

widsnoy's template

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1. 数论

1.1. 原根

- 阶: $\text{ord}_m(a)$ 是最小的正整数 n 使 $a^n \equiv 1 \pmod{m}$
- 原根: 若 g 满足 $(g, m) = 1$ 且 $\text{ord}_m(g) = \varphi(m)$ 则 g 是 m 的原根。若 m 是质数, 有 $g^i \pmod{m}, 0 < i < m$ 的取值各不相同。

原根的应用: m 是质数时, 若求 $a_k = \sum_{i+j \pmod{m-1}=k} f_i * g_j$ 可以通过原根转化为卷积形式(要求 0 处无取值)。具体而言, $[1, m-1]$ 可以映射到 $g^{[1, m-1]}$, 原式变为 $a_{g^k} = \sum_{g^{i+j \pmod{m-1}}=g^k} f_{g^i} * g_{g^j}$, 令 $f_i = f_{g^i}$ 则 $a_k = \sum_{(i+j) \pmod{m-1}=k} f_i * g_j$

```

1  int q[10005];
2  int getG(int n) {
3      int i, j, t = 0;
4      for (i = 2; (ll)(i * i) < n - 1; i++) {
5          if ((n - 1) % i == 0) q[t++] = i, q[t++] = (n - 1) / i;
6      }
7      for (i = 2; ; i++) {
8          for (j = 0; j < t; j++) if (fpow(i, q[j], n) == 1) break;
9          if (j == t) return i;
10     }
11     return -1;
12 }
13
14 vector<int> fpow(int kth) {
15     if (kth == 0) return e;
16     auto r = fpow(kth - 1);
17     r = multiply(r, r);
18     for (int i = p - 1; i < r.size(); i++) r[i % (p - 1)] = (r[i % (p - 1)] + r[i]) % mod;
19     r.resize(p - 1);
20     if (kk[kth] == '1') {
21         r = multiply(r, e);
22         for (int i = p - 1; i < r.size(); i++) r[i % (p - 1)] = (r[i % (p - 1)] + r[i]) % mod;
23         r.resize(p - 1);
24     }
25     return r;
26 }
27 void MAIN() {
28     g = getG(p);
29     int tmp = 1;
30     for (int i = 1; i < p; i++) {
31         tmp = tmp * 1ll * g % p;
32         mp[tmp] = i % (p - 1);
33     }
34     e.resize(p - 1);
35     for (int i = 0; i < p - 1; i++) e[i] = 0;
36     for (int i = 0; i < p; i++) {
37         for (int j = 0; j <= i; j++) {

```

```

38             if (binom[i][j] == 0) continue;
39             e[mp[binom[i][j]]]++;
40         }
41     }
42 }

```

1.2. 解不定方程

给出 $a, b, c, x_1, x_2, y_1, y_2$ ，求满足 $ax+by+c=0$ ，且 $x \in [x_1, x_2], y \in [y_1, y_2]$ 的整数解有多少对？

输入格式

第一行包含 7 个整数， $a, b, c, x_1, x_2, y_1, y_2$ ，整数间用空格隔开。

$a, b, c, x_1, x_2, y_1, y_2$ 的绝对值不超过 10^8 。

```

1  #define y1 miku
2
3  ll a, b, c, x1, x2, y1, y2;
4  ll exgcd(ll a, ll b, ll &x, ll &y) {
5      if (b) {
6          ll d = exgcd(b, a % b, y, x);
7          return y -= a / b * x, d;
8      } return x = 1, y = 0, a;
9  }
10
11 pll get_up(ll a, ll b, ll x1, ll x2) {
12     //x2>=ax+b>=x1
13     if (a == 0) return (b >= x1 && b <= x2) ? (pll){-1e18, 1e18} : (pll)
14     {1, 0};
15     ll L, R;
16     ll l = (x1 - b) / a - 3;
17     for (L = l; L * a + b < x1; L++);
18     ll r = (x2 - b) / a + 3;
19     for (R = r; R * a + b > x2; R--);
20     return {L, R};
21 }
22 pll get_dn(ll a, ll b, ll x1, ll x2) {
23     //x2>=ax+b>=x1
24     if (a == 0) return (b >= x1 && b <= x2) ? (pll){-1e18, 1e18} : (pll)
25     {1, 0};
26     ll L, R;
27     ll l = (x2 - b) / a - 3;
28     for (L = l; L * a + b > x2; L++);
29     ll r = (x1 - b) / a + 3;
30     for (R = r; R * a + b < x1; R--);
31     return {L, R};
32 }
33
34 void MAIN() {
35     cin >> a >> b >> c >> x1 >> x2 >> y1 >> y2;

