Contents

1 Basic

1.1 .vimrc

```
colo torte
syn on
se cin ai ar sm nu ru is
se mouse=a bs=2 ww+=<,>,[,] so=6 ts=4 sw=4 ttm=100
se makeprg=g++\ -Wall\ -Wshadow\ -O2\ -std=c++0x\ -o\
    %<\ %
au BufNewFile *.cpp 0r ~/default.cpp

map <F7> <ESC>:wa<CR>:make!<CR>
imap <F7> <ESC>:wa<CR>:make!<CR>
map <C-F7> <ESC>:tabe %<.in<CR>
map <F8> :cope <CR>
map <S-F8> :ccl <CR>
map <F9> :!./%< <CR>
map <C-F9> :!./%< < %<.in <CR>
```

1.2 IncreaseStackSize

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

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

1.3 Default Code

```
#include<bits/stdc++.h>
#include<cmath>
#include<cstdio>
#include<cstring>
#include<cstdlib>
#include<iostream>
#include<algorithm>
#include<vector>
using namespace std;
#define _SZ(n) memset((n),0,sizeof(n))
#define _SMO(n) memset((n),-1,sizeof(n))
#define _MC(n,m) memcpy((n),(m),sizeof(n))
#define _F first
#define _S second
#define _MP make_pair
#define _PB push_back
#define FOR(x,y) for(__typeof(y.begin())x=y.begin();x!=
    y.end();x++)
#define IOS ios_base::sync_with_stdio(0); cin.tie(0)
// Let's Fight!

int main()
{
  return 0;
}
```

2 Data Structure

2.1 Bigint

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

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

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

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

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

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

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

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

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

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

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

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

2.2 Leftist Heap

```
const int MAXSIZE = 10000;

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

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

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

2.3 extc_balance_tree

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

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

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

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

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

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

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

}
```

2.4 Treap

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

int nMem;

int get_rand(){
  return (rand()<<15) + rand();
}
int get_node(){
  tree[nMem] = Node();
  if (nMem >= MX) while(1);
  return nMem++;
}
void upd_node(int rt){
  if (!rt) return ;
  int lc=tree[rt].lc;
  int rc=tree[rt].rc;
  tree[rt].cnt = tree[lc].cnt + tree[rc].cnt + 1;
}
int merge(int a, int b){
  if (!a) return b;
  if (!b) return a;
  int res=0;
  if (tree[a].pri > tree[b].pri){
    res = a; //get_node();
    tree[res] = tree[a];
    tree[res].rc = merge(tree[res].rc,b);
  } else {
    res = b; //get_node();
    tree[res] = tree[b];
    tree[res].lc = merge(a,tree[res].lc);
  }
  upd_node(res);
  return res;
}
pair<int,int> split(int a, int k){
  if (k == 0) return _MP(0,a);
  if (k == tree[a].cnt) return _MP(a,0);
  int lc=tree[a].lc, rc=tree[a].rc;
  pair<int,int> res;
  int np=a; //get_node();
  //tree[np] = tree[a];
  if (tree[lc].cnt >= k){
    res = split(lc,k);
    tree[np].lc = res._S;
    res._S = np;
  } else {
    res = split(rc,k-tree[lc].cnt-1);
    tree[np].rc = res._F;
    res._F = np;
  }
  upd_node(res._F);
  upd_node(res._S);
  return res;
}
```

2.5 Heavy Light Decomposition

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

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

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

void DFS(int u){
  Chain &c = chain[belong[u]];
  c.init();
  for (int i=0; i<c.n; i++){
    u = c.vec[i];
    for (auto v : E[u]){
      if (fa[u] == v || (i && v == c.vec[i-1]))
          continue;
      DFS(v);
    }
  }
  c.build_tree(0,c.n-1,0);
}
void build_chain(){
  fr=bk=0; que[bk++] = 1; fa[1]=0;
  while (fr < bk){
    int u=que[fr++];
    for (auto v : E[u]){
      if (v == fa[u]) continue;
      que[bk++] = v;
      fa[v] = u;
    }
  }
  for (int i=bk-1,u,pos; i>=0; i--){
    u = que[i]; sz[u] = 1; pos = 0;
    for (auto v : E[u]){
      if (v == fa[u]) continue;
      sz[u] += sz[v];
      if (sz[v] > sz[pos]) pos=v;
    }
    if (pos == 0) belong[u] = u;
    else belong[u] = belong[pos];
    chain[belong[u]].vec._PB(u);
  }
  DFS(1);
}
```

