

1 Convolution

1.1 FFT

```

1 typedef complex<double> cd;
2 const double PI = acos(-1);
3
4 void FFT(vector<cd> &a, bool inv){
5
6     int n = a.size();
7
8     for (int i=1, j=0 ; i<n ; i++){
9         int bit = (n>>1);
10        for ( ; j&bit ; bit>>=1){
11            j ^= bit;
12        }
13        j ^= bit;
14        if (i<j){
15            swap(a[i], a[j]);
16        }
17    }
18
19    for (int len=2 ; len<=n ; len<<=1){
20        cd wlen = polar(1.0, (inv ? 2 : -2)*PI/len);
21
22        for (int i=0 ; i<n ; i+=len){
23            cd w(1);
24            for (int j=0 ; j<len/2 ; j++){
25                cd u = a[i+j];
26                cd v = a[i+j+len/2]*w;
27                a[i+j] = u+v;
28                a[i+j+len/2] = u-v;
29                w *= wlen;
30            }
31        }
32    }
33
34    if (inv){
35        for (auto &x : a){
36            x /= n;
37        }
38    }
39
40    return;
41 }
42
43 vector<cd> polyMul(vector<cd> a, vector<cd> b){
44     int sa = a.size(), sb = b.size(), n = 1;
45
46     while (n<sa+sb-1) n *= 2;
47     a.resize(n);
48     b.resize(n);
49     vector<cd> c(n);
50
51     FFT(a, 0);
52     FFT(b, 0);
53     for (int i=0 ; i<n ; i++) c[i] = a[i]*b[i];
54     FFT(c, 1);
55
56     c.resize(sa+sb-1);
57
58     return c;
59 }

```

1.2 FFT-2

```

1 typedef complex<double> cd;
2
3 void FFT(vector<cd> &a) {
4     int n = a.size(), L = 31-__builtin_clz(n);
5     vector<complex<long double>> R(2, 1);
6     vector<cd> rt(2, 1);
7     for (int k=2 ; k<n ; k*=2){
8         R.resize(n);
9         rt.resize(n);
10        auto x = polar(1.0L, acos(-1.0L) / k);
11        for (int i=k ; i<2*k ; i++){
12            rt[i] = R[i] = (i&1 ? R[i/2]*x : R[i/2]);
13        }
14    }
15
16    vector<int> rev(n);
17    for (int i=0 ; i<n ; i++){
18        rev[i] = (rev[i/2] | (i&1)<<L)/2;
19    }
20
21    for (int i=0 ; i<n ; i++){
22        if (i<rev[i]) swap(a[i], a[rev[i]]);
23    }
24
25    for (int k=1 ; k<n ; k*=2){
26        for (int i=0 ; i<n ; i+=2*k){
27            for (int j=0 ; j<k ; j++){
28                auto x = (double *)&rt[j+k];
29                auto y = (double *)&a[i+j+k];
30                cd z(x[0]*y[0] - x[1]*y[1], x[0]*y[1] + x[1]*y[0]);
31                a[i+j+k] = a[i+j]-z;
32                a[i+j] += z;
33            }
34        }
35    }
36
37    return;
38 }
39
40 vector<double> PolyMul(const vector<double> a, const vector<double> b){
41     if (a.empty() || b.empty()) return {};
42     vector<double> res(a.size()+b.size()-1);
43     int L = 32 - __builtin_clz(res.size());
44     vector<cd> in(n), out(n);
45
46     copy(a.begin(), a.end(), begin(in));
47     for (int i=0 ; i<b.size() ; i++){
48         in[i].imag(b[i]);
49     }
50     FFT(in);
51     for (cd& x : in) x *= x;
52     for (int i=0 ; i<n ; i++){
53         out[i] = in[-i & (n - 1)] - conj(in[i]);
54     }
55     FFT(out);
56
57     for (int i=0 ; i<res.size() ; i++){
58         res[i] = imag(out[i]) / (4 * n);
59     }
60
61     return res;
62 }

```

1.3 NTT-998244353

```

1 const int MOD = (119 << 23) + 1, ROOT = 62; // = 998244353
2 // For p < 2^30 there is also e.g. 5 << 25, 7 << 26, 479 << 21
3 // and 483 << 21 (same root). The last two are > 10^9.
4
5 // 9cd58a
6 void NTT(vector<int> &a) {
7     int n = a.size();
8     int L = 31-__builtin_clz(n);
9     vector<int> rt(2, 1);
10    for (int k=2, s=2 ; k<n ; k*=2, s++){
11        rt.resize(n);
12        int z[] = {1, qp(ROOT, MOD>>s)};
13        for (int i=k ; i<2*k ; i++){
14            rt[i] = rt[i/2]*z[i&1%MOD];
15        }
16    }
17
18    vector<int> rev(n);
19    for (int i=0 ; i<n ; i++){
20        rev[i] = (rev[i/2] | (i&1)<<L)/2;
21    }
22
23    for (int i=0 ; i<n ; i++){
24        if (i<rev[i]) swap(a[i], a[rev[i]]);
25    }
26
27    for (int k=1 ; k<n ; k*=2){
28        for (int i=0 ; i<n ; i+=2*k){
29            for (int j=0 ; j<k ; j++){
30                int z = rt[j+k]*a[i+j+k]%MOD, &ai = a[i+j];
31                a[i+j+k] = ai-z+(z>ai ? MOD : 0);
32                ai += (ai+z)>MOD ? z-MOD : z;
33            }
34        }
35    }
36
37    return;
38 }
39
40 // 0b0e99
41 vector<int> polyMul(vector<int> &a, vector<int> &b){
42     if (a.empty() || b.empty()) return {};
43     int s = a.size()+b.size()-1, B = 32-__builtin_clz(s), n = 1<<B;
44     int inv = qp(n, MOD-2);
45
46     vector<int> L(a), R(b), out(n);
47     L.resize(n), R.resize(n);
48     NTT(L), NTT(R);
49     for (int i=0 ; i<n ; i++){
50         out[-i&(n-1)] = L[i]*R[i]%MOD*inv%MOD;
51     }
52     NTT(out);
53
54     out.resize(s);
55     return out;
56 }

```

1.4 FFT-mod

```

1  /*
2  修改 const int MOD = 998244353 更改要取餘的數字
3  PolyMul(a, b) 回傳多項式乘法的結果 (c_k = \sum_{i+j} a_i+b_j
   mod MOD)
4
5  大約可以支援 5e5 · a_i, b_i 皆在 MOD 以下的非負整數
6  */
7  const int MOD = 998244353;
8  typedef complex<double> cd;
9
10 // b9c90a
11 void FFT(vector<cd> &a) {
12     int n = a.size(), L = 31-__builtin_clz(n);
13     vector<complex<long double>> R(2, 1);
14     vector<cd> rt(2, 1);
15     for (int k=2 ; k<n ; k*=2){
16         R.resize(n);
17         rt.resize(n);
18         auto x = polar(1.0L, acos(-1.0L) / k);
19         for (int i=k ; i<2*k ; i++){
20             rt[i] = R[i] = (i&1 ? R[i/2]*x : R[i/2]);
21         }
22     }
23
24     vector<int> rev(n);
25     for (int i=0 ; i<n ; i++){
26         rev[i] = (rev[i/2] | (i&1)<<(L)/2);
27     }
28     for (int i=0 ; i<n ; i++){
29         if (i<rev[i]) swap(a[i], a[rev[i]]);
30     }
31     for (int k=1 ; k<n ; k*=2){
32         for (int i=0 ; i<n ; i+=2*k){
33             for (int j=0 ; j<k ; j++){
34                 auto x = (double *)&rt[j+k];
35                 auto y = (double *)&a[i+j+k];
36                 cd z(x[0]*y[0] - x[1]*y[1], x[0]*y[1] + x[1]*
37                     y[0]);
38                 a[i+j+k] = a[i+j]-z;
39                 a[i+j] += z;
40             }
41         }
42     }
43     return;
44 }
45 // d3c65e
46 vector<int> PolyMul(vector<int> a, vector<int> b){
47     if (a.empty() || b.empty()) return {};
48
49     vector<int> res(a.size()+b.size()-1);
50     int B = 32-__builtin_clz(res.size()), n = (1<<B), cut =
51         int(sqrt(MOD));
52     vector<cd> L(n), R(n), outs(n), outl(n);
53
54     for (int i=0 ; i<a.size() ; i++){
55         L[i] = cd((int) a[i]/cut, (int)a[i]%cut);
56     }
57     for (int i=0 ; i<b.size() ; i++){
58         R[i] = cd((int) b[i]/cut, (int)b[i]%cut);
59     }
60     FFT(L);
61     FFT(R);
62     for (int i=0 ; i<n ; i++){
63         int j = -i&(n-1);

```

```

63         outl[j] = (L[i]+conj(L[j])) * R[i]/(2.0*n);
64         outs[j] = (L[i]-conj(L[j])) * R[i]/(2.0*n)/1i;
65     }
66     FFT(outl);
67     FFT(outs);
68     for (int i=0 ; i<res.size() ; i++){
69         int av = (int)(real(outl[i])+0.5), cv = (int)(imag(
70             outs[i])+0.5);
71         int bv = (int)(imag(outl[i])+0.5) + (int)(real(outs[i
72             ])+0.5);
73         res[i] = ((av%MOD*cut+bv) % MOD*cut+cv) % MOD;
74     }
75     return res;

```

2 Data-Structure

2.1 GP-Hash-Table

```

1 #include <ext/pb_ds/assoc_container.hpp>
2 using namespace __gnu_pbds;
3 typedef tree<int, null_type, less<int>, rb_tree_tag,
   tree_order_statistics_node_update> order_set;
4 struct custom_hash {
5     static uint64_t splitmix64(uint64_t x) {
6         // http://xorshift.di.unimi.it/splitmix64.c
7         x += 0x9e3779b97f4a7c15;
8         x = (x ^ (x >> 30)) * 0xbf58476d1ce4e5b9;
9         x = (x ^ (x >> 27)) * 0x94d049bb133111eb;
10        return x ^ (x >> 31);
11    }
12
13    size_t operator()(uint64_t x) const {
14        static const uint64_t FIXED_RANDOM = chrono::
15            steady_clock::now().time_since_epoch().count();
16        return splitmix64(x + FIXED_RANDOM);
17    }
18 };
19 gp_hash_table<int, int, custom_hash> ss;

```

2.2 Sparse-Table

```

1 vector<vector<int>> st;
2 void build(vector<int> v){
3     int h = __lg(v.size());
4     st.resize(h+1);
5     st[0] = v;
6
7     for (int i=1 ; i<=h ; i++){
8         int gap = (1<<(i-1));
9         for (int j=0 ; j+gap<st[i-1].size() ; j++){
10             st[i].push_back(min(st[i-1][j], st[i-1][j+gap]));
11         }
12     }
13 }

