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## 1 Basic

### 1.1 Shell script

```
g++ -O2 -std=c++14 -Dbbq -Wall -Wextra -Wshadow -o $1
    $1.cpp
chmod +x compile.sh
```

### 1.2 Default code

```
#include<bits/stdc++.h>
#include<ext/pb_ds/assoc_container.hpp>
using namespace std;
using namespace __gnu_pbds;
typedef long long ll;
typedef pair<int,int> pii;
typedef pair<ll,ll> pll;
#define FILL(i,n) memset(i,n,sizeof i)
#define X first
#define Y second
#define ET cout << "\n"
#define SZ(a) ((int)a.size())
#define ALL(v) v.begin(),v.end()
#define pb push_back
#define IOS() ios_base::sync_with_stdio(0);cin.tie(0);
#define bbq
#define debug(...) {\
    fprintf(stderr,"%s - %d (%s) = ",\
        __PRETTY_FUNCTION__,__LINE__,#__VA_ARGS__);\
    _do(__VA_ARGS__); \
}
#define DB(a,s,e) {for(int _i=s;_i<e;_i++) cerr << a[_i]\
    << " ";cerr << "\n";}
template<typename T>void _do(T &&x){cerr<<x<<endl;}
template<typename T,typename ...S> void _do(T &&x,S\
    &&...t){cerr<<x<<" ";_do(t...);}
template<typename a,typename b> ostream& operator << (\
    ostream &s,const pair<a,b> &p){return s<<"("<<p.X<<\
    ", "<<p.Y<<")";}
#else
#define debug(...)
#define DB(a,s,e)
#endif
```

### 1.3 vimrc

```
"This file should be placed at ~/.vimrc"
set re=1
set nu
set ai
set hls
set tabstop=4
set softtabstop=4
set shiftwidth=4
set expandtab
set ruler
set ic
set incsearch
set showcmd
set history=1000
set cursorline
set laststatus=2
nnoremap <c-l> :nohl<cr>
```

## 1.4 readchar

```
inline char readchar(){
    static const size_t bufsize = 65536;
    static char buf[bufsize];
    static char *p = buf, *end = buf;
    if (p == end) end = buf + fread_unlocked(buf, 1,
        bufsize, stdin), p = buf;
    return *p++;
}
```

## 1.5 Black Magic

```
//paring heap
#include <bits/stdc++.h>
using namespace std;
#include <ext/pb_ds/priority_queue.hpp>
typedef __gnu_pbds::priority_queue<int> heap;
int main(){
    heap h1,h2;
    h1.push(1); h1.push(3);
    h2.push(2); h2.push(4);
    h1.join(h2);
    cout<<h1.size()<< '\n';
    cout<<h2.size()<< '\n';
}

//rb_tree
#include <bits/stdc++.h>
#include <ext/pb_ds/assoc_container.hpp>
using namespace std;
typedef long long ll;
using namespace std;
using namespace __gnu_pbds;
int main(){
    ios_base::sync_with_stdio(0);cin.tie(0);
    tree<ll,null_type,less<ll>,rb_tree_tag,
        tree_order_statistics_node_update> st;
    tree<ll,ll,less<ll>,rb_tree_tag,
        tree_order_statistics_node_update> mp;

    st.insert(0);
    st.insert(2);
    st.insert(3);
    st.insert(4);
    cout<<*st.find_by_order(2)<<endl;
    cout<<st.order_of_key(1)<<endl;
}

//__int128_t
__int128_t,__float128_t
```

## 1.6 Texas hold'em

```
char suit[4]={'C','D','H','Y'}, ranks[13]={'2','3','4','5',
    '6','7','8','9','T','J','Q','K','A'};
int rk[256];
/*
for(int i=0;i<13;++i)
    rk[ranks[i]]=i;
for(int i=0;i<4;++i)
    rk[suit[i]]=i;
*/
struct cards{
    vector<pii> v;
    int suit_count[4],hands;
    void reset(){v.clear(),FILL(suit_count,0),hands=-1;}
    void insert(char a,char b){//suit,rank
        ++suit_count[rk[a]];
        int flag=0;
        for(auto &i:v)
            if(i.Y==rk[b])
            {
                ++i.X,flag=1;
                break;
            }
        if(!flag) v.pb(pii(1,rk[b]));
    }
};
```

```
}
void insert(string s){insert(s[0],s[1]);}
void ready(){
    int Straight=0,Flush=(*max_element(suit_count,
        suit_count+4))==5;
    sort(ALL(v),[](ii a,ii b){return a>b;});
    if(SZ(v)==5&&v[0].Y==v[1].Y+1&&v[1].Y==v[2].Y+1&&v[2].Y==v[3].Y+1&&v[3].Y==v[4].Y+1)
        Straight=1;
    else if(SZ(v)==5&&v[0].Y==12&&v[1].Y==3&&v[2].Y==2&&v[3].Y==1&&v[4].Y==0)
        v[0].Y=3,v[1].Y=2,v[2].Y=1,v[3].Y=0,v[4].Y=-1,
        Straight=1;
    if(Straight&&Flush) hands=1;
    else if(v[0].X==4) hands=2;
    else if(v[0].X==3&&v[1].X==2) hands=3;
    else if(Flush) hands=4;
    else if(Straight) hands=5;
    else if(v[0].X==3) hands=6;
    else if(v[0].X==2&&v[1].X==2) hands=7;
    else if(v[0].X==2) hands=8;
    else hands=9;
}
bool operator>(const cards &a)const{
    if(hands==a.hands) return v>a.v;
    return hands<a.hands;
}
};
```

## 2 Graph

### 2.1 BCC Vertex

```
vector<int> G[N];// 1-base
vector<int> bcc[N];
int low[N],vis[N],Time;
int bcc_id[N],bcc_cnt;// 1-base
bool is_cut[N];//whether is av
int st[N],top;
void dfs(int u,int pa=-1){
    int child=0;
    low[u]=vis[u]=++Time;
    st[top++]=u;
    for(int v:G[u])
        if(!vis[v]){
            dfs(v,u),++child;
            low[u]=min(low[u],low[v]);
            if(vis[u]<=low[v]){
                is_cut[u]=1;
                bcc[++bcc_cnt].clear();
                int t;
                do{
                    bcc_id[t=st[--top]]=bcc_cnt;
                    bcc[bcc_cnt].push_back(t);
                }while(t!=v);
                bcc_id[u]=bcc_cnt;
                bcc[bcc_cnt].push_back(u);
            }
        }
    else if(vis[v]<vis[u]&&v!=pa)
        low[u]=min(low[u],vis[v]);
    if(pa!=-1&&child<2)is_cut[u]=0;
}
inline void bcc_init(int n){
    Time=bcc_cnt=top=0;
    for(int i=1;i<=n;++i)
        G[i].clear(),vis[i]=0,is_cut[i]=0,bcc_id[i]=0;
}
```

### 2.2 Bridge

```
struct Bridge{//1-base
    int n,low[MAXN],dfn[MAXN],t;
    vector<pii> G[MAXN],edge;
    vector<bool> bri;
    void init(int _n){n=_n;
```

```

    for(int i=1;i<=n;++i) G[i].clear();
}
void add_edge(int a,int b){
    int x=edge.size();
    G[a].pb(pii(b,x)),G[b].pb(pii(a,x)),edge.pb(pii(a,b
));
}
void dfs(int x,int f){
    dfn[x]=low[x]=++t;
    for(auto i:G[x])
        if(!dfn[i.X])
            dfs(i.X,i.Y),low[x]=min(low[x],low[i.X]);
        else if(i.Y!=f) low[x]=min(low[x],low[i.X]);
    if(low[x]==dfn[x] && f!=-1) bri[f]=1;
}
void get_edge(){
    bri.clear(),bri.resize(edge.size(),0);
    FILL(low,0),FILL(dfn,0),t=0;
    for(int i=1;i<=n;++i)
        if(!dfn[i]) dfs(i,-1);
}
};

```

## 2.3 Strongly Connected Components

```

struct Strongly_CC{//1-base
    int low[MAXN],vis[MAXN],bln[MAXN],sz[MAXN],n,t,nScc;
    bitset<MAXN> instack;
    stack<int> st;
    vector<int> G[MAXN],SCC[MAXN];
    void init(int _n){n=_n;
        for(int i=1;i<=n;++i)
            G[i].clear();
    }
    void add_edge(int a,int b){
        G[a].pb(b);
    }
    void dfs(int u){
        vis[u]=low[u]=++t;
        instack[u]=1,st.push(u);
        for(int i:G[u])
            if(!vis[i]) dfs(i),low[u]=min(low[i],low[u]);
            else if(instack[i]&&vis[i]<vis[u])
                low[u]=min(low[u],vis[i]);
        if(low[u]==vis[u]){
            int tmp;
            do{
                tmp=st.top(),st.pop();
                instack[tmp]=0,bln[tmp]=nScc;
            }while(tmp!=u);
            ++nScc;
        }
    }
    void solve(){
        FILL(low,0),FILL(vis,0),FILL(bln,0),FILL(sz,0),t=
            nScc=0;
        for(int i=1;i<=n;++i) SG[i].clear();
        for(int i=1;i<=n;++i)
            if(!vis[i]) dfs(i);
        for(int i=1;i<=n;++i){
            ++sz[bln[i]],SCC[bln[i]].pb(i);
        }
    }
};

```

## 2.4 MinimumMeanCycle

```

ll road[MAXN][MAXN];//input here
struct MinimumMeanCycle{//0-base
    ll dp[MAXN+5][MAXN],n;
    pll solve(){//watch out overflow
        ll k=1,a=-1,b=-1,ta,tb,L=n+1;
        for(ll i=2;i<=L;++i)
            for(ll k=0;k<n;++k)
                for(ll j=0;j<n;++j)
                    dp[i][j]=min(dp[i-1][k]+road[k][j],dp[i][j]);
        for(ll i=0;i<n;++i)
        {
            if(dp[L][i]>=INF) continue;

```

```

            ta=0,tb=1;
            for(ll j=1;j<n;++j)
                if(dp[j][i]<INF&&ta*(L-j)<(dp[L][i]-dp[j][i])*
                    tb)
                    ta=dp[L][i]-dp[j][i],tb=L-j;
            if(ta==0) continue;
            if(a==-1) a=ta,b=tb;
            else if(a*tb>ta*b) a=ta,b=tb;
        }
        if(a!=-1) return k=__gcd(a,b),MP(a/k,b/k);
        return MP(-1LL,-1LL);
    }
    void init(int _n){n=_n;
        for(ll i=0;i<n;++i)
            for(ll j=0;j<n;++j)
                dp[i+2][j]=INF;
    }
};

```

## 2.5 Virtual Tree

```

void insert(int x){
    if(top==-1)
        return st[++top]=x,void();
    int p=LCA(st[top],x);
    if(p==st[top])
        return st[++top]=x,void();
    while(dep[st[top-1]]>dep[p])
        vG[st[top-1]].pb(st[top]),--top;
    vG[p].pb(st[top]),--top;
    if(st[top]!=p) st[++top]=p;
    st[++top]=x;
}
void ending(){
    while(top>0)
        vG[st[top-1]].pb(st[top]),--top;
}
void reset(int x){
    for(int i:vG[x])
        reset(i);
    vG[x].clear();
}

```

## 2.6 Maximum Clique

```

struct Maximum_Clique{
    typedef bitset<MAXN> bst;
    bst N[MAXN],empty;
    int p[MAXN],n,ans;
    void BronKerbosch2(bst R,bst P,bst X){
        if(P==empty&&X==empty)
            return ans=max(ans,(int)R.count()),void();
        bst tmp=P|X;
        int u;
        if((R|P|X).count()<=ans) return;
        for(int uu=0;uu<n;++uu){
            u=p[uu];
            if(tmp[u]==1) break;
        }
        //if (double(cLock())/CLOCKS_PER_SEC > .999) return
        ;
        bst now2=P&~N[u];
        for(int vv=0;vv<n;++vv){
            int v=p[vv];
            if(now2[v]==1){
                R[v]=1;
                BronKerbosch2(R,P&N[v],X&N[v]);
                R[v]=0,P[v]=0,X[v]=1;
            }
        }
    }
    void init(int _n){n=_n;
        for(int i=0;i<n;++i) N[i].reset();
    }
    void add_edge(int u,int v){N[u][v]=N[v][u]=1;}
    int solve(){//remember srand
        bst R,P,X;
        ans=0,P.flip();

```

```

    for(int i=0;i<n;++i) p[i]=i;
    random_shuffle(p,p+n),BronKerbosch2(R,P,X);
    return ans;
}
};

```

## 2.7 MinimumSteinerTree

```

// Minimum Steiner Tree
// O(V^3 T + V^2 2^T)
struct SteinerTree{//0-base
    static const int T=9,MAXN=70,INF=1e9;
    int n, dst[MAXN][MAXN], dp[1<T][MAXN], tdst[MAXN];
};
int vcost[MAXN];//the cost of vertexs
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] = vcost[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){
    shortest_path();
    int t=SZ(ter);
    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] = vcost[i];
    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] = vcost[ter[who]] + dst[ter[who]][i];
            continue;
        }
        for(int i=0; i<n; ++i)
            for(int submsk=(msk-1)&msk; submsk; submsk=(submsk-1)&msk)
                dp[msk][i] = min(dp[msk][i], dp[submsk][i] + dp[msk^submsk][i] - vcost[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;
}
};

```

## 2.8 Dominator Tree

```

struct dominator_tree{//1-base
    int n;
    vector<int> G[MAXN],rG[MAXN];
    int pa[MAXN],dfn[MAXN],id[MAXN],dfnCnt;
    int semi[MAXN],idom[MAXN],best[MAXN];

```

```

    vector<int> tree[MAXN];//dominator_tree
    void init(int _n){
        n=_n;
        for(int i=1;i<=n;++i)G[i].clear(),rG[i].clear();
    }
    void add_edge(int u,int v){
        G[u].push_back(v);
        rG[v].push_back(u);
    }
    void dfs(int u){
        id[dfn[u]=++dfnCnt]=u;
        for(auto v:G[u]) if(!dfn[v]){
            dfs(v),pa[dfn[v]]=dfn[u];
        }
    }
    int find(int y,int x){
        if(y<=x)return y;
        int tmp=find(pa[y],x);
        if(semi[best[y]]>semi[best[pa[y]]])
            best[y]=best[pa[y]];
        return pa[y]=tmp;
    }
    void tarjan(int root){
        dfnCnt=0;
        for(int i=1;i<=n;++i){
            dfn[i]=idom[i]=0;
            tree[i].clear();
            best[i]=semi[i]=i;
        }
        dfs(root);
        for(int i=dfnCnt;i>1;--i){
            int u=id[i];
            for(auto v:rG[u]) if(v=dfn[v]){
                find(v,i);
                semi[i]=min(semi[i],semi[best[v]]);
            }
            tree[semi[i]].push_back(i);
            for(auto v:tree[pa[i]]){
                find(v,pa[i]);
                idom[v] = semi[best[v]]==pa[i] ? pa[i] : best[v];
            }
            tree[pa[i]].clear();
        }
        for(int i=2; i<=dfnCnt; ++i){
            if(idom[i]!=semi[i]) idom[i]=idom[idom[i]];
            tree[id[idom[i]]].push_back(id[i]);
        }
    }
};