```

```

34     if (a == 0 && b == 0) return cout << (c == 0) * (y2 - y1 + 1) * (x2
- x1 + 1) << '\n', void();
35     ll x, y, d = exgcd(a, b, x, y);
36     c = -c;
37     if (c % d != 0) return cout << "0\n", void();
38     x *= c / d, y *= c / d;
39     ll sx = b / d, sy = -a / d;
40     //x + k * sx  y + k * sy
41     // 0<= 3 - k <= 4 [-1,3] [0,4]
42     auto A = (sx > 0 ? get_up(sx, x, x1, x2) : get_dn(sx, x, x1, x2));
43     auto B = (sy > 0 ? get_up(sy, y, y1, y2) : get_dn(sy, y, y1, y2));
44     A.fi = max(A.fi, B.fi), A.se = min(A.se, B.se);
45     cout << max(0ll, A.se - A.fi + 1) << '\n';
46 }

```

1.3. 中国剩余定理

考虑合并两个同余方程

$$\begin{cases} x \equiv a_1 \pmod{m_1} \\ x \equiv a_2 \pmod{m_2} \end{cases}$$

改写为不定方程形式

$$\begin{cases} x + m_1 y = a_1 \\ x + m_2 y = a_2 \end{cases}$$

取解集公共部分 $x = a_1 - m_1 y_1 = a_2 - m_2 y_2$, 若 $\gcd(m_1, m_2) \mid (a_1 - a_2)$ 有解, 可以得到 $x = \text{lcm}(m_1, m_2) + a_2 - m_2 y_2$ 化为同余方程的形式: $x \equiv a_2 - m_2 y_2 \pmod{\text{lcm}(m_1, m_2)}$

```

1 ll n, m, a;
2 ll exgcd(ll a, ll b, ll &x, ll &y) {
3     if (b != 0) {
4         ll g = exgcd(b, a % b, y, x);
5         return y -= a / b * x, g;
6     } return x = 1, y = 0, a;
7 }
8 ll getinv(ll a, ll mod) {
9     ll x, y;
10    exgcd(a, mod, x, y);
11    x = (x % mod + mod) % mod;
12    return x;
13 }
14 int get(ll x) {
15     return x < 0 ? -1 : 1;
16 }
17 ll mul(ll a, ll b, ll mod) {
18     ll res = 0;
19     if (a == 0 || b == 0) return 0;
20     ll f = get(a) * get(b);

```

```

21     a = abs(a), b = abs(b);
22     for (; b; b >>= 1, a = (a + a) % mod) if (b & 1) res = (res + a) %
mod;
23     res *= f;
24     if (res < 0) res += mod;
25     return res;
26 }
27 // m 互质
28 // int main() {
29 //     cin >> n;
30 //     ll phi = 1;
31 //     for (int i = 1; i <= n; i++) {
32 //         cin >> m[i] >> a[i];
33 //         phi *= m[i];
34 //     }
35 //     ll ans = 0;
36 //     for (int i = 1; i <= n; i++) {
37 //         ll p = phi / m[i], q = getinv(p, m[i]);
38 //         ans += mul(p, mul(q, a[i], phi), phi);
39 //         ans %= phi;
40 //     }
41 //     cout << ans << '\n';
42 // }
43 int main() {
44     cin >> n;
45     cin >> m >> a;
46     for (int i = 2; i <= n; i++) {
47         ll nm, na;
48         cin >> nm >> na;
49         ll x, y;
50         ll g = exgcd(m, -nm, x, y), d = (na - a) / g, md = abs(nm / g);
51         if ((na - a) % g) return -1;
52         x = mul(x, d, md);
53         ll lc = abs(m / g);
54         lc *= nm;
55         a = (a + mul(m, x, lc)) % lc;
56         m = lc;
57     }
58     cout << a << '\n';
59 }