```

```

15 // 回傳 [ll, rr) 的最小值
16 int RMQ(int ll, int rr){
17     int h = __lg(rr-ll);
18     return min(st[h][ll], st[h][rr-(1<<h)]);
19 }

```

2.3 Order-Set

```

1 // .find_by_order(k) 回傳第 k 小的值 (based-0)
2 // .order_of_key(k) 回傳有多少元素比 k 小
3
4 #include <ext/pb_ds/assoc_container.hpp>
5 using namespace __gnu_pbds;
6 typedef tree<int, null_type, less<int>, rb_tree_tag,
   tree_order_statistics_node_update> order_set;

```

2.4 BIT

```

1 vector<int> BIT(MAX_SIZE);
2 void update(int pos, int val){
3     for (int i=pos ; i<MAX_SIZE ; i+=i&-i){
4         BIT[i]+=val;
5     }
6 }
7
8 int query(int pos){
9     int ret=0;
10    for (int i=pos ; i>0 ; i-=i&-i){
11        ret+=BIT[i];
12    }
13    return ret;
14 }
15
16 // const int MAX_N = (1<<20)
17 // const int LOG_N = 20;
18 int k_th(int k){ // 回傳 BIT 中第 k 小的元素 (based-1)
19     int target = k-1, now = 0;
20     for (int i=LOG_N-1 ; i>=0 ; i--){
21         if (BIT[now+(1<<i)]<=k){
22             k -= BIT[now+(1<<i)];
23             now += 1<<i;
24         }
25     }
26     return now+1;
27 }

```

2.5 Treap

```

1 struct Treap{
2     Treap *l, *r;
3     int pri, val, sz;
4
5     Treap(int _val){
6         l = nullptr;
7         r = nullptr;
8         pri = rand();

```

```

9     val = _val;
10    sz = 1;
11  }
12 } *root;
13
14 int size(Treap *a){
15     return a ? a->sz : 0;
16 }
17
18 void pull(Treap *t){
19     t->sz = size(t->l)+size(t->r)+1;
20 }
21
22 Treap *merge(Treap *a, Treap *b){
23     // 如果一個為空，就回傳另一個
24     if (!a || !b) return a ? a : b;
25
26     if (a->pri>b->pri){
27         a->r = merge(a->r, b);
28         pull(a);
29         return a;
30     }else{
31         b->l = merge(a, b->l);
32         pull(b);
33         return b;
34     }
35 }
36
37 void split(Treap *&t, int k, Treap *&a, Treap *&b){
38     // 如果樹為空就直接返回
39     if (!t) a = b = nullptr;
40
41     else if (size(t->l)+1<=k){ // 用 k 分割 treap
42         // 如果以左子節點為根 + 目前節點合法：
43         a = t;
44         split(t->r, k-size(t->l)-1, a->r, b);
45         pull(a);
46     }else{
47         b = t;
48         split(t->l, k, a, b->l);
49         pull(b);
50     }
51 }
52
53 ostream & operator << (ostream &os, Treap *t){
54     if (t==0) return os;
55     os << t->l;
56     os << (char)t->val;
57     os << t->r;
58     return os;
59 }
60
61 void print(Treap *t){
62     if (t->l!=0) print(t->l);
63     cout << (char)t->val;
64     if (t->r!=0) print(t->r);
65 }
66

```

2.6 Persistent-Segment-Tree

```

2  全部都是 0-based
3
4  宣告
5  Persistent_Segment_Tree st(n+q);
6  st.build(v, 0);
7
8  函式：
9  update_version(pos, val, ver)：對版本 ver 的 pos 位置改成 val
10 query_version(ql, qr, ver)：對版本 ver 查詢 [ql, qr) 的區間和
11 clone_version(ver)：複製版本 ver 到最新的版本
12 */
13 struct Persistent_Segment_Tree{
14     int node_cnt = 0;
15     struct Node{
16         int lc = -1;
17         int rc = -1;
18         int val = 0;
19     };
20     vector<Node> arr;
21     vector<int> version;
22
23     Persistent_Segment_Tree(int sz){
24         arr.resize(32*sz);
25         version.push_back(node_cnt++);
26         return;
27     }
28
29     void pull(Node &c, Node a, Node b){
30         c.val = a.val+b.val;
31         return;
32     }
33
34     void build(vector<int> &v, int idx, int ll = 0, int rr = n){
35         auto &now = arr[idx];
36
37         if (rr-ll==1){
38             now.val = v[ll];
39             return;
40         }
41
42         int mid = (ll+rr)/2;
43         now.lc = node_cnt++;
44         now.rc = node_cnt++;
45         build(v, now.lc, ll, mid);
46         build(v, now.rc, mid, rr);
47         pull(now, arr[now.lc], arr[now.rc]);
48         return;
49     }
50
51     void update(int pos, int val, int idx, int ll = 0, int rr = n){
52         auto &now = arr[idx];
53
54         if (rr-ll==1){
55             now.val = val;
56             return;
57         }
58
59         int mid = (ll+rr)/2;
60         if (pos<mid){
61             arr[node_cnt] = arr[now.lc];
62             now.lc = node_cnt;
63             node_cnt++;
64             update(pos, val, now.lc, ll, mid);
65

```

```

66         }else{
67             arr[node_cnt] = arr[now.rc];
68             now.rc = node_cnt;
69             node_cnt++;
70             update(pos, val, now.rc, mid, rr);
71         }
72         pull(now, arr[now.lc], arr[now.rc]);
73         return;
74     }
75
76     void update_version(int pos, int val, int ver){
77         update(pos, val, version[ver]);
78     }
79
80     Node query(int ql, int qr, int idx, int ll = 0, int rr = n){
81         auto &now = arr[idx];
82
83         if (ql<=ll && rr<=qr) return now;
84         if (rr<=ql || qr<=ll) return Node();
85
86         int mid = (ll+rr)/2;
87
88         Node ret;
89         pull(ret, query(ql, qr, now.lc, ll, mid), query(ql, qr, now.rc, mid, rr));
90         return ret;
91     }
92
93     Node query_version(int ql, int qr, int ver){
94         return query(ql, qr, version[ver]);
95     }
96
97     void clone_version(int ver){
98         version.push_back(node_cnt);
99         arr[node_cnt] = arr[version[ver]];
100         node_cnt++;
101     }
102 };

```

2.7 Trie

```

1 struct Trie{
2     struct Data{
3         int nxt[2]={0, 0};
4     };
5
6     int sz=0;
7     vector<Data> arr;
8
9     void init(int n){
10         arr.resize(n);
11     }
12
13     void insert(int n){
14         int now=0;
15         for (int i=N; i>=0; i--){
16             int v=(n>>i)&1;
17             if (!arr[now].nxt[v]){
18                 arr[now].nxt[v]=++sz;
19             }
20             now=arr[now].nxt[v];
21         }
22     }
23 }

```

```

22     }
23
24     int query(int n){
25         int now=0, ret=0;
26         for (int i=N ; i>=0 ; i--){
27             int v=(n>>i)&1;
28             if (arr[now].nxt[1-v]){
29                 ret+=(1<<i);
30                 now=arr[now].nxt[1-v];
31             }else if (arr[now].nxt[v]){
32                 now=arr[now].nxt[v];
33             }else{
34                 return ret;
35             }
36         }
37         return ret;
38     }
39 } tr;
40

```

2.8 LC-Segment-Tree

```

1  /*
2  全部都是 0-based
3
4  宣告
5  LC_Segment_Tree st(n);
6
7  函式：
8  update(val)：將一個 pair <a, b> 代表插入一條  $y=ax+b$  的直線
9  query(x)：查詢所有直線在位置 x 的最小值
10 */
11 const int MAX_V = 1e6+10; // 值域最大值
12
13 struct LC_Segment_Tree{
14     struct Node{ //  $y = ax+b$ 
15         int a = 0;
16         int b = INF;
17
18         int y(int x){
19             return a*x+b;
20         }
21     };
22     vector<Node> arr;
23
24     LC_Segment_Tree(int n = 0){
25         arr.resize(4*n);
26     }
27
28     void update(Node val, int idx = 0, int ll = 0, int rr =
29         MAX_V){
30         if (rr-ll==1){
31             if (val.y(ll)<arr[idx].y(ll)){
32                 arr[idx] = val;
33             }
34             return;
35         }
36
37         int mid = (ll+rr)/2;
38         if (arr[idx].a > val.a) swap(arr[idx], val); // 原本
39             的線斜率要比較小
40

```

```

38     if (arr[idx].y(mid) < val.y(mid)){ // 交點在左邊
39         update(val, idx*2+1, ll, mid);
40     }else{ // 交點在右邊
41         swap(arr[idx], val); // 在左子樹中，新線比舊線還
42             要好
43         update(val, idx*2+2, mid, rr);
44     }
45     return;
46 }
47
48 int query(int x, int idx = 0, int ll = 0, int rr = MAX_V)
49 {
50     if (rr-ll==1){
51         return arr[idx].y(ll);
52     }
53
54     int mid = (ll+rr)/2;
55     if (x<mid){
56         return min(arr[idx].y(x), query(x, idx*2+1, ll,
57             mid));
58     }else{
59         return min(arr[idx].y(x), query(x, idx*2+2, mid,
60             rr));
61     }
62 }
63
64 }
65
66 };
67

```

2.9 Persistent-Disjoint-Set

```

1 struct Persistent_Disjoint_Set{
2     Persistent_Segment_Tree arr, sz;
3
4     void init(int n){
5         arr.init(n);
6         vector<int> v1;
7         for (int i=0 ; i<n ; i++){
8             v1.push_back(i);
9         }
10        arr.build(v1, 0);
11
12        sz.init(n);
13        vector<int> v2;
14        for (int i=0 ; i<n ; i++){
15            v2.push_back(1);
16        }
17        sz.build(v2, 0);
18    }
19
20    int find(int a){
21        int res = arr.query_version(a, a+1, arr.version.size()
22            -1).val;
23        if (res==a) return a;
24        return find(res);
25    }
26
27    bool unite(int a, int b){
28        a = find(a);
29        b = find(b);
30
31        if (a!=b){
32            int sz1 = sz.query_version(a, a+1, arr.version.
33                size()-1).val;
34

```

```

33        int sz2 = sz.query_version(b, b+1, arr.version.
34            size()-1).val;
35
36        if (sz1<sz2){
37            arr.update_version(a, b, arr.version.size()
38                -1);
39            sz.update_version(b, sz1+sz2, arr.version.
40                size()-1);
41        }else{
42            arr.update_version(b, a, arr.version.size()
43                -1);
44            sz.update_version(a, sz1+sz2, arr.version.
45                size()-1);
46        }
47
48        return true;
49    }
50
51    return false;
52 }
53
54 }
55
56 };
57

