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1 Basic

1.1 .vimrc

```
imap jj <Esc>

sy on
se sw=4 ts=4 sts=4 et nu sc hls cc=69
filetype plugin indent on
nn <F5> :!"/%<"<CR>
nn <F6> :!"/%<" < input.txt<CR>
au FileType cpp no <F9> :!g++ % -o
\ %< -std=c++14 -O3 -Wall -Wextra
\ -Wshadow -Wno-unused-result<CR>
no <expr> <silent> <Home> col( '.' ) ==
\ match(getline( '.' ), '\S') + 1
\ ? '0' : '^'
im <silent> <Home> <C-O><Home>
```

1.2 Increase Stack Size

```
//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);
        }
    }
}
```

2 Graph

2.1 HLD

```
struct segment_tree{
    #define MAXN 100100
    #define right(x) x << 1 | 1
    #define left(x) x << 1
    int* arr;
    LL sum[4*MAXN];
    const int inf = 1e9;

    void pull(int ind) {
        sum[ind] = sum[right(ind)]+sum[left(ind)];
    };
    /// root => 1
    void build(int ind, int l, int r) {

        if( r - l == 1 ) {
            sum[ind] = 0;
            return;
        }
        int mid = (l+r)>>1;
        build( left(ind), l, mid );
        build( right(ind), mid, r );
        pull(ind);
    }
    LL query_sum(int ind, int L, int R, int ql, int qr)
    {
        if( L >= qr || R <= ql ) return 0;
        if( R <= qr && L >= ql ) {
            return sum[ind];
        }
        int mid = (L+R)>>1;
        return query_sum(left(ind), L, mid, ql, qr) +
            query_sum(right(ind), mid, R, ql, qr);
    }
}
```

```

void modify(int ind, int L, int R, int ql, int qr,
            int x) {
    if( L >= qr || R <= ql ) return;
    if( R <= qr && L >= ql ) {
        sum[ind] = x;
        return;
    }
    int mid = (L+R)>>1;
    modify(left(ind), L, mid, ql, qr, x);
    modify(right(ind), mid, R, ql, qr, x);
    pull(ind);
}

};

struct Tree{
    segment_tree seg;
#define MAXN 100010
#define maxm (maxn<<1)
    int n;
    struct edge { int u, v; };
    vector<edge> e;
    void addedge(int x, int y) {
        G[x].pb( SZ(e) );
        G[y].pb( SZ(e) );
        e.pb( edge{x, y} );
    }
    int siz[MAXN], max_son[MAXN], pa[MAXN], dep[MAXN];
    /*size of subtree `index of max_son, parent index `
    depth*/
    int link_top[MAXN], link[MAXN], Time;
    /*chain top `index in segtree `time stamp*/
    std::vector<int> >G[MAXN];

    void init(int N) {
        n = N;
        e.clear();
        for(int i = 1; i <= n; i++) G[i].clear();
    }

    void find_max_son(int x){
        siz[x]=1;
        max_son[x]=-1;
        for(int e_ind : G[x]) {
            int v = e[e_ind].u == x ? e[e_ind].v : e[
                e_ind].u ;
            if( v == pa[x] )continue;
            pa[v] = x; dep[v] = dep[x] + 1;
            find_max_son(v);
            if(max_son[x] == -1 || siz[v] > siz[max_son
                [x]])
                max_son[x] = v;
            siz[x] += siz[v];
        }
    }

    void build_link(int x,int top){
        link[x] = ++Time; /*記錄x點的時間戳*/
        link_top[x] = top;
        if(max_son[x] == -1)return;
        build_link( max_son[x], top); /*優先走訪最大孩子
        */
        for(int e_ind : G[x]) {
            int v = e[e_ind].u == x ? e[e_ind].v : e[
                e_ind].u ;
            if( v == max_son[x] || v == pa[x] )continue
                ;
            build_link(v, v);
        }
    }

    inline int lca(int a,int b){
        /*求LCA, 可以在過程中對區間進行處理*/
        int ta=link_top[a],tb=link_top[b];
        while(ta != tb){
            if(dep[ta]<dep[tb]){
                std::swap(ta,tb);
                std::swap(a,b);
            }
            //interval [ link[ta], link[a] ]
            a = pa[ta];
            ta = link_top[a];
        }
        return dep[a] < dep[b] ? a:b;
    }
}

```

```

int query(int a,int b){
    int ret = 0;
    int ta=link_top[a],tb=link_top[b];
    while(ta != tb){
        if(dep[ta]<dep[tb]){
            std::swap(ta,tb);
            std::swap(a,b);
        }
        //interval [ link[ta],link[a] ]
        a = pa[ta];
        ta = link_top[a];
    }
    if( a == b ) return ret;
    else {
        if(dep[a]>dep[b])
            swap(a,b);
        //interval [ link[a],link[b] ]
        // if operate on edges ==> [ link[ max_son[
            ta] ], link[b] ]
    }
}

/// Heavy Light Decomposition
void HLD() {
    // root is indexed 1 here !
    find_max_son(1);
    build_link(1, 1);
}

void modify(int a, int b, int x) {
    // modify the path from a -> b to x
    //( which is [ link[a] .. link[b] ] on the
    segment tree)
    seg.modify(1, 1, n+1, link[a], link[b]+1, x);
    // this segment tree uses [ 1 ..n+1 ]
}

}tree;

```

2.2 Hungarian

```

// edge and node index starting from 0
// dfs version below
/* to do
#define __maxNodes
num_left = ?
*/
struct Edge {
    int from;
    int to;
    int weight;
    Edge(int f, int t, int w):from(f), to(t), weight(w)
    {}
};

vector<int> G[__maxNodes]; /* G[i] 存储顶点 i 出发的边
    的编号 */
vector<Edge> edges;
int num_nodes;
int num_left;
int num_right;
int num_edges;
int matching[__maxNodes]; /* matching result */
int check[__maxNodes];

bool dfs(int u) {
    for (auto i = G[u].begin(); i != G[u].end(); ++i) {
        // 对 u 的每个邻接点
        int v = edges[*i].to;
        if (!check[v]) { // 要求不在交替路中
            check[v] = true; // 放入交替路
            if (matching[v] == -1 || dfs(matching[v]))
                {
                    // 如果是未盖点, 说明交替路为增广路, 则
                    交换路径, 并返回成功
                    matching[v] = u;
                    matching[u] = v;
                    return true;
                }
        }
    }
    return false; // 不存在增广路, 返回失败
}

```

```

int hungarian() {
    int ans = 0;
    memset(matching, -1, sizeof(matching));
    for (int u=0; u < num_left; ++u) {
        if (matching[u] == -1) {
            memset(check, 0, sizeof(check));
            if (dfs(u)) ++ans;
        }
    }
    return ans;
}

```

2.3 KM

```

// 最小帶權匹配~ km算法
//http://acm.csie.org/ntujudge/contest_view.php?id=836&
    contest_id=449
#include <bits/stdc++.h>
using namespace std;

struct bipartite {
    #define maxn 602
    #define INF 0xffffffff
    int sx[maxn], sy[maxn], mat[maxn][maxn];
    int x[maxn], y[maxn], link[maxn];
    int N, M, slack;

    int DFS(int t) {
        int tmp;
        sx[t] = 1;
        for (int i = 0; i < M; i++) {
            if (!sy[i]) {
                tmp = x[t] + y[i] - mat[t][i];
                if (tmp == 0) {
                    sy[i] = 1;
                    if (link[i] == -1 || DFS(link[i])) {
                        link[i] = t;
                        return 1;
                    }
                }
            }
            else if (tmp < slack) slack = tmp;
        }
        return 0;
    }

    int KM() {
        for (int i = 0; i < N; i++) {
            x[i] = 0;
            for (int j = 0; j < M; j++) {
                if (mat[i][j] > x[i]) x[i] = mat[i][j];
            }
        }
        for (int j = 0; j < M; j++) { y[j] = 0; }
        memset(link, -1, sizeof(link));
        for (int i = 0; i < N; i++) {
            while (1) {
                memset(sx, 0, sizeof(sx));
                memset(sy, 0, sizeof(sy));
                slack = INF;
                if (DFS(i)) break;
                for (int j = 0; j < N; j++) {
                    if (sx[j]) x[j] -= slack;
                }
                for (int j = 0; j < M; j++) {
                    if (sy[j]) y[j] += slack;
                }
            }
        }

        int ans = 0;
        int cnt = 0;
        int t;
        for (int i = 0; i < M; i++) {
            {
                t = link[i];
                if (t >= 0 && mat[t][i] != -INF) {
                    cnt ++;
                    ans += mat[t][i];
                }
            }
        }
    }
}

