

# Contents

<b>1 Basic</b>	<b>1</b>
1.1 .vimrc	1
1.2 IncreaseStackSize	1
1.3 Default Code	1
<b>2 Data Structure</b>	<b>2</b>
2.1 Bigint	2
2.2 Leftist Heap	2
2.3 unordered_map	2
2.4 extc_balance_tree	3
2.5 Treap	3
2.6 Heavy Light Decomposition	3
<b>3 Graph</b>	<b>4</b>
3.1 Tarjan	4
3.2 Strongly Connected Components	4
3.3 DMST_with_sol	5
3.4 Maximum Clique	5
3.5 (+1) MinimumMeanCycle	6
<b>4 Flow</b>	<b>6</b>
4.1 ISAP	6
4.2 Dinic	6
4.3 Bipartite Matching (Augmenting Path)	7
4.4 Kuhn Munkres	7
4.5 SW-Mincut	7
4.6 Maximum Simple Graph Matching	8
4.7 2-Commodity Flow	8
4.8 (+1) SW-mincut $O(NM)$	9
<b>5 Math</b>	<b>10</b>
5.1 ax+by=gcd	10
5.2 Chinese Remainder	10
5.3 Fast Fourier Transform	10
5.4 (+1) ntt	11
5.5 Mod	11
5.6 (+1) Miller Rabin	12
5.7 (+1) Pollard Rho	12
5.8 Primes	12
5.9 (+1) PolynomialGenerator	12
5.10 Gauss Elimination	12
5.11 Simplex	12
5.12 Theorem	13
<b>6 Geometry</b>	<b>13</b>
6.1 Point operators	13
6.2 Intersection of two circles	13
6.3 Intersection of two lines	13
6.4 Half Plane Intersection	13
6.5 Point Class	14
6.6 Convex Hull	15
6.7 Minimum Covering Circle	15
6.8 (+1) KDTreeAndNearestPoint	15
6.9 (+1) MinkowskiSum	16
<b>7 Stringology</b>	<b>16</b>
7.1 Suffix Array	16
7.2 Suffix Array (SAIS TWT514)	17
7.3 Aho-Corasick Algorithm	17
7.4 Z value	18
7.5 Z value (palindrome ver.)	18
7.6 Lexicographically Smallest Rotation	18
7.7 Suffix Automaton	18
<b>8 Problems</b>	<b>19</b>
8.1 Find the maximum tangent (x,y is increasing)	19
8.2 Orange Protection	19

## 1 Basic

### 1.1 .vimrc

```

1 colo torte
1 syn on
2 se cin ai ar sm nu ru is
2 se mouse=a bs=2 ww+=<,>[,] so=6 ts=4 sw=4 ttm=100
2 se makeprg=g++\ -Wall\ -Wshadow\ -O2\ -std=c++0x\ -o\
3 %<\ %
3 au BufNewFile *.cpp 0r ~/default.cpp
4
4 map <F7> <ESC>:wa<CR>:make!<CR>
4 imap <F7> <ESC>:wa<CR>:make!<CR>
4 map <C-F7> <ESC>:tabe %<.in<CR>
5 map <F8> :cope <CR>
5 map <S-F8> :ccl <CR>
6 map <F9> :!./%< <CR>
6 map <C-F9> :!./%< < %<.in <CR>

```

### 1.2 IncreaseStackSize

```

//stack resize
asm( "mov %0,%esp\n" ::"g"(mem+10000000) );
//change esp to rsp if 64-bit system

//stack resize (linux)
#include <sys/resource.h>
void increase_stack_size() {
    const rlim_t ks = 64*1024*1024;
    struct rlimit rl;
    int res=getrlimit(RLIMIT_STACK, &rl);
    if(res==0){
        if(rl.rlim_cur<ks){
            rl.rlim_cur=ks;
            res=setrlimit(RLIMIT_STACK, &rl);
        }
    }
}

```

### 1.3 Default Code

```

#include<bits/stdc++.h>
#include<cmath>
#include<cstdio>
#include<cstring>
#include<cstdlib>
#include<iostream>
#include<algorithm>
#include<vector>
using namespace std;
#define FZ(n) memset((n),0,sizeof(n))
#define FMO(n) memset((n),-1,sizeof(n))
#define MC(n,m) memcpy((n),(m),sizeof(n))
#define F first
#define S second
#define MP make_pair
#define PB push_back
#define FOR(x,y) for(__typeof(y.begin())x=y.begin();x!=
y.end();x++)
#define IOS ios_base::sync_with_stdio(0); cin.tie(0)
// Let's Fight!

int main()
{
    return 0;
}

```

## 2 Data Structure

### 2.1 Bigint

```
const int bL = 1000;
const int bM = 10000;

struct Bigint{
    int v[bL],l;
    Bigint(){ memset(v, 0, sizeof(v));l=0; }

    void n(){
        for(;l;l--) if(v[l-1]) return;
    }

    Bigint(long long a){
        for(l=0;a;v[l++]=a%bM,a/=bM);
    }
    Bigint(char *a){
        l=0;
        int t=0,i=strlen(a),q=1;
        while(i){
            t+=(a[--i]-'0')*q;
            if((q*=10)>=bM) {
                v[l++]=t; t=0; q=1;
            }
        }
        if(t) v[l++]=t;
    }

    void prt() {
        if(l==0){ putchar('0');return; }
        printf("%d",v[l-1]);
        for(int i=l-2;i>=0;i--) printf("%.4d",v[i]);
    }

    int cp3(const Bigint &b)const {
        if(l!=b.l) return l>b.l?-1:-1;
        for(int i=l-1;i>=0;i--)
            if(v[i]!=b.v[i])
                return v[i]>b.v[i]?1:-1;
        return 0;
    }

    bool operator < (const Bigint &b)const{ return cp3(b)==-1; }
    bool operator == (const Bigint &b)const{ return cp3(b)==0; }
    bool operator > (const Bigint &b)const{ return cp3(b)==1; }

    Bigint operator + (const Bigint &b) {
        Bigint r;
        r.l=max(l,b.l);
        for(int i=0;i<r.l;i++) {
            r.v[i]=v[i]+b.v[i];
            if(r.v[i]>=bM) {
                r.v[i+1]+=r.v[i]/bM;
                r.v[i]%=bM;
            }
        }
        if(r.v[r.l]) r.l++;
        return r;
    }

    Bigint operator - (const Bigint &b) {
        Bigint r;
        r.l=l;
        for(int i=0;i<r.l;i++) {
            r.v[i]=v[i];
            if(i<b.l) r.v[i]-=b.v[i];
            if(r.v[i]<0) {
                r.v[i]+=bM;
                r.v[i+1]--;
            }
        }
        r.n();
        return r;
    }
}
```

```
Bigint operator * (const Bigint &b) {
    Bigint r;
    r.l=l+b.l;
    for(int i=0;i<l;i++) {
        for(int j=0;j<b.l;j++) {
            r.v[i+j]+=v[i]*b.v[j];
            if(r.v[i+j]>=bM) {
                r.v[i+j+1]+=r.v[i+j]/bM;
                r.v[i+j]%=bM;
            }
        }
    }
    r.n();
    return r;
}

Bigint operator / (const Bigint &b) {
    Bigint r;
    r.l=max(1,l-b.l+1);
    for(int i=r.l-1;i>=0;i--) {
        int d=0,u=bM-1,m;
        while(d<u) {
            m=(d+u)>>1;
            r.v[i]=m;
            if((r*b)>(*this)) u=m-1;
            else d=m;
        }
        r.v[i]=d;
    }
    r.n();
    return r;
}

Bigint operator % (const Bigint &b) {
    return (*this)-(*this)/b*b;
}
};
```

### 2.2 Leftist Heap

```
const int MAXSIZE = 10000;

class Node{
public:
    int num,lc,rc;
    Node () : num(0), lc(-1), rc(-1) {}
    Node (int _v) : num(_v), lc(-1), rc(-1) {}
}tree[MAXSIZE];

int merge(int x, int y){
    if (x == -1) return y;
    if (y == -1) return x;
    if (tree[x].num < tree[y].num)
        swap(x, y);
    tree[x].rc = merge(tree[x].rc, y);
    swap(tree[x].lc, tree[x].rc);
    return x;
}

/* Usage
merge: root = merge(x, y)
delmin: root = merge(root.lc, root.rc)
*/
```

### 2.3 unordered\_map

```
struct Key {
    int first,second;
    Key () {}
    Key (int _x, int _y) : first(_x), second(_y) {}
    bool operator == (const Key &b) const {
        return tie(F,S) == tie(b.F,b.S);
    }
};

struct KeyHasher {
    size_t operator()(const Key& k) const {
        return k.first + k.second*100000;
    }
}
```

```
};

typedef unordered_map<Key,int,KeyHasher> map_t;

int main(int argc, char** argv){
    map_t mp;
    for (int i=0; i<10; i++)
        mp[Key(i,0)] = i+1;
    for (int i=0; i<10; i++)
        printf("%d\n", mp[Key(i,0)]);

    return 0;
}
```

