Team notebook

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Contents

1 Attention

```
// Construct VScode
// 1. install vscode & msys2, check desktop path of vscode
// 2. open mingw64, not ucrt64, "pacman -S --needed
     base-devel mingw-w64-x86_64-toolchain"
// 3. add C:\\msys64\\mingw64\\bin to environment path
// 4. (re)open vscode, install C/C++, run, choose g++
// 5. open settings -> compiler -> add compilerPath
     "C:\\msys64\\mingw64\\bin\\g++.exe"

// Make Codebook
// notebook-generator ./ --author "Salmon" --initials
     Salmon --columns 3 --output "CodeBook.pdf" --size 8

// Init
#include <bits/stdc++.h>
using namespace std;
#define all(x) (x).begin(), (x).end()
#define endl "\n"
#define lrep(i, st, n) for(int i = st; i < n; i++)
#define rep(i, st, n) for(int i = st; i <= n; i++)
#define sz size()
#define pb(x) push_back(x)
#define ppb pop_back()
#define IO ios_base::sync_with_stdio(0); cin.tie(nullptr);
#define init(x, k) memset(x, k, sizeof(x));
#define vec_init(x, k) x.assign(x.size(), k);
#define lc 2*now
#define rc 2*now+1
#define mid (L+R)/2
typedef long long int ll;
typedef pair<int, int> pii;
typedef vector<int> vi;
typedef vector<pii> vii;
typedef pair<ll, ll> pll;
typedef vector<ll> vl;
typedef vector<pll> vll;
typedef struct {
    int from; int to;
    ll weight;
} edge;
typedef struct {
    ll sum;
} Node;
const ll llinf = 1e18;
const int inf = 1e9;
const int MOD = 1e9+7;
const int maxn = 2e5+5;

void solve(){

}
int main(){
    IO;
    int t = 1;
    cin >> t;
    while(t--){
        solve();
    }
}
```

2 DP

2.1 Bag

```
int dp[1005][100005];
vector<int> Page(1005, 0);
vector<int> Price(1005, 0);
int main(){
    int n, bud;
    cin >> n >> bud;
    for(int i = 1; i <= n; i++){
        int tmp; cin >> tmp;
        Price[i] = tmp;
    }
    for(int i = 1; i <= n; i++){
        int tmp; cin >> tmp;
        Page[i] = tmp;
    }
    memset(dp, 0, sizeof(dp));
    for(int i = 1; i <= n; i++){
        for(int j = 1; j <= bud; j++){
            if(j >= Price[i]){
                dp[i][j] = max(dp[i-1][j],
                     dp[i-1][j-Price[i]]+Page[i]);
            }
            else {
                dp[i][j] = dp[i-1][j];
            }
        }
    }
    cout << dp[n][bud] << endl;
}
```

2.2 Bitmask DP

```
// Bit_Mask_DP, Travel Exactly Once
int dp[(1 << 20) - 1][20];
vector<int> rev_adj[20];
int n, m;
const int mod = 1e9 + 7;
void solve(){
    cin >> n >> m;
    for(int i = 0; i < m; i++){
        int u, v; cin >> u >> v;
        rev_adj[--v].push_back(--u);
    }
    dp[1][0] = 1;
    for(int road = 0; road < (1 << n); road++){
        // Not include 1
        if(road & 1 == 0) continue;
        // include n but not all walked
        if(road & (1 << (n - 1)) && road != ((1 << n) - 1))
             continue;
        // DP
        for (int end = 0; end < n; end++) {
            // Not include end
                    if ((road & (1 << end)) == 0)
                         continue;
            // exclude end point is last road
                    int pre_road = road - (1 << end);
                    for (int pre_road_end : rev_adj[end])
                         {
                // pre_road_end is prev's end
                            if ((road & (1 <<
                                 pre_road_end))) {
                              dp[road][end] +=
                                   dp[pre_road][pre_road_end];
                              dp[road][end] %= mod;
                            }
                        }
                    }
            }
        }
        cout << dp[(1 << n) - 1][n - 1];
        // elevator rides
        // for(int i = 1; i < 1 << n; i++){
        //     used[i] = dp[i] = inf;
        //     for(int j = 0; j < n; j++){
        //         if(i & (1 << j)){ //  j
        //             int last = i ^ (1 << j);
        //             if(used[last] + s[j] <= x){
        //                 if(dp[last] < dp[i] || dp[last] ==
             dp[i] && used[last] + s[j] < used[i]){
        //                     used[i] = used[last] + s[j];
        //                     dp[i] = dp[last];
        //                 }
        //             }
        //             else {
        //                 if(dp[last] + 1 < dp[i] || dp[last] +
             1 == dp[i] && s[j] < used[i]){
        //                     used[i] = s[j];
        //                     dp[i] = dp[last] + 1;
        //                 }
        //             }
        //         }
        //     }
        // }
        // cout << dp[(1 << n) - 1];
}
```

2.3 Coin

```
// combine
// arrange: nested loop exchange
ll dp[2][1000001];
void solve(){
    int n, x; cin >> n >> x;
    vector<int> coin(n + 1);
    for(int i = 1; i <= n; i++){
        cin >> coin[i];
    }
    dp[0][0] = 1;
    for(int i = 1; i <= n; i++){
        for(int j = 0; j <= x; j++){
            dp[i & 1][j] = dp[!(i & 1)][j];
            if(j >= coin[i]){
                (dp[i & 1][j] += dp[i & 1][j - coin[i]]) %=
                     mod;
            }
        }
    }
    cout << dp[n & 1][x];
}
// Minimize coins nums
void solve(){
    int n, x; cin >> n >> x;
    vector<int> coin(n);
    for(int i = 0; i < n; i++){
        cin >> coin[i];
    }
    ll dp[x+1]; // init(dp, 0);
    dp[0] = 0;
    for(int i = 1; i <= x; i++){
        dp[i] = llinf;
        for(auto &j : coin){
            if(j <= i){
                dp[i] = min(dp[i], dp[i - j] + 1);
            }
        }
    }
    cout << (dp[x] == llinf ? -1 : dp[x]);
}
```

2.4 Edit Distance

```
ll dp[maxn][maxn];
void solve(){
    init(dp, 0);
    string s1, s2; cin >> s1 >> s2;
    int size1 = s1.sz, size2 = s2.sz;
    s1 = "0" + s1, s2 = "0" + s2;
    for(int i = 1; i <= size2; i++) dp[0][i] = i; // s2 =
         {}, s1 = ...;
    for(int i = 1; i <= size1; i++) dp[i][0] = i; // s1 =
         {}, s2 = ...;
    for(int i = 1; i <= size1; i++){
        for(int j = 1; j <= size2; j++){
            if(s1[i] == s2[j]){
                dp[i][j] = dp[i-1][j-1];
            }
            else {
                dp[i][j] = min(min(dp[i-1][j-1],
                     dp[i-1][j]), dp[i][j-1]) + 1;
                            // modify   // s1 del / s2 add
                                // s1 add s2 del
            }
        }
    }
    cout << dp[size1][size2];
}
```

2.5 Print LCS

```
void solve(){
```

```
    int m, n; cin >> m >> n;
    string s1, s2;
    cin >> s1 >> s2;
    s1.insert(s1.begin(), '1');
    s2.insert(s2.begin(), '1');
    int L = 0;
    int dp[m+1][n+1]; init(dp, 0);
    for(int i = 1; i <= m; i++){
        for(int j = 1; j <= n; j++){
            if(s1[i] == s2[j]){
                dp[i][j] = dp[i-1][j-1] + 1;
            }
            else {
                dp[i][j] = max(dp[i-1][j], dp[i][j-1]);
            }
        }
    }
    int length = dp[m][n];
    cout << length << "\n";
    vector<char> s(length);
    // along to dp to trace back
    while(m >= 1 && n >= 1){
        if(s1[m] == s2[n]){
            s[length - 1] = s1[m];
            m--;
            n--;
            length--;
        }
        else {
            if(dp[m-1][n] > dp[m][n-1]){
                m--;
            }
            else n--;
        }
    }
    for(auto c : s){
        cout << c;
    }
}
```

