Contents

1 Basic **1**
1.1 .vimrc 1
1.2 Increase Stack Size 1
1.3 digitDP 1
1.4 DP(convex hull optimization) 2
1.5 simulated annealing 2

2 Graph **3**
2.1 HLD 3
2.2 Hungarian 4
2.3 KM 5
2.4 Bi-vertex-connected Subgraph 5
2.5 Bi-edge-connected Subgraph 6
2.6 SCC 6
2.7 Edmond's Matching Algorithm 6
2.8 Tree Decomposition 7
2.9 Tree Longest Path 8

3 Flow **9**
3.1 Dinic Maxflow 9

4 Data Structure **10**
4.1 Disjoint Set 10
4.2 Djs + Seg 10
4.3 Sparse Table 11
4.4 Link Cut Tree 11
4.5 Treap 12

5 Math **12**
5.1 Prime Table 12
5.2 Miller Rabin Prime Test 12
5.3 Extended Euclidean Algorithm 13
5.4 Gauss Elimination 13
5.5 FFT 13
5.6 NNT 14
5.7 Big Number 16

6 string **18**
6.1 Palindromic Tree 18
6.2 Suffix Array 19
6.3 Longest Palindromic Substring 19

7 geometry **19**
7.1 Point Class 19
7.2 Intersection of Circles/Lines/Segments 19
7.3 Convex Hull 19
7.4 Half Plane Intersection 20

1 Basic

1.1 .vimrc

```
imap jj <Esc>

sy on
se sw=4 ts=4 sts=4 et nu sc hls cc=69
filet plugin indent on
nm <F5> :!"./%<"<CR>
nm <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);
    }
  }
}
```

1.3 digitDP

```
/**
简介
顾名思义，所谓的数位DP就是按照数字的个，十，百，千……
    位数进行的DP。
数位DP的题目有着非常明显的性质：
    询问[l,r]的区间内，有多少的数字满足某个性质
做法根据前缀和的思想，求出[0,l-1]和[0,r]中满足性质的数
    的个数，然后相减即可。

算法核心

LL dfs(int x,int pre,int bo,int limit);
一般需要以上参数（当然具体情况具体分析）。

    x表示当前的数位（一般都是从高位到低位）
    pre表示前一位的数字
    bo可以表示一些附加条件：是否有前项0，是否当前已经符
        合条件……
    limit这个很重要！它表示当前数位是否受到上一位的限
        制，比较抽象，举例说明
    如果上限是135，前两位已经是1和3了，现在到了个位，个
        位只能是5以下的数字

注：如果当前受限，不能够记忆化，也不能返回记忆化的结果
为了避免多次调用时 每次上限不同 而导致的错
**/
//http://acm.csie.org/ntujudge/view_code.php?id=106844
// Multiples
LL x;
int digit[100];
LL ten_pow[ 15 ];
bool ava[15];
LL dp[15][2][1000000];
LL dfs(int len, LL mod, bool bo, bool limit) {
    if( len < 0 ) return mod == 0;
    if( !limit && dp[len][bo][mod] != -1 ) return dp[
        len][bo][mod];
    int up = limit? digit[len] : 9;
    LL ret = 0;
    for(int i = 0; i <= up; i++) if( ava[i] || (i==0&&
        bo) ) {
        ret += dfs( len-1, (mod+ten_pow[len]*i)%x, bo
            &&(!i), limit&&(i==up) );
    }
    if( !limit ) dp[len][bo][mod] = ret;
    return ret;
}
LL solve(LL num) {
    int len = 0; digit[0] = 0;
    while( num ) {
        digit[len++] = num%10;
        num /= 10;
    }
    return dfs(len-1, 0,1, 1);
}
bool check(LL num) {
    while( num ) {
        if ( !ava[ num%10 ] ) return false;
        num /= 10;
    }
    return true;
}
int main() {
    LL A, B;
    cin>>x>>A>>B;
    ten_pow[0] = 1;
    mem( dp, -1);
    for(int i = 1; i < 15; i++)
        ten_pow[i] = (ten_pow[i-1]*10)%x;
    string dig; cin>>dig;
    mem(ava, false);
    for(char c : dig) ava[ c-'0' ] = 1;

    if( x <= 1000000 ) {
        cout<< solve(B) - solve(A-1) <<endl;
    }else {
        LL ans = 0;
        LL cur = 0;
        while( cur < A ) cur += x;
        while( cur <= B ) {
            if( check(cur) ) ans++;
            cur += x;
        }
        cout<<ans<<endl;
    }
}
```

1.4 DP(convex hull optimization)

```
//http://codeforces.com/contest/311/problem/B
struct line{
    LL slope, inter;
    LL value(LL x) { return x*slope + inter; }
};
bool check(line x, line y, line z) {
    return (z.slope - y.slope) * (z.inter - x.inter )
        >=
            ( z.slope - x.slope) * (z.inter - y.inter) ;
}

#define maxn 100005
int n, m, p;
LL a[maxn], d[maxn], dp[101][maxn], s[maxn];
int main() {
    cin>> n >> m >> p;
    for(int i = 2; i<=n; ++i) {
        d[i] = getint();
        d[i] += d[i-1];
    }
    for(int i = 1; i<=m; ++i) {
        int h; scanf("%d %lld", &h, a+i);
        a[i] -= d[h];
    }
    sort( a+1, a+1+m );
    for(int i=1;i<=m;i++) s[i] = a[i]+s[i-1];
    //start dp
    for(int i=1; i<=p;i++) {
        if( i == 1 ) {
            for(int j=1;j<=m;j++) dp[i][j] = j*a[j] - s
                [j];
        }else {
            deque<line> dq;
            dq.pb( {0, 0} );
            for(int j=1;j<=m;j++) {
                while( dq.size() >= 2 && dq[0].value(-a
                    [j]) > dq[1].value(-a[j]) ) dq.
                    pop_front();
                dp[i][j] = dq[0].value(-a[j]);

                line newline{ j, dp[i-1][j]+s[j] };
                while( dq.size() >= 2 && check(dq[dq.
                    size()-2], dq.back(), newline) ) dq
                    .pop_back();
                dq.pb( newline );
            /*
                if( i==1 ) {
                    dp[i][j] = j*a[j] - s[j];
                }else {
                    LL mn = 0;
                    for(int k = 1; k < j; k++) {
                        mn = min(mn, dp[i-1][k] + s[k]
                            - a[j]*k );
                    }
                    dp[i][j] = mn + a[j]*j-s[j];
                    // apply convex hull optimization
                }
            */
                dp[i][j] += a[j]*j - s[j];
            }
        }
    }
    cout << dp[p][m] << endl;
}
```