## 2.4 extc\_balance\_tree

```
#include <bits/extc++.h>
using namespace __gnu_pbds;
typedef tree<int,null_type,less<int>,rb_tree_tag,
            tree_order_statistics_node_update> set_t;

int main()
{
    // Insert some entries into s.
    set_t s;
    s.insert(12);
    s.insert(505);

    // The order of the keys should be: 12, 505.
    assert(*s.find_by_order(0) == 12);
    assert(*s.find_by_order(3) == 505);

    // The order of the keys should be: 12, 505.
    assert(s.order_of_key(12) == 0);
    assert(s.order_of_key(505) == 1);

    // Erase an entry.
    s.erase(12);

    // The order of the keys should be: 505.
    assert(*s.find_by_order(0) == 505);

    // The order of the keys should be: 505.
    assert(s.order_of_key(505) == 0);
}
```

## 2.5 Treap

```
class Node{
public:
    int pri,num,cnt,lc,rc;
    Node () : pri(-1), num(0), cnt(0), lc(0), rc(0) {}
    Node (int _num){
        pri = (rand()<<15) + rand();
        num = _num;
        cnt = 1;
        lc = rc = 0;
    }
}tree[MX];

int nMem;

int get_rand(){
    return (rand()<<15) + rand();
}

int get_node(){
    tree[nMem] = Node();
    if (nMem >= MX) while(1);
    return nMem++;
}

void upd_node(int rt){
    if (!rt) return ;
    int lc=tree[rt].lc;
    int rc=tree[rt].rc;
    tree[rt].cnt = tree[lc].cnt + tree[rc].cnt + 1;
}

int merge(int a, int b){
```

```
if (!a) return b;
if (!b) return a;
int res=0;
if (tree[a].pri > tree[b].pri){
    res = a; //get_node();
    tree[res] = tree[a];
    tree[res].rc = merge(tree[res].rc,b);
} else {
    res = b; //get_node();
    tree[res] = tree[b];
    tree[res].lc = merge(a,tree[res].lc);
}
upd_node(res);
return res;
}

pair<int,int> split(int a, int k){
    if (k == 0) return MP(0,a);
    if (k == tree[a].cnt) return MP(a,0);
    int lc=tree[a].lc, rc=tree[a].rc;
    pair<int,int> res;
    int np=a; //get_node();
    //tree[np] = tree[a];
    if (tree[lc].cnt >= k){
        res = split(lc,k);
        tree[np].lc = res.S;
        res.S = np;
    } else {
        res = split(rc,k-tree[lc].cnt-1);
        tree[np].rc = res.F;
        res.F = np;
    }
    upd_node(res.F);
    upd_node(res.S);
    return res;
}
```

## 2.6 Heavy Light Decomposition

```
int N, ip[MX];
int fa[MX],at[MX],belong[MX];
int fr,bk,sz[MX],que[MX];
vector<int> E[MX];

struct Chain{
    int n;
    vector<int> vec;
    vector<int> tree;

    void init(){
        n = vec.size();
        for (int i=0; i<n; i++){
            at[vec[i]] = i;
            tree.resize(4*n);
        }
        void build_tree(int l, int r, int id){
        }
        // Segment Tree
    }chain[MX];

    void DFS(int u){
        Chain &c = chain[belong[u]];
        c.init();
        for (int i=0; i<c.n; i++){
            u = c.vec[i];
            for (auto v : E[u]){
                if (fa[u] == v || (i && v == c.vec[i-1]))
                    continue;
                DFS(v);
            }
        }
        c.build_tree(0,c.n-1,0);
    }

    void build_chain(){
        fr=bk=0; que[bk++] = 1; fa[1]=0;
        while (fr < bk){
            int u=que[fr++];
            for (auto v : E[u]){
                if (v == fa[u]) continue;
                que[bk++] = v;
                fa[v] = u;
            }
        }
    }
}
```

```

    }
}
for (int i=bk-1,u,pos; i>=0; i--){
    u = que[i]; sz[u] = 1; pos = 0;
    for (auto v : E[u]){
        if (v == fa[u]) continue;
        sz[u] += sz[v];
        if (sz[v] > sz[pos]) pos=v;
    }
    if (pos == 0) belong[u] = u;
    else belong[u] = belong[pos];
    chain[belong[u]].vec.PB(u);
}
DFS(1);
}
vector<int> get_path(int u){
    vector<int> res;
    while (u){
        res.PB(belong[u]);
        u = fa[chain[belong[u]].vec.back()];
    }
    return res;
}
int jump_chain(int a){
    if (a == 0) return a;
    return fa[chain[belong[a]].vec.back()];
}
pair<int,int> findLCA(int u, int v){
    // at chain res.second
    // jump from u if res.first = 1 ( u ->* res.second )
    // jump from v if res.first = 2 ( v ->* res.second )
    vector<int> vec1,vec2;
    vec1 = get_path(u);
    vec2 = get_path(v);
    int a=u, b=v;
    for (auto v1 : vec1){
        for (auto v2 : vec2){
            if (v1 == v2)
                return sz[a] >= sz[b] ? MP(1,a) : MP(2,b);
            b = jump_chain(b);
        }
        a = jump_chain(a);
    }
    return MP(0,0);
}
int main(int argc, char** argv){
    scanf("%d", &N);
    for (int i=1; i<=N; i++)
        scanf("%d", &ip[i]);
    for (int i=0; i<N-1; i++){
        int u,v;
        scanf("%d%d", &u, &v);
        E[u].PB(v);
        E[v].PB(u);
    }
    build_chain();

    return 0;
}

```

## 3 Graph

### 3.1 Tarjan

```

const int MAXV = 101000;

int V, E;
vector<int> el[MAXV];
int dfn[MAXV], low[MAXV], did;
bool ins[MAXV];
stack<int> st;
int scc[MAXV], scn;

void tarjan(int u){
    cout << u << endl;
    dfn[u] = low[u] = ++did;
    st.push(u); ins[u] = true;

```

```

    for(int i=0; i<(int)el[u].size(); i++){
        int v = el[u][i];
        if(!dfn[v]){
            tarjan(v);
            low[u] = min(low[u], low[v]);
        }else if(ins[v]){
            low[u] = min(low[u], dfn[v]);
        }
    }

    if(dfn[u] == low[u]){
        int v;
        do{
            v = st.top();
            st.pop();
            scc[v] = scn;
            ins[v] = false;
        }while(v != u);
        scn ++;
    }
}

void calcscc(){
    did = scn = 0;
    for(int i=0; i<V; i++){
        if(!dfn[i]) tarjan(i);
    }
}

```

### 3.2 Strongly Connected Components

```

class Scc{
public:
    int n, nScc, vst[MAXN], bln[MAXN];
    vector<int> E[MAXN], rE[MAXN], vec;
    void init(int _n){
        n = _n;
        for (int i=0; i<MAXN; i++){
            E[i].clear();
            rE[i].clear();
        }
    }
    void add_edge(int u, int v){
        E[u].PB(v);
        rE[v].PB(u);
    }
    void DFS(int u){
        vst[u]=1;
        for (auto v : E[u])
            if (!vst[v]) DFS(v);
        vec.PB(u);
    }
    void rDFS(int u){
        vst[u] = 1;
        bln[u] = nScc;
        for (auto v : rE[u])
            if (!vst[v]) rDFS(v);
    }
    void solve(){
        nScc = 0;
        vec.clear();
        FZ(vst);
        for (int i=0; i<n; i++)
            if (!vst[i]) DFS(i);
        reverse(vec.begin(),vec.end());
        FZ(vst);
        for (auto v : vec){
            if (!vst[v]){
                rDFS(v);
                nScc++;
            }
        }
    }
};

```

### 3.3 DMST\_with\_sol

```
const int INF = 1029384756;

struct edge_t{
    int u,v,w;
    set< pair<int,int> > add,sub;
    edge_t(){
        u = -1;
        v = -1;
        w = 0;
    }
    edge_t(int _u, int _v, int _w){
        u = _u;
        v = _v;
        w = _w;
        add.insert(MP(_u,_v));
    }
    edge_t& operator += (const edge_t& obj) {
        w += obj.w;
        FOR (it, obj.add) {
            if (!sub.count(*it)) add.insert(*it);
            else sub.erase(*it);
        }
        FOR (it, obj.sub) {
            if (!add.count(*it)) sub.insert(*it);
            else add.erase(*it);
        }
        return *this;
    }

    edge_t& operator -= (const edge_t& obj) {
        w -= obj.w;
        FOR (it, obj.sub) {
            if (!sub.count(*it)) add.insert(*it);
            else sub.erase(*it);
        }
        for (auto it : obj.add) {
            if (!add.count(it)) sub.insert(it);
            else add.erase(it);
        }
        return *this;
    }
}eg[MXN*MXN],prv[MXN],EDGE_INF(-1,-1,INF);
int N,M;
int cycid,incycle[MXN],contracted[MXN];
vector<int> E[MXN];

edge_t dmst(int rt){
    edge_t cost;
    for (int i=0; i<N; i++){
        contracted[i] = 0;
        incycle[i] = 0;
        prv[i] = EDGE_INF;
    }
    cycid = 0;
    int u,v;
    while (true){
        for (v=0; v<N; v++){
            if (v != rt && !contracted[v] && prv[v].w
                == INF)
                break;
        }
        if (v >= N) break; // end
        for (int i=0; i<M; i++){
            if (eg[i].v == v && eg[i].w < prv[v].w){
                prv[v] = eg[i];
            }
        }
        if (prv[v].w == INF){ // not connected
            return EDGE_INF;
        }
        cost += prv[v];
        for (u=prv[v].u; u!=v && u!=-1; u=prv[u].u);
        if (u == -1) continue;
        incycle[v] = ++cycid;
        for (u=prv[v].u; u!=v; u=prv[u].u){
            contracted[u] = 1;
            incycle[u] = cycid;
        }
        for (int i=0; i<M; i++){
```

```
            if (incycle[eg[i].u] != cycid && incycle[eg
                [i].v] == cycid){
                eg[i] -= prv[eg[i].v];
            }
        }
        for (int i=0; i<M; i++){
            if (incycle[eg[i].u] == cycid) eg[i].u = v;
            if (incycle[eg[i].v] == cycid) eg[i].v = v;
            if (eg[i].u == eg[i].v) eg[i--] = eg[--M];
        }
        for (int i=0; i<N; i++){
            if (contracted[i]) continue;
            if (prv[i].u>=0 && incycle[prv[i].u] ==
                cycid)
                prv[i].u = v;
        }
        prv[v] = EDGE_INF;
    }
    return cost;
}

void solve(){
    edge_t cost = dmst(0);
    for (auto it : cost.add){ // find a solution
        E[it.F].PB(it.S);
        prv[it.S] = edge_t(it.F,it.S,0);
    }
}
```

