<len; i++) ans=(ans+mar[len-1][i]
            *poly[i][0]%mod)%mod;
        return ans;
    }
}
```



```
}mfp;
```

7 字串

7.1 KMP

```
/* len-failure[k]:
```

在k結尾的情況下，這個子字串可以由開頭
長度為(len-failure[k])的部分重複出現來表達

failure[k]為次長相同前綴後綴

如果我們不只想求最多，而且以0-base做為考量
，那可能的長度由大到小會是

failuer[k]、failure[failuer[k]-1]
、failure[failure[failuer[k]-1]-1]..
直到有值為0為止 */

```
int failure[MXN];
vector<int>ret;
void KMP(string& t, string& p){
    if (p.size() > t.size()) return;
    for (int i=1, j=failure[0]=-1; i<p.size(); ++i){
        while (j >= 0 && p[j+1] != p[i])
            j = failure[j];
        if (p[j+1] == p[i]) j++;
        failure[i] = j;
    }
    for (int i=0, j=-1; i<t.size(); ++i){
        while (j >= 0 && p[j+1] != t[i])
            j = failure[j];
        if (p[j+1] == t[i]) j++;
        if (j == p.size()-1){
            ret.push_back( i - p.size() + 1 );
            j = failure[j];
        }
    } return ;}
}
```

7.2 馬拉車

```
void manacher(char *s,int len,int *z){
    len=(len<<1)+1;
    for(int i=len-1;i>=0;i--){
        s[i]=i&1?s[i>>1]:'0';
        z[0]=1;
        for(int i=1,l=0,r=0;i<len;i++){
            z[i]=i<r?min(z[l+l-i],r-i):1;
            while(i-z[i]>=0&&i+z[i]<len&&s[i-z[i]]==s[i+z[i]])
                ++z[i];
            if(i+z[i]>r) l=i,r=i+z[i];
        }
    }
}
```

7.3 回文樹

```
// len[s]是對應的回文長度
// num[s]是有幾個回文後綴
// cnt[s]是這個回文子字串在整個字串中的出現次數
// fail[s]是他長度次長的回文後綴，aba的fail是a
const int MXN = 1000010;
struct PalT{
    int nxt[MXN][26],fail[MXN],len[MXN];
    int tot,lst,n,state[MXN],cnt[MXN],num[MXN];
    int diff[MXN],sfail[MXN],fac[MXN],dp[MXN];
    char s[MXN]={-1};
    int newNode(int l,int f){
        len[tot]=l,fail[tot]=f,cnt[tot]=num[tot]=0;
        memset(nxt[tot],0,sizeof(nxt[tot]));
        diff[tot]=(l>0?l-len[f]:0);
        sfail[tot]=(l>0&&diff[tot]==diff[f]?sfail[f]:f);
        return tot++;
    }
    int getfail(int x){
        while(s[n-len[x]-1]!=s[n]) x=fail[x];
        return x;
    }
    int getmin(int v){
        dp[v]=fac[n-len[sfail[v]]-diff[v]];
        if(diff[v]==diff[fail[v]])
            dp[v]=min(dp[v],dp[fail[v]]);
        return dp[v]+1;
    }
    int push(){
        int c=s[n]-'a',np=getfail(lst);
        if(!lst&&nxt[np][c]){
            lst=newNode(len[np]+2,nxt[getfail(fail[np])][c]);
            nxt[np][c]=lst; num[lst]=num[fail[lst]]+1;
        }
        fac[n]=n;
        for(int v=lst;len[v]>0;v=sfail[v])
            fac[n]=min(fac[n],getmin(v));
        return ++cnt[lst],lst;
    }
    void init(const char *_s){
        tot=lst=n=0;
        newNode(0,1),newNode(-1,1);
        for(;_s[n];) s[n+1]=_s[n],++n,state[n-1]=push();
        for(int i=tot-1;i>1;i--) cnt[fail[i]]+=cnt[i];
    }
}palt;
```

7.4 SA