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

  return 0;
}
```

3 Graph

3.1 Tarjan

```
const int MAXV = 101000;

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

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

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

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

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

3.2 Strongly Connected Components:Kosaraju's Algorithm

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

3.3 DMST_with_sol

```
const int INF = 1029384756;

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

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

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

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

3.4 Maximum Clique

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

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

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

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

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

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

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

3.5 (+1) MinimumMeanCycle

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

4 Flow

4.1 ISAP

```
class Isap{
public:
  static const int MXN = 10000;
  class Edge{
  public:
    int v,f,re;
    Edge (){ v=f=re=-1; }
    Edge (int _v, int _f, int _r){
      v = _v;
      f = _f;
      re = _r;
    }
  };
  int n,s,t,h[MXN],gap[MXN];
  vector<Edge> E[MXN];
  void init(int _n, int _s, int _t){
    n = _n;
    s = _s;
    t = _t;
    for (int i=0; i<n; i++)
      E[i].clear();
  }
  void add_edge(int u, int v, int f){
    E[u]._PB(Edge(v,f,E[v].size()));
    E[v]._PB(Edge(u,0,E[u].size()-1));
  }
  int DFS(int u, int nf, int res=0){
    if (u == t) return nf;
    for (auto &it : E[u]){
      if (h[u]==h[it.v]+1 && it.f>0){
        int tf = DFS(it.v,min(nf,it.f));
        res += tf;
        nf -= tf;
        it.f -= tf;
        E[it.v][it.re].f += tf;
        if (nf == 0) return res;
      }
    }
    if (nf){
      if (--gap[h[u]] == 0) h[s]=n;
      gap[++h[u]]++;
    }
    return res;
  }
  int flow(int res=0){
    _SZ(h);
    _SZ(gap);
    gap[0] = n;
    while (h[s] < n)
      res += DFS(s,2147483647);
    return res;
  }
}flow;
```

4.2 Dinic

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

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

4.3 Bipartite Matching (Augmenting Path)

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

4.4 Kuhn Munkres

```
struct KM{
// Maximum Bipartite Weighted Matching (Perfect Match)
  static const int MXN = 650;
  static const int INF = 2147483647; // long long
  int n,match[MXN],vx[MXN],vy[MXN];
  int edge[MXN][MXN],lx[MXN],ly[MXN],slack[MXN];
  // ^^^^ long long
  void init(int _n){
    n = _n;
    for (int i=0; i<n; i++)
      for (int j=0; j<n; j++)
        edge[i][j] = 0;
  }
  void add_edge(int x, int y, int w){ // long long
    edge[x][y] = w;
  }
  bool DFS(int x){
    vx[x] = 1;
    for (int y=0; y<n; y++){
      if (vy[y]) continue;
      if (lx[x]+ly[y] > edge[x][y]){
        slack[y] = min(slack[y], lx[x]+ly[y]-edge[x][y
            ]);
      } else {
        vy[y] = 1;
        if (match[y] == -1 || DFS(match[y])){
          match[y] = x;
          return true;
        }
      }
    }
    return false;
  }
  int solve(){
    fill(match,match+n,-1);
    fill(lx,lx+n,-INF);
    fill(ly,ly+n,0);
    for (int i=0; i<n; i++)
      for (int j=0; j<n; j++)
        lx[i] = max(lx[i], edge[i][j]);
    for (int i=0; i<n; i++){
      fill(slack,slack+n,INF);
      while (true){
        fill(vx,vx+n,0);
        fill(vy,vy+n,0);
        if ( DFS(i) ) break;
        int d = INF; // long long
        for (int j=0; j<n; j++)
          if (!vy[j]) d = min(d, slack[j]);
        for (int j=0; j<n; j++){
          if (vx[j]) lx[j] -= d;
          if (vy[j]) ly[j] += d;
          else slack[j] -= d;
        }
      }
    }
    int res=0;
    for (int i=0; i<n; i++)
      res += edge[match[i]][i];
    return res;
  }
}graph;
```

4.5 SW-Mincut