### 3.4 Maximum Clique

```
class MaxClique {
public:
    static const int MV = 210;

    int V;
    int el[MV][MV/30+1];
    int dp[MV];
    int ans;
    int s[MV][MV/30+1];
    vector<int> sol;

    void init(int v) {
        V = v; ans = 0;
        FZ(el); FZ(dp);
    }

    /* Zero Base */
    void addEdge(int u, int v) {
        if(u > v) swap(u, v);
        if(u == v) return;
        el[u][v/32] |= (1<<(v%32));
    }

    bool dfs(int v, int k) {
        int c = 0, d = 0;
        for(int i=0; i<(V+31)/32; i++) {
            s[k][i] = el[v][i];
            if(k != 1) s[k][i] &= s[k-1][i];
            c += __builtin_popcount(s[k][i]);
        }
        if(c == 0) {
            if(k > ans) {
                ans = k;
                sol.clear();
                sol.push_back(v);
                return 1;
            }
            return 0;
        }
        for(int i=0; i<(V+31)/32; i++) {
            for(int a = s[k][i]; a ; d++) {
                if(k + (c-d) <= ans) return 0;
                int lb = a&(-a), lg = 0;
                a ^= lb;
                while(lb!=1) {
                    lb = (unsigned int)(lb) >> 1;
                    lg ++;
                }
                int u = i*32 + lg;
```

```

        if(k + dp[u] <= ans) return 0;
        if(dfs(u, k+1)) {
            sol.push_back(v);
            return 1;
        }
    }
    return 0;
}

int solve() {
    for(int i=V-1; i>=0; i--) {
        dfs(i, 1);
        dp[i] = ans;
    }
    return ans;
}
};

```

### 3.5 (+1) MinimumMeanCycle

```

/* minimum mean cycle */
class Edge { public:
    int v,u;
    double c;
};
int n,m;
Edge e[MAXEDGE];
double d[MAXNUM][MAXNUM];
inline void relax(double &x,double val) { if(val<x) x=
    val; }
inline void bellman_ford() {
    int i,j;
    for(j=0;j<n;j++) d[0][j]=0.0;
    for(i=0;i<n;i++) {
        for(j=0;j<n;j++) d[i+1][j]=inf;
        for(j=0;j<m;j++)
            if(d[i][e[j].v]<inf-eps) relax(d[i+1][e[j].u],d[i]
                ][
                    e[j].v]+e[j].c);
    }
}
inline double karp_mmc() {
    // returns inf if no cycle, mmc otherwise
    int i,k; double mmc=inf,avg;
    bellman_ford();
    for(i=0;i<n;i++) {
        avg=0.0;
        for(k=0;k<n;k++) {
            if(d[n][i]<inf-eps) avg=max(avg,(d[n][i]-d[k][i])
                /(
                    n-k));
            else avg=max(avg,inf);
        }
        mmc=min(mmc,avg);
    }
    return mmc;
}

```

## 4 Flow

### 4.1 ISAP

```

class Isap{
public:
    static const int MXN = 10000;
    class Edge{
    public:
        int v,f,re;
        Edge (){ v=f=re=-1; }
        Edge (int _v, int _f, int _r){
            v = _v;
            f = _f;
            re = _r;
        }
    };
};

```

```

int n,s,t,h[MXN],gap[MXN];
vector<Edge> E[MXN];
void init(int _n, int _s, int _t){
    n = _n;
    s = _s;
    t = _t;
    for (int i=0; i<n; i++)
        E[i].clear();
}
void add_edge(int u, int v, int f){
    E[u].PB(Edge(v,f,E[v].size()));
    E[v].PB(Edge(u,0,E[u].size()-1));
}
int DFS(int u, int nf, int res=0){
    if (u == t) return nf;
    for (auto &it : E[u]){
        if (h[u]==h[it.v]+1 && it.f>0){
            int tf = DFS(it.v,min(nf,it.f));
            res += tf;
            nf -= tf;
            it.f -= tf;
            E[it.v][it.re].f += tf;
            if (nf == 0) return res;
        }
    }
    if (nf){
        if (--gap[h[u]] == 0) h[s]=n;
        gap[++h[u]]++;
    }
    return res;
}
int flow(int res=0){
    FZ(h);
    FZ(gap);
    gap[0] = n;
    while (h[s] < n)
        res += DFS(s,2147483647);
    return res;
}
}flow;

```

### 4.2 Dinic

```

class Dinic{
public:
    static const int MXN = 10000;
    class Edge{
    public:
        int v,f,re;
        Edge (){ v=f=re=-1; }
        Edge (int _v, int _f, int _r){
            v = _v;
            f = _f;
            re = _r;
        }
    };
    int n,s,t;
    int fr,bk,que[MXN],level[MXN];
    vector<Edge> E[MXN];
    void init(int _n, int _s, int _t){
        n = _n;
        s = _s;
        t = _t;
        for (int i=0; i<n; i++)
            E[i].clear();
    }
    void add_edge(int u, int v, int f){
        E[u].PB(Edge(v,f,E[v].size()));
        E[v].PB(Edge(u,0,E[u].size()-1));
    }
    bool BFS(){
        FMO(level);
        fr = bk = 0;
        que[bk++] = s;
        level[s] = 0;
        while (fr < bk){
            int u = que[fr++];
            for (auto it : E[u]){
                if (it.f > 0 && level[it.v] == -1){
                    level[it.v] = level[u]+1;

```

```

        que[bk++] = it.v;
    }
}
return level[t] != -1;
}
int DFS(int u, int nf){
    if (u == t) return nf;
    int res = 0;
    for (auto &it : E[u]){
        if (it.f > 0 && level[it.v] == level[u]+1){
            int tf = DFS(it.v, min(nf,it.f));
            res += tf; nf -= tf; it.f -= tf;
            E[it.v][it.re].f += tf;
            if (nf == 0) return res;
        }
    }
    if (!res) level[u] = -1;
    return res;
}
int flow(int res=0){
    while ( BFS() )
        res += DFS(s,2147483647);
    return res;
}
}flow;

```

### 4.3 Bipartite Matching (Augmenting Path)

```

bool DFS(int u){
    for (auto v : E[u]){
        if (!vst[v]){
            vst[v]=1;
            if (match[v] == -1 || DFS(match[v])){
                match[v] = u;
                match[u] = v;
                return true;
            }
        }
    }
    return false;
}
int DoMatch(int res=0){
    memset(match,-1,sizeof(match));
    for (int i=1; i<=N; i++){
        if (match[i] == -1){
            memset(vst,0,sizeof(vst));
            DFS(i);
        }
    }
    for (int i=1; i<=N; i++)
        if (match[i] != -1) res++;
    return res;
}

```

### 4.4 Kuhn Munkres

```

struct KM{
    // Maximum Bipartite Weighted Matching (Perfect Match)
    static const int MXN = 650;
    static const int INF = 2147483647; // Long Long
    int n,match[MXN],vx[MXN],vy[MXN];
    int edge[MXN][MXN],lx[MXN],ly[MXN],slack[MXN];
    // ^^^ Long Long
    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 x, int y, int w){ // Long Long
        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] == -1 || DFS(match[y])){
                match[y] = x;
                return true;
            }
        }
    }
    return false;
}
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 (true){
                fill(vx,vx+n,0);
                fill(vy,vy+n,0);
                if ( DFS(i) ) break;
                int d = INF; // Long Long
                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;
        }
    }
}graph;

```

### 4.5 SW-Mincut

```

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;
        FZ(edge);
        FZ(del);
    }
    void add_edge(int u, int v, int w){
        edge[u][v] += w;
        edge[v][u] += w;
    }
    void search(int &s, int &t){
        FZ(vst); FZ(wei);
        s = t = -1;
        while (true){
            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 = 2147483647;
        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;
}
}graph;

