

# ACM/ICPC Template Manaual

## QUST

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## 0 Include

```
1 //#include <bits/stdc++.h>
2 #include <algorithm>
3 #include <iostream>
4 #include
              <cstring>
5 #include
               <string>
6 #include
               <cstdio>
7
  #include
               <vector>
8 #include
               <cstdio>
9 #include
               <vector>
10 #include
                <stack>
11 #include
                <queue>
12 #include
                <cmath>
13 #include
                  <set>
14 #include
                  <map>
15 using namespace std;
#define rep(i,a,b) for(int i=a;i<=b;i++)</pre>
17 #define per(i,a,b) for(int i=a;i>=b;i--)
18 #define clr(a,x) memset(a,x,sizeof(a))
19 #define pb push_back
20 #define mp make_pair
21 #define all(x) (x).begin(),(x).end()
22 #define fi first
23 #define se second
24 #define SZ(x) ((int)(x).size())
25 typedef unsigned long long ull;
26 typedef long long ll;
27 typedef vector<int> vi;
28 typedef pair<int,int> pii;
  /*********head***********/
29
30 int work(){
31
       return 0;
32
   }
33
   int main(){
34
35
   #ifdef superkunn
       freopen("input.txt","rt",stdin);
36
   #endif
37
38
       work();
       return 0;
39
40 }
```

## 1 Math

## 1.1 Prime

#### 1.1.1 Eratosthenes Sieve

```
O(n \log \log n) maxn
   notprime[i] = 0/1 \ 0  1
1 const int maxn = "Edit";
   bool notprime[maxn] = {1, 1};
                                     // 0 && 1
   void GetPrime()
3
   {
4
        for (int i = 2; i < maxn; i++)</pre>
5
            if (!notprime[i] && i <= maxn / i) // √n</pre>
6
                for (int j = i * i; j < maxn; j += i)
7
                    notprime[j] = 1;
8
9
   }
   1.1.2 Eular Sieve
   O(n)
           phi[] prime[]
                           tot
     \mathbf{n}
1 const int maxn = "Edit";
2 bool vis[maxn];
3 int tot, phi[maxn], prime[maxn];
4 void CalPhi(int n)
5
        clr(vis, 0);
6
7
        phi[1] = 1;
8
        tot = 0;
9
        for (int i = 2; i < n; i++)
10
            if (!vis[i])
11
                prime[tot++] = i, phi[i] = i - 1;
12
            for (int j = 0; j < tot; j++)
13
14
                if (i * prime[j] > n) break;
15
                vis[i * prime[j]] = 1;
16
                if (i % prime[j] == 0)
17
18
                     phi[i * prime[j]] = phi[i] * prime[j];
19
20
21
                }
22
                else
                     phi[i * prime[j]] = phi[i] * (prime[j] - 1);
```

#### 1.1.3 Prime Factorization

```
fact[i][0]^{fact[i][1]}
```

}

}

 $\frac{23}{24}$ 

25 26 }

```
ll fact[100][2];
   int getFactors(ll x)
2
3
        int cnt = 0;
4
        for (int i = 0; prime[i] <= x / prime[i]; i++)</pre>
5
6
            fact[cnt][1] = 0;
7
            if (x % prime[i] == 0)
8
9
                fact[cnt][0] = prime[i];
10
                while (x % prime[i] == 0) fact[cnt][1]++, x /= prime[i];
11
12
                cnt++;
            }
13
        }
14
        if (x != 1) fact[cnt][0] = x, fact[cnt++][1] = 1;
15
        return cnt;
16
17
   }
   1.1.4 Miller Rabin
              2^{63}
   O(s \log n)
   bool Miller_Rabin(ll n, int s)
2
   {
        if (n == 2) return 1;
3
        if (n < 2 | | !(n & 1)) return 0;
4
        int t = 0;
5
        ll x, y, u = n - 1;
6
        while ((u \& 1) == 0) t++, u >>= 1;
7
        for (int i = 0; i < s; i++)
8
9
10
            ll\ a = rand() \% (n - 1) + 1;
            11 x = Pow(a, u, n);
11
            for (int j = 0; j < t; j++)
12
13
                ll y = Mul(x, x, n);
14
                if (y == 1 \&\& x != 1 \&\& x != n - 1) return 0;
15
16
                x = y;
17
            if (x != 1) return 0;
18
19
20
        return 1;
21 }
   1.1.5 Segment Sieve
      [a,b)
   is_prime[i-a]=true i
   a < b \le 10^{12}, b - a \le 10^6
1 const int maxn = "Edit";
2 bool is_prime_small[maxn], is_prime[maxn];
3 int prime[maxn];
4 int segment_sieve(ll a, ll b)
5
   {
6
        int tot = 0;
```

```
for (ll i = 0; i * i < b; ++i)
7
            is_prime_small[i] = true;
8
       for (ll i = 0; i < b - a; ++i)
9
            is_prime[i] = true;
10
       for (ll i = 2; i * i < b; ++i)
11
            if (is_prime_small[i])
12
13
                for (ll j = 2 * i; j * j < b; j += i)
14
                    is_prime_small[j] = false;
15
                for (ll j = max(2LL, (a + i - 1) / i) * i; j < b; j += i)
16
                    is_prime[j - a] = false;
17
18
       for (ll i = 0; i < b - a; ++i)
19
20
           if (is_prime[i]) prime[tot++] = i + a;
21
       return tot;
   }
22
   1.2 Eular phi
   1.2.1 Eular
   ll Euler(ll n)
1
2
3
       ll rt = n;
       for (int i = 2; i * i <= n; i++)
4
           if (n \% i == 0)
5
6
7
                rt -= rt / i;
8
                while (n \% i == 0) n /= i;
9
       if (n > 1) rt -= rt / n;
10
       return rt;
11
12 }
   1.2.2 Sieve
1 const int N = "Edit";
   int phi[N] = \{0, 1\};
   void CalEuler()
3
   {
4
       for (int i = 2; i < N; i++)
5
            if (!phi[i])
6
                for (int j = i; j < N; j += i)
7
8
                    if (!phi[j]) phi[j] = j;
9
                    phi[j] = phi[j] / i * (i - 1);
10
                }
11
12 }
   1.3 Basic Number Theory
   1.3.1 Extended Euclidean
  ll exgcd(ll a, ll b, ll &x, ll &y)
1
2
   {
3
       if (b) d = exgcd(b, a \% b, y, x), y -= x * (a / b);
```

```
else x = 1, y = 0;
       return d;
7 }
   1.3.2 ax+by=c
      : X = x + k * dx, Y = y - k * dy
1 #define Mod(a, b) (((a) % (b) + (b)) % (b))
   bool solve(ll a, ll b, ll c, ll& x, ll& y, ll& dx, ll& dy)
3
       if (a == 0 \&\& b == 0) return 0;
4
5
       11 x0, y0;
6
       11 d = exgcd(a, b, x0, y0);
       if (c % d != 0) return 0;
7
       dx = b / d, dy = a / d;
8
       x = Mod(x0 * c / d, dx);
9
       y = (c - a * x) / b;
10
       // y = Mod(y0 * c / d, dy); x = (c - b * y) / a;
11
12
       return 1;
13 }
   1.3.3 Multiplicative Inverse Modulo
     exgcd a m , gcd(a, m) == 1.
1 ll inv(ll a, ll m)
2
   {
3
       11 x, y;
       ll d = exgcd(a, m, x, y);
       return d == 1 ? (x + m) % m : -1;
5
6 }
   a 
1 ll inv(ll a, ll p) { return Pow(a, p - 2, p); }
1 for (int i = 2; i < n; i++) inv[i] = inv[p % i] * (p - p / i) % p;
   1.4 Modulo Linear Equation
   1.4.1 Chinese Remainder Theory
   X = r_i(modm_i); m_i
       X = re + k * mo
1 void crt(ll r[], ll m[], ll n, ll &re, ll &mo)
2
       mo = 1, re = 0;
3
       for (int i = 0; i < n; i++) mo *= m[i];</pre>
4
       for (int i = 0; i < n; i++)
5
6
           ll x, y, tm = mo / m[i];
7
           ll d = exgcd(tm, m[i], x, y);
8
           re = (re + tm * x * r[i]) % mo;
```

```
}
10
        re = (re + mo) \% mo;
11
   }
12
   1.4.2 ExCRT
   X = r_i(modm_i); m_i
       X = re + k * mo;
   bool excrt(ll r[], ll m[], ll n, ll &re, ll &mo)
1
2
3
        11 x, y;
        mo = m[0], re = r[0];
4
        for (int i = 1; i < n; i++)
5
6
7
            ll d = exgcd(mo, m[i], x, y);
            if ((r[i] - re) % d != 0) return 0;
8
            x = (r[i] - re) / d * x % (m[i] / d);
9
            re += x * mo;
10
            mo = mo / d * m[i];
11
            re %= mo;
12
13
        re = (re + mo) \% mo;
14
15
        return 1;
16 }
         Combinatorics
   1.5.1 Combination
   0 \leq m \leq n \leq 1000
   const int maxn = 1010;
1
   11 C[maxn][maxn];
2
  void CalComb()
3
   {
4
        C[0][0] = 1;
5
6
        for (int i = 1; i < maxn; i++)
7
            C[i][0] = 1;
8
            for (int j = 1; j \leftarrow i; j++) C[i][j] = (C[i-1][j-1] + C[i-1][j]) % mod;
9
10
   }
11
   0 \le m \le n \le 10^5, p
   const int maxn = 100010;
  ll f[maxn];
  ll inv[maxn]; //
   void CalFact()
4
5
        f[0] = 1;
6
7
        for (int i = 1; i < maxn; i++) f[i] = (f[i - 1] * i) % p;
        inv[maxn - 1] = Pow(f[maxn - 1], p - 2, p);
8
        for (int i = maxn - 2; \sim i; i--) inv[i] = inv[i + 1] * (i + 1) % p;
9
10
   ll C(int n, int m) { return f[n] * inv[m] % p * inv[n - m] % p; }
```

#### 1.5.2 Lucas

```
1 \le n, m \le 1000000000, 1 
1 const int maxp = 100010;
2 11 f[maxn];
   ll inv[maxn]; //
3
   void CalFact()
5
6
        f[0] = 1;
        for (int i = 1; i < maxn; i++) f[i] = (f[i - 1] * i) % p;
7
        inv[maxn - 1] = Pow(f[maxn - 1], p - 2, p);
8
        for (int i = maxn - 2; \sim i; i--) inv[i] = inv[i + 1] * (i + 1) % p;
9
10 }
11 ll Lucas(ll n, ll m, ll p)
12 {
        ll ret = 1;
13
        while (n && m)
14
15
            ll a = n \% p, b = m \% p;
16
            if (a < b) return 0;
17
            ret = ret * f[a] % p * inv[b] % p * inv[a - b] % p;
18
19
            n \neq p, m \neq p;
20
21
        return ret;
22 }
   1.5.3 Big Combination
   0 \le n \le 10^9, 0 \le m \le 10^4, 1 \le k \le 10^9 + 7
1 vector<int> v;
   int dp[110];
3 ll Cal(int l, int r, int k, int dis)
   {
4
        ll res = 1;
5
        for (int i = 1; i <= r; i++)</pre>
6
7
8
            int t = i;
9
            for (int j = 0; j < v.size(); j++)</pre>
10
11
                int y = v[j];
12
                while (t % y == 0) dp[j] += dis, t /= y;
13
            res = res * (ll)t % k;
14
15
16
        return res;
17
   11 Comb(int n, int m, int k)
19
   {
        clr(dp, 0);
20
        v.clear();
21
22
        int tmp = k;
        for (int i = 2; i * i <= tmp; i++)</pre>
23
            if (tmp \% i == 0)
24
25
            {
26
                int num = 0;
27
                while (tmp % i == 0) tmp /= i, num++;
```

```
v.pb(i);
28
29
         if (tmp != 1) v.pb(tmp);
30
         ll ans = Cal(n - m + 1, n, k, 1);
31
         for (int j = 0; j < v.size(); j++) ans = ans * Pow(v[j], dp[j], k) % k;
32
         ans = ans * inv(Cal(2, m, k, -1), k) % k;
33
34
         return ans;
35
   }
    1.5.4 Polya
                     gcd(i, n)
    N*N\atop,\frac{m^8+17m^4+6m^2}{24},\frac{c^{n^2+3}}{m^4+11m^2}+2c^{\frac{n^2+1}{2}}+2c^{n\frac{n+1}{2}}+2c^{\frac{n(n+1)}{2}}
1 // n c
   ll solve(int c, int n)
3
         if (n == 0) return 0;
4
         11 \text{ ans} = 0;
5
         for (int i = 1; i \le n; i++) ans += Pow(c, __gcd(i, n));
6
         if (n & 1) ans += n * Pow(c, n + 1 >> 1);
else ans += n / 2 * (1 + c) * Pow(c, n >> 1);
7
9
         return ans / n / 2;
10 }
    1.6 Fast Power
   ll Mul(ll a, ll b, ll mod)
1
2
         11 t = 0;
3
         for (; b; b >>= 1, a = (a << 1) \% mod)
4
             if (b \& 1) t = (t + a) \% mod;
5
         return t;
6
7
8
   ll Pow(ll a, ll n, ll mod)
9
    {
10
         ll t = 1;
         for (; n; n >>= 1, a = (a * a % mod))
11
              if (n \& 1) t = (t * a % mod);
12
13
         return t;
14 }
         Mobius Inversion
    1.7.1 Mobius
    F(n) = \sum_{d|n} f(d) \Rightarrow f(n) = \sum_{d|n} \mu(d) F(\frac{n}{d})
    F(n) = \sum_{n|d} f(d) \Rightarrow f(n) = \sum_{n|d} \mu(\frac{d}{n}) F(d)
1 ll ans;
2 const int maxn = "Edit";
3 int n, x, prime[maxn], tot, mu[maxn];
4 bool check[maxn];
5 void calmu()
```

```
{
6
7
        mu[1] = 1;
        for (int i = 2; i < maxn; i++)
8
9
            if (!check[i]) prime[tot++] = i, mu[i] = -1;
10
            for (int j = 0; j < tot; j++)
11
12
                if (i * prime[j] >= maxn) break;
13
                check[i * prime[j]] = true;
14
                if (i % prime[j] == 0)
15
16
17
                    mu[i * prime[j]] = 0;
18
                    break;
19
                else mu[i * prime[j]] = -mu[i];
20
            }
21
22
        }
23
   }
```