```

2.10 Add-Set-Segment-Tree

```

1 // [ll, rr), based-0
2 // 使用前記得 init(陣列大小), build(陣列名稱)
3 // add(ll, rr): 區間修改
4 // set(ll, rr): 區間賦值
5 // query(ll, rr): 區間求和 / 求最大值
6 struct SegmentTree{
7     struct node{
8         int add_tag = 0;
9         int set_tag = 0;
10        int sum = 0;
11        int ma = 0;
12    };
13
14    vector<node> arr;
15
16    SegmentTree(int n){
17        arr.resize(n<<2);
18    }
19
20    node pull(node A, node B){
21        node C;
22        C.sum = A.sum+B.sum;
23        C.ma = max(A.ma, B.ma);
24        return C;
25    }
26
27    // cce0c8
28    void push(int idx, int ll, int rr){
29        if (arr[idx].set_tag!=0){
30            arr[idx].sum = (rr-ll)*arr[idx].set_tag;
31            arr[idx].ma = arr[idx].set_tag;
32            if (rr-ll>1){
33                arr[idx*2+1].add_tag = 0;
34                arr[idx*2+1].set_tag = arr[idx].set_tag;
35                arr[idx*2+2].add_tag = 0;
36                arr[idx*2+2].set_tag = arr[idx].set_tag;
37            }
38            arr[idx].set_tag = 0;
39        }
40        if (arr[idx].add_tag!=0){
41

```

```

41     arr[idx].sum += (rr-ll)*arr[idx].add_tag;
42     arr[idx].ma += arr[idx].add_tag;
43     if (rr-ll>1){
44         arr[idx*2+1].add_tag += arr[idx].add_tag;
45         arr[idx*2+2].add_tag += arr[idx].add_tag;
46     }
47     arr[idx].add_tag = 0;
48 }
49 }
50
51 void build(vector<int> &v, int idx = 0, int ll = 0, int
52         rr = n){
53     if (rr-ll==1){
54         arr[idx].sum = v[ll];
55         arr[idx].ma = v[ll];
56     }else{
57         int mid = (ll+rr)/2;
58         build(v, idx*2+1, ll, mid);
59         build(v, idx*2+2, mid, rr);
60         arr[idx] = pull(arr[idx*2+1], arr[idx*2+2]);
61     }
62 }
63
64 void add(int ql, int qr, int val, int idx = 0, int ll =
65         0, int rr = n){
66     push(idx, ll, rr);
67     if (rr<=ql || qr<=ll) return;
68     if (ql<=ll && rr<=qr){
69         arr[idx].add_tag += val;
70         push(idx, ll, rr);
71         return;
72     }
73     int mid = (ll+rr)/2;
74     add(ql, qr, val, idx*2+1, ll, mid);
75     add(ql, qr, val, idx*2+2, mid, rr);
76     arr[idx]=pull(arr[idx*2+1], arr[idx*2+2]);
77
78 void set(int ql, int qr, int val, int idx=0, int ll=0,
79         int rr=n){
80     push(idx, ll, rr);
81     if (rr<=ql || qr<=ll) return;
82     if (ql<=ll && rr<=qr){
83         arr[idx].add_tag = 0;
84         arr[idx].set_tag = val;
85         push(idx, ll, rr);
86         return;
87     }
88     int mid = (ll+rr)/2;
89     set(ql, qr, val, idx*2+1, ll, mid);
90     set(ql, qr, val, idx*2+2, mid, rr);
91     arr[idx] = pull(arr[idx*2+1], arr[idx*2+2]);
92 }
93
94 node query(int ql, int qr, int idx = 0, int ll = 0, int
95         rr = n){
96     push(idx, ll, rr);
97     if (rr<=ql || qr<=ll) return node();
98     if (ql<=ll && rr<=qr) return arr[idx];
99
100     int mid = (ll+rr)/2;
101     return pull(query(ql, qr, idx*2+1, ll, mid), query(ql
102         , qr, idx*2+2, mid, rr));
103 }
104 } ST;

```

3 Dynamic-Programming

3.1 SOS-DP

```

1 // 總時間複雜度為  $O(n \cdot 2^n)$ 
2 // 計算  $dp[i] = i$  所有  $bit$   $mask$  子集的和
3 for (int i=0 ; i<n ; i++){
4     for (int mask=0 ; mask<(1<<n) ; mask++){
5         if ((mask>>i)&1){
6             dp[mask] += dp[mask^(1<<i)];
7         }
8     }
9 }

```

3.2 Digit-DP

```

1 #include <bits/stdc++.h>
2 using namespace std;
3
4 long long l, r;
5 long long dp[20][10][2][2]; // dp[pos][pre][Limit] = 後 pos
6 // 位 · pos 前一位是 pre · (是/否) 有上界 · (是/否) 有前綴零
7 // 的答案數量
8
9 long long memorize_search(string &s, int pos, int pre, bool
10     limit, bool lead){
11
12     // 已經被找過了 · 直接回傳值
13     if (dp[pos][pre][limit][lead]!=-1) return dp[pos][pre][
14         limit][lead];
15
16     // 已經搜尋完畢 · 紀錄答案並回傳
17     if (pos==(int)s.size()){
18         return dp[pos][pre][limit][lead] = 1;
19     }
20
21     // 枚舉目前的位數數字是多少
22     long long ans = 0;
23     for (int now=0 ; now<=(limit ? s[pos]-'0' : 9) ; now++){
24         if (now==pre){
25
26             // 1~9 絕對不能連續出現
27             if (pre!=0) continue;
28
29             // 如果已經不在前綴零的範圍內 · 0 不能連續出現
30             if (lead==false) continue;
31
32         }
33
34         ans += memorize_search(s, pos+1, now, limit&(now==(s[
35             pos]-'0')), lead&(now==0));
36     }
37
38     // 已經搜尋完畢 · 紀錄答案並回傳
39     return dp[pos][pre][limit][lead] = ans;
40 }
41
42 // 回傳 [0, n] 有多少數字符合條件
43 long long find_answer(long long n){
44     memset(dp, -1, sizeof(dp));
45 }

```

```

39     string tmp = to_string(n);
40
41     return memorize_search(tmp, 0, 0, true, true);
42 }
43
44 int main(){
45
46     // input
47     cin >> l >> r;
48
49     // output - 計算 [l, r] 有多少數字任意兩個位數都不相同
50     cout << find_answer(r)-find_answer(l-1) << "\n";
51
52     return 0;
53 }

```

3.3 整數拆分

$dp[i][x]$ = 要將整數 x 拆成 i 堆的「組合數」

$dp[i+1][x+1] += dp[i][x]$ (創造新的一堆)
 $dp[i][x+i] += dp[i][x]$ (把每一堆都增加1)

4 Geometry

4.1 Point-Struct

```

1 const int EPS = 1e-6;
2
3 typedef int pt;
4 struct point{
5     pt x, y;
6
7     point(pt _x = 0, pt _y = 0){
8         x = _x;
9         y = _y;
10    }
11
12    // 純量乘、除法
13    point operator * (pt a){return {a*x, a*y}};
14    point operator / (pt a){return {a/x, a/y}};
15
16    // 向量加、減法
17    point operator + (point a){return {x+a.x, y+a.y}};
18    point operator - (point a){return {x-a.x, y-a.y}};
19
20    // 內積、外積
21    double operator * (point a){return x*a.x+y*a.y};
22    double operator ^ (point a){return x*a.y-y*a.x};
23
24    // bool operator < (const point &a) const {return (x*a.y<
25        a.x*y);} // 極角排序 (順時鐘)
26    bool operator < (const point &a) const {return x==a.x ? y
27        <a.y : x<a.x;}
28    bool operator == (const point &a) const {return x==a.x &&
29        y==a.y;}
30
31    double dis(point a){return sqrtl(abs(x-a.x)*abs(x-a.x)+
32        abs(y-a.y)*abs(y-a.y));}
33 }

```

```

29 };
30
31 // 判斷向量正負：1=正數，0=0，-1=負數
32 int sign(double a){
33     if (abs(a)<EPS) return 0;
34     else return (a>0 ? 1 : -1);
35 }
36
37 // 判斷 ab 到 ac 的方向：1=逆時鐘，0=重疊，-1=順時鐘
38 int ori(point a, point b, point c){
39     return sign((b-a)^(c-a));
40 }

```

4.2 Line-Intersection

```

1 // c 是否在 ab 裡面
2 bool in(point a, point b, point c){
3     if (ori(a, b, c)) return 0;
4     return sign((a-c)*(b-c))<=0;
5 }
6
7 // 判斷 ab 是否跟 cd 相交
8 bool banana(point a, point b, point c, point d){
9     int s1=ori(a, b, c);
10    int s2=ori(a, b, d);
11    int s3=ori(c, d, a);
12    int s4=ori(c, d, b);
13    if (in(a, b, c) || in(a, b, d) || in(c, d, a) || in(c, d,
14        b)) return 1;
15    return (s1*s2<0) && (s3*s4<0);

```

4.3 Pick's-Theorem

給定頂點坐標均是整點的簡單多邊形。面積 = 內部格點數 + 邊上格點數/2 - 1

4.4 Point-In-Polygon

```

1 /*
2 可以在有 n 個點的簡單多邊形內，用 O(n) 的時間回傳：
3 1: 在多邊形內，0: 在多邊形上，-1: 在多邊形外
4 */
5 const int MAX_POS = 1e9+5; // [記得修改] 座標的最大值
6 int in_polygon(vector<point> &v, point a){
7     int c = v.size();
8     v.push_back(v[0]); // 已經用好循環了
9     point b = {MAX_POS, a.y+1};
10    int cnt = 0;
11
12    for (int i=0; i<n; i++){
13        if (in(v[i], v[i+1], a)) return 0;
14        if (banana(a, b, v[i], v[i+1])) cnt++;
15    }
16
17    return cnt%2 ? 1 : -1;
18 }

```

4.5 Convex-Hull

```

1 // e0a719
2 vector<point> convex_hull(vector<point> v){
3     sort(v.begin(), v.end());
4     v.resize(unique(v.begin(), v.end())-v.begin());
5     vector<point> hull;
6     for (int _=0; _<2; _++){
7         int sz=hull.size();
8         for (int i=0; i<v.size(); i++){
9             while (hull.size()-sz+2 && ori(hull[hull.size()-2], hull[hull.size()-1], v[i])<0){
10                 hull.pop_back();
11             }
12             hull.push_back(v[i]);
13         }
14         hull.pop_back();
15         reverse(v.begin(), v.end());
16     }
17     return hull;
18 }

```

5 Graph

5.1 Find-Bridge

```

1 vector<int> dep(MAX_N), low(MAX_N);
2 vector<pair<int, int>> bridge;
3 bitset<MAX_N> vis;
4
5 void dfs(int now, int pre){
6     vis[now] = 1;
7     low[now] = dep[now] = (now==1 ? 0 : dep[pre]+1);
8
9     for (auto x : G[now]){
10        if (x==pre){
11            continue;
12        }else if (vis[x]==0){
13            // 沒有走過的節點
14            dfs(x, now);
15            low[now] = min(low[now], low[x]);
16        }else if (vis[x]==1){
17            low[now] = min(low[now], dep[x]);
18        }
19    }
20
21    if (now!=1 && low[now]==dep[now]){
22        bridge.push_back({now, pre});
23    }
24    return;
25 }

