Suffix Array:

```
int wa[mx],wb[mx],wv[mx],Ws[mx];
//(1-indexed) sa[i] = starting position (0...n-1) of ith
lexicographically smallest suffix in s
//(0-indexed) Rank[i] = lexicographical rank of s[i....n-1] ((i+1)th
suffix by position)
//LCP[i] = longest common prefix of sa[i] & sa[i-1]
int sa[mx],Rank[mx],LCP[mx];
int cmp(int *r,int a,int b,int l) {return r[a]==r[b] &&
r[a+l]==r[b+l];}
//Suffix Array (O(nlogn))
//m = maximum possible ASCII value of a string character
(alphabet size)
//also, m = maximum number of distinct character in string
(when compressed)
void buildSA(string s,int* sa,int n,int m){
    int i,j,p,*x=wa,*y=wb,*t;
    for(i=0; i<m; i++) Ws[i]=0;
    for(i=0; i<n; i++) Ws[x[i]=s[i]]++;
    for(i=1; i<m; i++) Ws[i]+=Ws[i-1];
    for(i=n-1; i>=0; i--) sa[--Ws[x[i]]]=i;
    for(j=1,p=1; p<n; j<<=1,m=p){
        for(p=0,i=n-j; i<n; i++) y[p++]=i;
        for(i=0; i<n; i++) if(sa[i]>=j) y[p++]=sa[i]-j;
        for(i=0; i<n; i++) wv[i]=x[y[i]];
        for(i=0; i<m; i++) Ws[i]=0;
        for(i=0; i<n; i++) Ws[wv[i]]++;
        for(i=1; i<m; i++) Ws[i]+=Ws[i-1];
        for(i=n-1; i>=0; i--) sa[--Ws[wv[i]]]=y[i];
        for(t=x,x=y,y=t,p=1,x[sa[0]]=0,i=1; i<n; i++)
            x[sa[i]]=cmp(y,sa[i-1],sa[i],j) ? p-1 : p++;
    }
}
//Kasai's LCP algorithm (O(n))
void buildLCP(string s,int *sa,int n){
    int i,j,k=0;
    for(i=1; i<=n; i++) Rank[sa[i]]=i;
    for(i=0; i<n; LCP[Rank[i++]]=k)
        for(k?k--:0, j=sa[Rank[i]-1]; s[i+k]==s[j+k]; k++);
    return;}
// Pattern Subtring hisbe ace kina
bool Pattern(string &text,string &pat)
{   int lo=1,hi=text.size();
    while(lo<=hi)
    {   int mid=(lo+hi)/2;
        int ok=0;
        for(int i=0;i<pat.size();i++)
        { if(text[i+sa[mid]]>pat[i]) {ok=1;break;}
            if(text[i+sa[mid]]<pat[i]) {ok=-1;break;}
        }
        if(!ok) return true;
        if(ok>0) hi=mid-1;
        else lo=mid+1;
    }
    return false;
}
pair<int,int> Patterntern_occurence(string Text ,string Pattern)
{
    int n=Text.size();
    int m=Pattern.size();
    int be=1,en=n;
    while(be<en)
    {   int mid = (en+be)/2;
        int ok=0;
        for(int i=0;i<m;i++)
        {  if(Text[i+sa[mid]]>Pattern[i]){ok=1;break;}
            if(Text[i+sa[mid]]<Pattern[i]){ok=-1;break;}
        }
        if(ok+1) en=mid;
        else be=mid+1;
    }
    bool ok = 1;
    for(int i=0;i<m;i++) if(Text[i+sa[be]]!=Pattern[i]){ok=0;break;}
    if(!ok) return {-1,-1};
    pair<int,int> re;
    re.first=be;
    be=1,en=n;
    while(be<en)
    {  int mid = (en+be)/2;
        int ok=0;
        for(int i=0;i<m;i++)
        {  if(Text[i+sa[mid]]>Pattern[i]){ok=1;break;}
            if(Text[i+sa[mid]]<Pattern[i]){ok=-1;break;}
        }
        if(ok>0) en=mid;
        else be=mid+1;
    }
    ok = 1;
    for(int i=0;i<m;i++) if(Text[i+sa[en]]!=Pattern[i]){ok=0;break;}
    if(!ok) en--;
    re.second=en;
    return re;
}
/// this is for LCP from index i to index j.
/// just run a query from min(Rank[i-1],Rank[j-1])+1 to
max(Rank[i-1],Rank[j-1])
int ST[mx][22];
int Jump_LOG[mx];
void Build_Sparse(int n)
{      for(int i=1;i<=n;i++)ST[i][0]=LCP[i];
for(int i=2;i<=n;i++)Jump_LOG[i]=Jump_LOG[i-1]+!(i&(i-1));
                for(int j=1;(1<<j)<=n;j++){
            for(int i=1;(i+(1<<j)-1)<=n;i++){
            ST[i][j]=min(ST[i][j-1],ST[i+(1<<(j-1))][j-1]);
                        }
                }
}
int query(int i,int j){
                int boro_lav=Jump_LOG[j-i+1];
        return min(ST[i][boro_lav],ST[j-
(1<<boro_lav)+1][boro_lav]);
}
void solve(){
    buildSA(s,sa,n+1,130); //Important
    buildLCP(s,sa,n);
    for(int i=1;i<=n;i++) cout<<sa[i]<<" "; cout<<endl;
    for(int i=0;i<n;i++) cout<<Rank[i]<<" "; cout<<endl;
    for(int i=1;i<=n;i++) cout<<LCP[i]<<" ";
   pair<int,int>re=Patterntern_occurence(s,t);
   if(re.second==-1)printf("0\n");
  else printf("%d\n",re.second-re.first+1 );
}
```

Aho Corasick:

```
struct Aho_Corasick{
        int Trie[mx][27],Suffix_Link[mx];
        vector<int> Mark[mx];
        int Node;
        void Init() {
                fill(Trie[0],Trie[0]+26,-1);
                Mark[0].clear();
                Node=0;
        }
        void Insert(char ch[],int idx) {
                int len=strlen(ch);
                int cur=0;
                for(int i=0;i<len;i++){
                        int val=ch[i]-'a';
                        if(Trie[cur][val]==-1) {
                          Trie[cur][val]=++Node;
        fill(Trie[Node],Trie[Node]+26,-1);
                      Mark[Node].clear();
                                }
                        cur=Trie[cur][val];
                }
                Mark[cur].push_back(idx);
        }
        void Cal_Suffix_Link() {
                queue<int>q;
                Suffix_Link[0]=0;
                for(int i=0;i<26;i++){
                        if(Trie[0][i]!=-1){
                                q.push(Trie[0][i]);
                                Suffix_Link[Trie[0][i]]=0;
                        }
                        else Trie[0][i]=0;
                }
                while(!q.empty()){
                        int u=q.front();
                        q.pop();
                        for(int v: Mark[Suffix_Link[u]]){
                                Mark[u].push_back(v);
                        }
                        for(int i=0;i<26;i++) {
        if(Trie[u][i] != -1) {
                 Suffix_Link[Trie[u][i]] =    Trie[Suffix_Link[u]][i];
                 q.push(Trie[u][i]);
               }
               else
                 Trie[u][i] = Trie[Suffix_Link[u]][i];
            }
        }
 }
}Automata;
/// Pattern Occurence Count
int cnt[mx];
void Count_Pattern(char ch[]){
  int cur=0;
  int len=strlen(ch);
  for(int i=0;i<len;i++) {
        int val=ch[i]-'a';
        cur= Automata.Trie[cur][val];
        for(int id: Automata.Mark[cur])cnt[id]++;
  }
}
void solve(){
        char ch1[1000005],ch[mx];
        scanf("%d%s",&n,ch1);
        Automata.Init();
        for(int i=0;i<n;i++){
                scanf("%s",ch);
                Automata.Insert(ch,i);
        }
        Automata.Cal_Suffix_Link();
        Count_Pattern(ch1);
        /// print Occurence Frequency
        for(int i=0;i<n;i++){
                printf("%d\n",cnt[i]);
                cnt[i]=0;
        }
}
```

Hashing:

```
/*backup prime 307,367,1040160883,1066517951
,1e9+7,1e9+9,1072857881,1000004249 */
struct Hash_dui{
        ll base,mod;
        int sz;
        vector<int>Rev,Forw,P;
        Hash_dui(){}
        Hash_dui(const char* s,ll b,ll m)
        {
                sz=strlen(s),base=b,mod=m;

        Rev.resize(sz+2,0),Forw.resize(sz+2,0),P.resize(sz+2,1);
    for(int i=1;i<=sz;i++)P[i]=(base*P[i-1])%mod;
    for(int i=1;i<=sz;i++)Forw[i]=(Forw[i-1]*base+(s[i-1]-
'a'+1))%mod; /// digit hole s[i-1]-'0'
    for(int i=sz;i>=1;i--)Rev[i]=(Rev[i+1]*base+(s[i-1]-
'a'+1))%mod;  ///alphabet hole s[i-1]-'a'
        }
```

```
   void Single_char_ad(char cc)  {
            P.push_back((P.back()*base)% mod);
      Forw.push_back((Forw.back()*base+(cc-'a'+1))% mod);
   }
   inline int Range_Hash(int l,int r)  {
            int re_hash=Forw[r+1]-((ll)P[r-l+1]*Forw[l]%mod);
            if(re_hash<0)re_hash+=mod;
            return re_hash;
   }
   inline int Reverse_Hash(int l,int r) {
            int re_hash=Rev[l+1]-((ll)P[r-l+1]*Rev[r+2]%mod);
            if(re_hash<0)re_hash+=mod;
            return re_hash;
   }
};
struct Hash_Main
{
            Hash_dui h1,h2;
            Hash_Main(){}
            Hash_Main(const char* s){
                        h1=Hash_dui(s,1949313259, 2091573227);
                        h2=Hash_dui(s,1997293877, 2117566807);
            }
            void Char_Add(char cc){
                        h1.Single_char_ad(cc);
                        h2.Single_char_ad(cc);
            }
            inline ll Range_Hash(int l,int r) /// O base index
            {
                        return
((ll)h1.Range_Hash(l,r)<<32)^h2.Range_Hash(l,r);
            }
            inline ll Reverse_Hash(int l,int r) /// O base index
            {
                        return
((ll)h1.Reverse_Hash(l,r)<<32)^h2.Reverse_Hash(l,r);
            }
};
void solve(){
            int n;
            scanf("%d%s",&n,ch);
            string re=ch;
            Hash_Main h_ek(ch);
            ll h1=h_ek(l,r)//0 base
}
```

Manachers:

```
int oddPlen[mx],evenPlen[mx];
void Manachers(){
  int l=0,r=-1;
  for(int i=0;i<n;i++) {
    int k=(i>r)?1:min(oddPlen[l+r-i],r-i+1);
    while(k<=i && i+k<n && ch[i-k]==ch[i+k]) k++;
    oddPlen[i]=k--;
    if(i+k>r){
     l=i-k;
     r=i+k;
    }
  }
  l=0,r=-1;
  for(int i=0;i<n;i++){
    int k=(i>r)?0:min(evenPlen[l+r-i+1],r-i+1);
    while(k+1<=i && i+k<n && ch[i-k-1]==ch[i+k])k++;
    evenPlen[i]=k--;
    if(i+k>r){
     l=i-k-1;
     r=i+k;
    }
  }
}
void solve()
{   Manachers();
  for(int i=0;i<n;i++)printf("%d %d\n",oddPlen[i]*2-
1,evenPlen[i]*2);
}
```

Pi Table / Prefix Functions:

```
vector<int> Create_Pi_Table(const char* s){
            int sz=strlen(s);
            vector<int>pi(sz);
            for(int i=1;i<sz;i++){
                  int j=pi[i-1];
                  while(j>0 && s[i]!=s[j])j=pi[j-1];
                  if(s[j]==s[i])j++;
                  pi[i]=j;
            }
            return pi;
}
void solve(){
vector<int> pi=Create_Pi_Table(ch);
            for(int i=0;i<n;i++)printf("%d\n",pi[i] );
}
```