```

## 2.9 Minimum Arborescence

```

#define INF 0x3f3f3f3f
template<typename T>
struct zhu_liu{//O(VE)
    static const int MAXN=110;
    struct edge{
        int u,v;
        T w;
        edge(int u=0,int v=0,T w=0):u(u),v(v),w(w){}
    };
    vector<edge>E;// 0-base
    int pe[MAXN],id[MAXN],vis[MAXN];
    T in[MAXN];
    void init(){E.clear();}
    void add_edge(int u,int v,T w){
        if(u!=v)E.push_back(edge(u,v,w));
    }
    T build(int root,int n){
        T ans=0;
        for(;;){
            for(int u=0;u<n;++u)in[u]=INF;
            for(size_t i=0;i<E.size();++i)
                if(E[i].u!=E[i].v&&E[i].w<in[E[i].v])
                    pe[E[i].v]=i,in[E[i].v]=E[i].w;
            for(int u=0;u<n;++u)//no solution
                if(u!=root&&in[u]==INF)return -INF;
            int cntnode=0;
            memset(id,-1,sizeof(int)*n);

```

```

memset(vis,-1,sizeof(int)*n);
for(int u=0;u<n;++u){
    if(u!=root)ans+=in[u];
    int v=u;
    for(;vis[v]!=u&&id[v]==-1&&v!=root;v=E[pe[v]].u)
        vis[v]=u;
    if(v!=root&&id[v]==-1){
        for(int x=E[pe[v]].u;x!=v;x=E[pe[x]].u)
            id[x]=cntnode;
        id[v]=cntnode++;
    }
}
if(!cntnode)break;//no cycle
for(int u=0;u<n;++u)if(id[u]==-1)id[u]=cntnode++;
for(size_t i=0;i<E.size();++i){
    int v=E[i].v;
    E[i].u=id[E[i].u];
    E[i].v=id[E[i].v];
    if(E[i].u!=E[i].v)E[i].w=in[v];
}
n=cntnode;
root=id[root];
}
return ans;
}
};

```

```

return kth(o->r,k-sz(o->l)-1);
}
int Rank(node *o,int key){
    if(o->data<key) return sz(o->l)+1+Rank(o->r,key);
    else return Rank(o->l,key);
}
bool erase(node *&o,int k){
    if(!o)return 0;
    if(o->data==k){
        node *t=o;
        o->down(),o=merge(o->l,o->r);
        delete t;
        return 1;
    }
    node *&t=k<o->data?o->l:o->r;
    return erase(t,k)?o->up(),1:0;
}
void insert(node *&o,int k){
    node *a,*b;
    split(o,a,b,k),o=merge(a,merge(new node(k),b));
}
void interval(node *&o,int l,int r){
    node *a,*b,*c;
    split2(o,a,b,l-1),split2(b,b,c,r);
    //operate
    o=merge(a,merge(b,c));
}
}

```

## 2.10 Theory

```

/*
|Maximum independent edge set|=|V|-|Minimum edge cover|
|Maximum independent set|=|V|-|Minimum vertex cover|
*/

```

## 3 Data Structure

### 3.1 Treap

```

struct node{
    int data,sz;
    node *l,*r;
    node(int k):data(k),sz(1),l(0),r(0){}
    void up(){
        sz=1;
        if(l) sz+=1->sz;
        if(r) sz+=r->sz;
    }
    void down(){}
};
int sz(node *a){
    return a ? a->sz : 0;
}
node *merge(node *a,node *b){
    if(!a || !b) return a ? a : b;
    if(rand()%(sz(a)+sz(b))<sz(a))
        return a->down(),a->r=merge(a->r,b),a->up(),a;
    return b->down(),b->l=merge(a,b->l),b->up(),b;
}
void split(node *o,node *&a,node *&b,int k){
    if(!o) return a=b=0,void();
    o->down();
    if(o->data<=k) a=o,split(o->r,a->r,b,k),a->up();
    else b=o,split(o->l,a,b->l,k),b->up();
}
void split2(node *o,node *&a,node *&b,int k){
    if(sz(o)<=k) return a=o,b=0,void();
    o->down();
    if(sz(o->l)+1<=k) a=o,split2(o->r,a->r,b,k-sz(o->l)-1);
    else b=o,split2(o->l,a,b->l,k);
    o->up();
}
node *kth(node *o,int k){
    if(k<=sz(o->l)) return kth(o->l,k);
    if(k==sz(o->l)+1) return o;
}

```

## 3.2 Leftist Tree

```

struct node{
    ll v,data,sz,sum;
    node *l,*r;
    node(ll k):v(0),data(k),sz(1),l(0),r(0),sum(k){}
};
ll sz(node *p){return p ? p->sz : 0;}
ll V(node *p){return p ? p->v : -1;}
ll sum(node *p){return p ? p->sum : 0;}
node* merge(node *a,node *b){
    if(!a || !b) return a ? a : b;
    if(a->data<b->data) swap(a,b);
    a->r=merge(a->r,b);
    if(V(a->r)>V(a->l)) swap(a->r,a->l);
    a->v=V(a->r)+1,a->sz=sz(a->l)+sz(a->r)+1;
    a->sum=sum(a->l)+sum(a->r)+a->data;
    return a;
}
void pop(node *&o){
    node *tmp=o;
    o=merge(o->l,o->r);
    delete tmp;
}

```

## 3.3 Heavy light Decomposition

```

struct Heavy_light_Decomposition{//1-base
    int n,ulink[10005],deep[10005],mxson[10005],w[10005],
        pa[10005];
    int t,pl[10005],data[10005],dt[10005],bln[10005],edge[10005],et;
    vector<pii> G[10005];
    void init(int _n){n=_n,t=0,et=1;
        for(int i=1;i<=n;++i) G[i].clear(),mxson[i]=0;
    }
    void add_edge(int a,int b,int w){
        G[a].pb(pii(b,et)),G[b].pb(pii(a,et)),edge[et++]=w;
    }
    void dfs(int u,int f,int d){
        w[u]=1,pa[u]=f,deep[u]=d++;
        for(auto &i:G[u])
            if(i.X!=f){
                dfs(i.X,u,d),w[u]+=w[i.X];
                if(w[mxson[u]]<w[i.X])
                    mxson[u]=i.X;
            }
        else
            bln[i.Y]=u,dt[u]=edge[i.Y];
    }
}

```

```

void cut(int u,int link){
    data[p1[u]=t++]=dt[u],ulink[u]=link;
    if(!mxson[u]) return ;
    cut(mxson[u],link);
    for(auto i:G[u])
        if(i.X!=pa[u]&&i.X!=mxson[u])
            cut(i.X,i.X);
}
void build(){
    dfs(1,1,1),cut(1,1),/*build*/;
}
int query(int a,int b){
    int ta=ulink[a],tb=ulink[b],re=0;
    while(ta!=tb)
        if(deep[ta]<deep[tb])
            /*query*/,tb=ulink[b=pa[tb]];
        else
            /*query*/,ta=ulink[a=pa[ta]];
    if(a==b) return re;
    if(p1[a]>p1[b]) swap(a,b);
    /*query*/
    return re;
}
};

```

### 3.4 2D\_Segment Tree(區間 MAX)

```

int num[501][501],N,M; /*input here
struct seg_2D{
    struct node{
        int data;
        node *lc,*rc;
    }*root;
    node* merge(node *a,node *b,int l,int r){
        node *p=new node;
        p->data=max(a->data,b->data);
        if(l==r) return p;
        int m=l+r>>1;
        p->lc=merge(a->lc,b->lc,l,m);
        p->rc=merge(a->rc,b->rc,m+1,r);
        return p;
    }
    node* build(int l,int r,int x){
        node *p=new node;
        if(l==r)
            return p->data=num[x][l],p;
        int m=l+r>>1;
        p->lc=build(l,m,x),p->rc=build(m+1,r,x);
        p->data=max(p->lc->data,p->rc->data);
        return p;
    }
    int query(int L,int R,int l,int r,node *p){
        if(L<=l && R>=r) return p->data;
        int m=l+r>>1,re=0;
        if(L<=m) re=query(L,R,l,m,p->lc);
        if(R>m) re=max(re,query(L,R,m+1,r,p->rc));
        return re;
    }
};
struct seg_1D{
    struct node{
        seg_2D data;
        node *lc,*rc;
    }*root;
    node* s_build(int l,int r){
        node *p=new node;
        if(l==r)
            return p->data.root=p->data.build(1,M,1),p;
        int m=l+r>>1;
        p->lc=s_build(l,m),p->rc=s_build(m+1,r);
        p->data.root=p->data.merge(p->lc->data.root,p->rc->
            data.root,1,M);
        return p;
    }
    int s_query(int L,int R,int l,int r,node *p,int yl,
        int yr){
        if(L<=l && R>=r)
            return p->data.query(yl,yr,1,M,p->data.root);
        int m=l+r>>1,re=0;
        if(L<=m) re=s_query(L,R,l,m,p->lc,yl,yr);

```

```

        if(R>m) re=max(re,s_query(L,R,m+1,r,p->rc,yl,yr));
        return re;
    }
    void init(){
        root=s_build(1,N);
    }
    int query(int x1,int xr,int yl,int yr){
        return s_query(x1,xr,1,N,root,yl,yr);
    }
};

```

### 3.5 Smart Pointer

```

#ifndef REFERENCE_POINTER
#define REFERENCE_POINTER
template<typename T>
struct _RefCounter{
    T data;
    int ref;
    _RefCounter(const T&d=0):data(d),ref(0){}
};
template<typename T>
struct reference_pointer{
    _RefCounter<T> *p;
    T *operator->(){return &p->data;}
    T &operator*(){return p->data;}
    operator _RefCounter<T>*(){return p;}
    reference_pointer &operator=(const reference_pointer &t)
    ){
        if(p&&!--p->ref)delete p;
        p=t.p;
        p&&+p->ref;
        return *this;
    }
    reference_pointer(_RefCounter<T> *t=0):p(t){
        p&&+p->ref;
    }
    reference_pointer(const reference_pointer &t):p(t.p){
        p&&+p->ref;
    }
    ~reference_pointer(){
        if(p&&!--p->ref)delete p;
    }
};
template<typename T>
inline reference_pointer<T> new_reference(const T&nd){
    return reference_pointer<T>(new _RefCounter<T>(nd));
}
#endif
//note:
reference_pointer<int> a;
a = new_reference(5);
a = new_reference<int>(5);
a = new_reference((int)5);
reference_pointer<int> b = a;

struct P{
    int a,b;
    P(int _a,int _b):a(_a),b(_b){}
}p(2,3);
reference_pointer<P> a;
c = new_reference(P(1,2));
c = new_reference<P>(P(1,2));
c = new_reference(p);

```

### 3.6 LiChaoST

```

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; }
    };
    struct node{
        node *l, *r; line f;
        node(line v) { f = v; l = r = NULL; }
    };
    typedef node* pnode;

```



```

pnode root; int sz;
#define mid ((l+r)>>1)
void insert(line &v, int l, int r, pnode &nd){
    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(int x, int l, int r, pnode &nd){
    if(!nd) return LLONG_MAX;
    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 <= query_x <= sz */
void init(int _sz){ sz = _sz + 1; root = NULL; }
void add_line(LL m, LL c){ line v(m, c); insert(v, -
    sz, sz, root); }
LL query(LL x) { return query(x, -sz, sz, root); }
};

```

### 3.7 link cut tree

```

const int MXN = 100005;
const int MEM = 100005;
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;
}
}

```

### 3.8 KDTree

```

template<typename T, size_t kd> //kd??????
class kd_tree{
public:
    struct point{
        T d[kd];
        inline T dist(const point &x) const{
            T ret=0;
            for(size_t i=0;i<kd;++i) ret+=std::abs(d[i]-x.d[i]);
            return ret;
        }
        inline bool operator==(const point &p){
            for(size_t i=0;i<kd;++i){
                if(d[i]!=p.d[i]) return 0;
            }
            return 1;
        }
        inline bool operator<(const point &b) const{

```

```

        return d[0]<b.d[0];
    }
};
private:
struct node{
    node *l,*r;
    point pid;
    int s;
    node(const point &p):l(0),r(0),pid(p),s(1){}
    inline void up(){
        s=(l?l->s:0)+1+(r?r->s:0);
    }
}*root;
const double alpha,loga;
const T INF;///????INF,????
int maxn;
struct __cmp{
    int sort_id;
    inline bool operator()(const node*x,const node*y)
        const{
        return operator()(x->pid,y->pid);
    }
    inline bool operator()(const point &x,const point
        &y)const{
        if(x.d[sort_id]!=y.d[sort_id])
            return x.d[sort_id]<y.d[sort_id];
        for(size_t i=0;i<kd;++i){
            if(x.d[i]!=y.d[i])return x.d[i]<y.d[i];
        }
        return 0;
    }
}cmp;
void clear(node *o){
    if(!o)return;
    clear(o->l);
    clear(o->r);
    delete o;
}
inline int size(node *o){
    return o?o->s:0;
}
std::vector<node*> A;
node* build(int k,int l,int r){
    if(l>r)return 0;
    if(k==kd)k=0;
    int mid=(l+r)/2;
    cmp.sort_id=k;
    std::nth_element(A.begin()+l,A.begin()+mid,A.
        begin()+r+1,cmp);
    node *ret=A[mid];
    ret->l=build(k+1,l,mid-1);
    ret->r=build(k+1,mid+1,r);
    ret->up();
    return ret;
}
inline bool isbad(node*o){
    return size(o->l)>alpha*o->s||size(o->r)>alpha*o
        ->s;
}
void flatten(node *u,typename std::vector<node*>::
    iterator &it){
    if(!u)return;
    flatten(u->l,it);
    *it=u;
    flatten(u->r,++it);
}
inline void rebuild(node*&u,int k){
    if((int)A.size()<u->s)A.resize(u->s);
    typename std::vector<node*>::iterator it=A.begin
        ();
    flatten(u,it);
    u=build(k,0,u->s-1);
}
bool insert(node*&u,int k,const point &x,int dep){
    if(!u){
        u=new node(x);
        return dep<=0;
    }
    ++u->s;
    cmp.sort_id=k;
    if(insert(cmp(x,u->pid)?u->l:u->r,(k+1)%kd,x,dep
        -1)){