```
const int N = 300010;
struct SA{
#define REP(i,n) for ( int i=0; i<int(n); i++ )
#define REP1(i,a,b) for ( int i=(a); i<=int(b); i++ )
    bool _t[N*2];
    int _s[N*2], _sa[N*2], _c[N*2], x[N], _p[N], _q[N*2],
        hei[N], r[N];
    int operator [] (int i){ return _sa[i]; }
    void build(int *s, int n, int m){
        memcpy(_s, s, sizeof(int) * n);
        sais(_s, _sa, _p, _q, _t, _c, n, m);
        mkhei(n);
    }
    void mkhei(int n){
        REP(i,n) r[_sa[i]] = i;
        hei[0] = 0;
        REP(i,n) if(r[i]) {
            int ans = i>0 ? max(hei[r[i-1]] - 1, 0) : 0;
            while(_s[i+ans] == _s[_sa[r[i]-1]+ans]) ans++;
            hei[r[i]] = ans;
        }
    }
    void sais(int *s, int *sa, int *p, int *q, bool *t,
        int *c, int n, int z){
        bool uniq = t[n-1] = true, neq;
        int nn = 0, nmzx = -1, *nsa = sa + n, *ns = s + n,
            lst = -1;
#define MS0(x,n) memset((x),0,n*sizeof(*(x)))
#define MAGIC(XD) MS0(sa, n); \
        memcpy(x, c, sizeof(int) * z); \
        XD; \
        memcpy(x + 1, c, sizeof(int) * (z - 1)); \
        REP(i,n) if(sa[i] && !t[sa[i]-1]) sa[x[sa[i]
            ]-1]++ = sa[i]-1; \
        memcpy(x, c, sizeof(int) * z); \
        for(int i = n - 1; i >= 0; i--) if(sa[i] && t[sa[i]
            ]-1) sa[-x[sa[i]-1]] = sa[i]-1;
        MS0(c, z);
        REP(i,n) uniq &= ++c[s[i]] < 2;
        REP(i,z-1) c[i+1] += c[i];
        if (uniq) { REP(i,n) sa[--c[s[i]]] = i; return; }
        for(int i = n - 2; i >= 0; i--) t[i] = (s[i]==s[i
            +1] ? t[i+1] : s[i]<s[i+1]);
        MAGIC(REP1(i,1,n-1) if(t[i] && !t[i-1]) sa[-x[s[i]
            ]]=p[q[i]=nn++]=i);
        REP(i, n) if (sa[i] && t[sa[i]] && !t[sa[i]-1]) {
            neq=lst<0||memcmp(s+sa[i],s+lst,(p[q[sa[i]]+1]-sa
                [i])*sizeof(int));
            ns[q[lst=sa[i]]]=nmzx+=neq;
        }
        sais(ns, nsa, p + nn, q + n, t + n, c + z, nn, nmzx
            + 1);
        MAGIC(for(int i = nn - 1; i >= 0; i--) sa[-x[s[p[
            nsa[i]]]] = p[nsa[i]]);
    }
}sa;
int H[ N ], SA[ N ];
void suffix_array(int* ip, int len) {
    // should padding a zero in the back
    // ip is int array, len is array length
    // ip[0..n-1] != 0, and ip[len] = 0
    ip[len++] = 0;
    sa.build(ip, len, 128);
    for (int i=0; i<len; i++) {
        H[i] = sa.hei[i + 1];
    }
}
```

```

    SA[i] = sa._sa[i + 1];
}
// resulting height, sa array \in [0,len)
}

```

7.5 SAM

```

struct SAM{
    struct Node{
        array<int,26>next={};
        int link=0;
        int len=0;
    };
    vector<Node> s;
    int n;
    int last=1;
    int sz=2;
    SAM(int nn){
        n=nn*2+10;
        s.resize(n);
    }
    void add(int x){
        int p=last;
        if(s[p].next[x]){
            int q=s[p].next[x];
            if(s[p].len+1==s[q].len){
                last=q;return;
            }
            int r=sz++;
            s[r]=s[q];
            s[r].len=s[p].len+1;
            while(p&&s[p].next[x]==q){
                s[p].next[x]=r;
                p=s[p].link;
            }
            s[q].link=r;
            last=r;
            return;
        }
        int q=sz++;last=q;
        s[q].len=s[p].len+1;
        while(p&&!s[p].next[x]){
            s[p].next[x]=q;
            p=s[p].link;
        }
        if(!p){
            s[last].link=1;
            return;
        }
        q=s[p].next[x];
        if(s[p].len+1==s[q].len){
            s[last].link=q;
            return;
        }
        int r=sz++;
        s[r]=s[q];
        s[r].len=s[p].len+1;
        while(p&&s[p].next[x]==q){
            s[p].next[x]=r;
            p=s[p].link;
        }
        s[last].link=s[q].link=r;
    }
};

```

7.6 trie