```

```

    }
}
// 最大權 : 沒有負號
return -ans;
}

void init(int n, int m) {
    N = n, M = m;
    for (int i = 0; i < N; i++)
        for (int j = 0; j < M; j++)
            mat[i][j] = -INF;
}

void input() {
    for (int i = 0; i < N; i++)
        for (int j = 0; j < M; j++) {
            // fill in mat[i][j]
            // stands for the weighting , but
            // negative sign !
            // if 最大權 : 沒有負號
        }
}

}
}km;

int main(){
    int n,E;
    while (scanf("%d", &n) != EOF)
    {
        km.init(n, n);
        km.input();
        cout<< km.KM() <<endl;
    }
    return 0;
}

```

2.4 Bi-vertex-connected Subgraph

```

#include <bits/stdc++.h>
using namespace std;
#ifdef DEBUG
    #define debug(...) printf(__VA_ARGS__)
#else
    #define debug(...) (void)0
#endif
#define mp make_pair
#define pb push_back
#define LL long long
#define pii pair<int,int>
#define PII pair<long long, long long>
#define fi first
#define se second
#define all(x) (x).begin(),(x).end()
#define SZ(x) ((int)(x).size())
const int inf = 0x7fffffff; //beware overflow
const LL INF = 0x7fffffffffffffff; //beware overflow
#define mem(x, y) memset(x, (y), sizeof(x));
#define IOS ios_base::sync_with_stdio(0); cin.tie(0)
template<typename A, typename B>
ostream& operator <<(ostream &s, const pair<A,B> &p) {
    return s<<"("<<p.first<<","<<p.second<<")";
}

template<typename T>
ostream& operator <<(ostream &s, const vector<T> &c) {
    s << "[";
    for (auto it : c) s << it << " ";
    s << "]";
    return s;
}

template<typename T>
ostream& operator << (ostream &o, const set<T> &st) {
    o << "{";
    for (auto it=st.begin(); it!=st.end(); it++) o << (
        it==st.begin() ? "" : ", ") << *it;
    return o << "}";
}

template<typename T1, typename T2>
ostream& operator << (ostream &o, const map<T1, T2> &mp) {
    o << "{";
    for (auto it=mp.begin(); it!=mp.end(); it++) {

```

```

        o << (it==mp.begin()?"":", ") << it->fi << ":""
        << it->se;
    }
    o << "}";
    return o;
}

//    regard every vbcc as a set of edges
/** needed for tarjan */
#define maxn 100005
#define maxm 100005
int n, m;
struct Edge{int s, t;};
vector<Edge> edge;
int dfn[maxn], low[maxn];
stack<int> st;
bool vis[maxn];
int Time;
bool vis_e[maxn];
int bcnt, vbb[maxn];
vector<int> vb[maxn];
vector<int> G[maxn];
/** **/

void tarjan(int s){
    dfn[s] = low[s] = ++Time;
    vis[s] = true;
    for(int e_ind : G[s]){
        if(!vis_e[e_ind]){
            vis_e[e_ind] = true; st.push(e_ind);
            int to = edge[e_ind].s + edge[e_ind].t - s;
            if(!vis[to]){
                tarjan(to);
                low[s] = min(low[s], low[to]);
                if(low[to] >= dfn[s]){
                    vb[bcnt].clear();
                    while(1){
                        int t = st.top(); st.pop();
                        vbb[t] = bcnt;
                        vb[bcnt].push_back(t);
                        if(t == e_ind) break;
                    }
                    bcnt++;
                }
            }
            else
                low[s] = min(low[s], dfn[to]);
        }
    }
}

void init_tarjan() {
    mem(vis, false); mem(vis_e, false);
    Time = bcnt = 0; edge.clear();
    for(int i = 1; i <= n; i++) G[i].clear();
}

int main() {
    cin >> n >> m;
    init_tarjan();
    for(int i = 0; i < m; i++) {
        int a, b; scanf("%d %d", &a, &b);
        edge.push_back(Edge{a, b});
        G[a].push_back((int)edge.size()-1);
        G[b].push_back((int)edge.size()-1);
    }
    tarjan(1);
}

```

2.5 Bi-edge-connected Subgraph

```

/** needed for tarjan */
#define maxn 100005
#define maxm 100005
int n, m;
int dfn[maxn], low[maxn];
stack<int> st;

```

```

int Time;
int bcnt;
vector<int> G[maxn];
bool in_cyc[maxn];
/** **/

void tarjan(int s, int p){
    dfn[s] = low[s] = ++Time;
    st.push(s);
    for(int to : G[s]) if( to != p ){
        if(!dfn[to]) {
            tarjan(to, s);
            low[s] = min(low[s], low[to]);
            if( low[to] > dfn[s]) {
                // is cut_edge
                // pop stack 的過程也可以寫在這
                // 但最後(after tarjan)還要多判stack
                // not empty的情況
                /*
                if( low[to] > dfn[s]) {
                    in_cyc[bcnt] = st.top() != to;
                    while(1){
                        int t = st.top(); st.pop();
                        id[t] = bcnt;
                        if(t == to) break;
                    }
                    bcnt++;
                */
            }
        }
        else
            low[s] = min(low[s], dfn[to]);
    }

    if(low[s] == dfn[s]){
        in_cyc[bcnt] = st.top() != s;
        while(1){
            int t = st.top(); st.pop();
            id[t] = bcnt;
            if(t == s) break;
        }
        bcnt++;
    }
}

void init_tarjan() {
    Time = bcnt = 0;
}

int main() {
    cin >> n >> m;
    init_tarjan();
    for(int i = 0; i < m; i++) {
        int a, b; scanf("%d %d", &a, &b);
        G[a].pb(b), G[b].pb(a);
    }
    mem(in_cyc, false);
    tarjan(1, 1);
}

```

2.6 SCC

```

#include <bits/stdc++.h>

using namespace std;
#define mp make_pair
#define pb push_back
#define LL long long
#define pii pair<int, int>
#define PII pair<long long, long long>
#define fi first
#define se second

const int inf = 1e9;
const LL INF = 1e18;
const int mod = 1e9+7;
#define maxn 100050

int n, m;

```

```

vector<int> g[maxn];
stack<int> Stack;
int scnt, Time;
int belong[maxn], dfn[maxn], low[maxn], indegree[maxn];
bool instack[maxn];
void input(){
    cin >> n >> m;
    for(int i = 0; i < m; i++){
        int a, b; scanf("%d%d", &a, &b);
        g[a].pb(b);
    }
}
void init() {
    scnt = Time = 0;
    for(int i = 1; i <= n; i++)
        g[i].clear();
    while(!Stack.empty()) Stack.pop();
    memset(indegree, 0, sizeof(indegree));
    memset(dfn, 0, sizeof(dfn));
    memset(instack, false, sizeof(instack));
}
void dfs(int u) {
    dfn[u] = low[u] = ++Time;
    Stack.push(u); instack[u] = true;
    for(int v : g[u]) {
        if (!dfn[v]) {
            dfs(v);
            low[u] = min(low[u], low[v]);
        }
        else if(instack[v])
            low[u] = min(low[u], dfn[v]);
    }
    if(low[u] == dfn[u]) {
        scnt++;
        int tp;
        do{
            tp = Stack.top(); Stack.pop();
            instack[tp] = false;
            belong[tp] = scnt;
        } while(tp != u);
    }
}
void tarjan() {
    for(int i = 1; i <= n; i++)
        if(!dfn[i])
            dfs(i);
}
int main(){
    int T; cin >> T;
    while(T--){
        init();
        input();
        tarjan();
        for(int i = 1; i <= n; i++) {
            for(int v : g[i]) {
                if(belong[v] != belong[i])
                    indegree[belong[v]]++;
            }
        }
        LL ans = 0;
        for(int i = 1; i <= scnt; i++)
            if(!indegree[i]) ans++;
        cout << ans << endl;
    }
    return 0;
}