```

1.4. 卢卡斯定理

- p 为质数

$$\binom{n}{m} \bmod p = \binom{\left\lfloor \frac{n}{p} \right\rfloor}{\left\lfloor \frac{m}{p} \right\rfloor} \binom{n \bmod p}{m \bmod p} \bmod p$$

- p 不为质数

其中 $\text{calc}(n, x, p)$ 计算 $\frac{n!}{x^y} \bmod p$ 的结果，其中 y 是 $n!$ 含有 x 的个数

如果 p 是质数, 利用 Wilson 定理 $(p-1)! \equiv -1 \pmod{p}$ 可以 $O(\log P)$ 的计算 calc 。其他情况可以通过预处理 $\frac{n!}{n \text{ 以内所有 } p \text{ 倍数的乘积}}$ 达到同样的效果。

```

1 ll exgcd(ll a, ll b, ll &x, ll &y) {
2     if (b) {
3         ll d = exgcd(b, a % b, y, x);
4         return y -= a / b * x, d;
5     } else return x = 1, y = 0, a;
6 }
7 int getinv(ll v, ll mod) {
8     ll x, y;
9     exgcd(v, mod, x, y);
10    return (x % mod + mod) % mod;
11 }
12 ll fpow(ll a, ll b, ll p) {
13     ll res = 1;
14     for (; b; b >>= 1, a = a * 1ll * a % p) if (b & 1) res = res * 1ll *
a % p;
15     return res;
16 }
17 ll calc(ll n, ll x, ll p) {
18     if (n == 0) return 1;
19     ll s = 1;
20     for (ll i = 1; i <= p; i++) if (i % x) s = s * i % p;
21     s = fpow(s, n / p, p);
22     for (ll i = n / p * p + 1; i <= n; i++) if (i % x) s = i % p * s %
p;
23     return calc(n / x, x, p) * 1ll * s % p;
24 }
25 int get(ll x) {
26     return x < 0 ? -1 : 1;
27 }
28 ll mul(ll a, ll b, ll mod) {
29     ll res = 0;
30     if (a == 0 || b == 0) return 0;
31     ll f = get(a) * get(b);
32     a = abs(a), b = abs(b);
33     for (; b; b >>= 1, a = (a + a) % mod) if (b & 1) res = (res + a) %
mod;
34     res *= f;
35     if (res < 0) res += mod;
36     return res;
37 }
38 ll sublucas(ll n, ll m, ll x, ll p) {
39     ll cnt = 0;
40     for (ll i = n; i; ) cnt += (i = i / x);
41     for (ll i = m; i; ) cnt -= (i = i / x);
42     for (ll i = n - m; i; ) cnt -= (i = i / x);
43     return fpow(x, cnt, p) * calc(n, x, p) % p * getinv(calc(m, x, p),
p) % p * getinv(calc(n - m, x, p), p) % p;
44 }
45 ll lucas(ll n, ll m, ll p) {