2.6 Print LIS

```
// Rec Sequence LIS
void solve(){
    int n; cin >> n;
    vector<int> v(n);
    for(int i = 0; i < n; i++){
        cin >> v[i];
    }
    int dp[n]; vector<int> mono;
    mono.push_back(v[0]);
    dp[0] = 1; int L = 1;
    for(int i = 1; i < n; i++){
        if(v[i] > mono.back()){
            mono.push_back(v[i]);
            dp[i] = ++L;
        }
        else {
            auto it = lower_bound(all(mono), v[i]);
            *it = v[i];
            dp[i] = it - mono.begin() + 1;
        }
    }
    vector<int> ans;
    cout << L << endl;
    for(int i = n - 1; i >= 0; i--){
        if(dp[i] == L){
            ans.push_back(v[i]);
            L--;
        }
    }
    reverse(all(ans));
    for(auto i : ans){
        cout << i << " ";
    }
}
```

2.7 Projects

```
const int maxn = 2e5+5;
int n;
ll from[maxn], to[maxn], gain[maxn];
ll dp[400005];
vector<ll> rev_proj[400005];
void compress(map<int, int> mp){
    int now = 0;
    for(auto &i : mp){
        mp[i.first] = ++now;
    }
    for(int i = 1; i <= n; i++){
        rev_proj[mp[to[i]]].push_back({mp[from[i]],
            gain[i]});
    }
}
void solve(){cin >> n;
    map<int, int> comp;
    for(int i = 1; i <= n; i++){
        cin >> from[i] >> to[i] >> gain[i];
        comp[from[i]] = 1, comp[to[i]] = 1;
    }
    compress(comp);
    for(int i = 1; i <= 400004; i++){
        dp[i] = dp[i - 1];
        for(auto [from, gain] : rev_proj[i]){
            dp[i] = max(dp[i], dp[from - 1] + gain);
        }
    }
    cout << dp[400004];
}
// Monotonic DP in campus contest, use monotonic stack
// first is lowest mountain, second is pref in stack
```

2.8 Removal Game

```
ll dp[5005][5005];
void solve(){
    int n; cin >> n;
    ll pref = 0;
    vector<ll> v(n+1);
    for(int i = 1; i <= n; i++){
        cin >> v[i];
        pref += v[i];
    }
    // dp[i][j] = max_diff(i to j);
    for(int i = n; i > 0; i--){
        for(int j = 1; j <= n; j++){
            if(i > j) continue;
            else if(i == j){
                dp[i][j] = v[i];
            }
            else {
                dp[i][j] = max(v[i] - dp[i+1][j], v[j] -
                    dp[i][j-1]); // i+1, j-1, care dp's
                    order
            }
        }
    }
    // x + y = sum, dp[1][n] = x - y;
    cout << (pref + dp[1][n]) / 2;
}
```

3 Flow

3.1 Dinic

```
#include <bits/stdc++.h>
using namespace std;
bool vis[505];
int lev[505], n, m, ans;
typedef struct {
    int to, w, rev_ind;
} edge;
vector<edge> adj[505];
bool label_level(){ // Tag the depth, if can't reach end
     => return false
    memset(lev, -1, sizeof(lev));
    lev[1] = 0;
    queue<int> q;  q.push(1);
    while(!q.empty()){
        int u = q.front(); q.pop();
        for(auto i : adj[u]){
            if(i.w > 0 && lev[i.to] == -1){
                q.push(i.to);
                lev[i.to] = lev[u] + 1;
            }
        }
    }
    return (lev[n] == -1 ? false : true);
}
int dfs(int u, int flow){
    if(u == n) return flow;
    for(auto &i : adj[u]){
```

```
        if(lev[i.to] == lev[u] + 1 && !vis[i.to] && i.w >
             0) {
            vis[i.to] = true;
            int ret = dfs(i.to, min(flow, i.w));
            if(ret > 0) {
                i.w -= ret;
                adj[i.to][i.rev_ind].w += ret;
                return ret;
            }
        }
    }
    return 0;  // if can't reach end => return 0
}
void dinic(){
    while(label_level()){
        while(1){
            init(vis, 0);
            int tmp = dfs(1, inf);
            if(tmp == 0) break;
            ans += tmp;
        }
    }
}
void build(){
    for(int i = 1; i <= m; i++) {
        int u, v, w; cin >> u >> v >> w;
        adj[u].push_back({v, w, (int)adj[v].sz}); //
             inverse flow's index
        adj[v].push_back({u, 0, (int)adj[u].sz-1}); // have
             pushed one, need to -1
    }
}
// Police Chase, need to open adj to Augment && ori to
     determine what pb give
//  Dinicdfs2 , then use reach as u, if the edge pb has
     given && w == 0 && v is not in reach, is the ans
void dfs2(int now, unordered_set<int> &reach){
    if(!vis[now]){
        vis[now] = 1;
        reach.insert(now);
        for(auto i : adj[now]){
            if(i.w > 0){
                dfs2(i.to, reach);
            }
        }
    }
}
// two two pair // School Dance
// Dinic, then w == 0's edge, which pb has given is the ans

// Distinct Route
// edge set valid var, if we need to argument pos road,
     the reverse edge set true valid
// if we need argument the argumented edgeboth set false.
     Last, from v dfs ans times
bool get_road(int now, vector<int> &ans, vector<bool>
     &vis){
    if(now == 1) return true;
    for(auto &v : adj[now]){
        if(v.arg_valid && !vis[v.to]){
            ans.push_back(v.to);
            vis[v.to] = true;
            bool flag = get_road(v.to, ans, vis);
            if(flag){
                v.arg_valid = false;
                return true;
            }
            ans.pop_back();
        }
    }
    return false;
}
```

3.2 MCMF

```
// Ceiled MinCostMaxFlowif not, use dinic
typedef struct {
    int from, to, w, cost;
} edge;
int n, m, parcel;
vector<edge> adj; // set num to each edge
vector<int> p[505]; // p[u] has edge's num
int now_edge = 0;
void add_edge(int u, int v, int w, int cost){
    adj.push_back({u, v, w, cost});
    p[u].push_back(now_edge);
    now_edge++;
    adj.push_back({v, u, 0, -cost}); // argumenting path
         use -
    p[v].push_back(now_edge);
    now_edge++;
}
ll Bellman_Ford(){
    vector<ll> dis(n+1, inf); dis[1] = 0;
    vector<int> par(m);
    vector<int> flow_rec(n + 1, 0); flow_rec[1] = 1e9;
    for(int i = 1; i < n; i++){
        bool flag = 1;
        int size = adj.sz;
        for(int i = 0; i < size; i++){
            auto &[from, to, w, cost] = adj[i];
            if(w > 0 && dis[to] > dis[from] + cost){
                flag = 0;
                dis[to] = dis[from] + cost;
                par[to] = i;  // record num
                flow_rec[to] = min(flow_rec[from], w);
            }
        }
        if(flag) break;
    }
    if(dis[n] == 1e9) return 0;
    int mn_flow = flow_rec[n];
    int v = n;
    while(v != 1){
        int u = adj[par[v]].from;
        adj[par[v]].w -= mn_flow;
        adj[par[v] ^ 1].w += mn_flow;
        v = u;
    }
    mn_flow = min(mn_flow, parcel);
    parcel -= mn_flow;
    return mn_flow * dis[n];
}
void solve(){
    cin >> n >> m >> parcel;
    ll ans = 0;
    for(int i = 1; i <= m; i++){
        int u, v, w, cost; cin >> u >> v >> w >> cost;
        add_edge(u, v, w, cost);
    }
    while(parcel > 0){
        int tmp = Bellman_Ford();
        if(tmp == 0) break;
        ans += tmp;
    }
    cout << (parcel > 0 ? -1 : ans);
}
```