```

```

        if(!isbad(u))return 1;
        rebuild(u,k);
    }
    return 0;
}
node *findmin(node*o,int k){
    if(!o)return 0;
    if(cmp.sort_id==k)return o->l?findmin(o->l,(k+1)%
        kd):o;
    node *l=findmin(o->l,(k+1)%kd);
    node *r=findmin(o->r,(k+1)%kd);
    if(l&&!r)return cmp(l,o)?l:o;
    if(!l&&r)return cmp(r,o)?r:o;
    if(!l&&!r)return 0;
    if(cmp(l,r))return cmp(l,o)?l:o;
    return cmp(r,o)?r:o;
}
bool erase(node *&u,int k,const point &x){
    if(!u)return 0;
    if(u->pid==x){
        if(u->r);
        else if(u->l){
            u->r=u->l;
            u->l=0;
        }else{
            delete u;
            u=0;
            return 1;
        }
        --u->s;
        cmp.sort_id=k;
        u->pid=findmin(u->r,(k+1)%kd)->pid;
        return erase(u->r,(k+1)%kd,u->pid);
    }
    cmp.sort_id=k;
    if(erase(cmp(x,u->pid)?u->l:u->r,(k+1)%kd,x)){
        --u->s;return 1;
    }else return 0;
}
inline T heuristic(const T h[])const{
    T ret=0;
    for(size_t i=0;i<kd;++i)ret+=h[i];
    return ret;
}
int qM;
std::priority_queue<std::pair<T,point >>pQ;
void nearest(node *u,int k,const point &x,T *h,T &
    mndist){
    if(u==0||heuristic(h)>=mndist)return;
    T dist=u->pid.dist(x),old=h[k];
    /*mndist=std::min(mndist,dist);*/
    if(dist<mndist){
        pQ.push(std::make_pair(dist,u->pid));
        if((int)pQ.size()==qM+1){
            mndist=pQ.top().first,pQ.pop();
        }
    }
    if(x.d[k]<u->pid.d[k]){
        nearest(u->l,(k+1)%kd,x,h,mndist);
        h[k]=std::abs(x.d[k]-u->pid.d[k]);
        nearest(u->r,(k+1)%kd,x,h,mndist);
    }else{
        nearest(u->r,(k+1)%kd,x,h,mndist);
        h[k]=std::abs(x.d[k]-u->pid.d[k]);
        nearest(u->l,(k+1)%kd,x,h,mndist);
    }
    h[k]=old;
}
std::vector<point>in_range;
void range(node *u,int k,const point&mi,const point
    &ma){
    if(!u)return;
    bool is=1;
    for(int i=0;i<kd;++i)
        if(u->pid.d[i]<mi.d[i]||ma.d[i]<u->pid.d[i]){
            is=0;break;
        }
    if(is)in_range.push_back(u->pid);
    if(mi.d[k]<=u->pid.d[k])range(u->l,(k+1)%kd,mi,ma
        );
    if(ma.d[k]>=u->pid.d[k])range(u->r,(k+1)%kd,mi,ma
        );
}

```



```

    }
public:
    kd_tree(const T &INF, double a=0.75):root(0),alpha(a
    ),loga(log2(1.0/a)),INF(INF),maxn(1){}
    inline void clear(){
        clear(root),root=0,maxn=1;
    }
    inline void build(int n,const point *p){
        clear(root),A.resize(maxn=n);
        for(int i=0;i<n;++i)A[i]=new node(p[i]);
        root=build(0,0,n-1);
    }
    inline void insert(const point &x){
        insert(root,0,x,std::lg(size(root))/loga);
        if(root->s>maxn)maxn=root->s;
    }
    inline bool erase(const point &p){
        bool d=erase(root,0,p);
        if(root&&root->s<alpha*maxn)rebuild();
        return d;
    }
    inline void rebuild(){
        if(root)rebuild(root,0);
        maxn=root->s;
    }
    inline T nearest(const point &x,int k){
        qM=k;
        T mndist=INF,h[kd]={};
        nearest(root,0,x,h,mndist);
        mndist=pQ.top().first;
        pQ=std::priority_queue<std::pair<T,point >>();
        return mndist; /*???x?k?????*/
    }
    inline const std::vector<point> &range(const point&
        mi,const point&ma){
        in_range.clear();
        range(root,0,mi,ma);
        return in_range; /*???mi?ma???vector*/
    }
    inline int size(){return root?root->s:0;}
};

```

## 4 Flow/Matching

### 4.1 Dinic

```

struct MaxFlow{//0-base
    struct edge{
        int to,cap,flow,rev;
    };
    vector<edge> G[MAXN];
    int s,t,dis[MAXN],cur[MAXN],n;
    int dfs(int u,int cap){
        if(u==t || !cap) return cap;
        for(int &i=cur[u];i<(int)G[u].size();++i){
            edge &e=G[u][i];
            if(dis[e.to]==dis[u]+1 && e.flow!=e.cap){
                int df=dfs(e.to,min(e.cap-e.flow,cap));
                if(df){
                    e.flow+=df;
                    G[e.to][e.rev].flow-=df;
                    return df;
                }
            }
        }
        dis[u]=-1;
        return 0;
    }
    bool bfs(){
        FILL(dis,-1);
        queue<int> q;
        q.push(s),dis[s]=0;
        while(!q.empty()){
            int tmp=q.front();
            q.pop();
            for(auto &u:G[tmp])
                if(!dis[u.to] && u.flow!=u.cap){
                    q.push(u.to);
                }
        }
    }
};

```

```

        dis[u.to]=dis[tmp]+1;
    }
    return dis[t]!=-1;
}
int maxflow(int _s,int _t){
    s=_s,t=_t;
    int flow=0,df;
    while(bfs()){
        FILL(cur,0);
        while(df=dfs(s,INF)) flow+=df;
    }
    return flow;
}
void init(int _n){n=_n;
    for(int i=0;i<n;++i) G[i].clear();
}
void reset(){
    for(int i=0;i<n;++i)
        for(auto &j:G[i])
            j.flow=0;
}
void add_edge(int u,int v,int cap){
    G[u].pb(edge{v,cap,0,(int)G[v].size()});
    G[v].pb(edge{u,0,0,(int)G[u].size()-1});
}
};

```

### 4.2 Kuhn Munkres

```

struct KM{//0-base
    int n,match[MAXN],vx[MAXN],vy[MAXN];
    int edge[MAXN][MAXN],lx[MAXN],ly[MAXN],slack[MAXN];
    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 addEdge(int x, int y, int w){
        edge[x][y]=w;
    }
    bool DFS(int x){
        vx[x]=1;
        for(int y=0;y<n;++y){
            if(vy[y]) continue;
            if(lx[x]+ly[y]>edge[x][y])
                slack[y]=min(slack[y], lx[x]+ly[y]-edge[x][y]);
            else{
                vy[y]=1;
                if(!match[y] || DFS(match[y]))
                    return match[y] = x,1;
            }
        }
        return 0;
    }
    int solve(){
        fill(match,match+n,-1);
        fill(lx,lx+n,-INF),fill(ly,ly+n,0);
        for(int i=0;i<n;++i)
            for(int j=0;j<n;++j)
                lx[i]=max(lx[i],edge[i][j]);
        for(int i=0;i<n;++i){
            fill(slack,slack+n,INF);
            while(1){
                fill(vx,vx+n,0),fill(vy,vy+n,0);
                if(DFS(i)) break;
                int d=INF;
                for(int j=0;j<n;++j)
                    if(!vy[j]) d=min(d,slack[j]);
                for(int j=0;j<n;++j){
                    if(vx[j]) lx[j]-=d;
                    if(vy[j]) ly[j]+=d;
                    else slack[j]-=d;
                }
            }
        }
        int res=0;
        for(int i=0;i<n;++i) res+=edge[match[i]][i];
        return res;
    }
};

```

```
};
```

### 4.3 MincostMaxflow

```
struct MCMF{//0-base
    struct edge{
        ll from,to,cap,flow,cost,rev;
    }*past[MAXN];
    vector<edge> G[MAXN];
    bitset<MAXN> inq;
    ll dis[MAXN],up[MAXN],s,t,mx,n;
    bool BellmanFord(ll &flow,ll &cost){
        fill(dis,dis+n,INF);
        queue<ll> q;
        q.push(s),inq.reset(),inq[s]=1;
        up[s]=mx-flow,past[s]=0,dis[s]=0;
        while(!q.empty()){
            ll u=q.front();
            q.pop(),inq[u]=0;
            if(!up[u]) continue;
            for(auto &e:G[u])
                if(e.flow!=e.cap&&dis[e.to]>dis[u]+e.cost){
                    dis[e.to]=dis[u]+e.cost,past[e.to]=&e;
                    up[e.to]=min(up[u],e.cap-e.flow);
                    if(!inq[e.to]) inq[e.to]=1,q.push(e.to);
                }
        }
        if(dis[t]==INF) return 0;
        flow+=up[t],cost+=up[t]*dis[t];
        for(ll i=t;past[i];i=past[i]->from){
            auto &e=*past[i];
            e.flow+=up[t],G[e.to][e.rev].flow-=up[t];
        }
        return 1;
    }
    ll MinCostMaxFlow(ll _s,ll _t,ll &cost){
        s=_s,t=_t,cost=0;ll flow=0;
        while(BellmanFord(flow,cost));
        return flow;
    }
    void init(ll _n,ll _mx){n=_n,mx=_mx;
        for(int i=0;i<n;++i) G[i].clear();
    }
    void add_edge(ll a,ll b,ll cap,ll cost){
        G[a].pb(edge{a,b,cap,0,cost,G[b].size()});
        G[b].pb(edge{b,a,0,0,-cost,G[a].size()-1});
    }
};
```

### 4.4 Maximum Simple Graph Matching

```
struct GenMatch{//1-base
    int V,pr[MAXN];
    bool el[MAXN][MAXN];
    bool inq[MAXN],inp[MAXN],inb[MAXN];
    queue<int> qe;
    int st,ed,nb,bk[MAXN],djs[MAXN],ans;
    void init(int _V){V=_V;
        for(int i=0;i<V;++i){
            for(int j=0;j<V;++j)
                el[i][j]=0;
            pr[i]=bk[i]=djs[i]=0;
            inq[i]=inp[i]=inb[i]=0;
        }
        ans=0;
    }
    void add_edge(int u, int v){
        el[u][v]=el[v][u]=1;
    }
    int lca(int u,int v){
        for(int i=0;i<V;++i) inp[i]=0;
        while(1){
            u=djs[u],inp[u]=true;
            if(u==st) break;
            u=bk[pr[u]];
        }
        while(1){
            v=djs[v];
```

```
            if(inp[v]) return v;
            v=bk[pr[v]];
        }
        return v;
    }
    void upd(int u){
        int v;
        while(djs[u]!=nb){
            v=pr[u],inb[djs[u]]=inb[djs[v]]=true;
            u=bk[v];
            if(djs[u]!=nb) bk[u]=v;
        }
    }
    void blo(int u,int v){
        nb=lca(u,v);
        for (int i=0;i<V;++i) inb[i]=0;
        upd(u),upd(v);
        if(djs[u]!=nb) bk[u]=v;
        if(djs[v]!=nb) bk[v]=u;
        for(int tu=1;tu<=V;++tu)
            if(inb[djs[tu]]){
                djs[tu]=nb;
                if(!inq[tu])
                    qe.push(tu),inq[tu]=1;
            }
    }
    void flow(){
        for(int i=1;i<=V;++i)
            inq[i]=0,bk[i]=0,djs[i]=i;
        while(qe.size()) qe.pop();
        qe.push(st),inq[st]=1,ed=0;
        while(qe.size()){
            int u = qe.front();
            qe.pop();
            for(int v=1;v<=V;++v)
                if(el[u][v]&&djs[u]!=djs[v]&&pr[u]!=v)
                    if((v==st)||pr[v]>0&&bk[pr[v]]>0)
                        blo(u,v);
                    else if(!bk[v])
                        if(bk[v]=u,pr[v]>0)
                            if(!inq[pr[v]])
                                qe.push(pr[v]);
                    else;
                    else
                        return ed=v,void();
        }
    }
    void aug(){
        int u=ed,v,w;
        while(u>0)
            v=bk[u],w=pr[v],pr[v]=u,pr[u]=v,u=w;
    }
    int solve(){
        for(int i=0;i<V;++i) pr[i]=0;
        for(int u=1;u<=V;++u)
            if(!pr[u])
                if(st=u,flow(),ed>0)
                    aug(),++ans;
        return ans;
    }
};
```

### 4.5 Minimum Weight Matching (Clique version)

```
struct Graph{//0-base (Perfect Match)
    int n,edge[MAXN][MAXN];
    int match[MAXN],dis[MAXN],onstk[MAXN];
    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 1;
```

```

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 1;
                stk.pop_back(), onstk[v]=0;
            }
    }
onstk[u]=0, stk.pop_back();
return 0;
}
int solve(){// find a match
for(int i=0; i<n; i+=2)
    match[i]=i+1, match[i+1]=i;
while(1){
    int found=0;
    for(int i=0; i<n; ++i) dis[i]=onstk[i]=0;
    for(int i=0; i<n; ++i)
        if(stk.clear(), !onstk[i] && SPFA(i))
            for(found=1; stk.size()>=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]];
return ret>>1;
}
};

```

#### 4.6 SW-mincut

```

// global min cut
struct SW{ // O(V^3)
    static const int MXN = 514;
    int n, vst[MXN], del[MXN];
    int edge[MXN][MXN], wei[MXN];
    void init(int _n){
        n=_n, MEM(edge, 0), MEM(del, 0);
    }
    void addEdge(int u, int v, int w){
        edge[u][v]+=w, edge[v][u]+=w;
    }
    void search(int &s, int &t){
        MEM(vst, 0), MEM(wei, 0), s=t=-1;
        while(1){
            int mx=-1, cur=0;
            for(int i=0; i<n; ++i)
                if(!del[i] && !vst[i] && mx<wei[i])
                    cur=i, mx=wei[i];
            if(mx==-1) break;
            vst[cur]=1, s=t=cur;
            for(int i=0; i<n; ++i)
                if(!vst[i] && !del[i]) wei[i]+=edge[cur][i];
        }
    }
    int solve(){
        int res=INF;
        for(int i=0, x, y; i<n-1; ++i){
            search(x, y), res=min(res, wei[y]), del[y]=1;
            for(int j=0; j<n; ++j)
                edge[x][j]=(edge[j][x]+edge[y][j]);
        }
        return res;
    }
};