#### 1.7.2 Number of Coprime-pair

```
n \quad (n \le 100000), \quad n
   ll solve()
1
2
   {
        int b[100005];
3
        11 \text{ _max}, \text{ ans } = 0;
4
        clr(b, 0);
5
        for (int i = 0; i < n; i++)
6
7
8
             scanf("%d", &x);
9
             if (x > _max) _max = x;
             b[x]++;
10
11
        for (int i = 1; i <= _max; i++)
12
13
             int cnt = 0;
14
             for (ll j = i; j \le \max; j += i) cnt += b[j];
15
             ans += 1LL * mu[i] * cnt * cnt;
16
17
        return (ans - b[1]) / 2;
18
   }
19
```

#### 1.7.3 VisibleTrees

```
gcd(x,y) = 1 , x ≤ n,y ≤ m

1  ll solve(int n, int m)
2  {
3     if (n < m) swap(n, m);
4     ll ans = 0;
5     for (int i = 1; i <= m; ++i) ans += (ll)mu[i] * (n / i) * (m / i);
6     return ans;
7  }</pre>
```

#### 1.8 Fast Transformation

#### 1.8.1 FFT

```
1 const double PI = acos(-1.0);
3
  struct Complex
4
        double x, y; //
5
                         x+yi
6
        Complex(double _x = 0.0, double _y = 0.0) { x = _x, y = _y; }
7
        Complex operator-(const Complex& b) const { return Complex(x - b.x, y - b.y); }
        Complex operator+(const Complex& b) const { return Complex(x + b.x, y + b.y); }
8
        Complex operator*(const Complex& b) const { return Complex(x * b.x - y * b.y, x * b
9
        .y + y * b.x); }
10 };
11
   * FFT IFFT
13 * i (i
  * len 2
14
   */
15
   void change(Complex y[], int len)
16
17
   {
        for (int i = 1, j = len / 2; i < len - 1; i++)
18
19
            if (i < j) swap(y[i], y[j]);</pre>
20
            //
21
                   ,i<j
            //i +1,j +1, ij
22
            int k = len / 2;
23
            while (j >= k) j -= k, k /= 2;
24
            if (j < k) j += k;
25
        }
26
   }
27
28
   * FFT
29
  * len 2^k
   * on==1 DFT.on==-1 IDFT
32
33 void fft(Complex y[], int len, int on)
34 {
        change(y, len);
35
        for (int h = 2; h <= len; h <<= 1)
36
37
            Complex wn(cos(-on * 2 * PI / h), sin(-on * 2 * PI / h));
38
            for (int j = 0; j < len; <math>j += h)
39
40
                Complex w(1, 0);
41
                for (int k = j; k < j + h / 2; k++)
42
43
                    Complex u = y[k];
44
45
                    Complex t = w * y[k + h / 2];
                    y[k] = u + t, y[k + h / 2] = u - t;
46
                    W = W * Wn;
47
                }
48
            }
49
50
        if (on == -1)
51
52
            for (int i = 0; i < len; i++) y[i].x /= len;
53 }
```

#### 1.8.2 NTT

```
.G P G^{\frac{P-1}{n}} w_n = e^{\frac{2i\pi}{n}}
                                       P G 1.11
   const int mod = 119 << 23 | 1;</pre>
   const int G = 3;
3
   int wn[20];
4 void getwn()
5
  { //
6
        for (int i = 0; i < 20; i++) wn[i] = Pow(G, (mod - 1) / (1 << i), mod);
7
  void change(int y[], int len)
8
9
10
        for (int i = 1, j = len / 2; i < len - 1; i++)
11
            if (i < j) swap(y[i], y[j]);</pre>
12
            int k = len / 2;
13
            while (j >= k) j -= k, k /= 2;
14
            if (j < k) j += k;
15
16
17
   }
18
   void ntt(int y[], int len, int on)
19
        change(y, len);
20
21
        for (int h = 2, id = 1; h <= len; h <<= 1, id++)
22
            for (int j = 0; j < len; <math>j += h)
23
24
25
                int w = 1;
                for (int k = j; k < j + h / 2; k++)
26
27
                     int u = y[k] \% mod;
28
                     int t = 1LL * w * (y[k + h / 2] % mod) % mod;
29
                     y[k] = (u + t) \% \mod, y[k + h / 2] = ((u - t) \% \mod + \mod) \% \mod;
30
                     w = 1LL * w * wn[id] % mod;
31
32
                }
            }
33
34
        if (on == -1)
35
36
37
            int inv = Pow(len, mod - 2, mod);
38
            for (int i = 1; i < len / 2; i++) swap(y[i], y[len - i]);
39
            for (int i = 0; i < len; i++) y[i] = 1LL * y[i] * inv % mod;
40
41
   }
42
   1.8.3 FWT
   void fwt(int f[], int m)
        int n = __builtin_ctz(m);
3
        for (int i = 0; i < n; ++i)
4
            for (int j = 0; j < m; ++j)
5
6
                if (j & (1 << i))
7
                 {
                     int l = f[j \land (1 << i)], r = f[j];
8
                     f[j \land (1 << i)] = l + r, f[j] = l - r;
9
```

```
// or: f[j] += f[j \land (1 << i)];
10
                      // and: f[j \land (1 << i)] += f[j];
11
12
13
   void ifwt(int f[], int m)
14
   {
15
        int n = __builtin_ctz(m);
16
        for (int i = 0; i < n; ++i)
17
             for (int j = 0; j < m; ++j)
18
                 if (j & (1 << i))
19
20
21
                      int l = f[j \land (1 << i)], r = f[j];
                      f[j \land (1 \lessdot i)] = (l + r) / 2, f[j] = (l - r) / 2;
22
23
                     // or: f[j] -= f[j \land (1 << i)];
24
                     // and: f[j \land (1 << i)] -= f[j];
25
                 }
26
27 }
    1.9 Numerical Integration
   1.9.1 Adaptive Simpson's Rule
    \int_{a}^{b} f(x)dx \approx \frac{b-a}{6} [f(a) + 4f(\frac{a+b}{2}) + f(b)]
    |\ddot{S}(a,c) + S(c,b) - S(a,b)|/15 < \epsilon
1 double F(double x) {}
   double simpson(double a, double b)
2
   { // Simpson
3
        double c = a + (b - a) / 2;
4
        return (F(a) + 4 * F(c) + F(b)) * (b - a) / 6;
5
6
   double asr(double a, double b, double eps, double A)
7
   { // Simpson ( )
                        [a,b] Simpson A
        double c = a + (b - a) / 2;
9
        double L = simpson(a, c), R = simpson(c, b); if (fabs(L + R - A) \ll 15 * eps) return L + R + (L + R - A) / 15.0;
10
11
        return asr(a, c, eps / 2, L) + asr(c, b, eps / 2, R);
12
13
   double asr(double a, double b, double eps) { return asr(a, b, eps, simpson(a, b)); }
   1.9.2 Berlekamp-Massey
   const int N = 1 \ll 14;
   11 res[N], base[N], _c[N], _md[N];
   vector<int> Md;
3
   void mul(ll* a, ll* b, int k)
4
   {
5
        for (int i = 0; i < k + k; i++) _{c}[i] = 0;
6
        for (int i = 0; i < k; i++)
7
8
             if (a[i])
                 for (int j = 0; j < k; j++) _{c[i + j]} = (_{c[i + j]} + a[i] * b[j]) % mod;
9
10
        for (int i = k + k - 1; i >= k; i--)
11
             if (_c[i])
                 for (int j = 0; j < Md.size(); j++) _c[i - k + Md[j]] = (_c[i - k + Md[j]]
12
        - _c[i] * _md[Md[j]]) % mod;
        for (int i = 0; i < k; i++) a[i] = _c[i];
13
14 }
```

```
int solve(ll n, VI a, VI b)
16
   {
17
        ll ans = 0, pnt = 0;
18
        int k = a.size();
        assert(a.size() == b.size());
19
        for (int i = 0; i < k; i++) _md[k - 1 - i] = -a[i];
20
21
        _{md[k]} = 1;
        Md.clear();
22
23
        for (int i = 0; i < k; i++)
            if (_md[i] != 0) Md.push_back(i);
24
25
        for (int i = 0; i < k; i++) res[i] = base[i] = 0;
26
        res[0] = 1;
        while ((1LL << pnt) <= n) pnt++;</pre>
27
        for (int p = pnt; p >= 0; p--)
28
29
            mul(res, res, k);
30
31
            if ((n >> p) & 1)
32
                for (int i = k - 1; i >= 0; i--) res[i + 1] = res[i];
33
                res[0] = 0;
34
                for (int j = 0; j < Md.size(); j++) res[Md[j]] = (res[Md[j]] - res[k] * _md
35
        [Md[j]]) % mod;
36
37
38
        for (int i = 0; i < k; i++) ans = (ans + res[i] * b[i]) % mod;
39
        if (ans < 0) ans += mod;
        return ans;
40
41
   VI BM(VI s)
42
43
   {
        VI C(1, 1), B(1, 1);
44
        int L = 0, m = 1, b = 1;
45
        for (int n = 0; n < s.size(); n++)
46
47
            11 d = 0;
48
            for (int i = 0; i \le L; i++) d = (d + (ll)C[i] * s[n - i]) % mod;
49
            if (d == 0)
50
51
                ++m;
            else if (2 * L <= n)
52
53
                VI T = C;
54
                11 c = mod - d * Pow(b, mod - 2) % mod;
55
                while (C.size() < B.size() + m) C.pb(0);</pre>
56
                for (int i = 0; i < B.size(); i++) C[i + m] = (C[i + m] + c * B[i]) % mod;
57
                L = n + 1 - L, B = T, b = d, m = 1;
58
            }
59
            else
60
            {
61
                11 c = mod - d * Pow(b, mod - 2) % mod;
62
63
                while (C.size() < B.size() + m) C.pb(0);
64
                for (int i = 0; i < B.size(); i++) C[i + m] = (C[i + m] + c * B[i]) % mod;
65
                ++m;
66
            }
67
        return C;
68
69
   int gao(VI a, ll n)
70
71
   {
72
        VI c = BM(a);
```

```
c.erase(c.begin());
73
           for (int i = 0; i < c.size(); i++) c[i] = (mod - c[i]) % mod;
74
           return solve(n, c, VI(a.begin(), a.begin() + c.size()));
75
76 }
     1.10 Others
    n , , m
    int josephus(int n, int m)
 2
 3
           int r = 0;
           for (int k = 1; k \le n; ++k) r = (r + m) \% k;
 4
           return r + 1;
 5
    }
 6
    n^n
    int leftmost(int n)
 1
 2
           double m = n * log10((double)n);
 3
           double g = m - (11)m;
 4
 5
           return (int)pow(10.0, g);
    }
 6
    n!
 1
    int count(ll n)
 2
           if (n == 1) return 1;
 3
           return (int)ceil(0.5 * log10(2 * M_PI * n) + n * log10(n) - n * log10(M_E));
 4
 5
     1.11 Formula
            : n = \prod_{i=1}^{k} p_i^{a_i},
        1.
             (a) f(n) = \prod_{i=1}^{k} (a_i + 1)
             (b) g(n) = \prod_{i=1}^{k} (\sum_{j=0}^{a_i} p_i^j)
        2. n
                     n\varphi(n)/2
        3. gcd(n, i) = 1, gcd(n, n - i) = 1(1 \le i \le n)
            D(n) = (n-1)(D(n-2) + D(n-1)) = \sum_{i=2}^{n} \frac{(-1)^{k} n!}{k!} = \left[\frac{n!}{e} + 0.5\right]
        5. : p \text{ is prime } \Rightarrow (p-1)! \equiv -1 \pmod{p}
        6. : gcd(a, n) = 1 \Rightarrow a^{\varphi(n)} \equiv 1 \pmod{n}
        7. : gcd(n,p) = 1 \Rightarrow a^n \equiv a^{n\%\varphi(p)} \pmod{p}
            : n \qquad \pi(n), \lim_{n \to \infty} \pi(n) = \frac{n}{\ln n}
        9. : x N = log 10(n) + 1
            n! \approx \sqrt{2\pi n} (\frac{n}{2})^n
       10.
       11. a > 1, m, n > 0, gcd(a^m - 1, a^n - 1) = a^{gcd(m,n)} - 1
       12. a > b, gcd(a, b) = 1, gcd(a^m - b^m, a^n - b^n) = a^{gcd(m, n)} - b^{gcd(m, n)}
                                      G = \gcd(C_n^1, C_n^2, ..., C_n^{n-1}) = \begin{cases} n, & n \text{ is prime} \\ 1, & n \text{ has multy prime factors} \\ p, & n \text{ has single prime factor } p \end{cases}
            gcd(Fib(m), Fib(n)) = Fib(gcd(m, n))
```

13. 
$$gcd(m,n) = 1$$
, :

(a) 
$$m*n-m-n$$

(b) 
$$N = \frac{(m-1)(n-1)}{2}$$

14. 
$$(n+1)lcm(C_n^0, C_n^1, ..., C_n^{n-1}, C_n^n) = lcm(1, 2, ..., n+1)$$

15. 
$$p$$
 ,  $(x+y+...+w)^p \equiv x^p + y^p + ... + w^p \pmod{p}$ 

16. :1, 1, 2, 5, 14, 42, 132, 429, 1430, 4862, 16796, 58786, 208012 
$$h(0) = h(1) = 1, h(n) = \frac{(4n-2)h(n-1)}{n+1} = \frac{C_{2n}^n}{n+1} = C_{2n}^n - C_{2n}^{n-1}$$

17. 
$$:B_n = -\frac{1}{n+1} \sum_{i=0}^{n-1} C_{n+1}^i B_i$$

$$\sum_{i=1}^{n} i^{k} = \frac{1}{k+1} \sum_{i=1}^{k+1} C_{k+1}^{i} B_{k+1-i} (n+1)^{i}$$

#### 18. FFT

ггі			
$r \ 2^k + 1$	r	k	g
3	1	1	$\frac{g}{2}$
5	1	2	2
17	1	4	3
97	3	5	5
193	3	6	5
257	1	8	3
7681	15	9	17
12289	3	12	11
40961	5	13	3
65537	1	16	3
786433	3	18	10
5767169	11	19	3
7340033	7	20	3
23068673	11	21	3
104857601	25	22	3
167772161	5	25	3
469762049	7	26	3
998244353	119	23	3
1004535809	479	21	3
2013265921	15	27	31
2281701377	17	27	3
3221225473	3	30	5
75161927681	35	31	3
77309411329	9	33	7
206158430209	3	36	22
2061584302081	15	37	7
2748779069441	5	39	3
6597069766657	3	41	5
39582418599937	9	42	5
79164837199873	9	43	5
263882790666241	15	44	7
1231453023109121	35	45	3
1337006139375617	19	46	3
3799912185593857	27	47	5
4222124650659841	15	48	19
7881299347898369	7	50	6
31525197391593473	7	52	3
180143985094819841	5	55	6
1945555039024054273	27	56	5
4179340454199820289	29	57	3