4 Geometry

4.1 Convex Hull

```
vector<pii> P, L, U;
ll cross(pii o, pii a, pii b){ // OA OB >0 counterclock
    return (a.first - o.first) * (b.second - o.second) -
         (a.second-o.second) * (b.first-o.first);
}
ll Andrew_monotone_chain(ll n){
    sort(P.begin(), P.end());
    ll l = 0, u = 0; // upper and lower hull
    for (ll i=0; i<n; ++i){
        while (l >= 2 && cross(L[l-2], L[l-1], P[i]) <= 0){
            l--;
            L.pop_back();
        }
        while (u >= 2 && cross(U[u-2], U[u-1], P[i]) >= 0){
            u--;
            U.pop_back();
        }
        l++;
        u++;
        L.push_back(P[i]);
        U.push_back(P[i]);
    }
    cout << l << ' ' << u << '\n';
    return l + u;
}
int main(){
    ll n,x,y;
    cin >> n;
    for(ll i = 0;i < n;i++){
        cin >> x >> y;
        P.push_back({x,y});
    }
    ll ans = Andrew_monotone_chain(n) - 2;
    cout << ans << "\n";
    return 0;
}
```

4.2 Cross Product

```
const double EPS = 1e-9;
struct point{
    double x, y;
    point operator * (ll a){return {a * x, a * y};}
    point operator + (point b){return {x + b.x, y + b.y};}
    point operator - (point b){return {x - b.x, y - b.y};}
    double operator * (point b){return x * b.x + y * b.y;}
    double operator ^ (point b){return x * b.y - y * b.x;}
    bool operator < (point b){return x == b.x ? y < b.y : x
         < b.x;}
};
// len
double abs(point a){return sqrt(a.x * a.x + a.y * a.y);}
int sign(double a){
    if(abs(a) < EPS)
        return 0;
    else
        return (a > 0 ? 1 : -1);
}
//cross product
int ori(point a,point b,point c){
    return sign((b - a) ^ (c - a));
}
bool colinear(point a,point b,point c){
    return sign((b - a) ^ (c - a)) == 0;
}
bool between(point a,point b,point c){ // c between a and b
    if(!colinear(a,b,c))
        return false;
    return sign((a - c) * (b - c)) <= 0;
}
bool intersect(point a,point b,point c,point d){ //
     line(a,b) line(c,d)
    int abc = ori(a,b,c);
    int abd = ori(a,b,d);
    int cda = ori(c,d,a);
    int cdb = ori(c,d,b);
    if(abc == 0 || abd == 0)
        return between(a,b,c) || between(a,b,d) ||
             between(c,d,a) || between(c,d,b);
    return abc * abd <= 0 && cda * cdb <= 0;
}
int main(){
    int n;
    cin >> n;
    point p[1010];
    cin >> p[0].x >> p[0].y;
    ll ans = 0;
    for(int i = 1;i < n;i++){
        cin >> p[i].x >> p[i].y;
        ans += (p[i] ^ p[i - 1]);
    }
    ans += (p[0] ^ p[n - 1]);
    cout << abs(ans) << '\n';

    return 0;
}
```

5 Graph

5.1 2-SAT

```
// +(-) u or +(-) v
const int maxn = 1e5 + 5;
vector<int> adj[2 * maxn], rev_adj[2 * maxn];
vector<int> order;
int cat[2 * maxn];
int k = 1;
bool vis[2 * maxn];
void dfs(int now){
    if (!vis[now]){
        vis[now] = 1;
        for (auto v : adj[now]){
            dfs(v);
        }
        order.push_back(now);
    }
}
void rev_dfs(int now){
    if (!vis[now]){
        cat[now] = k;
        vis[now] = 1;
        for (auto v : rev_adj[now]){
            rev_dfs(v);
        }
    }
}
void solve(){
    int n, m;
    cin >> m >> n;
    for(int i = 1; i <= m; i++){
        int u, v;
        char a, b;
        cin >> a >> u >> b >> v;
        if (a == '-'){
            u = 2 * n - u + 1; // reverse
        }
        if (b == '-'){
            v = 2 * n - v + 1; // reverse
        }
        adj[2 * n - u + 1].push_back(v); // from -u to v;
             // if -u, then v
        adj[2 * n - v + 1].push_back(u); // from -v to u;
             // if -v, then u
        rev_adj[v].push_back(2 * n - u + 1);
        rev_adj[u].push_back(2 * n - v + 1);
    }
    for(int i = 1; i <= 2 * n; i++){
        if (!vis[i]){
            dfs(i);
        }
    }
    memset(vis, 0, sizeof(vis));
    reverse(all(order));
    for (auto i : order){
        if (!vis[i]){
            rev_dfs(i);
            k++;
        }
    }
    char ans[2 * n + 1];
    for(int i = 1; i <= n; i++){
        if (cat[i] == cat[2 * n - i + 1]){
            cout << "IMPOSSIBLE";
            return;
        }
        if (cat[i] > cat[2 * n - i + 1]){
            ans[i] = '+';
        }
        else ans[i] = '-';
    }
    for(int i = 1; i <= n; i++){
        cout << ans[i] << " ";
    }
}
```

5.2 Coin Collector And Topo DP

```
// Fing All SCC and Build a DAG, then Topo DP
const int maxn = 1e5+5;
vector<int> v, adj[maxn], rev_adj[maxn], DAG[maxn];
int order[maxn], coin[maxn], in[maxn];
int n, m, k = 0;
bool vis[maxn];
void dfs(int now){
    if(!vis[now]){
        vis[now] = 1;
        for(auto i : adj[now]){
            dfs(i);
        }
        v.push_back(now);
    }
}
void rev_dfs(int now){
    if(!vis[now]){
        vis[now] = 1;
        order[now] = k;
        for(auto i : rev_adj[now]){
            rev_dfs(i);
        }
    }
}
void solve(){
    cin >> n >> m;
    for(int i = 1; i <= n; i++){
        cin >> coin[i];
    }
    rep(i, 1, m){
        int u, v; cin >> u >> v;
        adj[u].push_back(v);
        rev_adj[v].push_back(u);
    }
    for(int i = 1; i <= n; i++){
        if(!vis[i]){
            dfs(i);
        }
    }
    reverse(all(v));
```

```
    init(vis, 0);
    for(auto i : v){
        if(!vis[i]){
            k++;
            rev_dfs(i);
        }
    }
    // Categorized SCC
    ll sum_coin[k + 1], dp_coin[k + 1];
    init(sum_coin, 0); init(dp_coin, 0);
    ll ans = -inf;
    for(int i = 1; i <= n; i++){
        sum_coin[order[i]] += coin[i]; // Now team(k) +=
            coin;
        for(auto j : adj[i]){
            if(order[i] != order[j]){
                DAG[order[i]].push_back(order[j]);
                in[order[j]]++;
            }
        }
    }
    // Topo DP
    queue<int> q;
    for(int i = 1; i <= k; i++){
        if(in[i] == 0){
            q.push(i);
        }
    }
    while(!q.empty()){
        int now = q.front(); q.pop();
        dp_coin[now] += sum_coin[now];
        ans = max(ans, dp_coin[now]);
        for(auto v : DAG[now]){
            in[v]--;
            dp_coin[v] = max(dp_coin[v], dp_coin[now]);
            if(in[v] == 0) q.push(v);
        }
    }
    cout << ans;
}
```

5.3 DFS and BFS

```
ll N = 1e6;
vector<int> adj[N];
bool vis[N];
void DFS(ll s){
    if(vis[s]) return;
    vis[s] = true;
    for(auto u: adj[s]){
        DFS(u);
    }
}
queue<ll> q;
ll dis[N];
void BFS(ll x){
    vis[x] = true;
    dis[x] = 0;
    q.push(x);
    while(!q.empty()){
        ll now = q.front();q.pop();
        for(auto nxt : adj[now]){
            if(vis[nxt]) continue;
            vis[nxt] = true;
            dis[nxt] = dis[now] + 1;
            q.push(nxt);
        }
    }
}
```