HLD(value in edge):

```
vector<pair<int,int>>g[mx];
int par[mx],sub_sz[mx];
int Head[mx],st[mx],sesh[mx];
int Rin[mx];  /// Segment Tree er init ye Tree[bode]=ar[Rin[be]]
likte hobe
int T;
using namespace Segment_Tree;
void sz_dfs(int u,int p){
            sub_sz[u]=1;
            par[u]=p;
            for(auto &v: g[u]){
                        if(v.first==p)continue;
                        sz_dfs(v.first,u);
                        sub_sz[u]+=sub_sz[v.first];
            if(sub_sz[v]>sub_sz[g[u][0].first])swap(v,g[u][0]);
            }
}
void hld_dfs(int u,int p,int cost){
    st[u]=++T;
    Rin[st[u]]=u;
    ar[st[u]]=cost; /// node ye nai , sgement tree build array
    for(auto v:g[u]) {
            if(v.first==p)continue;
            Head[v.first]= (v.first==g[u][0].first ? Head[u]:v.first);
            hld_dfs(v,u,v.second);
    }
    sesh[u]=T;
}
void hld_build(int root){
            T=0;
            Head[root]=root;
            sz_dfs(root,root);
            hld_dfs(root,root,0);
}
bool Is_it_parent(int p,int u){
            return st[p]<=st[u] && sesh[u]<=sesh[p];
}
int path_query(int u,int v){
            int re=-inf;
            while(1){
                        if(Is_it_parent(Head[u],v))break;
                        re=max(re,query(1,1,n,st[Head[u]],st[u]));  ///
for sum we  will do just add all query sum
                        u=par[Head[u]];
            }
            swap(u,v);
            while(1){
                        if(Is_it_parent(Head[u],v))break;
                        re=max(re,query(1,1,n,st[Head[u]],st[u]));  ///
for sum we  will do just add all query sum
                        u=par[Head[u]];
            }
            if(st[u]>st[v])swap(u,v);
            re=max(re,query(1,1,n,st[u]+1,st[v])); /// node hole
st[u] theke start
            return re;
}
void path_update(int u,int v,int val){
            while(1){
                        if(Is_it_parent(Head[u],v))break;
                        Rupdate(1,1,n,st[Head[u]],st[u],val);
                        u=par[Head[u]];
            }
            swap(u,v);
            while(1){
                        if(Is_it_parent(Head[u],v))break;
                        Rupdate(1,1,n,st[Head[u]],st[u],val);
                        u=par[Head[u]];
            }
            if(st[u]>st[v])swap(u,v);
            Rupdate(1,1,n,st[u]+1,st[v],val); /// node hole st[u]
theke start
}
void update_subtree(int u,int val){
            Rupdate(1,1,n,st[u]+1,sesh[u],val);
}
```

1D Sparse Table:

```
int ST[mx][MAX_logN];
int Jump_LOG[mx];
void Build_Sparse(){
            for(int i=1;i<=n;i++)ST[i][0]=ar[i];
for(int i=2;i<=n;i++)Jump_LOG[i]=Jump_LOG[i-1]+!(i&(i-1));
            for(int j=1;(1<<j)<=n;j++){
                        for(int i=1;(i+(1<<j)-1)<=n;i++){
        ST[i][j]=min(ST[i][j-1],ST[i+(1<<(j-1))][j-1]);
                        }
            }
}
int query(int i,int j){
            int boro_lav=Jump_LOG[j-i+1];
            return min(ST[i][boro_lav],ST[j-
(1<<boro_lav)+1][boro_lav]);
}
```

2D Sparse (Rectangle):

```
int ST[mx][mx][MAX_logN][MAX_logN];
void Build_2D_Sparse(){
            for(int i=1;i<=n;i++){
                        for(int j=1;j<=n;j++){
                                    ST[i][j][0][0]=ar[i][j];
                        }
                        for(int l=1;(1<<l)<=n;l++){
                                    int pre=1<<(l-1);
                                    for(int j=1;j+pre<=n;j++){
            ST[i][j][0][l]=min(ST[i][j][0][l-1],ST[i][j+pre][0][l-1]);
                                    }
                        }
            }
            for(int l=1;(1<<l)<=n;l++){
                        int pre=1<<(l-1);
                        for(int i=1;i+pre<=n;i++){
                                    for(int k=0;(1<<k)<=n;k++){
                                                for(int j=1;j<=n;j++){

            ST[i][j][l][k]=min(ST[i][j][l-1][k],ST[i+pre][j][l-1][k]);
                                                }
                                    }
                        }
            }
}
int query(int i,int j,int p,int q) {
            int boro_jum1=log2(p-i+1);
            int boro_jum2=log2(q-j+1);
            int pre1=1<<boro_jum1;
            int pre2=1<<boro_jum2;
            int re1=min(ST[i][j][boro_jum1][boro_jum2],ST[i][q-
pre2+1][boro_jum1][boro_jum2]);
            int re2=min(ST[p-
pre1+1][j][boro_jum1][boro_jum2],ST[p-pre1+1][q-
pre2+1][boro_jum1][boro_jum2]);
```

```
        return min(re1,re2);
}
```

2D Sparse (Square):

```
int ST[mx][mx][MAX_logN];
void Build_2D_Sparse(){
for(int l=0;(1<<l)<=n;l++){
for(int i=1;i+(1<<l)-1<=n;i++){
for(int j=1;j+(1<<l)-1<=n;j++){
if(l==0)ST[i][j][l]=ar[i][j];
else{
int pre=1<<(l-1);
int val1=min(ST[i][j][l-1],ST[i+pre][j][l-1]);
int val2=min(ST[i][j+pre][l-1],ST[i+pre][j+pre][l-1]);
ST[i][j][l]=min(val1,val2);
}}}}}
int query(int i,int j,int sz){
int boro_lav=log2(sz);
int pre=1<<(boro_lav);
int val1=min(ST[i][j][boro_lav],ST[i+sz-pre][j][boro_lav]);
int val2=min(ST[i][j+sz-pre][boro_lav],ST[i+sz-pre][j+sz-pre][boro_lav]);
return min(val1,val2);
}
```

MO:

```
namespace MO{
  const int N=100005;
  const int Q=100005;
  int ar[N],BlockId[N],ans[Q];
  bool vis[N];
  struct node {
        int l,r,id;
        node(){}
        node(int l,int r,int id){
                this->l=l;
                this->r=r;
                this->id=id;
        }
    bool operator < (const node& u)  {
        int a=BlockId[l],b=BlockId[u.l];
        if(a==b){
                return (a & 1 ? (r > u.r) : (r < u.r));
        }
        else return a<b;
    }
  }query[Q];
  int boro=0;
  int cnt[mx],cnt_tot[mx];
  void check(int pos)  {
        if(vis[pos]){
                cnt_tot[cnt[ar[pos]]]--;
                cnt[ar[pos]]--;
                if(cnt[ar[pos]])cnt_tot[cnt[ar[pos]]]++;
                if(cnt_tot[boro]==0)boro--;
        }
        else{
                if(cnt[ar[pos]])cnt_tot[cnt[ar[pos]]]--;
                cnt[ar[pos]]++;
                cnt_tot[cnt[ar[pos]]]++;
                if(cnt_tot[boro+1])boro++;
        }
   vis[pos]^=1;
  }
}
using namespace MO;
void solve(){
        int q;
        boro=0;
        scanf("%d%d",&n,&q);
        int sz=sqrt(n);
        for(int i=1;i<=n;i++){
                BlockId[i]=i/sz;
                vis[i]=false;
                scanf("%d",&ar[i]);
        }
        memset(cnt,0,sizeof(cnt));
        memset(cnt_tot,0,sizeof(cnt_tot));
        for(int i=1;i<=q;i++){
                int x,y;
                scanf("%d%d",&x,&y);
                query[i]=node(x,y,i);
        }
        sort(query+1,query+q+1);
        int left=query[1].l;
        int right=left-1;
        for(int i=1;i<=q;i++){
                node Now=query[i];
                while(left<Now.l)check(left++);
                while(left>Now.l)check(--left);
                while(right<Now.r)check(++right);
                while(right>Now.r)check(right--);
    ans[Now.id]=boro;
        } }
```

MO's On tree:

```
int n,m,ii,k,LOG;
int depth[mx];
int par[mx][25];
namespace MO{
  const int N=100005;
  const int Q=100005;
  int ar[N],br[N],BlockId[N],ans[Q];
  bool vis[N];
  struct node {
        int l,r,id,lca;
        node(){}
        node(int l,int r,int lca,int id){
                this->l=l;
                this->r=r;
                this->lca=lca;
                this->id=id;
        }
```

```
    bool operator < (const node& u) {
        int a=BlockId[l],b=BlockId[u.l];
        return (a==b)?(r<u.r):a<b;
    }
  }query[Q];
  int re=0,sz;
  int cnt[100005];
  void check(int pos) {
        if(vis[pos]){
                if(cnt[ar[pos]]==1)re--;
                cnt[ar[pos]]--;
        }
        else{
                if(cnt[ar[pos]]==0)re++;
                cnt[ar[pos]]++;
        }
        vis[pos]^=1;
  }
  vector<int> g[N];
  int Euler[2*N],st[N],en[N],Time;
  void dfs(int u,int p,int lvl) {
    st[u]=++Time;
    Euler[Time]=u;
    par[u][0]=p;
    depth[u]=lvl;
    for(int v:g[u])  {
         if(v==p)continue;
         dfs(v,u,lvl+1);
    }
    en[u]=++Time;
    Euler[Time]=u;
  }
}
using namespace MO;
void init(int root){
  dfs(root,-1,1);
  for(int j=1;j<LOG;j++)  {
    for(int i=1;i<=n;i++) {
      if(par[i][j-1]!=-1)  {
        par[i][j]=par[par[i][j-1]][j-1];
      }
      else par[i][j]=-1;
    }
  }
}
int lca(int u,int v){
  if(depth[u]<depth[v])swap(u,v);
  int log=1;
  while(1)  {
    int next=log+1;
    if(depth[u]<(1<<next))break;
    log++;
  }
  for(int i=log;i>=0;i--) {
    if(depth[u]-(1<<i)>=depth[v]) {
      u=par[u][i];
    }
  }
  if(u==v)return u;
  for(int i=log;i>=0;i--) {
    if(par[u][i]!=-1 && par[u][i]!=par[v][i]) {
      u=par[u][i];
      v=par[v][i];
    }
  }
  return par[v][0];
}
void solve(){
        int q;
        scanf("%d%d",&n,&q);
        LOG=log2(n)+1;
        Time=0;
        re=0;
        sz=sqrt(n);
for(int i=1;i<=n;i++)
scanf("%d",&ar[i]),br[i]=ar[i],BlockId[i]=i/sz,vis[i]=false,cnt[i]=0;
        // Compressing Coordinates . its a alternative of map
        sort(br+1,br+n+1);
        k = unique(br+1,br+n+1)-br-1;
        for(int i=1;i<=n;i++)
ar[i]=lower_bound(br+1,br+k+1,ar[i])-br;
        for(int i=1;i<n;i++){
                int x,y;
                scanf("%d%d",&x,&y);
                g[x].push_back(y);
                g[y].push_back(x);
        }
        init(1);
        for(int i=1;i<=q;i++){
    int x,y;
    scanf("%d%d",&x,&y);
    if(st[x]>st[y])swap(x,y);
    int p=lca(x,y);
    if(x==p)query[i]=node(st[x],st[y],-1,i);
    else query[i]=node(en[x],st[y],p,i);
        }
        sort(query+1,query+1+q);
  int left=query[1].l;
        int right=left-1;
        for(int i=1;i<=q;i++){
                node Now=query[i];
                while(left<Now.l)check(Euler[left++]);
                while(left>Now.l)check(Euler[--left]);
                while(right<Now.r)check(Euler[++right]);
                while(right>Now.r)check(Euler[right--]);
    if(Now.lca!=-1)check(Now.lca);
    ans[Now.id]=re;
    if(Now.lca!=-1)check(Now.lca);
        }
        for(int i=1;i<=q;i++)printf("%d\n",ans[i]);
  for(int i=1;i<=n;i++)g[i].clear();
}
```

Trie (max min xor subarray):

```
int Trie[mx][2];
int End[mx];
int ar[50005];
int Trie[50000*32][2];
int n,ii,st=1;
void Insert(int val){
  int cur=1;
  for(int i=31;i>=0;i--){
    int bit=0;
    if(((1<<i) & val))bit=1;
    if(Trie[cur][bit]==0)Trie[cur][bit]=++st;
    cur=Trie[cur][bit];
  }
  End[cur]=val;
}
int query_min(int val){
  int cur=1;
  for(int i=31;i>=0;i--)   {
    int bit=0;
    if(((1<<i) & val))bit=1;
    if(Trie[cur][bit])cur=Trie[cur][bit];
    else if(Trie[cur][bit^1])cur=Trie[cur][bit^1];
  }
  return End[cur]^val;
}
int query_max(int val){
  int cur=1;
  for(int i=31;i>=0;i--){
    int bit=0;
    if(((1<<i) & val))bit=1;
    if(Trie[cur][bit^1])cur=Trie[cur][bit^1];
    else if(Trie[cur][bit])cur=Trie[cur][bit];
  }
  return End[cur]^val;
}
void solve(){
  int suffix=0;
  int re_min=INT_MAX,re_max=0;
  Insert(0);
  for(int i=1;i<=n;i++)  {
    scanf("%d",&ar[i]);
    suffix^=ar[i];
    re_min=min(re_min,query_min(suffix));
    re_max=max(re_max,query_max(suffix));
    Insert(suffix);
  }
}
```

SegTree :

Bracket Sequence:

```
struct info{
  int open,close,ans;
};
info Merge(info a,info b){
  info re;
  int valid=min(a.open,b.close);
  re.open=a.open+b.open-valid;
  re.close=a.close+b.close-valid;
  re.ans=a.ans+b.ans+valid;     /// this code works for maximum
length of correct bracket sequence in l to r range
  return re;
}
```