```
typedef long long LL;
typedef long double LD;
typedef std::pair<int,int> PII;

const int N=514;
const int INF=2147483647>>1;

int n, m, del[N], vst[N], wei[N], rd[N][N];

PII sw(){
    MSET(vst,0);
    MSET(wei,0);
    int p1=-1,p2=-1,mx,cur=0;
    while(1){
        mx=-1;
        REP(i,1,n){
            if (!del[i] && !vst[i] && mx<wei[i]){
                cur=i;
                mx=wei[i];
            }
        }
        if (mx==-1) break;
        vst[cur]=1;
        p1=p2;
        p2=cur;
        REP(i,1,n)
            if (!vst[i] && !del[i])
                wei[i]+=rd[cur][i];
    }
    return std::MP(p1,p2);
}
void input(){
    REP(i,1,n){
        del[i]=0;
        REP(j,1,n)
            rd[i][j] = 0;
```

```
    }
    REP(i,1,m){
        int u,v,c;
        scanf("%d%d%d",&u,&v,&c);
        ++u; ++v;
        rd[u][v]+=c;
        rd[v][u]+=c;
    }
}
void solve(){
    int ans=INF;
    PII tmp;
    REP(i,1,n-1){
        tmp=sw();
        int x=tmp.F;
        int y=tmp.S;
        if (wei[y] < ans) ans=wei[y];
        del[y]=1;
        REP(j,1,n){
            rd[j][x]+=rd[j][y];
            rd[x][j]+=rd[y][j];
        }
    }
    printf("%d\n", ans);
}

int main(){
    while (~scanf("%d%d", &n, &m)){
        input();
        solve();
    }
    return 0;
}
```

4.6 Maximum Simple Graph Matching

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

    while(qe.size()) qe.pop();
    qe.push(st);
    inq[st] = 1;
    ed = 0;
    while(qe.size()) {
      int u = qe.front(); qe.pop();
      for(int v = 1; v <= V; v++)
        if(el[u][v] && (djs[u] != djs[v]) && (pr[u] !=
            v)) {
          if((v == st) || ((pr[v] > 0) && bk[pr[v]] >
              0))
            blo(u,v);
          else if(bk[v] == 0) {
            bk[v] = u;
            if(pr[v] > 0) {
              if(!inq[pr[v]]) qe.push(pr[v]);
            } else {
              ed = v;
              return;
            }
          }
        }
    }
  }
  void aug() {
    int u,v,w;
    u = ed;
    while(u > 0) {
      v = bk[u];
      w = pr[v];
      pr[v] = u;
      pr[u] = v;
      u = w;
    }
  }
  int solve() {
    memset(pr,0,sizeof(pr));
    for(int u = 1; u <= V; u++)
      if(pr[u] == 0) {
        st = u;
        flow();
        if(ed > 0) {
          aug();
          ans ++;
        }
      }
    return ans;
  }
};

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

4.7 2-Commodity Flow

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

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

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

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

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

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

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

    return 0;
}

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

    int flow = 0;

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

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

    return flow;
}

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

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

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

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

        int ans = 0;

        S = N;
        T = N + 1;

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

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

        ans = get_flow();

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

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

        ans = min(ans, get_flow());

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

    return 0;
}
```

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

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

```
      adj[v].PB(u);
      adj[u].PB(v);
    }
    cost[v][u]+=c;
    cost[u][v]+=c;
  }
  void merge(int v,int u) {
    merged[u]=1;
    for(int i=0;i<n;i++)
      append(v,i,cost[u][i]);
    // --8<-- include only if cut is explicitly
        needed
    djs.merge(v,u);
    //
        --8<----------------------------------------

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

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

5 Math

5.1 ax+by=gcd