5.4 DSU

```
// After each day, print the number of components
// and the size of the largest component
const int maxn = 2e5+5;
int ans, mx_sz = 1;
int boss[maxn];
int set_sz[maxn];
int find_boss(int x){
    if(boss[x] == x) return x;
    return boss[x] = find_boss(boss[x]);
}
void dsu(int x, int y){
    int boss_x = find_boss(x);
    int boss_y = find_boss(y);
    if(boss_x != boss_y){
        ans--;
        if(set_sz[boss_x] < set_sz[boss_y]){
            swap(boss_x, boss_y);
        }
        boss[boss_y] = boss_x;
        set_sz[boss_x] += set_sz[boss_y];
        mx_sz = max(mx_sz, set_sz[boss_x]);
    }
    cout << ans << " " << mx_sz << endl;
}
void solve(){
    int n, q; cin >> n >> q;
    ans = n;
    for(int i = 1; i <= n; i++){
        boss[i] = i;
        set_sz[i] = 1;
    }
    for(int i = 1; i <= q; i++){
        int x, y;
        cin >> x >> y;
        dsu(x, y);
    }
}
```

5.5 EulerRoad

```
// Undirected: check adj[i].sz == odd => IMPOSSIBLEroad.sz
     != m+1 => IMPOSSIBLE
// Directed: minimize to 1 -> 2, so check in_degree ==
     out_degree
int n, m;
set<int> adj[maxn];// rev_adj[maxn];
int in[maxn];
void dfs(int now, vector<int> &road){
    while(!adj[now].empty()){
        int nxt = *adj[now].begin();
        adj[now].erase(nxt);
        dfs(nxt, road);
    }
    road.push_back(now);
}
void solve(){
    cin >> n >> m;
    init(in, 0);
    for(int i = 1; i <= m; i++){
        int u, v; cin >> u >> v;
        adj[u].insert(v);
        in[v]++;
    }
    in[1]++;
    in[n]--;
    for(int i = 1; i <= n; i++){
        if(adj[i].size() != in[i]){
            cout << "IMPOSSIBLE";
            return;
        }
    }
    vector<int> road;
    dfs(1, road);
    if(road.size() != m+1){
        cout << "IMPOSSIBLE";
        return;
    }
    reverse(all(road));
    for(auto i : road) cout << i << " ";
}
```

5.6 FloydWarshall

```
const int maxn = 505;
ll graph[maxn][maxn];
ll dis[maxn][maxn];
ll n, m, q; ll a, b, c;
const ll INF = 1e18;
int main(){
    cin >> n >> m >> q;
    for(int i = 0; i <= n; i++) {
        for(int j = 0; j <= n; j++) {
            graph[i][j] = INF;
        }
    }
    for(int i = 0; i < m; i++){
        cin >> a >> b >> c;
        graph[a][b] = min(graph[a][b], c);
        graph[b][a] = min(graph[b][a], c);
    }
    for(int i = 0; i <= n; i++) {
```

```
        for(int j = 0; j <= n; j++) {
            dis[i][j] = graph[i][j];
        }
    }
    for(int i = 0; i <= n; i++) // self to self is 0
        dis[i][i] = 0;

    for(int k = 1; k <= n; k++){
        for(int i = 1; i <= n; i++){
            for(int j = 1; j <= n; j++){
                dis[i][j] = min(dis[i][j], dis[i][k] +
                     dis[k][j]);
            }
        }
    }
    for(int i = 0; i < q; i++){
        cin >> a >> b;
        cout << (dis[a][b] >= INF ? -1 : dis[a][b]) << "\n";
    }
}
```

5.7 MaxDistance

```
// Max_Dis, Use Topo, Use queue
// If 1 can't reach n, still may be relaxedShould dis[n] <
     0
// Only Directed Graph
void print_ans(int n, vector<int> &par){
    deque<int> ans;
    int now = n;
    while(now != 1){
        ans.push_front(now);
        now = par[now];
    }
    ans.push_front(1);
    cout << ans.size() << endl;
    for(auto i : ans){
        cout << i << " ";
    }
}
void solve(){
    int n, m;
    cin >> n >> m;
    vector<int> dis(n + 1, -inf); dis[1] = 0;
    vector<int> graph[n+1];
    vector<bool> vis(n+1, 0);
    vector<int> par(n+1);
    vector<int> in(n+1, 0);
    queue<int> q;
    for(int i = 1; i <= m; i++){
        int u, v; cin >> u >> v;
        graph[u].push_back(v);
        in[v]++;
    }
    for(int i = 1; i <= n; i++){
        if(in[i] == 0) q.push(i);
    }
    while(!q.empty()){
        int u = q.front(); q.pop();
        for(auto nxt : graph[u]){
            if(dis[nxt] < dis[u] + 1){
                dis[nxt] = dis[u] + 1;
                par[nxt] = u;
            }
            in[nxt]--; if(in[nxt] == 0) q.push(nxt);
        }
        vis[u] = 1;
    }
    if(dis[n] < 0){
        cout << "IMPOSSIBLE";
    }
    else print_ans(n, par);
}
```

5.8 NegCyc Using BellmanFord

```
typedef struct{
    int from; int to;
    ll weight;
} edge;
// NegCyc_Finding_Road
vector<edge> graph;
int main(){
    int src = 0;
    int n, m;   cin >> n >> m;
    vector<int> par(n + 1), dis(n + 1);
    for(int i = 0; i < m; i++){
        int a, b, w; cin >> a >> b >> w;
        graph.push_back({a, b, w});
    }
    for(int i = 1; i <= n; i++){
        dis[i] = 1e9 + 5;
    }
    dis[1] = 0;
    for(int i = 0; i <= n; i++){
        src = 0;
        for(auto [a, b, w] : graph){
            if(dis[b] > dis[a] + w){
                dis[b] = dis[a] + w;
                par[b] = a;
                src = b;
            }
        }
    }
    if(src){
        vector<int> ans;
        cout << "YES" << endl;
        for(int i = 0; i <= n; i++) src = par[src];
        ans.push_back(src);
        for(int i = par[src]; i != src; i = par[i]){
            ans.push_back(i);
        }
        ans.push_back(src);
        reverse(all(ans));
        for (auto i : ans){
            cout << i << " ";
        }
    }
    else {
        cout << "NO" << endl;
    }
}
```

5.9 NegWeights Max Distance

```
const int maxn = 2505;
int m, n;
vector<edge> graph;
vector<pair<int, int>> adj[maxn];
vector<ll> rev_adj[maxn];
ll dis[maxn];
bool vis[maxn] = {0};
bool nvis[maxn] = {0};
void dfs(int par, int now){
    if (vis[now] == 1) return;
    vis[now] = 1;
    for (auto [i, w] : adj[now]){
        if (i != par){
            dfs(now, i);
        }
    }
}
void rev_dfs(int par, int now){
    if (nvis[now] == 1) return;
    nvis[now] = 1;
    for (auto i : rev_adj[now]){
        if (i != par){
            rev_dfs(now, i);
        }
    }
}
void solve(){
    cin >> n >> m;
    for(int i = 1; i <= m; i++){
        int u, v, w;
        cin >> u >> v >> w;
        graph.push_back({u, v, w});
        adj[u].push_back({v, w});
        rev_adj[v].push_back(u);
    }
    for(int i = 1; i <= n; i++) dis[i] = -inf;
    dis[1] = 0;
    for(int i = 1; i <= n; i++){
        for (auto [u, v, w] : graph){
            if (dis[u] + w > dis[v]){
                dis[v] = dis[u] + w;
            }
        }
    }
    dfs(0, 1);
    rev_dfs(0, n);
    for (auto [u, v, w] : graph){
        if (dis[u] + w > dis[v] && nvis[u] && nvis[v] &&
             vis[u] && vis[v]){
            cout << -1;
            return;
        }
```

```
    }
    cout << dis[n];
}
```