Kth element merge sort tree:

```
int query(int node,int be,int en,int l,int r,int k){
  if(be==en)return seg[node][0];
 int pos
=upper_bound(seg[node*2+1].begin(),seg[node*2+1].end(),r)
  -lower_bound(seg[node*2+1].begin(),seg[node*2+1].end(),l);
  int mid=(be+en)/2;
  if(pos>=k)  {
    return query(node*2+1,be,mid,l,r,k);
  }
  else return query(node*2+2,mid+1,en,l,r,k-pos);
}
```

Delete Type Id Found:

```
int id_query(int node,int be,int en,int pos){
        if(be==en)return be;
        int mid=(be+en)/2;
        if(Present[node*2]>=pos){
        return id_query(node*2,be,mid,pos);
        }
        else return id_query(node*2+1,mid+1,en,pos-
Present[node*2]);
}
```

Rang max subarray / suffix-prefix sum:

```
struct info{
ll  max_pref,max_suf,ans,sum;
  void Merge(info p1,info p2){
sum=p1.sum+p2.sum;
max_pref=max(p1.max_pref,p1.sum+p2.max_pref);
max_suf=max(p2.max_suf,p2.sum+p1.max_suf);
ans=max(max(p1.ans,p2.ans),p1.max_suf+p2.max_pref);
}};
void Relax(int node,int be,int en){
        if(!cur[node])return;
        Tree[node].sum=Lazy[node]*(en-be+1);
        Tree[node].max_pref=max(0LL,Tree[node].sum);
        Tree[node].max_suf=max(0LL,Tree[node].sum);
        Tree[node].ans=max(0LL,Tree[node].sum);
        if(be!=en){
                Lazy[node*2]=Lazy[node];
                Lazy[node*2+1]=Lazy[node];
                cur[node*2]=true;
                cur[node*2+1]=true;
        }
        cur[node]=false;
        Lazy[node]=0;
}
```

Centroid Decomposition:

```
 int dis[18][mx],re[mx],vis[mx];
int p[mx],sub[mx],lvl[mx];
vector<int>g[mx],ng[mx];
/* p[u] = parent of u in centroid tree
dis[x][u] = distance from u to a parent of u at level x of centroid tree
if u is in subtree of centroid c, then dis[lvl[c]][u] = dist(c, l)
If (x, y) edge exist, then x must be in g[y] and y must be in g[x]*/
/* we can do more pre work in dfs function*/
void dfs(int l,int u,int par){
        if(par!=-1)dis[l][u]=dis[l][par]+1;
        for(int v:g[u])
                if(v!=par && !vis[v])dfs(l,v,u);
}
int centroid(int u,int par,int r){
        for(int v:g[u])
if(v!=par && !vis[v] && sub[v]>r)return centroid(v,u,r);
return u;
}
void pre_cal(int u,int par){
sub[u]=1;
for(int v:g[u])
        if(v!=par && !vis[v])pre_cal(v,u),sub[u]+=sub[v];
}
void decompose(int u,int par){
        pre_cal(u,-1);
        int tem=centroid(u,-1,sub[u]>>1);
        vis[tem]=1,p[tem]=par,lvl[tem]=0;
        if(par!=-1)lvl[tem]=lvl[par]+1,ng[par].push_back(tem);
        dfs(lvl[tem],tem,-1);
        for(int v:g[tem])
                if(v!=par && !vis[v])decompose(v,tem);
}
void update(int u){
for(int v=u;v!=-1;v=p[v])re[v]=min(re[v],dis[lvl[v]][u]);
}
int query(int u){
        int ans=1e9;
        for(int v=u;v!=-1;v=p[v])
                ans=min(ans,re[v]+dis[lvl[v]][u]);
        return ans;
}
int lca(int u,int v){
        if(lvl[u]<lvl[v])swap(u,v);
        while(lvl[u]>lvl[v])u=p[u];
        while(u!=v && p[u]!=-1)u=p[u],v=p[v];
        return u;
}
int dist(int u,int v){
        int lc=lca(u,v);
        return dis[lvl[lc]][u]+dis[lvl[lc]][v];
}
int GetRoot(int u){
        while(p[u]!=-1)u=p[u];
        return u;
}
/// for all pair
void update(int u,int p){
        int val=dis[lvl[p]][u];
        for(int i=0;i<20;i++){
                cnt[i][chk(val,i)]++;
        }
        for(int v:ng[u])update(v,p);
}
void query(int u,int p){
        int val=dis[lvl[p]][u]^ar[p];
        for(int i=0;i<20;i++){
                ans+=cnt[i][!chk(val,i)]*(1LL<<i);
        }
        for(int v:ng[u])query(v,p);
}
void Go_Ahead(int u){
        memset(cnt,0,sizeof(cnt));
        for(int i=0;i<20;i++)cnt[i][chk(ar[u],i)]++;
        for(int v:ng[u]){
                query(v,u);
                update(v,u);
        }
        ans+=ar[u];
        for(int v:ng[u])Go_Ahead(v);
}
// at first call decompose(1,-1)
```

Dinic:

```
const ll eps = 0;
struct edge {
   int a, b;
   ll cap,flow;
   int yo, x, y;
};
struct Dinic {
   int s,t,d[mx], ptr[mx] ;
   //int Id[mx][mx];
   vector<edge>e;
   vector<int>g[mx];
   void init() {
      e.clear();
      memset(d,0,sizeof(d));
      for(int i = 0; i < mx ; i++)g[i].clear();
      // for(int i=0;i<mx;i++)
      // {
      //    for(int j=0;j<mx;j++)
      //    {
      //             Id[i][j]=0;
      //    }
      // }
   }
   void addEdge(int a,int b,ll cap, int x = -1, int y= -1) {
      edge e1 = { a, b, cap, 0, 1, x, y } ;
      edge e2 = { b, a, 0, 0, 0, x, y } ;
   //  Id[a][b]=e.size();
    g[a].push_back((int)e.size());
    e.push_back(e1);
   //  Id[b][a]=e.size();
    g[b].push_back((int)e.size());
    e.push_back(e2);
  }
  bool bfs() {
    queue < int > Q ;
    Q.push(s);
    memset(d,-1,sizeof(d));
    d[s]=0 ;
    while (!Q.empty()) {
      int u=Q.front() ;
      Q.pop() ;
      for(int i=0; i<g[u].size(); i++) {
        int id=g[u][i];
        int v=e[id].b;
       //  printf("%d %d %0.3lf
%0.3lf\n",u,v,e[id].cap,e[id].flow);
        if(d[v]==-1&&e[id].flow<e[id].cap) {
          Q.push(v) ;
          d[v]=d[u]+1 ;
        }} }
    return d[t]!=-1 ;
  }
  ll dfs(int u,ll flow) {
    if (flow<=eps)  return 0 ;
    if ( u==t )  return flow ;
    for(int& i = ptr[u] ; i<g[u].size(); i++) {
      int id = g[u][i];
      int v =  e[id].b ;
      if ( d[v] != d[u]+1 )  continue ;
      ll pushed = dfs (v,min (flow,e[id].cap-e[id].flow)) ;
      //cout << "pushed " << pushed << endl;
      if (pushed>eps) {
        e [id].flow+=pushed ;
        e [id^1].flow-=pushed ;
        return pushed ;
      }
    }
    return 0 ;
  }
  ll dinic() {
    ll flow = 0 ;
    while(true) {
      if(!bfs())  break ;
      memset(ptr, 0, sizeof(ptr)) ;
      while (true){
        ll pushed = dfs(s,INF );
        if(pushed<=eps)break;
        flow += pushed ;
      }
    }
    return flow ;
  }
};
```

Upper Lower Limit:

```
Dinic dc;
int x,y;
struct tem{
  int u,v,a,b;
};
vector<tem>ed;
ll func(ll val){
  dc.init();
  dc.s=n+1;
  dc.t=n+2;
  /// for upperbound(0,val)
  // dc.addEdge(y,n+3,val); /// sink to super super source
  // dc.addEdge(n+1,x,0); /// sink to source
  // dc.addEdge(n+3,n+2,0); /// super super source to super
sink
  // dc.addEdge(n+3,x,val);  /// super super source to source
  /// for lowerbound(val,inf)
  dc.addEdge(y,n+3,INF); /// sink to super super source
  dc.addEdge(n+1,x,val); /// sink to source
  dc.addEdge(n+3,n+2,val); /// super super source to super sink
  dc.addEdge(n+3,x,INF);  /// super super source to source
  for(auto it:ed){
    dc.addEdge(n+1,it.v,it.a);
    dc.addEdge(it.u,n+2,it.a);
    dc.addEdge(it.u,it.v,it.b-it.a);
  }
  return dc.dinic();
}
void solve(){
  scanf("%d%d",&n,&m);
  scanf("%d%d",&x,&y);
  dc.addEdge(y,x,INF);
  dc.s=n+1;
  dc.t=n+2;
  ll val=0;
  ll en=0;
  for(int i=1;i<=m;i++){
    int u,v,a,b;
    scanf("%d%d%d%d",&u,&v,&a,&b);
    ed.push_back({u,v,a,b});
    val+=a;
    en+=b;
    dc.addEdge(n+1,v,a);
    dc.addEdge(u,n+2,a);
    dc.addEdge(u,v,b-a);
  }
  if(dc.dinic()<val){
    printf("0\n");
    return;
  }
  ll be=val;
  ll re=be;
```

```
   while(be<=en){
      ll mid=(be+en)/2;
      ll have=func(mid);
      if(have>=mid+val)  {
         re=mid;
         be=mid+1;
      }
      else en=mid-1;
   }
   printf("%lld\n",re);
}
```

Hopcroft_Karp:

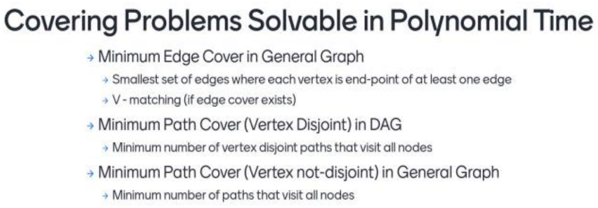
```
#define mx 40005
#define INF (1<<28)
struct Hopcroft_Karp
{
            vector< int > g[mx];
            int n, m, Matching[mx], Distance[mx];
            // n: number of nodes on left side, nodes are
numbered 1 to n
            // m: number of nodes on right side, nodes are
numbered n+1 to n+m
            void init(int num){

for(inti=0;i<=num;i++)Matching[i]=0,Distance[i]=0,g[i].clear();
}
  void addEdge(int u,int v) {
            g[u].push_back(v);
   }
            bool bfs() {
               int i, u, v, len;
               queue< int > q;
               for(i=1; i<=n; i++) {
                  if(Matching[i]==0) {
                     Distance[i] = 0;
                     q.push(i);
                  }
                  else Distance[i] = INF;
               }
               Distance[0] = INF;
               while(!q.empty()) {
                  u = q.front(); q.pop();
                  if(u!=0) {
                     for(int v:g[u]) {
                           if(Distance[Matching[v]]==INF) {
                           Distance[Matching[v]] = Distance[u] + 1;
                           q.push(Matching[v]);
                        }
                     }
                  }
               }
               return (Distance[0]!=INF);
            }
            bool dfs(int u) {
               int i, v, len;
               if(u!=0) {
                  for(int v:g[u]) {
                     if(Distance[Matching[v]]==Distance[u]+1) {
                        if(dfs(Matching[v])) {
                           Matching[v] = u;
                           Matching[u] = v;
                           return true;
                        }
                     }
                  }
                  Distance[u] = INF;
                  return false;
               }
               return true;
            }
            int hopcroft_karp() {
               int Matchinging = 0, i;
               while(bfs())
                  for(i=1; i<=n; i++)
                     if(Matching[i]==0 && dfs(i))
                        Matchinging++;
               return Matchinging;
            }
};
Hopcroft_Karp hk;
```

Hungarian (visit all node with minimum cost):

```
#define INF 1e18
pair<ll,vector<int>> hungarian(vector<vector<ll>>mat,int f,int
sz){
   vector<int>par(sz+1,0),way(sz+1,0),match(sz+1,0);
   vector<bool>vis(sz+1,0);
   vector<ll>U(sz+1,0),V(sz+1,0),MinV(sz+1,0);
   for(int i=1;i<=sz;i++) {
      for(int j=1;j<=sz;j++) {
         mat[i][j]*=f;
      }
   }
   int a,b,d;
   ll r,w;
   for(int i=1;i<=sz;i++){
      par[0]=i;
      b=0;
      for(int j=1;j<=sz;j++)MinV[j]=INF,vis[j]=0;
      do{
         vis[b]=1;
         a=par[b],d=0,w=INF;
         for(int j=1;j<=sz;j++)  {
            if(!vis[j])  {
               r=mat[a][j]-U[a]-V[j];
               if(r<MinV[j])MinV[j]=r,way[j]=b;
               if(MinV[j]<w)w=MinV[j],d=j;
            }
         }
         for(int j=0;j<=sz;j++)  {
            if(vis[j])U[par[j]]+=w,V[j]-=w;
            else MinV[j]-=w;
         }
         b=d;
      }
      while(par[b]!=0);
      do{
         d=way[b];
         par[b]=par[d],b=d;
      }
      while(b!=0);
   }
   for(int j=1;j<=sz;j++)match[par[j]]=j;
   return {-f*V[0],match};
}
// called hungarain(mat,1,n)
```