```
typedef pair<int, int> pii;

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

5.2 Chinese Remainder

```
int pfn; // number of distinct prime factors
int pf[MAXNUM]; // prime factor powers
int rem[MAXNUM]; // corresponding remainder
int pm[MAXNUM];
inline void generate_primes() {
  int i,j;
  pnum=1;
  prime[0]=2;
  for(i=3;i<MAXVAL;i+=2) {
    if(nprime[i]) continue;
    prime[pnum++]=i;
    for(j=i*i;j<MAXVAL;j+=i) nprime[j]=1;
  }
}
inline int inverse(int x,int p) {
  int q,tmp,a=x,b=p;
  int a0=1,a1=0,b0=0,b1=1;
  while(b) {
    q=a/b; tmp=b; b=a-b*q; a=tmp;
    tmp=b0; b0=a0-b0*q; a0=tmp;
    tmp=b1; b1=a1-b1*q; a1=tmp;
  }
  return a0;
}
inline void decompose_mod() {
  int i,p,t=mod;
  pfn=0;
  for(i=0;i<pnum&&prime[i]<=t;i++) {
    p=prime[i];
    if(t%p==0) {
      pf[pfn]=1;
      while(t%p==0) {
        t/=p;
        pf[pfn]*=p;
      }
      pfn++;
    }
  }
  if(t>1) pf[pfn++]=t;
}
inline int chinese_remainder() {
  int i,m,s=0;
  for(i=0;i<pfn;i++) {
    m=mod/pf[i];
    pm[i]=(long long)m*inverse(m,pf[i])%mod;
    s=(s+(long long)pm[i]*rem[i])%mod;
  }
  return s;
}
```

5.3 Miller Rabin

```
long long power(long long x,long long p,long long mod){
  long long s=1,m=x;
  while(p) {
    if(p&1) s=mult(s,m,mod);
    p>>=1;
    m=mult(m,m,mod);
  }
```

```
  return s;
}
bool witness(long long a,long long n,long long u,int t)
    {
  long long x=power(a,u,n);
  for(int i=0;i<t;i++) {
    long long nx=mult(x,x,n);
    if(nx==1&&x!=1&&x!=n-1) return 1;
    x=nx;
  }
  return x!=1;
}
bool miller_rabin(long long n,int s=100) {
  // iterate s times of witness on n
  // return 1 if prime, 0 otherwise
  if(n<2) return 0;
  if(!(n&1)) return n==2;
  long long u=n-1;
  int t=0;
  // n-1 = u*2^t
  while(u&1) {
    u>>=1;
    t++;
  }
  while(s--) {
    long long a=randll()%(n-1)+1;
    if(witness(a,n,u,t)) return 0;
  }
  return 1;
}
```

5.4 Mod

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

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

5.5 Primes

```
/*
* 12721
* 13331
* 14341
* 75577
* 123457
* 222557
* 556679
* 999983
* 1097774749
* 1076767633
* 100102021
* 999997771
* 1001010013
* 1000512343
* 987654361
* 999991231
* 999888733
* 98789101
* 987777733
* 999991921
* 1010101333
* 1010102101
* 1000000000039
* 100000000000037
* 2305843009213693951
* 4611686018427387847
* 9223372036854775783
* 18446744073709551557
*/
```

5.6 Gauss Elimination

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

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

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

5.7 (+1) PolynomialGenerator

```
class PolynomialGenerator {
  /* for a nth-order polynomial f(x), *
   * given f(0), f(1), ..., f(n) *
   * express f(x) as sigma_i{c_i*C(x,i)} */
  public:
    int n;
    vector<long long> coef;
    // initialize and calculate f(x), vector _fx should
         be
    // filled with f(0) to f(n)
      PolynomialGenerator(int _n,vector<long long> _fx)
          :n(_n
          ),coef(_fx) {
        for(int i=0;i<n;i++)
          for(int j=n;j>i;j--)
            coef[j]-=coef[j-1];
      }
    // evaluate f(x), runs in O(n)
    long long eval(int x) {
      long long m=1,ret=0;
      for(int i=0;i<=n;i++) {
        ret+=coef[i]*m;
        m=m*(x-i)/(i+1);
      }
      return ret;
    }
};
```