```

#### 4.7 BoundedFlow

```

struct BoundedFlow{//0-base
    struct Edge{
        int to, cap, flow, rev;
    };
    vector<Edge> G[MAXN];
    int n, s, t, dis[MAXN], cur[MAXN], cnt[MAXN];
    void init(int _n){n=_n;
        for(int i=0; i<n+2; ++i) G[i].clear(), cnt[i]=0;
    }
    void add_edge(int u, int v, int lcap, int rcap){
        cnt[u]-=lcap, cnt[v]+=lcap;
        G[u].pb(Edge{v, rcap, lcap, (int)G[v].size()});
        G[v].pb(Edge{u, 0, 0, (int)G[u].size()-1});
    }
    void add_edge(int u, int v, int cap){
        G[u].pb(Edge{v, cap, 0, (int)G[v].size()});
        G[v].pb(Edge{u, 0, 0, (int)G[u].size()-1});
    }
    int dfs(int u, int cap){
        if(u==t || !cap) return cap;
        for(int &i=cur[u]; i<(int)G[u].size(); ++i){
            Edge &e=G[u][i];
            if(dis[e.to]==dis[u]+1 && e.flow!=e.cap){
                int df=dfs(e.to, min(e.cap-e.flow, cap));
                if(df){
                    e.flow+=df;
                    G[e.to][e.rev].flow-=df;
                    return df;
                }
            }
        }
        dis[u]=-1;
        return 0;
    }
    bool bfs(){
        FILL(dis, -1);
        queue<int> q;
        q.push(s), dis[s]=0;
        while(!q.empty()){
            int tmp=q.front();
            q.pop();
            for(auto &u:G[tmp])
                if(!dis[u.to] && u.flow!=u.cap){
                    q.push(u.to);
                    dis[u.to]=dis[tmp]+1;
                }
        }
        return dis[t]!=-1;
    }
    int maxflow(int _s, int _t){
        s=_s, t=_t;
        int flow=0, df;
        while(bfs()){
            FILL(cur, 0);
            while(df=dfs(s, INF)) flow+=df;
        }
        return flow;
    }
    bool solve(){
        int sum=0;
        for(int i=0; i<n; ++i)
            if(cnt[i]>0) add_edge(n+1, i, cnt[i]), sum+=cnt[i];
            else if(cnt[i]<0) add_edge(i, n+2, -cnt[i]);
        if(sum!=maxflow(n+1, n+2)) sum=-1;
        for(int i=0; i<n; ++i)
            if(cnt[i]>0) G[n+1].pop_back(), G[i].pop_back();
            else if(cnt[i]<0) G[i].pop_back(), G[n+2].pop_back();
        return sum!=-1;
    }
    int solve(int _s, int _t){
        add_edge(_t, _s, INF);
        if(!solve()) return -1; //invalid flow
        int x=G[_t].back().flow;
        return G[_t].pop_back(), G[_s].pop_back(), x;
    }
};

```

#### 4.8 Gomory Hu tree

```

struct Gomory_Hu_tree{//0-base
    MaxFlow Dinic;
    int n;
    vector<pii> G[MAXN];
    void init(int _n){n=_n;
        for(int i=0;i<n;++i) G[i].clear();
    }
    void solve(vector<int> &v){
        if(v.size()<=1) return;
        int s=rand()%SZ(v);
        swap(v.back(),v[s]),s=v.back();
        int t=v[rand()%SZ(v)-1];
        vector<int> L,R;
        int x=(Dinic.reset(),Dinic.maxflow(s,t));
        G[s].pb(pii(t,x)),G[t].pb(pii(s,x));
        for(int i:v)
            if(~Dinic.dis[i]) L.pb(i);
            else R.pb(i);
        solve(L),solve(R);
    }
    void build(){
        vector<int> v(n);
        for(int i=0;i<n;++i) v[i]=i;
        solve(v);
    }
}ght;//test by BZOJ 4519
MaxFlow &Dinic=ght.Dinic;

```

## 4.9 NumberofMaximalClique

```

// bool g[][] : adjacent array indexed from 1 to n
void dfs(int sz){
    int i, j, k, t, cnt, best = 0;
    if(ne[sz]==ce[sz]){ if (ce[sz]==0) ++ans; return; }
    for(t=0, i=1; i<=ne[sz]; ++i){
        for(cnt=0, j=ne[sz]+1; j<=ce[sz]; ++j)
            if (!g[lst[sz][i]][lst[sz][j]]) ++cnt;
        if (t==0 || cnt<best) t=i, best=cnt;
    } if (t && best<=0) return;
    for (k=ne[sz]+1; k<=ce[sz]; ++k) {
        if (t>0){ for (i=k; i<=ce[sz]; ++i)
            if (!g[lst[sz][t]][lst[sz][i]]) break;
        swap(lst[sz][k], lst[sz][i]);
    } i=lst[sz][k]; ne[sz+1]=ce[sz+1]=0;
    for (j=1; j<k; ++j)if (g[i][lst[sz][j]])
        lst[sz+1][++ne[sz+1]]=lst[sz][j];
    for (ce[sz+1]=ne[sz+1], j=k+1; j<=ce[sz]; ++j)
        if (g[i][lst[sz][j]]) lst[sz+1][++ce[sz+1]]=lst[sz][j];
    dfs(sz+1); ++ne[sz]; --best;
    for (j=k+1, cnt=0; j<=ce[sz]; ++j) if (!g[i][lst[sz][j]]) ++cnt;
    if (t==0 || cnt<best) t=k, best=cnt;
    if (t && best<=0) break;
}
void work(){
    ne[0]=0; ce[0]=0;
    for(int i=1; i<=n; ++i) lst[0][++ce[0]]=i;
    ans=0; dfs(0);
}

```

## 4.10 isap

```

struct Maxflow {
    static const int MAXV = 20010;
    static const int INF = 1000000;
    struct Edge {
        int v, c, r;
        Edge(int _v, int _c, int _r):
            v(_v), c(_c), r(_r) {}
    };
    int s, t;
    vector<Edge> G[MAXV*2];
    int iter[MAXV*2], d[MAXV*2], gap[MAXV*2], tot;
    void init(int x) {
        tot = x+2;
        s = x+1, t = x+2;
        for(int i = 0; i <= tot; i++) {

```

```

            G[i].clear();
            iter[i] = d[i] = gap[i] = 0;
        }
    }
    void addEdge(int u, int v, int c) {
        G[u].push_back(Edge(v, c, SZ(G[v])));
        G[v].push_back(Edge(u, 0, SZ(G[u]) - 1));
    }
    int dfs(int p, int flow) {
        if(p == t) return flow;
        for(int &i = iter[p]; i < SZ(G[p]); i++) {
            Edge &e = G[p][i];
            if(e.c > 0 && d[p] == d[e.v]+1) {
                int f = dfs(e.v, min(flow, e.c));
                if(f) {
                    e.c -= f;
                    G[e.v][e.r].c += f;
                    return f;
                }
            }
        }
        if( (--gap[d[p]]) == 0) d[s] = tot;
        else {
            d[p]++;
            iter[p] = 0;
            ++gap[d[p]];
        }
        return 0;
    }
    int solve() {
        int res = 0;
        gap[0] = tot;
        for(res = 0; d[s] < tot; res += dfs(s, INF));
        return res;
    }
} flow;

```

## 5 String

### 5.1 KMP

```

int F[MAXN];
vector<int> match(string A, string B){
    vector<int> ans;
    F[0]=-1,F[1]=0;
    for(int i=1,j=0;i<B.size();F[++i]=++j){
        if(B[i]==B[j]) F[i]=F[j];//optimize
        while(j!=-1&&B[i]!=B[j]) j=F[j];
    }
    for(int i=0,j=0;i-j+B.size()<=A.size();++i,++j){
        while(j!=-1&&A[i]!=B[j]) j=F[j];
        if(j==B.size()-1) ans.pb(i-j);
    }
    return ans;
}

```

### 5.2 Z-value

```

int z[100005];
void Z_value(string s){
    int L=0,R=0;
    for(int i=1;i<SZ(s);i++){
        if(i>R){
            L=R=i;
            while(R<SZ(s) && s[R-L]==s[R]) ++R;
            z[i]=R-L;R--;
        }
        else{
            int k=i-L;
            if(z[k]<R-i+1) z[i]=z[k];
            else{
                L=i;
                while(R<SZ(s) && s[R-L]==s[R]) ++R;
                z[i]=R-L;R--;
            }
        }
    }
}

```

```

}
}

```

### 5.3 Manacher

```

int z[MAXN];
int Manacher(string tmp){
    string s="&";
    int l=0,r=0,x,ans;
    for(char c:tmp) s.pb('%'),s.pb(c);
    s.pb('%'),ans=0,x=0;
    for(int i=1;i<SZ(s);++i){
        z[i]=r > i ? min(z[2*l-i],r-i) : 1;
        while(s[i+z[i]]==s[i-z[i]])++z[i];
        if(z[i]+i>r)r=z[i]+i,l=i;
    }
    for(int i=1;i<SZ(s);++i)
        if(s[i]=='%')
            x=max(x,z[i]);
    ans=x/2*2,x=0;
    for(int i=1;i<SZ(s);++i)
        if(s[i]!='%')
            x=max(x,z[i]);
    return max(ans,(x-1)/2*2+1);
}

```

### 5.4 Suffix Array

```

struct suffix_array{
    int box[MAXN],tp[MAXN],k,m;
    bool not_equ(int *ra,int a,int b,int k,int n){
        return ra[a]!=ra[b]||a+k>n||b+k>n||ra[a+k]!=ra[b+k];
    }
    void radix(int *box,int *key,int *it,int *ot,int m,
        int n){
        fill_n(box,m,0);
        for(int i=0;i<n;++i) ++box[key[i]];
        partial_sum(box,box+m,box);
        for(int i=n-1;i>=0;--i) ot[--box[key[it[i]]]]=it[i];
    }
    void make_sa(int *sa,int *ra,string s,int n){
        for(int i=0;i<n;++i) ra[i]=s[i];
        do{
            iota(tp,tp+k,n-k),iota(sa+k,sa+n,0);
            radix(box,ra+k,sa+k,tp+k,m,n-k);
            radix(box,ra,tp,sa,m,n);
            tp[sa[0]]=0,m=1;
            for(int i=1;i<n;++i){
                m+=not_equ(ra,sa[i],sa[i-1],k,n);
                tp[sa[i]]=m-1;
            }
            for(int i=0;i<n;++i) ra[i]=tp[i];
            k*=2;
        }while(k<n&&m!=n);
    }
    void make_he(int *he,int *sa,int *ra,string s,int n){
        for(int j=0,k=0;j<n;++j){
            if(ra[j])
                for(;s[j+k]==s[sa[ra[j]-1]+k];++k);
            he[ra[j]]=k,k=max(0,k-1);
        }
    }
    int sa[MAXN],ra[MAXN],he[MAXN];
    void build(string s){
        FILL(sa,0),FILL(ra,0),FILL(he,0);
        FILL(box,0),FILL(tp,0),k=1,m=256;
        make_sa(sa,ra,s,s.size());
        make_he(he,sa,ra,s,s.size());
    }
};

```

### 5.5 SAIS

```

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[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)
}

```

### 5.6 Aho-Corasick Automatan

```

const int len=400000,sigma=26;
struct AC_Automatan{
    int nx[len][sigma],fl[len],cnt[len],pri[len],top;
    int newnode(){
        fill(nx[top],nx[top]+sigma,-1);
        return top++;
    }
    void init(){top=1,newnode();}
}

```

```

int input(string &s){//return the end_node of string
int X=1;
for(char c:s){
if(!~nx[X][c-'a'])nx[X][c-'a']=newnode();
X=nx[X][c-'a'];
}
return X;
}
void make_fl(){
queue<int> q;
q.push(1),fl[1]=0;
for(int t=0;!q.empty();){
int R=q.front();
q.pop(),pri[t++]=R;
for(int i=0;i<sigma;++i)
if(~nx[R][i]){
int X=nx[R][i],Z=f1[R];
for(;Z&&!~nx[Z][i];)Z=f1[Z];
f1[X]=Z?nx[Z][i]:1,q.push(X);
}
}
}
void get_v(string &s){
int X=1;
fill(cnt,cnt+top,0);
for(char c:s){
while(X&&!~nx[X][c-'a'])X=f1[X];
X=X?nx[X][c-'a']:1,++cnt[X];
}
for(int i=top-2;i>0;--i) cnt[f1[pri[i]]]+=cnt[pri[i]];
}
};

```

## 5.7 Smallest Rotation

```

string mcp(string s){
int n=SZ(s),i=0,j=1;
s+=s;
while(i<n&&j<n){
int k=0;
while(k<n&&s[i+k]==s[j+k]) ++k;
if(s[i+k]<s[j+k]) j+=k+1;
else i+=k+1;
if(i==j) ++j;
}
int ans=i<n?i:j;
return s.substr(ans,n);
}

int z[MAXN];
int Manacher(string tmp){
string s="&";
int l=0,r=0,x,ans;
for(char c:tmp) s.pb('%'),s.pb(c);
s.pb('%'),ans=0,x=0;
for(int i=1;i<SZ(s);++i){
z[i]=r > i ? min(z[2*l-i],r-i) : 1;
while(s[i+z[i]]==s[i-z[i]])++z[i];
if(z[i]+i>r)r=z[i]+i,l=i;
}
for(int i=1;i<SZ(s);++i)
if(s[i]=='%')
x=max(x,z[i]);
ans=x/2*2,x=0;
for(int i=1;i<SZ(s);++i)
if(s[i]!='%')
x=max(x,z[i]);
return max(ans,(x-1)/2*2+1);
}

```

## 5.8 De Bruijn sequence

```

constexpr int MAXC = 10, MAXN = 100000 + 10;
struct DBseq {
int C, N, K, L, buf[MAXC * MAXN]; //K <= C^N
void dfs(int *out, int t, int p, int &ptr) {