```

2.7 Steiner Tree(PECaveros)

```

// Minimum Steiner Tree
// O(V^3 T + V^2 2^T)
struct SteinerTree{
#define V 33
#define T 8
#define INF 1023456789
    int n, dst[ V ][ V ], dp[ 1 << T ][ V ], tdst[ V ];
    void init( int _n ){
        n = _n;
        for( int i = 0 ; i < n ; i ++ ){

```

```

            for( int j = 0 ; j < n ; j ++ )
                dst[ i ][ j ] = INF;
            dst[ i ][ i ] = 0;
        }
    }
    void add_edge( int ui , int vi , int wi ){
        dst[ ui ][ vi ] = min( dst[ ui ][ vi ] , wi );
        dst[ vi ][ ui ] = min( dst[ vi ][ ui ] , wi );
    }
    void shortest_path(){
        for( int k = 0 ; k < n ; k ++ )
            for( int i = 0 ; i < n ; i ++ )
                for( int j = 0 ; j < n ; j ++ )
                    dst[ i ][ j ] = min( dst[ i ][ j ],
                                            dst[ i ][ k ] + dst[ k ][ j ] );
    }
    int solve( const vector<int>& ter ){
        int t = (int)ter.size();
        for( int i = 0 ; i < ( 1 << t ) ; i ++ )
            for( int j = 0 ; j < n ; j ++ )
                dp[ i ][ j ] = INF;
        dp[ 0 ][ i ] = 0;
        for( int msk = 1 ; msk < ( 1 << t ) ; msk ++ ){
            if( msk == ( msk & (-msk) ) ){
                int who = __lg( msk );
                for( int i = 0 ; i < n ; i ++ )
                    dp[ msk ][ i ] = dst[ ter[ who ] ][ i ];
                continue;
            }
            for( int i = 0 ; i < n ; i ++ )
                for( int submsk = ( msk - 1 ) & msk ; submsk ;
                    submsk = ( submsk - 1 ) & msk )
                    dp[ msk ][ i ] = min( dp[ msk ][ i ],
                                            dp[ submsk ][ i ] +
                                            dp[ msk ^ submsk ][ i ] );
            for( int i = 0 ; i < n ; i ++ ){
                tdst[ i ] = INF;
                for( int j = 0 ; j < n ; j ++ )
                    tdst[ i ] = min( tdst[ i ],
                                    dp[ msk ][ j ] + dst[ j ][ i ] );
            }
            for( int i = 0 ; i < n ; i ++ )
                dp[ msk ][ i ] = tdst[ i ];
        }
        int ans = INF;
        for( int i = 0 ; i < n ; i ++ )
            ans = min( ans , dp[ ( 1 << t ) - 1 ][ i ] );
        return ans;
    }
} solver;

```

2.8 Edmond's Matching Algorithm

```

// 带花树, Edmonds's matching algorithm, 一般图最大匹配
// Problem: http://acm.timus.ru/problem.aspx?space=1&num=1099
#include <cstdio>
#include <cstdlib>
#include <cstring>
#include <iostream>
#include <algorithm>
using namespace std;
const int N=250;
int n;
int head;
int tail;
int Start;
int Finish;
int link[N]; //表示哪个点匹配了哪个点
int Father[N]; //这个就是增广路的Father……但是用起来太精髓了
int Base[N]; //该点属于哪朵花
int Q[N];
bool mark[N];
bool map[N][N];
bool InBlossom[N];

```

```

bool in_Queue[N];

void CreateGraph(){
    int x,y;
    scanf("%d",&n);
    while (scanf("%d%d",&x,&y)!=EOF)
        map[x][y]=map[y][x]=1;
}

void BlossomContract(int x,int y){
    fill(mark,mark+n+1,false);
    fill(InBlossom,InBlossom+n+1,false);
#define pre Father[link[i]]
    int lca,i;
    for (i=x;i==pre) {i=Base[i]; mark[i]=true; }
    for (i=y;i==pre) {i=Base[i]; if (mark[i]) {lca=i; break;}} //寻找lca之旅.....一定要注意i=Base[i]
    for (i=x;Base[i]!=lca;i=pre){
        if (Base[pre]!=lca) Father[pre]=link[i]; //对于
        BFS树中的父边是匹配边的点, Father向后跳
        InBlossom[Base[i]]=true;
        InBlossom[Base[link[i]]]=true;
    }
    for (i=y;Base[i]!=lca;i=pre){
        if (Base[pre]!=lca) Father[pre]=link[i]; //同理
        InBlossom[Base[i]]=true;
        InBlossom[Base[link[i]]]=true;
    }
#undef pre
    if (Base[x]!=lca) Father[x]=y; //注意不能从lca
    这个奇环的关键点跳回来
    if (Base[y]!=lca) Father[y]=x;
    for (i=1;i<=n;i++){
        if (InBlossom[Base[i]]){
            Base[i]=lca;
            if (!in_Queue[i]){
                Q[++tail]=i;
                in_Queue[i]=true; //要注意如果本来连
                向BFS树中父结点的边是非匹配边的点,可
                能是没有入队的
            }
        }
    }
}

void Change(){
    int x,y,z;
    z=Finish;
    while (z){
        y=Father[z];
        x=link[y];
        link[y]=z;
        link[z]=y;
        z=x;
    }
}

void FindAugmentPath(){
    fill(Father,Father+n+1,0);
    fill(in_Queue,in_Queue+n+1,false);
    for (int i=1;i<=n;i++) Base[i]=i;
    head=0; tail=1;
    Q[1]=Start;
    in_Queue[Start]=1;
    while (head!=tail){
        int x=Q[head];
        for (int y=1;y<=n;y++){
            if (map[x][y] && Base[x]!=Base[y] && link[x]
                !=y) //无意义的边
                if (Start==y || link[y] && Father[link[y]]
                    ) //精髓地用Father表示该点是否
                    BlossomContract(x,y);
            else if (!Father[y]){
                Father[y]=x;
                if (link[y]){
                    Q[++tail]=link[y];
                    in_Queue[link[y]]=true;
                }
            }
            else{
                Finish=y;
                Change();
            }
        }
        head++;
    }
}

```

```

        return;
    }
}

void Edmonds(){
    memset(link,0,sizeof(link));
    for (Start=1;Start<=n;Start++){
        if (link[Start]==0)
            FindAugmentPath();
    }
}

void output(){
    fill(mark,mark+n+1,false);
    int cnt=0;
    for (int i=1;i<=n;i++){
        if (link[i]) cnt++;
        printf("%d\n",cnt);
        for (int i=1;i<=n;i++){
            if (!mark[i] && link[i]){
                mark[i]=true;
                mark[link[i]]=true;
                printf("%d %d\n",i,link[i]);
            }
        }
    }
}

int main(){
    // freopen("input.txt","r",stdin);
    CreateGraph();
    Edmonds();
    output();
    return 0;
}