## 2 String Processing

#### 2.1 KMP

```
//MAXN
   int nxt[MAXN];
2
   void initkmp(char x[],int m){
3
        int i=0, j=nxt[0]=-1;
4
        while(i<m){</pre>
5
            while(j!=-1&&x[i]!=x[j])j=nxt[j];
6
7
            nxt[++i]=++j;
        }
8
   }
9
  //x:pa y:tx
10
   int kmp(char x[],int m,char y[],int n){
        int i,j,ans;
12
        i=j=ans=0;
13
14
        initkmp(x,m);
        while(i<n){</pre>
15
            while(j!=-1&&y[i]!=x[j])j=nxt[j];
16
            i++,j++;
17
            if(j>=m){}
18
19
                 ans++;
                 j=nxt[j];
20
21
                 //pos:i-m
22
            }
23
24
        return ans;
25
   }
```

#### 2.2 ExtendKMP

```
1 //next[i]:x[i...m-1] x[0...m-1]
^2 //extend[i]:y[i...n-1] x[0...m-1]
3 const int N = "Edit"
4 int next[N], extend[N];
5 void pre_ekmp(char x[], int m)
6
   {
7
       next[0] = m;
8
       int j = 0;
       while (j + 1 < m \&\& x[j] == x[j + 1]) j++;
9
       next[1] = j;
10
       int k = 1;
11
       for (int i = 2; i < m; i++)
12
13
            int p = next[k] + k - 1;
14
            int L = next[i - k];
15
            if (i + L 
16
                next[i] = L;
17
            else
18
            {
19
                j = max(0, p - i + 1);
20
21
                while (i + j < m \&\& x[i + j] == x[j]) j++;
22
                next[i] = j;
                k = i;
23
            }
24
       }
25
26 }
```

```
void ekmp(char x[], int m, char y[], int n)
27
   {
28
       pre_ekmp(x, m, next);
29
       int j = 0;
30
       while (j < n \&\& j < m \&\& x[j] == y[j]) j++;
31
       extend[0] = j;
32
       int k = 0;
33
       for (int i = 1; i < n; i++)
34
35
            int p = extend[k] + k - 1;
36
37
            int L = next[i - k];
38
            if (i + L 
                extend[i] = L;
39
            else
40
            {
41
                j = max(0, p - i + 1);
42
                while (i + j < n \& j < m \& y[i + j] == x[j]) j++;
43
                extend[i] = j, k = i;
44
            }
45
46
       }
   }
47
   2.3 Manacher
   const int MAXN=3e5;//more than two times
   char s[MAXN],str[MAXN];
```

```
3
   int len1,len2,p[MAXN];
4
   void init(){
        str[0]='$';
5
        str[1]='#';
6
7
        rep(i,0,len1-1){
            str[i*2+2]=s[i];
8
9
            str[i*2+3]='#';
10
        len2=len1*2+2;
11
        str[len2]='*';
12
13
   }
   void manacher(){
14
15
        int id=0, mx=0;
        rep(i,1,len2-1){
16
            if(mx>i)p[i]=min(p[2*id-i],mx-i);
17
            else p[i]=1;
18
            while(str[i+p[i]]==str[i-p[i]])p[i]++;
19
20
            if(p[i]+i>mx){
21
                mx=p[i]+i;
22
                id=i;
23
            }
        }
24
25
   }
   int work(){
        while(scanf("%s",s)!=E0F){
27
            len1=strlen(s);
28
            init();
29
            manacher();
30
            int ans=0;
31
            rep(i,0,len2-1){
32
                ans=max(ans,p[i]);
33
34
            }
```

```
printf("%d\n",ans-1);
35
36
        return 0;
37
38 }
        Aho-Corasick Automaton
   const int maxn = "Edit";
1
2
   struct Trie
   {
3
        int ch[maxn][26], f[maxn], val[maxn];
4
        int sz, rt;
5
6
        int newnode() { clr(ch[sz], -1), val[sz] = 0; return sz++; }
7
        void init() { sz = 0, rt = newnode(); }
        inline int idx(char c) { return c - 'A'; };
8
        void insert(const char* s)
9
10
            int u = 0, n = strlen(s);
11
            for (int i = 0; i < n; i++)
12
            {
13
                int c = idx(s[i]);
14
                if (ch[u][c] == -1) ch[u][c] = newnode();
15
                u = ch[u][c];
16
            }
17
            val[u]++;
18
19
        }
20
        void build()
21
22
            queue<int> q;
            f[rt] = rt;
23
24
            for (int c = 0; c < 26; c++)
25
26
                if (~ch[rt][c])
27
                     f[ch[rt][c]] = rt, q.push(ch[rt][c]);
                else
28
29
                     ch[rt][c] = rt;
30
31
            while (!q.empty())
32
33
                int u = q.front();
                q.pop();
34
                // val[u] |= val[f[u]];
35
                for (int c = 0; c < 26; c++)
36
37
38
                     if (~ch[u][c])
                         f[ch[u][c]] = ch[f[u]][c], q.push(ch[u][c]);
39
                    else
40
                         ch[u][c] = ch[f[u]][c];
41
42
                }
            }
43
        }
44
45
        int query(const char* s)
46
47
            int u = rt, n = strlen(s);
48
            int res = 0;
49
            for (int i = 0; i < n; i++)
50
```

51

{

```
int c = idx(s[i]);
52
                u = ch[u][c];
53
                int tmp = u;
54
                while (tmp != rt)
55
56
                     res += val[tmp];
57
                     val[tmp] = 0;
58
                     tmp = f[tmp];
59
                }
60
            }
61
62
            return res;
63
        }
  };
64
   2.5 Suffix Array
           , O(nlogn)
   //
   const int maxn = "Edit";
   char s[maxn];
4 int sa[maxn], t[maxn], t2[maxn], c[maxn], rank[maxn], height[maxn];
5 //n
              0 \sim m - 1
6
  void build_sa(int m, int n)
7
8
        n++;
9
        int *x = t, *y = t2;
10
11
        for (int i = 0; i < m; i++) c[i] = 0;
        for (int i = 0; i < n; i++) c[x[i] = s[i]]++;
12
        for (int i = 1; i < m; i++) c[i] += c[i - 1];
13
        for (int i = n - 1; \sim i; i--) sa[--c[x[i]]] = i; for (int k = 1; k <= n; k <<= 1)
14
15
16
17
            // sa
18
            int p = 0;
            for (int i = n - k; i < n; i++) y[p++] = i;
19
            for (int i = 0; i < n; i++)
20
21
                if (sa[i] >= k) y[p++] = sa[i] - k;
22
23
            for (int i = 0; i < m; i++) c[i] = 0;
            for (int i = 0; i < n; i++) c[x[y[i]]]++;
24
            for (int i = 0; i < m; i++) c[i] += c[i - 1];
25
            for (int i = n - 1; \sim i; i--) sa[--c[x[y[i]]]] = y[i];
26
            // say
27
            swap(x, y);
28
            p = 1;
29
            x[sa[0]] = 0;
30
31
            for (int i = 1; i < n; i++)
                x[sa[i]] = y[sa[i - 1]] == y[sa[i]] && y[sa[i - 1] + k] == y[sa[i] + k] ? p
32
         -1:p++;
            if (p >= n) break; //
33
                                       ,sa
34
            m = p;
        }
35
36
        n--;
37
        int k = 0;
        for (int i = 0; i <= n; i++) rank[sa[i]] = i;</pre>
38
        for (int i = 0; i < n; i++)
39
40
            if (k) k--;
41
```

```
int j = sa[rank[i] - 1];
42
            while (s[i + k] == s[j + k]) k++;
43
            height[rank[i]] = k;
44
45
       }
   }
46
47
   int dp[maxn][30];
48
   void initrmq(int n)
49
50
        for (int i = 1; i <= n; i++)
51
            dp[i][0] = height[i];
52
53
       for (int j = 1; (1 << j) <= n; j++)
            for (int i = 1; i + (1 << j) - 1 <= n; i++)
54
                dp[i][j] = min(dp[i][j-1], dp[i+(1 << (j-1))][j-1]);
55
56
   int rmq(int 1, int r)
57
58
   {
       int k = 31 - \_builtin\_clz(r - l + 1);
59
60
       return min(dp[l][k], dp[r - (1 << k) + 1][k]);
61 }
62 int lcp(int a, int b)
63 { //
       a = rank[a], b = rank[b];
64
65
       if (a > b) swap(a, b);
66
       return rmq(a + 1, b);
67 }
   2.6 Suffix Automation
   const int maxn = "Edit";
2
   struct SAM
3
   {
4
       int len[maxn << 1], link[maxn << 1], ch[maxn << 1][26];</pre>
       int sz, rt, last;
5
       int newnode(int x = 0)
6
7
8
            len[sz] = x;
9
            link[sz] = -1;
10
            clr(ch[sz], -1);
            return sz++;
11
12
13
       void init() { sz = last = 0, rt = newnode(); }
       void extend(int c)
14
15
16
            int np = newnode(len[last] + 1);
17
            int p;
            for (p = last; \sim p \&\& ch[p][c] == -1; p = link[p]) ch[p][c] = np;
18
            if (p == -1)
19
                link[np] = rt;
20
21
            else
22
            {
                int q = ch[p][c];
23
                if (len[p] + 1 == len[q])
24
                    link[np] = q;
25
26
                else
27
                {
                    int nq = newnode(len[p] + 1);
28
29
                    memcpy(ch[nq], ch[q], sizeof(ch[q]));
```

```
link[nq] = link[q], link[q] = link[np] = nq;
30
                     for (; \sim p \& ch[p][c] == q; p = link[p]) ch[p][c] = nq;
31
                }
32
33
            last = np;
34
35
        int topcnt[maxn], topsam[maxn << 1];</pre>
36
37
        void sort()
        { //
38
            clr(topcnt, 0);
39
            for (int i = 0; i < sz; i++) topcnt[len[i]]++;</pre>
40
41
            for (int i = 0; i < maxn - 1; i++) topcnt[i + 1] += topcnt[i];
            for (int i = 0; i < sz; i++) topsam[--topcnt[len[i]]] = i;
42
        }
43
   };
44
   2.7 HashString
1 const ll B1=1e7+7;
   const ll B2=1e9+7;
3
   char pa[10004];
   char tx[1000006];
   int work(){
5
6
        int T;
        scanf("%d",&T);
7
        while(T--){
8
            scanf("%s%s",pa,tx);
9
            int pl=strlen(pa);
10
            int tl=strlen(tx);
11
12
            ll w=1;
            rep(i,1,pl)w=(w*B1)%B2;
13
            ll ph=0,th=0;
14
            rep(i,0,pl-1){
15
                ph=(ph*B1+pa[i])%B2;
16
                th=(th*B1+tx[i])%B2;
17
18
            }
19
            int ans=0;
            for(int i=0;i+pl<=tl;i++){</pre>
20
21
                if(ph==th)ans++;
22
                if(i+pl<tl)th=(th*B1+tx[i+pl]-tx[i]*w)%B2;</pre>
23
            printf("%d\n",ans);
24
25
26
        return 0;
27
   }
```

#### 3 Data Structure

### 3.1 Binary Indexed Tree

```
1 //add(pos,a) sum(r)-sum(l-1)
2 //add(l,a) add(r+1,-a) sum(pos)
3 const int MAXN=100000;
    struct BIT{
4
         int n,c[MAXN<<1];</pre>
5
         void init(int _n){n=_n;for(int i=0;i<=n;i++)c[i]=0;}</pre>
6
         void add(int i,int v){for(;i<=n;i+=i&-i)c[i]+=v;}</pre>
         int sum(int i){int s=0;for(;i>0;i-=i&-i)s+=c[i];return s;}
    }bit;
    3.1.1 poj3468
    a_i = \sum_{i=1}^x d_i
    \sum_{i=1}^{x} a_i = \sum_{i=1}^{x} \sum_{j=1}^{i} d_j = \sum_{i=1}^{x} (x - i + 1) d_i
\sum_{i=1}^{x} a_i = (x + 1) \sum_{i=1}^{x} d_i - \sum_{i=1}^{x} d_i \times i
1 const int MAXN=1e5+5;
2 int n,q,x,y,z;
3 long long c1[MAXN],c2[MAXN];
4
    void add(int x,int y){
         for(int i=x;i<=n;i+=i&(-i))c1[i]+=y,c2[i]+=1LL*x*y;</pre>
5
6
    11 sum(int x){
7
         ll ans(0);
8
         for(int i=x;i;i-=i&(-i))ans+=1LL*(x+1)*c1[i]-c2[i];
9
         return ans;
10
    }
11
12 char op[5];
    int work(){
13
         scanf("%d%d",&n,&q);
14
         int a1,a2;
15
16
         a1=0;
17
         rep(i,1,n)
              scanf("%d",&a2);
18
              add(i,a2-a1);
19
              a1=a2;
20
21
         while(q--){
22
              scanf("%s",op);
23
              if(op[0]=='Q'){
    scanf("%d%d%d",&x,&y,&z);
    printf("%lld\n",sum(y)-sum(x-1));
24
25
26
              }else{
27
                   scanf("%d%d%d",&x,&y,&z);
28
29
                   add(x,z);
30
                   add(y+1,-z);
31
              }
         }
32
         return 0;
33
    }
34
```