```

//01 bitwise trie
struct trie{
    trie *nxt[2]; // 差別
    int cnt; //紀錄有多少個數字以此節點結尾
    int sz; //有多少數字的前綴包括此節點
    trie():cnt(0),sz(0){
        memset(nxt,0,sizeof(nxt));
    }
};
//創建新的字典樹
trie *root;
void insert(int x){
    trie *now = root; // 每次從根節點開始
    for(int i=22;i>=0;i--){ // 從最高位元開始往低位元走
        now->sz++;

```

```

        //cout<<(x>>i&1)<<endl;
        if(now->nxt[x>>i&1] == NULL){ //判斷當前第 i 個
            位元是 0 還是 1
            now->nxt[x>>i&1] = new trie();
        }
        now = now->nxt[x>>i&1]; //走到下一個位元
    }
    now->cnt++;
    now->sz++;
}

```

7.7 Z-value

```

int z[MAXN];
void Z_value(const string& s) { //z[i] = lcp(s[1...],s[
    i...])
    int i, j, left, right, len = s.size();
    left=right=0; z[0]=len;
    for(i=1;i<len;i++) {
        j=max(min(z[i-left],right-i),0);
        for(;i+j<len&&s[i+j]==s[j];j++);
        z[i]=j;
        if(i+z[i]>right) {
            right=i+z[i];
            left=i;
        }
    }
}

```

7.8 minRotation

```

//rotate(begin(s),begin(s)+minRotation(s),end(s))
int minRotation(string s) {
    int a = 0, N = s.size(); s += s;
    rep(b,0,N) rep(k,0,N) {
        if(a+k == b || s[a+k] < s[b+k])
            {b += max(0, k-1); break;}
        if(s[a+k] > s[b+k]) {a = b; break;}
    } return a;
}

```

8 DP

8.1 數位 dp

```

int dp[MXN_LEN][PRE_NUM][LIMIT][F0];
int DP(const string &s, int i = 0, int pre = 0, bool
    lim = 1, bool f0 = 1) {
    if (dp[i][pre][lim][f0]) return dp[i][pre][lim][f0];
    if (i == s.size()) return dp[i][pre][lim][f0] = 1;
    int res = 0, h = lim ? s[i] - '0' : 9;
    for (int j = 0; j <= h; j++)
        if (abs(j - pre) >= 2 || f0)
            res += DP(s, i + 1, j, j == h && lim, f0 &&
                !j);
    return dp[i][pre][lim][f0] = res;
}

```

8.2 SOS dp

```

for(int i = 0; i<(1<<N); ++i)
    F[i] = A[i];
for(int i = 0; i < N; ++i) for(int mask = 0; mask < (1<<
    N); ++mask){
    if(mask & (1<<i))
        F[mask] += F[mask^(1<<i)];
}

```

8.3 p-median

```

void p_Median(){
    for (int i=1; i<=N; ++i)
        for (int j=i; j<=N; ++j){
            m = (i+j)/2,d[i][j] = 0; // m 是中位數 · d[i
            ][j] 為距離的總和
            for (int k=i; k<=j; ++k) d[i][j] += abs(arr
                [k] - arr[m]);
        }
    for (int p=1; p<=P; ++p)
        for (int n=1; n<=N; ++n){
            dp[p][n] = 1e9;
            for (int k=p; k<=n; ++k)
                if (dp[p-1][k-1] + d[k][n] < dp[p][n]){

```

```

        dp[p][n] = dp[p-1][k-1] + d[k][n];
        r[p][n] = k; // 從第k個位置往右到第
                     j個位置
    }
}

```

9 Other

9.1 黑魔法

```

#include <bits/extc++.h>
using namespace __gnu_pbds;
typedef tree<int,null_type,less<int>,rb_tree_tag,
            tree_order_statistics_node_update> set_t;
#include <ext/pb_ds/assoc_container.hpp>
typedef cc_hash_table<int,int> umap_t;
typedef priority_queue<int> heap;
#include<ext/rope>
using namespace __gnu_cxx;
int main(){
    // Insert some entries into s.
    set_t s; s.insert(12); s.insert(505);
    // The order of the keys should be: 12, 505.
    assert(*s.find_by_order(0) == 12);
    assert(*s.find_by_order(3) == 505);
    // The order of the keys should be: 12, 505.
    assert(s.order_of_key(12) == 0);
    assert(s.order_of_key(505) == 1);
    // Erase an entry.
    s.erase(12);
    // The order of the keys should be: 505.
    assert(*s.find_by_order(0) == 505);
    // The order of the keys should be: 505.
    assert(s.order_of_key(505) == 0);