```

2.9 Tree Decomposition

```

//codeforces Digit Tree
//http://codeforces.com/problemset/problem/715/C
#include <bits/stdc++.h>
using namespace std;
#ifdef DEBUG
#define debug(...) printf(__VA_ARGS__)
#else
#define debug(...) (void)0
#endif
#define mp make_pair
#define pb push_back
#define LL long long
#define pii pair<int,int>
#define PII pair<long long, long long>
#define fi first
#define se second
#define all(x) (x).begin(),(x).end()
#define SZ(x) ((int)(x).size())
const int inf = 0x7fffffff; //beware overflow
const LL INF = 0x7fffffffffffffff; //beware overflow
#define mem(x, y) memset(x, (y), sizeof(x));
#define IOS ios_base::sync_with_stdio(0); cin.tie(0)
template<typename A, typename B>
ostream& operator <<(ostream &s, const pair<A,B> &p) {
    return s<<"("<<p.first<<","<<p.second<<")";
}
template<typename T>
ostream& operator <<(ostream &s, const vector<T> &c) {
    s << "[";
    for (auto it : c) s << it << " ";
    s << "]";
    return s;
}
template<typename T>
ostream& operator << (ostream &o, const set<T> &st) {
    o << "{";
    for (auto it=st.begin(); it!=st.end(); it++) o << (
        it==st.begin() ? "" : ", " ) << *it;
    return o << "}";
}
template<typename T1, typename T2>
ostream& operator << (ostream &o, const map<T1, T2> &mp) {
    o << "{";
    for (auto it=mp.begin(); it!=mp.end(); it++) o << (
        it==mp.begin() ? "" : ", " ) << *it;
    return o << "}";
}

```

```

    o << "{}";
    for (auto it=mp.begin(); it!=mp.end(); it++) {
        o << (it==mp.begin()?"":", ") << it->fi << " ";
        << it->se;
    }
    o << "}";
    return o;
}

typedef long long ll;

bool isprime[100005];
vector<LL> primes;
LL M, PHI;
#define MOD M
ll modpow(ll a, ll b) {
    ll r = 1;
    while(b) {
        if(b&1) r=(r*a)%MOD;
        a=(a*a)%MOD;
        b>>= 1;
    }
    return r;
}

void Sieve(int n) {
    memset(isprime, 1, sizeof(isprime));
    isprime[1] = false;
    for(int i = 2; i <= n; i++) {
        if(isprime[i]) {
            primes.pb(i);
            for(int j = 2*i; j <= n; j += i)
                isprime[j] = false;
        }
    }
}

LL phi(LL n) {
    ll num = 1; ll num2 = n;
    for(ll i = 0; primes[i]*primes[i] <= n; i++) {
        if(n%primes[i]==0) {
            num2/=primes[i];
            num*=(primes[i]-1);
        }
        while(n%primes[i]==0) {
            n/=primes[i];
        }
    }
    if(n>1) {
        num2/=n; num*=(n-1);
    }
    n = 1;
    num *= num2;
    return num;
}

ll inv(ll a) {
    return modpow(a, PHI-1);
}

#define maxn 100005
struct edge{
    int u, v, dig;
    int no(int x) {
        return x == u ? v : u;
    }
};
vector<edge> e;
vector<int> G[maxn];
LL n, ans;
bool vis[maxn];
int sz[maxn], dep[maxn];
LL tenPow[maxn];
int dfs(int u, int p, int d) {
    sz[u] = 1;
    dep[u] = d;
    for(int eind : G[u]) {
        int v = e[eind].no(u);
        if( v == p || vis[v] ) continue;
        sz[u] += dfs(v, u, d+1);
    }
    return sz[u];
}

int findCenter(int u, int p, int treesize) {
    for(int eind : G[u]) {

```

```

        int v = e[eind].no(u);
        if( v == p || vis[v] ) continue;
        if( sz[v]*2 > treesize)
            return findCenter( v, u, treesize);
    }
    return u;
}

LL up[maxn], down[maxn];
int belong[maxn];
map<LL, LL> tot;
vector<map<LL, LL> > vec;
vector<int> pt;

void calc(int u, int p, int b, int d) {
    pt.pb( u );
    belong[u] = b;
    dep[u] = d;

    int id = find_if( all(G[u]), [u,p](int x) { return
        e[x].no(u) == p; } ) - G[u].begin();
    down[u] = ( down[p]*10 + e[ G[u][id] ].dig )%M;
    up[u] = (tenPow[ d-1 ]*e[ G[u][id] ].dig + up[p] )
        %M;

    for(int eind : G[u]) {
        int v = e[eind].no(u);
        if( vis[v] || v == p ) continue;
        calc( v, u, b, d+1);
    }

    vec[b][ up[u] ]++;
    tot[ up[u] ]++;
}

LL solve(int cent) {
    //cent is the root now
    vector<int> L;
    for(int eind : G[cent]) {
        int v = e[eind].no(cent);
        if( !vis[v] ) {
            L.pb( v );
        }
    }
    vec.clear();
    vec.resize( SZ(L), {} );
    tot.clear();
    up[cent] = down[cent] = 0;
    dep[cent] = 0;
    pt.clear();
    for(int i = 0; i < SZ(L); i++)
        calc( L[i], cent, i, 1);

    LL ret = 0;
    for(int u : pt) {
        LL tmp = (-down[u]+M)%M;
        tmp = ( tmp*inv( tenPow[ dep[u] ] ) )%M;
        ret += tot[ tmp ] - vec[ belong[u] ][ tmp ];
    }
    assert( (LL)count_if(all(pt), [] (int x) { return
        up[x] == 0; } ) == tot[0] );
    LL tmp = tot[0] + (LL)count_if(all(pt), [] (int x)
        { return down[x] == 0; } );
    debug( "%lld\n", tmp );
    return ret+tmp;
}

void solveAll(int node) {
    dfs(node, -1, 0);
    int cent = findCenter(node, -1, sz[node]);
    ans += solve( cent );
    debug( "%d %lld\n", cent, ans );
    vis[cent] = true;
    for(int eind : G[cent]) {
        int v = e[eind].no(cent);
        if( vis[v] ) continue;
        solveAll(v);
    }
}

int main() {
    cin>>n>>M;
    Sieve( 100000 );
    PHI = phi(M);

```



```

    for(int i = 0; i < n-1; i++) {
        int a, b, c; scanf("%d %d %d", &a, &b, &c);
        G[a].pb( SZ(e) ); G[b].pb( SZ(e) );
        e.pb( edge{a, b, c} );
    }
    //init
    tenPow[0] = 1;
    for(int i = 1; i < maxn; i++) tenPow[i] = (tenPow[i-1]*10)%M;
    ans = 0;
    mem( vis, false );
    solveAll(0);
    cout<<ans<<endl;
}

```

2.10 Tree Longest Path

```

/** codeforces 592D - Super M */
#include <bits/stdc++.h>

using namespace std;

#define mp make_pair
#define pb push_back
#define LL long long
#define pii pair<int,int>
#define PII pair<long long, long long>
#define fi first
#define se second

const int inf = 1e9;
const LL INF = 1e18;
const int mod = 1e9+7;
#define maxn 123460

int n, m;
vector<int> g[maxn];
bool is[maxn];
int dep[maxn], R, max_depth, A;
int cnt[maxn], parent[maxn];

bool dfs(int u, int par = 0){
    parent[u] = par;
    dep[u] = dep[par] + 1;
    if(dep[u] > max_depth && is[u])
        max_depth = dep[u], R = u;
    bool ret = is[u];
    for(int v : g[u])
        if(v != par)
            ret |= dfs(v, u);
    if(ret) A++;
    return ret;
}

int find_center(int start) {
    R = start; dep[0] = -1; max_depth = 0;
    dfs(start);
    max_depth = 0; dep[R] = -1;
    dfs(R, R);
    int ret = R, d = max_depth/2;
    while( d>0 ) {
        d--;
        ret = parent[ret];
    }
    return ret;
}

int S, dis, max_length;
bool dfs1(int u, int par = 0) {
    dep[u] = dep[par] + 1;
    if(is[u])
        if(dep[u] > max_length)
            max_length = dep[u], S = u;
        else if(dep[u] == max_length && u < S)
            S = u;

    bool c = false;
    for(int v : g[u])
        if( v != par )
            dfs1(v, u);
}

```

```

int main(){
    cin >> n >> m;
    for(int i = 0; i < n-1; i++){
        int a, b; scanf("%d%d", &a, &b);
        g[a].pb(b), g[b].pb(a);
    }
    memset(is, false, sizeof(is));
    int tmp;
    for(int i = 0; i < m; i++){
        cin>>tmp; is[tmp] = true;
    }
    int C = find_center(tmp);
    dep[0] = -1; S = inf; dis = (max_depth+1)/2;
    // distance(center, any other node) <= (longestpath + 1) / 2
    dfs1(C);
    if( max_depth & 1)
        dfs1(parent[C]);
    cout << S << endl << A-2-max_depth << endl;
    return 0;
}