#### 3.2 Segment Tree

```
1 #define lson rt << 1</pre>
                                //
2 #define rson rt << 1 | 1
3 #define Lson l, m, lson
                                //
4 #define Rson m + 1, r, rson //
                                // lson rson rt
5 void PushUp(int rt);
                                                     // rt ,m ( )
6 void PushDown(int rt[, int m]);
7 void build(int l, int r, int rt);
                                                     // rt , [l, r]
8 void update([...,] int l, int r, int rt)
                                                     // rt[l, r]
9 int query(int L, int R, int l, int r, int rt)
                                                    // rt[l, r] [L, R]
   3.2.1 Single-point Update
1 const int maxn = "Edit";
2 int sum[maxn << 2]; // sum[rt]</pre>
3 void PushUp(int rt) { sum[rt] = sum[lson] + sum[rson]; }
4 void build(int l, int r, int rt)
5
       if (l == r)
6
7
            scanf("%d", &sum[rt]); //
8
9
           return;
       }
10
11
       int m = (l + r) >> 1;
       build(Lson);
12
       build(Rson);
13
14
       PushUp(rt);
15 }
   void update(int p, int add, int l, int r, int rt)
16
17
       if (l == r)
18
19
            sum[rt] += add;
20
            return:
21
22
       int m = (l + r) >> 1;
23
       if (p \ll m)
24
           update(p, add, Lson);
25
26
           update(p, add, Rson);
27
28
       PushUp(rt);
29
30 int query(int L, int R, int l, int r, int rt)
31
  {
       if (L <= 1 && r <= R) return sum[rt];</pre>
32
       int m = (l + r) >> 1, s = 0;
33
       if (L \le m) s += query(L, R, Lson);
34
35
       if (m < R) s += query(L, R, Rson);
36
       return s;
37 }
   3.2.2 Interval Update
1 const int maxn = "Edit";
  int seg[maxn << 2], sum[maxn << 2]; // seg[rt] , PushDown</pre>
3 void PushUp(int rt) { sum[rt] = sum[lson] + sum[rson]; }
```

```
void PushDown(int rt, int m)
5
   {
        if (seg[rt] == 0) return;
6
        seg[lson] += seg[rt];
7
        seg[rson] += seg[rt];
sum[lson] += seg[rt] * (m - (m >> 1));
8
9
10
        sum[rson] += seg[rt] * (m >> 1);
        seg[rt] = 0;
11
12
   }
13 void build(int l, int r, int rt)
   {
14
15
        seg[rt] = 0;
        if(l == r)
16
17
            scanf("%lld", &sum[rt]);
18
19
            return;
20
21
        int m = (l + r) >> 1;
        build(Lson);
22
23
        build(Rson);
        PushUp(rt);
24
25 }
26 void update(int L, int R, int add, int l, int r, int rt)
27 {
28
        if (L <= 1 && r <= R)
29
            seg[rt] += add;
30
            sum[rt] += add * (r - l + 1);
31
            return;
32
33
        PushDown(rt, r - l + 1);
34
35
        int m = (l + r) >> 1;
        if (L <= m) update(L, R, add, Lson);</pre>
36
        if (m < R) update(L, R, add, Rson);</pre>
37
        PushUp(rt);
38
39
40
  int query(int L, int R, int l, int r, int rt)
41
        if (L <= 1 && r <= R) return sum[rt];</pre>
42
43
        PushDown(rt, r - l + 1);
44
        int m = (l + r) >> 1, ret = 0;
        if (L <= m) ret += query(L, R, Lson);</pre>
45
        if (m < R) ret += query(L, R, Rson);</pre>
46
47
        return ret;
   }
48
   3.3 Splay Tree
1 #define key_value ch[ch[root][1]][0]
   const int maxn = "Edit";
3 struct Splay
   {
4
        int a[maxn];
5
        int sz[maxn], ch[maxn][2], fa[maxn];
6
        int key[maxn], rev[maxn];
7
8
        int root, tot;
        int stk[maxn], top;
9
10
        void init(int n)
```

```
{
11
            tot = 0, top = 0;
12
            root = newnode(0, -1);
13
            ch[root][1] = newnode(root, -1);
14
            for (int i = 0; i < n; i++) a[i] = i + 1;
15
            key_value = build(0, n - 1, ch[root][1]);
16
            pushup(ch[root][1]);
17
            pushup(root);
18
19
        int newnode(int p = 0, int k = 0)
20
21
22
            int x = top ? stk[top--] : ++tot;
            fa[x] = p;
23
            sz[x] = 1;
24
            ch[x][0] = ch[x][1] = 0;
25
            key[x] = k;
26
27
            rev[x] = 0;
28
            return x;
29
30
        void pushdown(int x)
31
32
            if (rev[x])
33
34
                swap(ch[x][0], ch[x][1]);
35
                if (ch[x][0]) rev[ch[x][0]] ^= 1;
                if (ch[x][1]) rev[ch[x][1]] ^= 1;
36
                rev[x] = 0;
37
38
39
        void pushup(int x) { sz[x] = sz[ch[x][0]] + sz[ch[x][1]] + 1; }
40
41
        void rotate(int x, int d)
42
            int y = fa[x];
43
            pushdown(y), pushdown(x);
44
            ch[y][d ^ 1] = ch[x][d];
45
            fa[ch[x][d]] = y;
46
47
            if (fa[y]) ch[fa[y]][ch[fa[y]][1] == y] = x;
            fa[x] = fa[y];
48
            ch[x][d] = y;
49
            fa[y] = x;
50
            pushup(y);
51
52
        void splay(int x, int goal = 0)
53
54
            pushdown(x);
55
            while (fa[x] != goal)
56
57
                if (fa[fa[x]] == goal)
58
                     rotate(x, ch[fa[x]][0] == x);
59
                else
60
61
                 {
                     int y = fa[x];
62
                     int d = ch[fa[y]][0] == y;
63
                     ch[y][d] == x ? rotate(x, d ^ 1) : rotate(y, d);
64
                     rotate(x, d);
65
66
67
            }
68
            pushup(x);
69
            if (goal == 0) root = x;
```

```
70
        int kth(int r, int k)
71
72
73
            pushdown(r);
            int t = sz[ch[r][0]] + 1;
74
75
            if (t == k) return r;
            return t > k ? kth(ch[r][0], k) : kth(ch[r][1], k - t);
76
77
        int build(int 1, int r, int p)
78
79
            if (l > r) return 0;
80
81
            int mid = l + r \gg 1;
            int x = newnode(p, a[mid]);
82
            ch[x][0] = build(l, mid - 1, x);
83
            ch[x][1] = build(mid + 1, r, x);
84
            pushup(x);
85
86
            return x;
87
        }
        void select(int 1, int r)
88
89
            splay(kth(root, 1), 0);
90
            splay(kth(ch[root][1], r - l + 2), root);
91
        }
92
93
        //
94 };
```

#### 3.4 Functional Segment Tree

k

```
1 //poj 2104
2 #include<cstdio>
3 #include<iostream>
4 #include<cmath>
5 #include<queue>
6 #include<stack>
7 #include<set>
8 #include<map>
9 #include<algorithm>
10 #include<vector>
11 #include<string>
12 #include<cstring>
13 using namespace std;
#define rep(i,a,b) for(int i=a;i<=b;i++)</pre>
#define per(i,a,b) for(int i=a;i>=b;i--)
16 #define pb push_back
17 #define mp make_pair
18 #define all(x) (x).begin(),(x).end()
19 typedef long long ll;
20 typedef vector<int> vi;
21 typedef pair<int,int> pii;
22 const int MAXN=1e5+6;
int n,m,cnt,x,y,k,root[MAXN],a[MAXN];
24 struct node{int l,r,sum;}T[MAXN*40];
25 vi v;
26 int getid(int x){return lower_bound(all(v),x)-v.begin()+1;}
27 void update(int l,int r,int &x,int y,int pos){
```

```
28
       x=++cnt;
29
       T[x]=T[y];
       T[x].sum++;
30
       if(l==r)return;
31
32
       int mid=(l+r)>>1;
       if(mid>=pos)update(l,mid,T[x].l,T[y].l,pos);
33
       else update(mid+1,r,T[x].r,T[y].r,pos);
34
35
   }
   int query(int l,int r,int x,int y,int k){
36
       if(l==r)return l;
37
38
       int sum=T[T[y].l].sum-T[T[x].l].sum;
39
       int mid=(l+r)>>1;
       if(sum>=k)return query(l,mid,T[x].l,T[y].l,k);
40
       else return query(mid+1,r,T[x].r,T[y].r,k-sum);
41
   }
42
   int work(){
43
       scanf("%d%d",&n,&m);
44
       v.clear();
45
       rep(i,1,n)scanf("%d",&a[i]),v.pb(a[i]);
46
       sort(all(v)), v.erase(unique(all(v)), v.end());
47
       cnt=0;
48
       rep(i,1,n)update(1,n,root[i],root[i-1],getid(a[i]));
49
       rep(i,1,m)scanf("%d%d%d",&x,&y,&k),printf("%d\n",v[query(1,n,root[x-1],root[y],k)
50
       -17);
51
       return 0;
   }
52
   int main(){
53
   #ifdef superkunn
54
        freopen("input.txt", "rt", stdin);
55
   #endif
56
57
       work();
       return 0;
58
   }
59
   3.5 Sparse Table
   const int maxn = "Edit";
   int mmax[maxn][30], mmin[maxn][30];
   int a[maxn], n, k;
   void init()
4
5
        for (int i = 1; i \le n; i++) mmax[i][0] = mmin[i][0] = a[i];
6
       for (int j = 1; (1 << j) <= n; j++)
7
            for (int i = 1; i + (1 << j) - 1 <= n; i++)
8
9
            {
                mmax[i][j] = max(mmax[i][j - 1], mmax[i + (1 << (j - 1))][j - 1]);
10
11
                mmin[i][j] = min(mmin[i][j - 1], mmin[i + (1 << (j - 1))][j - 1]);
12
            }
13 }
  // op=0/1 [l,r] /
int rmq(int l, int r, int op)
16
   {
       int k = 31 - \_builtin\_clz(r - l + 1);
17
       if (op == 0)
18
            return max(mmax[l][k], mmax[r - (1 << k) + 1][k]);
19
       return min(mmin[l][k], mmin[r - (1 << k) + 1][k]);</pre>
20
  }
21
     RMQ
```

```
void init()
1
2
   {
        for (int i = 0; (1 << i) <= n; i++)
3
            for (int j = 0; (1 << j) <= m; j++)
4
5
                if (i == 0 \&\& j == 0) continue;
6
                for (int row = 1; row + (1 << i) - 1 <= n; row++)
7
                    for (int col = 1; col + (1 << j) - 1 <= m; col++)
8
9
                            dp[row][col][i][j] = max(dp[row][col][i - 1][j],
10
                                                 dp[row + (1 << (i - 1))][col][i - 1][j]);
11
12
                        else
                            dp[row][col][i][j] = max(dp[row][col][i][j - 1],
13
                                                 dp[row][col + (1 << (j - 1))][i][j - 1]);
14
            }
15
16
   int rmq(int x1, int y1, int x2, int y2)
17
18
       int kx = 31 - \_builtin\_clz(x2 - x1 + 1);
19
       int ky = 31 - \_builtin\_clz(y2 - y1 + 1);
20
       int m1 = dp[x1][y1][kx][ky];
21
       int m2 = dp[x2 - (1 << kx) + 1][y1][kx][ky];
22
       int m3 = dp[x1][y2 - (1 << ky) + 1][kx][ky];
23
24
       int m4 = dp[x2 - (1 << kx) + 1][y2 - (1 << ky) + 1][kx][ky];
25
       return max(max(m1, m2), max(m3, m4));
26 }
   3.6 Heavy-Light Decomposition
   const int maxn = "Edit";
1
2
   struct HLD
3
   {
4
       int n, dfs_clock;
       int sz[maxn], top[maxn], son[maxn], dep[maxn], fa[maxn], id[maxn];
5
       vector<int> G[maxn];
6
       void init(int n)
7
8
        {
9
            this->n = n, clr(son, -1), dfs_clock = 0;
10
            for (int i = 0; i < n; i++) G[i].clear();
11
12
       void add_edge(int u, int v) { G[u].pb(v), G[v].pb(u); }
       void dfs(int u, int p, int d)
13
14
            dep[u] = d, fa[u] = p, sz[u] = 1;
15
16
            for (auto& v : G[u])
17
                if (v == p) continue;
18
19
                dfs(v, u, d + 1);
20
                sz[u] += sz[v];
                if (son[u] == -1 \mid | sz[v] > sz[son[u]]) son[u] = v;
21
            }
22
23
       void link(int u, int t)
24
25
            top[u] = t, id[u] = ++dfs\_clock;
26
27
            if (son[u] == -1) return;
28
            link(son[u], t);
            for (auto& v : G[u])
29
```

```
if (v != son[u] && v != fa[u]) link(v, v);
30
        }
//
31
32
        int query_path(int u, int v)
33
34
35
            int ret = 0;
            while (top[u] != top[v])
36
37
                 if (dep[top[u]] < dep[top[v]]) swap(u, v);</pre>
38
39
                 ret += query(id[top[u]], id[u]);
                 u = fa[top[u]];
40
41
            }
            if (dep[u] > dep[v]) swap(u, v);
42
            ret += query(id[u], id[v]);
43
        }
44
   };
45
```

### 3.7 Link-Cut Tree

```
1 const int maxn = "Edit";
   struct LCT
3
   {
       int val[maxn], sum[maxn]; //
4
       int rev[maxn], ch[maxn][2], fa[maxn];
5
6
       int stk[maxn];
7
       inline void init(int n)
8
        { //
            for (int i = 1; i <= n; i++) scanf("%d", val + i);</pre>
9
10
       inline bool isroot(int x) { return ch[fa[x]][0] != x && ch[fa[x]][1] != x; }
11
12
       inline bool get(int x) { return ch[fa[x]][1] == x; }
       void pushdown(int x)
13
       {
14
            if (!rev[x]) return;
15
            swap(ch[x][0], ch[x][1]);
            if (ch[x][0]) rev[ch[x][0]] ^= 1;
17
18
            if (ch[x][1]) rev[ch[x][1]] ^= 1;
19
            rev[x] ^= 1;
20
21
       void pushup(int x) { sum[x] = val[x] + sum[ch[x][0]] + sum[ch[x][1]]; }
       void rotate(int x)
22
23
24
            int y = fa[x], z = fa[fa[x]], d = get(x);
            if (!isroot(y)) ch[z][get(y)] = x;
25
            fa[x] = z;
26
            ch[y][d] = ch[x][d \land 1], fa[ch[y][d]] = y;
27
            ch[x][d ^ 1] = y, fa[y] = x;
28
29
            pushup(y), pushup(x);
30
       }
       void splay(int x)
31
32
33
            int top = 0;
34
            stk[++top] = x;
            for (int i = x; !isroot(i); i = fa[i]) stk[++top] = fa[i];
35
            for (int i = top; i; i--) pushdown(stk[i]);
36
            for (int f; !isroot(x); rotate(x))
37
```

```
if (!isroot(f = fa[x])) rotate(get(x) == get(f) ? f : x);
38
39
       void access(int x)
40
       {
41
           for (int y = 0; x; y = x, x = fa[x]) splay(x), ch[x][1] = y, pushup(x);
42
43
       int find(int x) { access(x), splay(x); while (ch[x][0]) x = ch[x][0]; return x; }
44
       void makeroot(int x) { access(x), splay(x), rev[x] ^{-1}; }
45
       void link(int x, int y) { makeroot(x), fa[x] = y, splay(x); }
46
       void cut(int x, int y) { makeroot(x), access(y), splay(y), fa[x] = ch[y][0] = 0; }
47
       void update(int x, int v) { val[x] = v, access(x), splay(x); }
48
       int query(int x, int y) { makeroot(y), access(x), splay(x); return sum[x]; }
49
   };
50
```