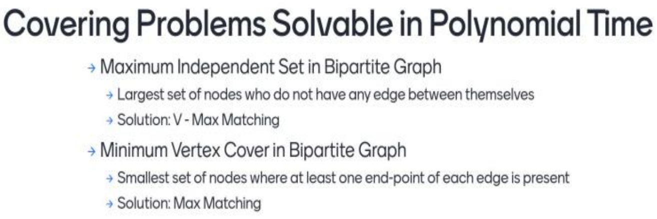
Min Cost Max Flow:

```
typedef long long T1;//for cost
typedef long long T2;//for flow
const int maxn = 20100;
const T1 INF = 1e12;
const T2 inf = 1e12;
const T1 eps = 0;
struct Edge {
   int from, to;
   T2 cap, flow;
   T1 cost;
};
int n,m,k,ii;
struct MCMF {//0-indexed
   int n, m, s, t;
   vector<Edge> edges;
   vector<int> G[maxn];
   int p[maxn],inq[maxn];
   T1 d[maxn];
   T2 a[maxn];
   void init() {
      for(int i = 0; i < n; i++) G[i].clear();
      edges.clear();
   }
   void AddEdge(int from,int to,T2 cap,T1 cost) {
      edges.push_back((Edge){from, to, cap, 0, cost});
      edges.push_back((Edge){to, from, 0, 0, -cost});
      m = edges.size();
      G[from].push_back(m-2);
      G[to].push_back(m-1);
   }
   pair<T1,T2> Mincost() {//bellmanFord
      T1 tot_cost = 0;
      T2 tot_flow = 0;
      while(true) {
         for(int i = 0; i < n; i++) d[i] = INF;
         d[s] = 0;
         p[s] = 0;
         a[s] = inf;
         bool up=true;
         while(up) {
            up=false;
            for(int u = 0; u < n; u++) {
               if(d[u]-INF>=-eps)continue;
               for(int j:G[u]) {
                  Edge &e=edges[j];
                  if(e.cap > e.flow && d[e.to] > d[u] + e.cost+eps) {
                     d[e.to] = d[u] + e.cost;
                     p[e.to] = j;
                     a[e.to] = min(a[u], e.cap - e.flow);
                     up=true;
                  }
               }
            }
         }
         if(abs(d[t]-INF)<=eps)break;
         tot_cost += (T1)d[t] * a[t];
         tot_flow += (T2)a[t];
         int u = t;
         while(u != s) {
            edges[p[u]].flow += a[t];
            edges[p[u]^1].flow -= a[t];
            u = edges[p[u]].from;
         }
      }
      return {tot_cost,tot_flow};
   }
   pair<T1,T2> Mincost2() {//SPFA
      T1 tot_cost = 0;
      T2 tot_flow = 0;
      while(true) {
         for(int i = 0; i < n; i++) d[i] = INF;
         memset(inq, 0, sizeof(inq));
         d[s] = 0;
         inq[s] = 1;
         p[s] = 0;
         a[s] = inf;
         queue<int> Q;
         srand(time(NULL));
         Q.push(s);
         while(!Q.empty()) {
            int u = Q.front();
            Q.pop();
            inq[u] = 0;
            for(int i = 0; i < G[u].size(); i++) {
               Edge& e = edges[G[u][i]];
               if(e.cap > e.flow && d[e.to] > d[u] + e.cost+eps) {
                  d[e.to] = d[u] + e.cost;
                  p[e.to] = G[u][i];
                  a[e.to] = min(a[u], e.cap - e.flow);
                  if(!inq[e.to]) {
                     Q.push(e.to);
                     inq[e.to] = 1;
                  }
               }
            }
        }
        if(abs(d[t]-INF)<=eps)break;
        tot_cost += (T1)d[t] * a[t];
        tot_flow += a[t];
        int u = t;
        while(u != s) {
          edges[p[u]].flow += a[t];
          edges[p[u]^1].flow -= a[t];
          u = edges[p[u]].from;
        }
    }
    return {tot_cost,tot_flow};
  }
} mcmf;
```



Covering Problems Solvable in Polynomial Time

- Minimum Edge Cover in General Graph
  - Smallest set of edges where each vertex is end-point of at least one edge
  - V - matching (if edge cover exists)
- Minimum Path Cover (Vertex Disjoint) in DAG
  - Minimum number of vertex disjoint paths that visit all nodes
- Minimum Path Cover (Vertex not-disjoint) in General Graph
  - Minimum number of paths that visit all nodes



Covering Problems Solvable in Polynomial Time

- Maximum Independent Set in Bipartite Graph
  - Largest set of nodes who do not have any edge between themselves
  - Solution: V - Max Matching
- Minimum Vertex Cover in Bipartite Graph
  - Smallest set of nodes where at least one end-point of each edge is present
  - Solution: Max Matching

Kuhn:

```
struct BPM{
bool Done[mx];
  vector<int>g[mx];
  int macth[mx];
  void addEdge(int u,int v)  {
    g[u].push_back(v);
  }
  void init() {
        for(int i=0;i<mx;i++)g[i].clear();
  }
  bool Tem_Matching(int u){
    for(int i=0;i<(int)g[u].size();i++){
        int v=g[u][i];
      if(Done[v]) continue;
      Done[v] = true;
      if(macth[v]==-1 || Tem_Matching(macth[v])) {
        macth[v] = u;
        return true;
      }
    }
    return false;
  }
  int Max_Matching(int num) {
        // Be Careful with this section. when passin num.
    memset(macth,-1,sizeof(macth));
    int re = 0;
    for(int i=1;i<=num;i++)  {
      memset(Done,false,sizeof(Done));
      if(Tem_Matching(i)) re++;
    }
    return re;
  }
};
```

LCA(value on edge):

```
int par[mx][20];
ll ans[mx][20];
int depth[mx],LOG;
vector<pair<int,ll>>g[mx];
void dfs(int u,int p,int lvl){
  par[u][0]=p;
  depth[u]=lvl;
  for(auto it:g[u])  {
    int v=it.first;
    ll w=it.second;
    if(v==p)continue;
    ans[v][0]=w;
    dfs(v,u,lvl+1);
  }
}
void init(int root){
  dfs(root,-1,1);
  for(int j=1;j<LOG;j++) {
    for(int i=1;i<=n;i++)  {
      if(par[i][j-1]!=-1){
        par[i][j]=par[par[i][j-1]][j-1];
        ans[i][j]=max(ans[i][j-1],ans[par[i][j-1]][j-1]);
      }
      else par[i][j]=-1;
    }
  }
}
ll query(int u,int v){
        if(u==v)return 0;
  if(depth[u]<depth[v])swap(u,v);
  int diff=depth[u]-depth[v];
  ll re=0;
  for(int i=LOG-1;i>=0;i--)  {
    if(diff>=(1<<i)) {
      diff-=(1<<i);
      re=max(re,ans[u][i]);
      u=par[u][i];
    }
  }
  if(u==v)return re;
  for(int i=LOG-1;i>=0;i--)  {
    if( par[u][i]!=par[v][i]){
      re=max({re,ans[u][i],ans[v][i]});
      u=par[u][i];
      v=par[v][i];
    }
  }
  re=max({re,ans[u][0],ans[v][0]});
  return re;
}
int dist(int u,int v){
  return depth[u]+depth[v]-2*depth[lca(u,v)];
}
int kth_parent(int u,int k){
  for(int i=LOG-1;i>=0;i--) {
    if(k>=(1<<i))  {
      k-=(1<<i);
      u=par[u][i];
    }
    if(u==-1)return u;
  }
  return u;
}
solve(){
for(int i=1;i<=n;i++){
        g[i].clear();
        for(int j=0;j<LOG;j++)ans[i][j]=0,par[i][j]=-1;
}
 LOG=log2(n)+1;
}
```

LCA(value in node):

```
//dfs function ye ans[u][0] line likha jabe nah
// init function same
// query function er sesh ye ei 3 line likhbo
  re=max(re,ans[u][0]);
  re=max(re,ans[v][0]);
  re=max(re,ans[par[v][0]][0]);
for(int i=1;i<=n;i++){
        scanf("%d",&ar[i]);
        ans[i][0]=ar[i];
}
```

DSU:

```
int Size[mx];
int Findparent(int x){
  return (x==parent[x])?x:(parent[x]=Findparent(parent[x]));
}
void Union(int x,int y){
  int px=Findparent(x);
  int py=Findparent(y);
  if(px==py)return;
  if(Size[px]>Size[py]) {
    Size[px]+=Size[py];
    parent[py]=px;
  }
  else {
    Size[py]+=Size[px];
    parent[px]=py;    }
}
void initialize(){
  for(int i=0;i<=n;i++)parent[i]=i,Size[i]=1;
}
```

Bellman Ford:

```
vector<Edge>E;
ll dist[100];
bool bellman_ford(){
  /// here i can start from 1 .if given that stating node i can set dist[src]=0
  for(int i=1;i<=n;i++)dist[i]=10000000;
  dist[1]=0;
  for(int i=1;i<n;i++)
    for(Edge it: E)
      if(dist[it.v]>dist[it.u]+it.w)
        dist[it.v]=dist[it.u]+it.w;
  for(Edge it:E)
    if(dist[it.v]>dist[it.u]+it.w)return true;//negative cycle
  return false;
}
```

Floyed Warshal:

```
for(int i=1;i<=n;i++){
        for(int j=1;j<=n;j++){
                if(i==j || dis[i][j]>0)continue;
                dis[i][j]=1e18;
        }
}
for(int l=1;l<=n;l++){
for(int i=1;i<=n;i++){
for(int j=1;j<=n;j++){
dis[i][j]=min(dis[i][j],dis[i][l]+dis[l][j]);}}}
```

Articulation Point:

```
vector<int>g[mx];
int articular_point[mx];
int st[mx],low[mx];
int Time=1;
int dfs(int u,int p){
  st[u]=low[u]=Time++;
  int child=0;
  for(auto it:g[u]) {
    if(it==p)continue;
    if(st[it]==0) {
      child++;
      dfs(it,u);
      if(st[u]<=low[it])articular_point[u]=1;
      low[u]=min(low[u],low[it]);
    }
    else low[u]=min(low[u],st[it]);
  }
  return child;
}
void solve(){
 for(int i=1;i<=n;i++) {
   if(st[i])continue;
   articular_point[i]=(dfs(i,-1)>1);
 }
}
```

Articulations Bridge:

```
vector<int>g[mx];
vector<pair<int,int>>Bridge;
int st[mx],low[mx];
int Time=1;
void dfs(int u,int p){
   st[u]=low[u]=Time++;
   int child=0;
   for(auto it:g[u])  {
      if(it==p)continue;
      if(st[it]==0){
         dfs(it,u);
         if(st[u]<low[it])Bridge.push_back({u,it});
         low[u]=min(low[u],low[it]);
      }
      else low[u]=min(low[u],st[it]);
   }
}
void solve(){
  for(int i=1;i<=n;i++) {
     if(st[i])continue;
     dfs(i,-1);
  }
}
```

Strongly Connected Component:

```
vector<int>g[mx],g_rev[mx],st(mx),en(mx),component[mx],option,visit;
vector<pair<int,int>>dekhi;
int node,edge,cnt,tem;
int mp[mx];
void dfs1(int u){
   visit[u]=true;
   st[u]=++cnt;
   for(auto it:g[u]) {
      if(visit[it])continue;
      dfs1(it);
   }
   en[u]=++cnt;
}
void dfs2(int u){
   visit[u]=true;
   component[cnt].push_back(u);
   for(auto it:g_rev[u])  {
      if(visit[it])continue;
      dfs2(it);
   }
}
void clean(){
   for(int i=1;i<=node+2;i++)  {
      g[i].clear();
      g_rev[i].clear();
      component[i].clear();
   }
   option.clear();
   cnt=0;
   st.clear();
   en.clear();
   dekhi.clear();
   memset(mp,0,sizeof(mp));
}
void solve(){
   scanf("%d%d",&node,&edge);
   for(int i=1;i<=edge;i++)  {
      int u,v;
      scanf("%d%d",&u,&v);///directed graph
      g[u].push_back(v);
      g_rev[v].push_back(u);
      mp[u]++;
      mp[v]++;
   }
   visit.assign(node+2,false);
   for(int i=1;i<=node;i++) {
      if(visit[i]==true || mp[i]==0)continue;
      dfs1(i);
   }
   for(int i=1;i<=node;i++) {
      if(visit[i]==true && mp[i])dekhi.push_back({en[i],i});
   }
   sort(dekhi.begin(),dekhi.end());
   reverse(dekhi.begin(),dekhi.end());
   visit.assign(node+2,false);
   cnt=1;
   for(int i=0;i<dekhi.size();i++)  {
      int pos=dekhi[i].second;
      if(visit[pos] || mp[pos]==0)continue;
      dfs2(pos);
      cnt++;
   }
   for(int i=1;i<cnt;i++) {
      for(auto it:component[i])  {
         cout<<it<<" ";
      }
      cout<<endl;
   }}
```