```

5.2 Find-AP

```

1 vector<int> dep(MAX_N), low(MAX_N), AP;
2 bitset<MAX_N> vis;
3

```

```

4 void dfs(int now, int pre){
5     int cnt = 0;
6     bool ap = 0;
7     vis[now] = 1;
8     low[now] = dep[now] = (now==1 ? 0 : dep[pre]+1);
9
10    for (auto x : G[now]){
11        if (x==pre){
12            continue;
13        }else if (vis[x]==0){
14            cnt++;
15            dfs(x, now);
16            low[now] = min(low[now], low[x]);
17            if (low[x]>=dep[now]) ap=1;
18        }else{
19            low[now] = min(low[now], dep[x]);
20        }
21    }
22
23    if ((now==pre && cnt>=2) || (now!=pre && ap)){
24        AP.push_back(now);
25    }
26 }

```

5.3 MCMF

```

1 // frostray 會用，所以他超強
2 struct Flow {
3     struct Edge {
4         int u, rc, k, rv;
5     };
6     vector<vector<Edge>> G;
7     vector<int> par, par_eid;
8     Flow(int n) : G(n + 1), par(n + 1), par_eid(n + 1) {}
9
10    // v->u | 流量: c, cost: k
11    void add(int v, int u, int c, int k) {
12        G[v].push_back({u, c, k, (int)G[u].size()});
13        G[u].push_back({v, 0, -k, (int)G[v].size() - 1});
14    }
15    int spfa(int s, int t) {
16        fill(par.begin(), par.end(), -1);
17        vector<int> dis(par.size(), LONG_LONG_MAX);
18        vector<bool> in_q(par.size(), false);
19        queue<int> Q;
20        dis[s] = 0; in_q[s] = true;
21        Q.push(s);
22        while (!Q.empty()) {
23            int v = Q.front(); Q.pop();
24            in_q[v] = false;
25            for (int i = 0; i < (int)G[v].size(); i++) {
26                auto [u, rc, k, rv] = G[v][i];
27                if (rc > 0 && dis[v] + k < dis[u]) {
28                    dis[u] = dis[v] + k;
29                    par[u] = v;
30                    par_eid[u] = i;
31                    if (!in_q[u]) Q.push(u);
32                    in_q[u] = true;
33                }
34            }
35        }
36        return dis[t];
37    }

```



```

38 // <最大流・最小費用>
39 pair<int, int> flow(int s, int t) {
40     int fl = 0, cost = 0, d;
41     while ((d = spfa(s, t)) < LONG_LONG_MAX) {
42         int cur = LONG_LONG_MAX;
43         for (int v = t; v != s; v = par[v])
44             cur = min(cur, G[par[v]][par_eid[v]].rc);
45         fl += cur;
46         cost += d * cur;
47         for (int v = t; v != s; v = par[v]) {
48             G[par[v]][par_eid[v]].rc -= cur;
49             G[v][G[par[v]][par_eid[v]].rv].rc += cur;
50         }
51     }
52     return {fl, cost};
53 }
54 };
55

```

5.4 HLD

```

1 #include <bits/stdc++.h>
2 #define int long long
3 using namespace std;
4
5 const int N = 100005;
6 vector<int> G[N];
7 struct HLD {
8     vector<int> pa, sz, depth, mxson, topf, id;
9     int n, idcnt = 0;
10    HLD(int _n) : n(_n), pa(_n + 1), sz(_n + 1), depth(_n + 1), mxson(_n + 1), topf(_n + 1), id(_n + 1) {}
11    void dfs1(int v = 1, int p = -1) {
12        pa[v] = p; sz[v] = 1; mxson[v] = 0;
13        depth[v] = (p == -1 ? 0 : depth[p] + 1);
14        for (int u : G[v]) {
15            if (u == p) continue;
16            dfs1(u, v);
17            sz[v] += sz[u];
18            if (sz[u] > sz[mxson[v]]) mxson[v] = u;
19        }
20    }
21    void dfs2(int v = 1, int top = 1) {
22        id[v] = ++idcnt;
23        topf[v] = top;
24        if (mxson[v]) dfs2(mxson[v], top);
25        for (int u : G[v]) {
26            if (u == mxson[v] || u == pa[v]) continue;
27            dfs2(u, u);
28        }
29    }
30    // query 為區間資料結構
31    int path_query(int a, int b) {
32        int res = 0;
33        while (topf[a] != topf[b]) { /// 若不在同一條鍊上
34            if (depth[topf[a]] < depth[topf[b]]) swap(a, b);
35            res = max(res, 0ll); // query : l = id[topf[a]],
36                                // r = id[a]
37            a = pa[topf[a]];
38        }
39        /// 此時已在同一條鍊上
40        if (depth[a] < depth[b]) swap(a, b);
41

```

```

40     res = max(res, 0ll); // query : l = id[b], r = id[a]
41     return res;
42 }
43 };

```

5.5 Tree-Isomorphism

```

1 #include <bits/stdc++.h>
2 #pragma GCC optimize("O3,unroll-loops")
3 #define fastio ios::sync_with_stdio(0), cin.tie(0), cout.tie(0)
4 #define dbg(x) cerr << #x << " = " << x << endl
5 #define int long long
6 using namespace std;
7
8 // declare
9 const int MAX_SIZE = 2e5+5;
10 const int INF = 9e18;
11 const int MOD = 1e9+7;
12 const double EPS = 1e-6;
13 typedef vector<vector<int>> Graph;
14 typedef map<vector<int>, int> Hash;
15
16 int n, a, b;
17 int id1, id2;
18 pair<int, int> c1, c2;
19 vector<int> sz1(MAX_SIZE), sz2(MAX_SIZE);
20 vector<int> we1(MAX_SIZE), we2(MAX_SIZE);
21 Graph g1(MAX_SIZE), g2(MAX_SIZE);
22 Hash m1, m2;
23 int testcase=0;
24
25 void centroid(Graph &g, vector<int> &s, vector<int> &w, pair<int, int> &rec, int now, int pre){
26     s[now]=1;
27     w[now]=0;
28     for (auto x : g[now]){
29         if (x!=pre){
30             centroid(g, s, w, rec, x, now);
31             s[now]+=s[x];
32             w[now]=max(w[now], s[x]);
33         }
34     }
35     w[now]=max(w[now], n-s[now]);
36     if (w[now]<=n/2){
37         if (rec.first==0) rec.first=now;
38         else rec.second=now;
39     }
40 }
41
42 int dfs(Graph &g, Hash &m, int &id, int now, int pre){
43     vector<int> v;
44     for (auto x : g[now]){
45         if (x!=pre){
46             int add=dfs(g, m, id, x, now);
47             v.push_back(add);
48         }
49     }
50     sort(v.begin(), v.end());
51
52     if (m.find(v)!=m.end()){
53         return m[v];
54     }
55

```

```

55 }else{
56     m[v]=++id;
57     return id;
58 }
59 }
60
61 void solve1(){
62     // init
63     id1=0;
64     id2=0;
65     c1={0, 0};
66     c2={0, 0};
67     fill(sz1.begin(), sz1.begin()+n+1, 0);
68     fill(sz2.begin(), sz2.begin()+n+1, 0);
69     fill(we1.begin(), we1.begin()+n+1, 0);
70     fill(we2.begin(), we2.begin()+n+1, 0);
71     for (int i=1; i<=n; i++){
72         g1[i].clear();
73         g2[i].clear();
74     }
75     m1.clear();
76     m2.clear();
77
78     // input
79     cin >> n;
80     for (int i=0; i<=n-1; i++){
81         cin >> a >> b;
82         g1[a].push_back(b);
83         g1[b].push_back(a);
84     }
85     for (int i=0; i<=n-1; i++){
86         cin >> a >> b;
87         g2[a].push_back(b);
88         g2[b].push_back(a);
89     }
90
91     // get tree centroid
92     centroid(g1, sz1, we1, c1, 1, 0);
93     centroid(g2, sz2, we2, c2, 1, 0);
94
95     // process
96     int res1=0, res2=0, res3=0;
97     if (c2.second!=0){
98         res1=dfs(g1, m1, id1, c1.first, 0);
99         m2=m1;
100         id2=id1;
101         res2=dfs(g2, m1, id1, c2.first, 0);
102         res3=dfs(g2, m2, id2, c2.second, 0);
103     }else if (c1.second!=0){
104         res1=dfs(g2, m1, id1, c2.first, 0);
105         m2=m1;
106         id2=id1;
107         res2=dfs(g1, m1, id1, c1.first, 0);
108         res3=dfs(g1, m2, id2, c1.second, 0);
109     }else{
110         res1=dfs(g1, m1, id1, c1.first, 0);
111         res2=dfs(g2, m1, id1, c2.first, 0);
112     }
113
114     // output
115     cout << (res1==res2 || res1==res3 ? "YES" : "NO") << endl;
116
117     return;
118 }
119

```

```

120 }
121
122 signed main(void){
123     fastio;
124
125     int t=1;
126     cin >> t;
127     while (t--){
128         solve1();
129     }
130     return 0;
131 }

```

5.6 Bridge BCC

```

1 #include <bits/stdc++.h>
2 using namespace std;
3
4 const int N = 200005;
5 vector<int> G[N];
6 int low[N], depth[N];
7 bool vis[N];
8 vector<vector<int>> bcc;
9 stack<int> stk;
10
11 void dfs(int v, int p) {
12     stk.push(v);
13     vis[v] = true;
14     low[v] = depth[v] = (p == -1 ? 1 : depth[p] + 1);
15     for (int u : G[v]) {
16         if (u == p) continue;
17         if (!vis[u]) {
18             /// (v, u) 是樹邊
19             dfs(u, v);
20             low[v] = min(low[v], low[u]);
21         } else {
22             /// (v, u) 是回邊
23             low[v] = min(low[v], depth[u]);
24         }
25     }
26     /// v 在不依靠父邊的情況下永遠沒辦法走到它的祖先
27     if (low[v] == depth[v]) {
28         bcc.emplace_back();
29         while (stk.top() != v) {
30             bcc.back().push_back(stk.top());
31             stk.pop();
32         }
33         bcc.back().push_back(stk.top());
34         stk.pop();
35     }
36 }