```

```

46     int cnt = 0;
47     ll a[21], mo[21];
48     for (ll i = 2; i * i <= p; i++) if (p % i == 0) {
49         mo[++cnt] = 1;
50         while (p % i == 0) mo[cnt] *= i, p /= i;
51         a[cnt] = sublucas(n, m, i, mo[cnt]);
52     }
53     if (p != 1) mo[++cnt] = p, a[cnt] = sublucas(n, m, p, mo[cnt]);
54     ll phi = 1;
55     for (int i = 1; i <= cnt; i++) phi *= mo[i];
56     ll ans = 0;
57     for (int i = 1; i <= cnt; i++) {
58         ll p = phi / mo[i], q = getinv(p, mo[i]);
59         ans += mul(p, mul(q, a[i], phi), phi);
60         ans %= phi;
61     }
62     return ans;
63 }

```

1.5. BSGS

求解 $a^x \equiv n \pmod{p}$, a, p 不一定互质

```

1  int fpow(int a, int b, int p) {
2      int res = 1;
3      for (; b; b >>= 1, a = a * 1ll * a % p) if (b & 1) res = res * 1ll *
a % p;
4      return res;
5  }
6  ll exgcd(ll a, ll b, ll &x, ll &y) {
7      if (b == 0) return x = 1, y = 0, a;
8      ll d = exgcd(b, a % b, y, x);
9      y -= a / b * x;
10     return d;
11 }
12 int inv(int a, int p) {
13     ll x, y;
14     ll g = exgcd(a, p, x, y);
15     if (g != 1) return -1;
16     return (x % p + p) % p;
17 }
18 int BSGS(int a, int b, int p) {
19     if (p == 1) return 1;
20     unordered_map<int, int> x;
21     int m = sqrt(p + 0.5) + 1;
22     int v = inv(fpow(a, m, p), p);
23     int e = 1;
24     for(int i = 1; i <= m; i++) {
25         e = e * 1ll * a % p;
26         if(!x.count(e)) x[e] = i;
27     }

```



```

28     for(int i = 0; i <= m; i++) {
29         if(x.count(b)) return i * m + x[b];
30         b = b * 1ll * v % p;
31     }
32     return -1;
33 }
34 pii exBSGS(int a, int n, int p) {
35     int d, q = 0, sum = 1;
36     if (n == 1) return {0, gcd(a, p) == 1 ? BSGS(a, 1, p) : 0};
37     a %= p, n %= p;
38     while((d = gcd(a, p)) != 1) {
39         if(n % d) return {-1, -1};
40         q++; n /= d; p /= d;
41         sum = (sum * 1ll * a / d) % p;
42         if(sum == n) return {q, gcd(a, p) == 1 ? BSGS(a, 1, p) : 0};
43     }
44     int v = inv(sum, p);
45     n = n * 1ll * v % p;
46     int ans = BSGS(a, n, p);
47     if(ans == -1) return {-1, -1};
48     return {ans + q, BSGS(a, 1, p)};
49 }

```

1.6. 数论函数

$$1. \varphi(n) = n \prod \left(1 - \frac{1}{p}\right)$$

$$2. \mu(n) = \begin{cases} 1, n=1 \\ (-1)^{\text{质因子个数}}, n \text{ 无平方因子} \\ 0, n \text{ 有平方因子} \end{cases}$$

$$3. \mu * \text{id} = \varphi, \mu * 1 = \varepsilon, \varphi * 1 = \text{id}$$

• 有一个表格, $a_{i,j} = \gcd(i, j)$, 支持某一列一行乘一个数, 查询整个表格的和。

因为 $\gcd(n, m) = \sum_{i|n \wedge i|m} \varphi(i)$, 对每个 $\varphi(i)$ 维护一个大小为 $\lfloor \frac{n}{i} \rfloor$ 的表格, 初始值全是 $\varphi(i)$, (x, y) 对应 $(x * i, y * i)$ 。对大表格的修改可以转化为对小表格的修改, 只需要对每行每列维护一个懒标记就行。