1.5 simulated annealing

```
//http://mikucode.blogspot.tw/2015/03/algorithm.html
//尋找和所有點距離和最小的點
#include <cstdio>
#include <cstdlib>
#include <cmath>
#define F(n) Fi(i,n)
#define Fi(i,n) for(int i=0;i<n;i++)
#define N 1010
using namespace std;
int X[N],Y[N],n;
inline double pow2(double x){
    return x*x;
}
double check(double x,double y){
    double ans=0;
    F(n)ans+=sqrt(pow2(x-X[i])+pow2(y-Y[i]));
    return ans;
}
int main(){

    while(~scanf("%d",&n) ) {
        F(n) scanf("%d%d",X+i,Y+i);
        double x=0,y=0,tx,ty,tans,l=10000,ans;
        ans=check(x,y);
        while(l>1e-4) {
            int tmp=rand();
            tx=x+l*cos(tmp);ty=y+l*sin(tmp);
            tans=check(tx,ty);
            if(tans<ans) ans=tans,x=tx,y=ty;
            else l*=0.9;
        }
        printf("%.9f\n",2*ans);
    }
}
```

```
//尋找兩個點使他們跟給定的四個點最小生成樹最小
#include <cstdio>
#include <cstdlib>
```

```
#include <cmath>
#include <algorithm>
#define F(n) Fi(i,n)
#define Fi(i,n) Fl(i,0,n)
#define Fl(i,l,n) for(int i=l;i<n;i++)
#define N 10
using namespace std;
int X[N],Y[N],n,F[N],e;
struct E{
    int a,b;
    double c;
}G[N*2];
struct V{
    double x,y;
    V operator+(double l){
        int tmp=rand();
        return (V){x+l*cos(tmp),y+l*sin(tmp)};
    }
}v[N];
int find(int x){
    return x==F[x]?x:F[x]=find(F[x]);
}
inline double pow2(double x){
    return x*x;
}
double check(V s1,V s2){
    double ans=0;
    e=0;v[4]=s1,v[5]=s2;
    F(5)Fl(j,i+1,6)
        G[e++]=(E){i,j,sqrt(pow2(v[i].x-v[j].x)+pow2(v[
            i].y-v[j].y))};
    F(6)F[i]=i;
    sort(G,G+e,[](E a,E b){return a.c<b.c;});
    F(e){
        if(find(G[i].a)!=find(G[i].b)){
            ans+=G[i].c;
            F[find(G[i].a)]=find(G[i].b);
        }
    }
    return ans;
}
int main(){
    scanf("%d",&n);
    while(n--){
        F(4) scanf("%lf%lf",&v[i].x,&v[i].y);
        double ttans,tans,ans,l1=10000,l2;
        V s1=(V){0,0},s2=(V){0,0},ts1,ts2,tmp;
        ans=check(s1,s2);
        while(l1>1e-3){
            l2=10000;
            ts1=s1+l1;
            tans=check(ts1,s2);
            tmp=s2;
            while(l2>1e-3){
                ts2=s2+l2;
                ttans=check(ts1,ts2);
                if(ttans<tans)tans=ttans,s2=ts2;
                else l2*=0.9;
            }
            if(tans<ans)ans=tans,s1=ts1;
            else l1*=0.9,s2=tmp;
        }
        printf("%f\n",2*ans);
    }
}
```

2 Graph

2.1 HLD

```
//we can reference the problem Greatest graph
///http://acm.csie.org/ntujudge/problemdata/2582.pdf
//this template operate on edges
#define maxn 100005
struct segment_tree{
    #define right(x) x << 1 | 1
    #define left(x) x << 1
    int* arr;
    int m[4*maxn];
    int tag[4*maxn];
    const int inf = 1e9;

    void init() {
        //memset(tag, -1, sizeof(tag));
        fill(tag, tag+4*maxn, inf);
    }
    void pull(int ind) {
        m[ind] = min(m[right(ind)] ,m[left(ind)]);
    };
    void push(int ind) {
        if(tag[ind] != inf) {
            tag[left(ind)] = min(tag[left(ind)], tag[
                ind]);
            tag[right(ind)] = min(tag[right(ind)], tag[
                ind]);
            m[left(ind)] = min( m[left(ind)], tag[left(
                ind)]);
            m[right(ind)] = min( m[right(ind)], tag[
                right(ind)]);
            tag[ind] = inf;
        }
    }
    /// root => 1
    void build(int ind, int l, int r) {

        if( r - l == 1) {
            m[ind] =  arr[l];
            return;
        }
        int mid = (l+r)>>1;
        build( left(ind), l, mid );
        build( right(ind), mid, r );
        pull(ind);
    }
    int query_min(int ind, int L, int R, int ql, int qr
        ) {
        if( L >= qr || R <= ql ) return 1e9;
        if( R <= qr && L >= ql ) {
            return m[ind];
        }
        push(ind);
        int mid = (L+R)>>1;
        return min( query_min(left(ind), L, mid, ql, qr
            ), query_min(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 ) {

            m[ind] = min(m[ind], x);
            tag[ind] = min(tag[ind], x);

            return;
        }
        push(ind);
        int mid = (L+R)>>1;
        modify(left(ind), L, mid, ql, qr, x);
        modify(right(ind), mid, R, ql, qr, x);
        pull(ind);
    }
};

int seg_arr[maxn];
struct Tree{
    segment_tree seg;
    int n;
    struct Edge { int u, v, c; };
    vector<Edge> e;
    void addEdge(int x, int y, int c) {
        G[x].pb( SZ(e) );
        G[y].pb( SZ(e) );
        e.pb( Edge{x, y, c}  );
    }
    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],timer;
    /*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();
        timer=0;
        pa[1] = 1;
        dep[1] = 0;
    }
    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] = timer++;/*記錄x點的時間戳*/
        link_top[x] = top;
        if(max_son[x] != -1)
            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 == pa[x] ) {
                seg_arr[ link[x] ] = e[e_ind].c;
            }
            if( v == max_son[x] || v == pa[x] )continue
                ;
            // edge from x => v
            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 modify(int a,int b, int c){

        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] ]
            //same interval if operate on edges
            seg.modify(1, 1, n, link[ta], link[a]+1, c)
                ;
            a = pa[ta];
            ta = link_top[a];
        }
        //a, b are on the same chain
        if( a == b ) ; // interval [ link[a], link[a]
            ], if operate on edges => no edge
        else {
            if(dep[a]>dep[b])
                swap(a,b);
            //interval [ link[a],link[b] ]
            // if operate on edges ==> [ link[ max_son[
                a] ], link[b] ]
                seg.modify(1, 1, n, link[ max_son[a] ],
                    link[b]+1, c);
            }
        }
        /*
        void modify(int a, int b, int c) {
            if( a==b ) return;
            if( link_top[a] == link_top[b]) {
                if( dep[a] > dep[b] ) swap(a, b);
                seg.modify(1, 1, n, link[a]+1, link[b]+1, c
                    );
                assert( link[a]+1 == link[ max_son[a]] );
                return;
            }
            if(dep[link_top[a]] < dep[link_top[b]])
                swap(a, b);
            // a is the node with deeper link_top
            seg.modify( 1, 1, n, link[link_top[a]], link[a]
                + 1, c);
            modify( pa[link_top[a]], b, c);
        }
        */

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


int main() {
    int T;cin>>T;
    while(T--) {
        int n,m ;
        scanf("%d %d",&n, &m);
        int ans = 0;
        tree.init(n);
        for(int i=0;i<n-1;i++) {
            int a, b, c;
            scanf("%d%d%d",&a,&b,&c);
            //a--, b--; be careful here
            tree.addEdge(a, b, c);
            ans += c;
        }
        tree.HLD();

        tree.seg.arr = seg_arr;
        tree.seg.build(1, 1, n);

    }
    return 0;
}
```

2.2 Hungarian

```
// edge and node index starting from 0
// dfs version below
//complexity O ( V*E )
/* 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 0xffffff
    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

