Contents

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 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);
```

1.3 vimrc

```
"This file should be placed at ~/.vimrc"
se nu ai hls et ru ic is sc cul
se re=1 ts=4 sts=4 sw=4 ls=2 mouse=a
hi cursorline cterm=none ctermbg=89
syntax on
nnoremap <c-l> :nohl<cr>
inoremap {<ENTER> {}<LEFT><ENTER><ENTER><UP><TAB>
```

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[1].Y=0,v[0].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;
  }
};
```

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+=l->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;
  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));
}
```

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[pl[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(pl[a]>pl[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,l),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 xl,int xr,int yl,int yr){
    return s_query(xl,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 o;
    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,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, nmxz = -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[s[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[s[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]]]=nmxz+=neq;
    }
    sais(ns, nsa, p + nn, q + n, t + n, c + z, nn, nmxz
        + 1);
    MAGIC(for(int i = nn - 1; i >= 0; i--) sa[--x[s[p[
        nsa[i]]]]] = p[nsa[i]]);
  }
}sa;
int H[ N ], SA[ N ];
void suffix_array(int* ip, int len) {
  // should padding a zero in the back
  // ip is int array, len is array length
  // ip[0..n-1] != 0, and ip[len] = 0
  ip[len++] = 0;
  sa.build(ip, len, 128);
  for (int i=0; i<len; i++) {
    H[i] = sa.hei[i + 1];
    SA[i] = sa._sa[i + 1];
  }
  // resulting height, sa array \in [0,len)
}
```

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=fl[R];
          for(;Z&&!~nx[Z][i];)Z=fl[Z];
          fl[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=fl[X];
      X=X?nx[X][c-'a']:1,++cnt[X];
    }
```

```
    for(int i=top-2;i>0;--i) cnt[fl[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] = l - 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;
  }
} palt;
```

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++;
    }
  }
}
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;
}
```

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 : pirmes <= 13
// n < 2^64               7 :
// 2, 325, 9375, 28178, 450775, 9780504, 1795265022
bool Miller_Rabin(ll a,ll n){
  if((a=a%n)==0) return 1;
  if(n&1^1) return n==2;
  ll 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)>=0&&at(i)<_base)continue;
    if(i+1u==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.carry(),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.carry(),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;
      }//¾ªk¥carry·|·¸¦
  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;
```

```
}
```

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
* 1000000000039
* 1000000000000037
* 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;
            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;
        }
    }
};
```

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[i].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 disjuct( 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] ||
                    disjuct(c[i], c[j], -1));
    for( int i = 0 ; i < C ; i ++ ){
      int E = 0, cnt = 1;
      for( int j = 0 ; j < C ; j ++ )
        if( j != i && overlap[j][i] )
          cnt ++;
      for( int j = 0 ; j < C ; j ++ )
        if( i != j && g[i][j] ){
          Pt aa, bb;
          CCinter(c[i], c[j], aa, bb);
          D A=atan2(aa.Y - c[i].O.Y, aa.X - c[i].O.X);
          D B=atan2(bb.Y - c[i].O.Y, bb.X - c[i].O.X);
          eve[E ++] = Teve(bb, B, 1);
          eve[E ++] = Teve(aa, A, -1);
          if(B > A) cnt ++;
        }
      if( E == 0 ) Area[ cnt ] += pi * c[i].R * c[i].R;
      else{
        sort( eve , eve + E );
        eve[E] = eve[0];
        for( int j = 0 ; j < E ; j ++ ){
          cnt += eve[j].add;
          Area[cnt] += (eve[j].p ^ eve[j + 1].p) * .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(|V|^6) */
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 ){
  // sign1 = 1 for outer tang, -1 for inter tang
  vector<Line> ret;
  double d_sq = norm2( c1.O - c2.O );
  if( d_sq < eps ) return ret;
  double d = sqrt( d_sq );
  Pt v = ( c2.O - c1.O ) / 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.O + n * c1.R;
    Pt p2 = c2.O + n * ( c2.R * sign1 );
    if( fabs( p1.X - p2.X ) < eps and
        fabs( p1.Y - p2.Y ) < eps )
      p2 = p1 + perp( c2.O - c1.O );
    ret.push_back( { p1 , p2 } );
  }
  return ret;
}
```

8.14 minMaxEnclosingRectangle

```
pdd solve(vector<pll> &dots){
  vector<pll> 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){
    pll 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[i])*sin(deg)*sin(deg));
  }
  return pdd(Min,Max);
}
```

8.15 Minkowski Sum

```
/* convex hull Minkowski Sum*/
#define INF 100000000000000LL
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("%lld%lld",&pt[i].X,&pt[i].Y);
  scanf("%d",&m);
  for(i=0;i<m;i++) scanf("%lld%lld",&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("%lld%lld",&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("%lld %lld",&p.X,&p.Y);
    p.X*=3; p.Y*=3;
    puts(inConvex(p)?"YES":"NO");
  }
}
```

9 Else

9.1 Mo's Alogrithm(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 Alogrithm 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));
    }
  }
}
```