5.8 Fast Fourier Transform

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

6 Geometry

6.1 Point operators

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

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

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

pdd operator * (const double c, const pdd p){
  return pdd(p._x * c, p._y * c);
}
pdd operator - (const pdd p){
  return (-1.0) * p;
}
double operator * (const pdd p1, const pdd p2){
  return p1._x * p2._x + p1._y * p2._y;
}
double operator % (const pdd p1, const pdd p2){
  return p1._x * p2._y - p2._x * p1._y;
}
```

6.2 Intersection of two circles

Let $\mathbf{O_1} = (x_1, y_1), \mathbf{O_2} = (x_2, y_2)$ be two centers of circles, r_1, r_2 be the radius. If:
$d = |\mathbf{O_1} - \mathbf{O_2}|$ $\mathbf{u} = \frac{1}{2}(\mathbf{O_1} + \mathbf{O_2}) + \frac{(r_2^2 - r_1^2)}{2d^2}(\mathbf{O_1} - \mathbf{O_2})$
$\mathbf{v} = \frac{\sqrt{(r_1+r_2+d)(r_1-r_2+d)(r_1+r_2-d)(-r_1+r_2+d)}}{2d^2}(y_1 - y_2, -x_1 + x_2)$ then $\mathbf{u} + \mathbf{v}, \mathbf{u} - \mathbf{v}$ are the two intersections of the circles, provided that $d < r_1 + r_2$.

6.3 Intersection of two lines

```
#include<bits/stdc++.h>

using namespace std;
const double EPS = 1e-9;

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

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

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

6.4 Half Plane Intersection

```
#include<bits/stdc++.h>

using namespace std;

#define _PB push_back
#define _MP make_pair
#define _x first
#define _y second

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

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

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

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

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

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


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

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

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

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

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

deque<Line> dq;

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

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

```
        lst.pop_back();
      }else continue;
    }
  }
  lst._PB(lnlst[stlst[i]]);
}

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

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

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

  while(dsz >= 2){
    Line l1 = dq[0];
    Line l2 = dq[1];

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

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

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

}

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


int main(){

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

  halfPlaneInter();

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

}
```

6.5 Point Class

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

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

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

6.6 Convex Hull

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

6.7 Minimum Covering Circle

```
struct Mcc{
  // return pair of center and r^2
  static const int MAXN = 1000100;
  int n;
```

```
  Point p[MAXN],cen;
  double r2;

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

  pair<Point,double> solve(){
    random_shuffle(p,p+n);
    r2=0;
    for (int i=0; i<n; i++){
      if ((cen-p[i]).len2() <= r2) continue;
      cen = p[i];
      r2 = 0;
      for (int j=0; j<i; j++){
        if ((cen-p[j]).len2() <= r2) continue;
        cen = Point((p[i].x+p[j].x)*0.5, (p[i].y+p[j].y
            )*0.5);
        r2 = (cen-p[j]).len2();
        for (int k=0; k<j; k++){
          if ((cen-p[k]).len2() <= r2) continue;
          cen = center(p[i],p[j],p[k]);
          r2 = (cen-p[k]).len2();
        }
      }
    }
    return _MP(cen,r2);
  }
}mcc;
```

6.8 (+1) KDTreeAndNearestPoint