Matrix Expo:

```
#define MAX 105
#define ll long long int
const ll MOD = 1e9 + 7;
const ll MOD2 = MOD * MOD * 3;
inline ll bigMod(ll a,ll b){
   ll res=1;
   while(b){
      if(b&1) res=(res*a)%MOD;
      a=(a*a)%MOD; b>>=1;
   }
   return res;
}
inline ll inv(ll n) {return bigMod(n,MOD-2);}
inline ll Mul(ll a,ll b) {return (a*b)%MOD;}
inline ll Div(ll a,ll b) {return Mul(a,inv(b));}
/* 1 base row columun index */
struct Matrix{
    int row, col;
    ll m[MAX][MAX];
    Matrix() {memset(m,0,sizeof(m));}
    void Set(int r,int c) {row = r; col = c;}
    Matrix(int r,int c) {memset(m,0,sizeof(m)); Set(r,c);}
    void normalize(){
        for(int i=1; i<=row; i++){
            for(int j=1; j<=col; j++){
                m[i][j] %= MOD;
                if(m[i][j] < 0) m[i][j] += MOD;
            }
        }
    }
};
Matrix Multiply(Matrix A,Matrix B){
    Matrix ans(A.row,B.col);
    for(int i=1;i<=A.row;i++){
        for(int j=1;j<=B.col;j++){
            ans.m[i][j]=0;
            ll sm = 0;
            for(int k=1;k<=A.col;k++){
                sm+=(A.m[i][k]*B.m[k][j]);
                if(sm >= MOD2) sm -= MOD2;
            }
            ans.m[i][j] = sm % MOD;
        }
    }
    return ans;
}
Matrix Power(Matrix mat,ll p){
    Matrix res(mat.row , mat.col);
    Matrix ans(mat.row , mat.col);
    int n = ans.row;
    for(int i=1;i<=n;i++){
        for(int j=1;j<=n;j++){
            ans.m[i][j]=0;
            res.m[i][j]=mat.m[i][j];
        }
        ans.m[i][i]=1;
    }
    while(p){
        if(p&1) ans=Multiply(ans,res);
        res=Multiply(res,res);
        p=p/2;
    }
    return ans;
}
```

// Gaussian Elimination Offline

```
ll a[MAX], n; //0 base index
ll maxxor(){
    int r = 0; ll ret = 0;
    for(int c = 63; c >= 0; c--){
        int idx = -1;
        for(int i = r; i < n && idx < 0; i++)
            if(a[i] >> c & 1) idx = i;
        if(idx == -1) continue;
        swap(a[r], a[idx]);
        for(int i = 0; i < n; i++) if(i != r)
                if(a[i] >> c & 1) a[i] ^= a[r];
        r++;
    }
    for(int i = 0; i < n; i++) ret = max(ret, ret ^ a[i]);
    return ret;
}
```

Inclusion Exclusion:

```
/// koto gulo number ace[1,n] jara a1 or a2 or a3...,am dara divide
/// if m=3 and 3 values are a1,a2,a3 then
/// |a1 U a2 U a3|=|a1|+|a2|+|a3|-|a1 union a2|-|a2 union a3|-|a1 union a3|+|a1 union a2 union a3|
/// if number of cadidate is odd do add or do substract
/// time complexity 2^m.
/// for better perform use recusive
void func(int idx,int cnt,ll lcm){
    if(lcm>n)break;
    if(idx==m) {
        if(cnt==0)return;
        if(cnt & 1)re1+=n/lcm;
        else re1-=n/lcm;
        return;
    }
    func(idx+1,cnt+1,(lcm*ar[idx])/__gcd(lcm,(ll)ar[idx]));
    func(idx+1,cnt,lcm);
}
void solve(){
    scanf("%lld%d",&n,&m);
    for(int i=0;i<m;i++)scanf("%d",&ar[i]);
    ///using bitmask
    for(int i=1; i<(1<<m);i++) {
        ll lcm=1;
        int cnt=0;
        for(int j=0;j<m;j++) {
            if(i & (1<<j)) {
                cnt++;
                lcm=(lcm*ar[j])/__gcd(lcm,(ll)ar[j]);
                if(lcm>n)break;
            }
        }
        if(cnt&1)re+=n/lcm;
        else re-=n/lcm;
    }
}
```

Linear sieve:

```
bitset<mx>is_composite;
vector<int>prime;
int phi[mx],mobius[mx];
void seive(int n){
  phi[1]=mobius[1]=1;
  for(int i=2;i<=n;i++) {
   mobius[i]=1;
    if(!is_composite[i]){
      prime.push_back(i);
      phi[i]=i-1;           ///i is prime
    }
    for(int j=0;j<prime.size() && i*prime[j]<=n;j++)  {
      is_composite[i*prime[j]]=true;
      if(i%prime[j]==0) {
        phi[i*prime[j]]=phi[i]*prime[j];   ///prime[j] divides i
        break;
      }
      else {
        phi[i*prime[j]]=phi[i]*phi[prime[j]];  ///prime[j] do not
divide i
      }
    }
  }
  for(int val:prime) {
    int temp=val*val;
        if(temp>n)break;
    for(int j=temp;j<=n;j+=temp)mobius[j]=0;
  }
  for(int val:prime){
    for(int j=val;j<=n;j+=val)mobius[j]*=-1;
  }
}
```

Eulor totient:

```
int phi[mx];
void eulor_totient(int n){
  for(int i=2; i<=n; i++) phi[i]=i;
  for(int i=2;i<=n;i+=2) {
    phi[i]>>=1;
  }
  for(int i=3; i<=n; i+=2) {
    if(phi[i]==i) {
      phi[i]--;
      for(int j=2*i; j<=n; j+=i)
        phi[j]-=(phi[j]/i);
    }
  }
}
```

CRT:

```
ll ar[mx],br[mx];
struct GCD_type { ll x, y, d; };
GCD_type ex_GCD(ll a, ll b){
  if (b == 0) return {1, 0, a};
  GCD_type pom = ex_GCD(b, a % b);
  return {pom.y, pom.x - a / b * pom.y, pom.d};
}
ll normalize(ll val,ll mod){
 val%=mod;
  if(val<0)val+=mod;
  return val;
}
void solve(){
 ll ans=br[1]; /// here br remainder
 ll lcm=ar[1];
 bool f=true;
 for(int i=2;i<=n;i++) {
   auto pom=ex_GCD(lcm,ar[i]);
   ll x1=pom.x;
   ll d=pom.d;
   if((br[i]-ans)%d!=0){
     f=false;break;
   }
   ans=ans+x1*(br[i]-ans)/d%(ar[i]/d)*lcm;
   ans=normalize(ans,lcm*ar[i]/d);
   lcm=(lcm*ar[i])/__gcd(lcm,ar[i]);
 }
 if(f)printf("%lld %lld\n",ans,lcm);  /// here is the smallest
answer .next xth answer will be ans+x*lcm where x=[1,2,....]
}
```

Extended Euclidean (inverse):

```
int Extended_Euclidean(int a,int b,int &x,int &y)
{
        if(b==0){
                x=1;y=0;
                return a;
        }
        int d=Extended_Euclidean(b,a%b,y,x);
        y=y-(a/b)*x;
        return d;
}
int Inverse_Modulo(int a,int m){
        int x,y,d;
        d=Extended_Euclidean(a,m,x,y);
        if(d==1) return (x+m)%m;
        return -1; //No Solution
}
```

Big Mod, Fact:

```
ll bigmod(ll e,ll x){
  if(!x)return 1;
  ll p=bigmod(e,x/2);
  p=(p*p)%mod;
  if(x%2)p=(p*e)%mod;
  return p;
}
void fact_cal(){
  fact[0]=1,inv[0]=1;
  for(int i=1;i<=mx-3;i++){
    fact[i]=(fact[i-1]*i)%mod;
  }
  inv[mx-3]=bigmod(fact[mx-3],mod-2);
  for(int i=mx-4;i>=1;i--)inv[i]=(inv[i+1]*(i+1))%mod;
}
```

Stirling Number of 2nd kind:

```
ll dp[mx][mx];
ll func(int nn,int kk){
  if(kk==1)return 1;
  if(nn==kk)return 1;
  if(kk==0)return 0;
  ll &val=dp[nn][kk];
  if(val!=-1)return val;
  val=func(nn-1,kk-1)+1LL*kk*func(nn-1,kk);
  return val;
}
```

Pollard RHO:

```
#define pii pair<ll,int>
ll Mul(ll a,ll b,ll Mod){
 ll Ans=0;
  while(b){
    if(b&1) {Ans+=a; if(Ans>=Mod) Ans-=Mod;}
    a+=a; if(a>=Mod) a-=Mod;
    b>>=1;
  }
  return Ans;
}
ll bigMod(ll n,ll r,ll Mod){
  if(r==0) return 1LL;
  ll ret=bigMod(n,r/2,Mod);
  ret=Mul(ret,ret,Mod);
  if(r%2==1) ret=Mul(ret,n,Mod);
  return ret;
}
//Miller-Rabin
bool witness(ll wit,ll n){
 if(wit>=n) return false;
 int s=0; ll t=n-1;
 while(t%2==0) s++,t/=2;
 wit=bigMod(wit,t,n);
 if(wit==1 || wit==n-1) return false;
 for(int i=1;i<s;i++){
  wit=Mul(wit,wit,n);
  if(wit==1) return true;
  if(wit==n - 1) return false;
 }
 return true;
}
//Is n prime?
bool miller(ll n){
 if(n==2) return true;
 if(n%2==0 || n<2) return false;
 if(witness(2,n) || witness(7,n) || witness(61,n)) return false;
 return true;
}
// Pollard's Rho
// a must not equal 0 or -2.
// returns a divisor, a proper one when succeeded, equal to n if failed
// in case of failure, change a
ll rho(ll n,ll a) {
 auto f=[&](ll x) {return (Mul(x,x,n)+a)%n; };
 ll x=2,y=2;
 for(int i=1;;i++){
  x=f(x); y=f(f(y));
  ll d=__gcd(n,abs(x-y));
  if(d!=1) return d;
 }
 return n;
}
ll get_factor(ll n){
 if(n%2==0) return 2;
 if(n%3==0) return 3;
 if(n%5==0) return 5;
 while(true){
  ll a=2+rand()%100;
  ll d=rho(n,a);
  if(d!=n) return d;
 }
 return n;
}
void factorize(ll n,vector<ll> &x) {
 if(n==1) return;
 else if(miller(n)) x.push_back(n);
 else{
  ll d=get_factor(n);
  factorize(d,x);
  factorize(n/d,x);
 }
}
vector<ll>factorize(ll n) {vector<ll>x; factorize(n, x); return x;}
vector<pii>Factors; // store factor
vector<ll>Divisors;//strore divisors
void findDiv(int pos,ll val){
  if(pos<0) {Divisors.push_back(val); return;}
  ll Now=1;
  for(int i=0;i<=Factors[pos].second;i++){
    findDiv(pos-1,val*Now);
    Now=Now*Factors[pos].first;
  }
}
void findAllDiv(ll n){
  vector<ll>now=factorize(n);
  sort(now.begin(),now.end());
  Factors.clear();
  Divisors.clear();
  int Count=1;
  for(int i=1;i<now.size();i++){
    if(now[i]==now[i-1]) Count++;
    else {Factors.push_back({now[i-1],Count}); Count=1;}
  }
  Factors.push_back({now.back(),Count});
  findDiv(Factors.size()-1,1);
}
```