## Graph Theory

#### Union-Find Set

```
const int MAXN=1e6+5;
  struct DSU{
2
3
       int p[MAXN];
       void init(int n){for(int i=0;i<=n;i++)p[i]=i;}</pre>
       int findp(int x){return x==p[x]?x:p[x]=findp(p[x]);}
5
6
       void unite(int x,int y){x=findp(x);y=findp(y);if(x==y)return;p[y]=x;}
       bool same(int x,int y){return findp(x)==findp(y);}
  }dsu;
  4.2
        Minimal Spanning Tree
```

#### 4.2.1 Kruskal

```
1 //poj 1258
2 #include<cstdio>
3 #include<algorithm>
4 using namespace std;
5 const int MAXE=1e5+5;
  const int MAXN=1e5+5;
7
   struct DSU{
8
        int p[MAXN];
9
        void init(int n){for(int i=0;i<=n;i++)p[i]=i;}</pre>
10
        int findp(int x){return x==p[x]?x:p[x]=findp(p[x]);}
11
        void unite(int x,int y){x=findp(x);y=findp(y);if(x==y)return;p[y]=x;}
        bool same(int x,int y){return findp(x)==findp(y);}
12
   }dsu;
13
   struct edge{int u,v,cost;}es[MAXE];
   bool cmp(const edge &x,const edge &y){return x.cost<y.cost;}</pre>
16
  int V,E;
17
   int kruskal(){
        sort(es,es+E,cmp);
18
        dsu.init(V);
19
20
        int res=0;
        for(int i=0;i<E;i++){</pre>
21
22
            if(!dsu.same(es[i].u,es[i].v)){
23
                dsu.unite(es[i].u,es[i].v);
24
                res+=es[i].cost;
            }
25
26
27
        return res;
28
   int main(){
29
        while(~scanf("%d",&V)){
30
31
            E=0;
            for(int i=1;i<=V;i++){</pre>
32
                 for(int j=1;j<=V;j++){</pre>
33
34
                     int w;
                     scanf("%d",&w);
35
36
                     if(i==j)continue;
                     es[E].u=i;
37
                     es[E].v=j;
38
                     es[E].cost=w;
39
40
                     E++;
                }
41
```

```
42
            printf("%d\n",kruskal());
43
44
45
        return 0;
   }
46
   4.3
         Shortest Path
   4.3.1 Dijkstra
   //cf 610 A
2 #include<bits/stdc++.h>
3 using namespace std;
   const int INF=1e9;
   const int MAXV=5e3+50;
   const int MAXE=1e5+50;
6
7
   int V;
   struct edge{int to,cost;};
8
   vector<edge> G[MAXV];
   typedef pair<int, int> P;
10
   int d[MAXV];
11
12
   void dijkstra(int s){
13
        priority_queue<P,vector<P>,greater<P> > que;
        fill(d,d+V+1,INF);
14
        d[s]=0;
15
16
        que.push(P(0,s));
17
        while(!que.empty()){
18
            P t=que.top();
19
            que.pop();
            int v=t.second;
20
            if(d[v]<t.first)continue;</pre>
21
            for(int i=0;i<G[v].size();i++){</pre>
22
                edge e=G[v][i];
23
24
                 if(d[e.to]>d[v]+e.cost){
                     d[e.to]=d[v]+e.cost;
25
                     que.push(P(d[e.to],e.to));
26
27
                }
            }
28
        }
29
30
   }
31
   int mat[405][405];
   int main(){
32
        int n,m;
33
        scanf("%d%d",&n,&m);
34
35
        V=n;
        for(int i=1;i<=m;i++){</pre>
36
            int u,v;
37
            scanf("%d%d",&u,&v);
38
            G[u].push_back(edge{v,1});
39
            G[v].push_back(edge{u,1});
40
            mat[u][v]=mat[v][u]=1;
41
        }
42
        dijkstra(1);
43
        int ans;
44
        if(d[n]==INF){
45
            printf("-1");
46
            return 0;
47
48
        ans=d[n];
49
```

```
for(int i=1;i<=n;i++)G[i].clear();</pre>
50
        for(int i=1;i<=n;i++){</pre>
51
            for(int j=1;j<=n;j++){
   if(i==j)continue;</pre>
52
53
                 if(mat[i][j]==0){
54
                     G[i].push_back(edge{j,1});
55
                 }
56
            }
57
        }
58
        dijkstra(1);
59
60
        if(d[n]==INF){
            printf("-1");
61
            return 0;
62
        }
63
        printf("%d",max(ans,d[n]));
64
        return 0;
65
   }
66
   4.3.2 Spfa
1 //poj 3259
2 #include<cstdio>
3 #include<iostream>
4 #include<algorithm>
5 #include<queue>
6 #include<cstring>
7
  using namespace std;
8 const int INF=1e9;
9 const int MAXV=500+5;
10 const int MAXE=2700+5;
11 int tot;
12 int head[MAXV];
13 struct node{
14
        int to,cost,next;
15 }edge[MAXE<<1];</pre>
16 int d[MAXV];
17 queue<int> que;
18 bool inq[MAXV];
19 int qtime[MAXV];
20
   void init(){
        tot=0:
21
22
        memset(head,-1,sizeof(head));
23
   void add_edge(int u,int v,int x){
24
        edge[tot].to=v;
25
26
        edge[tot].cost=x;
        edge[tot].next=head[u];
27
        head[u]=tot++;
28
29
   }
   bool spfa(int n){
30
        memset(d,-1,sizeof(d));
31
32
        d\Gamma17=0;
33
        while(!que.empty())que.pop();
        memset(inq,0,sizeof(inq));
34
        memset(qtime,0,sizeof(qtime));
35
36
        que.push(1);
        ina[1]=1;
37
38
        qtime[1]++;
```

```
while(!que.empty()){
39
            int u=que.front();
40
            que.pop();
41
            inq[u]=0;
42
            for(int i=head[u];i!=-1;i=edge[i].next){
43
                 int v=edge[i].to;
44
                 int w=edge[i].cost;
45
                 if(d[v]==-1|[d[u]+w<d[v]){
46
                     d[v]=d[u]+w;
47
                     if(!inq[v]){
48
49
                          inq[v]=1;
50
                          que.push(v);
                          qtime[v]++;
51
52
                          if(qtime[v]>n){
53
                              return false;
                          }
54
                     }
55
                 }
56
57
            }
58
        }
59
        return true;
   }
60
   int main(){
61
62
        int kase;
        scanf("%d",&kase);
63
        while(kase--){
64
            init();
65
            int n,m,w;
66
            scanf("%d%d%d",&n,&m,&w);
67
            while(m--){
68
                 int u,v,x;
scanf("%d%d%d",&u,&v,&x);
69
70
71
                 add_edge(u,v,x);
72
                 add_edge(v,u,x);
73
            }
74
            while(w--){
75
                 int u,v,x;
76
                 scanf("%d%d%d",&u,&v,&x);
                 add_edge(u,v,-x);
77
78
            if(!spfa(n)){
79
                 puts("YES");
80
            }else{
81
82
                 puts("N0");
83
            }
84
85
        return 0;
   }
86
          Topo Sort
         ,G ,deg ,map
    Ans
1 const int maxn = "Edit";
   int Ans[maxn];
3 vector<int> G[maxn];
```

```
int deg[maxn];
   map<PII, bool> S;
   void init(int n)
6
7
   {
8
        S.clear();
        for (int i = 0; i < n; i++) G[i].clear();</pre>
9
10
        clr(deg, 0), clr(Ans, 0);
11
12 void add_edge(int u, int v)
13
   {
        if (S[mp(u, v)]) return;
14
15
        G[u].pb(v), S[mp(u, v)] = 1, deg[v]++;
   }
16
   bool Toposort(int n)
17
18
        int tot = 0;
19
        queue<int> q;
20
21
        for (int i = 0; i < n; ++i)
            if (deg[i] == 0) q.push(i);
22
23
        while (!q.empty())
24
        {
            int u = q.front();
25
            que.pop();
26
27
            Ans[tot++] = u;
28
            for (auto& v : G[u])
                if (--deg[v] == 0) q.push(t);
29
30
        if (tot < n - 1) return false;
31
        return true;
32
33 }
   4.5 LCA
   4.5.1 Tarjan
   Tarjan
      O(n+q)
1 const int maxn = "Edit";
2 int par[maxn];
                              //
3 int ans[maxn];
                              //
  vector<int> G[maxn];
 4
                              //
   vector<PII> query[maxn]; //
5
   bool vis[maxn];
6
   inline void init(int n)
7
8
   {
9
        for (int i = 1; i <= n; i++)
10
            G[i].clear(), query[i].clear();
11
            par[i] = i, vis[i] = 0;
12
        }
13
14
   }
   inline void add_edge(int u, int v) { G[u].pb(v); }
   inline void add_query(int id, int u, int v)
16
17
   {
        query[u].pb(mp(v, id));
18
19
        query[v].pb(mp(u, id));
20
21 void tarjan(int u)
```

```
22
   {
        vis[u] = 1;
23
24
        for (auto& v : G[u])
25
26
            if (vis[v]) continue;
27
            tarjan(v);
28
            unite(u, v);
29
        for (auto& q : query[u])
30
31
            int &v = q.X, &id = q.Y;
32
33
            if (!vis[v]) continue;
            ans[id] = find(v);
34
35
        }
   }
36
   4.5.2 LCArmq
1 #include<bits/stdc++.h>
2 #define MAXV 100005
3 #define MAXLOGV 32
4 using namespace std;
5 int N,M,Q;
6 int st[MAXLOGV][MAXV];
7 vector<int> G[MAXV];
8
   int root;
9
  int vs[MAXV*2];
10 int depth[MAXV*2];
11
   int id[MAXV];
   void dfs(int v,int p,int d,int &k){
12
13
        id[v]=k;
14
        vs[k]=v;
15
        depth[k++]=d;
16
        for(int i=0;i<G[v].size();i++){</pre>
17
            if(G[v][i]!=p){
                 dfs(G[v][i],v,d+1,k);
18
19
                 vs[k]=v;
                 depth[k++]=d;
20
21
            }
22
        }
23
   }
24
   int getMin(int x, int y){
        return depth[x]<depth[y]?x:y;</pre>
25
   }
26
27
   void rmq_init(int n){
28
        for(int i=0;i<n;++i) st[0][i]=i;</pre>
29
        for(int i=1;1<<i<n;++i)</pre>
30
            for(int j=0; j+(1<< i)-1< n; ++j)
31
                 st[i][j]=getMin(st[i-1][j],st[i-1][j+(1<<(i-1))]);
32
33
   }
   void init(int V){
34
35
        int k=0;
36
        dfs(root, -1, 0, k);
        rmq_init(V*2-1);
37
   }
38
   int query(int 1, int r){
39
40
        int k=31-__builtin_clz(r-l+1);
```

```
return getMin(st[k][l],st[k][r-(1<<k)+1]);</pre>
41
42
   }
   int lca(int u,int v){
43
        if(u==v) return u;
44
        return vs[query(min(id[u],id[v]),max(id[u],id[v]))];
45
46
   int dis(int u,int v){
47
        return depth[id[u]]+depth[id[v]]-2*depth[id[lca(u,v)]];
48
   }
49
  int main()
50
   {
51
        scanf("%d%d",&N,&M);
52
        for(int i=0;i<M;i++){</pre>
53
            int x,y;
54
            scanf("%d%d",&x,&y);
55
            G[x].push_back(y);
56
            G[y].push_back(x);
57
        }
58
        root=0;
59
        init(N);
60
        scanf("%d",&Q);
61
        while(Q--){
62
            int x,y;
63
            scanf("%d%d",&x,&y);
64
            printf("%d\n",lca(x,y));
65
66
67
        return 0;
   }
68
        Depth-First Traversal
   4.6.1 Biconnected-Component
1 // bccno
2 const int maxn = "Edit";
3 int pre[maxn], iscut[maxn], bccno[maxn], dfs_clock, bcc_cnt;
4 vector<int> G[maxn], bcc[maxn];
  stack<PII> s;
6
   void init(int n)
7
   {
8
        for (int i = 0; i < n; i++) G[i].clear();
9
   }
   inline void add_edge(int u, int v) { G[u].pb(v), G[v].pb(u); }
10
   int dfs(int u, int fa)
11
12
   {
        int lowu = pre[u] = ++dfs_clock;
13
        int child = 0;
14
        for (auto& v : G[u])
15
16
        {
            PII e = mp(u, v);
17
            if (!pre[v])
18
19
                // v
20
21
                s.push(e);
                child++;
22
                int lowv = dfs(v, u);
23
                lowu = min(lowu, lowv); // low
24
                if (lowv >= pre[u])
25
26
                {
```

```
iscut[u] = true;
27
                    bcc_cnt++;
28
                    bcc[bcc_cnt].clear(); // !bcc 1
29
                    for (;;)
30
31
                        PII x = s.top();
32
33
                        s.pop();
                        if (bccno[x.X] != bcc_cnt)
34
                            bcc[bcc\_cnt].pb(x.X), bcc[x.X] = bcc\_cnt;
35
                        if (bccno[x.Y] != bcc_cnt)
36
37
                            bcc[bcc\_cnt].pb(x.Y), bcc[x.Y] = bcc\_cnt;
38
                        if (x.X == u \&\& x.Y == v) break;
                    }
39
                }
40
41
            else if (pre[v] < pre[u] && v != fa)</pre>
42
43
44
                s.push(e);
                lowu = min(lowu, pre[v]); //
45
46
47
       if (fa < 0 && child == 1) iscut[u] = 0;
48
       return lowu;
49
50 }
51 void find_bcc(int n)
52 {
53
       clr(pre, 0), clr(iscut, 0), clr(bccno, 0);
54
       dfs_clock = bcc_cnt = 0;
55
       for (int i = 0; i < n; i++)
56
            if (!pre[i]) dfs(i, -1);
57
58 }
   4.6.2 Strongly Connected Component
1 //cf 999 E
2 #include<bits/stdc++.h>
3 using namespace std;
4 typedef long long ll;
5 const int MAXN = 5005;//
6 const int MAXM = 5005;//
   struct Edge{
7
8
       int to,next;
   } edge[MAXM];
10 int head[MAXN],tot;
int Low[MAXN],DFN[MAXN],Stack[MAXN],Belong[MAXN];//Belong 1~scc
12 int Index,top;
13 int scc;//
14 bool Instack[MAXN];
15 void init(){
       tot = 0;
16
       memset(head, -1, sizeof(head));
17
   }
18
   void addedge(int u,int v){
19
       edge[tot].to = v;
20
       edge[tot].next = head[u];
21
       head[u] = tot++;
22
23 }
```

```
void Tarjan(int u){
24
25
        int v;
        Low[u] = DFN[u] = ++Index;
26
27
        Stack[top++] = u;
        Instack[u] = true;
28
        for(int i = head[u]; i != -1; i = edge[i].next){
29
            v = edge[i].to;
30
            if( !DFN[v] ){
31
32
                Tarjan(v);
                if( Low[u] > Low[v] )Low[u] = Low[v];
33
34
            }
35
            else if(Instack[v] && Low[u] > DFN[v])
                Low[u] = DFN[v];
36
37
        if(Low[u] == DFN[u]){
38
39
            SCC++;
            do{
40
                v = Stack[--top];
41
                Instack[v] = false;
42
                Belong[v] = scc;
43
44
            while( v != u);
45
        }
46
47
   }
48
   void solve(int N){
        memset(DFN,0,sizeof(DFN));
49
        memset(Instack,0,sizeof(Instack));
50
        Index = scc = top = 0;
51
        for(int i = 1; i <= N; i++)
52
            if(!DFN[i])
53
54
                Tarjan(i);
55
   int u[MAXM],v[MAXM],in[MAXN],vis[MAXN];
56
   int n,m,s;
57
   void dfs(int x){
58
59
        Belong[x]=Belong[s];
60
        vis[x]=true;
61
        for(int i=head[x];i!=-1;i=edge[i].next){
            int e=edge[i].to;
62
63
            if(!vis[e])dfs(e);
        }
64
   }
65
   int main(){
66
        scanf("%d%d%d",&n,&m,&s);
67
        init();
68
69
        for(int i=1;i<=m;i++){</pre>
70
            scanf("%d%d",&u[i],&v[i]);
            addedge(u[i],v[i]);
71
72
        }
73
        solve(n);
74
        dfs(s);
75
        int ans=0;
        for(int i=1;i<=m;i++){</pre>
76
            if(Belong[u[i]]!=Belong[v[i]]){
77
78
                in[Belong[v[i]]]++;
            }
79
80
81
        set<int> ss;
        for(int i=1;i<=n;i++){</pre>
82
```

```
ss.insert(Belong[i]);
83
84
        set<int>::iterator it;
85
        for(it=ss.begin();it!=ss.end();it++){
86
87
            if(*it!=Belong[s]){
                if(in[*it]==0){
88
89
                     ans++;
                }
90
            }
91
92
        }
93
        printf("%d",ans);
        return 0;
94
   }
95
   4.6.3 2-SAT
   //hdu 3062
   #include<bits/stdc++.h>
3 using namespace std;
4 const int MAXV=1e4;
5 int V;
6 vector<int> G[MAXV];
7 vector<int> rG[MAXV];
   vector<int> vs;
  bool used[MAXV];
10
  int Belong[MAXV];
11
   void init(int x){
12
        V=x;
        for(int i=0;i<MAXV;i++){</pre>
13
            G[i].clear();
14
15
            rG[i].clear();
16
        }
17
   }
   void add_edge(int u,int v){
18
        G[u].push_back(v);
19
20
        rG[v].push_back(u);
21
   }
22
   void dfs(int v){
23
        used[v]=true;
24
        for(int i=0;i<G[v].size();i++)</pre>
            if(!used[G[v][i]]) dfs(G[v][i]);
25
        vs.push_back(v);
26
27
   }
   void rdfs(int v,int k){
28
29
        used[v]=true;
30
        Belong[v]=k;
        for(int i=0;i<rG[v].size();i++)</pre>
31
            if(!used[rG[v][i]]) rdfs(rG[v][i],k);
32
   }
33
   int scc(){
34
        memset(used,0,sizeof(used));
35
        vs.clear();
36
37
        for(int v=1;v<=V;v++){//from 1 to V</pre>
38
            if(!used[v]) dfs(v);
        }
39
40
        int k=0;
        memset(used,0,sizeof(used));
41
42
        for(int i=vs.size()-1;i>=0;i--){
```

```
if(!used[vs[i]]) rdfs(vs[i],k++);
43
44
         return k;
45
    }
46
    bool judge(){
47
         for(int i=1;i<V;i+=2){</pre>
48
              if(Belong[i]==Belong[i+1])return false;
49
50
         return true;
51
    }
52
53
    int main(){
54
         int n,m;
         while(scanf("%d%d",&n,&m)!=EOF){
55
              init(2*n);
56
              for(int i=1;i<=m;i++){</pre>
57
                  int a1,a2,c1,c2;
scanf("%d%d%d%d",&a1,&a2,&c1,&c2);
add_edge(((a1*2+c1))+1,((a2*2+c2)^1)+1);
58
59
60
                   add_edge(((a2*2+c2))+1,((a1*2+c1)^1)+1);
61
              }
62
63
              scc();
64
              printf("%s\n", judge()?"YES":"NO");
65
66
         return 0;
67
   }
```