```
const INF = 1100000000;

class NODE{ public:
  int x,y,x1,x2,y1,y2;
  int i,f;
  NODE *L,*R;
};
inline long long dis(NODE& a,NODE& b){
  long long dx=a.x-b.x;
  long long dy=a.y-b.y;
  return dx*dx+dy*dy;
}
NODE node[100000];
bool cmpx(const NODE& a,const NODE& b){ return a.x<b.x;
    }
bool cmpy(const NODE& a,const NODE& b){ return a.y<b.y;
    }
NODE* KDTree(int L,int R,int dep){
  if(L>R) return 0;
  int M=(L+R)/2;
  if(dep%2==0){
    nth_element(node+L,node+M,node+R+1,cmpx);
    node[M].f=0;
  }else{
    nth_element(node+L,node+M,node+R+1,cmpy);
    node[M].f=1;
  }
  node[M].x1=node[M].x2=node[M].x;
  node[M].y1=node[M].y2=node[M].y;
  node[M].L=KDTree(L,M-1,dep+1);
  if(node[M].L){
    node[M].x1=min(node[M].x1,node[M].L->x1);
    node[M].x2=max(node[M].x2,node[M].L->x2);
    node[M].y1=min(node[M].y1,node[M].L->y1);
    node[M].y2=max(node[M].y2,node[M].L->y2);
  }
  node[M].R=KDTree(M+1,R,dep+1);
  if(node[M].R){
    node[M].x1=min(node[M].x1,node[M].R->x1);
    node[M].x2=max(node[M].x2,node[M].R->x2);
    node[M].y1=min(node[M].y1,node[M].R->y1);
    node[M].y2=max(node[M].y2,node[M].R->y2);
  }
  return node+M;
}
inline int touch(NODE* r,int x,int y,long long d){
  long long d2;
  d2 = (long long)(sqrt(d)+1);
  if(x<r->x1-d2 || x>r->x2+d2 || y<r->y1-d2 || y>r->y2+
      d2)
    return 0;
  return 1;
}
void nearest(NODE* r,int z,long long &md){
  if(!r || !touch(r,node[z].x,node[z].y,md)) return;
  long long d;
  if(node[z].i!=r->i){
    d=dis(*r,node[z]);
    if(d<md) md=d;
  }
  if(r->f==0){
    if(node[z].x<r->x){
      nearest(r->L,z,md);
      nearest(r->R,z,md);
    }else{
      nearest(r->R,z,md);
      nearest(r->L,z,md);
    }
  }else{
    if(node[z].y<r->y){
      nearest(r->L,z,md);
      nearest(r->R,z,md);
    }else{
      nearest(r->R,z,md);
      nearest(r->L,z,md);
    }
  }
}
int main(){
  int TT,n,i;
  long long d;
  NODE* root;
  scanf("%d",&TT);
  while(TT--){
    scanf("%d",&n);
    for(i=0;i<n;i++){
      scanf("%d %d",&node[i].x,&node[i].y);
      node[i].i=i;
    }
    root=KDTree(0,n-1,0);
    for(i=0;i<n;i++){
      d=9000000000000000000LL;
      nearest(root,i,d);
      ans[node[i].i]=d;
    }
  }
}
```

6.9 (+1) MinkowskiSum

```
/* convex hull Minkowski Sum*/
#define INF 100000000000000LL
class PT{ public:
  long long x,y;
  int POS(){
    if(y==0) return x>0?0:1;
    return y>0?0:1;
  }
};
PT pt[300000],qt[300000],rt[300000];
long long Lx,Rx;
int dn,un;
inline bool cmp(PT a,PT b){
  int pa=a.POS(),pb=b.POS();
  if(pa==pb) return (a^b)>0;
  return pa<pb;
```