    heap h1 , h2; h1.join( h2 );
    rope<char> r[ 2 ];
    r[ 1 ] = r[ 0 ]; // persistenet
    string t = "abc";
    r[ 1 ].insert( 0 , t.c_str() );
    r[ 1 ].erase( 1 , 1 );
    cout << r[ 1 ].substr( 0 , 2 );
}

```

9.2 CDQ

9.3 DLX

```

// given n*m 0-1 matrix
// find a set of rows s.t.
// for each column, there's exactly one 1
#define N 1024 //row
#define M 1024 //column
#define NM ((N+2)*(M+2))
char A[N][M]; //n*m 0-1 matrix
int used[N]; //answer: the row used
int id[N][M];
int L[NM],R[NM],D[NM],U[NM],C[NM],S[NM],ROW[NM];
void remove(int c){
    L[R[c]]=L[c]; R[L[c]]=R[c];
    for( int i=D[c]; i!=c; i=D[i] ){
        for( int j=R[i]; j!=i; j=R[j] ){
            U[D[j]]=U[j]; D[U[j]]=D[j]; S[C[j]]--;
        }
    }
}
void resume(int c){
    for( int i=D[c]; i!=c; i=D[i] ){
        for( int j=L[i]; j!=i; j=L[j] ){
            U[D[j]]=D[U[j]]=j; S[C[j]]++;
        }
    }
    L[R[c]]=R[L[c]]=c;
}
int dfs(){
    if(R[0]==0) return 1;
    int md=100000000,c;
    for( int i=R[0]; i!=0; i=R[i] ){
        if(S[i]<md){ md=S[i]; c=i; }
    }
    if(md==0) return 0;
    remove(c);
    for( int i=D[c]; i!=c; i=D[i] ){
        used[ROW[i]]=1;

```

```

        for( int j=R[i]; j!=i; j=R[j] ) remove(C[j]);
        if(dfs()) return 1;
        for( int j=L[i]; j!=i; j=L[j] ) resume(C[j]);
        used[ROW[i]]=0;
    }
    resume(c);
    return 0;
}
int exact_cover(int n,int m){
    for( int i=0; i<=m; i++ ){
        R[i]=i+1; L[i]=i-1; U[i]=D[i]=i;
        S[i]=0; C[i]=i;
    }
    R[m]=0; L[0]=m;
    int t=m+1;
    for( int i=0; i<n; i++ ){
        int k=-1;
        for( int j=0; j<m; j++ ){
            if(!A[i][j]) continue;
            if(k==-1) L[t]=R[t]=t;
            else{ L[t]=k; R[t]=R[k]; }
            k=t; D[t]=j+1; U[t]=U[j+1];
            L[R[t]]=R[L[t]]=U[D[t]]=D[U[t]]=t;
            C[t]=j+1; S[C[t]]++; ROW[t]=i; id[i][j]=t++;
        }
    }
    for( int i=0; i<n; i++ ) used[i]=0;
    return dfs();
}

```

9.4 Hiber Curve

```

long long hilbert(int n,int x,int y){
    long long res=0;
    for(int s=n/2;s>=1){
        int rx=(x&s)>0,ry=(y&s)>0; res+=s*11l*s*((3*rx)^ry)
        ;
        if(ry==0){ if(rx==1) x=s-1-x,y=s-1-y; swap(x,y); }
    }
    return res;
}

```

9.5 模擬退火

```

mt19937 rng((unsigned long long)(new char));
auto rnd = [&]() -> double {
    return 2 * ((double)rng() / rng.max()) - 1;
};

auto run = [&](int l, int r, int u, int d) -> double {
    double x = (l+r)/2., y = (u+d)/2., s = cal(x, y)
    );
    double nx, ny;
    for (double t = hypot(l-r, u-d); t >= 1e-8; t
        *= 0.99995) {
        do {
            nx = x + t * rnd();
            ny = y + t * rnd();
        } while (!safe(nx, ny));
        if (chmax(s, cal(nx, ny)))
            x = nx, y = ny;
    }
    return s;
};

```