## 4.7 Eular Path

```
(
                )
         ( ,
                   ),
G
- G
- G
           )
               0 2.
G
- G
- G
G
- G
– u
        _{1,v}
                      (u ,v )
              1,
G
- G
- G
```

#### 4.7.1 Fleury

,

```
1 const int maxn = "Edit";
   int G[maxn][maxn];
   int deg[maxn][maxn];
   vector<int> Ans;
   inline void init() { clr(G, 0), clr(deg, 0); }
   inline void AddEdge(int u, int v) { deg[u]++, deg[v]++, G[u][v]++, G[v][u]++; }
   void Fleury(int s)
7
   {
8
9
        for (int i = 0; i < n; i++)
            if (G[s][i])
10
11
12
                G[s][i]--, G[i][s]--;
                Fleury(i);
13
14
        Ans.pb(s);
15
   }
16
        Bipartite Graph Matching
      1.
      2.
            =|G|-
          N \times N
                                 );
         (a)
                                        , \quad p_1, p_2, \dots p_k
         (b)
                p_1, p_2, \ldots, p_k, p_1, p_k
                    G
                   =|G|-
      3.
   4.8.1 Hungry(Matrix)
      :O(VE).
1 const int maxn = "Edit";
  int uN, vN; //uN
                                 ,∨N
   int g[maxn][maxn]; // g[i][j] i->j
   int linker[maxn];
   bool used[maxn];
5
   bool dfs(int u)
6
7
   {
        for (int v = 0; v < vN; v++)
8
            if (g[u][v] && !used[v])
9
10
                used[v] = true;
11
                if (linker[v] == -1 || dfs(linker[v]))
12
                {
13
14
                    linker[v] = u;
15
                    return true;
                }
16
            }
17
        return false;
18
19
  }
```

```
20 int hungary()
21
   {
22
        int res = 0;
23
        clr(linker, -1);
24
        for (int u = 0; u < uN; u++)
25
26
            clr(used, 0);
27
            if (dfs(u)) res++;
28
        }
29
        return res;
30
  }
   4.8.2 Hungry(List)
      init()
       addedge(u,v)
1 const int maxn = "Edit";
2 int n;
3 vector<int> G[maxn];
   int linker[maxn];
4
   bool used[maxn];
   inline void init(int n)
6
7
   {
        for (int i = 0; i < n; i++) G[i].clear();</pre>
8
9
10
   inline void addedge(int u, int v) { G[u].pb(v); }
   bool dfs(int u)
12
   {
        for (auto& v : G[u])
13
14
15
            if (!used[v])
16
                used[v] = true;
17
                if (linker[v] == -1 || dfs(linker[v]))
18
19
                     linker[v] = u;
20
21
                     return true;
                }
22
23
            }
24
25
        return false;
26
27 int hungary()
28
   {
        int ans = 0;
29
30
        clr(linker, -1);
        for (int u = 0; u < n; v++)
31
32
            clr(used, 0);
33
34
            if (dfs(u)) ans++;
35
36
        return ans;
   }
37
```

## 4.8.3 Hopcroft-Carp

```
O(\sqrt{n}*E)
         , \quad (0)
   uN
   const int maxn = "Edit";
2 vector<int> G[maxn];
   int uN;
4 int Mx[maxn], My[maxn];
5 int dx[maxn], dy[maxn];
  int dis;
   bool used[maxn];
7
8 inline void init(int n)
9 {
        for (int i = 0; i < n; i++) G[i].clear();</pre>
10
11 }
inline void addedge(int u, int v) { G[u].pb(v); }
13
   bool bfs()
   {
14
        queue<int> q;
15
        dis = INF;
16
        clr(dx, -1), clr(dy, -1);
17
        for (int i = 0; i < uN; i++)
18
19
            if (Mx[i] == -1)
20
                q.push(i), dx[i] = 0;
21
        while (!q.empty())
22
            int u = q.front();
23
24
            q.pop();
25
            if (dx[u] > dis) break;
26
            for (auto& v : G[u])
27
                if (dy[v] == -1)
28
29
30
                     dy[v] = dx[u] + 1;
31
                     if (My[v] == -1)
32
                         dis = dy[v];
33
                     else
34
                     {
35
                         dx[My[v]] = dy[v] + 1;
36
                         q.push(My[v]);
37
                     }
38
                }
39
            }
40
        return dis != INF;
41
42
   bool dfs(int u)
43
44
   {
        for (auto& v : G[u])
45
46
            if (!used[v] && dy[v] == dx[u] + 1)
47
48
                used[v] = true;
49
                if (My[v] != -1 \&\& dy[v] == dis) continue;
50
                if (My[v] == -1 \mid I \mid dfs(My[v]))
51
52
53
                     My[v] = u, Mx[u] = v;
                     return true;
54
55
                }
            }
56
        }
57
```

```
return false;
58
59
   int MaxMatch()
60
61
   {
62
        int res = 0;
        clr(Mx, -1), clr(My, -1);
63
        while (bfs())
64
65
        {
            clr(used, false);
66
            for (int i = 0; i < uN; i++)
67
68
                if (Mx[i] == -1 \&\& dfs(i)) res++;
69
        }
70
        return res;
   }
71
   4.8.4 Hungry(Multiple)
1 const int maxn = "Edit";
   const int maxm = "Edit";
  int uN, vN;
3
                        //u,v ,
  int g[maxn][maxm]; //
  int linker[maxm][maxn];
6 bool used[maxm];
7
   int num[maxm]; //
   bool dfs(int u)
8
9
   {
        for (int v = 0; v < vN; v++)
10
            if (g[u][v] && !used[v])
11
12
                used[v] = true;
13
                if (linker[v][0] < num[v])</pre>
14
15
                     linker[v][++linker[v][0]] = u;
16
                     return true;
17
18
19
                for (int i = 1; i <= num[0]; i++)</pre>
20
                     if (dfs(linker[v][i]))
21
22
                         linker[v][i] = u;
23
                         return true;
24
25
26
        return false;
27
   }
28
  int hungary()
29
   {
        int res = 0;
30
        for (int i = 0; i < vN; i++) linker[i][0] = 0;</pre>
31
32
        for (int u = 0; u < uN; u++)
33
34
            clr(used, 0);
            if (dfs(u)) res++;
35
36
37
        return res;
38
   }
```