```
}
int minkowskiSum(int n,int m){
  int i,j,r,p,q,fi,fj;
  for(i=1,p=0;i<n;i++){
    if(pt[i].y<pt[p].y || (pt[i].y==pt[p].y && pt[i].x<
        pt[p].x)) p=i; }
  for(i=1,q=0;i<m;i++){
    if(qt[i].y<qt[q].y || (qt[i].y==qt[q].y && qt[i].x<
        qt[q].x)) q=i; }
  rt[0]=pt[p]+qt[q];
  r=1; i=p; j=q; fi=fj=0;
  while(1){
    if((fj&&j==q) || ((!fi||i!=p) && cmp(pt[(p+1)%n]-pt
        [
          p],qt[(q+1)%m]-qt[q]))){
      rt[r]=rt[r-1]+pt[(p+1)%n]-pt[p];
      p=(p+1)%n;
      fi=1;
    }else{
      rt[r]=rt[r-1]+qt[(q+1)%m]-qt[q];
      q=(q+1)%m;
      fj=1;
    }
    if(r<=1 || ((rt[r]-rt[r-1])^(rt[r-1]-rt[r-2]))!=0)
      r
      ++;
    else rt[r-1]=rt[r];
    if(i==p && j==q) break;
  }
  return r-1;
}
void initInConvex(int n){
  int i,p,q;
  long long Ly,Ry;
  Lx=INF; Rx=-INF;
  for(i=0;i<n;i++){
    if(pt[i].x<Lx) Lx=pt[i].x;
    if(pt[i].x>Rx) Rx=pt[i].x;
  }
  Ly=Ry=INF;
  for(i=0;i<n;i++){
    if(pt[i].x==Lx && pt[i].y<Ly){ Ly=pt[i].y; p=i; }
    if(pt[i].x==Rx && pt[i].y<Ry){ Ry=pt[i].y; q=i; }
  }
  for(dn=0,i=p;i!=q;i=(i+1)%n){ qt[dn++]=pt[i]; }
  qt[dn]=pt[q]; Ly=Ry=-INF;
  for(i=0;i<n;i++){
    if(pt[i].x==Lx && pt[i].y>Ly){ Ly=pt[i].y; p=i; }
    if(pt[i].x==Rx && pt[i].y>Ry){ Ry=pt[i].y; q=i; }
  }
  for(un=0,i=p;i!=q;i=(i+n-1)%n){ rt[un++]=pt[i]; }
  rt[un]=pt[q];
}
inline int inConvex(PT p){
  int L,R,M;
  if(p.x<Lx || p.x>Rx) return 0;
  L=0;R=dn;
  while(L<R-1){ M=(L+R)/2;
    if(p.x<qt[M].x) R=M; else L=M; }
    if(tri(qt[L],qt[R],p)<0) return 0;
    L=0;R=un;
    while(L<R-1){ M=(L+R)/2;
      if(p.x<rt[M].x) R=M; else L=M; }
      if(tri(rt[L],rt[R],p)>0) return 0;
      return 1;
}
int main(){
  int n,m,i;
  PT p;
  scanf("%d",&n);
  for(i=0;i<n;i++) scanf("%I64d %I64d",&pt[i].x,&pt[i].
      y);
  scanf("%d",&m);
  for(i=0;i<m;i++) scanf("%I64d %I64d",&qt[i].x,&qt[i].
      y);
  n=minkowskiSum(n,m);
  for(i=0;i<n;i++) pt[i]=rt[i];
  scanf("%d",&m);
  for(i=0;i<m;i++) scanf("%I64d %I64d",&qt[i].x,&qt[i].
      y);
  n=minkowskiSum(n,m);
  for(i=0;i<n;i++) pt[i]=rt[i];
  initInConvex(n);
  scanf("%d",&m);
  for(i=0;i<m;i++){
    scanf("%I64d %I64d",&p.x,&p.y);
    p.x*=3; p.y*=3;
    puts(inConvex(p)?"YES":"NO");
  }
}
```

7 Stringology

7.1 Suffix Array

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

void suffix_array(char *ip){

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

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

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

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

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

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

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

7.2 Suffix Array (SAIS TWT514)

```
struct SA{
#define REP(i,n) for ( int i=0; i<int(n); i++ )
#define REP1(i,a,b) for ( int i=(a); i<=int(b); i++ )
    static const int MXN = 300010;
    bool _t[MXN*2];
    int _s[MXN*2], _sa[MXN*2], _c[MXN*2], x[MXN], _p[
        MXN], _q[MXN*2], hei[MXN], r[MXN];
    int operator [] (int i){ return _sa[i]; }
```