```
//    regard every vbcc as a set of edges
//    so vb[i] is a vector that contains a set of edge
    indexes
/** 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[maxm];
int bcnt, vbb[maxm];
vector<int> vb[maxm];
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

```
struct SCC{
    #define maxn 1005
    vector<int> G[maxn];
    stack<int> Stack;
    int scnt, Time;
    int belong[maxn], dfn[maxn], low[maxn];
    bool instack[maxn];
    void init(int n) {
        scnt = Time = 0;
        for(int i = 0; i < n; i++) G[i].clear();
        while(!Stack.empty()) Stack.pop();
        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(int n) {
        //zero based here
        for(int i = 0; i < n; i++)
            if(!dfn[i])
                dfs(i);
    }
};
```

2.7 Edmond's Matching Algorithm

```
//http://acm.csie.org/ntujudge/contest_view.php?id=370&
    contest_id=466
#include <bits/stdc++.h>
using namespace std;
//带花树,Edmonds's matching algorithm,一般图最大匹配
// have to be a undirected graph
#define MAXN 505
vector<int>G[MAXN];//用vector存圖
int pa[MAXN],match[MAXN],st[MAXN],S[MAXN],vis[MAXN];
int t,n;
inline int lca(int u,int v){//找花的花托
    for(++t;;swap(u,v)){
        if(u==0)continue;
        if(vis[u]==t)return u;
        vis[u]=t;//這種方法可以不用清空vis陣列
        u=st[pa[match[u]]];
    }
}
#define qpush(u) q.push(u),S[u]=0
inline void flower(int u,int v,int l,queue<int> &q){
    while(st[u]!=l){
        pa[u]=v;//所有未匹配邊的pa都是雙向的
        if(S[v=match[u]]==1)qpush(v);//所有奇點變偶點
        st[u]=st[v]=l,u=pa[v];
    }
}
inline bool bfs(int u){
    for(int i=1;i<=n;++i)st[i]=i;//st[i]表示第i個點的集
        合
    memset(S+1,-1,sizeof(int)*n);//-1:沒走過 0:偶點 1:
        奇點
    queue<int>q;qpush(u);
    while(q.size()){
        u=q.front(),q.pop();
        for(size_t i=0;i<G[u].size();++i){
            int v=G[u][i];
            if(S[v]==-1){
                pa[v]=u,S[v]=1;
                if(!match[v]){//有增廣路直接擴充
                    for(int lst;u;v=lst,u=pa[v])
                        lst=match[u],match[u]=v,match[v
                            ]=u;
                    return 1;
                }
                qpush(match[v]);
            }else if(!S[v]&&st[v]!=st[u]){
                int l=lca(st[v],st[u]);//遇到花，做花的
                    處理
                flower(v,u,l,q),flower(u,v,l,q);
            }
        }
    }
    return 0;
}
inline int blossom(){
    memset(pa+1,0,sizeof(int)*n);
    memset(match+1,0,sizeof(int)*n);
    int ans=0;
    for(int i=1;i<=n;++i)
        if(!match[i]&&bfs(i))++ans;
    return ans;
}
void solve() {
    cin>>n;
    int m;cin>>m;
    while(m--) {
        int a,b;
        scanf("%d %d", &a, &b);
        a++, b++;
        // since node indexed [ 1 .. n ] in this
            template
        #define pb push_back
        //Multiedge and self-cycles are not forbidden
        G[a].pb( b );
        G[b].pb( a );
    }
    cout<< blossom() <<endl;
    for(int i = 1; i <= n; i++) G[i].clear();
}
int main() {
    int t;cin>>t;
    while(t--) solve();
}
```

2.8 Tree Decomposition

```
//codeforces Digit Tree
//http://codeforces.com/problemset/problem/715/C


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;
}
```

2.9 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

```
//Circulation problems
http://www.win.tue.nl/~nikhil/courses/2013/2WO08/
    scribenotes26febv02.pdf


Flow problems with boundary

1.feasible flow in a network with both upper and lower
    capacity constraints, no source or sink:
  capacities are changed to upper bound - lower bound.

  Add a new source and a sink.
  let M[v] = (sum of lower bounds of ingoing edges to v
      ) - (sum of lower bounds of outgoing edges from
      v).
  For all v,
    if M[v]>0 then add edge (S,v) with capacity M,
    otherwise add (v,T) with capacity -M.

   Actually, this equals to doing the following steps
       for every edges
   edges u --> v with lb
   addEdge(s, v, lb) and addEdge( u, t, lb)

   If all outgoing edges from S are full, then a
       feasible flow exists, it is the flow plus the
       original lower bounds.

2.maximum flow in a network with both upper and lower
    capacity constraints, with source s and sink t :
  //referenced from the book 挑戰城市競賽acm-icpc and
  //http://web.engr.illinois.edu/~jeffe/teaching/
      algorithms/2009/notes/18-maxflowext.pdf
  a. add edge (t,s) with capacity infinity.
  // Binary search for the lower bound, check whether a
       feasible exists for a network WITHOUT source or
      sink ??


  b. add new source and sink, ss and tt
      for all edges u --> v with lb
      addEdge( ss, v, lb) and addEdge( u, tt, lb)
  c. f1 = maxFlow of current graph
  d. if ss -> other verticles aren't all used ==> no
      feasible solution
  e. addEdge(ss, s, inf), addEdge(t, tt, inf),
      removeEdge(t, s) (not necessary)
  f. f2 = maxFlow of current graph
  c. final answer will be f2 - the sum of edge demands
```

3.1 Dinic Maxflow

```
//http://acm.csie.org/ntujudge/problem.php?id=2581
//French Fries Festival
//dinic runs in O( V^2*E )

#define maxn 500
struct Edge{ int to, cap, rev; };
struct Dinic{
    vector<Edge> G[maxn];
    int dis[maxn], iter[maxn];
    void init(int n) {
        //zero based
      for(int i = 0; i < n; i++) G[i].clear();
    }
    void addEdge(int from, int to, int cap) {
        vector<Edge>::iterator it;
        if( ( it=find_if( all(G[from]), [to](Edge& e) {
             return e.to == to; } )) != G[from].end() )
             {
           it->cap += cap;
           return;
        }
      G[from].pb(Edge{to, cap, (int)G[to].size()});
      G[to].pb(Edge{from, 0, (int)G[from].size()-1});
        //if undirected 0 will be cap
    }
    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 maxFlow(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;
    }
}dinic, dinic2;
void solve() {
    int n,m,k; cin>>n>>m>>k;
    // flow problem with lower bounds;
    int s = 0, t = n+2, ss = n+3, tt = n+4;
    dinic.init( n+5 );
    dinic.addEdge(s, 1, k);
    dinic.addEdge(n+1, t, k);
    //
    int slb = 0;
    while(m--) {
        int l, r, a, b; scanf("%d %d %d %d", &l, &r, &a
            , &b);
        slb += a;
        r++;
        dinic.addEdge(l, r, b-a);
        dinic.addEdge(ss, r, a);
        dinic.addEdge(l, tt, a);
    }
    dinic2  = dinic;

    dinic.addEdge(t, s, k);
    int f1 = dinic.maxFlow(ss, tt);
    if( !all_of( all(dinic.G[ss]), [](Edge x) { return
        x.cap == 0; } ) ) {
        puts("-1"); return;
    }

    dinic2.addEdge(ss, s, 1e9);
    dinic2.addEdge(t, tt, 1e9);

    int f2 = dinic2.maxFlow(ss, tt);
    // maxflow in current graph is f2 - slb
    printf("%d\n", (f2 - slb)*n );
}
int main() {
    int t;cin>>t;
    while(t--)
        solve();
}
```