```

3 Flow

3.1 Dinic Maxflow

```

/** Uva 820 */
#include <bits/stdc++.h>

using namespace std;

#define mp make_pair
#define pb push_back
#define LL long long
#define pii pair<int,int>
#define PII pair<long long, long long>
#define fi first
#define se second

const int inf = 0x7fffffff;
const LL INF = 0x7fffffffffffffff;
const int mod = 1e9+7;
#define maxn 105

int n;
struct edge{ int to, cap, rev; };
vector<edge> g[maxn];
int dis[maxn], iter[maxn];
void addedge(int from, int to, int cap) {
    g[to].pb(edge{from, cap, (int)g[from].size()});
    g[from].pb(edge{to, cap, (int)g[to].size()-1});
}

bool bfs(int s, int t) {
    memset(dis, -1, sizeof(dis));
    queue<int> que;
    que.push(s); dis[s] = 0;
    while(!que.empty()) {
        int tp = que.front(); que.pop();
        for(edge e : g[tp]) {
            if(e.cap > 0 && dis[e.to] == -1)
                dis[e.to] = dis[tp] + 1, que.push(e.to);
        }
    }
    return dis[t] != -1;
}

int dfs(int v, int t, int f) {
    if( v == t ) return f;
    for(int &i = iter[v]; i < g[v].size(); i++) {
        edge &e = g[v][i];
        if(e.cap > 0 && dis[v] < dis[e.to]) {
            int d = dfs(e.to, t, min(f, e.cap));
            if(d > 0) {
                e.cap -= d;
                g[e.to][e.rev].cap += d;
                f += d;
                return d;
            }
        }
    }
}

return 0;

```



```

}
int dinic(int s, int t) {
    int ret = 0;
    while( bfs(s, t) ) {
        memset(iter, 0, sizeof(iter));
        int f;
        while(( f = dfs(s, t, inf) ) > 0 )
            ret += f;
    }
    return ret;
}

void init() {
    for(int i = 1; i <= n; i++)
        g[i].clear();
}

int main(){
    int cnt = 1;
    while(scanf("%d", &n) == 1 && n != 0) {
        init();
        int s, t, c; scanf("%d%d%d", &s, &t, &c);
        while(c--) {
            int from, to, cap; scanf("%d%d%d", &from, &to, &cap);
            addedge(from, to, cap);
        }
        printf("Network %d\n", cnt++);
        printf("The bandwidth is %d.\n\n", dinic(s, t));
    }
    return 0;
}

```

4 Data Structure

4.1 Disjoint Set

```

struct Disjoint_set {
    #define MAX_N 500005
    // define MAX_N
    int pa[MAX_N], Rank[MAX_N];
    int sz[MAX_N];
    void init_union_find(int V) {
        for(int i=0; i<V; i++) {
            pa[i] = i;
            Rank[i] = 0;
            sz[i] = 1;
        }
    }
    int find(int x) {
        return x == pa[x] ? x : pa[x] = find(pa[x]);
    }

    int unite(int x, int y) {
        x = find(x), y = find(y);
        int S = sz[x]+sz[y];
        if(x != y){
            if(Rank[x] < Rank[y]) {
                pa[x] = y;
                sz[y]=S;
                return y;
            }
            else{
                pa[y] = x;
                sz[x] = S;
                if(Rank[x] == Rank[y]) Rank[x] ++;
                return x;
            }
        }
    }
    bool same(int x, int y) {
        return find(x) == find(y);
    }
}

```

4.2 Sparse Table

```

//codeforces 689D
#define maxn 200005

template< typename T, typename Cmp = less<T> >
struct RMQ {
    T d[maxn][20];
    Cmp cmp;
    int w[maxn], sz;

    void init(const T *a, int n) {
        int i, j;

        for (w[0] = -1, i = 1; i <= n; ++i) w[i] = (i &
            (i - 1)) ? w[i - 1] : w[i - 1] + 1;
        for (sz = n, i = 0; i < n; ++i) d[i][0] = a[i];
        for (j = 1; (1 << j) <= n; ++j) {
            for (i = 0; i + (1 << j) <= n; ++i) {
                d[i][j] = cmp(d[i][j - 1], d[i + (1 <<
                    (j - 1))][j - 1]) ? d[i][j - 1] : d
                    [i + (1 << (j - 1))][j - 1];
            }
        }
    }
    // index of a [l .. r]
    const T &query(int l, int r) const {
        int x = w[r - l + 1];
        return cmp(d[l][x], d[r - (1 << x) + 1][x]) ? d
            [l][x] : d[r - (1 << x) + 1][x];
    }
};
int a[maxn], b[maxn];
int n;
RMQ<int> s;
RMQ<int, greater<int>> t;

int main() {
    cin>>n;
    for(int i = 0; i < n; i++) scanf("%d", &a[i]);
    for(int i = 0; i < n; i++) scanf("%d", &b[i]);

    s.init(b, n);
    t.init(a, n);
    int c, d;
    LL ans = 0;
    for(int i=0; i<n; i++) {
        if( a[i] > b[i]) continue;

        int ub = n+1, lb = i;
        while( ub-lb>1) {
            int mid = (ub+lb)>>1;
            if( t.query(i, mid-1) - s.query(i, mid-1) >
                0) ub = mid;
            else lb = mid;
        }
        int up = ub;

        ub = n+1, lb = i;
        while( ub-lb>1) {
            int mid = (ub+lb)>>1;
            if( t.query(i, mid-1) - s.query(i, mid-1)
                >= 0) ub = mid;
            else lb = mid;
        }
        int down = ub;
        ans += up-down;
    }
    cout << ans << endl;

    return 0;
}

```

4.3 Treap

```

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

struct Treap{
    Treap *l, *r;
    int pri, key, val;

```

```

    Treap(int _val, int _key):
        val(_val), key(_key), l(NULL), r(NULL), pri(
            rand()){}
};

// We assure that key value in A treap is greater than
// that in treap B
Treap *merge( Treap *a, Treap *b){
    if(a==NULL || b==NULL) return (!a) ? b : a;
    if(a->pri > b->pri){
        a->r = merge(a->r, b);
        return a;
    }else{
        b->l = merge(a, b->l);
        return b;
    }
}

void split(Treap *t, int k, Treap *&a, Treap *&b){
    if( !t ) a = b = NULL;
    else if( t->key <= k){
        a = t;
        split(t->r, k, a->r, b);
    }else{
        b = t;
        split(t->l, k, a, b->l);
    }
}

Treap* insert( Treap *t, int k, int _val){
    Treap *tl, *tr;
    split(t, k, tl, tr);
    return merge(tl, merge(new Treap(_val, k) , tr));
}

Treap* remove( Treap* t, int k){
    Treap *tl, *tr;
    split(t, k-1, tl, t);
    split(t, k, t, tr);
    return merge(tl, tr);
}

int main(){
    return 0;
}

```

5 Math

5.1 Prime Table

```

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

    int prime[1000000]={2,3,5,7};
    int sz=4;
    // biggest prime < ub
    int ub=(1<<20);

    int check(int num){
        int k = 0;
        for(k = 0; k < sz && prime[k]*prime[k] <= num;
            k++){
            if( num % prime[k]==0) return 0;
        }
        return 1;
    }

    void buildprime(){
        int currentPrime=7;
        int j=4;
        for(sz=4,j=4; currentPrime<ub; sz++, j=6-j){
            currentPrime=currentPrime+j;
            if (check(currentPrime)) {
                prime[sz] = currentPrime;
            }
            else{
                sz--;
            }
        }
    }
}ptable;