2D Geometry:

```
typedef double Tf;
typedef Tf Ti;     /// use long long for exactness
const Tf PI = acos(-1), EPS = 1e-9;
```

```
int dcmp(Tf x) { return abs(x) < EPS ? 0 : (x<0 ? -1 : 1);}
struct Point {
  Ti x, y;
  Point(Ti x = 0, Ti y = 0) : x(x), y(y) {}
  Point operator + (const Point& u) const { return Point(x + u.x, y
+ u.y); }
  Point operator - (const Point& u) const { return Point(x - u.x, y -
u.y); }
  Point operator * (const long long u) const { return Point(x * u, y
* u); }
  Point operator * (const Tf u) const { return Point(x * u, y * u); }
  Point operator / (const Tf u) const { return Point(x / u, y / u); }
  bool operator == (const Point& u) const { return dcmp(x - u.x)
== 0 && dcmp(y - u.y) == 0; }
  bool operator != (const Point& u) const { return !(*this == u); }
  bool operator < (const Point& u) const { return dcmp(x - u.x) <
0 || (dcmp(x - u.x) == 0 && dcmp(y - u.y) < 0); }
  friend istream &operator >> (istream &is, Point &p) { return is
>> p.x >> p.y; }
  friend ostream &operator << (ostream &os, const Point &p) {
return os << p.x << " " << p.y; }
};
Ti dot(Point a, Point b) { return a.x * b.x + a.y * b.y; }
Ti cross(Point a, Point b) { return a.x * b.y - a.y * b.x; }
Tf length(Point a) { return sqrt(dot(a, a)); }
Ti sqLength(Point a) { return dot(a, a); }
Tf distance(Point a, Point b) {return length(a-b);}
Tf angle(Point u) { return atan2(u.y, u.x); }
// returns angle between oa, ob in (-PI, PI]
Tf angleBetween(Point a, Point b) {
  double ans = angle(b) - angle(a);
  return ans <= -PI ? ans + 2*PI : (ans > PI ? ans - 2*PI : ans);
}
// Rotate a ccw by rad radians
Point rotate(Point a, Tf rad) {
  static_assert(is_same<Tf, Ti>::value);
  return Point(a.x * cos(rad) - a.y * sin(rad), a.x * sin(rad) + a.y *
cos(rad));
}
// rotate a ccw by angle th with cos(th) = co && sin(th) = si
Point rotatePrecise(Point a, Tf co, Tf si) {
  static_assert(is_same<Tf, Ti>::value);
  return Point(a.x * co - a.y * si, a.y * co + a.x * si);
}
Point rotate90(Point a) { return Point(-a.y, a.x); }
// scales vector a by s such that length of a becomes s
Point scale(Point a, Tf s) {
  static_assert(is_same<Tf, Ti>::value);
  return a / length(a) * s;
}
// returns an unit vector perpendicular to vector a
Point normal(Point a) {
  static_assert(is_same<Tf, Ti>::value);
  Tf l = length(a);
  return Point(-a.y / l, a.x / l);
```

```
}
// returns 1 if c is left of ab, 0 if on ab && -1 if right of ab
int orient(Point a, Point b, Point c) {
  return dcmp(cross(b - a, c - a));
}
bool half(Point p){      // returns true for point above x axis or on
negative x axis
  return p.y > 0 || (p.y == 0 && p.x < 0);
}
bool polarComp(Point p, Point q){  //to be used in sort()
function
  return make_tuple(half(p), 0) < make_tuple(half(q), cross(p,
q));}
struct Segment {
  Point a, b;
  Segment(Point aa, Point bb) : a(aa), b(bb) {}
};
typedef Segment Line;
struct Circle {
    Point o;
    Tf r;
    Circle(Point o = Point(0, 0), Tf r = 0) : o(o), r(r) {}
    // returns true if point p is in || on the circle
    bool contains(Point p) {
      return dcmp(sqLength(p - o) - r * r) <= 0;
    }
    // returns a point on the circle rad radians away from +X CCW
    Point point(Tf rad) {
      static_assert(is_same<Tf, Ti>::value);
      return Point(o.x + cos(rad) * r, o.y + sin(rad) * r);
    }
    // area of a circular sector with central angle rad
    Tf area(Tf rad = PI + PI) { return rad * r * r / 2; }
    // area of the circular sector cut by a chord with central angle
alpha
    Tf sector(Tf alpha) { return r * r * 0.5 * (alpha - sin(alpha)); }
};
namespace Linear {
  // returns true if point p is on segment s
  bool onSegment(Point p, Segment s) {
    return dcmp(cross(s.a - p, s.b - p)) == 0 && dcmp(dot(s.a - p,
s.b - p)) <= 0;
  }
  // returns true if segment p && q touch or intersect
  bool segmentsIntersect(Segment p, Segment q) {
    if(onSegment(p.a, q) || onSegment(p.b, q)) return true;
    if(onSegment(q.a, p) || onSegment(q.b, p)) return true;

    Ti c1 = cross(p.b - p.a, q.a - p.a);
    Ti c2 = cross(p.b - p.a, q.b - p.a);
    Ti c3 = cross(q.b - q.a, p.a - q.a);
    Ti c4 = cross(q.b - q.a, p.b - q.a);
    return dcmp(c1) * dcmp(c2) < 0 && dcmp(c3) * dcmp(c4) < 0;
  }
  bool linesParallel(Line p, Line q) {
    return dcmp(cross(p.b - p.a, q.b - q.a)) == 0;
  }
  // lines are represented as a ray from a point: (point, vector)
  // returns false if two lines (p, v) && (q, w) are parallel or
collinear
  // true otherwise, intersection point is stored at o via
reference
  bool lineLineIntersection(Point p, Point v, Point q, Point w,
Point& o) {
    static_assert(is_same<Tf, Ti>::value);
    if(dcmp(cross(v, w)) == 0) return false;
    Point u = p - q;
    o = p + v * (cross(w,u)/cross(v,w));
    return true;
  }
  // returns false if two lines p && q are parallel or collinear
  // true otherwise, intersection point is stored at o via
reference
  bool lineLineIntersection(Line p, Line q, Point& o) {
    return lineLineIntersection(p.a, p.b - p.a, q.a, q.b - q.a, o);
  }
  // returns the distance from point a to line l
  Tf distancePointLine(Point p, Line l) {
    return abs(cross(l.b - l.a, p - l.a) / length(l.b - l.a));
  }
  // returns the shortest distance from point a to segment s
  Tf distancePointSegment(Point p, Segment s) {
    if(s.a == s.b) return length(p - s.a);
    Point v1 = s.b - s.a, v2 = p - s.a, v3 = p - s.b;
    if(dcmp(dot(v1, v2)) < 0)     return length(v2);
    else if(dcmp(dot(v1, v3)) > 0)  return length(v3);
    else return abs(cross(v1, v2) / length(v1));
  }
  // returns the shortest distance from segment p to segment q
  Tf distanceSegmentSegment(Segment p, Segment q) {
    if(segmentsIntersect(p, q)) return 0;
    Tf ans = distancePointSegment(p.a, q);
    ans = min(ans, distancePointSegment(p.b, q));
    ans = min(ans, distancePointSegment(q.a, p));
    ans = min(ans, distancePointSegment(q.b, p));
    return ans;
  }
  // returns the projection of point p on line l
  Point projectPointLine(Point p, Line l) {
    static_assert(is_same<Tf, Ti>::value);
    Point v = l.b - l.a;
    return l.a + v * ((Tf) dot(v, p - l.a) / dot(v, v));
  }
}  // namespace Linear
typedef vector<Point> Polygon;
namespace Polygonal {
  // returns the signed area of polygon p of n vertices
  Tf signedPolygonArea(Polygon p) {
    Tf ret = 0;
    for(int i = 0; i < (int) p.size() - 1; i++)
      ret += cross(p[i]-p[0],  p[i+1]-p[0]);
    return ret / 2;
  }
  // given a polygon p of n vertices, generates the convex hull in
ch
  // in CCW && returns the number of vertices in the convex hull
  int convexHull(Polygon p, Polygon &ch) {
    sort(p.begin(), p.end());
    int n = p.size();
    ch.resize(n + n);
    int m = 0;    // preparing lower hull
    for(int i = 0; i < n; i++) {
      while(m > 1 && dcmp(cross(ch[m - 1] - ch[m - 2], p[i] - ch[m -
1])) <= 0) m--;
      ch[m++] = p[i];
    }
    int k = m;    // preparing upper hull
    for(int i = n - 2; i >= 0; i--) {
      while(m > k && dcmp(cross(ch[m - 1] - ch[m - 2], p[i] - ch[m -
2])) <= 0) m--;
      ch[m++] = p[i];
    }
    if(n > 1) m--;
    ch.resize(m);
    return m;
  }
  // for a point o and polygon p returns:
  //   -1 if o is strictly inside p
  //  0 if o is on a segment of p
  //  1 if o is strictly outside p
  // computes via winding numbers
  int pointInPolygon(Point o, Polygon p) {
    using Linear::onSegment;
    int wn = 0, n = p.size();
    for(int i = 0; i < n; i++) {
      int j = (i + 1) % n;
      if(onSegment(o, Segment(p[i], p[j])) || o == p[i]) return 0;
      int k = dcmp(cross(p[j] - p[i], o - p[i]));
      int d1 = dcmp(p[i].y - o.y);
      int d2 = dcmp(p[j].y - o.y);
      if(k > 0 && d1 <= 0 && d2 > 0) wn++;
      if(k < 0 && d2 <= 0 && d1 > 0) wn--;
    }
    return wn ? -1 : 1;
  }
  // returns the longest line segment of l that is inside or on the
  // simply polygon p. O(n lg n). TESTED: TIMUS 1955
  Tf longestSegInPoly(Line l, const Polygon &p) {
    using Linear::lineLineIntersection;
    int n = p.size();
    vector<pair<Tf, int>> ev;
    for(int i=0; i<n; ++i) {
      Point a = p[i], b = p[(i + 1) % n], z = p[(i - 1 + n) % n];
      int ora = orient(l.a, l.b, a), orb = orient(l.a, l.b, b), orz =
orient(l.a, l.b, z);
```

```
     if(!ora) {
       Tf d = dot(a - l.a, l.b - l.a);
       if(orz && orb) {
         if(orz != orb) ev.emplace_back(d, 0);
       }
       else if(orz) ev.emplace_back(d, orz);
       else if(orb) ev.emplace_back(d, orb);
     }
     else if(ora == -orb) {
       Point ins;
       lineLineIntersection(l, Line(a, b), ins);
       ev.emplace_back(dot(ins - l.a, l.b - l.a), 0);
     }  }
   sort(ev.begin(), ev.end());
   Tf ret = 0, cur = 0, pre = 0;
   bool active = false;
   int sign = 0;
   for(auto &qq : ev) {
     int tp = qq.second;
     Tf d = qq.first;
     if(sign) {
       cur += d - pre;
       ret = max(ret, cur);
       if(tp != sign) active = !active;
       sign = 0;
     }
     else {
       if(active) cur += d - pre, ret = max(ret, cur);
       if(tp == 0) active = !active;
       else sign = tp;
     }
     pre = d;
     if(!active) cur = 0;
   }
   ret /= length(l.b - l.a);
   return ret;
  }
}  // namespace Polygonal
namespace Convex {
  ///Tested on Kattis::fenceortho
  void rotatingCalipersGetRectangle(Point* p, int n, Tf& area,
Tf& perimeter) {
    using Linear::distancePointLine;
    static_assert(is_same<Tf, Ti>::value);
    p[n] = p[0];
    int l = 1, r = 1, j = 1;
    area = perimeter = 1e100;

    for(int i = 0; i < n; i++) {
      Point v = (p[i + 1] - p[i]) / length(p[i + 1] - p[i]);
      while(dcmp(dot(v, p[r % n] - p[i]) - dot(v, p[(r + 1) % n] - p[i]))
< 0) r++;
      while(j < r || dcmp(cross(v, p[j % n] - p[i]) - cross(v, p[(j + 1)
% n] - p[i])) < 0) j++;
      while(l < j || dcmp(dot(v, p[l % n] - p[i]) - dot(v, p[(l + 1) % n]
- p[i])) > 0) l++;
      Tf w = dot(v, p[r % n] - p[i]) - dot(v, p[l % n] - p[i]);
      Tf h = distancePointLine(p[j % n], Line(p[i], p[i + 1]));
      area = min(area, w * h);
      perimeter = min(perimeter, 2 * w + 2 * h);
    }  }
  // returns the left side of polygon u after cutting it by ray a->b
  Polygon cutPolygon(Polygon u, Point a, Point b) {
    using Linear::lineLineIntersection, Linear::onSegment;
    Polygon ret;
    int n = u.size();
    for(int i = 0; i < n; i++) {
      Point c = u[i], d = u[(i + 1) % n];
      if(dcmp(cross(b-a, c-a)) >= 0) ret.push_back(c);
      if(dcmp(cross(b-a, d-c)) != 0) {
        Point t;
        lineLineIntersection(a, b - a, c, d - c, t);
        if(onSegment(t, Segment(c, d))) ret.push_back(t);
      } }
    return ret;
  }
  // returns true if point p is in or on triangle abc
  bool pointInTriangle(Point a, Point b, Point c, Point p) {
    return dcmp(cross(b - a, p - a)) >= 0
      && dcmp(cross(c - b, p - b)) >= 0
      && dcmp(cross(a - c, p - c)) >= 0;
  }
  // pt must be in ccw order with no three collinear points
  // returns inside = -1, on = 0, outside = 1
  int pointInConvexPolygon(const Polygon &pt, Point p) {
    int n = pt.size();
    assert(n >= 3);
    int lo = 1, hi = n - 1;
    while(hi - lo > 1) {
      int mid = (lo + hi) / 2;
      if(dcmp(cross(pt[mid] - pt[0], p - pt[0])) > 0) lo = mid;
      else  hi = mid;
    }
    bool in = pointInTriangle(pt[0], pt[lo], pt[hi], p);
    if(!in) return 1;
    if(dcmp(cross(pt[lo] - pt[lo - 1], p - pt[lo - 1])) == 0) return 0;
    if(dcmp(cross(pt[hi] - pt[lo], p - pt[lo])) == 0) return 0;
    if(dcmp(cross(pt[hi] - pt[(hi + 1) % n], p - pt[(hi + 1) % n])) ==
0) return 0;
    return -1;
  }
  // Extreme Point for a direction is the farthest point in that
direction