3.2 sw mincut

```
//referenced from bcw's codebook
#include <cstdio>
#include <iostream>
#include <algorithm>
using namespace std;

struct SW{ // O(V^3) 0-base
    static const int MXN = 514;
    int n,vst[MXN],del[MXN];
    int edge[MXN][MXN],wei[MXN];
    void init(int _n){
        n = _n;
        for (int i=0; i<n; i++) {
            for (int j=0; j<n; j++)
                edge[i][j] = 0;
            del[i] = 0;
        }
    }
    void add_edge(int u, int v, int w){
        edge[u][v] += w;
        edge[v][u] += w;
    }
    void search(int &s, int &t){
        for (int i=0; i<n; i++)
            vst[i] = wei[i] = 0;
        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;
int main() {
    int n, m;
    while(cin>> n >> m ) {
        graph.init(n);
        while(m--) {
            int a, b, c; scanf("%d %d %d", &a, &b, &c);
            graph.add_edge(a, b, c);
        }
        cout << graph.solve() << endl;
    }
}
```

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 Djs + Seg

```
// demo ==> undo djs + segtree with offline
// this program doesn't consider the problem of
    overflowing varaible ans
// http://acm.csie.org/ntujudge/view_code.php?id
    =108190&contest_id=472

#define maxn 100005
#define maxm 500005
//can be used to solve dynamic connectivity problem
//can be used with segment tree ==> offline
struct DisjointSet {
  // save() is like recursive
  // undo() is like return
  int n, fa[maxn], sz[maxn];
  vector<pair<int*,int>> h;
  vector<int> sp;
  int ans;
  void init(int tn) {
    ans = 0;
    n=tn;
    for (int i=0; i<n; i++) {
      fa[i]=i;
      sz[i]=1;
    }
    sp.clear(); h.clear();
  }
  void assign(int *k, int v) {
    h.pb({k, *k});
    *k=v;
  }
  void save() { sp.pb(SZ(h)); }
  void undo() {
    assert(!sp.empty());
    int last=sp.back(); sp.pop_back();
    while (SZ(h)!=last) {
      auto x=h.back(); h.pop_back();
      *x.fi=x.se;
    }
  }
  int f(int x) {
    while (fa[x]!=x) x=fa[x];
    return x;
  }
  void uni(int x, int y) {
    x=f(x); y=f(y);
    if (x==y) return ;
    if (sz[x]<sz[y]) swap(x, y);
    //nans stands for new answer
    int t = sz[x]+sz[y];
    int nans = ans - (sz[x]*sz[x]-sz[x]) - (sz[y]*sz[y
        ]-sz[y]) + t*t-t;
    assign(&sz[x], sz[x]+sz[y]);
    assign(&fa[y], x);
    assign(&ans, nans);
  }
}djs;

int n, m;
map<int, int> ma[maxn];
vector<pii> seg[4*maxm];
LL ans[maxm];
void add(int ql, int qr, int a, int b, int id=1, int l
    =0, int r=m) {
    if( qr <= l || ql >= r ) return;
    if( l >= ql && r <= qr ) {
        seg[id].pb( mp(a, b) );
        return ;
    }
    int mid = (l+r)>>1;
    add( ql, qr, a, b, id*2, l, mid);
    add( ql, qr, a, b, id*2+1, mid, r);
}
void dfs(int u=1, int l=0, int r=m) {

    djs.save();
    for(pii v : seg[u] )  djs.uni( v.fi, v.se );

    if( r-l > 1 ) {
        int mid = (l+r)>>1;
        dfs(u*2, l, mid);
        dfs(u*2+1, mid, r);
    }else {
        // do sth here
        ans[l] = djs.ans;
    }

    djs.undo();
}
int main() {
    scanf("%d %d", &n, &m);
    for(int i = 0; i < m; i++) {
        int a, b; scanf("%d %d",&a, &b);
        a--, b--; if( b < a ) swap(a, b);

        if( ma[a].count(b) ) {
            add(ma[a][b], i, a, b);
            ma[a].erase(b);
        }else ma[a][b] = i;
    }
    for(int i = 0; i < n; i++) if( !ma[i].empty() ) {
        for(auto p : ma[i])
            add( p.se, m, i, p.fi);
    }
    djs.init(n);
    dfs();
    for(int i =0; i < m;i++) printf("%lld\n", ans[i]);
}
```

4.3 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;
}
```

4.4 Link Cut Tree