```

5.2 Miller Rabin Prime Test

```

#include <cstdio>
#include <vector>
#include <map>
#include <algorithm>
using namespace std;

long long mul(unsigned long long a, unsigned long long
    b, unsigned long long mod) {
    long long ret = 0;
    for (a %= mod, b %= mod; b != 0; b >>= 1, a <<= 1,
        a = a >= mod ? a - mod : a) {
        if (b&1) {
            ret += a;
            if (ret >= mod) ret -= mod;
        }
    }
    return ret;
}

long long mpow2(long long x, long long y, long long mod
    ) {
    long long ret = 1;
    while (y) {
        if (y&1)
            ret = mul(ret, x, mod);
        y >>= 1, x = mul(x, x, mod);
    }
    return ret % mod;
}

int isPrime(long long p, int it) { // implements by
    miller-babin
    if (p < 2) return 0;
    if (p == 2) return 1;
    if (!(p&1)) return 0;
    long long q = p-1, a, t;
    int k = 0, b = 0;
    while (!(q&1)) q >>= 1, k++;

    while(it--) {
        a = rand()%(p-4) + 2;
        t = mpow2(a, q, p);
        b = (t == 1) || (t == p-1);
        for (int i = 1; i < k && !b; i++) {
            t = mul(t, t, p);
            if (t == p-1)
                b = 1;
        }
        if (b == 0)
            return 0;
    }

    return 1;
}

int main() {

    int testcase;
    scanf("%d", &testcase);
    while (testcase--) {
        long long n;
        scanf("%lld", &n);
        puts(isPrime(n, 1000)? "YES": "NO");
    }
    return 0;
}

```

5.3 Extended Euclidean Algorithm

```

/** normal gcd function using recursion */
int gcd(int a, int b){
    if(b == 0) return a;
    return gcd(b, a%b);
}

// Find solution of ax + by = gcd(a, b)
// ps : x, y may be negative
int extgcd(int a, int b, int& x, int& y){

```

```

int d = a;
if(b != 0) {
    d = extgcd(b, a%b, y, x);
    y -= (a/b) * x;
} else {
    x = 1, y = 0;
}
return d;
}

```

5.4 Gauss Elimination

```

// solving linear equations with gauss elimination
#include <iostream>
#include <cmath>
#include <vector>

```

```
using namespace std;
```

```

void print(vector< vector<double> > A) {
    int n = A.size();
    for (int i=0; i<n; i++) {
        for (int j=0; j<n+1; j++) {
            cout << A[i][j] << "\t";
            if (j == n-1) {
                cout << "| ";
            }
        }
        cout << "\n";
    }
    cout << endl;
}

```

```

vector<double> gauss(vector< vector<double> > A) {
    int n = A.size();

```

```

    for (int i=0; i<n; i++) {
        // Search for maximum in this column
        double maxEl = abs(A[i][i]);
        int maxRow = i;
        for (int k=i+1; k<n; k++) {
            if (abs(A[k][i]) > maxEl) {
                maxEl = abs(A[k][i]);
                maxRow = k;
            }
        }

        // Swap maximum row with current row (column by column)
        for (int k=i; k<n+1; k++) {
            double tmp = A[maxRow][k];
            A[maxRow][k] = A[i][k];
            A[i][k] = tmp;
        }

        // Make all rows below this one 0 in current column
        for (int k=i+1; k<n; k++) {
            double c = -A[k][i]/A[i][i];
            for (int j=i; j<n+1; j++) {
                if (i==j) {
                    A[k][j] = 0;
                } else {
                    A[k][j] += c * A[i][j];
                }
            }
        }
    }
}

```

```

// Solve equation Ax=b for an upper triangular matrix A
vector<double> x(n);
for (int i=n-1; i>=0; i--) {
    x[i] = A[i][n]/A[i][i];
    for (int k=i-1; k>=0; k--) {
        A[k][n] -= A[k][i] * x[i];
    }
}
return x;
}

```

```

int main() {
    int n;
    cin >> n;

    vector<double> line(n+1,0);
    vector< vector<double> > A(n,line);

    // Read input data
    for (int i=0; i<n; i++) {
        for (int j=0; j<n; j++) {
            cin >> A[i][j];
        }
    }

    for (int i=0; i<n; i++) {
        cin >> A[i][n];
    }

    // Print input
    print(A);

    // Calculate solution
    vector<double> x(n);
    x = gauss(A);

    // Print result
    cout << "Result:\n";
    for (int i=0; i<n; i++) {
        cout << x[i] << " ";
    }
    cout << endl;
}

```

5.5 FFT

```

typedef long double ld;
/* N must be 2^k and greater than array.size()
 * FFT( a );
 * FFT( b );
 * for(int i = 0; i<N; ++i) c[i] = conj(a[i] * b[i]);
 * FFT( c );
 * for(int i = 0; i<N; ++i) c[i] = conj(c[i]);
 * for(int i = 0; i<N; ++i) c[i] /= N;
 */
void FFT(vector< complex<ld> >& v) {
    int N = v.size();
    for(int i = 1, j = 0; i<N; ++i) {
        for(int k = N>>1; !((j^=k)&k); k>>=1);
        if(i>j) swap(v[i],v[j]);
    }
    for(int k = 2; k<=N; k<=<=1) {
        ld w = -2.0*pi/k;
        complex<ld> deg(cos(w),sin(w));
        for(int j = 0; j<N; j+=k) {
            complex<ld> theta(1,0);
            for(int i = j; i<j+k/2; ++i) {
                complex<ld> a = v[i];
                complex<ld> b = v[i+k/2]*theta;
                v[i] = a+b;
                v[i+k/2] = (a-b);
                theta *= deg;
            }
        }
    }
}

```

5.6 NNT

```

/*
NTT( a );
NTT( b );
for(int i = 0; i<N; ++i)
    c[i] = (long long) a[i] * b[i] % mod;
NTT( c, true );
for(int i = 0; i<N; ++i)
    c[i] = (786433LL-12) * c[i] % mod;
*/

```

```
constexpr int mod = 786433;
constexpr int N = 65536;

void NTT(vector< int >& v, bool flag = false)
{
    for(int i = 1, j = 0; i<N; ++i)
    {
        for(int k = N>>1; !((j^=k)&k); k>>=1);
        if(i>j) swap(v[i], v[j]);
    }
    for(int k = 2; k<=N; k<=1)
    {
        int deg = mypow(flag ? 524289 : 3, N / k);
        for(int j = 0; j<N; j+=k)
        {
            int theta = 1;
            for(int i = j; i<j+k/2; ++i)
            {
                int a = v[i];
                int b = (long long) v[i+k/2]*theta%mod;
                v[i] = (a+b) % mod;
                v[i+k/2] = (a-b+mod)%mod;
                theta = (long long) theta * deg % mod;
            }
        }
    }
}
```

6 string

6.1 Palindromic Tree

```
/**
    template

    len 表示所代表的回文子串長度
    next[c] 表示所代表的回文子串在頭尾各增加一個字符c
            後的回文子串其節點編號
    fail( sufflink ) 表示所代表的回文子串不包括本身的
            最長後綴回文子串的節點編號
    cnt(非必要) 表示所代表的回文子串在整體字串出現的
            次數(在建構完成後呼叫count()才能計算)
    //num(非必要) 表示所代表的回文子串其後綴為回文字
            串的個數 <= not included
**/
struct palindromic_tree{
    struct node{
        int next[26], fail, len; /*這些是必要的元素*/
        int cnt; /*這些是額外維護的元素*/
        node(int l=0): fail(0), len(l), cnt(0), num(0){
            for(int i=0; i<26; ++i) next[i]=0;
        }
    };
    std::vector<node> St;
    std::vector<char> s;
    int last, n;
    palindromic_tree(): St(2), last(1), n(0){
        St[0].fail=1;
        St[1].len=-1;
        s.push_back(-1);
    }
    inline void clear(){
        St.clear();
        s.clear();
        last=1;
        n=0;
        St.push_back(0);
        St.push_back(-1);
        St[0].fail=1;
        s.push_back(-1);
    }
    inline int get_fail(int x){
        while(s[n-St[x].len-1]!=s[n]) x=St[x].fail;
        return x;
    }
    inline void add(int c){
        s.push_back(c-'a');
    }
}
```

```
++n;
int cur=get_fail(last);
if(!St[cur].next[c]){
    int now=St.size();
    St.push_back(St[cur].len+2);
    St[now].fail=St[get_fail(St[cur].fail)].next[c];
    /*不用擔心會找到空節點，由證明的過程可知*/
    St[cur].next[c]=now;
    St[now].num=St[St[now].fail].num+1;
}
last=St[cur].next[c];
++St[last].cnt;
}
inline void count(){/*cnt必須要在構造完後呼叫count()
    去計算*/
    std::vector<node>::reverse_iterator i=St.rbegin();
    for(; i!=St.rend(); ++i){
        St[i->fail].cnt+=i->cnt;
    }
}
inline int size(){/*傳回其不同的回文子串個數*/
    return St.size()-2;
}
};
```