```

```

if (ptr >= L) return;
if (t > N) {
if (N % p == 0) {
for (int i = 1; i <= p && ptr < L; ++i)
out[ptr++] = buf[i];
}
} else {
buf[t] = buf[t - p], dfs(out, t + 1, p, ptr);
for (int j = buf[t - p] + 1; j < C; ++j)
buf[t] = j, dfs(out, t + 1, t, ptr);
}
}
void solve(int _c, int _n, int _k, int *out) {
int p = 0;
C = _c, N = _n, K = _k, L = N + K - 1;
dfs(out, 1, 1, p);
if (p < L) fill(out + p, out + L, 0);
}
} db;

```

## 5.9 SAM

```

const int MAXM = 1000010;
struct SAM{
int tot, root, lst, mom[MAXM], mx[MAXM];
int acc[MAXM], nxt[MAXM][33];
int newNode(){
int res = ++tot;
fill(nxt[res], nxt[res]+33, 0);
mom[res] = mx[res] = acc[res] = 0;
return res;
}
void init(){
tot = 0;
root = newNode();
mom[root] = 0, mx[root] = 0;
lst = root;
}
void push(int c){
int p = lst;
int np = newNode();
mx[np] = mx[p]+1;
for(; p && nxt[p][c] == 0; p = mom[p])
nxt[p][c] = np;
if(p == 0) mom[np] = root;
else{
int q = nxt[p][c];
if(mx[p]+1 == mx[q]) mom[np] = q;
else{
int nq = newNode();
mx[nq] = mx[p]+1;
for(int i = 0; i < 33; i++)
nxt[nq][i] = nxt[q][i];
mom[nq] = mom[q];
mom[q] = nq;
mom[np] = nq;
for(; p && nxt[p][c] == q; p = mom[p])
nxt[p][c] = nq;
}
}
lst = np;
}
void push(char *str){
for(int i = 0; str[i]; i++)
push(str[i]-'a'+1);
}
} sam;

```

## 5.10 PalTree

```

/*
* sfail: compressed fail links with same diff
* O(Lgn): Length of sfail link path
*/
const int MAXN = 1e6+10;
struct PalT{
int tot,lst;

```



```

int nxt[MAXN][26], len[MAXN];
int fail[MAXN], diff[MAXN], sfail[MAXN];
char* s;
int newNode(int l, int _fail) {
    int res = ++tot;
    fill(nxt[res], nxt[res]+26, 0);
    len[res] = l, fail[res] = _fail;
    diff[res] = 1 - len[_fail];
    if (diff[res] == diff[_fail])
        sfail[res] = sfail[_fail];
    else
        sfail[res] = _fail;
    return res;
}
void push(int p) {
    int np = lst;
    int c = s[p] - 'a';
    while (p-len[np]-1 < 0 || s[p] != s[p-len[np]-1])
        np = fail[np];
    if ((lst=nxt[np][c])) return;
    int nq_f = 0;
    if (len[np]+2 == 1) nq_f = 2;
    else {
        int tf = fail[np];
        while (p-len[tf]-1 < 0 || s[p] != s[p-len[tf]-1])
            tf = fail[tf];
        nq_f = nxt[tf][c];
    }
    int nq = newNode(len[np]+2, nq_f);
    nxt[np][c] = nq;
    lst=nq;
}
void init(char* _s){
    s = _s;
    tot = 0;
    newNode(-1, 1);
    newNode(0, 1);
    diff[2] = 0;
    lst = 2;
}
} pal;

```

```

int cyclic_lcs() {
    // a, b, al, bl should be properly filled
    // note: a WILL be altered in process
    // -- concatenated after itself
    char tmp[MAXL];
    if(al>bl) {
        swap(al,bl);
        strcpy(tmp,a);
        strcpy(a,b);
        strcpy(b,tmp);
    }
    strcpy(tmp,a);
    strcat(a,tmp);
    // basic lcs
    for(int i=0;i<=2*al;i++) {
        dp[i][0]=0;
        pred[i][0]=U;
    }
    for(int j=0;j<=bl;j++) {
        dp[0][j]=0;
        pred[0][j]=L;
    }
    for(int i=1;i<=2*al;i++) {
        for(int j=1;j<=bl;j++) {
            if(a[i-1]==b[j-1]) dp[i][j]=dp[i-1][j-1]+1;
            else dp[i][j]=max(dp[i-1][j],dp[i][j-1]);
            if(dp[i][j-1]==dp[i][j]) pred[i][j]=L;
            else if(a[i-1]==b[j-1]) pred[i][j]=LU;
            else pred[i][j]=U;
        }
    }
    // do cyclic lcs
    int clcs=0;
    for(int i=0;i<al;i++) {
        clcs=max(clcs,lcs_length(i));
        reroot(i+1);
    }
    // recover a
    a[al]='\0';
    return clcs;
}

```

## 5.11 cyclicLCS

```

#define L 0
#define LU 1
#define U 2
const int mov[3][2]={0,-1, -1,-1, -1,0};
int al,bl;
char a[MAXL*2],b[MAXL*2]; // 0-indexed
int dp[MAXL*2][MAXL];
char pred[MAXL*2][MAXL];
inline int lcs_length(int r) {
    int i=r+al,j=bl,l=0;
    while(i>r) {
        char dir=pred[i][j];
        if(dir==LU) l++;
        i+=mov[dir][0];
        j+=mov[dir][1];
    }
    return l;
}
inline void reroot(int r) { // r = new base row
    int i=r,j=1;
    while(j<=bl&&pred[i][j]!=LU) j++;
    if(j>bl) return;
    pred[i][j]=L;
    while(i<2*al&&j<=bl) {
        if(pred[i+1][j]==U) {
            i++;
            pred[i][j]=L;
        } else if(j<bl&&pred[i+1][j+1]==LU) {
            i++;
            j++;
            pred[i][j]=L;
        } else {
            j++;
        }
    }
}
}

```

## 6 Math

### 6.1 ax+by=gcd

```

pii gcd(int a,int b){
    if(b==0) return pii(1,0);
    else{
        int p=a/b;
        pii q=gcd(b,a%b);
        return MP(q.Y,q.X-q.Y*p);
    }
}

```

### 6.2 floor and ceil

```

int floor(int a,int b){
    return a/b-(a%b&&a<0^b<0);
}
int ceil(int a,int b){
    return a/b+(a%b&&a<0^b>0);
}

```

### 6.3 Miller Rabin

```

// n < 4,759,123,141      3 : 2, 7, 61
// n < 1,122,004,669,633  4 : 2, 13, 23, 1662803
// n < 3,474,749,660,383  6 : pirmses <= 13
// n < 2^64               7 :
// 2, 325, 9375, 28178, 450775, 9780504, 1795265022
bool Miller_Rabin(ll a,ll n){
    if((a==0)%n==0) return 1;
    if(n&1^1) return n==2;
}

```

```

11 tmp=(n-1)/((n-1)&(-n+1)),t=__lg((n-1)&(-n+1)),x=1;
for(;tmp;tmp/=2,a=mul(a,a,n))
    if(tmp&1) x=mul(x,a,n);
if(x==1 || x==n-1) return 1;
while(--t)
    if((x=mul(x,x,n))==n-1) return 1;
return 0;
}

```

## 6.4 Big number

```

template<typename T>
inline string to_string(const T& x){
    stringstream ss;
    return ss<<x,ss.str();
}
struct bigN:vector<ll>{
    const static int base=1000000000, width=log10(base);
    bool negative;
    bigN(const_iterator a, const_iterator b):vector<ll>(a, b){}
    bigN(string s){
        if(s.empty())return;
        if(s[0]=='-')negative=1, s=s.substr(1);
        else negative=0;
        for(int i=int(s.size())-1; i>=0; i-=width){
            ll t=0;
            for(int j=max(0, i-width+1); j<=i; ++j)
                t=t*10+s[j]-'0';
            push_back(t);
        }
        trim();
    }
    template<typename T>
    bigN(const T& x):bigN(to_string(x)){}
    bigN():negative(0){}
    void trim(){
        while(size()&&back())pop_back();
        if(empty())negative=0;
    }
    void carry(int _base=base){
        for(size_t i=0; i<size(); ++i){
            if(at(i)>=_base)continue;
            if(i+1==size())push_back(0);
            int r=at(i)%_base;
            if(r<0)r+=_base;
            at(i+1)+=(at(i)-r)/_base, at(i)=r;
        }
    }
    int abscmp(const bigN& b)const{
        if(size()>b.size())return 1;
        if(size()<b.size())return -1;
        for(int i=int(size())-1; i>=0; --i){
            if(at(i)>b[i])return 1;
            if(at(i)<b[i])return -1;
        }
        return 0;
    }
    int cmp(const bigN& b)const{
        if(negative!=b.negative)return negative?-1:1;
        return negative?-abscmp(b):abscmp(b);
    }
    bool operator<(const bigN& b)const{return cmp(b)<0;}
    bool operator>(const bigN& b)const{return cmp(b)>0;}
    bool operator<=(const bigN& b)const{return cmp(b)<=0;}
    bool operator>=(const bigN& b)const{return cmp(b)>=0;}
    bool operator==(const bigN& b)const{return !cmp(b);}
    bool operator!=(const bigN& b)const{return cmp(b)!=0;}
    bigN abs()const{
        bigN res=*this;
        return res.negative=0, res;
    }
    bigN operator-()const{
        bigN res=*this;
        return res.negative=!negative, res.trim(), res;
    }
    bigN operator+(const bigN& b)const{
        if(negative)return -(*this)+(-b);
        if(b.negative)return *this-(-b);
        bigN res=*this;

```

```

        if(b.size()>size())res.resize(b.size());
        for(size_t i=0; i<b.size(); ++i)res[i]+=b[i];
        return res.trim(), res;
    }
    bigN operator-(const bigN& b)const{
        if(negative)return -(*this)-(-b);
        if(b.negative)return *this+(-b);
        if(abscmp(b)<0)return -(b-(*this));
        bigN res=*this;
        if(b.size()>size())res.resize(b.size());
        for(size_t i=0; i<b.size(); ++i)res[i]-=b[i];
        return res.trim(), res;
    }
    bigN operator*(const bigN& b)const{
        bigN res;
        res.negative=negative!=b.negative;
        res.resize(size()+b.size());
        for(size_t i=0; i<size(); ++i)
            for(size_t j=0; j<b.size(); ++j)
                if((res[i+j]+=at(i)*b[j])>=base){
                    res[i+j+1]+=res[i+j]/base;
                    res[i+j]%=base;
                }
        return res.trim(), res;
    }
    bigN operator/(const bigN& b)const{
        int norm=base/(b.back()+1);
        bigN x=abs()*norm;
        bigN y=b.abs()*norm;
        bigN q, r;
        q.resize(x.size());
        for(int i=int(x.size())-1; i>=0; --i){
            r=r*base+x[i];
            int s1=r.size()<=y.size()?0:r[y.size()];
            int s2=r.size()<y.size()?0:r[y.size()-1];
            int d=(ll(base)*s1+s2)/y.back();
            r=r-y*d;
            while(r.negative)r=r+y, --d;
            q[i]=d;
        }
        q.negative=negative!=b.negative;
        return q.trim(), q;
    }
    bigN operator%(const bigN& b)const{
        return *this-(*this/b)*b;
    }
    friend istream& operator>>(istream& ss, bigN& b){
        string s;
        return ss>>s, b=s, ss;
    }
    friend ostream& operator<<(ostream& ss, const bigN& b)
    {
        if(b.negative)ss<<"-";
        ss<<(b.empty()?0:b.back());
        for(int i=int(b.size())-2; i>=0; --i)
            ss<<setw(width)<<setfill('0')<<b[i];
        return ss;
    }
    template<typename T>
    operator T(){
        stringstream ss;
        ss<<*this;
        T res;
        return ss>>res, res;
    }
};

```

## 6.5 Fraction

```

struct fraction{
    ll n, d;
    fraction(const ll& _n=0, const ll& _d=1):n(_n), d(_d){
        ll t=__gcd(n, d);
        n/=t, d/=t;
        if(d<0) n=-n, d=-d;
    }
    fraction operator-()const{
        return fraction(-n, d);
    }
    fraction operator+(const fraction& b)const{

```

```

    return fraction(n*b.d+b.n*d,d*b.d);
}
fraction operator-(const fraction &b)const{
    return fraction(n*b.d-b.n*d,d*b.d);
}
fraction operator*(const fraction &b)const{
    return fraction(n*b.n,d*b.d);
}
fraction operator/(const fraction &b)const{
    return fraction(n*b.d,d*b.n);
}
void print(){
    cout << n;
    if(d!=1) cout << "/" << d;
}
};

```

## 6.6 Simultaneous Equations

```

struct matrix { //n * (m + 1)
    static constexpr int MAXN = 110;
    int n, m;
    fraction M[MAXN][MAXN + 1], sol[MAXN];
    matrix(int n = 0, int m = 0): n(n), m(m), M(), sol
    () {}
    int solve() { //-1: inconsistent, >= 0: rank
        for (int i = 0; i < n; ++i) {
            int piv = 0;
            while (piv < m && !M[i][piv].n) ++piv;
            if (piv == m) continue;
            for (int j = 0; j < n; ++j) {
                if (i == j) continue;
                fraction tmp = -M[j][piv] / M[i][piv];
                for (int k = 0; k <= m; ++k) M[j][k] =
                    tmp * M[i][k] + M[j][k];
            }
        }
        int rank = 0;
        for (int i = 0; i < n; ++i) {
            int piv = 0;
            while (piv < m && !M[i][piv].n) ++piv;
            if (piv == m && M[i][m].n) return -1;
            else if (piv < m) ++rank, sol[piv] = M[i][m]
                / M[i][piv];
        }
        return rank;
    }
};

```

## 6.7 Pollard Rho

```

// does not work when n is prime
ll f(ll x, ll mod){ return add(mul(x,x,mod),1,mod); }
ll pollard_rho(ll n){
    if(!(n&1)) return 2;
    while(1){
        ll y=2,x=rand()%(n-1)+1,res=1;
        for(int sz=2;res==1;y=x,sz*=2)
            for(int i=0;i<sz&&res<=1;++i)
                x=f(x,n),res=__gcd(abs(x-y),n);
        if(res!=0&&res!=n) return res;
    }
}

```

## 6.8 Simplex Algorithm

```

const int MAXN = 111;
const int MAXM = 111;
const double eps = 1E-10;
double a[MAXN][MAXM], b[MAXN], c[MAXM], d[MAXN][MAXM];
double x[MAXM];
int ix[MAXN + MAXM]; // !!! array ALL indexed from 0
// max{cx} subject to {Ax<=b,x>=0}
// n: constraints, m: vars !!!
// x[] is the optimal solution vector