```
//https://github.com/yzgysjr/ACM-ICPC-Templates/blob/
    master/Data%20Structure/Link%20Cut%20Tree.cpp
struct node { int rev; node *pre, *ch[2]; } base[MAXN],
     nil, *null;
typedef node *tree;
#define isRoot(x) (x->pre->ch[0] != x && x->pre->ch[1]
    != x)
#define isRight(x) (x->pre->ch[1] == x)
inline void MakeRev(tree t) { if (t != null) { t->rev
    ^= 1; swap(t->ch[0], t->ch[1]); } }
inline void PushDown(tree t) { if (t->rev) { MakeRev(t
    ->ch[0]); MakeRev(t->ch[1]); t->rev = 0; } }
inline void Rotate(tree x) {
  tree y = x->pre; PushDown(y); PushDown(x);
  int d = isRight(x);
  if (!isRoot(y)) y->pre->ch[isRight(y)] = x; x->pre =
      y->pre;
  if ((y->ch[d] = x->ch[!d]) != null) y->ch[d]->pre = y
      ;
  x->ch[!d] = y; y->pre = x; Update(y);
}
inline void Splay(tree x) {
  PushDown(x); for (tree y; !isRoot(x); Rotate(x)) {
    y = x->pre; if (!isRoot(y)) Rotate(isRight(x) !=
        isRight(y) ? x : y);
  } Update(x);
}
inline void Splay(tree x, tree to) {
  PushDown(x); for (tree y; (y = x->pre) != to; Rotate(
      x)) if (y->pre != to)
    Rotate(isRight(x) != isRight(y) ? x : y);
  Update(x);
}
inline tree Access(tree t) {
  tree last = null; for (; t != null; last = t, t = t->
      pre) Splay(t),t->ch[1] = last, Update(t);
  return last;
}
inline void MakeRoot(tree t) { Access(t); Splay(t);
    MakeRev(t); }
inline tree FindRoot(tree t) { Access(t); Splay(t);
    tree last = null;
  for ( ; t != null; last = t, t = t->ch[0]) PushDown(t
      ); Splay(last); return last;
}
inline void Join(tree x, tree y) { MakeRoot(y); y->pre
    = x; }
inline void Cut(tree t) {Access(t); Splay(t); t->ch
    [0]->pre = null; t->ch[0] = null; Update(t);}
inline void Cut(tree x, tree y) {
  tree upper = (Access(x), Access(y));
  if (upper == x) { Splay(x); y->pre = null; x->ch[1] =
       null; Update(x); }
  else if (upper == y) { Access(x); Splay(y); x->pre =
      null; y->ch[1] = null; Update(y); }
  else assert(0); // `impossible to happen`
}
inline int Query(tree a, tree b) { // `query the cost
    in path a <-> b, lca inclusive`
  Access(a); tree c = Access(b); // c is lca
  int v1 = c->ch[1]->maxCost; Access(a);
  int v2 = c->ch[1]->maxCost;
  return max(max(v1, v2), c->cost);
}
void Init() {
  null = &nil; null->ch[0] = null->ch[1] = null->pre =
      null; null->rev = 0;
  Rep(i, 1, N) { node &n = base[i]; n.rev = 0; n.pre =
      n.ch[0] = n.ch[1] = null; }
}
//compressed version
//http://trinklee.blog.163.com/blog/static
    /238158060201521101957375/
const int N=30010;
int n,fa[N],son[N][2],val[N],siz[N],stmp,rev[N];
#define swap(a,b) (stmp=a,a=b,b=stmp)
void pu(int t){siz[t]=siz[son[t][0]]+siz[son[t][1]]+1;}
void pd(int t){rev[t]?rev[t]=0,rev[son[t][0]]^=1,rev[
    son[t][1]]^=1,swap(son[t][0],son[t][1]),1:1;}
bool nr(int t){return son[fa[t]][0]==t||son[fa[t]][1]==
    t;}
void rtt(int t,int f=0,bool p=0){
    p=son[f=fa[t]][1]==t,
    fa[t]=fa[f],nr(f)?son[fa[f]][son[fa[f]][1]==f]=t:1,
    (son[f][p]=son[t][!p])?fa[son[f][p]]=f:1,
    pu(son[fa[f]=t][!p]=f);
}
void pv(int t){if(nr(t))pv(fa[t]);pd(t);}
void splay(int t,int f=0){
    for(pv(t);nr(t);rtt(t))nr(f=fa[t])?
    rtt(son[f][1]==t^son[fa[f]][1]==f?t:f),1:1;pu(t);
}
void access(int t,int la=0){for(;t;splay(t),son[t][1]=
    la,la=t,t=fa[t]);}
void makeroot(int t){access(t),splay(t),rev[t]^=1;}
void link(int u,int v){makeroot(u),fa[u]=v;}
void cut(int u,int v){makeroot(u),access(v),splay(v),
    son[v][0]=fa[u]=0;}
```

4.5 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 <bits/stdc++.h>

using namespace std;

typedef long long LL;
LL mul(LL a, LL b, const LL mod) {
    LL x = 0,y = a % mod;
    while (b > 0) {
        if ( b&1 )
            x = (x + y) % mod;
        y = (y * 2) % mod;
        b >>= 1;
    }
    return x % mod;
}
/*
LL mul(LL lhs, LL rhs, const LL mod ) {
    return ( lhs * rhs ) % mod;
}
*/
LL mypow(LL b, LL e,const LL mod) {
    LL x = 1;
    LL y = b;
    while ( e ) {
        if ( e&1 ) x = mul(x, y, mod);
        y = mul(y, y, mod);
        e >>= 1;
    }
    return x;
}
const int testbase[] = {2, 3, 5, 7, 11, 13, 17, 19, 23,
     29, 31, 37};
bool isprime(const LL p) {
    if (p < 2) return false;
    if (p != 2 && !(p&1) ) return false;
    LL d = p - 1;
    while ( !(d&1) ) d >>= 1;
    for( int a : testbase ) {

        LL td = d;
        if( a >= p-1 ) return true;
        LL st = mypow(a, td, p);
        while ( td != p - 1 && st != 1 && st != p - 1)
            {
            st = mul(st, st, p);
            td <<= 1;
        }
        if ( st != p - 1 && !(td&1) ) return false;
    }
    return true;
}
int main() {
    int T;
    scanf("%d",&T);
    while(T--) {
        LL q;
        scanf("%lld",&q);
        puts(isprime(q)?"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:\t";
    for (int i=0; i<n; i++) {
        cout << x[i] << " ";
    }
    cout << endl;
}
```

5.5 FFT

```
//pEcaveros
// const int MAXN = 262144;
// (must be 2^k)
// before any usage, run pre_fft() first
//
// To implement poly. multiply:
//
// fft( n , a );
// fft( n , b );
// for( int i = 0 ; i < n ; i++ )
//   c[ i ] = a[ i ] * b[ i ];
// fft( n , c , 1 );
//
// then you have the result in c :: [cplx]
typedef long double ld;
typedef complex<ld> cplx;
const ld PI = acosl(-1);
const cplx I(0, 1);
cplx omega[MAXN+1];
void pre_fft(){
  for(int i=0; i<=MAXN; i++)
    omega[i] = exp(i * 2 * PI / MAXN * I);
}
// n must be 2^k
void fft(int n, cplx a[], bool inv=false){
  int basic = MAXN / n;
  int theta = basic;
  for (int m = n; m >= 2; m >>= 1) {
    int mh = m >> 1;
    for (int i = 0; i < mh; i++) {
      cplx w = omega[inv ? MAXN-(i*theta%MAXN)
                         : i*theta%MAXN];
      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 = (theta * 2) % MAXN;
  }
  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]);
  }
  if (inv)
    for (i = 0; i < n; i++)
      a[i] /= n;
}
```

```
//http://sd-invol.github.io/2016/02/13/FFT-mod-prime/
struct Complex {
    double x , y;
    Complex (double _x = 0 , double _y = 0) {
        x = _x , y = _y;
    }
    Complex operator + (const Complex &r) const {
        return Complex(x + r.x , y + r.y);
    }
    Complex operator - (const Complex &r) const {
        return Complex(x - r.x , y - r.y);
    }
    Complex operator * (const Complex &r) const {
        return Complex(x * r.x - y * r.y , x * r.y + y
            * r.x);
    }
    Complex conj () const {
        return Complex(x , -y);
    }
    double operator = (const double a) {
        *this = Complex(a , 0);
        return a;
    }
};
const double pi = acos(-1.0);
//fft with modulo, code referenced from the internet
/*
    fftMod::fftPrepare(len);
    fftMod::convolution(res, le, ri, len, r-1);
*/
namespace fftMod{
    const int N = 1 << 18;
    const int Mod = 1e9 + 7;
    // to do, M should be about sqrt(Mod)
    const int M = 32768;
    int p[N] , I[N] ;
    int t1[N] , t2[N] , t3[N];

    Complex w[N];
    int rev[N];

    void fftPrepare(int n) {
        int LN = __builtin_ctz(n);
        for (int i = 0 ; i < n ; ++ i) {
            double ang = 2 * pi * i / n;
            w[i] = Complex(cos(ang) , sin(ang));
            rev[i] = (rev[i >> 1] >> 1) | ((i & 1) << (
                LN - 1));
        }
    }
    void FFT(Complex P[], int n, int oper) {
        for (int i = 0 ; i < n ; i ++) {
            if (i < rev[i]) {
                swap(P[i], P[rev[i]]);
            }
        }
        for (int d = 0; (1 << d) < n; d++) {
            int m = 1 << d, m2 = m * 2 , rm = n / m2;
            for (int i = 0; i < n; i += m2) {
                for (int j = 0; j < m; j++) {
                    Complex &P1 = P[i + j + m], &P2 = P
                        [i + j];
                    Complex t = w[rm * j] * P1;
                    P1 = P2 - t;
                    P2 = P2 + t;
                }
            }
        }
    }

    Complex A[N] , B[N] , C1[N] , C2[N];
    void convolution(vector<int> &res, vector<int> &a,
        vector<int> &b, int len, int K) {
        // a[ 0 .. len ) and b[ 0 .. len )'s
            convolution % Mod
        // stored in res[ 0 .. K+1 )
        for (int i = 0 ; i < len ; ++ i) {
            A[i] = Complex(a[i] / M , a[i] % M);
            B[i] = Complex(b[i] / M , b[i] % M);
        }
        FFT(A , len , 1); FFT(B , len , 1);

        for (int i = 0 ; i < len ; ++ i) {
            int j = i ? len - i : i;
            Complex a1 = (A[i] + A[j].conj()) * Complex
                (0.5 , 0);
            Complex a2 = (A[i] - A[j].conj()) * Complex
                (0 , -0.5);
            Complex b1 = (B[i] + B[j].conj()) * Complex
                (0.5 , 0);
            Complex b2 = (B[i] - B[j].conj()) * Complex
                (0 , -0.5);
            Complex c11 = a1 * b1 , c12 = a1 * b2;
            Complex c21 = a2 * b1 , c22 = a2 * b2;
            C1[j] = c11 + c12 * Complex(0 , 1);
            C2[j] = c21 + c22 * Complex(0 , 1);
        }
        FFT(C1 , len , -1); FFT(C2 , len , -1);

        for (int i = 0 ; i <= K ; ++ i) {
            int x = (LL)(C1[i].x / len + 0.5) % Mod;
            int y1 = (LL)(C1[i].y / len + 0.5) % Mod;
            int y2 = (LL)(C2[i].x / len + 0.5) % Mod;
            int z = (LL)(C2[i].y / len + 0.5) % Mod;
            res[i] = ((LL)x * M * M + (LL)(y1 + y2) * M
                + z) % Mod;
        }
    }
};
```