6.2 Suffix Array

```
/** Suffix Array **/
struct SuffixArray{

    /**
        DA(倍增)算法求 SA[N] 与 Rank[N] (時間O(NlogN), 空
        間O(N))
        sa[i] : 表示 排在第i位的后綴 起始下标 , sa[ 0 .. n
        ] ==> sa[0] = n 是空字串
        consider
            sa[ 1
            .. n ]
        stores
            [ 0
            .. n )
        Rank[i] : 表示后綴 suffix(i)排在第几, Rank[ 0 .. n
        ] ==> Rank[n] = 0 空字串
        consider
            ==>
            Rank[
            0 .. n
            )
        stores
            [ 1
            .. n ]

        lcp[i] : 表示 suffix ( sa[i-1] ) 与 suffix ( sa[i]
        ) 的LCP 值, lcp[ 1 .. n ], lcp[1] = 0 (與空字串
        比較)
        h[i]: 表示 suffix(i)与其排名前一位的 LCP值, h[ 0 ..
        n )
        LCP : longest common prefix

        **/
        #define N maxn
        int cmp(int *r, int a, int b, int l){
            return (r[a]==r[b]) && (r[a+l]==r[b+l]);
        }
        // 用于比较第一关键字与第二关键字,
        // 比较特殊的地方是,预处理的时候,r[n]=0(小于前面出
        现过的字符)
        int wa[N], wb[N], ws[N], wv[N];
        int r[N], sa[N];
        int Rank[N], lcp[N];
        void DA(int n, int m){ //此处n比输入的n要多1, 为人工
            添加的一个字符, 用于避免CMP时越界
            int i, j, p, *x=wa, *y=wb;
            for(i=0; i<n; ++i) ws[i]=0;
            for(i=0; i<n; ++i) ws[x[i]=r[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*=2,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++) ws[i]=0;
        for (i=0;i<n;i++) wv[i]=x[y[i]];
        for (i=0;i<n;i++) ws[wv[i]]++;
        for (i=1;i<n;i++) ws[i]+=ws[i-1];
        for (i=n-1;i>=0;i--) sa[-ws[wv[i]]]=y[i];
        for (swap(x,y),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++;
    }
}
void calLcp(int n){ // 此处N为实际长度
    int i,j,k=0; // height[]的合法范围为 1-N, 其中0是结尾加入的字符
    for (i=1;i<n;i++) Rank[sa[i]]=i; // 根据SA求Rank
    for (i=0;i<n; lcp[Rank[i++]] = k) // 定义: h[i] = height[ Rank[i] ]
        for (k?k--:0,j=sa[Rank[i]-1]; r[i+k]==r[j+k]; k++); //根据 h[i] >= h[i-1]-1 来优化计算 height过程
}
void init(char *s, int len) {
    for(int i = 0; i < len; i++) r[i] = (int)s[i];
    r[len] = 0;
}
}SA;

char str[maxn];
int main() {
    scanf("%s",str);
    int n = strlen(str);

    SA.init(str, n);
    SA.DA(r,sa,n+1,128); //注意区分此处为n+1,因为添加了一个结尾字符用于区别比较
    calLcp(n);

// /** demonstrate
assert(sa[0] == n);
for(int i = 0; i <= n; i++) printf("%d ", sa[i]);
printf("\n");
assert(Rank[n] == 0);
for(int i = 0; i <= n; i++) printf("%d ", Rank[i]);
printf("\n");
//height[0] 沒有意義
assert(height[1] == 0); //since sa[0] is 空字串
printf(" ");
for(int i = 1; i <= n; i++) printf("%d ", height[i]);
printf("\n");
// **/
}

```

6.3 Longest Palindromic Substring

```

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

//#define DEBUG

#ifdef DEBUG
#define debug(...) printf(__VA_ARGS__)
#else
#define debug(...) (void)0
#endif
#define mp make_pair
#define pb push_back
#define LL long long
#define pii pair<int,int>
#define PII pair<long long, long long>
#define fi first
#define se second

```

```

#define all(x) (x).begin(),(x).end()
#define SZ(x) ((int)(x).size())
const int inf = 0x7fffffff; //beware overflow
const LL INF = 0x7fffffffffffffff; //beware overflow
const LL mod = 1e9+7;
#define IOS ios_base::sync_with_stdio(0); cin.tie(0)
template<typename A, typename B>
ostream& operator <<(ostream &s, const pair<A,B> &p) {
    return s<<"("<<p.first<<","<<p.second<<")";
}
template<typename T>
ostream& operator <<(ostream &s, const vector<T> &c) {
    s << "[";
    for (auto it : c) s << it << " ";
    s << "]";
    return s;
}
template<typename T>
ostream& operator << (ostream &o, const set<T> &st) {
    o << "{";
    for (auto it=st.begin(); it!=st.end(); it++) o << (
        it==st.begin() ? "" : ", " ) << *it;
    return o << "}";
}
template<typename T1, typename T2>
ostream& operator << (ostream &o, const map<T1, T2> &mp) {
    o << "{";
    for (auto it=mp.begin(); it!=mp.end(); it++) {
        o << (it==mp.begin()?"":", ") << it->fi << ":""
            << it->se;
    }
    o << "}";
    return o;
}

#define maxn 200001
char t[maxn];
char s[maxn * 2];
int z[maxn * 2];
int N;
int longest_palindromic_substring() {
    // t穿插特殊字元, 存放到s。
    int n = strlen(t);
    N = n * 2 + 1;
    memset(s, '.', N);
    for (int i=0; i<n; ++i) s[i*2+1] = t[i];
    s[N] = '\0';
    z[0] = 1; // if無須使用, then無須計算。

    int L = 0, R = 0;
    for (int i=1; i<N; ++i) // 從z[1]開始
    {
        z[i] = (R > i) ? min(z[2*L-i], R-i) : 1;
        while (i-z[i] >= 0 && i+z[i] < N &&
            s[i-z[i]] == s[i+z[i]]) z[i]++;
        if (i+z[i] > R) L = i, R = i+z[i];
    }

    /*
    // 尋找最長迴文子字串的長度
    n = 0;
    int p = 0;
    for (int i=1; i<N; ++i) // 從z[1]開始
        if (z[i] > n)
            n = z[p = i];

    /*
    // longest 從中心到外端的長度 => (n-2)/2
    //cout << "最長迴文子字串的長度是" << (2*n-1) / 2;

    /*
    // 印出最長迴文子字串, 記得別印特殊字元。
    for (int i=p-z[p]+1; i<=p+z[p]-1; ++i)
        if (i & 1) {
            cout << s[i];
        }

    /*
    return (2*n-1)/2;
}
int nxt[maxn * 2];
int main() {

```

```

int T;cin>>T;
while(T--){
    scanf("%s", t);
    #ifdef DEBUG
        cout << longest_palindromic_substring() << endl;
    #else
        longest_palindromic_substring();
    #endif
    memset(nxt, -1, sizeof(nxt));
    for(int i = 0; i < N; i++) {
        nxt[ i-z[i]+1 ] = i+1;
    }
    int leftmost = 0;
    for(int i = 0; i < N; i++) {
        leftmost = max(leftmost, nxt[i]);
        nxt[i] = max(leftmost, nxt[i]);
    }
    int ans = 0;
    for(int cur = 0; cur<N-1; ) {
        cur = nxt[cur];
        ans++;
    }
    cout<< ans <<endl;
}
return 0;
}