```

## 4.6 Maximum Simple Graph Matching

```

struct GenMatch { // 1-base
    static const int MAXN = 250;
    int V;
    bool el[MAXN][MAXN];
    int pr[MAXN];
    bool inq[MAXN], inp[MAXN], inb[MAXN];
    queue<int> qe;
    int st, ed;
    int nb;
    int bk[MAXN], djs[MAXN];
    int ans;
    void init(int _V) {
        V = _V;
        FZ(el); FZ(pr);
        FZ(inq); FZ(inp); FZ(inb);
        FZ(bk); FZ(djs);
        ans = 0;
    }
    void add_edge(int u, int v) {
        el[u][v] = el[v][u] = 1;
    }
    int lca(int u, int v) {
        memset(inp, 0, sizeof(inp));
        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);
        memset(inb, 0, sizeof(inb));
        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() {
        memset(inq, false, sizeof(inq));
        memset(bk, 0, sizeof(bk));
        for(int i = 1; i <= V; i++)
            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] == 0) {
                        bk[v] = u;
                        if(pr[v] > 0) {
                            if(!inq[pr[v]]) qe.push(pr[v]);
                        } else {
                            ed = v;
                            return;
                        }
                    }
                }
        }
    }
    void aug() {
        int u, v, w;
        u = ed;
        while(u > 0) {
            v = bk[u];
            w = pr[v];
            pr[v] = u;
            pr[u] = v;
            u = w;
        }
    }
    int solve() {
        memset(pr, 0, sizeof(pr));
        for(int u = 1; u <= V; u++)
            if(pr[u] == 0) {
                st = u;
                flow();
                if(ed > 0) {
                    aug();
                    ans++;
                }
            }
        return ans;
    }
};

int main() {
    gp.init(V);
    for(int i=0; i<E; i++) {
        int u, v;
        cin >> u >> v;
        gp.edge(u, v);
    }
    cout << gp.solve() << endl;
}

```

## 4.7 2-Commodity Flow

```

const int MAXN = 64;
const int INF = 1029384756;

int N;
int s1, s2, t1, t2, d1, d2, S, T;
int edge[MAXN][MAXN];
int cap[MAXN][MAXN];

int h[MAXN], gap[MAXN];
bool vis[MAXN];

int isap(int v, int f)
{
    if(v == T) return f;

    if(vis[v]) return 0;
    vis[v] = true;

    for(int i=0; i<N+2; i++)
    {
        if(cap[v][i] <= 0) continue;
        if(h[i] != h[v] - 1) continue;
        int res = isap(i, min(cap[v][i], f));
        if(res > 0)

```



```

    {
        cap[v][i] -= res;
        cap[i][v] += res;
        return res;
    }
}

gap[h[v]]--;
if(gap[h[v]] <= 0) h[S] = N + 4;
h[v]++;
gap[h[v]]++;

return 0;
}

int get_flow()
{
    for(int i=0; i<MAXN; i++)
    {
        h[i] = gap[i] = 0;
    }
    gap[0] = N + 2;

    int flow = 0;

    while(h[S] <= N + 3)
    {
        for(int i=0; i<N+2; i++)
        {
            vis[i] = false;
        }

        int df = isap(S, INF);
        flow += df;
    }

    return flow;
}

int main()
{
    ios_base::sync_with_stdio(0);

    int TT;
    cin>>TT;
    while(TT-->0)
    {
        cin>>N;
        cin>>s1>>t1>>d1>>s2>>t2>>d2;

        for(int i=0; i<MAXN; i++)
        {
            for(int j=0; j<MAXN; j++)
            {
                edge[i][j] = 0;
            }
        }

        for(int i=0; i<N; i++)
        {
            string s;
            cin>>s;
            for(int j=0; j<N; j++)
            {
                if(s[j] == 'X') edge[i][j] = 0;
                else if(s[j] == 'O') edge[i][j] = 1;
                else if(s[j] == 'N') edge[i][j] = INF;
            }
        }

        int ans = 0;

        S = N;
        T = N + 1;

        //first
        for(int i=0; i<MAXN; i++)
        {
            for(int j=0; j<MAXN; j++)
            {
                cap[i][j] = edge[i][j];
            }
        }
    }
}

```

```

    }

    cap[S][s1] = cap[t1][T] = d1;
    cap[S][s2] = cap[t2][T] = d2;

    ans = get_flow();

    //second
    for(int i=0; i<MAXN; i++)
    {
        for(int j=0; j<MAXN; j++)
        {
            cap[i][j] = edge[i][j];
        }
    }

    cap[S][s1] = cap[t1][T] = d1;
    cap[S][t2] = cap[s2][T] = d2;

    ans = min(ans, get_flow());

    cout<<(ans == d1 + d2 ? "Yes" : "No")<<endl;
}

return 0;
}

```

#### 4.8 (+1) SW-mincut $O(NM)$

```

// {{ StorerWagner
const int inf=1000000000;
// should be larger than max.possible mincut
class StorerWagner {
public:
    int n,mc; // node id in [0,n-1]
    vector<int> adj[MAXN];
    int cost[MAXN][MAXN];
    int cs[MAXN];
    bool merged[MAXN],sel[MAXN];
    // --8<-- include only if cut is explicitly needed
    DisjointSet djs;
    vector<int> cut;
    //--8<-----
    StorerWagner(int _n):n(_n),mc(inf),djs(_n) {
        for(int i=0;i<n;i++)
            merged[i]=0;
        for(int i=0;i<n;i++)
            for(int j=0;j<n;j++)
                cost[i][j]=cost[j][i]=0;
    }
    void append(int v,int u,int c) {
        if(v==u) return;
        if(!cost[v][u]&&c) {
            adj[v].PB(u);
            adj[u].PB(v);
        }
        cost[v][u]+=c;
        cost[u][v]+=c;
    }
    void merge(int v,int u) {
        merged[u]=1;
        for(int i=0;i<n;i++)
            append(v,i,cost[u][i]);
        // --8<-- include only if cut is explicitly
        // needed
        djs.merge(v,u);
        // --8<-----
    }
    void phase() {
        priority_queue<pii> pq;
        for(int v=0;v<n;v++) {
            if(merged[v]) continue;
            cs[v]=0;
            sel[v]=0;
            pq.push(MP(0,v));
        }
        int v,s,pv;
        while(pq.size()) {

```

```

    if(cs[pq.top().S]>pq.top().F) {
        pq.pop();
        continue;
    }
    pv=v;
    v=pq.top().S;
    s=pq.top().F;
    pq.pop();
    sel[v]=1;
    for(int i=0;i<adj[v].size();i++) {
        int u=adj[v][i];
        if(merged[u]||sel[u]) continue;
        cs[u]+=cost[v][u];
        pq.push(MP(cs[u],u));
    }
}
if(s<mc) {
    mc=s;
    // --8<-- include only if cut is explicitly
    needed -----
    cut.clear();
    for(int i=0;i<n;i++)
        if(djs.getrep(i)==djs.getrep(v)) cut.PB(i);
    //--8<-----
}
merge(v,pv);
}
int mincut() {
    if(mc==inf) {
        for(int t=0;t<n-1;t++)
            phase();

        return mc;
    }
    // --8<-- include only if cut is explicitly needed
    -----
    vector<int> getcut() { // return one side of the
        cut
        mincut();
        return cut;
    }
    //--8<-----
};
// }}}

```

## 5 Math

### 5.1 $ax+by=\gcd$

```

typedef pair<int, int> pii;

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

```

### 5.2 Chinese Remainder

```

int pfn; // number of distinct prime factors
int pf[MAXNUM]; // prime factor powers
int rem[MAXNUM]; // corresponding remainder
int pm[MAXNUM];
inline void generate_primes() {
    int i,j;
    pnum=1;
    prime[0]=2;
    for(i=3;i<MAXVAL;i+=2) {
        if(nprime[i]) continue;
        prime[pnum++]=i;
        for(j=i*i;j<MAXVAL;j+=i) nprime[j]=1;
    }
}

```

```

inline int inverse(int x,int p) {
    int q,tmp,a=x,b=p;
    int a0=1,a1=0,b0=0,b1=1;
    while(b) {
        q=a/b; tmp=b; b=a-b*q; a=tmp;
        tmp=b0; b0=a0-b0*q; a0=tmp;
        tmp=b1; b1=a1-b1*q; a1=tmp;
    }
    return a0;
}
inline void decompose_mod() {
    int i,p,t=mod;
    pfn=0;
    for(i=0;i<pnum&&prime[i]<=t;i++) {
        p=prime[i];
        if(t%p==0) {
            pf[pfn]=1;
            while(t%p==0) {
                t/=p;
                pf[pfn]*=p;
            }
            pfn++;
        }
    }
    if(t>1) pf[pfn++]=t;
}
inline int chinese_remainder() {
    int i,m,s=0;
    for(i=0;i<pfn;i++) {
        m=mod/pf[i];
        pm[i]=(long long)m*inverse(m,pf[i])%mod;
        s=(s+(long long)pm[i]*rem[i])%mod;
    }
    return s;
}