#### 4.8.5 Kuhn-Munkres

```
1 const int maxn = "Edit";
                                            //
  int nx, ny;
   int g[maxn][maxn];
                                            //
   int linker[maxn], lx[maxn], ly[maxn]; //y
                                                   ,x,y
   int slack[N];
   bool visx[N], visy[N];
   bool dfs(int x)
7
8
   {
9
        visx[x] = true;
10
        for (int y = 0; y < ny; y++)
11
12
            if (visy[y]) continue;
            int tmp = lx[x] + ly[y] - g[x][y];
13
            if (tmp == 0)
14
15
                visy[y] = true;
16
                if (linker[y] == -1 || dfs(linker[y]))
17
18
19
                     linker[y] = x;
20
                     return true;
                }
21
22
23
            else if (slack[y] > tmp)
24
                slack[y] = tmp;
25
        return false;
26
27
   }
   int KM()
28
29
   {
        clr(linker, -1), clr(ly, 0);
30
31
        for (int i = 0; i < nx; i++)
32
33
            lx[i] = -INF;
            for (int j = 0; j < ny; j++)
34
                if (g[i][j] > lx[i]) lx[i] = g[i][j];
35
36
37
        for (int x = 0; x < nx; x++)
38
            clr(slack, 0x3f);
39
            for (;;)
40
41
                clr(visx, 0), clr(visy, 0);
42
                if (dfs(x)) break;
43
                int d = INF;
44
                for (int i = 0; i < ny; i++)
45
46
                     if (!visy[i] && d > slack[i]) d = slack[i];
                for (int i = 0; i < nx; i++)
47
                     if (visx[i]) lx[i] -= d;
48
                for (int i = 0; i < ny; i++)
49
50
                     if (visy[i])
51
                         ly[i] += d;
52
                     else
                         slack[i] -= d;
53
            }
54
55
        int res = 0;
56
        for (int i = 0; i < ny; i++)
57
            if (~linker[i]) res += g[linker[i]][i];
58
59
        return res;
```

```
60 }
    4.9 Network Flow
1 struct Edge
2
         int from, to, cap, flow;
3
         Edge(int u, int v, int c, int f)
4
             : from(u), to(v), cap(c), flow(f) {}
5
   };
1 struct Edge
2
    {
         int from, to, cap, flow, cost;
3
         Edge(int u, int v, int c, int f, int w)
4
             : from(u), to(v), cap(c), flow(f), cost(w) {}
6 };
               S \quad T, \quad S \quad X \qquad \quad , \quad Y \qquad T \quad \quad , \qquad \quad X \quad \quad Y
            m
                                                             \{p_1, p_2\}
                                                                       , 1,
                                                                                         T, x,
                     , T
                                                    O(\log m)
                                 m
         k
                                    k
                     , \qquad w \qquad [u,v) \quad u \rightarrow v, \quad 1, \quad -w \qquad \qquad i \rightarrow i+1, \quad k, \quad 0 \quad ,
               G( ),
            s t, s
                                              S - \{s\}
                        , ;
    4.9.1 EdmondKarp
    const int maxn = "Edit";
    struct EdmonsKarp // O(v*E*E)
2
3
    {
         int n, m;
4
         vector<Edge> edges; //
5
         vector<int> G[maxn]; // ,G[i][j] i j e
6
         int a[maxn];
                               // i
7
         int p[maxn];
                                 // p
8
         void init(int n)
9
10
             for (int i = 0; i < n; i++) G[i].clear();</pre>
11
12
             edges.clear();
13
         void AddEdge(int from, int to, int cap)
14
15
             edges.pb(Edge(from, to, cap, 0));
16
             edges.pb(Edge(to, from, 0, 0)); //
17
```

```
m = edges.size();
18
            G[from].pb(m - 2);
19
            G[to].pb(m - 1);
20
21
        int Maxflow(int s, int t)
22
23
            int flow = 0;
24
25
            for (;;)
26
            {
                 clr(a, 0);
27
28
                 queue<int> q;
29
                 q.push(s);
                 a[s] = INF;
30
                 while (!q.empty())
31
32
                     int x = q.front();
33
34
                     q.pop();
                     for (int i = 0; i < G[x].size(); i++)</pre>
35
36
                         Edge& e = edges[G[x][i]];
37
                         if (!a[e.to] && e.cap > e.flow)
38
39
                              p[e.to] = G[x][i];
40
41
                              a[e.to] = min(a[x], e.cap - e.flow);
42
                              q.push(e.to);
43
44
                     if (a[t]) break;
45
46
                 if (!a[t]) break;
47
                 for (int u = t; u != s; u = edges[p[u]].from)
48
49
                     edges[p[u]].flow += a[t];
50
                     edges[p[u] ^1].flow -= a[t];
51
52
                 flow += a[t];
53
54
            }
55
            return flow;
        }
56
   };
57
   4.9.2 Dinic
   const int maxn = "Edit";
   struct Dinic
2
3
   {
        int n, m, s, t;
                               // , ( ),
4
        vector<Edge> edges; // edge[e] edge[e^1]
5
        vector<int> G[maxn]; // ,G[i][j] i j e
6
        bool vis[maxn];
                               //BFS
7
        int d[maxn];
                               // i
8
9
        int cur[maxn];
                               //
10
        void init(int n)
11
12
            this -> n = n;
            for (int i = 0; i < n; i++) G[i].clear();</pre>
13
14
            edges.clear();
        }
15
```

```
void AddEdge(int from, int to, int cap)
16
17
            edges.pb(Edge(from, to, cap, 0));
18
            edges.pb(Edge(to, from, 0, 0));
19
20
            m = edges.size();
            G[from].pb(m - 2);
21
22
            G[to].pb(m - 1);
23
24
        bool BFS()
25
26
            clr(vis, 0);
27
            clr(d, 0);
28
            queue<int> q;
29
            q.push(s);
            d[s] = 0;
30
            vis[s] = 1;
31
            while (!q.empty())
32
33
                 int x = q.front();
34
35
                 q.pop();
                 for (int i = 0; i < G[x].size(); i++)</pre>
36
37
                     Edge& e = edges[G[x][i]];
38
39
                     if (!vis[e.to] && e.cap > e.flow)
40
                          vis[e.to] = 1;
41
                          d[e.to] = d[x] + 1;
42
                          q.push(e.to);
43
                     }
44
                 }
45
46
            }
            return vis[t];
47
48
        int DFS(int x, int a)
49
50
            if (x == t | | a == 0) return a;
51
52
            int flow = 0, f;
53
            for (int& i = cur[x]; i < G[x].size(); i++)</pre>
54
55
                 Edge& e = edges[G[x][i]];
56
                 if (d[x] + 1 == d[e.to] && (f = DFS(e.to, min(a, e.cap - e.flow))) > 0)
57
58
                     e.flow += f;
59
                     edges[G[x][i] \land 1].flow -= f;
60
                     flow += f;
61
62
                     a -= f;
                     if (a == 0) break;
63
                 }
64
65
            }
66
            return flow;
67
        int Maxflow(int s, int t)
68
69
            this -> s = s;
70
71
            this->t = t;
            int flow = 0;
72
            while (BFS())
73
74
            {
```

```
clr(cur, 0);
75
                flow += DFS(s, INF);
76
77
78
            return flow;
       }
79
80
   };
   4.9.3 ISAP
   const int maxn = "Edit";
   struct ISAP
3
   {
       4
5
       vector<int> G[maxn]; // ,G[i][j] i j e
6
7
       bool vis[maxn];
                             //BFS
       int d[maxn];
                             // i
8
                             //
       int cur[maxn];
9
10
       int p[maxn];
                             //
       int num[maxn];
                             //
11
       void init(int n)
12
13
       {
            this->n = n;
14
            for (int i = 0; i < n; i++) G[i].clear();</pre>
15
            edges.clear();
16
17
       }
18
       void AddEdge(int from, int to, int cap)
19
            edges.pb(Edge(from, to, cap, 0));
20
            edges.pb(Edge(to, from, 0, 0));
21
22
            int m = edges.size();
23
            G[from].pb(m - 2);
24
           G[to].pb(m - 1);
25
       int Augument()
26
27
28
            int x = t, a = INF;
29
           while (x != s)
30
            {
31
                Edge& e = edges[p[x]];
32
                a = min(a, e.cap - e.flow);
                x = edges[p[x]].from;
33
            }
34
35
           x = t;
           while (x != s)
36
37
                edges[p[x]].flow += a;
38
                edges[p[x] ^1].flow -= a;
39
                x = edges[p[x]].from;
40
41
42
            return a;
43
       }
       void BFS()
44
45
            clr(vis, 0);
46
            clr(d, 0);
47
48
            queue<int> q;
49
            q.push(t);
```

```
d[t] = 0;
50
             vis[t] = 1;
51
             while (!q.empty())
52
53
54
                  int x = q.front();
55
                  q.pop();
                  int len = G[x].size();
56
                  for (int i = 0; i < len; i++)
57
58
                      Edge& e = edges[G[x][i]];
59
                      if (!vis[e.from] && e.cap > e.flow)
60
61
                          vis[e.from] = 1;
62
                          d[e.from] = d[x] + 1;
63
                          q.push(e.from);
64
                      }
65
                  }
66
             }
67
68
         int Maxflow(int s, int t)
69
70
             this -> s = s;
71
             this->t = t;
72
73
             int flow = 0;
74
             BFS();
             clr(num, 0);
75
             for (int i = 0; i < n; i++)</pre>
76
                  if (d[i] < INF) num[d[i]]++;</pre>
77
             int x = s;
78
             clr(cur, 0);
79
80
             while (d[s] < n)
81
82
                  if(x == t)
83
                      flow += Augumemt();
84
85
                      X = S;
86
87
                  int ok = 0;
                  for (int i = cur[x]; i < G[x].size(); i++)</pre>
88
89
                      Edge& e = edges[G[x][i]];
90
                      if (e.cap > e.flow && d[x] == d[e.to] + 1)
91
92
93
                          ok = 1;
                          p[e.to] = G[x][i];
94
                          cur[x] = i;
95
96
                          x = e.to;
                          break;
97
                      }
98
99
100
                  if (!ok) //Retreat
101
102
                      int m = n - 1;
                      for (int i = 0; i < G[x].size(); i++)
103
104
                           Edge& e = edges[G[x][i]];
105
                          if (e.cap > e.flow) m = min(m, d[e.to]);
106
107
                      if (--num[d[x]] == 0) break; //gap
108
```

```
num[d[x] = m + 1]++;
109
                      cur[x] = 0;
110
                      if (x != s) x = edges[p[x]].from;
111
                 }
112
113
114
             return flow;
         }
115
    };
116
    4.9.4 MinCost MaxFlow
    const int maxn = "Edit";
 2
    struct MCMF
 3
    {
         int n, m;
 4
         vector<Edge> edges;
 5
         vector<int> G[maxn];
 6
 7
         int inq[maxn]; //
 8
         int d[maxn];
                        //bellmanford
 9
         int p[maxn];
                         //
         int a[maxn];
                        //
10
         void init(int n)
11
12
13
             this -> n = n;
             for (int i = 0; i < n; i++) G[i].clear();</pre>
14
15
             edges.clear();
16
         void AddEdge(int from, int to, int cap, int cost)
17
18
             edges.pb(Edge(from, to, cap, 0, cost));
19
20
             edges.pb(Edge(to, from, 0, 0, -cost));
             m = edges.size();
21
22
             G[from].pb(m - 2);
23
             G[to].pb(m - 1);
24
25
         bool BellmanFord(int s, int t, int& flow, ll& cost)
26
             for (int i = 0; i < n; i++) d[i] = INF;
27
28
             clr(inq, 0);
29
             d[s] = 0;
             inq[s] = 1;
30
             p[s] = 0;
31
             a[s] = INF;
32
             queue<int> q;
33
             q.push(s);
34
             while (!q.empty())
35
36
             {
                 int u = q.front();
37
38
                 q.pop();
                 inq[u] = 0;
39
                 for (int i = 0; i < G[u].size(); i++)</pre>
40
41
42
                      Edge& e = edges[G[u][i]];
                      if (e.cap > e.flow && d[e.to] > d[u] + e.cost)
43
44
                          d[e.to] = d[u] + e.cost;
45
                          p[e.to] = G[u][i];
46
                          a[e.to] = min(a[u], e.cap - e.flow);
47
```

```
if (!inq[e.to])
48
49
                             q.push(e.to);
50
                             inq[e.to] = 1;
51
                         }
52
53
                    }
                }
54
55
            if (d[t] == INF) return false; //
56
            flow += a[t];
57
            cost += (l1)d[t] * (l1)a[t];
58
            for (int u = t; u != s; u = edges[p[u]].from)
59
60
                edges[p[u]].flow += a[t];
61
                edges[p[u] ^ 1].flow -= a[t];
62
63
            return true;
64
        }
65
        int MincostMaxflow(int s, int t, ll& cost)
66
67
            int flow = 0;
68
            cost = 0;
69
            while (BellmanFord(s, t, flow, cost));
70
71
            return flow;
        }
72
73 };
```

# 5 Computational Geometry

#### 5.1 Basic Function

```
#define zero(x) ((fabs(x) < eps ? 1 : 0))
   #define sqn(x) (fabs(x) < eps ? 0 : ((x) < 0 ? -1 : 1))
4 struct point
5
       double x, y;
6
       point(double a = 0, double b = 0) { x = a, y = b; }
7
       point operator-(const point& b) const { return point(x - b.x, y - b.y); }
8
       point operator+(const point& b) const { return point(x + b.x, y + b.y); }
9
10
       bool operator==(point& b) { return zero(x - b.x) && zero(y - b.y); }
11
12
       // ( )
       double operator*(const point& b) const { return x * b.x + y * b.y; }
13
       // ( )
14
       double operator^(const point& b) const { return x * b.y - y * b.x; }
15
       point rotate(point b, double a)
17
18
           double dx, dy;
19
           (*this - b).split(dx, dy);
20
           double tx = dx * cos(a) - dy * sin(a);
21
           double ty = dx * sin(a) + dy * cos(a);
22
23
           return point(tx, ty) + b;
24
       //
25
              a b
26
       void split(double& a, double& b) { a = x, b = y; }
27
   };
28 struct line
29 = \{
       point s, e;
30
       line() {}
31
       line(point ss, point ee) { s = ss, e = ee; }
32
   };
33
   5.2 Position
   5.2.1 Point-Point
double dist(point a, point b) { return sqrt((a - b) * (a - b)); }
   5.2.2 Line-Line
1 // <0, *> ; <1, *> ; <2, P>
  pair<int, point> spoint(line l1, line l2)
2
3
       point res = l1.s;
4
       if (sgn((11.s - 11.e) \wedge (12.s - 12.e)) == 0)
5
           return mp(sqn((l1.s - l2.e) ^ (l2.s - l2.e)) != 0, res);
6
       double t = ((11.s - 12.s) \land (12.s - 12.e)) / ((11.s - 11.e) \land (12.s - 12.e));
7
       res.x += (l1.e.x - l1.s.x) * t;
8
       res.y += (l1.e.y - l1.s.y) * t;
9
10
       return mp(2, res);
11 }
```

```
5.2.3 Segment-Segment
```

```
1 bool segxseg(line l1, line l2)
2
   {
3
       return
4
           max(11.s.x, 11.e.x) >= min(12.s.x, 12.e.x) &&
5
            max(12.s.x, 12.e.x) >= min(11.s.x, 11.e.x) &&
            max(11.s.y, 11.e.y) >= min(12.s.y, 12.e.y) &&
6
            max(12.s.y, 12.e.y) >= min(11.s.y, 11.e.y) &&
7
            sgn((l2.s - l1.e) \land (l1.s - l1.e)) * sgn((l2.e-l1.e) \land (l1.s - l1.e)) <= 0 &&
8
            sgn((11.s - 12.e) \wedge (12.s - 12.e)) * sgn((11.e-12.e) \wedge (12.s - 12.e)) <= 0;
9
10 }
   5.2.4 Line-Segment
1 //11 ,12
2 bool segxline(line l1, line l2)
3
       return sgn((l2.s - l1.e) ^ (l1.s - l1.e)) * sgn((l2.e - l1.e) ^ (l1.s - l1.e)) <=
4
       0;
5 }
   5.2.5 Point-Line
1 double pointtoline(point p, line l)
2
       point res;
3
       double t = ((p - l.s) * (l.e - l.s)) / ((l.e - l.s) * (l.e - l.s));
4
       res.x = 1.s.x + (1.e.x - 1.s.x) * t, res.y = 1.s.y + (1.e.y - 1.s.y) * t;
5
       return dist(p, res);
6
7
  }
   5.2.6 Point-Segment
   double pointtosegment(point p, line l)
2
3
       point res:
       double t = ((p - l.s) * (l.e - l.s)) / ((l.e - l.s) * (l.e - l.s));
4
       if (t >= 0 && t <= 1)
5
            res.x = l.s.x + (l.e.x - l.s.x) * t, res.y = l.s.y + (l.e.y - l.s.y) * t;
6
7
       else
            res = dist(p, l.s) < dist(p, l.e) ? l.s : l.e;
8
9
       return dist(p, res);
10 }
   5.2.7 Point on Segment
   bool PointOnSeg(point p, line l)
1
2
3
       return
            sgn((1.s - p) \wedge (1.e-p)) == 0 \&\&
4
5
            sgn((p.x - l.s.x) * (p.x - l.e.x)) <= 0 &&
6
            sgn((p.y - l.s.y) * (p.y - l.e.y)) <= 0;
7 }
```

#### 5.3 Polygon 5.3.1 Area 1 double area(point p[], int n) 2 3 double res = 0; for (int i = 0; i < n; i++) res $+= (p[i] \land p[(i + 1) \% n]) / 2;$ 4 return fabs(res); 6 } 5.3.2 Point in Convex < 0 > 0)// : [0,n) 3 // -1: 4 // 0 : 5 // 1 6 int PointInConvex(point a, point p∏, int n) 7 { for (int i = 0; i < n; i++) 8 if $(sgn((p[i] - a) \land (p[(i + 1) \% n] - a)) < 0)$ 9 10 return -1; else if (PointOnSeg(a, line(p[i], p[(i + 1) % n]))) 11 return 0; 1213 return 1; 14 } 5.3.3 Point in Polygon 3, 0~n-1 1 // ,poly[] 2 // -1: 3 // 0 : 4 // 1 5 int PointInPoly(point p, point poly[], int n) { 6 int cnt; 7 line ray, side; 8 9 cnt = 0;10 ray.s = p;11 ray.e.y = p.y; ray.e.x = -100000000000.0; // -INF, 12 for (int i = 0; i < n; i++) 13 14 side.s = poly[i], side.e = poly[(i + 1) % n]; 15 if (PointOnSeg(p, side)) return 0; 16 17 if (sgn(side.s.y - side.e.y) == 0)18 19 continue; if (PointOnSeg(sid e.s, r ay)) 20 21 cnt += (sgn(side.s.y - side.e.y) > 0);22else if (PointOnSeg(side.e, ray)) cnt += (sgn(side.e.y - side.s.y) > 0);23 else if (segxseg(ray, side)) 24