```

5.7 Cut BCC

```

1 #include <bits/stdc++.h>
2 using namespace std;
3
4 const int N = 200005;
5 vector<int> G[N];

```

```

6 int low[N], depth[N];
7 bool vis[N];
8 vector<vector<int>> bcc;
9 stack<int> stk;
10
11 void dfs(int v, int p) {
12     stk.push(v);
13     vis[v] = true;
14     low[v] = depth[v] = (p == -1 ? 1 : depth[p] + 1);
15     for (int u : G[v]) {
16         if (u == p) continue;
17         if (!vis[u]) {
18             /// (v, u) 是樹邊
19             dfs(u, v);
20             low[v] = min(low[v], low[u]);
21             /// u 無法在不經過父邊的情況走到 v 的祖先
22             if (low[u] >= depth[v]) {
23                 bcc.emplace_back();
24                 while (stk.top() != u) {
25                     bcc.back().push_back(stk.top());
26                     stk.pop();
27                 }
28                 bcc.back().push_back(stk.top());
29                 stk.pop();
30                 bcc.back().push_back(v);
31             }
32         } else {
33             /// (v, u) 是回邊
34             low[v] = min(low[v], depth[u]);
35         }
36     }
37 }

```

5.8 圓方樹

```

1 #include <bits/stdc++.h>
2 #define lp(i,a,b) for(int i=(a);i<(b);i++)
3 #define pii pair<int,int>
4 #define pb push_back
5 #define ins insert
6 #define ff first
7 #define ss second
8 #define opa(x) cerr << #x << " = " << x << ", ";
9 #define op(x) cerr << #x << " = " << x << endl;
10 #define ops(x) cerr << x;
11 #define etr cerr << endl;
12 #define spc cerr << ' ';
13 #define BAE(x) (x).begin(), (x).end()
14 #define STL(x) cerr << #x << " : "; for(auto &qwe:x) cerr << qwe << ' '; cerr << endl;
15 #define deb1 cerr << "deb1" << endl;
16 #define deb2 cerr << "deb2" << endl;
17 #define deb3 cerr << "deb3" << endl;
18 #define deb4 cerr << "deb4" << endl;
19 #define deb5 cerr << "deb5" << endl;
20 #define bye exit(0);
21 using namespace std;
22
23 const int mxn = (int)(2e5) + 10;
24 const int mxlg = 17;
25 int last_special_node = (int)(1e5) + 1;
26 vector<int> E[mxn], F[mxn];

```

```

27
28 struct edg{
29     int fr, to;
30     edg(int _fr, int _to){
31         fr = _fr;
32         to = _to;
33     }
34 };
35 ostream& operator<<(ostream& os, edg x){os << x.fr << "--" <<
36     x.to;}
37 vector<edg> EV;
38
39 void tarjan(int v, int par, stack<int>& S){
40     static vector<int> dfn(mxn), low(mxn);
41     static vector<bool> to_add(mxn);
42     static int nowT = 0;
43
44     int childs = 0;
45     nowT += 1;
46     dfn[v] = low[v] = nowT;
47     for(auto &ne:E[v]){
48         int i = EV[ne].to;
49         if(i == par) continue;
50         if(!dfn[i]){
51             S.push(ne);
52             tarjan(i, v, S);
53             childs += 1;
54             low[v] = min(low[v], low[i]);
55
56             if(par >= 0 && low[i] >= dfn[v]){
57                 vector<int> bcc;
58                 int tmp;
59                 do{
60                     tmp = S.top(); S.pop();
61                     if(!to_add[EV[tmp].fr]){
62                         to_add[EV[tmp].fr] = true;
63                         bcc.pb(EV[tmp].fr);
64                     }
65                     if(!to_add[EV[tmp].to]){
66                         to_add[EV[tmp].to] = true;
67                         bcc.pb(EV[tmp].to);
68                     }
69                 }while(tmp != ne);
70                 for(auto &j:bcc){
71                     to_add[j] = false;
72                     F[last_special_node].pb(j);
73                     F[j].pb(last_special_node);
74                 }
75                 last_special_node += 1;
76             }
77         } else{
78             low[v] = min(low[v], dfn[i]);
79             if(dfn[i] < dfn[v]){ // edge i--v will be visited
80                 twice at here, but we only need one.
81                 S.push(ne);
82             }
83         }
84     }
85
86     int dep[mxn], jmp[mxn][mxlg];
87     void dfs_lca(int v, int par, int depth){
88         dep[v] = depth;
89         for(auto &i:F[v]){
90             if(i == par) continue;

```



```

91     jmp[i][0] = v;
92     dfs_lca(i, v, depth + 1);
93 }
94 }
95
96 inline void build_lca(){
97     jmp[1][0] = 1;
98     dfs_lca(1, -1, 1);
99     lp(j, 1, mxlg){
100         lp(i, 1, mxn){
101             jmp[i][j] = jmp[jmp[i][j-1]][j-1];
102         }
103     }
104 }
105
106 inline int lca(int x, int y){
107     if(dep[x] < dep[y]){ swap(x, y); }
108
109     int diff = dep[x] - dep[y];
110     lp(j, 0, mxlg){
111         if((diff >> j) & 1){
112             x = jmp[x][j];
113         }
114     }
115     if(x == y) return x;
116
117     for(int j = mxlg - 1; j >= 0; j--){
118         if(jmp[x][j] != jmp[y][j]){
119             x = jmp[x][j];
120             y = jmp[y][j];
121         }
122     }
123     return jmp[x][0];
124 }
125
126 inline bool can_reach(int fr, int to){
127     if(dep[to] > dep[fr]) return false;
128
129     int diff = dep[fr] - dep[to];
130     lp(j, 0, mxlg){
131         if((diff >> j) & 1){
132             fr = jmp[fr][j];
133         }
134     }
135     return fr == to;
136 }
137
138 int main(){
139     ios::sync_with_stdio(false); cin.tie(0);
140     // freopen("test_input.txt", "r", stdin);
141     int n, m, q; cin >> n >> m >> q;
142     lp(i, 0, m){
143         int u, v; cin >> u >> v;
144         E[u].pb(EV.size());
145         EV.pb(edg(u, v));
146         E[v].pb(EV.size());
147         EV.pb(edg(v, u));
148     }
149     E[0].pb(EV.size());
150     EV.pb(edg(0, 1));
151     stack<int> S;
152     tarjan(0, -1, S);
153     build_lca();
154
155     lp(queries, 0, q){
156         int fr, to, relay; cin >> fr >> to >> relay;

```

```

157         if(fr == relay || to == relay){
158             cout << "NO\n";
159             continue;
160         }
161         if((can_reach(fr, relay) || can_reach(to, relay)) &&
162            dep[relay] >= dep[lca(fr, to)]){
163             cout << "NO\n";
164             continue;
165         }
166         cout << "YES\n";
167     }

```

5.9 Dijkstra

```

1 // 可以在  $O(E \log E)$  的時間複雜度解決在無負權有向圖單點源最短路
2
3 const int INF = 2e18; // 要確保 INF 開的足夠大
4
5 vector<vector<pair<int, int>>> G(n); // G[i] = <節點, 權重>
6 vector<int> dis(n, INF);
7 priority_queue<pair<int, int>, vector<pair<int, int>>,
8               greater<pair<int, int>>> pq;
9
10 dis[s] = 0;
11 pq.push({0, s});
12
13 while (pq.size()){
14     int now_dis = pq.top().first;
15     int now_node = pq.top().second;
16     pq.pop();
17
18     if (now_dis > dis[now_node]) continue;
19
20     for (auto x : G[now_node]){
21         if (now_dis + x.second < dis[x.first]){
22             dis[x.first] = now_dis + x.second;
23             pq.push({x.first, dis[x.first]});
24         }
25     }
26 }

```

5.10 SCC 與縮點

```

1 /*
2 給定一個有向圖，迴傳傳縮點後的圖、SCC 的資訊
3 所有點都以 based-0 編號
4
5 函式：
6 SCC_compress G(n): 宣告一個有 n 個點的圖
7 .add_edge(u, v): 加上一條邊 u -> v
8 .compress:  $O(n \log n)$  計算 G3、SCC、SCC_id 的資訊，並把縮點後
9 的結果存在 result 裡
10
11 SCC[i] = 某個 SCC 中的所有點
12 SCC_id[i] = 第 i 個點在第幾個 SCC
13 */
14 // c8b146
15 struct SCC_compress{

```

```

16 int n = 0, m = 0;
17 vector<vector<int>> G, inv_G, result;
18 vector<pair<int, int>> edges;
19 vector<bool> vis;
20 vector<int> order;
21
22 vector<vector<int>> SCC;
23 vector<int> SCC_id;
24
25 SCC_compress(int _n){
26     n = _n;
27     G.resize(n);
28     inv_G.resize(n);
29     result.resize(n);
30     vis.resize(n);
31     SCC_id.resize(n);
32 }
33
34 void add_edge(int u, int v){
35     G[u].push_back(v);
36     inv_G[v].push_back(u);
37     edges.push_back({u, v});
38     m++;
39 }
40
41 void dfs1(vector<vector<int>> &G, int now){
42     vis[now] = 1;
43     for (auto x : G[now]){
44         if (vis[x]==0){
45             dfs1(G, x);
46         }
47     }
48     order.push_back(now);
49     return;
50 }
51
52 void dfs2(vector<vector<int>> &G, int now){
53     SCC_id[now] = SCC.size()-1;
54     SCC.back().push_back(now);
55     vis[now] = 1;
56
57     for (auto x : G[now]){
58         if (vis[x]==0){
59             dfs2(G, x);
60         }
61     }
62     return;
63 }
64
65 void compress(){
66     fill(vis.begin(), vis.end(), 0);
67     for (int i=0; i<n; i++){
68         if (vis[i]==0){
69             dfs1(G, i);
70         }
71     }
72
73     fill(vis.begin(), vis.end(), 0);
74     reverse(order.begin(), order.end());
75     for (int i=0; i<n; i++){
76         if (vis[order[i]]==0){
77             SCC.push_back(vector<int>());
78             dfs2(inv_G, order[i]);
79         }
80     }

```

```

81     for (int i=0 ; i<m ; i++){
82         if (SCC_id[edges[i].first]!=SCC_id[edges[i].
            second]){
83             result[SCC_id[edges[i].first]].push_back(
                SCC_id[edges[i].second]);
84         }
85     }
86     for (int i=0 ; i<SCC.size() ; i++){
87         sort(result[i].begin(), result[i].end());
88         result[i].resize(unique(result[i].begin(), result
            [i].end())-result[i].begin());
89     }
90 }
91 };

```

```

47     }
48 }
49 if (dis[t]==INF) break;
50
51 fill(it.begin(), it.end(), 0);
52 while (true){
53     int df = dfs(s, t, INF);
54     if (df<=0) break;
55     ans += df;
56 }
57 }
58 return ans;
59 }
60 };