```

### 5.3 Fast Fourier Transform

```

typedef complex<double> cplx;
const int PI = acos(-1);
const cplx I(0, 1);
void fft(int n, cplx a[]) {
    double theta = 2 * PI / n;
    for (int m = n; m >= 2; m >>= 1) {
        int mh = m >> 1;
        for (int i = 0; i < mh; i++) {
            cplx w = exp(i*theta*I);
            for (int j = i; j < n; j += m) {
                int k = j + mh;
                cplx x = a[j] - a[k];
                a[j] += a[k];
                a[k] = w * x;
            }
        }
        theta *= 2;
    }
    int i = 0;
    for (int j = 1; j < n - 1; j++) {
        for (int k = n >> 1; k > (i ^= k); k >>= 1);
        if (j < i) swap(a[i], a[j]);
    }
}

```

### 5.4 (+1) ntt

```

int P=605028353,root=3,MAXNUM=262144;
// Remember coefficient are mod P
/*
p=a*2^n+1

```

n	2 <sup>n</sup>	p	a	root
5	32	97	3	5
6	64	193	3	5
7	128	257	2	3
8	256	257	1	3
9	512	7681	15	17
10	1024	12289	12	11
11	2048	12289	6	11
12	4096	12289	3	11

```

13 8192      40961      5      3
14 16384     65537     4      3
15 32768     65537     2      3
16 65536     65537     1      3
17 131072    786433    6     10
18 262144    786433    3     10 (605028353,
    2308, 3)
19 524288    5767169   11     3
20 1048576   7340033    7     3
21 2097152   23068673   11     3
22 4194304   104857601   25     3
23 8388608   167772161   20     3
24 16777216   167772161   10     3
25 33554432   167772161   5      3 (1107296257, 33,
    10)
26 67108864   469762049   7      3
27 134217728 2013265921   15     31
*/
int bigmod(long long a,int b){
    if(b==0)return 1;
    return (bigmod((a*a)%P,b/2)*(b%2?a:111))%P;
}
int inv(int a,int b){
    if(a==1)return 1;
    return (((long long)(a-inv(b%a,a))*b+1)/a)%b;
}
std::vector<long long> ps(MAXNUM);
std::vector<int> rev(MAXNUM);
struct poly{
    std::vector<unsigned int> co;
    int n;//polynomial degree = n
    poly(int d){n=d;co.resize(n+1,0);}
    void trans2(int NN){
        int r=0,st,N;
        unsigned int a,b;
        while((1<r)<(NN>>1))++r;
        for(N=2;N<=NN;N<=1,--r){
            for(st=0;st<NN;st+=N){
                int i,ss=st+(N>>1);
                for(i=(N>>1)-1;i>=0;--i){
                    a=co[st+i]; b=(ps[i<r]*co[ss+i])%P;
                    co[st+i]=a+b; if(co[st+i]>=P)co[st+i]-=P;
                    co[ss+i]=a+P-b; if(co[ss+i]>=P)co[ss+i]-=P;
                }
            }
        }
    }
    void trans1(int NN){
        int r=0,st,N;
        unsigned int a,b;
        for(N=NN;N>1;N>=1,++r){
            for(st=0;st<NN;st+=N){
                int i,ss=st+(N>>1);
                for(i=(N>>1)-1;i>=0;--i){
                    a=co[st+i]; b=co[ss+i];
                    co[st+i]=a+b; if(co[st+i]>=P)co[st+i]-=P;
                    co[ss+i]=(a+P-b)*ps[i<r]%P;
                }
            }
        }
    }
    poly operator*(const poly& _b)const{
        poly a=*this,b=_b;
        int k=n+b.n,i,N=1;
        while(N<=k)N*=2;
        a.co.resize(N,0); b.co.resize(N,0);
        int r=bigmod(root,(P-1)/N,Ni=inv(N,P);
        ps[0]=1;
        for(i=1;i<N;++i)ps[i]=(ps[i-1]*r)%P;
        a.trans1(N);b.trans1(N);
        for(i=0;i<N;++i)a.co[i]=((long long)a.co[i]*b.co[i]
            )%P;
        ;
        r=inv(r,P);
        for(i=1;i<N/2;++i)std::swap(ps[i],ps[N-i]);
        a.trans2(N);
        for(i=0;i<N;++i)a.co[i]=((long long)a.co[i]*Ni)%P;
        a.n=n+_b.n; return a;
    }
};

```

## 5.5 Mod

```

/// _fd(a,b) floor(a/b).
/// _rd(a,m) a-floor(a/m)*m.
/// _pv(a,m,r) largest x s.t x<=a && x%m == r.
/// _nx(a,m,r) smallest x s.t x>=a && x%m == r.
/// _ct(a,b,m,r) |A| , A = { x : a<=x<=b && x%m == r }.

int _fd(int a,int b){ return a<0?(-~a/b-1):a/b; }
int _rd(int a,int m){ return a-_fd(a,m)*m; }
int _pv(int a,int m,int r)
{
    r=(r%m+m)%m;
    return _fd(a-r,m)*m+r;
}
int _nt(int a,int m,int r)
{
    m=abs(m);
    r=(r%m+m)%m;
    return _fd(a-r-1,m)*m+r+m;
}
int _ct(int a,int b,int m,int r)
{
    m=abs(m);
    a=_nt(a,m,r);
    b=_pv(b,m,r);
    return (a>b)?0:((b-a+m)/m);
}

```

## 5.6 (+1) 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 : primes <= 13
// n < 3,825,123,056,546,413,051 9 : primes <= 23
long long power(long long x,long long p,long long mod){
    long long s=1,m=x;
    while(p) {
        if(p&1) s=mult(s,m,mod);
        p>>=1;
        m=mult(m,m,mod);
    }
    return s;
}
bool witness(long long a,long long n,long long u,int t)
{
    long long x=power(a,u,n);
    for(int i=0;i<t;i++){
        long long nx=mult(x,x,n);
        if(nx==1&&x!=1&&x!=n-1) return 1;
        x=nx;
    }
    return x!=1;
}
bool miller_rabin(long long n,int s=100) {
    // iterate s times of witness on n
    // return 1 if prime, 0 otherwise
    if(n<2) return 0;
    if(!(n&1)) return n==2;
    long long u=n-1;
    int t=0;
    // n-1 = u*2^t
    while(u&1) {
        u>>=1;
        t++;
    }
    while(s--) {
        long long a=randll()%(n-1)+1;
        if(witness(a,n,u,t)) return 0;
    }
    return 1;
}

```

## 5.7 (+1) Pollard Rho

```

/* pollard rho */
// does not work when n is prime
long long modit(long long x, long long mod) {
    if(x >= mod) x -= mod;
    //if(x < 0) x += mod;
    return x;
}
long long mult(long long x, long long y, long long mod) {
    long long s = 0, m = x % mod;
    while(y) {
        if(y & 1) s = modit(s + m, mod);
        y >>= 1;
        m = modit(m * 2, mod);
    }
    return s;
}
long long f(long long x, long long mod) {
    return modit(mult(x, x, mod) + 1, mod);
}
long long pollard_rho(long long n) {
    long long x, x2;
    if(!(n & 1)) return 2;
    //x = x2 = randLL() % n;
    x = x2 = 2;
    while(1) {
        x = f(x, n); x2 = f(f(x2, n), n);
        long long d = __gcd(abs(x - x2), n);
        if(d != 1 && d != n) return d;
    }
}

```

## 5.8 Primes

```

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

```

## 5.9 (+1) PolynomialGenerator

```

class PolynomialGenerator {
    /* for a nth-order polynomial f(x), *
    * given f(0), f(1), ..., f(n) *
    * express f(x) as sigma_i{c_i * C(x,i)} */
public:
    int n;
    vector<long long> coef;
    // initialize and calculate f(x), vector _fx should
    be

```

```

// filled with f(0) to f(n)
    PolynomialGenerator(int _n, vector<long long> _fx)
        : n(_n)
        , coef(_fx) {
        for(int i=0; i<n; i++)
            for(int j=n; j>i; j--)
                coef[j] -= coef[j-1];
    }
    // evaluate f(x), runs in O(n)
    long long eval(int x) {
        long long m = 1, ret = 0;
        for(int i=0; i<n; i++) {
            ret += coef[i] * m;
            m = m * (x - i) / (i + 1);
        }
        return ret;
    }
};

```

## 5.10 Gauss Elimination

```

const int MAX = 300;
const double EPS = 1e-8;

double mat[MAX][MAX];
void Gauss(int n) {
    for(int i=0; i<n; i++) {
        bool ok = 0;
        for(int j=i; j<n; j++) {
            if(fabs(mat[j][i]) > EPS) {
                swap(mat[j], mat[i]);
                ok = 1;
                break;
            }
        }
        if(!ok) continue;

        double fs = mat[i][i];
        for(int j=i+1; j<n; j++) {
            double r = mat[j][i] / fs;
            for(int k=i; k<n; k++) {
                mat[j][k] -= mat[i][k] * r;
            }
        }
    }
}

```

## 5.11 Simplex

```

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+1];
        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;
}
}

```

## 5.12 Theorem