5.10 Planet Queries II

```
// now on a and want to reach b, the min steps, directed
int n, q;
int dp[30][maxn];
vector<vector<int>> cycles;
int no[maxn]; // Order & Can be in cycle, or out
int cycle_idx[maxn];
bool vis[maxn];
void set_out_of_cycle_no(int now, unordered_set<int>
     &done){
    if (done.find(now) != done.end())
        return;
    set_out_of_cycle_no(dp[0][now], done);
    done.insert(now);
    no[now] = no[dp[0][now]] - 1;
}
int will_go_to(int u, int k){ // return the node when walk
     k
    for(int i = 0; i <= 18; i++){
        if (k & (1 << i)){
            u = dp[i][u];
        }
    }
    return u;
}
void find_cycle(int now){
    unordered_set<int> appear;
    vector<int> vec;
    bool flag = true;
    while (appear.find(now) == appear.end()){
        appear.insert(now);
        vec.push_back(now);
        if (vis[now]){ // Didn't Find Cycle
            flag = false;
            break;
        }
        now = dp[0][now];
    }
    for (auto i : vec) vis[i] = true;
    if (!flag) return;
    int z = find(vec.begin(), vec.end(), now) -
         vec.begin(); // start pushing from last now
    int m = vec.size();
    vector<int> cycle;
    for (int i = z; i < m; i++){
        cycle.push_back(vec[i]);
    }
    cycles.push_back(cycle);
}
void solve(){
    cin >> n >> q;
    for(int u = 1; u <= n; u++){
        cin >> dp[0][u];
    }
    for(int i = 1; i <= 18; i++){ // Make Chart
        for(int u = 1; u <= n; u++){
            dp[i][u] = dp[i - 1][dp[i - 1][u]];
        }
    }
    for(int i = 1; i <= n; i++){
        if (!vis[i]) find_cycle(i);
    }
    ll idx = 0;
    memset(no, -1, sizeof(no));
    memset(cycle_idx, -1, sizeof(cycle_idx));
    unordered_set<int> done;
    for (auto &i : cycles){
        ll c = 0;
        for (auto &j : i){
            no[j] = c++;
            cycle_idx[j] = idx;
            done.insert(j);
        }
        idx++;
    }
    for(int i = 1; i <= n; i++) set_out_of_cycle_no(i,
         done);
    for(int i = 1; i <= q; i++){
        int u, v;  cin >> u >> v;
        // Same Cycle
        if (cycle_idx[u] == cycle_idx[v] && cycle_idx[u] !=
             -1 && cycle_idx[v] != -1){
            int cyc_size = cycles[cycle_idx[u]].size();
            cout << (no[v] - no[u] + cyc_size) % cyc_size
                 << "\n";
        }
        else if (cycle_idx[u] == -1 && cycle_idx[v] == -1){
             // Both are not in a Cycle
            if (no[u] > no[v]){
                cout << -1 << "\n";
                continue;
            }
            ll jump = no[v] - no[u];
            if (will_go_to(u, jump) == v){
                cout << jump << "\n";
            }
            else cout << -1 << "\n";
        }
        else if (cycle_idx[u] == -1 && cycle_idx[v] != -1){
             // v is in cycle, Smaller Binary Search
            int l = -1, r = n;
            while (l <= r){
                int m = (l + r) / 2;
                if (cycle_idx[will_go_to(u, m)] ==
                     cycle_idx[v]){
                    r = m - 1;
                }
                else
                    l = m + 1;
            }
            if (l != -1 && l <= n){
                int in_cycle_of_u = will_go_to(u, l);
                int cycle_size = cycles[cycle_idx[v]].size();
                cout << l + (no[v] - no[in_cycle_of_u] +
                     cycle_size) % cycle_size << "\n";
            }
            else cout << -1 << "\n";
        }
        else { // u is death in the cycle, can't reach
            cout << -1 << "\n";
        }
    }
}
```

5.11 Planets Cycles

```
vi dis, v;
vector<bool> vis;
ll step;
queue<ll> path;
void dfs(ll x){
    path.push(x);
    if (vis[x]){
        step += dis[x];
        return;
    }
    vis[x] = true;
    step++;
    dfs(v[x]);
}
// count path_dis to rep
int main(){
    v.assign(n + 1, 0);
    dis.assign(n + 1, 0);
    vis.assign(n + 1, false);
    for (int i = 1; i <= n; i++){
        cin >> v[i];
    }
    for (int i = 1; i <= n; i++){
        step = 0;
        int is_outof_cycle = 1;
        dfs(i);
        while (!path.empty()){
            if (path.front() == path.back()){
                is_outof_cycle = 0;
            }
            dis[path.front()] = step;
            step -= is_outof_cycle;
            path.pop();
        }
    }
    for (int i = 1; i <= n; i++){
        cout << dis[i] << ' ';
    }
    cout << '\n';
}
```

5.12 PosCycle Finding

```
const int maxn = 1e5+5;
vector<int> graph[maxn];
int color[maxn], parent[maxn];
```

```
bool vis[maxn];
int n, m;
void print_ans(int ori){
    int now = parent[ori];
    deque<int> ans;
    ans.push_front(ori);
    while(now != ori){
        ans.push_front(now);
        now = parent[now];
    }
    ans.push_front(ori);
    cout << ans.size() << endl;
    for(auto i : ans){
        cout << i << " ";
    }
    exit(0);
}
void dfs(int now){
    color[now] = 1;
    vis[now] = 1;
    for(auto nxt : graph[now]){
        parent[nxt] = now;
        if(color[nxt] == 1){
            print_ans(nxt);
        }
        else if(color[nxt] == 0){
            dfs(nxt);
        }
    }
    color[now] = 2;
}
void solve(){
    cin >> n >> m;
    for(int i = 1; i <= m; i++){
        int u, v; cin >> u >> v;
        graph[u].push_back(v);
    }
    for(int i = 1; i <= n; i++){
        if(!vis[i])
            dfs(i);
    }
    cout << "IMPOSSIBLE";
}
```

5.13 Prim

```
int n, m;
ll ans = 0;
vector<pair<int, int>> adj[maxn];
bool Prim(){
    int node_sz = 0;
    priority_queue<pii, vii, greater<pii>> pq;
    pq.push({0, 1});
    bool vis[maxn]; init(vis, false);
    while(!pq.empty()){
        auto [cost, u] = pq.top(); pq.pop();
        if(vis[u]) continue;
        vis[u] = true;
        ans += cost;
        node_sz++;
        for(auto [v, cost] : adj[u]){
            if(!vis[v])
                pq.push({cost, v});
        }
    }
    if(node_sz == n) return true;
    return false;
}
void solve(){
    cin >> n >> m;
    for(int i = 1; i <= m; i++){
        int u, v, cost; cin >> u >> v >> cost;
        adj[u].push_back({v, cost});
        adj[v].push_back({u, cost});
    }
    if(Prim()) cout << ans;
    else cout << "IMPOSSIBLE";
}
```

5.14 State Dijkstra

```
// Flight Discount
int n, m;
vll graph[maxn];
ll dis[maxn][2];  // 0 for not used
void dijkstra(){
    priority_queue<vector<ll>, vector<vector<ll>>,
         greater<vector<ll>>> pq; // 0 for w, 1 for u, 2
         for discount
    for(int i = 1; i <= n; i++){
        dis[i][0] = dis[i][1] = inf;
    }
    dis[1][0] = dis[1][1] = 0;
    pq.push({0, 1, 0});
    while(!pq.empty()){
        auto nxt = pq.top(); pq.pop();
        ll dist = nxt[0], u = nxt[1]; bool us = nxt[2];
        if(dis[u][us] < dist) continue; // is out of time,
             pass
        if(us){
            for(auto [v, w] : graph[u]){
                if(dis[u][1] + w < dis[v][1]){
                    dis[v][1] = dis[u][1] + w;
                    pq.push({dis[v][1], v, 1});
                }
            }
        }
        else {
            for(auto [v, w] : graph[u]){
                if(dis[u][0] + w < dis[v][0]){
                    dis[v][0] = dis[u][0] + w;
                    pq.push({dis[v][0], v, 0});
                }
                if(dis[u][0] + w / 2 < dis[v][1]){
                    dis[v][1] = dis[u][0] + w / 2;
                    pq.push({dis[v][1], v, 1});
                }
            }
        }
    }
    cout << min(dis[n][0], dis[n][1]);
}
void solve(){
    cin >> n >> m;
    for(int i = 1; i <= m; i++){
        int u, v, w;
        cin >> u >> v >> w;
        graph[u].push_back({v, w});
    }
    dijkstra();
}
```