```

```

// usage :
// value = simplex(a, b, c, N, M);
double simplex(double a[MAXN][MAXM], double b[MAXN],
    double c[MAXM], int n, int m){
    ++m;
    int r = n, s = m - 1;
    memset(d, 0, sizeof(d));
    for (int i = 0; i < n + m; ++i) ix[i] = i;
    for (int i = 0; i < n; ++i) {
        for (int j = 0; j < m - 1; ++j) d[i][j] = -a[i][j];
        d[i][m - 1] = 1;
        d[i][m] = b[i];
        if (d[r][m] > d[i][m]) r = i;
    }
    for (int j = 0; j < m - 1; ++j) d[n][j] = c[j];
    d[n + 1][m - 1] = -1;
    for (double dd;; ) {
        if (r < n) {
            int t = ix[s]; ix[s] = ix[r + m]; ix[r + m] = t;
            d[r][s] = 1.0 / d[r][s];
            for (int j = 0; j <= m; ++j)
                if (j != s) d[r][j] *= -d[r][s];
            for (int i = 0; i <= n + 1; ++i) if (i != r) {
                for (int j = 0; j <= m; ++j) if (j != s)
                    d[i][j] += d[r][j] * d[i][s];
                d[i][s] *= d[r][s];
            }
        }
        r = -1; s = -1;
        for (int j = 0; j < m; ++j)
            if (s < 0 || ix[s] > ix[j]) {
                if (d[n + 1][j] > eps ||
                    (d[n + 1][j] > -eps && d[n][j] > eps))
                    s = j;
            }
        if (s < 0) break;
        for (int i = 0; i < n; ++i) if (d[i][s] < -eps) {
            if (r < 0 ||
                (dd = d[r][m] / d[r][s] - d[i][m] / d[i][s])
                < -eps ||
                (dd < eps && ix[r + m] > ix[i + m]))
                r = i;
        }
        if (r < 0) return -1; // not bounded
    }
    if (d[n + 1][m] < -eps) return -1; // not executable
    double ans = 0;
    for(int i=0; i<m; i++) x[i] = 0;
    for (int i = m; i < n + m; ++i) { // the missing
        enumerated x[i] = 0
        if (ix[i] < m - 1){
            ans += d[i - m][m] * c[ix[i]];
            x[ix[i]] = d[i - m][m];
        }
    }
    return ans;
}

```

## 6.9 chineseRemainder

```

LL solve(LL x1, LL m1, LL x2, LL m2) {
    LL g = __gcd(m1, m2);
    if((x2 - x1) % g) return -1; // no sol
    m1 /= g; m2 /= g;
    pair<LL,LL> p = gcd(m1, m2);
    LL lcm = m1 * m2 * g;
    LL res = p.first * (x2 - x1) * m1 + x1;
    return (res % lcm + lcm) % lcm;
}

```

## 6.10 cantor expansion

```

#define MAXN 11
int factorial[MAXN];
inline void init(){
    factorial[0]=1;
    for(int i=1;i<=MAXN;++i){
        factorial[i]=factorial[i-1]*i;
    }
}

```

```

}
}
inline int encode(const std::vector<int> &s){
    int n=s.size(),res=0;
    for(int i=0;i<n;++i){
        int t=0;
        for(int j=i+1;j<n;++j){
            if(s[j]<s[i])++t;
        }
        res+=t*factorial[n-i-1];
    }
    return res;
}
inline std::vector<int> decode(int a,int n){
    std::vector<int> res;
    std::vector<bool> vis(n,0);
    for(int i=n-1;i>=0;--i){
        int t=a/factorial[i],j;
        for(j=0;j<n;++j){
            if(!vis[j]){
                if(t==0)break;
                --t;
            }
        }
        res.push_back(j);
        vis[j]=1;
        a%=factorial[i];
    }
    return res;
}

```

```

        w[i] = val_t(cos(arg), sin(arg));
    }
}
void bitrev(val_t *a, int n) {
    int i = 0;
    for (int j = 1; j < n - 1; ++j) {
        for (int k = n >> 1; (i ^ k) < k; k >>= 1)
            ;
        if (j < i) swap(a[i], a[j]);
    }
}
void trans(val_t *a, int n, bool inv = false) {
    bitrev(a, n);
    for (int L = 2; L <= n; L <= 1) {
        int dx = MAXN / L;
        for (int i = 0; i < n; i += L) {
            for (int j = i, x = 0; j < i + (L >> 1)
                ; ++j, x += dx) {
                val_t tmp = a[j + (L >> 1)] * w[x];
                a[j + (L >> 1)] = a[j] - tmp;
                a[j] += tmp;
            }
        }
    }
    if (inv) {
        reverse(a + 1, a + n);
        for (int i = 0; i < n; ++i) a[i] /= n;
    }
}
};

```

## 6.11 Algorithms about Primes

```

/*
* 12721
* 13331
* 14341
* 75577
* 123457
* 222557
* 556679
* 999983
* 1097774749
* 1076767633
* 100102021
* 999997771
* 1001010013
* 1000512343
* 987654361
* 999991231
* 999888733
* 98789101
* 987777733
* 999991921
* 1010101333
* 1010102101
* 100000000039
* 10000000000037
* 2305843009213693951
* 4611686018427387847
* 9223372036854775783
* 18446744073709551557
*/

```

## 7 Polynomial

### 7.1 Fast Fourier Transform

```

template<int MAXN>
struct FFT {
    using val_t = complex<double>;
    const double PI = acos(-1);
    val_t w[MAXN];
    FFT() {
        for (int i = 0; i < MAXN; ++i) {
            double arg = 2 * PI * i / MAXN;

```

### 7.2 Number Theory Transform

```

//(2^16)+1, 65537, 3
//7*17*(2^23)+1, 998244353, 3
//1255*(2^20)+1, 1315962881, 3
//51*(2^25)+1, 1711276033, 29
template<int MAXN, LL P, LL RT> //MAXN must be 2^k
struct NTT {
    LL w[MAXN];
    LL mpow(LL a, LL n) {
        LL r = 1;
        while (n) {
            if (n & 1) r = r * a % P;
            n >>= 1, a = a * a % P;
        }
        return r;
    }
    LL inv(LL a) {
        return mpow(a, P - 2);
    }
    NTT() {
        LL dw = mpow(RT, (P - 1) / MAXN);
        w[0] = 1;
        for (int i = 1; i < MAXN; ++i) w[i] = w[i - 1]
            * dw % P;
    }
    void bitrev(LL *a, int n) {
        int i = 0;
        for (int j = 1; j < n - 1; ++j) {
            for (int k = n >> 1; (i ^ k) < k; k >>= 1)
                ;
            if (j < i) swap(a[i], a[j]);
        }
    }
    void operator()(LL *a, int n, bool f = false) { //0
        <= a[i] < P
        bitrev(a, n);
        for (int L = 2; L <= n; L <= 1) {
            int dx = MAXN / L;
            for (int i = 0; i < n; i += L) {
                for (int j = i, x = 0; j < i + (L >> 1)
                    ; ++j, x += dx) {
                    LL tmp = a[j + (L >> 1)] * w[x] % P
                    ;
                    if ((a[j + (L >> 1)] = a[j] - tmp)
                        < 0) a[j + (L >> 1)] += P;
                    if ((a[j] += tmp) >= P) a[j] -= P;
                }
            }
        }
    }
};

```

```

    }
    if (f) {
        reverse(a + 1, a + n);
        LL invn = inv(n);
        for (int i = 0; i < n; ++i) a[i] = a[i] *
            invn % P;
    }
};

```

### 7.3 Fast Walsh Transform

```

/*
x: a[j], y: a[j + (L >> 1)]
or: (x, y + x), (x, y - x)
and: (x + y, y), (x - y, y)
xor: (x + y, x - y), (x + y, x - y)/2
*/
void fwt(val_t *a, int n) { //or
    for (int L = 2; L <= n; L <= 1) {
        for (int i = 0; i < n; i += L) {
            for (int j = i; j < i + (L >> 1); ++j) {
                a[j + (L >> 1)] += a[j]; //inv: a[j + (
                    L >> 1)] -= a[j];
            }
        }
    }
}

```

### 7.4 Polynomial Operation

```

template<int MAXN, LL P, LL RT>
struct PolyOp {
    NTT<MAXN, P, RT> ntt;
    const LL INV2 = ntt.inv(2);
    int get_sz(int n) {
        int sz = 1;
        while (sz < n) sz <= 1;
        return sz;
    }
    void mul(LL *a, int n, LL *b, int m, LL *c) {
        static LL buf1[MAXN], buf2[MAXN];
        int sz = get_sz(n + m - 1);
        copy(a, a + n, buf1), fill(buf1 + n, buf1 + sz,
            0);
        copy(b, b + m, buf2), fill(buf2 + m, buf2 + sz,
            0);
        ntt(buf1, sz), ntt(buf2, sz);
        for (int i = 0; i < sz; ++i) c[i] = buf1[i] *
            buf2[i] % P;
        ntt(c, sz, true);
    }
    void inv(LL *a, int n, LL *b) {
        static LL buf[MAXN];
        if (n == 1) return b[0] = ntt.inv(a[0]), void();
        inv(a, (n + 1) / 2, b);
        int sz = get_sz(n * 2);
        copy(a, a + n, buf), fill(buf + n, buf + sz, 0);
        fill(b + n, b + sz, 0);
        ntt(buf, sz), ntt(b, sz);
        for (int i = 0; i < sz; ++i) {
            b[i] *= (2 - b[i] * buf[i]) % P;
            if ((b[i] % P) < 0) b[i] += P;
        }
        ntt(b, sz, true), fill(b + n, b + sz, 0);
    }
    LL _msqrt(LL x) {
        for (LL i = 0; i <= P / 2; ++i) if (i * i % P
            == x) return i;
        return -1;
    }
    void sqrt(LL *a, int n, LL *b) {
        static LL invb[MAXN], buf[MAXN];
        if (n == 1) return b[0] = _msqrt(a[0]), void();
        sqrt(a, (n + 1) / 2, b);
        int sz = get_sz(n * 2);
    }

```

```

    inv(b, n, invb);
    copy(a, a + n, buf), fill(buf + n, buf + sz, 0);
    ;
    ntt(b, sz), ntt(invb, sz), ntt(buf, sz);
    for (int i = 0; i < sz; ++i) {
        if ((b[i] += buf[i] * invb[i] % P) >= P) b[
            i] -= P;
        b[i] = b[i] * INV2 % P;
    }
    ntt(b, sz, true), fill(b + n, b + sz, 0);
}
void div(LL *a, int n, LL *b, int m, LL *q, LL *r)
{
    static LL invb[MAXN], buf[MAXN];
    if (n < m) {
        fill(q, q + m, 0), copy(a, a + n, r), fill(
            r + n, r + m, 0);
        return;
    }
    int mod_sz = n - m + 1;
    copy(b, b + m, buf), reverse(buf, buf + m);
    if (m < mod_sz) fill(buf + m, buf + mod_sz, 0);
    inv(buf, mod_sz, invb);
    copy(a, a + n, buf), reverse(buf, buf + n);
    mul(buf, mod_sz, invb, mod_sz, q);
    fill(q + mod_sz, q + n, 0), reverse(q, q +
        mod_sz);
    mul(b, m, q, mod_sz, buf);
    for (int i = 0; i < n; ++i) {
        if ((r[i] = a[i] - buf[i]) < 0) r[i] += P;
    }
}
void dx(LL *a, int n, LL *b) {
    b[n - 1] = 0;
    for (int i = 1; i < n; ++i) b[i - 1] = i * a[i]
        % P;
}
void Sx(LL *a, int n, LL *b) {
    b[0] = 0;
    for (int i = 1; i < n; ++i) b[i] = ntt.inv(i) *
        a[i - 1] % P;
}
};

```

## 8 Geometry

### 8.1 Default Code

```

typedef pair<double, double> pdd;
typedef pair<pdd, pdd> Line;
const double eps = 1e-12;
pdd operator+(const pdd &a, const pdd &b)
{ return pdd(a.X + b.X, a.Y + b.Y); }
pdd operator-(const pdd &a, const pdd &b)
{ return pdd(a.X - b.X, a.Y - b.Y); }
pdd operator*(const pdd &a, const double &b)
{ return pdd(a.X * b, a.Y * b); }
pdd operator/(const pdd &a, const double &b)
{ return pdd(a.X / b, a.Y / b); }
double dot(const pdd &a, const pdd &b)
{ return a.X * b.X + a.Y * b.Y; }
double cross(const pdd &a, const pdd &b)
{ return a.X * b.Y - a.Y * b.X; }
double abs2(const pdd &a)
{ return dot(a, a); }
double abs(const pdd &a)
{ return sqrt(dot(a, a)); }
int ori(const pdd &a, const pdd &b, const pdd &c) {
    double res = cross(b - a, c - a);
    if (fabs(res) < eps) return 0;
    return res > 0 ? 1 : -1;
}
bool collinearity(const pdd &p1, const pdd &p2, const
    pdd &p3) {
    return fabs(cross(p1 - p3, p2 - p3)) < eps;
}
bool btw(const pdd &p1, const pdd &p2, const pdd &p3) {
    if (!collinearity(p1, p2, p3)) return 0;
}

```

```

    return dot(p1-p3,p2-p3)<eps;
}
bool seg_intersect(const pdd &p1,const pdd &p2,const
    pdd &p3,const pdd &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);
    return a123*a124<=0&&a341*a342<=0;
}
pdd intersect(const pdd &p1,const pdd &p2,const pdd &p3
    ,const pdd &p4){
    double a123=cross(p2-p1,p3-p1);
    double a124=cross(p2-p1,p4-p1);
    return (p4*a123-p3*a124)/(a123-a124);
}
pdd foot(const pdd &p1,const pdd &p2,const pdd &p3){
    pdd tmp=p2-p1;
    swap(tmp.X,tmp.Y),tmp.Y*=-1;
    return intersect(p1,p2,p3,p3+tmp);
}

```

## 8.2 Convex hull

```

struct convex_hull{
    vector<pdd> dots;
    void add_dot(double a,double b){
        dots.pb(pdd(a,b));
    }
    vector<pdd> hull(){
        vector<pdd> ans;
        sort(dots.begin(),dots.end());
        ans.pb(dots[0]),ans.pb(dots[1]);
        for(int i=2;i<SZ(dots);++i){
            while(SZ(ans)>=2)
                if(ori(ans[SZ(ans)-2],ans.back(),dots[i])<=0)
                    ans.pop_back();
                else break;
            ans.pb(dots[i]);
        }
        for(int i=SZ(dots)-2,t=SZ(ans);i>=0;--i){
            while(SZ(ans)>t)
                if(ori(ans[SZ(ans)-2],ans.back(),dots[i])<=0)
                    ans.pop_back();
                else break;
            ans.pb(dots[i]);
        }
        ans.pop_back();
        return ans;
    }
};