5.6 NNT

```
//pEcaveros
LL P=2013265921,root=31;
int MAXNUM=4194304;
// Remember coefficient are mod P
/* p=a*2^n+1
n   2^n          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 */
LL bigmod(LL a,LL b){
  if(b==0)return 1;
  return (bigmod((a*a)%P,b/2)*(b%2?a:1LL))%P;
}
LL inv(LL a,LL b){
  if(a==1)return 1;
  return (((LL)(a-inv(b%a,a))*b+1)/a)%b;
}
std::vector<LL> ps(MAXNUM), rev(MAXNUM);
struct poly{
  std::vector<LL> 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]=((LL)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]=((LL)a.co[i]*Ni)%P;
    a.n=n+_b.n; return a;
  }
};
```

```
constexpr int mod = 1e9+7;
typedef vector<int> VEC;
// ntt + Crt, code referenced from the internet
namespace nttCrt {
    constexpr int magic[3] = {1004535809, 998244353,
        104857601};
    constexpr int MOD = 1000000007;
    constexpr int G = 3;
    int P;
    inline int quick_mod(int x, int k, int MOD) {
```

```
    int ans = 1;
    while (k) {
        if (k&1) ans = 1LL * ans * x % MOD;
        x = 1LL * x * x % MOD;
        k >>= 1;
    }
    return ans;
}
inline void change(int *y, int len) {
    for(int i = 1, j = len / 2; i < len - 1; i++) {
        if(i < j) swap(y[i], y[j]);
        //交换互为小标反转的元素，i<j保证交换一次
        //i做正常的+1，j左反转类型的+1,始终保持i和j
            是反转的
        int k = len / 2;
        while(j >= k) {
            j -= k;
            k /= 2;
        }
        if(j < k) j += k;
    }
}
inline void ntt(int *y, int len, int on) {
    change(y, len);
    for(int h = 2; h <= len; h <<= 1) {
        int wn = quick_mod(G, (P - 1) / h, P);
        for(int j = 0; j < len; j += h) {
            int w = 1;
            for(int k = j; k < j + h / 2; k++) {
                int u = y[k] % P;
                int t = 1LL * w * y[k + h / 2] % P;
                y[k] = (u + t) % P;
                y[k + h / 2] = ((u - t) % P + P) %
                    P;
                w = 1LL * w * wn % P;
            }
        }
    }
    if(on == -1) {
        for (int i = 1; i < len / 2; i++)
            swap(y[i], y[len - i]);
        int inv = quick_mod(len, P - 2, P);
        for(int i = 0; i < len; i++)
            y[i] = 1LL * y[i] * inv % P;
    }
}

int n;
int r[3][3];

inline int CRT(int *a) {
    int sb[3] = {a[0], a[1], a[2]};
    for(int i = 0; i < 3; ++i) {
        for(int j = 0; j < i; ++j) {
            int t = (sb[i] - sb[j]) % magic[i];
            if(t < 0) t += magic[i];
            sb[i] = 1LL * t * r[j][i] % magic[i];
        }
    }
    int mul = 1, ans = sb[0] % MOD;
    for(int i = 1; i < 3; ++i) {
        mul = 1LL * mul * magic[i - 1] % MOD;
        ans = (ans + 1LL * sb[i] * mul) % MOD;
    }
    return ans;
}
int tmp[maxn][3];
int x1[maxn*2], x2[maxn*2];

inline void gao(vector<int>& res, vector<int> &a,
     vector<int> &b ,int len, int kk) {

    for (int ti = 0; ti < 3; ti++) {
        P = magic[ti];
        int k;
        for ( k = 0; k < SZ(a) && k < len; k++) x1[
            k] = a[k];
        for ( ;k < len; k++) x1[k] = 0;
        for ( k = 0; k < SZ(b) && k < len; k++) x2[
            k] = b[k];
        for ( ;k < len; k++) x2[k] = 0;
```

```
            ntt(x1, len, 1); ntt(x2, len, 1);
            for (int i = 0; i < len; i++) x1[i] = 1LL *
                 x1[i] * x2[i] % P;
            ntt(x1, len, -1);

            for (int i = 0; i <= kk; i++) tmp[i][ti] =
                x1[i];
        }
        for (int i = 0; i <= kk; i++) res[i] = CRT(tmp
        [i])  ;
    }
    inline void init() {
        for (int i = 0; i < 3; i++) {
            for (int j = 0; j < 3; j++) {
                r[i][j] = quick_mod(magic[i], magic[j]
                    - 2, magic[j]);
            }
        }
    }
};
```