5.15 Vis Dijkstra

```
void solve(){
    int n, m, noon, night;
    cin >> n >> m >> noon >> night;
    ll dis[n + 1];
    vector<ll> graph[n + 1];
    bool vis[n + 1];
    for(int i = 1; i <= m; i++){
        int u, v, w; cin >> u >> v >> w;
        graph[u].push_back({v, w});
        graph[v].push_back({u, w});
    }
    priority_queue<vector<ll>, vector<vector<ll>>,
         greater<vector<ll>>> pq;
    // noon is -
    for(int i = 1; i <= n; i++){
        dis[i] = inf;  vis[i] = 0;
    }
    pq.push({0, -noon, 1});
    dis[1] = 0;
    while(!pq.empty()){
        vector<ll> now = pq.top(); pq.pop();
        ll now_noon = -now[1], u = now[2];
        if(vis[u]) continue;
        for(auto [nxt, w] : graph[u]){
            if(noon < w) continue; // never pass
            ll tmp = dis[u] + (now_noon >= w ? w : now_noon
                 + night + w);
            if(tmp < dis[nxt]){
                dis[nxt] = tmp;
                pq.push({dis[nxt], -(now_noon >= w ?
                     now_noon - w : noon - w), nxt});
            }
        }
        vis[u] = true;
    }
    if(dis[n] == inf) cout << -1 << endl;
    else cout << dis[n] << endl;
}
// Investigation
for(auto [v, w] : graph[u]){
    if(dis[u] + w < dis[v]){
        dis[v] = dis[u] + w;
        pq.push({dis[v], v});
```

```
        min_price_nums[v] = min_price_nums[u];
        max_dis_min_price[v] = max_dis_min_price[u] + 1;
        min_dis_min_price[v] = min_dis_min_price[u] + 1;
    }
    else if(dis[u] + w == dis[v]){
        min_price_nums[v] = (min_price_nums[u] +
             min_price_nums[v]) % mod;
        max_dis_min_price[v] = max(max_dis_min_price[u] +
             1, max_dis_min_price[v]);
        min_dis_min_price[v] = min(min_dis_min_price[u] +
             1, min_dis_min_price[v]);
    }
}
```

6 Math

6.1 Prime

```
// a^(m-1)    1 (mod m)
// a^(m-2)    1/a (mod m)
// EXP2: cout << fast_exp(x, fast_exp(y, p, MOD - 1), MOD)
// Filter + DP; DP save min factorrecurfactor
     decomposition
// FacNums = (x+1)(y+1)(z+1)...
// FacSum = (a^0+a^1...+a^x)(b^0+...+b^y)
// FacMul = N(x+1)(y+1)(z+1)/2
ll fast_exp(ll x, ll p, ll mod){
    ll ans = 1;
    while(p > 0){
        if(p & 1) ans = (ans * x) % mod;
        x = x * x % mod;
        p >>= 1;
    }
    return ans;
}
ll quick_mul(ll a, ll b){
    ll ans = 0;
    a %= MOD;
    while(b > 0){
        if(b & 1){
            ans = (ans + a) % MOD;
        }
        a = (a << 1) % MOD;
        b >>= 1;
    }
    return ans;
}
```

7 Queries

7.1 BIT

```
int n, nums[100], BIT[100], iiBIT[100][100];
// 1D-BIT
void modify(int x, int mod){
    for(; x <= n; x += (x&-x)){
        BIT[x] += mod;
    }
}
ll query(int a, int b) {
       ll ans = 0;
       for (; b; b -= b&-b) ans += BIT[b];
       for (a--; a; a -= a&-a) ans -= BIT[a];
       return ans;
}
// 2D-BIT // Forest Queries (Area)
void modify(int x, int y, int mod){
    for(; x <= n; x += (x&-x)){
        for(int tmp = y; tmp <= n; tmp += (tmp&-tmp)){
            iiBIT[x][tmp] += mod;
        }
    }
}
ll query(int x1, int y1, int x2, int y2){
    ll ans = 0;
    x1--, y1--;
    int tmp1, tmp2;

    for(tmp1 = x2; tmp1; tmp1 -= (tmp1&-tmp1)){
        for(tmp2 = y2; tmp2; tmp2 -= tmp2&-tmp2){
            ans += iiBIT[tmp1][tmp2];
        }
    }
    for(tmp1 = x1; tmp1; tmp1 -= (tmp1&-tmp1)){
        for(tmp2 = y2; tmp2; tmp2 -= tmp2&-tmp2){
            ans -= iiBIT[tmp1][tmp2];
        }
    }
    for(tmp1 = x2; tmp1; tmp1 -= (tmp1&-tmp1)){
        for(tmp2 = y1; tmp2; tmp2 -= tmp2&-tmp2){
            ans -= iiBIT[tmp1][tmp2];
        }
    }
    for(tmp1 = x1; tmp1; tmp1 -= (tmp1&-tmp1)){
        for(tmp2 = y1; tmp2; tmp2 -= tmp2&-tmp2){
            ans += iiBIT[tmp1][tmp2];
        }
    }
    return ans;
}
```

7.2 Increasing Array Queries

```
const int maxn = 2e5+5;
int n, q;
ll nums[maxn], prefix[maxn], ans[maxn], BIT[maxn],
     contrib[maxn];
vector<pair<int, int>> queries[maxn];
void update(int pos, ll val) {
       for (; pos <= n; pos += pos & -pos) BIT[pos] += val;
}
ll query(int a, int b) {
       ll ans = 0;
       for (; b; b -= b&-b) ans += BIT[b];
       for (a--; a; a -= a&-a) ans -= BIT[a];
       return ans;
}
void solve(){
    cin >> n >> q;
    for(int i = 1; i <= n; i++){
        cin >> nums[i];
        prefix[i] = prefix[i-1] + nums[i];
    }
    nums[n + 1] = 1e9;
    prefix[n + 1] = 2e18;
    for(int i = 1; i <= q; i++){
        int a, b; cin >> a >> b;
        queries[a].push_back({b, i});
    }
    deque<int> mono; mono.push_front(n+1);
    for(int i = n; i > 0; i--){ // question from start at n
         to start at 1
        while (nums[i] >= nums[mono.front()]) {
                  update(mono.front(),
                       -contrib[mono.front()]); //
                       mono.front's contrib become 0
                  mono.pop_front();
            }
            contrib[i] = (mono.front() - 1 - i) * nums[i] -
                  (prefix[mono.front() - 1] - prefix[i]);
            update(i, contrib[i]);
            mono.push_front(i);
        for (auto j : queries[i]) { // pos is the index in
             mono <= end's
                  int pos = upper_bound(mono.begin(),
                       mono.end(), j.first) -
                       mono.begin() - 1;
                  ans[j.second] = (pos ? query(i,
                       mono[pos - 1]) : 0) // smaller
                       than y's mono
                    // mono to y caculate directly
                            + (j.first - mono[pos])
                                 * nums[mono[pos]]
                     - (prefix[j.first] -
                          prefix[mono[pos]]);
            }
        }
    for(int i = 1; i <= q; i++){
        cout << ans[i] << endl;
    }
}
```

7.3 Mo

```
typedef struct {
    int l, r, ind;
} query;
query queries[100];
int n, block, nums[100];
bool cmp(query a, query b){
    int block_a = a.l / block;
    int block_b = b.l / block;
    if(block_a != block_b) return block_a < block_b;
```

```
    return a.r < b.r;
}
void Mo(){
    // sort
    int cl = 1, cr = 0;
    for(auto i : queries){
        while(cl < i.l){} // remove
        while(cr > i.r){} // remove
        while(cl > i.l){} // add
        while(cr < i.r){} // add
    }
}
// Compress too big nums, gives new nums to them
void compress(){
    vector<pair<int, int>> compress(n);
    for(int i = 0; i < n; i++){
        cin >> nums[i];
        compress[i-1] = {nums[i], i};
    }
    sort(compress.begin(), compress.end(), cmp);
    int pre = compress[0].first, new_num = 0;
    nums[compress[0].second] = 0;
    for(auto it = compress.begin() + 1, end =
          compress.end(); it != end; it++){
        if((*it).first != pre){
            pre = (*it).first;
            new_num++;
        }
        nums[(*it).second] = new_num;
    }
}
```