```

/*
Lucas' Theorem:
For non-negative integer n,m and prime P,
C(m,n) mod P = C(m/M,n/M) * C(m%M,n%M) mod P
= mult_i ( C(m_i,n_i) )
where m_i is the i-th digit of m in base P.
--
Sum of Two Squares Thm (Legendre)
For a given positive integer N, let
D1 = (# of positive integers d dividing N that d=1(
mod 4))
D3 = (# of positive integers d dividing N that d=3(
mod 4))
then N can be written as a sum of two squares in
exactly
R(N) = 4(D1-D3) ways.
--
Difference of D1-D3 Thm
Let N = 2^t * [p1^e1 * ... * pr^er] * [q1^f1 * ... *
qs^fs]
<- mod 4 = 1 prime -> <- mod 4 = 3
prime ->
then D1 - D3 = (e1+1)(e2+1)...(er+1) ... if (fi)s all
even
0 ... if any fi is odd
*/

```

## 6 Geometry

### 6.1 Point operators

```

#include<bits/stdc++.h>
using namespace std;

#define _x first
#define _y second
typedef pair<double, double> pdd;

pdd operator + (const pdd p1, const pdd p2){
    return pdd(p1._x + p2._x, p1._y + p2._y);
}
pdd operator - (const pdd p1, const pdd p2){
    return pdd(p1._x - p2._x, p1._y - p2._y);
}

pdd operator * (const double c, const pdd p){
    return pdd(p._x * c, p._y * c);
}
pdd operator - (const pdd p){
    return (-1.0) * p;
}

double operator * (const pdd p1, const pdd p2){
    return p1._x * p2._x + p1._y * p2._y;
}
double operator % (const pdd p1, const pdd p2){
    return p1._x * p2._y - p2._x * p1._y;
}

```

### 6.2 Intersection of two circles

Let  $\mathbf{O}_1 = (x_1, y_1), \mathbf{O}_2 = (x_2, y_2)$  be two centers of circles,  $r_1, r_2$  be the radius. If:

$$d = |\mathbf{O}_1 - \mathbf{O}_2| \quad \mathbf{u} = \frac{1}{2}(\mathbf{O}_1 + \mathbf{O}_2) + \frac{(r_2^2 - r_1^2)}{2d^2}(\mathbf{O}_1 - \mathbf{O}_2)$$

$$\mathbf{v} = \frac{\sqrt{(r_1 + r_2 + d)(r_1 - r_2 + d)(r_1 + r_2 - d)(-r_1 + r_2 + d)}}{2d^2}(y_1 - y_2, -x_1 + x_2)$$

then  $\mathbf{u} + \mathbf{v}, \mathbf{u} - \mathbf{v}$  are the two intersections of the circles, provided that  $d < r_1 + r_2$ .

### 6.3 Intersection of two lines

```

#include<bits/stdc++.h>
using namespace std;
const double EPS = 1e-9;

pdd interPnt(pdd p1, pdd p2, pdd q1, pdd q2){
    double f1 = (p2 - p1) % (q1 - p1);
    double f2 = (p2 - p1) % (p1 - q2);
    double f = (f1 + f2);

    if(fabs(f) < EPS) return pdd(nan(""), nan(""));

    return (f2 / f) * q1 + (f1 / f) * q2;
}

```

### 6.4 Half Plane Intersection

```

#include<bits/stdc++.h>
using namespace std;

#define PB push_back
#define MP make_pair
#define _x first
#define _y second

const int MXL = 5000;
const double EPS = 1e-8;

typedef pair<double, double> pdd;
typedef pair<pdd, pdd> Line;

pdd operator + (const pdd p1, const pdd p2){

```

```

    return pdd(p1._x + p2._x, p1._y + p2._y);
}

pdd operator - (const pdd p1, const pdd p2){
    return pdd(p1._x - p2._x, p1._y - p2._y);
}

pdd operator * (const double c, const pdd p){
    return pdd(p._x * c, p._y * c);
}

double operator % (const pdd p1, const pdd p2){
    return p1._x * p2._y - p2._x * p1._y;
}

vector<Line> lnlst;
double atn[MXL];

bool lncmp(int l1, int l2){
    return atn[l1] < atn[l2];
}

pdd interPnt(pdd p1, pdd p2, pdd q1, pdd q2){
    double f1 = (p2 - p1) % (q1 - p1);
    double f2 = (p2 - p1) % (p1 - q2);
    double f = (f1 + f2);

    if(fabs(f) < EPS) return pdd(nan("")), nan(""));

    return (f2 / f) * q1 + (f1 / f) * q2;
}

deque<Line> dq;

void halfPlaneInter(){
    int n = lnlst.size();
    vector<int> stlst;
    for(int i=0; i<n; i++){
        stlst.PB(i);
        pdd d = lnlst[i].second - lnlst[i].first;
        atn[i] = atan2(d._y, d._x);
    }
    sort(stlst.begin(), stlst.end(), lncmp);
    vector<Line> lst;

    for(int i=0; i<n; i++){
        if(i) {
            int j = i-1;
            Line li = lnlst[stlst[i]];
            Line lj = lnlst[stlst[j]];
            pdd di = li.second - li.first;
            pdd dj = lj.second - lj.first;
            if(fabs(di%dj) < EPS){
                if(di % (lj.second - li.second) < 0) {
                    lst.pop_back();
                } else continue;
            }
        }
        lst.PB(lnlst[stlst[i]]);
    }

    dq.PB(lst[0]);
    dq.PB(lst[1]);
    for(int i=2; i<n; i++){
        int dsz = dq.size();
        Line l = lst[i];
        while(dsz >= 2){
            Line l1 = dq[dsz-1];
            Line l2 = dq[dsz-2];

            pdd it12 = interPnt(l1.first, l1.second, l2.first, l2.second);

            if((l.second - l.first) % (it12 - l.first) < 0){
                dq.pop_back();
                dsz--;
            } else break;
        }

        while(dsz >= 2){
            Line l1 = dq[0];

```

```

        Line l2 = dq[1];

        pdd it12 = interPnt(l1.first, l1.second, l2.first, l2.second);

        if((l.second - l.first) % (it12 - l.first) < 0){
            dq.pop_front();
            dsz--;
        } else break;
    }

    Line l1 = dq[dsz - 1];
    if(!std::isnan(interPnt(l1.first, l1.second, l1.first, l1.second)._x)){
        dq.PB(l1);
    }
}

int dsz = dq.size();
while(dsz >= 2){
    Line l1 = dq[dsz - 1];
    Line l2 = dq[dsz - 2];
    Line l = dq[0];
    pdd it12 = interPnt(l1.first, l1.second, l2.first, l2.second);
    if(std::isnan(it12._x)) {
        dq.pop_back();
        dq.pop_back();
        dsz -= 2;
    } else if((l.second - l.first) % (it12 - l.first) < 0){
        dq.pop_back();
        dsz--;
    } else break;
}

int main(){
    int N;
    cin >> N;
    for(int i=0; i<N; i++){
        double x1, x2, y1, y2;
        cin >> x1 >> y1 >> x2 >> y2;
        lnlst.PB(MP(pdd(x1, y1), pdd(x2, y2)));
    }

    halfPlaneInter();

    int dsz = dq.size();
    cout << dsz << endl;
    for(int i=0; i<dsz; i++){
        int j = (i+1) % dsz;
        pdd it = interPnt(dq[i].first, dq[i].second, dq[j].first, dq[j].second);
        cout << it._x << ' ' << it._y << endl;
    }
}

```

## 6.5 Point Class

```

struct Point{
    typedef double T;
    T x, y;

    Point() : x(0), y(0) {}
    Point(T _x, T _y) : x(_x), y(_y) {}

    bool operator < (const Point &b) const{
        return tie(x,y) < tie(b.x,b.y);
    }
    bool operator == (const Point &b) const{
        return tie(x,y) == tie(b.x,b.y);
    }
    Point operator + (const Point &b) const{
        return Point(x+b.x, y+b.y);
    }
}

```

```

Point operator - (const Point &b) const{
    return Point(x-b.x, y-b.y);
}
T operator * (const Point &b) const{
    return x*b.x + y*b.y;
}
T operator % (const Point &b) const{
    return x*b.y - y*b.x;
}
Point operator * (const T &b) const{
    return Point(x*b, y*b);
}
T abs(){
    return sqrt(abs2());
}
T abs2(){
    return x*x + y*y;
}
};

```

## 6.6 Convex Hull

```

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

```

## 6.7 Minimum Covering Circle

```

struct Mcc{
    // return pair of center and r^2
    static const int MAXN = 1000100;
    int n;
    Point p[MAXN], cen;
    double r2;

    void init(int _n, Point _p[]){
        n = _n;
        memcpy(p, _p, sizeof(Point)*n);
    }
    double sqr(double a){ return a*a; }
    Point center(Point p0, Point p1, Point p2) {
        Point a = p1-p0;
        Point b = p2-p0;
        double c1=a.len2()*0.5;
        double c2=b.len2()*0.5;
        double d = a % b;
        double x = p0.x + (c1 * b.y - c2 * a.y) / d;
        double y = p0.y + (a.x * c2 - b.x * c1) / d;
        return Point(x,y);
    }

    pair<Point, double> solve(){
        random_shuffle(p, p+n);
        r2=0;
        for (int i=0; i<n; i++){
            if ((cen-p[i]).len2() <= r2) continue;
            cen = p[i];
            r2 = 0;
            for (int j=0; j<i; j++){

```