1.7. 莫比乌斯反演

$$1. \text{ 若 } f(n) = \sum_{d|n} g(d), \text{ 则 } g(n) = \sum_{d|n} \mu\left(\frac{n}{d}\right) f(d)$$

$$\begin{aligned}
 \sum_{d|n} \mu\left(\frac{n}{d}\right) f(d) &= \sum_{d|n} \mu\left(\frac{n}{d}\right) \sum_{k|d} g(k) \\
 &= \sum_{k|n} g(k) \sum_{d|\frac{n}{k}} \mu(d) \\
 &= \sum_{k|n} g(k) \left[\frac{n}{k} = 1\right] = g(n)
 \end{aligned}$$

$$2. \text{ 若 } f(n) = \sum_{n|d} g(d), \text{ 则 } g(n) = \sum_{n|d} \mu\left(\frac{d}{n}\right) f(d)$$

$$3. d(nm) = \sum_{i|n} \sum_{j|m} [\gcd(i, j) = 1]$$

常见的一些推式子套路：

1. 证明是否积性函数，只需要观察是否满足 $f(p^i)f(q^j) = f(p^i q^j)$ 即可，用线性筛积性函数也是同理。
2. 形如 $\sum_{d|n} \mu(d) \sum_{k|\frac{n}{d}} \varphi(k) \lfloor \frac{n}{dk} \rfloor$ 的式子，这时候令 $T = dk$ ，枚举 T 就能得到 d, k 一个卷积的形式。如果是底数和指数，这时候不能线性筛，但是可以调和级数暴力算函数值。

1.8. 整除分块

1. 下取整

```
1 for (int i = 1, j; i <= min(n, m); i = j + 1) {
2     j = min(n / (n / i), m / (m / i));
3     // n / {i, ..., j} = n / i
4 }
```

1. 上取整

$$\lceil \frac{n}{i} \rceil = \lfloor \frac{n+i-1}{i} \rfloor = \lfloor \frac{n-1}{i} \rfloor + 1$$

1.9. 区间筛

- 求解一个区间内的素数

如果是合数那么一定不大于 \sqrt{x} 的约数，使用这个范围内的数埃氏筛即可。

1.10. Min25 筛

能在 $O\left(\frac{n^{\frac{3}{4}}}{\log(n)}\right)$ 时间求出 $F(n) = \sum_{i=1}^n f(i)$ 的值，要求积性函数能快速求出 $f(p^k)$ 处的点值。

- 定义 $R(i)$ 表示 i 的最小质因子

$$G(n, j) = \sum_{i=1}^n f(i) [i \in \text{prime} \vee R(i) > P_j]$$

考虑递推

$$G(n, j) = \begin{cases} G(n, j-1) & \text{IF } p_j \times p_j > n \\ G(n, j-1) - f(p_j) \left(G\left(\frac{n}{p_j}, j-1\right) - \sum_{i=1}^{j-1} f(p_i) \right) & \text{IF } p_j \times p_j \leq n \end{cases}$$

根据整除分块， G 函数的第一维只用 \sqrt{n} 种取值，将其存在 $w[]$ 中，且用 $\text{id1}[]$ 和 $\text{id2}[]$ 分别存数字对应的下标位置。因为最后只需要知道 $G(x, \text{pcnt})$ 所以第二维可以滚掉。

- 定义 $S(n, j) = \sum_{i=1}^n f(i) [R(i) \geq p_j]$

质数部分答案显然为 $G(n, \text{pcnt}) - \sum_{i=1}^{j-1} f(p_i)$ ，合数部分考虑提出最小的质因子 p^k ，得到 $S(n, j)$ 的递推式

$$S(n, j) = G(n, \text{pcnt}) - \sum_{i=1}^{j-1} f(p_i) + \sum_{i=j}^{\text{pcnt}} \sum_{k=1}^{p_i^{k+1} \leq n} f(p^k) S\left(\frac{n}{p^k}, j+1\right) + f(p^{k+1})$$