7.4 Segment

```
const int maxn = 2e5 + 5;
typedef struct {
    int set_val, add, sum, val;
} node;
int n, q; node tree[4 * maxn]; int nums[maxn];
#define lc 2*now
#define rc 2*now+1
#define mid (L+R)/2 // LR is now range, lr is target range
// Pull
void pull(int now){ // update now with 2 children
    // use  lcrc  to undate now
    // tree[now].sum = tree[lc].sum + tree[rc].sum;
    // tree[now].prefix = max(tree[lc].sum+tree[rc].prefix,
          tree[lc].prefix);
    // tree[now].suffix = max(tree[lc].suffix+tree[rc].sum,
          tree[rc].suffix);
    // tree[now].middle_max = max(max(tree[lc].middle_max,
          tree[rc].middle_max),
          tree[lc].suffix+tree[rc].prefix);
    // tree[now].middle_max = max(max(tree[now].middle_max,
          tree[now].prefix), tree[now].suffix);
}
// Lazy
void push(int now, int child){
    if(tree[now].set_val){
        tree[child].set_val = 1;
        tree[child].val = tree[now].val;
        tree[child].add = tree[now].add;
    }
    else {
        tree[child].add += tree[now].add;
    }
}
void apply_tag(int now, int L, int R){
    if(tree[now].set_val)
        tree[now].sum = (R-L+1)*tree[now].val;
    tree[now].sum += (R-L+1)*tree[now].add;
    if(L != R){ // can go lower
        push(now, lc);
        push(now, rc);
    }
    tree[now].add = tree[now].set_val = 0; // Reset
}
// Build
void build(int L, int R, int now){
    if(L == R){
        // init tree[now];
        return;
    }
    int M = mid;
    build(L, M, lc);
    build(M + 1, R, rc);
    pull(now);
}
// modify
void modify(int l, int r, int L, int R, int now){
    if(R < l || r < L || L > n) // invalid range
        return;
    if(l <= L && R <= r){
        // modify tree[now];
        // tree[now].add += add; // modify_add
        // tree[now].set_val = 1; // modify_mod
               // tree[now].val = mod;
               // tree[now].add = 0; // Set is more prior
        return;
    }
    int M = mid;
    apply_tag(now, L, R);
    modify(l, r, L, M, lc);
    modify(l, r, M+1, R, rc);
    apply_tag(lc, L, M);      // need
    apply_tag(rc, M+1, R);    // need
    pull(now); // update now with 2 children
}
// query
ll query(int l, int r, int L, int R, int now){
    int M = mid;
    if(R < l || r < L || L > n){
        return 0;
    }
    // apply_tag(now, L, R); // Lazy to uncomment
    if(l <= L && R <= r){
        return tree[now].sum;
    }
        return query(l, r, L, M, lc) + query(l, r, M+1, R,
              rc);
    // if(l <= L && R <= r) return tree[now].val;
    // if(r <= M) return query(l, r, L, M, lc);
    // else if(l > M) return query(l, r, M+1, R, rc);
        // return query(l, r, L, M, lc) & query(l, r, M+1,
              R, rc);
}
// pizza_queries
// Left(s < t): dis_l = (pizza[s] - s) + t;
// Right(t < s): dis_r = (pizza[s] + s) - t;

// List Removals
// Use seg_tree to maintain how many nums have been
     selected in the range
// Use binary_Search to find "mod" nums have been selected
     before ans
// if ans - mod == posnums[ans] is the answerand we modify
     tree[pos]

// polynomial queries
//  Lazy_segset  under and distance
```

7.5 Treap

```
struct Treap {
    Treap *l, *r;
    int pri, subsize; char val; bool rev_valid;
    Treap(int val){
        this->val = val;
        pri = rand();
        l = r = nullptr;
        subsize = 1; rev_valid = 0;
    }
    void pull(){  // update subsize or other information
        subsize = 1;
        for(auto i: {l,r}){
            if(i) subsize += i->subsize;
        }
    }
};
int size(Treap *treap) {
    if (treap == NULL) return 0;
    return treap->subsize;
}
// lazy
void push(Treap *t){
    if(!t) return;
    if(t->rev_valid){
        swap(t->l, t->r);
        if(t->l) t->l->rev_valid ^= 1;
        if(t->r) t->r->rev_valid ^= 1;
    }
    t->rev_valid = false;
}
Treap *merge(Treap *a, Treap *b){
    if(!a || !b) return a ? a : b;
    // push(a); push(b);  // lazy
    if(a->pri > b->pri){
        a->r = merge(a->r, b); // a->r = new, inorder, make
              sense
        a->pull();
```

```
        return a;
    }
    else {
        b->l = merge(a, b->l); // new->l = a, inorder, make
             sense
        b->pull();
        return b;
    }

}
pair<Treap*, Treap*> split(Treap *root, int k) { // find
     1~k
        if (root == nullptr) return {nullptr, nullptr};
    // push(root); // lazy
        if (size(root->l) < k) {
                auto [a, b] = split(root->r, k -
                     size(root->l) - 1);
                root->r = a;
                root->pull();
                return {root, b};
        }
    else {
                auto [a, b] = split(root->l, k);
                root->l = b;
                root->pull();
                return {a, root};
        }
}
void Print(Treap *t){
    if(t){
        // push(t);   // lazy
        Print(t->l);
        cout << t->val;
        Print(t->r);
    }
}
void substring_rev(){
    int n, m; cin >> n >> m;
    Treap *root = nullptr;
    string str; cin >> str;
    for(auto c : str){
        root = merge(root, new Treap(c));
    }
    for(int i = 1; i <= m; i++){
        int x, y; cin >> x >> y;
        auto [a, b] = split(root, x-1); // a: 1~x-1, b: x~n
        auto [c, d] = split(b, y-x+1); // Use b to split
        // c->rev_valid ^= true;
        // push(c);
        b = merge(a, d);  // Notice the order
        root = merge(b, c);
    }
    Print(root);
}
```

8 Sorting and Searching

8.1 Binary Search

```
int main(){
    int l = 1, r = 10;
    // 1 to tar, find tar
    while(l <= r){
        int m = (l + r) / 2;
        if(check(m)) l = m + 1;
        else r = m - 1;
    }
    cout << r;
    // tar to end
    while(l <= r){
        int m = (l + r) / 2;
        if(check(m)) r = m - 1;
        else l = m + 1;
    }
    cout << l;
}
```

8.2 Concert Ticket

```
// Better than Binary Search
int main(){
    int n, m; cin >> n >> m;
    multiset<int> tik;
    for(int i = 0; i < n; i++){
        int tmp; cin >> tmp;
        tik.insert(tmp);
    }
    while(m--){
        int x; cin >> x;
        auto it = tik.upper_bound(x);
        if(it == tik.begin()){
            cout << -1 << " ";
            continue;
        }
        it--;
        cout << *it << " ";
        tik.erase(it);
    }
}
```

8.3 Restaurant Customers

```
int main(){
    vector<pair<int, int>> times;
    int n; cin >> n;
    for(int i = 0; i < n; i++){
        int u, v; cin >> u >> v;
        times.push_back({u, 1});
        times.push_back({v, -1});
    }
    sort(times.begin(), times.end());
    int now_people = 0, ans = 0;
    for(auto [t, x] : times){
        ans = max(ans, (now_people += x));
    }
    cout << ans;
}
```