```

                if ((cen-p[j]).len2() <= r2) continue;
                cen = Point((p[i].x+p[j].x)*0.5, (p[i].y+p[j].y)*0.5);
                r2 = (cen-p[j]).len2();
                for (int k=0; k<j; k++){
                    if ((cen-p[k]).len2() <= r2) continue;
                    cen = center(p[i], p[j], p[k]);
                    r2 = (cen-p[k]).len2();
                }
            }
        }
        return MP(cen, r2);
    }
}mcc;

```

## 6.8 (+1) KDTreeAndNearestPoint

```

const INF = 1100000000;

class NODE{ public:
    int x,y,x1,x2,y1,y2;
    int i,f;
    NODE *L,*R;
};

inline long long dis(NODE& a, NODE& b){
    long long dx=a.x-b.x;
    long long dy=a.y-b.y;
    return dx*dx+dy*dy;
}

NODE node[100000];
bool cmpx(const NODE& a, const NODE& b){ return a.x<b.x; }
bool cmpy(const NODE& a, const NODE& b){ return a.y<b.y; }

NODE* KDTree(int L, int R, int dep){
    if(L>R) return 0;
    int M=(L+R)/2;
    if(dep%2==0){
        nth_element(node+L, node+M, node+R+1, cmpx);
        node[M].f=0;
    }else{
        nth_element(node+L, node+M, node+R+1, cmpy);
        node[M].f=1;
    }
    node[M].x1=node[M].x2=node[M].x;
    node[M].y1=node[M].y2=node[M].y;
    node[M].L=KDTree(L, M-1, dep+1);
    if(node[M].L){
        node[M].x1=min(node[M].x1, node[M].L->x1);
        node[M].x2=max(node[M].x2, node[M].L->x2);
        node[M].y1=min(node[M].y1, node[M].L->y1);
        node[M].y2=max(node[M].y2, node[M].L->y2);
    }
    node[M].R=KDTree(M+1, R, dep+1);
    if(node[M].R){
        node[M].x1=min(node[M].x1, node[M].R->x1);
        node[M].x2=max(node[M].x2, node[M].R->x2);
        node[M].y1=min(node[M].y1, node[M].R->y1);
        node[M].y2=max(node[M].y2, node[M].R->y2);
    }
    return node+M;
}

inline int touch(NODE* r, int x, int y, long long d){
    long long d2;
    d2 = (long long)(sqrt(d)+1);
    if(x<r->x1-d2 || x>r->x2+d2 || y<r->y1-d2 || y>r->y2+d2)
        return 0;
    return 1;
}

void nearest(NODE* r, int z, long long &md){
    if(!r || !touch(r, node[z].x, node[z].y, md)) return;
    long long d;
    if(node[z].i!=r->i){
        d=dis(*r, node[z]);
        if(d<md) md=d;
    }
    if(r->f==0){
        if(node[z].x<r->x){
            nearest(r->L, z, md);

```



```

        nearest(r->R,z,md);
    }else{
        nearest(r->R,z,md);
        nearest(r->L,z,md);
    }
}else{
    if(node[z].y<r->y){
        nearest(r->L,z,md);
        nearest(r->R,z,md);
    }else{
        nearest(r->R,z,md);
        nearest(r->L,z,md);
    }
}
}
}
}

int main(){
    int TT,n,i;
    long long d;
    NODE* root;
    scanf("%d",&TT);
    while(TT--){
        scanf("%d",&n);
        for(i=0;i<n;i++){
            scanf("%d %d",&node[i].x,&node[i].y);
            node[i].i=i;
        }
        root=KdTree(0,n-1,0);
        for(i=0;i<n;i++){
            d=900000000000000000LL;
            nearest(root,i,d);
            ans[node[i].i]=d;
        }
    }
}
}

```

## 6.9 (+1) MinkowskiSum

```

/* convex hull Minkowski Sum */
#define INF 1000000000000000LL
class PT{ public:
    long long x,y;
    int POS(){
        if(y==0) return x>0?0:1;
        return y>0?0:1;
    }
};
PT pt[300000],qt[300000],rt[300000];
long long Lx,Rx;
int dn,un;
inline bool cmp(PT a,PT b){
    int pa=a.POS(),pb=b.POS();
    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;
    long long 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("%I64d %I64d",&pt[i].x,&pt[i].y);
    scanf("%d",&m);
    for(i=0;i<m;i++) scanf("%I64d %I64d",&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("%I64d %I64d",&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("%I64d %I64d",&p.x,&p.y);
        p.x*=3; p.y*=3;
        puts(inConvex(p)? "YES": "NO");
    }
}

```

## 7 Stringology

## 7.1 Suffix Array

```
const int MAX = 1020304;
int ct[MAX], he[MAX], rk[MAX], sa[MAX], tsa[MAX], tp[
    MAX][2];

void suffix_array(char *ip){

    int len = strlen(ip);
    int alp = 256;

    memset(ct, 0, sizeof(ct));
```



```

for(int i=0;i<len;i++) ct[ip[i]+1]++;
for(int i=1;i<alp;i++) ct[i]+=ct[i-1];
for(int i=0;i<len;i++) rk[i]=ct[ip[i]];

for(int i=1;i<len;i*=2){
    for(int j=0;j<len;j++){
        if(j+i>len) tp[j][1]=0;
        else tp[j][1]=rk[j+i]+1;

        tp[j][0]=rk[j];
    }
    memset(ct, 0, sizeof(ct));
    for(int j=0;j<len;j++) ct[tp[j][1]+1]++;
    for(int j=1;j<len+2;j++) ct[j]+=ct[j-1];
    for(int j=0;j<len;j++) tsa[ct[tp[j][1]]+1]=j;

    memset(ct, 0, sizeof(ct));
    for(int j=0;j<len;j++) ct[tp[j][0]+1]++;
    for(int j=1;j<len+1;j++) ct[j]+=ct[j-1];
    for(int j=0;j<len;j++) sa[ct[tp[j][0]]+1]=tsa[j];

    rk[sa[0]]=0;
    for(int j=1;j<len;j++){
        if( tp[sa[j]][0] == tp[sa[j-1]][0] &&
           tp[sa[j]][1] == tp[sa[j-1]][1] )
            rk[sa[j]] = rk[sa[j-1]];
        else
            rk[sa[j]] = j;
    }
}

for(int i=0,h=0;i<len;i++){
    if(rk[i]==0) h=0;
    else{
        int j=sa[rk[i]-1];
        h=max(0,h-1);
        for(;ip[i+h]==ip[j+h];h++);
    }
    he[rk[i]]=h;
}
}

```

## 7.2 Suffix Array (SAIS TWT514)

```

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++ )
    static const int MXN = 300010;
    bool _t[MXN*2];
    int _s[MXN*2], _sa[MXN*2], _c[MXN*2], x[MXN], _p[MXN], _q[MXN*2], hei[MXN], r[MXN];
    int operator [] (int i){ return _sa[i]; }
    void build(int *s, int n, int m){
        memcpy(_s, s, sizeof(int) * n);
        sais(_s, _sa, _p, _q, _t, _c, n, m);
        mkhei(n);
    }
    void mkhei(int n){
        REP(i,n) r[_sa[i]] = i;
        hei[0] = 0;
        REP(i,n) if(r[i]) {
            int ans = i>0 ? max(hei[r[i-1]] - 1, 0) : 0;
            while(_s[i+ans] == _s[_sa[r[i]-1]+ans]) ans++;
            hei[r[i]] = ans;
        }
    }
    void sais(int *s, int *sa, int *p, int *q, bool *t, int *c, int n, int z){
        bool uniq = t[n-1] = true, neq;
        int nn = 0, nmzx = -1, *nsa = sa + n, *ns = s + n, lst = -1;
#define MS0(x,n) memset((x),0,n*sizeof(*(x)))
#define MAGIC(XD) MS0(sa, n); \
        memcpy(x, c, sizeof(int) * z); \
        XD; \
        memcpy(x + 1, c, sizeof(int) * (z - 1)); \

```

```

        REP(i,n) if(sa[i] && !t[sa[i]-1]) sa[x[s[sa[i]-1]]+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]]]=nmzx+=neq;
        }
        sais(ns, nsa, p + nn, q + n, t + n, c + z, nn, nmzx + 1);
        MAGIC(for(int i = nn - 1; i >= 0; i--) sa[--x[p[nsa[i]]]] = p[nsa[i]]);
    }
};

int main(){
    // s is int array
    SA *sa = new SA();
    sa->build(s,n,128);
}

```

## 7.3 Aho-Corasick Algorithm

```

class ACautomata{
public:
    class Node{
    public:
        int cnt,dp;
        Node *go[26], *fail;
        Node (){
            cnt = 0;
            dp = -1;
            memset(go,0,sizeof(go));
            fail = 0;
        }
    };

    Node *root, pool[1048576];
    int nMem;

    Node* new_Node(){
        pool[nMem] = Node();
        return &pool[nMem++];
    }

    void init(){
        nMem = 0;
        root = new_Node();
    }

    void add(const string &str){
        insert(root,str,0);
    }

    void insert(Node *cur, const string &str, int pos){
        if (pos >= (int)str.size()){
            cur->cnt++;
            return;
        }
        int c = str[pos]-'a';
        if (cur->go[c] == 0){
            cur->go[c] = new_Node();
        }
        insert(cur->go[c],str,pos+1);
    }

    void make_fail(){
        queue<Node*> que;
        que.push(root);
        while (!que.empty()){
            Node* fr=que.front();

```

```

    que.pop();
    for (int i=0; i<26; i++){
        if (fr->go[i]){
            Node *ptr = fr->fail;
            while (ptr && !ptr->go[i])
                ptr = ptr->fail;
            if (!ptr)
                fr->go[i]->fail = root;
            else
                fr->go[i]->fail = ptr->go[i];
            que.push(fr->go[i]);
        }
    }
}
};

```

## 7.4 Z value

```

char s[MAXLEN];
int len, z[MAXLEN];
void Z_value() {
    int i, j, left, right;
    left=right=0; z[0]=len;
    for(i=1; i<len; i++) {
        j=max(min(z[i-left], right-i), 0);
        for(; i+j<len && s[i+j]==s[j]; j++);
        z[i]=j;
        if(i+z[i]>right) {
            right=i+z[i];
            left=i;
        }
    }
}

```

## 7.5 Z value (palindrome ver.)