```
    void build(int *s, int n, int m){
        memcpy(_s, s, sizeof(int) * n);
        sais(_s, _sa, _p, _q, _t, _c, n, m);
        mkhei(n);
    }
    void mkhei(int n){
        REP(i,n) r[_sa[i]] = i;
        hei[0] = 0;
        REP(i,n) if(r[i]) {
            int ans = i>0 ? max(hei[r[i-1]] - 1, 0) :
                0;
            while(_s[i+ans] == _s[_sa[r[i]-1]+ans]) ans
                ++;
            hei[r[i]] = ans;
        }
    }
    void sais(int *s, int *sa, int *p, int *q, bool *t,
         int *c, int n, int z){
        bool uniq = t[n-1] = true, neq;
        int nn = 0, nmxz = -1, *nsa = sa + n, *ns = s +
             n, lst = -1;
#define MS0(x,n) memset((x),0,n*sizeof(*(x)))
#define MAGIC(XD) MS0(sa, n); \
        memcpy(x, c, sizeof(int) * z); \
        XD; \
        memcpy(x + 1, c, sizeof(int) * (z - 1)); \
        REP(i,n) if(sa[i] && !t[sa[i]-1]) sa[x[s[sa[i
            ]-1]]++] = sa[i]-1; \
        memcpy(x, c, sizeof(int) * z); \
        for(int i = n - 1; i >= 0; i--) if(sa[i] && t[
            sa[i]-1]) sa[--x[s[sa[i]-1]]] = sa[i]-1;
        MS0(c, z);
        REP(i,n) uniq &= ++c[s[i]] < 2;
        REP(i,z-1) c[i+1] += c[i];
        if (uniq) { REP(i,n) sa[--c[s[i]]] = i; return;
             }
        for(int i = n - 2; i >= 0; i--) t[i] = (s[i]==s
            [i+1] ? t[i+1] : s[i]<s[i+1]);
        MAGIC(REP1(i,1,n-1) if(t[i] && !t[i-1]) sa[--x[
            s[i]]]=p[q[i]=nn++]=i);
        REP(i, n) if (sa[i] && t[sa[i]] && !t[sa[i]-1])
             {
            neq=lst<0||memcmp(s+sa[i],s+lst,(p[q[sa[i
                ]]+1]-sa[i])*sizeof(int));
            ns[q[lst=sa[i]]]=nmxz+=neq;
        }
        sais(ns, nsa, p + nn, q + n, t + n, c + z, nn,
            nmxz + 1);
        MAGIC(for(int i = nn - 1; i >= 0; i--) sa[--x[s
            [p[nsa[i]]]]] = p[nsa[i]]);
    }
};

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

7.3 Aho-Corasick Algorithm

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

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

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

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

7.4 Z value

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

7.5 Z value (palindrome ver.)

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

int main(){

  cin >> ip;
  len = strlen(ip);

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

```
  }
  int l=0, r=0;
  zv[0] = 1;

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

        while( l>0 && r<l2-1 && op[l-1] == op[r+1] ){
          l --;
          r ++;
        }
        zv[i] = r - l + 1;
      }else if( nr > r ){
        zv[i] = (r - i) * 2 + 1;
      }
    }
  }

  return 0;
}
```

7.6 Suffix Automaton

```
class SAM{ //SuffixAutomaton
public:
  class State{
  public:
    State *par, *go[26];
    int val;
    State (int _val) :
        par(0), val(_val){
      MSET(go,0);
    }
  };
  State *root, *tail;

  void init(const string &str){
    root = tail = new State(0);
    for (int i=0; i<SZ(str); i++)
      extend(str[i]-'a');
  }
  void extend(int w){
    State *p = tail, *np = new State(p->val+1);
    for ( ; p && p->go[w]==0; p=p->par)
      p->go[w] = np;
    if (p == 0){
      np->par = root;
    } else {
      if (p->go[w]->val == p->val+1){
        np->par = p->go[w];
      } else {
        State *q = p->go[w], *r = new State(0);
        *r = *q;
        r->val = p->val+1;
        q->par = np->par = r;
        for ( ; p && p->go[w]==q; p=p->par)
          p->go[w] = r;
      }
    }
    tail = np;
  }
};
```

8 Problems

8.1 Find the maximun tangent (x,y is increasing)

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

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

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