9 string

9.1 kmp

```
#include <bits/stdc++.h>
using namespace std;
struct KMP {
    string s;
    vector<int> failure;
    KMP(string s) {
        this->s = s;
        failure.resize(s.size(), -1);
    }
    void buildFailFunction() {
        for(int i = 1; i < s.size(); i++) {
            int now = failure[i - 1];
            while(now != -1 && s[now + 1] != s[i]) now =
                 failure[now];
            if (s[now + 1] == s[i]) failure[i] = now + 1;
        }
    }
    void KMPmatching(string &sub) {
        for(int i = 0, now = -1; i < s.size(); i++) {
            // now is the compare sucessed length -1
            while (s[i] != sub[now + 1] && now != -1) now =
                 failure[now];
            // f stores if comparison fail, move to where
            if (s[i] == sub[now + 1]) now++;
            if (now + 1 == sub.size()) {
                cout << "found a match start at position "
                     << i - now << "\n";
                now = failure[now];
            }
        }
    }
};
int main(){
    string s = "BABA";
    string sub = "BA";
    KMP kmp(s);
    kmp.buildFailFunction();
    kmp.KMPmatching(sub);
}
```

10 Tree

10.1 LCA

```
#include <bits/stdc++.h> // LCA from 1
using namespace std;
const int maxn = 2e5+5;
```

```cpp
int boss[maxn];
int height[maxn];
int arr[18][maxn];
vector<int> tree[maxn];
void Calculate_H(int now_node){
    for(auto nxt_node : tree[now_node]){
        height[nxt_node] = height[now_node] + 1;
        Calculate_H(nxt_node);
    }
}
int Find_Ancestor(int k, int h){
    for(int i = 0; i <= 17; i++){
        if(h & (1 << i)) k = arr[i][k];
    }
    return k;
}
int main(){
    memset(arr, 0, sizeof(arr));
    int n, q; cin >> n >> q;
    boss[1] = 1;
    for(int i = 2; i <= n; i++){
        int tmp; cin >> tmp;  // tmp to i
        boss[i] = tmp;
        tree[tmp].push_back(i);
    }
    Calculate_H(1);
    for(int i = 2; i <= n; i++){
        arr[0][i] = boss[i];
    }
    for(int i = 1; i <= 17; i++){ // make chart
        for(int j = 1; j <= n; j++){
            arr[i][j] = arr[i - 1][arr[i - 1][j]];
        }
    }
    while(q--){
        int a, b; cin >> a >> b;
        if(height[a] < height[b]) swap(a, b);
        a = Find_Ancestor(a, height[a] - height[b]); //
             same depth from 1
        if(a == b){ // same point
            cout << a << "\n";
            continue;
        }
        for(int i = 17; i >= 0; i--){
            if(arr[i][a] != arr[i][b]){ // if a, b up 2 ^ i
                  not the same point
                a = arr[i][a];
                b = arr[i][b];
            }
        }
        cout << arr[0][a] << "\n"; // more one
    }
}
```

10.2 Subordinates DP

```cpp
#include <bits/stdc++.h>
using namespace std;
const int maxn = 2e5+5;
vector<int> tree[maxn];
int sub[maxn];
void dfs(int now){
    for(auto nxt : tree[now]){
        dfs(nxt);
        sub[now] += sub[nxt] + 1;
    }
}
int main(){
    memset(sub, 0, sizeof(sub));
    int n; cin >> n;
    for(int i = 2; i <= n; i++){
        int b; cin >> b;
        tree[b].push_back(i);
    }
    dfs(1);
    for(int i = 1; i <= n; i++){
        cout << sub[i] << " ";
    }
}
```

10.3 Tree Centroid

```cpp
#include <bits/stdc++.h>
using namespace std;
const int maxn = 2e5+5;
vector<int> tree[maxn];
int cen = 0, n;
int dfs(int par, int now){
    bool flag = 1;
    int size = 0;
    for(auto nxt : tree[now]){
        if(par != nxt){
            int subsize = dfs(now, nxt);
            if(subsize > n / 2) flag = false;
            size += subsize;
        }
    }
    if(n - 1 - size > n / 2) flag = false;
    if(flag) cen = now;
    return size + 1;
}
int main(){
    cin >> n;
    for(int i = 1; i < n; i++){
        int u, v; cin >> u >> v;
        tree[u].push_back(v);
        tree[v].push_back(u);
    }
    for(int i = 1; i <= n; i++){
        for(auto nxt : tree[i])
            dfs(i, nxt);
        if(cen) break;
    }
}
```

10.4 Tree Sum Distances

```cpp
#include <bits/stdc++.h>
using namespace std;
const int maxn = 2e5+5;
vector<int> tree[maxn];
vector<int> subtree(maxn, 1);
long long ans[maxn];
int n;
void dfs(int par, int now, int depth){
    ans[1] += depth;
    for(auto nxt : tree[now]){
        if(par != nxt) {
            dfs(now, nxt, depth + 1);
            subtree[now] += subtree[nxt];
        }
    }
}
void find_ans(int par, int now){
// each sub's dis make - 1, non subnode + 1
    for(auto nxt : tree[now]){
        if(par != nxt){
            ans[nxt] = ans[now] + (n - subtree[nxt]) -
                  subtree[nxt];
            find_ans(now, nxt);
        }
    }
}
int main(){
    cin >> n;
    for(int i = 1; i < n; i++){
        int u, v; cin >> u >> v;
        tree[u].push_back(v);
        tree[v].push_back(u);
    }
    dfs(0, 1, 0);
    find_ans(0, 1);
    for(int i = 1; i <= n; i++){
        cout << ans[i] << " ";
    }
}
```

10.5 Unweighted Tree Distances

```cpp
#include <bits/stdc++.h>
using namespace std;
const int maxn = 2e5+5;
int dep1[maxn], dep2[maxn];
vector<int> tree[maxn];
int start, maxdep = 1, End;
void dfs1(int par, int now){
    for(auto nxt : tree[now]){
        if(par != nxt){
            dep1[nxt] = dep1[now] + 1;
            if(dep1[nxt] > maxdep){
                maxdep = dep1[nxt];
                start = nxt;
            }
```

```
            dfs1(now, nxt);
        }
    }
}
void find_depth1(int par, int now){
    for(auto nxt : tree[now]){
        if(par != nxt){
            dep1[nxt] = dep1[now] + 1;
            if(dep1[nxt] > maxdep){
                maxdep = dep1[nxt];
                End = nxt;
            }
            find_depth1(now, nxt);
        }
    }
}
void find_depth2(int par, int now){
    for(auto nxt : tree[now]){
        if(par != nxt){
            dep2[nxt] = dep2[now] + 1;
            find_depth2(now, nxt);
        }
    }
}
int main(){
    int n; cin >> n;
    for(int i = 1; i < n; i++){
        int u, v; cin >> u >> v;
        tree[u].push_back(v);
        tree[v].push_back(u);
    }
    dep1[1] = 1;
    dfs1(0, 1);
    dep1[start] = 1;
    maxdep = 1;
    find_depth1(start, start);
    dep2[End] = 1;
    find_depth2(End, End);
    for(int i = 1; i <= n; i++){
        cout << max(dep1[i], dep2[i]) - 1 << " ";
    }
}
```

10.6 Weighted Tree Distance

```
#include <bits/stdc++.h> // weighted tree centroid
using namespace std;
const int maxn = 1e5+5;
using ll = long long;
vector<pair<int, int>> tree[maxn];
ll dp[maxn];
ll ans = 0;
void DP(int now, int par){
    ll mx1 = 0; ll mx2 = 0;
    for(auto [nxt, w] : tree[now]){
        if(nxt == par) continue;
        DP(nxt, now);
        if(mx1 < w + dp[nxt]){ // mx2 = mx1mx1 = new mx
            mx2 = mx1; mx1 = w + dp[nxt];
        }
        else if(mx2 < w + dp[nxt]){ // mx2 = new
            mx2 = w + dp[nxt];
        }
    }
    dp[now] = mx1;
    ans = max(ans, mx1 + mx2);
}
int main(){
    int n; cin >> n;
    memset(dp, 0, sizeof(dp));
    for(int i = 1; i < n; i++){
        int u, v, w; cin >> u >> v >> w;
        tree[u].push_back({v, w});
        tree[v].push_back({u, w});
    }
    DP(1, 0);
    cout << (ans < 0 ? 0 : ans);
}
```