  // poly is a convex polygon, sorted in CCW, doesn't contain
redundant points
  // u is the direction for extremeness
  int extremePoint(const Polygon &poly, Point u = Point(0, 1)) {
    int n = (int) poly.size();
    int a = 0, b = n;
    while(b - a > 1) {
      int c = (a + b) / 2;
      if(dcmp(dot(poly[c] - poly[(c + 1) % n], u)) >= 0 &&
dcmp(dot(poly[c] - poly[(c - 1 + n) % n], u)) >= 0) {
        return c;
      }
      bool a_up = dcmp(dot(poly[(a + 1) % n] - poly[a], u)) >= 0;
      bool c_up = dcmp(dot(poly[(c + 1) % n] - poly[c], u)) >= 0;
      bool a_above_c = dcmp(dot(poly[a] - poly[c], u)) > 0;
      if(a_up && !c_up) b = c;
      else if(!a_up && c_up) a = c;
      else if(a_up && c_up) {
        if(a_above_c) b = c;
        else a = c;
      }
      else {
        if(!a_above_c) b = c;
        else a = c;
      } }
    if(dcmp(dot(poly[a] - poly[(a + 1) % n], u)) > 0 &&
dcmp(dot(poly[a] - poly[(a - 1 + n) % n], u)) > 0)
      return a;
    return b % n;
  }
  // For a convex polygon p and a line l, returns a list of
segments
  // of p that are touch or intersect line l.
  // the i'th segment is considered (p[i], p[(i + 1) modulo |p|])
  // #1 If a segment is collinear with the line, only that is
returned
  // #2 Else if l goes through i'th point, the i'th segment is added
  // If there are 2 or more such collinear segments for #1,
  // any of them (only one, not all) should be returned (not
tested)
  // Complexity: O(lg |p|)
  vector<int> lineConvexPolyIntersection(const Polygon &p, Line
l) {
    assert((int) p.size() >= 3);
    assert(l.a != l.b);
    int n = p.size();
    vector<int> ret;
    Point v = l.b - l.a;
    int lf = extremePoint(p, rotate90(v));
    int rt = extremePoint(p, rotate90(v) * Ti(-1));
    int olf = orient(l.a, l.b, p[lf]);
    int ort = orient(l.a, l.b, p[rt]);
    if(!olf || !ort) {
      int idx = (!olf ? lf : rt);
      if(orient(l.a, l.b, p[(idx - 1 + n) % n]) == 0)
        ret.push_back((idx - 1 + n) % n);
      else  ret.push_back(idx);
      return ret;
    }
    if(olf == ort) return ret;
    for(int i=0; i<2; ++i) {
      int lo = i ? rt : lf;
      int hi = i ? lf : rt;
      int olo = i ? ort : olf;
      while(true) {
        int gap = (hi - lo + n) % n;
        if(gap < 2) break;
        int mid = (lo + gap / 2) % n;
        int omid = orient(l.a, l.b, p[mid]);
        if(!omid) {
          lo = mid;
          break;
        }
        if(omid == olo) lo = mid;
        else hi = mid;
      }
      ret.push_back(lo);
    }
    return ret;
  }
  // Calculate [ACW, CW] tangent pair from an external point
  constexpr int CW = -1, ACW = 1;
  bool isGood(Point u, Point v, Point Q, int dir) { return orient(Q,
u, v) != -dir; }
  Point better(Point u, Point v, Point Q, int dir) { return orient(Q,
u, v) == dir ? u : v; }
  Point pointPolyTangent(const Polygon &pt, Point Q, int dir, int
lo, int hi) {
    while(hi - lo > 1) {
      int mid = (lo + hi) / 2;
      bool pvs = isGood(pt[mid], pt[mid - 1], Q, dir);
      bool nxt = isGood(pt[mid], pt[mid + 1], Q, dir);
      if(pvs && nxt) return pt[mid];
      if(!(pvs || nxt)) {
        Point p1 = pointPolyTangent(pt, Q, dir, mid + 1, hi);
        Point p2 = pointPolyTangent(pt, Q, dir, lo, mid - 1);
        return better(p1, p2, Q, dir);
      }
      if(!pvs) {
        if(orient(Q, pt[mid], pt[lo]) == dir)        hi = mid - 1;
        else if(better(pt[lo], pt[hi], Q, dir) == pt[lo])   hi = mid - 1;
        else  lo = mid + 1;
      }
      if(!nxt) {
        if(orient(Q, pt[mid], pt[lo]) == dir)        lo = mid + 1;
        else if(better(pt[lo], pt[hi], Q, dir) == pt[lo])   hi = mid - 1;
        else  lo = mid + 1;
      }
    }
    Point ret = pt[lo];
    for(int i = lo + 1; i <= hi; i++) ret = better(ret, pt[i], Q, dir);
    return ret;
  }
  // [ACW, CW] Tangent
  pair<Point, Point> pointPolyTangents(const Polygon &pt, Point
Q) {
    int n = pt.size();
    Point acw_tan = pointPolyTangent(pt, Q, ACW, 0, n - 1);
    Point cw_tan = pointPolyTangent(pt, Q, CW, 0, n - 1);
    return make_pair(acw_tan, cw_tan);
  }
}
namespace Circular {
  // Extremely inaccurate for finding near touches
  // compute intersection of line l with circle c
  // The intersections are given in order of the ray (l.a, l.b)
  vector<Point> circleLineIntersection(Circle c, Line l) {
    static_assert(is_same<Tf, Ti>::value);
    vector<Point> ret;
    Point b = l.b - l.a, a = l.a - c.o;
    Tf A = dot(b, b), B = dot(a, b);
    Tf C = dot(a, a) - c.r * c.r, D = B*B - A*C;
    if (D < -EPS) return ret;
    ret.push_back(l.a + b * (-B - sqrt(D + EPS)) / A);
    if (D > EPS)
      ret.push_back(l.a + b * (-B + sqrt(D)) / A);
    return ret;
  }
  // signed area of intersection of circle(c.o, c.r) &&
  // triangle(c.o, s.a, s.b) [cross(a-o, b-o)/2]
  Tf circleTriangleIntersectionArea(Circle c, Segment s) {
    using Linear::distancePointSegment;
    Tf OA = length(c.o - s.a);
    Tf OB = length(c.o - s.b);
    // sector
    if(dcmp(distancePointSegment(c.o, s) - c.r) >= 0)
      return angleBetween(s.a-c.o, s.b-c.o) * (c.r * c.r) / 2.0;
    // triangle
    if(dcmp(OA - c.r) <= 0 && dcmp(OB - c.r) <= 0)
      return cross(c.o - s.b, s.a - s.b) / 2.0;
    // three part: (A, a) (a, b) (b, B)
    vector<Point> Sect = circleLineIntersection(c, s);
    return circleTriangleIntersectionArea(c, Segment(s.a, Sect[0]))
      + circleTriangleIntersectionArea(c, Segment(Sect[0], Sect[1]))
      + circleTriangleIntersectionArea(c, Segment(Sect[1], s.b));
  }
  // area of intersecion of circle(c.o, c.r) && simple polyson(p[])
  // Tested : https://codeforces.com/gym/100204/problem/F -
Little Mammoth
  Tf circlePolyIntersectionArea(Circle c, Polygon p) {
    Tf res = 0;
    int n = p.size();
    for(int i = 0; i < n; ++i)
      res += circleTriangleIntersectionArea(c, Segment(p[i], p[(i +
1) % n]));
    return abs(res);
  }
  // locates circle c2 relative to c1
  // interior       (d < R - r)      ----> -2
  // interior tangents (d = R - r)      ----> -1
  // concentric     (d = 0)
  // secants        (R - r < d < R + r) ---->  0
  // exterior tangents (d = R + r)      ---->  1
  // exterior       (d > R + r)      ---->  2
  int circleCirclePosition(Circle c1, Circle c2) {
    Tf d = length(c1.o - c2.o);
    int in = dcmp(d - abs(c1.r - c2.r)), ex = dcmp(d - (c1.r + c2.r));
    return in < 0 ? -2 : in == 0 ? -1 : ex == 0 ? 1 : ex > 0 ? 2 : 0;
  }
  // compute the intersection points between two circles c1 &&
c2
  vector<Point> circleCircleIntersection(Circle c1, Circle c2) {
    static_assert(is_same<Tf, Ti>::value);
    vector<Point> ret;
    Tf d = length(c1.o - c2.o);
    if(dcmp(d) == 0) return ret;
    if(dcmp(c1.r + c2.r - d) < 0) return ret;
    if(dcmp(abs(c1.r - c2.r) - d) > 0) return ret;
    Point v = c2.o - c1.o;
    Tf co = (c1.r * c1.r + sqLength(v) - c2.r * c2.r) / (2 * c1.r *
length(v));
    Tf si = sqrt(abs(1.0 - co * co));
    Point p1 = scale(rotatePrecise(v, co, -si), c1.r) + c1.o;
    Point p2 = scale(rotatePrecise(v, co, si), c1.r) + c1.o;
    ret.push_back(p1);
    if(p1 != p2) ret.push_back(p2);
    return ret;
  }
  // intersection area between two circles c1, c2
  Tf circleCircleIntersectionArea(Circle c1, Circle c2) {
    Point AB = c2.o - c1.o;
    Tf d = length(AB);
    if(d >= c1.r + c2.r) return 0;
    if(d + c1.r <= c2.r) return PI * c1.r * c1.r;
    if(d + c2.r <= c1.r) return PI * c2.r * c2.r;
    Tf alpha1 = acos((c1.r * c1.r + d * d - c2.r * c2.r) / (2.0 * c1.r *
d));
    Tf alpha2 = acos((c2.r * c2.r + d * d - c1.r * c1.r) / (2.0 * c2.r *
d));
    return c1.sector(2 * alpha1) + c2.sector(2 * alpha2);
  }
  // returns tangents from a point p to circle c
  vector<Point> pointCircleTangents(Point p, Circle c) {
    static_assert(is_same<Tf, Ti>::value);
    vector<Point> ret;
    Point u = c.o - p;
    Tf d = length(u);
    if(d < c.r) ;
    else if(dcmp(d - c.r) == 0) {
      ret = { rotate(u, PI / 2) };
    }
    else {
      Tf ang = asin(c.r / d);
      ret = { rotate(u, -ang), rotate(u, ang) };
    }return ret; }
  // returns the points on tangents that touches the circle
```

```
 vector<Point> pointCircleTangencyPoints(Point p, Circle c) {
  static_assert(is_same<Tf, Ti>::value);
  Point u = p - c.o;
  Tf d = length(u);
  if(d < c.r) return {};
  else if(dcmp(d - c.r) == 0)   return {c.o + u};
  else {
   Tf ang = acos(c.r / d);
   u = u / length(u) * c.r;
   return { c.o + rotate(u, -ang), c.o + rotate(u, ang) };
  }
 }
 // for two circles c1 && c2, returns two list of points a && b
 // such that a[i] is on c1 && b[i] is c2 && for every i
 // Line(a[i], b[i]) is a tangent to both circles
 // CAUTION: a[i] = b[i] in case they touch | -1 for c1 = c2
 int circleCircleTangencyPoints(Circle c1, Circle c2,
vector<Point> &a, vector<Point> &b) {
  a.clear(), b.clear();
  int cnt = 0;
  if(dcmp(c1.r - c2.r) < 0) {
   swap(c1, c2); swap(a, b);
  }
  Tf d2 = sqLength(c1.o - c2.o);
  Tf rdif = c1.r - c2.r, rsum = c1.r + c2.r;
  if(dcmp(d2 - rdif * rdif) < 0) return 0;
  if(dcmp(d2) == 0 && dcmp(c1.r - c2.r) == 0) return -1;
  Tf base = angle(c2.o - c1.o);
  if(dcmp(d2 - rdif * rdif) == 0) {
   a.push_back(c1.point(base));
   b.push_back(c2.point(base));
   cnt++;
   return cnt; }
  Tf ang = acos((c1.r - c2.r) / sqrt(d2));
  a.push_back(c1.point(base + ang));
  b.push_back(c2.point(base + ang));
  cnt++;
  a.push_back(c1.point(base - ang));
  b.push_back(c2.point(base - ang));
  cnt++;
  if(dcmp(d2 - rsum * rsum) == 0) {
   a.push_back(c1.point(base));
   b.push_back(c2.point(PI + base));
   cnt++;
  }
  else if(dcmp(d2 - rsum * rsum) > 0) {
   Tf ang = acos((c1.r + c2.r) / sqrt(d2));
   a.push_back(c1.point(base + ang));
   b.push_back(c2.point(PI + base + ang));
   cnt++;
   a.push_back(c1.point(base - ang));
   b.push_back(c2.point(PI + base - ang));
   cnt++;}
  return cnt;
 }}
```

```
// Given a bunch of segments. Check if any two intersect.
// Sweep Line. O(n lg n). TESTED: CF 1359F
namespace IntersectingSegments {
 Tf yvalSegment(const Line &s, Tf x) {
  if(dcmp(s.a.x - s.b.x) == 0) return s.a.y;
  return s.a.y + (s.b.y - s.a.y) * (x - s.a.x) / (s.b.x - s.a.x);
 }
 struct SegCompare {
  bool operator () (const Segment &p, const Segment &q) const
{
   Tf x = max(min(p.a.x, p.b.x), min(q.a.x, q.b.x));
   return dcmp(yvalSegment(p, x) - yvalSegment(q, x)) < 0;
  }  };
 multiset<Segment, SegCompare> st;
 typedef multiset<Segment, SegCompare>::iterator iter;
 iter prev(iter it) {
  return it == st.begin() ? st.end() : --it;
 }
 iter next(iter it) {
  return it == st.end() ? st.end() : ++it;}
 struct Event {
  Tf x; int tp, id;
  Event(Ti x, int tp, int id) : x(x), tp(tp), id(id) { }
  bool operator < (const Event &p) const {
   if(dcmp(x - p.x)) return x < p.x;
   return tp > p.tp;
  }};
 bool anyIntersection(const vector<Segment> &v) {
  using Linear::segmentsIntersect;
  vector<Event> ev;
  for(int i=0; i<(int) v.size(); ++i) {
   ev.push_back(Event(min(v[i].a.x, v[i].b.x), +1, i));
   ev.push_back(Event(max(v[i].a.x, v[i].b.x), -1, i));
  }
  sort(ev.begin(), ev.end());
  st.clear();
  vector<iter> where(v.size());
  for(auto &cur : ev) {
   int id = cur.id;
   if(cur.tp == 1) {
    iter nxt = st.lower_bound(v[id]);
    iter pre = prev(nxt);
    if(pre != st.end() && segmentsIntersect(*pre, v[id]))   return
true;
    if(nxt != st.end() && segmentsIntersect(*nxt, v[id]))   return
true;
    where[id] = st.insert(nxt, v[id]); }
   else {
    iter nxt = next(where[id]);
    iter pre = prev(where[id]);
    if(pre != st.end() && nxt != st.end() &&
segmentsIntersect(*pre, *nxt))
     return true;
    st.erase(where[id]);  } }
  return false; }}}}
```