```

5.11 Dinic

```

1 // 時間複雜度：O(V^2E)
2 struct Flow{
3     struct Edge{
4         int v, rc, rid;
5     };
6     vector<vector<Edge>> G;
7     void add(int u, int v, int c){
8         G[u].push_back({v, c, G[v].size()});
9         G[v].push_back({u, 0, G[u].size()-1});
10    }
11    vector<int> dis, it;
12
13    Flow(int n){
14        G.resize(n);
15        dis.resize(n);
16        it.resize(n);
17    }
18
19    int dfs(int u, int t, int f){
20        if (u==t || f==0) return f;
21        for (int &i=it[u] ; i<G[u].size() ; i++){
22            auto &[v, rc, rid] = G[u][i];
23            if (dis[v]!=dis[u]+1) continue;
24            int df = dfs(v, t, min(f, rc));
25            if (df<=0) continue;
26            rc -= df;
27            G[v][rid].rc += df;
28            return df;
29        }
30        return 0;
31    }
32
33    int flow(int s, int t){
34        int ans = 0;
35        while (true){
36            fill(dis.begin(), dis.end(), INF);
37            queue<int> q;
38            q.push(s);
39            dis[s] = 0;
40
41            while (q.size()){
42                int u = q.front(); q.pop();
43                for (auto [v, rc, rid] : G[u]){
44                    if (rc<=0 || dis[v]>INF) continue;
45                    dis[v] = dis[u]+1;
46                    q.push(v);

```

6 Math

6.1 Burnside's-Lemma

$$\sum_{k=1}^n \frac{c(k)}{n}$$

- n : 有多少種置換方式 (例如：旋轉方式)
- $c(k)$: 所有可能中 · 經過 k 次旋轉後 · 仍不會和別人相同的方式的數量

6.2 線性篩

```

1 const int MAX_N = 5e5;
2
3 // lpf[i] = i 的最小質因數
4 vector<int> prime, lpf(MAX_N);
5
6 void prime_init(){
7     for (int i=2 ; i<MAX_N ; i++){
8         if (lpf[i]==0){
9             lpf[i]=i;
10            prime.push_back(i);
11        }
12
13        for (int j : prime){
14            if (i*j>=MAX_N) break;
15            lpf[i*j]=j;
16            if (lpf[i]==j) break;
17        }
18    }
19 }

```

6.3 Lucas's-Theorem

```

1 // 對於很大的  $C^n_m$  對質數  $p$  取模 · 只要  $p$  不大就可以用。
2 int Lucas(int n, int m, int p){
3     if (m==0) return 1;
4     return (C(n%p, m%p, p)*Lucas(n/p, m/p, p)%p);
5 }

```

6.4 Matrix

```

1 struct Matrix{
2     int n, m;
3     vector<vector<int>> arr;
4
5     Matrix(int _n, int _m){
6         n = _n;
7         m = _m;
8         arr.resize(n, vector<int>(m));
9     }
10
11     Matrix operator * (const Matrix B){
12         Matrix ret(n, B.m);
13
14         for (int i=0 ; i<n ; i++){
15             for (int j=0 ; j<B.m ; j++){
16                 for (int k=0 ; k<m ; k++){
17                     ret.arr[i][j] += arr[i][k]*B.arr[k][j];
18                     ret.arr[i][j] %= MOD;
19                 }
20             }
21         }
22         return ret;
23     }
24 };
25

```

6.5 最大質因數

```

1 void max_fac(int n, int &ret){
2     if (n<=ret || n<2) return;
3     if (isprime(n)){
4         ret = max(ret, n);
5         return;
6     }
7
8     int p = Pollard_Rho(n);
9     max_fac(p, ret), max_fac(n/p, ret);
10 }

```

6.6 中國剩餘定理 (m 互質)

```

1 vector<int> a, m;
2
3 int extgcd(int a, int b, int &x, int &y){
4     if (b==0){
5         x=1, y=0;
6         return a;
7     }
8
9     int ret=extgcd(b, a%b, y, x);
10    y-=a/b*x;
11    return ret;
12 }
13
14 // n = 有幾個式子 · 求解  $x \equiv a_i \pmod{m_i}$ 
15 int CRT(int n, vector<int> &a, vector<int> &m){
16     int p=1, ans=0;

```

```

17 |
18 | vector<int> M(n), inv_M(n);
19 |
20 | for (int i=0 ; i<n ; i++) p*=m[i];
21 | for (int i=0 ; i<n ; i++){
22 |     M[i]=p/m[i];
23 |     extgcd(M[i], m[i], inv_M[i], tmp);
24 |     ans+=a[i]*inv_M[i]*M[i];
25 |     ans%=p;
26 | }
27 |
28 | return (ans%p+p)%p;
29 | }

```

6.7 中國剩餘定理 (m 不互質)

```

1 | int extgcd(int a, int b, int &x, int &y){
2 |     if (b==0){
3 |         x=1, y=0;
4 |         return a;
5 |     }
6 |
7 |     int ret=extgcd(b, a%b, y, x);
8 |     y-=a/b*x;
9 |     return ret;
10 | }
11 |
12 | // 對於方程組的式子兩兩求解
13 | // {是否有解, {a, m}}
14 | pair<bool, pair<int, int>> CRT(int a1, int m1, int a2, int m2
15 | ){
16 |     int g=__gcd(m1, m2);
17 |     if ((a2-a1)%g!=0) return {0, {-1, -1}};
18 |
19 |     int x, y;
20 |     extgcd(m1, m2, x, y);
21 |
22 |     x=(a2-a1)*x/g; // 兩者不能相反
23 |     a1=x*m1+a1;
24 |     m1=m1*m2/g;
25 |     a1=(a1%m1+m1)%m1;
26 |     return {1, {a1, m1}};

```

6.8 歐拉公式

```

1 | // phi(n) = 小於 n 並與 n 互質的正整數數量。
2 | // O(sqrt(n)) · 回傳 phi(n)
3 | int phi(int n){
4 |     int ret = n;
5 |
6 |     for (int i=2 ; i*i<=n ; i++){
7 |         if (n%i==0){
8 |             while (n%i==0) n /= i;
9 |             ret = ret*(i-1)/i;
10 |        }
11 |    }
12 |    if (n>1) ret = ret*(n-1)/n;
13 |

```

```

14 |     return ret;
15 | }
16 |
17 | // O(n log n) · 回傳 1~n 的 phi 值
18 | vector<int> phi_1_to_n(int n){
19 |     vector<int> phi(n+1);
20 |     phi[0]=0;
21 |     phi[1]=1;
22 |
23 |     for (int i=2 ; i<=n ; i++){
24 |         phi[i]=i-1;
25 |     }
26 |
27 |     for (int i=2 ; i<=n ; i++){
28 |         for (int j=2*i ; j<=n ; j+=i){ // 枚舉所有倍數
29 |             phi[j]-=phi[i];
30 |         }
31 |     }
32 |
33 |     return phi;
34 | }

```

6.9 卡特蘭數

任意括號序列： $C_n = \frac{1}{n+1} \binom{2n}{n}$

6.10 歐拉定理

若 a, m 互質，則：

$$a^n \bmod m = a^{n \bmod \varphi(m)} \bmod m$$

若 a, m 可能是任何數，則：

$$a^{\varphi(m) + [n \bmod \varphi(m)]} \bmod m$$

6.11 Fraction

```

1 | #include <bits/stdc++.h>
2 | using namespace std;
3 |
4 | /// Fraction template starts ///
5 | #define fraction_template_bonus_check
6 | const long long ll_overflow_warning_value = (long long)(3e9);
7 |
8 | long long gcd(long long a, long long b){
9 |     if(a == 0) return b;
10 |    if(b == 0) return a;
11 |    if(a < b) return gcd(b,a);
12 |    return gcd(b, a%b);
13 | }
14 | struct frac{
15 |     long long a, b;
16 |     frac(long long _a = 0, long long _b = 1){
17 |         a = _a; b = _b;
18 |         if(b == 0){
19 |             cerr << "Error: division by zero\n";

```

```

20 |             cerr << "Called : Constructor(" << _a << ", " <<
21 |                 _b << ")\n";
22 |             return;
23 |         }
24 |         if(a == 0){b = 1; return;}
25 |         if(b < 0){a = -a; b = -b;}
26 |         long long gcd_ab = gcd(std::abs(a), b);
27 |         if(gcd_ab != 1){a /= gcd_ab; b /= gcd_ab;}
28 |
29 |         #ifdef fraction_template_bonus_check
30 |         if(std::abs(a) > ll_overflow_warning_value || b >
31 |             ll_overflow_warning_value){
32 |             cerr << "Overflow warning : " << a << "/" << b <<
33 |                 "\n";
34 |             #endif // fraction_template_bonus_check
35 |         }
36 |         frac operator+(frac const &B){
37 |             return frac(a*(B.b)+(B.a)*b, b*(B.b));
38 |         }
39 |         frac operator-(frac const &B){
40 |             return frac(a*(B.b)-(B.a)*b, b*(B.b));
41 |         }
42 |         frac operator*(frac const &B){
43 |             return frac(a*(B.a), b*(B.b));
44 |         }
45 |         frac operator/(frac const &B){
46 |             return frac(a*(B.b), b*(B.a));
47 |         }
48 |         frac abs(){
49 |             a = std::abs(a);
50 |             return *this;
51 |         }
52 |
53 |         bool operator<(frac const &B){
54 |             return a*B.b < B.a*b;
55 |         }
56 |         bool operator<=(frac const &B){
57 |             return a*B.b <= B.a*b;
58 |         }
59 |         bool operator>(frac const &B){
60 |             return a*B.b > B.a*b;
61 |         }
62 |         bool operator>=(frac const &B){
63 |             return a*B.b >= B.a*b;
64 |         }
65 |         bool operator==(frac const &B){
66 |             return a * B.b == B.a * b;
67 |         }
68 |         bool operator!=(frac const &B){
69 |             return a * B.b != B.a * b;
70 |         }
71 |     };
72 |     ostream& operator<<(ostream &os, const frac& A){
73 |         os << A.a << "/" << A.b;
74 |         return os;
75 |     }
76 |     /// Fraction template ends ///
77 |
78 | void test(frac A, frac B){
79 |     cout << "A = " << A << endl;
80 |     cout << "B = " << B << endl;
81 |     cout << endl;
82 |     cout << "A + B = " << A + B << endl;
83 |     cout << "A - B = " << A - B << endl;
84 |     cout << "A * B = " << A * B << endl;
85 |     cout << "A / B = " << A / B << endl;

```

```

83 |     cout << endl;
84 |     cout << "(A < B) = " << (A < B) << endl;
85 |     cout << "(A <= B) = " << (A <= B) << endl;
86 |     cout << "(A > B) = " << (A > B) << endl;
87 |     cout << "(A >= B) = " << (A >= B) << endl;
88 |     cout << "(A == B) = " << (A == B) << endl;
89 |     cout << "(A != B) = " << (A != B) << endl;
90 |     cout << "-----\n";
91 |     return;
92 | }
93 |
94 | int main(){
95 |     frac tmp1(-7, 2);
96 |     frac tmp2(5, 3);
97 |     test(tmp1, tmp2);
98 |
99 |     frac tmp3(-7);
100 |    frac tmp4(0);
101 |    test(tmp3, tmp4);
102 |    return 0;
103 | }

```

6.12 錯排公式

錯排公式：(n 個人中，每個人皆不再原來位置的組合數)

$$dp_i = \begin{cases} 1 & i = 0 \\ 0 & i = 1 \\ (i-1)(dp_{i-1} + dp_{i-2}) & \text{otherwise} \end{cases}$$