```

## 8.3 External bisector

```

pdd external_bisector(pdd p1,pdd p2,pdd p3){//213
    pdd L1=p2-p1,L2=p3-p1;
    L2=L2*abs(L1)/abs(L2);
    return L1+L2;
}

```

## 8.4 Heart

```

pdd excenter(pdd p0,pdd p1,pdd p2,double &radius){
    p1=p1-p0,p2=p2-p0;
    double x1=p1.X,y1=p1.Y,x2=p2.X,y2=p2.Y;
    double m=2.*(x1*y2-y1*x2);
    center.X=(x1*x1*y2-x2*x2*y1+y1*y2*(y1-y2))/m;
    center.Y=(x1*x2*(x2-x1)-y1*y1*x2+x1*y2*y2)/m;
    return radius=abs(center),center+p0;
}

pdd incenter(pdd p1,pdd p2,pdd p3,double &radius){
    double a=abs(p2-p1),b=abs(p3-p1),c=abs(p3-p2);

```

```

    double s=(a+b+c)/2,area=sqrt(s*(s-a)*(s-b)*(s-c));
    pdd L1=external_bisector(p1,p2,p3),L2=
        external_bisector(p2,p1,p3);
    return radius=area/s,intersect(p1,p1+L1,p2,p2+L2),
}

pdd escenter(pdd p1,pdd p2,pdd p3){//213
    pdd L1=external_bisector(p1,p2,p3),L2=
        external_bisector(p2,p2+p2-p1,p3);
    return intersect(p1,p1+L1,p2,p2+L2);
}

pdd barycenter(pdd p1,pdd p2,pdd p3){
    return (p1+p2+p3)/3;
}

pdd orthocenter(pdd p1,pdd p2,pdd p3){
    pdd L1=p3-p2,L2=p3-p1;
    swap(L1.X,L1.Y),L1.X*=-1;
    swap(L2.X,L2.Y),L2.X*=-1;
    return intersect(p1,p1+L1,p2,p2+L2);
}

```

## 8.5 Polar Angle Sort

```

pdd c;//sort base
int Quadrant(pdd a){
    if(a.X>0&&a.Y>=0) return 1;
    if(a.X<=0&&a.Y>0) return 2;
    if(a.X<0&&a.Y<=0) return 3;
    if(a.X>=0&&a.Y<0) return 4;
}
bool cmp(pdd a,pdd b){
    a=a-c,b=b-c;
    if(Quadrant(a)!=Quadrant(b))
        return Quadrant(a)<Quadrant(b);
    if(cross(b,a)==0) return abs(a)<abs(b);
    return cross(b,a)>0;
}
bool cmp(pdd a,pdd b){
    a=a-c,b=b-c;
    if(fabs(atan2(a.Y,a.X)-atan2(b.Y,b.X))>eps)
        return atan2(a.Y,a.X)<atan2(b.Y,b.X);
    return abs(a)<abs(b);
}

```

## 8.6 Intersection of two circles

```

vector<pdd> interCircle(pdd o1 ,double r1 ,pdd o2 ,
    double r2){
    if(abs(o1-o2)<max(r1,r2)-min(r1,r2)) return {};
    double d2=abs2(o1-o2);
    double d=sqrt(d2);
    if(d>r1+r2) return {};
    pdd u = (o1+o2)*0.5 + (o1-o2)*((r2*r2-r1*r1)/(2*d2));
    double A = sqrt((r1+r2+d)*(r1-r2+d)*(r1+r2-d)*(-r1+r2
        +d));
    pdd v = pdd(o1.Y-o2.Y,-o1.X+o2.X)*A/(2*d2);
    return {u+v, u-v};
}

```

## 8.7 Intersection of polygon and circle

```

// Divides into multiple triangle, and sum up
// test by HDU2892
const double PI=acos(-1);
double _area(pdd pa, pdd pb, double r){
    if(abs(pa)<abs(pb)) swap(pa, pb);
    if(abs(pb)<eps) return 0;
    double S, h, theta;
    double a=abs(pb),b=abs(pa),c=abs(pb-pa);
    double cosB = dot(pb,pb-pa) / a / c, B = acos(cosB);
    double cosC = dot(pa,pb) / a / b, C = acos(cosC);
    if(a > r){
        S = (C/2)*r*r;
        h = a*b*sin(C)/c;

```



```

    if (h < r && B < PI/2) S -= (acos(h/r)*r*r - h*sqrt
        (r*r-h*h));
}
else if(b > r){
    theta = PI - B - asin(sin(B)/r*a);
    S = .5*a*r*sin(theta) + (C-theta)/2*r*r;
}
else S = .5*sin(C)*a*b;
return S;
}
double area_poly_circle(const vector<pdd> poly, const
    pdd &O, const double r){
    double S=0;
    for(int i=0; i<SZ(poly); ++i)
        S += _area(poly[i]-O, poly[(i+1)%SZ(poly)]-O, r)*ori(O,
            poly[i], poly[(i+1)%SZ(poly)]);
    return fabs(S);
}

```

## 8.8 Intersection of line and circle

```

vector<pdd> line_interCircle(const pdd &p1, const pdd &
    p2, const pdd &c, const double r){
    pdd ft=foot(p1,p2,c), vec=p2-p1;
    double dis=abs(c-ft);
    if(fabs(dis-r)<eps) return vector<pdd>{ft};
    if(dis>r) return {};
    vec=vec*sqrt(r*r-dis*dis)/abs(vec);
    return vector<pdd>{ft+vec, ft-vec};
}

```

## 8.9 Half plane intersection

```

bool isin( Line l0, Line l1, Line l2 ){
    // Check inter(l1, l2) in l0
    pdd p = intersect(l1.X, l1.Y, l2.X, l2.Y);
    return cross(l0.Y - l0.X, p - l0.X) > eps;
}
/* If no solution, check: 1. ret.size() < 3
 * Or more precisely, 2. interPnt(ret[0], ret[1])
 * in all the lines. (use (l.Y - l.X) ^ (p - l.X) > 0
 */
/* --- Line.X --- Line.Y --- */
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;
        pdd d = lines[i].Y - lines[i].X;
        ata[i] = atan2(d.Y, d.X);
    }
    sort(ord.begin(), ord.end(), [&](int i, int j){
        if( fabs(ata[i] - ata[j]) < eps )
            return (cross(lines[i].Y-lines[i].X,
                lines[j].Y-lines[j].X))<0;
        return ata[i] < ata[j];
    });
    vector<Line> fin;
    for (int i=0; i<sz; ++i)
        if (!i || fabs(ata[ord[i]] - ata[ord[i-1]]) > eps)
            fin.pb(lines[ord[i]]);
    deque<Line> dq;
    for (int i=0; i<SZ(fin); ++i){
        while(SZ(dq)>=2&&!isin(fin[i], dq[SZ(dq)-2], dq.back
            ()))
            dq.pop_back();
        while(SZ(dq)>=2&&!isin(fin[i], dq[0], dq[1]))
            dq.pop_front();
        dq.push_back(fin[i]);
    }
    while(SZ(dq)>=3&&!isin(dq[0], dq[SZ(dq)-2], dq.back()))
        dq.pop_back();
    while(SZ(dq)>=3&&!isin(dq.back(), dq[0], dq[1]))
        dq.pop_front();
    vector<Line> res(ALL(dq));
    return res;
}

```

## 8.10 Convexhull3D

```

#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; }

```

## 8.11 CircleCover

```

#define N 1021
struct CircleCover{
    int C; Circ c[ N ];
    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 {};
        if( norm( o1 - o2 ) < max(r1, r2) - min(r1, r2) )
            return {};
        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;
    }
    struct 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 disjunct( Circ& a, Circ &b, int x )
    {return sign( norm( a.O - b.O ) - a.R - b.R ) > x;}
    bool contain( Circ& a, Circ &b, int x )
    {return sign( a.R - b.R - norm( a.O - b.O ) ) > 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] ||
                    disjunct(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) * .5;
            D theta = eve[j + 1].ang - eve[j].ang;
            if (theta < 0) theta += 2. * pi;
            Area[cnt] +=
                (theta - sin(theta)) * c[i].R*c[i].R * .5;
        }
    }
}
};

```

## 8.12 DelaunayTriangulation

*/\* Delaunay Triangulation:*

*Given a sets of points on 2D plane, find a triangulation such that no points will strictly inside circumcircle of any triangle.*

*find : return a triangle contain given point  
add\_point : add a point into triangulation*

*A Triangle is in triangulation iff. its has\_chd is 0.  
Region of triangle u: iterate each u.edge[i].tri,  
each points are u.p[(i+1)%3], u.p[(i+2)%3]*

*calculation involves  $O(\sqrt{V})$  \*/*

```

const int N = 100000 + 5;
const type inf = 2e3;
type eps = 1e-6; // 0 when integer
type sqr(type x) { return x*x; }
// return p4 is in circumcircle of tri(p1,p2,p3)
bool in_cc(const Pt& p1, const Pt& p2, const Pt& p3,
    const Pt& p4){
    type u11 = p1.X - p4.X; type u12 = p1.Y - p4.Y;
    type u21 = p2.X - p4.X; type u22 = p2.Y - p4.Y;
    type u31 = p3.X - p4.X; type u32 = p3.Y - p4.Y;
    type u13 = sqr(p1.X)-sqr(p4.X)+sqr(p1.Y)-sqr(p4.Y);
    type u23 = sqr(p2.X)-sqr(p4.X)+sqr(p2.Y)-sqr(p4.Y);
    type u33 = sqr(p3.X)-sqr(p4.X)+sqr(p3.Y)-sqr(p4.Y);
    type det = -u13*u22*u31 + u12*u23*u31 + u13*u21*u32
        - u11*u23*u32 - u12*u21*u33 + u11*u22*u33;
    return det > eps;
}
type side(const Pt& a, const Pt& b, const Pt& p)
{ return (b - a) ^ (p - a); }
typedef int SdRef;
struct Tri;
typedef Tri* TriRef;
struct Edge {
    TriRef tri; SdRef side;
    Edge():tri(0), side(0){}
    Edge(TriRef _tri, SdRef _side):tri(_tri), side(_side)
    {}
};
struct Tri {
    Pt p[3];
    Edge edge[3];
    TriRef chd[3];
    Tri() {}
    Tri(const Pt& p0, const Pt& p1, const Pt& p2) {
        p[0] = p0; p[1] = p1; p[2] = p2;
        chd[0] = chd[1] = chd[2] = 0;
    }
    bool has_chd() const { return chd[0] != 0; }
    int num_chd() const {
        return chd[0] == 0 ? 0
            : chd[1] == 0 ? 1
            : chd[2] == 0 ? 2 : 3;
    }
    bool contains(Pt const& q) const {
        for( int i = 0 ; i < 3 ; i ++ )
            if( side(p[i], p[(i + 1) % 3] , q) < -eps )
                return false;
    }
}

```

```

    return true;
}
} pool[ N * 10 ], *tris;
void edge( Edge a, Edge b ){
    if(a.tri) a.tri->edge[a.side] = b;
    if(b.tri) b.tri->edge[b.side] = a;
}
struct Trig { // Triangulation
    Trig(){
        the_root = // Tri should at least contain all
                    points
        new(tris++)Tri(Pt(-inf,-inf),Pt(+inf+inf,-inf),Pt
                    (-inf,+inf+inf));
    }
    TriRef find(Pt p){const{ return find(the_root,p); }
    void add_point(const Pt& p){ add_point(find(the_root,
        p),p); }
    TriRef the_root;
    static TriRef find(TriRef root, const Pt& p) {
        while( true ){
            if( !root->has_chd() )
                return root;
            for( int i = 0; i < 3 && root->chd[i] ; ++i )
                if (root->chd[i]->contains(p)) {
                    root = root->chd[i];
                    break;
                }
        }
        assert( false ); // "point not found"
    }
    void add_point(TriRef root, Pt const& p) {
        TriRef tab,tbc,tca;
        /* split it into three triangles */
        tab=new(tris++) Tri(root->p[0],root->p[1],p);
        tbc=new(tris++) Tri(root->p[1],root->p[2],p);
        tca=new(tris++) Tri(root->p[2],root->p[0],p);
        edge(Edge(tab,0), Edge(tbc,1));
        edge(Edge(tbc,0), Edge(tca,1));
        edge(Edge(tca,0), Edge(tab,1));
        edge(Edge(tab,2), root->edge[2]);
        edge(Edge(tbc,2), root->edge[0]);
        edge(Edge(tca,2), root->edge[1]);
        root->chd[0] = tab;
        root->chd[1] = tbc;
        root->chd[2] = tca;
        flip(tab,2);
        flip(tbc,2);
        flip(tca,2);
    }
    void flip(TriRef tri, SdRef pi) {
        TriRef trj = tri->edge[pi].tri;
        int pj = tri->edge[pi].side;
        if (!trj) return;
        if (!in_cc(tri->p[0],tri->p[1],tri->p[2],trj->p[pj]
            )) return;
        /* flip edge between tri,trj */
        TriRef trk = new(tris++) Tri(tri->p[(pi+1)%3], trj
            ->p[pj], tri->p[pi]);
        TriRef trl = new(tris++) Tri(trj->p[(pj+1)%3], tri
            ->p[pi], trj->p[pj]);
        edge(Edge(trk,0), Edge(trl,0));
        edge(Edge(trk,1), tri->edge[(pi+2)%3]);
        edge(Edge(trk,2), trj->edge[(pj+1)%3]);
        edge(Edge(trl,1), trj->edge[(pj+2)%3]);
        edge(Edge(trl,2), tri->edge[(pi+1)%3]);
        tri->chd[0]=trk; tri->chd[1]=trl; tri->chd[2]=0;
        trj->chd[0]=trk; trj->chd[1]=trl; trj->chd[2]=0;
        flip(trk,1); flip(trk,2);
        flip(trl,1); flip(trl,2);
    }
};
vector<TriRef> triang;
set<TriRef> vst;
void go( TriRef now ){
    if( vst.find( now ) != vst.end() )
        return;
    vst.insert( now );
    if( !now->has_chd() ){
        triang.push_back( now );
        return;
    }
    for( int i = 0 ; i < now->num_chd() ; i ++ )