5.7 Big Number

```
//http://blog.csdn.net/hackbuteer1/article/details
    /6595881
#include<iostream>
#include<string>
#include<iomanip>
#include<algorithm>
using namespace std;

#define MAXN 9999
#define MAXSIZE 10
#define DLEN 4

class BigNum
{
private:
    int a[500];     //可以控制大数的位数
    int len;        //大数长度
public:
    BigNum(){ len = 1;memset(a,0,sizeof(a)); }   //构造函
        数
    BigNum(const int);        //将一个int类型的变量转化为
        大数
    BigNum(const char*);      //将一个字符串类型的变量转化
        为大数
    BigNum(const BigNum &);   //拷贝构造函数
    BigNum &operator=(const BigNum &);    //重载赋值运算
        符，大数之间进行赋值运算

    friend istream& operator>>(istream&,  BigNum&);    //
        重载输入运算符
    friend ostream& operator<<(ostream&,  BigNum&);    //
        重载输出运算符

    BigNum operator+(const BigNum &) const;    //重载加法
        运算符，两个大数之间的相加运算
    BigNum operator-(const BigNum &) const;    //重载减法
        运算符，两个大数之间的相减运算
    BigNum operator*(const BigNum &) const;    //重载乘法
        运算符，两个大数之间的相乘运算
    BigNum operator/(const int   &) const;    //重载除法
        运算符，大数对一个整数进行相除运算

    BigNum operator^(const int  &) const;    //大数的n次
        方运算
    int    operator%(const int  &) const;    //大数对一个
        int类型的变量进行取模运算
    bool   operator>(const BigNum & T)const;    //大数和另
        一个大数的大小比较
    bool   operator>(const int & t)const;      //大数和一
        个int类型的变量的大小比较

    void print();       //输出大数
```

```
};
BigNum::BigNum(const int b)      //将一个int类型的变量转
      化为大数
{
  int c,d = b;
  len = 0;
  memset(a,0,sizeof(a));
  while(d > MAXN)
  {
    c = d - (d / (MAXN + 1)) * (MAXN + 1);
    d = d / (MAXN + 1);
    a[len++] = c;
  }
  a[len++] = d;
}
BigNum::BigNum(const char*s)      //将一个字符串类型的变
      量转化为大数
{
  int t,k,index,l,i;
  memset(a,0,sizeof(a));
  l=strlen(s);
  len=l/DLEN;
  if(l%DLEN)
    len++;
  index=0;
  for(i=l-1;i>=0;i-=DLEN)
  {
    t=0;
    k=i-DLEN+1;
    if(k<0)
      k=0;
    for(int j=k;j<=i;j++)
      t=t*10+s[j]-'0';
    a[index++]=t;
  }
}
BigNum::BigNum(const BigNum & T) : len(T.len)  //拷贝构
      造函数
{
  int i;
  memset(a,0,sizeof(a));
  for(i = 0 ; i < len ; i++)
    a[i] = T.a[i];
}
BigNum & BigNum::operator=(const BigNum & n)    //重载赋
      值运算符，大数之间进行赋值运算
{
  int i;
  len = n.len;
  memset(a,0,sizeof(a));
  for(i = 0 ; i < len ; i++)
    a[i] = n.a[i];
  return *this;
}
istream& operator>>(istream & in,  BigNum & b)    //重载
      输入运算符
{
  char ch[MAXSIZE*4];
  int i = -1;
  in>>ch;
  int l=strlen(ch);
  int count=0,sum=0;
  for(i=l-1;i>=0;)
  {
    sum = 0;
    int t=1;
    for(int j=0;j<4&&i>=0;j++,i--,t*=10)
    {
      sum+=(ch[i]-'0')*t;
    }
    b.a[count]=sum;
    count++;
  }
  b.len =count++;
  return in;

}
ostream& operator<<(ostream& out,  BigNum& b)   //重载
      输出运算符
{
  int i;
  cout << b.a[b.len - 1];
  for(i = b.len - 2 ; i >= 0 ; i--)
  {
    cout.width(DLEN);
    cout.fill('0');
    cout << b.a[i];
  }
  return out;
}

BigNum BigNum::operator+(const BigNum & T) const   //两
      个大数之间的相加运算
{
  BigNum t(*this);
  int i,big;      //位数
  big = T.len > len ? T.len : len;
  for(i = 0 ; i < big ; i++)
  {
    t.a[i] +=T.a[i];
    if(t.a[i] > MAXN)
    {
      t.a[i + 1]++;
      t.a[i] -=MAXN+1;
    }
  }
  if(t.a[big] != 0)
    t.len = big + 1;
  else
    t.len = big;
  return t;
}
BigNum BigNum::operator-(const BigNum & T) const   //两
      个大数之间的相减运算
{
  int i,j,big;
  bool flag;
  BigNum t1,t2;
  if(*this>T)
  {
    t1=*this;
    t2=T;
    flag=0;
  }
  else
  {
    t1=T;
    t2=*this;
    flag=1;
  }
  big=t1.len;
  for(i = 0 ; i < big ; i++)
  {
    if(t1.a[i] < t2.a[i])
    {
      j = i + 1;
      while(t1.a[j] == 0)
        j++;
      t1.a[j--]--;
      while(j > i)
        t1.a[j--] += MAXN;
      t1.a[i] += MAXN + 1 - t2.a[i];
    }
    else
      t1.a[i] -= t2.a[i];
  }
  t1.len = big;
  while(t1.a[len - 1] == 0 && t1.len > 1)
  {
    t1.len--;
    big--;
  }
  if(flag)
    t1.a[big-1]=0-t1.a[big-1];
  return t1;
}

BigNum BigNum::operator*(const BigNum & T) const   //两
      个大数之间的相乘运算
{
  BigNum ret;
  int i,j,up;
  int temp,temp1;
  for(i = 0 ; i < len ; i++)
  {
    up = 0;
    for(j = 0 ; j < T.len ; j++)
    {
      temp = a[i] * T.a[j] + ret.a[i + j] + up;
      if(temp > MAXN)
      {
        temp1 = temp - temp / (MAXN + 1) * (MAXN + 1);
        up = temp / (MAXN + 1);
        ret.a[i + j] = temp1;
      }
      else
      {
        up = 0;
        ret.a[i + j] = temp;
      }
    }
    if(up != 0)
      ret.a[i + j] = up;
  }
  ret.len = i + j;
  while(ret.a[ret.len - 1] == 0 && ret.len > 1)
    ret.len--;
  return ret;
}
BigNum BigNum::operator/(const int & b) const    //大数
    对一个整数进行相除运算
{
  BigNum ret;
  int i,down = 0;
  for(i = len - 1 ; i >= 0 ; i--)
  {
    ret.a[i] = (a[i] + down * (MAXN + 1)) / b;
    down = a[i] + down * (MAXN + 1) - ret.a[i] * b;
  }
  ret.len = len;
  while(ret.a[ret.len - 1] == 0 && ret.len > 1)
    ret.len--;
  return ret;
}
int BigNum::operator %(const int & b) const    //大数对
    一个int类型的变量进行取模运算
{
  int i,d=0;
  for (i = len-1; i>=0; i--)
  {
    d = ((d * (MAXN+1))% b + a[i])% b;
  }
  return d;
}
BigNum BigNum::operator^(const int & n) const    //大数
    的n次方运算
{
  BigNum t,ret(1);
  int i;
  if(n<0)
    exit(-1);
  if(n==0)
    return 1;
  if(n==1)
    return *this;
  int m=n;
  while(m>1)
  {
    t=*this;
    for( i=1;i<<1<=m;i<<=1)
    {
      t=t*t;
    }
    m-=i;
    ret=ret*t;
    if(m==1)
      ret=ret*(*this);
  }
  return ret;
}
bool BigNum::operator>(const BigNum & T) const    //大数
    和另一个大数的大小比较
{
  int ln;
  if(len > T.len)
    return true;
  else if(len == T.len)
  {
    ln = len - 1;
    while(a[ln] == T.a[ln] && ln >= 0)
      ln--;
    if(ln >= 0 && a[ln] > T.a[ln])
      return true;
    else
      return false;
  }
  else
    return false;
}
bool BigNum::operator >(const int & t) const    //大数
    和一个int类型的变量的大小比较
{
  BigNum b(t);
  return *this>b;
}

void BigNum::print()    //输出大数
{
  int i;
  cout << a[len - 1];
  for(i = len - 2 ; i >= 0 ; i--)
  {
    cout.width(DLEN);
    cout.fill('0');
    cout << a[i];
  }
  cout << endl;
}
int main(void)
{
  int i,n;
  BigNum x[101];      //定义大数的对象数组
  x[0]=1;
  for(i=1;i<101;i++)
    x[i]=x[i-1]*(4*i-2)/(i+1);
  while(scanf("%d",&n)==1 && n!=-1) {
    x[n].print();
  }
}
```