6.13 Quick-Pow

```

1 | int qp(int b, int p, int m = MOD){
2 |     int ret = 1;
3 |     for ( ; p ; p>>=1){
4 |         if (p&1) ret = ret*b%m;
5 |         b = b*b%m;
6 |     }
7 |     return ret;
8 | }

```

6.14 二元一次方程式

$$\begin{cases} ax + by = c \\ dx + ey = f \end{cases} = \begin{cases} x = \frac{ed-bf}{ad-bc} \\ y = \frac{af-ec}{ad-bc} \end{cases}$$

若 $x = \frac{0}{0}$ 且 $y = \frac{0}{0}$ ，則代表無限多組解。若 $x = \frac{*}{0}$ 且 $y = \frac{*}{0}$ ，則代表無解。

6.15 Josephus

```

1 | // 有 n 個人，第偶數個報數的人被刪掉，問第 k 個被踢掉的是誰
2 | int solve(int n, int k){
3 |     if (n==1) return 1;

```

```

4 |     if (k<=(n+1)/2){
5 |         if (2*k>n) return 2*k%n;
6 |         else return 2*k;
7 |     }else{
8 |         int res=solve(n/2, k-(n+1)/2);
9 |         if (n&1) return 2*res+1;
10 |        else return 2*res-1;
11 |     }
12 | }

```

6.16 數論分塊

```

1 | /*
2 | 時間複雜度為 O(sqrt(n))
3 | 區間為 [L, r]
4 | */
5 | for(int i=1 ; i<=n ; i++){
6 |     int l = i, r = n/(n/i);
7 |     i = r;
8 |     ans.push_back(r);
9 | }

```

6.17 Miller-Rabin

```

1 | // O(1)
2 | typedef Uint unsigned long long
3 | Uint modmul(Uint a, Uint b, Uint m) {
4 |     int ret = a*b - m*(Uint)(1.L/m*a*b);
5 |     return ret + m*(ret < 0) - m*(ret>=(int)m);
6 | }
7 |
8 | int qp(int b, int p, int m){
9 |     int ret = 1;
10 |    for ( ; p ; p>>=1){
11 |        if (p&1){
12 |            ret = modmul(ret, b, m);
13 |        }
14 |        b = modmul(b, b, m);
15 |    }
16 |    return ret;
17 | }
18 |
19 | // ed23aa
20 | vector<int> llsprp = {2, 325, 9375, 28178, 450775, 9780504,
21 |                     1795265022};
22 | bool isprime(int n, vector<int> sprp = llsprp){
23 |     if (n==2) return 1;
24 |     if (n<2 || n%2==0) return 0;
25 |
26 |     int t = 0;
27 |     int u = n-1;
28 |     for ( ; u%2==0 ; t++) u>>=1;
29 |
30 |     for (int i=0 ; i<sprp.size() ; i++){
31 |         int a = sprp[i]%n;
32 |         if (a==0 || a==1 || a==n-1) continue;
33 |         int x = qp(a, u, n);
34 |         if (x==1 || x==n-1) continue;
35 |         for (int j=0 ; j<t ; j++){

```

```

35 |             x = modmul(x, x, n);
36 |             if (x==1) return 0;
37 |             if (x==n-1) break;
38 |         }
39 |
40 |         if (x==n-1) continue;
41 |         return 0;
42 |     }
43 |
44 |     return 1;
45 | }

```

6.18 Pollard-Rho

```

1 | mt19937 seed(chrono::steady_clock::now().time_since_epoch().
2 | count());
3 | int rnd(int l, int r){
4 |     return uniform_int_distribution<int>(l, r)(seed);
5 | }
6 | // O(n^{1/4}) 回傳 1 或自己的因數、記得先判斷 n 是不是質數
7 | // (用 Miller-Rabin)
8 | // c1670c
9 | int Pollard_Rho(int n){
10 |    int s = 0, t = 0;
11 |    int c = rnd(1, n-1);
12 |
13 |    int step = 0, goal = 1;
14 |    int val = 1;
15 |
16 |    for (goal=1 ; ; goal<=1, s=t, val=1){
17 |        for (step=1 ; step<=goal ; step++){
18 |
19 |            t = ((__int128)t*t+c)%n;
20 |            val = ((__int128)val*abs(t-s)%n;
21 |
22 |            if ((step % 127) == 0){
23 |                int d = __gcd(val, n);
24 |                if (d>1) return d;
25 |            }
26 |
27 |            int d = __gcd(val, n);
28 |            if (d>1) return d;
29 |        }
30 |    }

```

7 Misc

7.1 Xor-Basis

```

1 | vector<int> basis;
2 | void add_vector(int x){
3 |     for (auto v : basis){
4 |         x=min(x, x^v);
5 |     }
6 |     if (x) basis.push_back(x);

```

```

7 }
8
9 // 給一數字集合 S · 求能不能 XOR 出 x
10 bool check(int x){
11     for (auto v : basis){
12         x=min(x, x^v);
13     }
14     return x;
15 }
16
17 // 給一數字集合 S · 求能 XOR 出多少數字
18 // 答案等於 2^{basis 的大小}
19
20 // 給一數字集合 S · 求 XOR 出最大的數字
21 int get_max(){
22     int ans=0;
23     for (auto v : basis){
24         ans=max(ans, ans^v);
25     }
26     return ans;
27 }

```

7.2 Default-Code

```

1 #include <bits/stdc++.h>
2 #define int long long
3 #define fastio ios::sync_with_stdio(0), cin.tie(0);
4 using namespace std;
5
6 #ifdef LOCAL
7 #define cout cout << "\033[0;32m"
8 #define cerr cerr << "\033[0;31m"
9 #define endl "\n" << "\033[0m"
10 #else
11 #pragma GCC optimize("O3,unroll-loops")
12 #pragma GCC target("avx,avx2,sse,sse2,sse3,sse4,popcnt")
13 #define endl "\n"
14 #endif
15
16 const int MAX_N = 5e5+10;
17 const int INF = 2e18;
18
19 int n, tmp;
20 vector<int> v;
21
22 void solve1(){
23
24     return;
25 }
26
27 signed main(){
28
29     fastio;
30
31     int t = 1;
32     while (t--){
33         solve1();
34     }
35
36     return 0;
37 }

```

7.3 Radix-Sort

```

1 // 值域限制: 0 ~ 1073741823(2^30-1)
2 inline void radix_sort(vector<int> &a, int n){
3     static int cnt[32768] = {0};
4     vector<int> tmpa(n);
5     for(int i = 0; i < n; ++i)
6         ++cnt[a[i] & 32767];
7     for(int i = 1; i < 32768; ++i)
8         cnt[i] += cnt[i-1];
9     static int temp;
10    for(int i = n-1; i >= 0; --i){
11        temp = a[i] & 32767;
12        --cnt[temp];
13        tmpa[cnt[temp]] = a[i];
14    }
15
16    static int cnt2[32768] = {0};
17    for(int i = 0; i < n; ++i)
18        ++cnt2[(tmpa[i]>>15)];
19    for(int i = 1; i < 32768; ++i)
20        cnt2[i] += cnt2[i-1];
21
22    for(int i = n-1; i >= 0; --i){
23        temp = (tmpa[i]>>15);
24        --cnt2[temp];
25        a[cnt2[temp]] = tmpa[i];
26    }
27    return;
28 }

```

7.4 Set-Pq-Sort

```

1 // priority_queue
2 struct cmp{
3     bool operator () (Data a, Data b){
4         return a.x<b.x;
5     }
6 };
7 priority_queue<Data, vector<Data>, cmp> pq;
8
9 // set
10 struct Data{
11     int x;
12
13     bool operator < (const Data &b){
14         return x<b.x;
15     }
16 };

```

7.5 2-SAT

```

1 #include <bits/stdc++.h>
2 using namespace std;
3
4 struct TWO_SAT {
5     int n, N;
6     vector<vector<int>> G, rev_G;
7     deque<bool> used;

```

```

8     vector<int> order, comp;
9     deque<bool> assignment;
10    void init(int _n) {
11        n = _n;
12        N = _n * 2;
13        G.resize(N + 5);
14        rev_G.resize(N + 5);
15    }
16    void dfs1(int v) {
17        used[v] = true;
18        for (int u : G[v]) {
19            if (!used[u])
20                dfs1(u);
21        }
22        order.push_back(v);
23    }
24    void dfs2(int v, int c1) {
25        comp[v] = c1;
26        for (int u : rev_G[v]) {
27            if (comp[u] == -1)
28                dfs2(u, c1);
29        }
30    }
31    bool solve() {
32        order.clear();
33        used.assign(N, false);
34        for (int i = 0; i < N; ++i) {
35            if (!used[i])
36                dfs1(i);
37        }
38        comp.assign(N, -1);
39        for (int i = 0, j = 0; i < N; ++i) {
40            int v = order[N - i - 1];
41            if (comp[v] == -1)
42                dfs2(v, j++);
43        }
44        assignment.assign(n, false);
45        for (int i = 0; i < N; i += 2) {
46            if (comp[i] == comp[i + 1])
47                return false;
48            assignment[i / 2] = (comp[i] > comp[i + 1]);
49        }
50        return true;
51    }
52    void add_disjunction(int a, bool na, int b, bool nb) { //
53        // A or B
54        // na means whether a is negative or not
55        // nb means whether b is negative or not
56        a = 2 * a ^ na;
57        b = 2 * b ^ nb;
58        int neg_a = a ^ 1;
59        int neg_b = b ^ 1;
60        G[neg_a].push_back(b);
61        G[neg_b].push_back(a);
62        rev_G[b].push_back(neg_a);
63        rev_G[a].push_back(neg_b);
64        return;
65    }
66    void get_result(vector<int> &res) {
67        res.clear();
68        for (int i = 0; i < n; ++i)
69            res.push_back(assignment[i]);
70    }
71 }
72 /* CSES Giant Pizza
73 3 5

```

```

73 + 1 + 2
74 - 1 + 3
75
76 - + + + -
77 */
78 int main() {
79     int n, m;
80     cin >> n >> m;
81     TWO_SAT E;
82     E.init(m);
83
84     char c1, c2;
85     int inp1, inp2;
86     for (int i = 0; i < n; i++) {
87         cin >> c1 >> inp1;
88         cin >> c2 >> inp2;
89         E.add_disjunction(inp1 - 1, c1 == '-', inp2 - 1, c2
90             == '-');
91     }
92
93     bool able = E.solve();
94     if (able) {
95         vector<int> ans;
96         E.get_result(ans);
97         for (int i : ans)
98             cout << (i == true ? '+' : '-') << ' ';
99         cout << '\n';
100     } else {
101         cout << "IMPOSSIBLE\n";
102     }
103
104     return 0;
105 }