// **Ashik's extra formula**

inner circle radius, r = area * s
outer circle area, A = (abc)/4R

BitMask:

```
ll Set(ll N,ll pos)  return N=N|(1LL<<pos);
ll Reset(ll N,ll pos)  return N=N & ~(1LL<<pos);
bool chk(ll N,ll pos) return (bool)(N &(1LL<<pos));
///int id= __builtin_ctz(mask); its give the position of the first one from the left
/// int tot= __builtin_popcount(mask); number of one bit .
```

Digit Dp All digit sum:

```
ll dp[15][2][400][2];
const ll mpos=11;
char ch[40];
void convert(ll n){
   for(ll i=0; i<mpos; i++){
      ch[i]=(n%10)+'0';
      n/=10;
   }
   reverse(ch,ch+mpos);
   ch[mpos]=0;
}
ll func(ll pos,ll smallornot,ll digitvalcnt,ll startornot){
   if(pos==mpos)
      return digitvalcnt;
   if(dp[pos][smallornot][digitvalcnt][startornot]!=-1)
      return dp[pos][smallornot][digitvalcnt][startornot];
   ll be=0, en=9,re=0;
   if(!smallornot)
      en=ch[pos]-'0';
   for(ll i=be; i<=en; i++)
   {
      ll ismallornot= smallornot | (i<en);
      ll idigitvalcnt=digitvalcnt+ i;
      ll istartornot= startornot | (i!=0);
      re+=func(pos+1,ismallornot,idigitvalcnt,istartornot);
   }
   return dp[pos][smallornot][digitvalcnt][startornot]=re;
}
func(0,0,0,0);
```

SOS DP:

```
memset(dp,-1,sizeof(dp));
for(int i=1;i<=n;i++){
            scanf("%d",&ar[i]);
            dp[ar[i]]=ar[i];
}
for(int i=0;i<22;i++){
for(int mask=0;mask<(1<<22);mask++){
if(chk(mask,i))dp[mask]=max(dp[mask],dp[mask^(1<<i)]);
            }
}
int boro=(1<<22)-1;
for(int i=1;i<=n;i++){
            printf("%d ",dp[boro^ar[i]]);
}
```

```
/* iterate all the submask of a mask
for(int mask=1;mask<(1<<sz);mask++) {
      int tmask=mask&(mask-1);
      while(tmask) {
         cout<<tmask<<endl;
        // dp[mask]=min(dp[mask],dp[tmask]+dp[mask^tmask]);
         tmask=(tmask-1)&mask;
      }
   }*/
```

Combinatorics Notes:

///0*nC0+1*nC1+2*nC2+3*nC3+.....+n*nCn=n*2^(n-1).
///0Cr+1Cr+2Cr+3Cr+4Cr+5Cr+6Cr+....+nCr= (n+1)C(r+1)
///(nC0)^2+(nC1)^2+(nC2)^2+....+(nCn)^2=(2*n)Cn
///how many ways you can go to (0,0) to (n,m) coordinate(you can only up and right).
like n=2,m=3,so = 5!/(2!*3!)
if there are more than two dimensions you will do just total moves time! / (x axis moves times!* y axis moves time! *.....)
///you have n balls k bucket # of ways insert the ball into bucket such that every bucket has more than 0 balls
total ways is (n-1)C(k-1).
modification , any numbers of ball then answer is,(n+k-1)C(k-1)
modification , per bucket condition 0<=k_i<x_i
for 0<=k_i, RESULT1 =(n+k-1)C(k-1)
for k_i>=x_i, val_i=kCi*(n-i*x_i+k-1)C(k-1)
RESULT2 = ((-k)^1)*val_1+((-k)^2)*val_2+((-k)^1)*val_3+.....((-k)^k)*val_k
[But some time we have not calculated overall val1 to valk ,Because (n-(x*kth)+k-1) will be <0]
Final result=RESULT1-RESULT2
///catalan number Cn=(1/(n+1))*((2*n)Cn)
In other form Cn=((2*n)C(n))-((2*n)C(n+1))

Bitset:

```
bitset<mx>bt;
bt.set() /// all bit 1
bt.reset() ///all bit 0
bt.count() // total number of 1 bit
bt._Find_first() // palce of the first 1 bit
bt._Find_next() // next one bit
for(int i=bt._Find_first();i<mx;i=bt._Find_next()) // for traversing all 1 node
```

Iterative Stack:

```
template<typename T, typename Container = std::deque<T>>
class iterable_stack
: public std::stack<T, Container>
{
   using std::stack<T, Container>::c;
public:
   auto begin() { return std::begin(c); }
   auto end() { return std::end(c); }

   auto begin() const { return std::begin(c); }
   auto end() const { return std::end(c); }
};
 iterable_stack<int> st;
```

```
    st.push(2);
    for(auto i: st)
    std::cout << i << ' ';
```

PBDS:

```
#include <ext/pb_ds/assoc_container.hpp>
#include <ext/pb_ds/tree_policy.hpp>
using    namespace __gnu_pbds;
typedef tree<int, null_type, less<int>, rb_tree_tag,
tree_order_statistics_node_update> ordered_set;
solve(){
    ordered_set os;
    // 10. how many numbers are smaller than a given value(7)
    cout << os.order_of_key(7);
    // 12. how many numbers are greater than a given value(7)
    cout << os.size() - os.order_of_key(8) << "\n";
    // 14. if the given numbers are sorted in ascending order,
what is the k'th number
    cout << *os.find_by_order(2) << "\n";
    // 16. delete the k'th smallest number
    os.erase(os.find_by_order(k));
    // 22. what is the smallest number which is greater than or
equal to a given number(7)
    cout << *os.lower_bound(7) << "\n";
    // 23. what is the smallest number which is greater than to a
given number(7)
    cout << *os.upper_bound(7) << "\n";
}
```

Ashraful's Template:

```
s.sh:
for((i=1;i<100;i++));do
            ./gen $i>int
            ./a<int>out1
            ./brute<int>out2
            diff out1 out2 || break
Done
gen.cpp:
mt19937_64
rng(chrono::steady_clock::now().time_since_epoch().count());
ll my_rand(ll l, ll r) {
    return uniform_int_distribution<ll>(l, r) (rng);
}
```

Ashik's Fast I/O:

```
#define faster_io
ios_base::sync_with_stdio(0);cin.tie(0);cout.tie(0);
#define watch2(x,y) cout<< _LINE_ << " says: " <<#x<<" =
"<<x<<" "<<#y<<" = "<<y <<endl
freopen("input.txt","r",stdin); ("output.txt","w",stdout);
```

BIG Integer:

```
import static java.lang.System.in;
import java.util.Scanner;
import java.math.BigInteger;
public class Main {
    public static void main(String[] args)  {
        Scanner in = new Scanner(System.in);
        int n;
        n = in.nextInt();
        BigInteger ci;
        ci = new BigInteger("1");
        //BigInteger b = in.nextBigInteger();
        //BigInteger carry;
        //carry = (a.multiply(b)).divide(a.gcd(b));
        for(int i=1; i<=n + 1; i++)   {
            int temp = 4 * (i + 1) - 6;
            BigInteger tem = BigInteger.valueOf(temp);
            ci = ci.multiply(tem);
            ci = ci.divide(BigInteger.valueOf(i+1));
        }
        System.out.println(ci);
    }
}
```

De-arrangement:

d(n)=(n−1)·(d(n−1)+d(n−2))whered(0)=1,d(1)=0

Fibonacchi:

Fn=15–√(1+5–√2)n−15–√(1−5–√2)n

GCD:

159. $\gcd(a,b)\cdot \operatorname{lcm}(a,b) = |a{\cdot}b|$

160. $\gcd(a, \operatorname{lcm}(b,c)) = \operatorname{lcm}(\gcd(a,b), \gcd(a,c))$.

161. $\operatorname{lcm}(a, \gcd(b,c)) = \gcd(\operatorname{lcm}(a,b), \operatorname{lcm}(a,c))$.

162. For non-negative integers a and b, where a and b are not both zero, $\gcd(n^a-1, n^b-1) = n^{\gcd(a,b)} - 1$

163. $\gcd(a,b) = \sum\limits_{k|a \text{ and } k|b} \phi(k)$

164. $\sum\limits_{i=1}^{n}[\gcd(i,n)=k] = \phi\left(\frac{n}{k}\right)$

165. $\sum\limits_{k=1}^{n}\gcd(k,n) = \sum\limits_{d|n} d\cdot\phi\left(\frac{n}{d}\right)$

166. $\sum\limits_{k=1}^{n} x^{\gcd(k,n)} = \sum\limits_{d|n} x^d\cdot\phi\left(\frac{n}{d}\right)$

167. $\sum\limits_{k=1}^{n}\frac{1}{\gcd(k,n)} = \sum\limits_{d|n}\frac{1}{d}\cdot\phi\left(\frac{n}{d}\right) = \frac{1}{n}\sum\limits_{d|n} d\cdot\phi(d)$

168. $\sum\limits_{k=1}^{n}\frac{k}{\gcd(k,n)} = \frac{n}{2}\cdot\sum\limits_{d|n}\frac{1}{d}\cdot\phi\left(\frac{n}{d}\right) = \frac{n}{2}\cdot\frac{1}{n}\cdot\sum\limits_{d|n} d\cdot\phi(d)$

169. $\sum\limits_{k=1}^{n}\frac{n}{\gcd(k,n)} = 2*\sum\limits_{k=1}^{n}\frac{k}{\gcd(k,n)} - 1$, for $n > 1$

170. $\sum\limits_{i=1}^{n}\sum\limits_{j=1}^{n}[\gcd(i,j)=1] = \sum\limits_{d=1}^{n}\mu(d)\lfloor\frac{n}{d}\rfloor^2$

171. $\sum\limits_{i=1}^{n}\sum\limits_{j=1}^{n}\gcd(i,j) = \sum\limits_{d=1}^{n}\phi(d)\lfloor\frac{n}{d}\rfloor^2$

172. $\sum\limits_{i=1}^{n}\sum\limits_{j=1}^{n} i\cdot j[\gcd(i,j)=1] = \sum\limits_{i=1}^{n}\phi(i)i^2$

173. $F(n) = \sum\limits_{i=1}^{n}\sum\limits_{j=1}^{n}\operatorname{lcm}(i,j) = \sum\limits_{l=1}^{n}\left(\frac{\left(1+\lfloor\frac{n}{l}\rfloor\right)\left(\lfloor\frac{n}{l}\rfloor\right)}{2}\right)^2\sum\limits_{d|l}\mu(d)ld$

174. $\gcd(\operatorname{lcm}(a,b), \operatorname{lcm}(b,c), \operatorname{lcm}(a,c)) = \operatorname{lcm}(\gcd(a,b), \gcd(b,c), \gcd(a,c))$

175. $\gcd(A_L, A_{L+1}, \ldots, A_R) = \gcd(A_L, A_{L+1}-A_L, \ldots, A_R - A_{R-1})$.'

176. Given n, If $SUM = LCM(1,n) + LCM(2,n) + \ldots + LCM(n,n)$
then SUM = $\frac{n}{2}(\sum\limits_{d|n}(\phi(d)\times d) + 1$

/* Good Luck Ashik, Selim, Ashraful */