```

```

        go( now->chd[ i ] );
    }
}
void build( int n , Pt* ps ){
    tris = pool;
    random_shuffle(ps, ps + n);
    Trig tri;
    for(int i = 0; i < n; ++ i)
        tri.add_point(ps[i]);
    go( tri.the_root );
}

```

### 8.13 Tangent line of two circles

```

vector<Line> go( const Cir& c1 , const Cir& c2 , int
    sign1 ){
    vector<Line> ret;
    // sign1 = 1 for outer tang, -1 for inter tang
    double d_sq = norm2( c1.0 - c2.0 );
    if( d_sq < eps ) return ret;
    double d = sqrt( d_sq );
    Pt v = ( c2.0 - c1.0 ) / d;
    double c = ( c1.R - sign1 * c2.R ) / d;
    if( c * c > 1 ) return ret;
    double h = sqrt( max( 0.0 , 1.0 - c * c ) );
    for( int sign2 = 1 ; sign2 >= -1 ; sign2 -= 2 ){
        Pt n = { v.X * c - sign2 * h * v.Y ,
            v.Y * c + sign2 * h * v.X };
        Pt p1 = c1.0 + n * c1.R;
        Pt p2 = c2.0 + n * ( c2.R * sign1 );
        if( fabs( p1.X - p2.X ) < eps and
            fabs( p1.Y - p2.Y ) < eps )
            p2 = p1 + perp( c2.0 - c1.0 );
        ret.push_back( { p1 , p2 } );
    }
    return ret;
}

```

### 8.14 minMaxEnclosingRectangle

```

pdd solve(vector<p11> &dots){
    vector<p11> hull;
    const double INF=1e18,qi=acos(-1)/2*3;
    cv.dots=dots;
    hull=cv.hull();
    double Max=0,Min=INF,deg;
    ll n=hull.size();
    hull.pb(hull[0]);
    for(int i=0,u=1,r=1,l; i<n;++i){
        p11 nw=hull[i+1]-hull[i];
        while(cross(nw,hull[u+1]-hull[i])>cross(nw,hull[u]-
            hull[i]))
            u=(u+1)%n;
        while(dot(nw,hull[r+1]-hull[i])>dot(nw,hull[r]-hull
            [i]))
            r=(r+1)%n;
        if(!i) l=(r+1)%n;
        while(dot(nw,hull[l+1]-hull[i])<dot(nw,hull[l]-hull
            [i]))
            l=(l+1)%n;
        Min=min(Min,(double)(dot(nw,hull[r]-hull[i])-dot(nw
            ,hull[l]-hull[i]))*cross(nw,hull[u]-hull[i])/
            abs2(nw));
        deg=acos((double)dot(hull[r]-hull[l],hull[u]-hull[i]
            )/abs(hull[r]-hull[l])/abs(hull[u]-hull[i]));
        deg=(qi-deg)/2;
        Max=max(Max,(double)abs(hull[r]-hull[l])*abs(hull[u]
            -hull[l])*sin(deg)*sin(deg));
    }
    return pdd(Min,Max);
}

```

### 8.15 Minkowski Sum

```

/* convex hull Minkowski Sum*/
#define INF 10000000000000LL
int pos( const Pt& tp ){

```

```

if( tp.Y == 0 ) return tp.X > 0 ? 0 : 1;
return tp.Y > 0 ? 0 : 1;
}
#define N 300030
Pt pt[ N ], qt[ N ], rt[ N ];
LL Lx,Rx;
int dn,un;
inline bool cmp( Pt a, Pt b ){
    int pa=pos( a ),pb=pos( b );
    if(pa==pb) return (a^b)>0;
    return pa<pb;
}
int minkowskiSum(int n,int m){
    int i,j,r,p,q,fi,fj;
    for(i=1,p=0;i<n;i++){
        if( pt[i].Y<pt[p].Y ||
            (pt[i].Y==pt[p].Y && pt[i].X<pt[p].X) ) p=i; }
    for(i=1,q=0;i<m;i++){
        if( qt[i].Y<qt[q].Y ||
            (qt[i].Y==qt[q].Y && qt[i].X<qt[q].X) ) q=i; }
    rt[0]=pt[p]+qt[q];
    r=1; i=p; j=q; fi=fj=0;
    while(1){
        if((fj&&j==q) ||
            ( (!fi || i!=p) &&
              cmp(pt[(p+1)%n]-pt[p],qt[(q+1)%m]-qt[q]) ) ) ){
            rt[r]=rt[r-1]+pt[(p+1)%n]-pt[p];
            p=(p+1)%n;
            fi=1;
        }else{
            rt[r]=rt[r-1]+qt[(q+1)%m]-qt[q];
            q=(q+1)%m;
            fj=1;
        }
        if(r<=1 || ((rt[r]-rt[r-1])^(rt[r-1]-rt[r-2]))!=0)
            r++;
        else rt[r-1]=rt[r];
        if(i==p && j==q) break;
    }
    return r-1;
}
void initInConvex(int n){
    int i,p,q;
    LL Ly,Ry;
    Lx=INF; Rx=-INF;
    for(i=0;i<n;i++){
        if(pt[i].X<Lx) Lx=pt[i].X;
        if(pt[i].X>Rx) Rx=pt[i].X;
    }
    Ly=Ry=INF;
    for(i=0;i<n;i++){
        if(pt[i].X==Lx && pt[i].Y<Ly){ Ly=pt[i].Y; p=i; }
        if(pt[i].X==Rx && pt[i].Y<Ry){ Ry=pt[i].Y; q=i; }
    }
    for(dn=0,i=p;i!=q;i=(i+1)%n){ qt[dn++]=pt[i]; }
    qt[dn]=pt[q]; Ly=Ry=-INF;
    for(i=0;i<n;i++){
        if(pt[i].X==Lx && pt[i].Y>Ly){ Ly=pt[i].Y; p=i; }
        if(pt[i].X==Rx && pt[i].Y>Ry){ Ry=pt[i].Y; q=i; }
    }
    for(un=0,i=p;i!=q;i=(i+n-1)%n){ rt[un++]=pt[i]; }
    rt[un]=pt[q];
}
inline int inConvex(Pt p){
    int L,R,M;
    if(p.X<Lx || p.X>Rx) return 0;
    L=0;R=dn;
    while(L<R-1){ M=(L+R)/2;
        if(p.X<qt[M].X) R=M; else L=M; }
    if(tri(qt[L],qt[R],p)<0) return 0;
    L=0;R=un;
    while(L<R-1){ M=(L+R)/2;
        if(p.X<rt[M].X) R=M; else L=M; }
    if(tri(rt[L],rt[R],p)>0) return 0;
    return 1;
}
int main(){
    int n,m,i;
    Pt p;
    scanf("%d",&n);
    for(i=0;i<n;i++) scanf("%Ld%Ld",&pt[i].X,&pt[i].Y);
    scanf("%d",&m);

```

```

    for(i=0;i<m;i++) scanf("%Ld%Ld",&qt[i].X,&qt[i].Y);
    n=minkowskiSum(n,m);
    for(i=0;i<n;i++) pt[i]=rt[i];
    scanf("%d",&m);
    for(i=0;i<m;i++) scanf("%Ld%Ld",&qt[i].X,&qt[i].Y);
    n=minkowskiSum(n,m);
    for(i=0;i<n;i++) pt[i]=rt[i];
    initInConvex(n);
    scanf("%d",&m);
    for(i=0;i<m;i++){
        scanf("%Ld %Ld",&p.X,&p.Y);
        p.X*=3; p.Y*=3;
        puts(inConvex(p)? "YES": "NO");
    }
}

```

## 9 Else

### 9.1 Mo's Algorithm(With modification)

```

struct QUERY{//BLOCK=N^{2/3}
    int L,R,id,LBid,RBid,T;
    QUERY(int l,int r,int id,int lb,int rb,int t):
        L(l),R(r),id(id),LBid(lb),RBid(rb),T(t){}
    bool operator<(const QUERY &b)const{
        if(LBid!=b.LBid) return LBid<b.LBid;
        if(RBid!=b.RBid) return RBid<b.RBid;
        return T<b.T;
    }
};
vector<QUERY> query;
int cur_ans,arr[MAXN],ans[MAXN];
void addTime(int L,int R,int T){}
void subTime(int L,int R,int T){}
void add(int x){}
void sub(int x){}
void solve(){
    sort(ALL(query));
    int L=0,R=0,T=-1;
    for(auto q:query){
        while(T<q.T) addTime(L,R,++T);
        while(T>q.T) subTime(L,R,T--);
        while(R<q.R) add(arr[++R]);
        while(L>q.L) add(arr[--L]);
        while(R>q.R) sub(arr[R--]);
        while(L<q.L) sub(arr[L--]);
        ans[q.id]=cur_ans;
    }
}

```

### 9.2 Mo's Algorithm On Tree

```

const int MAXN=40005;
vector<int> G[MAXN]; //1-base
int n,B,arr[MAXN],ans[100005],cur_ans;
int in[MAXN],out[MAXN],dfn[MAXN*2],dft;
int deep[MAXN],sp[___lg(MAXN*2)+1][MAXN*2],bln[MAXN],spt;
bitset<MAXN> inset;
struct QUERY{
    int L,R,Lid,id,lca;
    QUERY(int l,int r,int _id):L(l),R(r),lca(0),id(_id){}
    bool operator<(const QUERY &b){
        if(Lid!=b.Lid) return Lid<b.Lid;
        return R<b.R;
    }
};
vector<QUERY> query;
void dfs(int u,int f,int d){
    deep[u]=d,sp[0][spt]=u,bln[u]=spt++;
    dfn[dft]=u,in[u]=dft++;
    for(int v:G[u])
        if(v!=f)
            dfs(v,u,d+1),sp[0][spt]=u,bln[u]=spt++;
    dfn[dft]=u,out[u]=dft++;
}

```

```

int lca(int u, int v){
    if(bln[u]>bln[v]) swap(u,v);
    int t=__lg(bln[v]-bln[u]+1);
    int a=sp[t][bln[u]], b=sp[t][bln[v]-(1<<t)+1];
    if(deep[a]<deep[b]) return a;
    return b;
}
void sub(int x){}
void add(int x){}
void flip(int x){
    if(inset[x]) sub(arr[x]);
    else add(arr[x]);
    inset[x]=~inset[x];
}
void solve(){
    B=sqrt(2*n), dft=spt=cur_ans=0, dfs(1,1,0);
    for(int i=1, x=2; x<2*n; ++i, x<<=1)
        for(int j=0; j+x<=2*n; ++j)
            if(deep[sp[i-1][j]]<deep[sp[i-1][j+x/2]])
                sp[i][j]=sp[i-1][j];
            else sp[i][j]=sp[i-1][j+x/2];
    for(auto &q:query){
        int c=lca(q.L, q.R);
        if(c==q.L || c==q.R)
            q.L=out[c==q.L?q.R:q.L], q.R=out[c];
        else if(out[q.L]<in[q.R])
            q.lca=c, q.L=out[q.L], q.R=in[q.R];
        else q.lca=c, c=in[q.L], q.L=out[q.R], q.R=c;
        q.Lid=q.L/B;
    }
    sort(ALL(query));
    int L=0, R=-1;
    for(auto q:query){
        while(R<q.R) flip(dfn[++R]);
        while(L>q.L) flip(dfn[--L]);
        while(R>q.R) flip(dfn[R--]);
        while(L<q.L) flip(dfn[L++]);
        if(q.lca) add(arr[q.lca]);
        ans[q.id]=cur_ans;
        if(q.lca) sub(arr[q.lca]);
    }
}

```

### 9.3 DynamicConvexTrick

```

// only works for integer coordinates!!

bool Flag; // 0: insert Line, 1: Lower_bound x
template<class val = ll, class compare = less<val>> //
    sort lines with comp
struct DynamicConvexTrick{
    static const ll minx = 0, maxx = ll(1e9) + 5;
    static compare comp;
    struct Line{
        val a, b, l, r; // Line ax + b in [l, r]
        Line(val _a, val _b, val _l = minx, val _r =
            maxx):a(_a), b(_b), l(_l), r(_r){}
        val operator () (val x) const {
            return a * x + b;
        }
    };
    struct cmp{
        bool operator () (const Line a, const Line b){
            if(Flag == 0) return comp(a.a, b.a);
            return a.r < b.l;
        }
    };
    inline val idiv(val a, val b){
        return a / b - (a % b && a < 0 ^ b < 0);
    }
    set<Line, cmp> st;
    void ins(val a, val b){
        Flag = 0;
        Line L(a, b);
        auto it = st.lower_bound(L);
        if(it != st.begin() && it != st.end())
            if(!comp((*prev(it))(it->l - 1), L(it->l -
                1)) && !comp((*it)(it->l), L(it->l)))
                return;
        while(it != st.end()){

```

```

            if(it->a == L.a && !comp(it->b, L.b)) return
                ;
            if(comp((*it)(it->r), L(it->r))) it = st.
                erase(it);
            else{
                Line M = *it;
                st.erase(it);
                L.r = max(idiv(L.b - M.b, M.a - L.a),
                    minx);
                M.l = L.r + 1;
                it = st.insert(M).X;
                break;
            }
        }
        while(it != st.begin()){
            auto pit = prev(it);
            if(comp((*pit)(pit->l), L(pit->l))) st.erase
                (pit);
            else{
                Line M = *pit;
                st.erase(pit);
                M.r = min(idiv(L.b - M.b, M.a - L.a),
                    maxx - 1);
                L.l = M.r + 1;
                st.insert(M);
                break;
            }
        }
        st.insert(L);
    }
    val operator () (val x){
        Flag = 1;
        auto it = st.lower_bound({0, 0, x, x});
        return (*it)(x);
    }
};

```

DynamicConvexTrick<> DCT;

## 10 JAVA

### 10.1 Big number

```

import java.util.Scanner;
import java.math.BigInteger;

public class JAVA{
    public static void main(String[] args){
        Scanner cin = new Scanner(System.in);
        String a, b, c;
        while(cin.hasNext()){
            a = cin.next();
            b = cin.next();
            c = cin.next();
            BigInteger ia = new BigInteger(a);
            BigInteger ic = new BigInteger(c);
            if(b.charAt(0) == '+')
                System.out.printf("%s\n", ia.add(ic));
            if(b.charAt(0) == '-')
                System.out.printf("%s\n", ia.subtract(ic));
            if(b.charAt(0) == '*')
                System.out.printf("%s\n", ia.multiply(ic));
            if(b.charAt(0) == '/')
                System.out.printf("%s\n", ia.divide(ic));
        }
    }
}

```