```

7.6 Enumerate-Subset

```

1 // 時間複雜度  $O(3^n)$ 
2 // 枚舉每個 mask 的子集
3 for (int mask=0 ; mask<(1<n) ; mask++){
4     for (int s=mask ; s>=0 ; s=(s-1)&m){
5         // s 是 mask 的子集
6         if (s==0) break;
7     }
8 }

```

7.7 Fast-Input

```

1 // fast IO
2 // 6f8879
3 inline char readchar(){
4     static char buffer[BUFSIZ], * now = buffer + BUFSIZ, *
5         end = buffer + BUFSIZ;
6     if (now == end)
7     {
8         if (end < buffer + BUFSIZ)
9             return EOF;
10        end = (buffer + fread(buffer, 1, BUFSIZ, stdin));
11        now = buffer;
12    }
13 }

```

```

12     return *now++;
13 }
14 inline int nextint(){
15     int x = 0, c = readchar(), neg = false;
16     while(('0' > c || c > '9') && c!='-' && c!=EOF) c =
17         readchar();
18     if(c == '-') neg = true, c = readchar();
19     while('0' <= c && c <= '9') x = (x<<3) + (x<<1) + (c^'0')
20         , c = readchar();
21     if(neg) x = -x;
22     return x; // returns 0 if EOF
23 }

```

7.8 setup

```

1 se nu rnu bs=2 sw=4 ts=4 hls ls=2 si acd bo=all mouse=a
2
3 :inoremap " ""<Esc>i
4 :inoremap {<CR> {<CR><Esc>ko
5 :inoremap [{ {<ESC>i
6
7 map <F9> :w<bar>!g++ "%" -o %:r -std=c++17 -Wall -Wextra -
8     Wshadow -O2 -DLOCAL -g -fsanitize=undefined,address<CR>
9 map <F8> :!./%:r<CR>
10
11 ca hash w !cpp -dD -P -fpreprocessed \\\ tr -d "[:space:]" \\\
12     md5sum \\\ cut -c-6

```

8 String

8.1 Hash

```

1 mt19937 rnd(chrono::steady_clock::now().time_since_epoch().
2     count());
3 int A = rnd(), B = 1000000007;
4
5 vector<int> myPow, myPre;
6 void hash_init(string s){
7     myPow.resize(s.size());
8     myPre.resize(s.size());
9
10    for (int i=0 ; i<s.size() ; i++){
11        if (i==0){
12            myPow[i] = 1;
13            myPre[i] = s[i];
14        }else{
15            myPow[i] = myPow[i-1]*A%B;
16            myPre[i] = (myPre[i-1]*A+s[i])%B;
17        }
18    }
19
20    return;
21 }
22
23 int hash_value(int l, int r){ // 取得 s[l..r] 的數值
24     if (l==0) return myPre[r];
25     return ((myPre[r]-myPre[l-1]*myPow[r-l+1])%B+B)%B;
26 }

```

8.2 Manacher

```

1 string Manacher(string str) {
2     string tmp = "$#";
3     for(char i : str) {
4         tmp += i;
5         tmp += '#';
6     }
7
8     vector<int> p(tmp.size(), 0);
9     int mx = 0, id = 0, len = 0, center = 0;
10    for(int i=1 ; i<(int)tmp.size() ; i++) {
11        p[i] = mx > i ? min(p[id*2-i], mx-i) : 1;
12
13        while(tmp[i+p[i]] == tmp[i-p[i]]) p[i]++;
14        if(mx<i+p[i]) mx = i+p[i], id = i;
15        if(len<p[i]) len = p[i], center = i;
16    }
17    return str.substr((center-len)/2, len-1);
18 }

```

8.3 Suffix-Array

```

1 /*
2  s = temmie
3  pos = 6 5 1 4 3 2 0
4  rnk = 6 2 5 4 3 1 0
5
6 注意 · pos 跟 rnk 的大小為 s.size()+1
7 pos:
8 (空字串) -> e -> emmie -> ie -> mie -> mmie -> temmie
9 rnk[i] = i 在 pos 的哪個位置 (第幾小的陣列)
10 */
11
12 vector<int> pos, rnk;
13
14 // 51f72a
15 void Radix_Sort(vector<array<int, 3>> &v){
16     int n = v.size();
17
18     for (int p=1 ; p>=0 ; p--){
19         vector<int> cnt(n);
20         for (auto x : v){
21             cnt[x[p]]++;
22         }
23
24         vector<array<int, 3>> tmp(n);
25         vector<int> ptr(n); // ptr[i] = 目前 second 是 i 的元
26             素要放在哪個位置
27         ptr[0] = 0;
28         for (int i=1 ; i<n ; i++){
29             ptr[i] = ptr[i-1]+cnt[i-1];
30         }
31         for (auto x : v){
32             int i = x[p];
33             tmp[ptr[i]] = x;
34             ptr[i]++;
35         }
36         v = tmp;
37     }
38     return;
39 }

```



```

38 }
39
40 // a4b26a
41 void Build_SA(string s){
42     s += (char)(0);
43     int n = s.size();
44     rnk.resize(n);
45     pos.resize(n);
46
47     vector<array<int, 2>> tmp(n);
48     for (int i=0 ; i<n ; i++) tmp[i] = {s[i], i};
49     sort(tmp.begin(), tmp.end());
50     for (int i=0 ; i<n ; i++) pos[i] = tmp[i][1];
51     rnk[pos[0]] = 0;
52     for (int i=1 ; i<n ; i++){
53         if (tmp[i][0]==tmp[i-1][0]) rnk[pos[i]] = rnk[pos[i-1]]+1;
54         else rnk[pos[i]] = rnk[pos[i-1]]+1;
55     }
56
57     for (int k=0 ; (1<<k)<n ; k++){
58         vector<array<int, 3>> tmp(n);
59         for (int i=0 ; i<n ; i++) tmp[i] = {rnk[i], rnk[(i+(1<<k))%n], i};
60         Radix_Sort(tmp);
61         for (int i=0 ; i<n ; i++) pos[i] = tmp[i][2];
62         rnk[pos[0]] = 0;
63         for (int i=1 ; i<n ; i++){
64             if (tmp[i][0]==tmp[i-1][0] && tmp[i][1]==tmp[i-1][1]) rnk[pos[i]] = rnk[pos[i-1]];
65             else rnk[pos[i]] = rnk[pos[i-1]]+1;
66         }
67     }
68 }

```

8.4 Longest-Common-Prefix-Array

```

1  /*
2  3  rnk:
4  (空字串) -> e -> emmie -> ie -> mie -> mmie -> temmie
5
6  lcp[i] = 第 i 小的後綴跟 i-1 小的後綴的 lcp (based-1)
7  [ (無意義, -1), 0, 1, 0, 0, 1, 0 ]
8  */
9  vector<int> pos, rnk;
10 vector<int> lcp;
11
12 // 2c4535
13 void Build_LCP(string s){
14     int n = s.size();
15     s += '$';
16     lcp.resize(s.size());
17     lcp[0] = -1;
18
19     int k = 0;
20     for(int i=0 ; i<n ; i++){
21         int pi = rnk[i];
22         int j = pos[pi-1];
23
24         while(i+k<n && j+k<n && s[i+k]==s[j+k]) k++;
25     }

```

```

26     lcp[pi] = k;
27     k = max((int)0, k-1);
28 }
29 }

```

8.5 KMP

```

1 // 給一個字串 S · 定義函數 \pi(i) = k 代表 S[1 ... k] = S[i-k
2   +1 ... i]
3 // 61e853
4 vector<int> KMP(string &s){
5     vector<int> ret(n);
6
7     for (int i=1 ; i<n ; i++){
8         int j = ret[i-1];
9         while (j>0 && s[i]!=s[j]){
10             j = ret[i-1];
11         }
12         if (s[i]==s[j]) j++;
13         ret[i] = j;
14     }
15
16     return ret;
17 }

```

8.6 Z-Function

```

1 // 定義一個長度為 n 的文本為 T · 則陣列 Z 的 Z[i] 代表 T[0:n]
2   和 T[i:n] 最長共同前綴
3 // bcfbd6
4 vector<int> z_function(string s){
5     vector<int> ret(s.size());
6     int ll = 0, rr = 0;
7
8     for (int i=1 ; i<s.size() ; i++){
9         int j = 0;
10
11         if (i<rr) j = min(ret[i-ll], rr-i);
12         while (s[j]==s[i+j]) j++;
13         ret[i] = j;
14
15         if (i+j>rr){
16             ll = i;
17             rr = i+j;
18         }
19     }
20
21     ret[0] = s.size();
22     return ret;
23 }

```

Contents

1 Convolution	1	4.2 Line-Intersection	6	6.10 歐拉定理	11
1.1 FFT	1	4.3 Pick's-Theorem	6	6.11 Fraction	11
1.2 FFT-2	1	4.4 Point-In-Polygon	6	6.12 錯排公式	12
1.3 NTT-998244353	1	4.5 Convex-Hull	6	6.13 Quick-Pow	12
1.4 FFT-mod	1	5 Graph	6	6.14 二元一次方程式	12
2 Data-Structure	2	5.1 Find-Bridge	6	6.15 Josephus	12
2.1 GP-Hash-Table	2	5.2 Find-AP	6	6.16 數論分塊	12
2.2 Sparse-Table	2	5.3 MCMF	6	6.17 Miller-Rabin	12
2.3 Order-Set	2	5.4 HLD	7	6.18 Pollard-Rho	12
2.4 BIT	2	5.5 Tree-Isomorphism	7	7 Misc	12
2.5 Treap	2	5.6 Bridge BCC	8	7.1 Xor-Basis	12
2.6 Persistent-Segment-Tree	3	5.7 Cut BCC	8	7.2 Default-Code	13
2.7 Trie	3	5.8 圓方樹	8	7.3 Radix-Sort	13
2.8 LC-Segment-Tree	4	5.9 Dijkstra	9	7.4 Set-Pq-Sort	13
2.9 Persistent-Disjoint-Set	4	5.10 SCC 與縮點	9	7.5 2-SAT	13
2.10 Add-Set-Segment-Tree	4	5.11 Dinic	10	7.6 Enumerate-Subset	14
3 Dynamic-Programming	5	6 Math	10	7.7 Fast-Input	14
3.1 SOS-DP	5	6.1 Burnside's-Lemma	10	7.8 setup	14
3.2 Digit-DP	5	6.2 線性篩	10	8 String	14
3.3 整數拆分	5	6.3 Lucas's-Theorem	10	8.1 Hash	14
4 Geometry	5	6.4 Matrix	10	8.2 Manacher	14
4.1 Point-Struct	5	6.5 最大質因數	10	8.3 Suffix-Array	14
		6.6 中國剩餘定理 (m 互質)	10	8.4 Longest-Common-Prefix-Array	15
		6.7 中國剩餘定理 (m 不互質)	11	8.5 KMP	15
		6.8 歐拉公式	11	8.6 Z-Function	15
		6.9 卡特蘭數	11		