5.8 Simplex

```
//reference from bcw's codebook
const int maxn = 111;
const int maxm = 111;
const double eps = 1E-10;

double a[maxn][maxm], b[maxn], c[maxm], d[maxn][maxm];
double x[maxm];
int ix[maxn + maxm]; // !!! array all indexed from 0
// max{cx} subject to {Ax<=b,x>=0}
// n: constraints, m: vars !!!
// x[] is the optimal solution vector
//
// usage :
// value = simplex(a, b, c, N, M);
double simplex(double a[maxn][maxm], double b[maxn],
    double c[maxm], int n, int m) {
    ++m;
    int r = n, s = m - 1;
    memset(d, 0, sizeof(d));
    for (int i = 0; i < n + m; ++i) ix[i] = i;
    for (int i = 0; i < n; ++i) {
        for (int j = 0; j < m - 1; ++j) d[i][j] = -a[i
            ][j];
        d[i][m - 1] = 1;
        d[i][m] = b[i];
        if (d[r][m] > d[i][m]) r = i;
    }
    for (int j = 0; j < m - 1; ++j) d[n][j] = c[j];
    d[n + 1][m - 1] = -1;
    for (double dd;; ) {
        if (r < n) {
            int t = ix[s]; ix[s] = ix[r + m]; ix[r + m]
                = t;
            d[r][s] = 1.0 / d[r][s];
            for (int j = 0; j <= m; ++j) if (j != s) d[
                r][j] *= -d[r][s];
            for (int i = 0; i <= n + 1; ++i) if (i != r
                ) {
                for (int j = 0; j <= m; ++j) if (j != s
                    ) d[i][j] += d[r][j] * d[i][s];
                d[i][s] *= d[r][s];
            }
        }
        r = -1; s = -1;
        for (int j = 0; j < m; ++j) if (s < 0 || ix[s]
            > ix[j]) {
            if (d[n + 1][j] > eps || (d[n + 1][j] > -
                eps && d[n][j] > eps)) s = j;
        }
        if (s < 0) break;
        for (int i = 0; i < n; ++i) if (d[i][s] < -eps)
             {
            if (r < 0 || (dd = d[r][m] / d[r][s] - d[i
                ][m] / d[i][s]) < -eps || (dd < eps &&
                ix[r + m] > ix[i + m])) r = i;
        }
        if (r < 0) return -1; // not bounded
    }
    if (d[n + 1][m] < -eps) return -1; // not
        executable
    double ans = 0;
    for(int i=0; i<m; i++) x[i] = 0;
    for (int i = m; i < n + m; ++i) { // the missing
        enumerated x[i] = 0
        if (ix[i] < m - 1)
        {
            ans += d[i - m][m] * c[ix[i]];
            x[ix[i]] = d[i-m][m];
        }
    }
    return ans;
}
```

6 string

6.1 Palindromic Tree

```
/**
回文自動機包含以下元素:

    狀態St, 所有節點的集合, 一開始兩個節點, 0表示偶數長
        度串的根和1表示奇數長度串的根
    last 新增加一個字符後所形成的最長回文串的節點編號
    s 當前的字符串(一開始設s[0]=-1(可以是任意一個在串S
        中不會出現的字符))
    n 表示添加的字符個數


每個節點代表一個不同的回文子字串, 我們在每個節點會儲存
    一些數值:

    len 表示所代表的回文子字串長度
    next[c] 表示所代表的回文子字串在頭尾各增加一個字符c
        後的回文字串其節點編號
    sufflink 表示所代表的回文子字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字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字串其後綴為回文字
        串的個數 <== not included
**/
struct palindromic_tree{
    struct node{
        int next[26],sufflink,len; /*這些是必要的元素*/
        int l, r; // this node is s[ l .. r ]
        int cnt, num;           /*這些是額外維護的元素*/
        node(int l=0):sufflink(0),len(l),cnt(0),num(0){
            for(int i=0;i<26;++i)next[i]=0;
        }
    };
    std::vector<node> St;
    std::string s; //current string [ 1 .. n ]
    int last,n;
    palindromic_tree():St(2),last(1),n(0){
        St[0].sufflink=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].sufflink=1;
        s.push_back(-1);
    }
    inline int get_sufflink(int x){
        while( s[n-St[x].len-1] != s[n] ) x=St[x].
            sufflink;
        return x;
    }
    inline void add(int c){
        s.push_back(c-='a');
        ++n;
        int cur=get_sufflink(last);
        if(!St[cur].next[c]){
            int now=St.size();
            St.push_back(St[cur].len+2);
            St[now].sufflink=St[get_sufflink(St[cur].
                sufflink)].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].sufflink].num+1;
            St[now].l = n - St[now].len + 1, St[now].r
                = n;
        }
        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->sufflink].cnt+=i->cnt;
        }
    }
    inline int size(){/*傳回其不同的回文子串個數*/
        return St.size()-2;
    }
}ptree;
```

6.2 Suffix Array

6.3 Longest Palindromic Substring

```
//ntu judge Earse
#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 {
    double x, y;
    P(double _x=0, double _y=0) :x(_x), y(_y) {};
    void read() {
        scanf("%lf%lf",&x,&y);
    }
    void print() {
        printf("%f %f\n", x, y);
    }
} p[N];
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, double a ) { return P{a*b.x,a*b.y};
    }
P operator /( P a, double b ) { return P{a.x/b,a.y/b};
    }
P& operator /=( P &a, double b ) { return a=a/b; }
double operator *( P a, P b ) { return a.x*b.x+a.y*b.y;
    }
double operator ^( P a, P b ) { return a.x*b.y-a.y*b.x;
    }
double x( P o, P a, P b ) { return (a-o)^(b-o); }
double dot( P o, P a, P b ) { return (a-o)*(b-o); }
```

7.2 Intersection of Circles/Lines/Segments

//PECaveros

```
vector<P> interCircle( P o1 , double r1 , P o2 , double
    r2 ){
  double d2 = ( o1 - o2 ) * ( o1 - o2 );
  double d = sqrt(d2);
  if( d > r1 + r2 ) return {};
  P u = (o1+o2)*0.5 + (o1-o2)*((r2*r2-r1*r1)/(2*d2));
  double A = sqrt((r1+r2+d)*(r1-r2+d)*(r1+r2-d)*(-r1+r2
      +d));
  P v = P( 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
*/
```