```

const int MAX = 1000;
int len;
char ip[MAX];
char op[MAX*2];
int zv[MAX*2];

int main(){
    cin >> ip;
    len = strlen(ip);

    int l2 = len*2 - 1;
    for(int i=0; i<l2; i++){
        if(i&1) op[i] = '@';
        else op[i] = ip[i/2];
    }
    int l=0, r=0;
    zv[0] = 1;

    for(int i=1; i<l2; i++){
        if( i > r ){
            l = r = i;
            while( l>0 && r<l2-1 && op[l-1] == op[r+1] ){
                l--;
                r++;
            }
            zv[i] = (r-l+1);
        }else{
            int md = (l+r)/2;
            int j = md + md - i;
            zv[i] = zv[j];
            int q = zv[i] / 2;
            int nr = i + q;
            if( nr == r ){
                l = i + i - r;

                while( l>0 && r<l2-1 && op[l-1] == op[r+1] ){
                    l--;
                    r++;
                }
            }
            zv[i] = r - l + 1;
        }
    }
}

```

```

        }else if( nr > r ){
            zv[i] = (r - i) * 2 + 1;
        }
    }
    return 0;
}

```

## 7.6 Lexicographically Smallest Rotation

```

string solve(string str){
    int N = str.length();
    str += str;
    int i=0, j=1, k=0;
    while (j<N && k<N){
        if (str[i+k] == str[j+k]) k++;
        else {
            if (k == 0 && str[i] > str[j]){
                i++; j++;
            } else if (str[i+k] < str[j+k]){
                j += k+1;
            } else {
                i += k+1;
                j = i + 1;
            }
            k=0;
        }
    }
    string ret = "";
    for (int l=0; l<N; l++)
        ret += str[i+l];
    return ret;
}

```

## 7.7 Suffix Automaton

```

class SAM{ public:
    class State{ public:
        int par, go[26], val;
        State () : par(0), val(0){ FZ(go); }
        State (int _val) : par(0), val(_val){ FZ(go); }
    };
    vector<State> vec;
    int root, tail;

    void init(int arr[], int len){
        vec.resize(2);
        vec[0] = vec[1] = State(0);
        root = tail = 1;
        for (int i=0; i<len; i++)
            extend(arr[i]);
    }
    void extend(int w){
        int p = tail, np = vec.size();
        vec.PB(State(vec[p].val+1));
        for ( ; p && vec[p].go[w]==0; p=vec[p].par)
            vec[p].go[w] = np;
        if (p == 0){
            vec[np].par = root;
        } else {
            if (vec[vec[p].go[w]].val == vec[p].val+1){
                vec[np].par = vec[p].go[w];
            } else {
                int q = vec[p].go[w], r = vec.size();
                vec.PB(vec[q]);
                vec[r].val = vec[p].val+1;
                vec[q].par = vec[np].par = r;
                for ( ; p && vec[p].go[w] == q; p=vec[p].par)
                    vec[p].go[w] = r;
            }
        }
        tail = np;
    }
};

```

## 8 Problems

### 8.1 Find the maximum tangent (x,y is increasing)

```
typedef long long LL;
const int MAXN = 100010;
struct Coord{
    LL x, y;
    Coord operator - (Coord ag) const{
        Coord res;
        res.x = x - ag.x;
        res.y = y - ag.y;
        return res;
    }
}sum[MAXN], pnt[MAXN], ans, calc;

inline bool cross(Coord a, Coord b, Coord c){
    return (c.y - a.y) * (c.x - b.x) > (c.x - a.x) * (c.y - b.y);
}

int main(){
    int n, l, np, st, ed, now;
    scanf("%d %d\n", &n, &l);
    sum[0].x = sum[0].y = np = st = ed = 0;
    for (int i = 1, v; i <= n; i++){
        scanf("%d", &v);
        sum[i].y = sum[i - 1].y + v;
        sum[i].x = i;
    }
    ans.x = now = 1;
    ans.y = -1;
    for (int i = 0; i <= n - 1; i++){
        while (np > 1 && cross(pnt[np - 2], pnt[np - 1], sum[i]))
            np--;
        if (np < now && np != 0) now = np;
        pnt[np++] = sum[i];
        while (now < np && !cross(pnt[now - 1], pnt[now], sum[i + 1]))
            now++;
        calc = sum[i + 1] - pnt[now - 1];
        if (ans.y * calc.x < ans.x * calc.y){
            ans = calc;
            st = pnt[now - 1].x;
            ed = i + 1;
        }
    }
    double res = (sum[ed].y - sum[st].y) / (sum[ed].x - sum[st].x);
    printf("%f\n", res);
    return 0;
}
```

### 8.2 Orange Protection

```
/*
 * Given a Tree and the power of every node.
 * Each Node can protect the nodes whose distance <=
 * cover[i] with it
 * output the number of each node that it can protect.
 */
const int MXN = 100005;

int cover[MXN], ans[MXN];
int N, ok[MXN];
int fr, bk, que[MXN], vst[MXN], dis[MXN], fa[MXN], sz[MXN];
vector<int> E[MXN];

int bit[MXN];
int lb(int a){ return a & -a; }
void reset_bit(int st){
    for (int i = st+1; i < MXN; i+=lb(i))
        bit[i] = 0;
}
void update(int st){
    for (int i = st+1; i < MXN; i+=lb(i))
```

```
        bit[i]++;
}
int query(int st, int ret = 0){
    for (int i = st+1; i > 0; i-=lb(i))
        ret += bit[i];
    return ret;
}

void BFS(int st){
    fr = bk = 0;
    que[bk++] = st;
    vst[st] = 1;
    dis[st] = 0;
    while (fr < bk){
        int u = que[fr++];
        for (auto v : E[u]){
            if (!ok[v] || vst[v]) continue;
            vst[v] = 1;
            dis[v] = dis[u] + 1;
            fa[v] = u;
            que[bk++] = v;
        }
    }
    for (int i=0; i<bk; i++)
        vst[que[i]] = 0;
}

int find_centroid(int st){
    int ret=-1, cnt=MXN+100;
    BFS(st);
    for (int i = bk-1; i>=0; i--){
        int u = que[i], mx = 0;
        sz[u] = 1;
        for (auto v : E[u]){
            if (!ok[v] || v == fa[u]) continue;
            sz[u] += sz[v];
            mx = max(mx, sz[v]);
        }
        mx = max(mx, bk-sz[u]);
        if (mx < cnt){
            ret = u;
            cnt = mx;
        }
    }
    return ret;
}

void solve(int u){
    int root = find_centroid(u);
    ok[root] = 0;
    for (auto v : E[root])
        if (ok[v]) solve(v);

    for (auto v : E[root]){
        if (!ok[v]) continue;
        BFS(v);
        for (int i=0; i<bk; i++){
            dis[que[i]]++;
            update(dis[que[i]]);
        }
        for (int i=0; i<bk; i++){
            int it = que[i];
            ans[it] -= query(cover[it] - dis[it]);
        }
        for (int i=0; i<bk; i++)
            reset_bit(dis[que[i]]);
    }
    BFS(root);
    for (int i=0; i<bk; i++) update(dis[que[i]]);
    for (int i=0; i<bk; i++){
        int v = que[i];
        ans[v] += query(cover[v] - dis[v]);
    }
    for (int i=0; i<bk; i++) reset_bit(dis[que[i]]);

    ok[root] = 1;
}

int main(int argc, char** argv){
    scanf("%d", &N);
    for (int i=0; i<N; i++){
        scanf("%d", &cover[i]);
        cover[i] = min(cover[i], N);
    }
```

```
}
for (int i=0,u,v; i<N-1; i++){
    scanf("%d%d", &u, &v);
    u--; v--;
    E[u].PB(v);
    E[v].PB(u);
}
fill(ok,ok+N,1);
FZ(vst); FZ(ans); FZ(bit);
solve(0);
for (int i=0; i<N; i++)
    printf("%d\n", ans[i]);
return 0;
}
```