25

26 27

28 }

cnt++;

return cnt % 2 == 1 ? 1 : -1;

```
5.3.4 Judge Convex
1 //
2 // 1~n-1
3 bool isconvex(point poly[], int n)
4
       bool s[3];
5
       clr(s, 0);
6
       for (int i = 0; i < n; i++)
7
8
           s[sgn((poly[(i + 1) % n] - poly[i]) ^ (poly[(i + 2) % n] - poly[i])) + 1] = 1;
9
           if (s[0] && s[2]) return 0;
10
11
12
       return 1;
13 }
   5.4 Integer Points
   5.4.1 On Segment
int OnSegment(line l) { return __gcd(fabs(l.s.x - l.e.x), fabs(l.s.y - l.e.y)) + 1; }
   5.4.2 On Polygon Edge
1 int OnEdge(point p□, int n)
2
       int i, ret = 0;
3
       for (i = 0; i < n; i++)
4
           ret += \__gcd(fabs(p[i].x - p[(i + 1) % n].x), fabs(p[i].y - p[(i + 1) % n].y));
5
       return ret;
6
7
   }
   5.4.3 Inside Polygon
1 int InSide(point p□, int n)
2
   {
3
       int i, area = 0;
4
       for (i = 0; i < n; i++)
           area += p[(i + 1) % n].y * (p[i].x - p[(i + 2) % n].x);
5
       return (fabs(area) - OnEdge(n, p)) / 2 + 1;
6
   }
7
   5.5 Circle
   5.5.1 Circumcenter
   point waixin(point a, point b, point c)
2
       double a1 = b.x - a.x, b1 = b.y - a.y, c1 = (a1 * a1 + b1 * b1) / 2;
3
       double a2 = c.x - a.x, b2 = c.y - a.y, c2 = (a2 * a2 + b2 * b2) / 2;
4
       double d = a1 * b2 - a2 * b1;
5
       return point(a.x + (c1 * b2 - c2 * b1) / d, a.y + (a1 * c2 - a2 * c1) / d);
6
7 }
```

# 6 Dynamic Programming

## 6.1 Subsequence

```
6.1.1 Max Sum
```

```
1 // a n,
2 int MaxSeqSum(int a[], int n)
3 {
4    int rt = 0, cur = 0;
5    for (int i = 0; i < n; i++)
6         cur += a[i], rt = max(cur, rt), cur = max(0, cur);
7    return rt;
8 }</pre>
```

#### 6.1.2 Longest Increase

```
// 1 ,LIS() , lis[] const int N = "Edit";
1 //
  int len, a[N], b[N], f[N];
  int Find(int p, int l, int r)
   {
5
6
        while (l \ll r)
7
8
            int mid = (l + r) \gg 1;
9
            if (a[p] > b[mid])
                l = mid + 1;
10
            else
11
                r = mid - 1;
12
13
        return f[p] = 1;
14
15
16 int LIS(int lis[], int n)
17 {
        int len = 1;
18
        f[1] = 1, b[1] = a[1];
19
        for (int i = 2; i <= n; i++)
20
21
            if (a[i] > b[len])
22
                b[++len] = a[i], f[i] = len;
23
24
            else
                b[Find(i, 1, len)] = a[i];
25
26
        for (int i = n, t = len; i >= 1 && t >= 1; i--)
27
            if (f[i] == t) lis[--t] = a[i];
28
29
        return len;
30 }
31
32 //
        (0,
  int dp[N];
  int LIS(int a[], int n)
35  {
        clr(dp, 0x3f);
36
        for (int i = 0; i < n; i++) *lower_bound(dp, dp + n, a[i]) = a[i];
37
        return lower_bound(dp, dp + n, INF) - dp;
38
39 }
```

#### 6.1.3 Longest Common Increase

```
1
2 int LCIS(int a□, int b□, int n, int m)
3 {
       clr(dp, 0);
4
       for (int i = 1; i <= n; i++)
5
6
7
            int ma = 0;
            for (int j = 1; j <= m; j++)
8
9
                dp[i][j] = dp[i - 1][j];
10
                if (a[i] > b[j]) ma = max(ma, dp[i - 1][j]);
11
                if (a[i] == b[j]) dp[i][j] = ma + 1;
12
13
14
       return *max_element(dp[n] + 1, dp[n] + 1 + m);
15
16 }
   6.2 Digit Statistics
   int a[20];
   11 dp[20][state];
2
   ll dfs(int pos, /*state */, bool lead /* */, bool limit /* */)
3
4
       // , , 0, pos==-1
5
       if (pos == -1) return 1;
6
7
           1,
8
            pos,
       if (!limit && !lead && dp[pos][state] != -1) return dp[pos][state];
9
10
       int up = limit ? a[pos] : 9; // limit
11
12
       11 \text{ ans} = 0;
       for (int i = 0; i \le up; i++) //,
13
14
            if () ...
15
           else if () ...
16
           ans += dfs(pos - 1, /* */, lead && i == 0, limit && i == a[pos])
17
18
           /*
19
                 , state i */
20
       }
21
22
       if (!limit && !lead) dp[pos][state] = ans;
23
24
             lead, lead
25
26
       return ans;
27
  ll solve(ll x)
28
29
   {
       int pos = 0;
30
       do //
31
32
           a[pos++] = x \% 10;
33
       while (x \neq 10);
                                 */, /* */, true, true);
       return dfs(pos - 1 /*
34
35
36 }
```

## Others

#### 7.1 Matrix

```
7.1.1 Matrix FastPow
```

```
1 typedef vector<ll> vec;
2 typedef vector<vec> mat;
3 mat mul(mat& A, mat& B)
4
        mat C(A.size(), vec(B[0].size()));
5
        for (int i = 0; i < A.size(); i++)</pre>
6
             for (int k = 0; k < B.size(); k++)</pre>
7
                 if (A[i][k]) //
8
                      for (int j = 0; j < B[0].size(); j++)
    C[i][j] = (C[i][j] + A[i][k] * B[k][j]) % mod;</pre>
9
10
        return C;
11
12 }
13 mat Pow(mat A, ll n)
   {
14
        mat B(A.size(), vec(A.size()));
15
16
        for (int i = 0; i < A.size(); i++) B[i][i] = 1;</pre>
17
        for (; n; n >>= 1, A = mul(A, A))
             if (n \& 1) B = mul(B, A);
18
19
        return B;
20 }
    7.1.2 Gauss Elimination
   void gauss()
1
2
3
        int now = 1, to;
4
        double t;
```

```
for (int i = 1; i <= n; i++, now++)
5
6
7
            /*for (to = now; !a[to][i] && to <= n; to++);
8
            //
            if (to != now)
9
                for (int j = 1; j \le n + 1; j++)
10
                    swap(a[to][j], a[now][j]);*/
11
```

for (int j = 1;  $j \le n + 1$ ; j++) a[now][j] /= t;

# 7.2 Tricks

}

12

13

14

15 16

17

18 19

20

21 }

#### 7.2.1 Stack-Overflow

t = a[now][i];

}

for (int j = 1; j <= n; j++)

t = a[i][i];

**if** (j != now)

1 #pragma comment(linker, "/STACK:1024000000,1024000000")

for (int k = 1;  $k \le n + 1$ ; k++) a[j][k] -= t \* a[now][k];

#### 7.2.2 Fast-Scanner

```
template <class T>
1
   inline bool scan_d(T &ret){
       char c;
3
       int sgn;
4
       if (c = getchar(), c == EOF) return 0; //EOF
5
       while (c != '-' \&\& (c < '0' || c > '9')) c = getchar();
6
       sqn = (c == '-') ? -1 : 1;
7
       ret = (c == '-') ? 0 : (c - '0');
8
       while (c = getchar(), c >= '0' \&\& c <= '9') ret = ret * 10 + (c - '0');
9
       ret *= sgn;
10
       return 1;
11
   }
12
13
   inline void out(int x){
14
       if(x<0)
           putchar('-');
15
16
            X=-X;
17
       if (x > 9) out(x / 10);
18
       putchar(x % 10 + '0');
19
20 }
   7.2.3 Strok-Sscanf
1 // get some integers in a line
2 gets(buf);
3 int v;
4 char *p = strtok(buf, " ");
5 while (p){
       sscanf(p, "%d", &v);
6
       p = strtok(NULL," ");
7
8 }
   7.3 Mo Algorithm
                 \sqrt{x},
1 //cf 671 E
2 #include <bits/stdc++.h>
3 using namespace std;
```

```
4 typedef long long ll;
5 const int MAXN=1<<20;
6 struct node{
       int l,r,id;
7
8 }Q[MAXN];
9 int n,m,k;
10 int block;
11 int a[MAXN];
12 int pre[MAXN];
13 ll cnt[MAXN];
14 ll ANS, ans [MAXN];
15 bool cmp(node x,node y){
       if(x.l/block==y.l/block)return x.r<y.r;</pre>
16
17
       else return x.l/block<y.l/block;</pre>
18 }
19 void add(int x){
```

```
ANS+=cnt[pre[x]^k];
20
21
         cnt[pre[x]]++;
    }
22
    void del(int x){
23
24
         cnt[pre[x]]--;
         ANS-=cnt[pre[x]^k];
25
26
    }
    int main(){
27
         scanf("%d%d%d",&n,&m,&k);
28
         block=(int)sqrt(n);
29
30
         pre[0]=0;
31
         for(int i=1;i<=n;i++){</pre>
              scanf("%d",&a[i]);
32
             pre[i]=a[i]^pre[i-1];
33
34
         for(int i=1;i<=m;i++){</pre>
35
              scanf("%d%d",&Q[i].1,&Q[i].r);
36
37
              Q[i].id=i;
38
39
         sort(Q+1,Q+1+m,cmp);
         ANS=0;
40
         memset(cnt,0,sizeof(cnt));
41
         cnt[0]=1;
42
43
         int L=1, R=0;
44
         for(int i=1;i<=m;i++){</pre>
              while(L>Q[i].1){L--;add(L-1);};
45
             while(L<Q[i].l){del(L-1);L++;}</pre>
46
             while(R<Q[i].r){R++;add(R);};</pre>
47
             while(R>Q[i].r){del(R);R--;};
48
             ans[Q[i].id]=ANS;
49
50
         for(int i=1;i<=m;i++){</pre>
51
             printf("%lld\n",ans[i]);
52
53
         return 0;
54
   }
55
    7.4 BigNum
    7.4.1 High-precision
1 java
    7.5 VIM
1 syntax on
2
    set nu
   set tabstop=4
3
   set shiftwidth=4
 4
5
   set cin
6
   set mouse=a
7
   map<F3> :call setline(1,'')<CR>
8
   func SetTitle()
9
10 let l = 0
   let l = l + 1 | call setline(l,'#include <algorithm>')
let l = l + 1 | call setline(l,'#include <iostream>')
let l = l + 1 | call setline(l,'#include <cstring>')
```

```
let l = l + 1 | call setline(l, '#include
                                                                                                                  <string>')
let l = l + 1 | call setline(l, '#include

let l = l + 1 | call setline(l, '#include

let l = l + 1 | call setline(l, '#include

let l = l + 1 | call setline(l, '#include

let l = l + 1 | call setline(l, '#include

let l = l + 1 | call setline(l, '#include

let l = l + 1 | call setline(l, '#include

let l = l + 1 | call setline(l, '#include

let l = l + 1 | call setline(l, '#include

let l = l + 1 | call setline(l, '#include

let l = l + 1 | call setline(l, '#include

let l = l + 1 | call setline(l, '#include
                                                                                                                  <cstdio>')
                                                                                                                  <vector>')
                                                                                                                  <cstdio>')
                                                                                                                  <vector>')
                                                                                                                    <stack>')
                                                                                                                    <queue>')
                                                                                                                    <cmath>')
                                                                                                                        <set>')
 23 let l = l + 1 \mid call setline(l, '#include')
                                                                                                                         <map>')
       let l = l + 1 | call setline(l, 'using namespace std;')
 let l = l + 1 \mid call \ setline(l, '#define \ rep(i,a,b) \ for(int \ i=a;i<=b;i++)')
 let l = l + 1 \mid call \ setline(l, '#define \ per(i, a, b) \ for(int i=a; i>=b; i--)')
       let l = l + 1 | call setline(l, '#define clr(a,x) memset(a,x, sizeof(a))')
let l = l + 1 | call setline(l, '#define clr(a,x) memset(a,x,sizeof(a))'
let l = l + 1 | call setline(l, '#define pb push_back')
let l = l + 1 | call setline(l, '#define mp make_pair')
let l = l + 1 | call setline(l, '#define all(x) (x).begin(),(x).end()')
let l = l + 1 | call setline(l, '#define fi first')
let l = l + 1 | call setline(l, '#define se second')
let l = l + 1 | call setline(l, '#define SZ(x) ((int)(x).size())')
let l = l + 1 | call setline(l, 'typedef unsigned long long ull;')
let l = l + 1 | call setline(l, 'typedef long long ll;')
let l = l + 1 | call setline(l, 'typedef vector<int> vi;')
let l = l + 1 | call setline(l, 'typedef pair<int.int> pii:')
 37 let l = l + 1 | call setline(l, 'typedef pair<int, int> pii;')
38 let l = l + 1 | call setline(l,'/**********head**************/')
 39 let l = l + 1 \mid call setline(l, 'int work(){'})
 40 let l = l + 1 \mid call setline(l,'')
       let l = l + 1 \mid call setline(l,')
                                                                                              return 0;')
        let l = l + 1 | call setline(l,'}')
42  let l = l + 1 | call setline(l,'s')
43  let l = l + 1 | call setline(l,'int main(){')
44  let l = l + 1 | call setline(l,'#ifdef superkunn')
45  let l = l + 1 | call setline(l,' freopen("input.
46  let l = l + 1 | call setline(l,'#endif')
47  let l = l + 1 | call setline(l,' work();')
48  let l = l + 1 | call setline(l,' return 0;')
                                                                                              freopen("input.txt","rt",stdin);')
       let l = l + 1 \mid call setline(l,')
 49
 50
         endfunc
```

## 7.6 BASH

7.6.1 a.sh