```

7 geometry

7.1 Point Class

```

const double eps = 1e-10;
#define N 100
struct P {
    type x,y;
    void read() {
        scanf("%lf%lf",&x,&y);
    }
    void print() {
        printf("%f %f\n", x, y);
    }
} p[N];
#define type double
bool operator <( P a, P b ) { return tie(a.x,a.y)<tie(b.x,b.y); }
P operator +( P a, P b ) { return P{a.x+b.x,a.y+b.y}; }
P operator -( P a, P b ) { return P{a.x-b.x,a.y-b.y}; }
P operator *( P b, type a ) { return P{a*b.x,a*b.y}; }
P operator /( P a, type b ) { return P{a.x/b,a.y/b}; }
P& operator /=( P &a, type b ) { return a=a/b; }
type operator *( P a, P b ) { return a.x*b.x+a.y*b.y; }
type operator ^( P a, P b ) { return a.x*b.y-a.y*b.x; }
type X( P o, P a, P b ) { return (a-o)^(b-o); }
type dot( P o, P a, P b ) { return (a-o)*(b-o); }

```

7.2 Intersection of Circles/Lines/Segments

//PECaveros

```

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

```

```

P interPnt( P p1, P p2, P q1, P q2){
    double f1 = ( p2 - p1 ) ^ ( q1 - p1 );
    double f2 = ( p2 - p1 ) ^ ( p1 - q2 );
    double f = ( f1 + f2 );
    if( fabs( f ) < eps ) return Pt( nan(""), nan("") );
    return q1 * ( f2 / f ) + q2 * ( f1 / f );
}

```

```

int ori( const PLL& o , const PLL& a , const PLL& b ){
    LL ret = ( a - o ) ^ ( b - o );
    return ret / max( 1ll , abs( ret ) );
}
// p1 == p2 || q1 == q2 need to be handled
bool banana( const PLL& p1 , const PLL& p2 ,
              const PLL& q1 , const PLL& q2 ){
    if( ( ( p2 - p1 ) ^ ( q2 - q1 ) ) == 0 ){ // parallel
        if( ori( p1 , p2 , q1 ) ) return false;
        return ( ( p1 - q1 ) * ( p2 - q1 ) ) <= 0 ||
               ( ( p1 - q2 ) * ( p2 - q2 ) ) <= 0 ||
               ( ( q1 - p1 ) * ( q2 - p1 ) ) <= 0 ||
               ( ( q1 - p2 ) * ( q2 - p2 ) ) <= 0;
    }
    return (ori( p1, p2, q1 ) * ori( p1, p2, q2 )<=0) &&
           (ori( q1, q2, p1 ) * ori( q1, q2, p2 )<=0);
}

```

7.3 Convex Hull

```

#define REP(i,n) for ( int i=0; i<int(n); i++ )
int n;
void input() {
    scanf("%d",&n);
    REP(i,n) p[i].read();
}

```

```

P findCenter() {
    p[n]=p[0];
    P center=P{0,0};
    REP(i,n) {
        double v=p[i]*p[i+1];
        center.x += (p[i].x+p[i+1].x)*v;
        center.y += (p[i].y+p[i+1].y)*v;
    }
    double area=0;
    REP(i,n) area+=p[i]*p[i+1];
    area /= 2;
    center /= 6*area;
    return center;
}

```

```

P q1[N],q2[N],q[N];
void convex() {
    sort(p,p+n);
    int m1=0,m2=0;
    REP(i,n) {
        while ( m1>=2 && X(q1[m1-2],q1[m1-1],p[i]) >= 0 ) m1--;
        while ( m2>=2 && X(q2[m2-2],q2[m2-1],p[i]) <= 0 ) m2--;
        q1[m1++]=q2[m2++]=p[i];
    }
    int m=0;
    REP(i,m1) q[m++]=q1[i];
    for ( int i=m2-2; i>=1; i-- ) q[m++]=q2[i];
    q[m]=q[0];
}
void solve() {
    convex();
    // continue ...
}

```

7.4 Half Plane Intersection

//<http://acm.csie.org/ntujudge/problemdata/2575.pdf>
//<http://www.csie.ntnu.edu.tw/~u91029/Half-planeIntersection.html>

/**
預先使用四個半平面，設定一個極大的正方形邊界，讓半平面交集擁有邊界。
二、逐一加入每個半平面，求出當下的半平面交集（凸多邊形）。
online 演算法，隨時維護一個半平面交集。每次更新需時 $O(N)$ ，總時間複雜度為 $O(N^2)$ ， N 是半平面數目。

```

**/
#include <bits/stdc++.h>
using namespace std;
#define mp make_pair

typedef complex<double> Point;
typedef vector<Point> Polygon;
typedef pair<Point, Point> Line;
#define x real()
#define y imag()

// 兩向量叉積
double cross(Point& a, Point& b) {
    return a.x * b.y - a.y * b.x;
}

// 向量oa與向量ob進行叉積
double cross(Point& o, Point& a, Point& b) {
    return (a.x-o.x) * (b.y-o.y) - (a.y-o.y) * (b.x-o.x);
}

// 多邊形面積
double area(Polygon& p) {
    double a = 0;
    int n = p.size();
    for (int i=0; i<n; ++i)
        a += cross(p[i], p[(i+1)%n]);
    return fabs(a) / 2;
}

// 兩線交點
Point intersection(Point& a1, Point& a2, Point& b1,
    Point& b2) {
    Point a = a2 - a1, b = b2 - b1, s = b1 - a1;
    return a1 + a * cross(b, s) / cross(b, a);
}

// 一個凸多邊形與一個半平面的交集
Polygon halfplane_intersection(Polygon& p, Line& line)
{
    Polygon q;
    Point p1 = line.first, p2 = line.second;

    // 依序窮舉凸多邊形所有點，判斷是否在半平面上。
    // 如果凸多邊形與半平面分界線有相交，就求交點。
    int n = p.size();
    for (int i=0; i<n; ++i)
    {
        double c = cross(p1, p2, p[i]);
        double d = cross(p1, p2, p[(i+1)%n]);
        if (c >= 0) q.push_back(p[i]);
        if (c * d < 0) q.push_back(intersection(p1, p2,
            p[i], p[(i+1)%n]));
    }
    return q;
}

#define maxn 550
//Line line[maxn];
Point v[maxn];
double ans[maxn];
int main() {
    int T; cin >> T;
    while(T--) {
        int n;
        double w, h;
        scanf("%d %lf %lf", &n, &w, &h);
        // 預先設定一個極大的正方形邊界
        Polygon p, org;
        /** initialize
        p.push_back(Point(-1e9, -1e9));
        p.push_back(Point(-1e9, 1e9));
        p.push_back(Point(1e9, 1e9));
        p.push_back(Point(1e9, -1e9));
        */
        p.push_back(Point(0,0));
        p.push_back(Point(0,h));
        p.push_back(Point(w,h));
        p.push_back(Point(w,0));
        org = p;

        for (int i=0; i<n; i++) {
            double a, b;
            scanf("%lf %lf", &a, &b);
            v[i] = Point(a, b);
        }
        // 每一個半平面都與目前的半平面交集求交集
        for (int i=0; i<n; ++i)
        {
            p = org;
            for (int j = 0; j < n; j++) {
                if (i==j) continue;
                Line line;
                // find perpendicular line to line i_j
                Point a((v[i].x+v[j].x)/2, (v[i].y+v[j].y)/2);
                Point b(a.x+(v[i].y-v[j].y), a.y-(v[i].x-v[j].x));
                line = cross(a, b, v[i]) >= 0 ? mp(a, b) : mp(b, a);
                p = halfplane_intersection(p, line);
                if (area(p) == 0) break; // 退化或者空集合
            }
            ans[i] = area(p);
        }
        for (int i = 0; i < n; i++) printf("%.9f\n", ans[i]);
    }
}
/*
10
3 4 4
1 1 2 2 3 3
*/

```