递归边界是 $n = 1 \vee p_j > n, S(n, j) = 0$

$$\sum_{i=1}^n f(i) = S(n, 1) + f(1)$$

```

1 #include <cstdio>
2 #include <cmath>
3
4 typedef long long ll;
5 const int N = 4e6 + 5, MOD = 1e9 + 7;
6 const ll i6 = 166666668, i2 = 500000004;
7 ll n, id1[N], id2[N], su1[N], su2[N], p[N], sqr, w[N], g[N], h[N];
8 int cnt, m;
9 bool vis[N];
10
11 ll add(ll a, ll b) {a %= MOD, b %= MOD; return (a + b >= MOD) ? a + b - MOD : a + b;}
12 ll mul(ll a, ll b) {a %= MOD, b %= MOD; return a * b % MOD;}
13 ll dec(ll a, ll b) {a %= MOD, b %= MOD; return ((a - b) % MOD + MOD) % MOD;}
14
15 void init(int m) {
16     for (ll i = 2; i <= m; i++) {
17         if (!vis[i]) p[++cnt] = i, su1[cnt] = add(su1[cnt - 1], i), su2[cnt] = add(su2[cnt - 1], mul(i, i));
18         for (int j = 1; j <= cnt && i * p[j] <= m; j++) {
19             vis[p[j] * i] = 1;
20             if (i % p[j] == 0) break;
21         }
22     }
23 }
24
25 ll S(ll x, int y) {
26     if (p[y] > x || x <= 1) return 0;
27     int k = (x <= sqr) ? id1[x] : id2[n / x];
28     ll res = dec(dec(g[k], h[k]), dec(su2[y - 1], su1[y - 1]));
29     for (int i = y; i <= cnt && p[i] * p[i] <= x; i++) {
30         ll pow1 = p[i], pow2 = p[i] * p[i];
31         for (int e = 1; pow2 <= x; pow1 = pow2, pow2 *= p[i], e++) {
32             ll tmp = mul(mul(pow1, dec(pow1, 1)), S(x / pow1, i + 1));
33             tmp = add(tmp, mul(pow2, dec(pow2, 1)));
34             res = add(res, tmp);
35         }
36     }
37     return res;
38 }
39
40 int main() {
41     scanf("%lld", &n);

```

```

42  sqr = sqrt(n + 0.5) + 1;
43  init(sqr);
44  for (ll l = 1, r; l <= n; l = r + 1) {
45      r = n / (n / l);
46      w[++m] = n / l;
47      g[m] = mul(w[m] % MOD, (w[m] + 1) % MOD);
48      g[m] = mul(g[m], (2 * w[m] + 1) % MOD);
49      g[m] = mul(g[m], i6);
50      g[m] = dec(g[m], 1);
51      h[m] = mul(w[m] % MOD, (w[m] + 1) % MOD);
52      h[m] = mul(h[m], i2);
53      h[m] = dec(h[m], 1);
54      (w[m] <= sqr) ? id1[w[m]] = m : id2[r] = m;
55  }
56  for (int j = 1; j <= cnt; j++)
57      for (int i = 1; i <= m && p[j] * p[j] <= w[i]; i++) {
58          int k = (w[i] / p[j] <= sqr) ? id1[w[i] / p[j]] : id2[n / (w[i] /
p[j])];
59          g[i] = dec(g[i], mul(mul(p[j], p[j]), dec(g[k], su2[j - 1])));
60          h[i] = dec(h[i], mul(p[j], dec(h[k], su1[j - 1])));
61      }
62  //printf("%lld\n", g[1] - h[1]);
63  printf("%lld\n", add(S(n, 1), 1));
64  return 0;
65 }

```

2. 图论

2.1. 找环

```

1  const int N = 5e5 + 5;
2  int n, m, col[N], pre[N], pre_edg[N];
3  vector<pii> G[N];
4  vector<vector<int>> resp, rese;
5  //point
6  void get_cyc(int u, int v) {
7      if (!resp.empty()) return;
8      vector<int> cyc;
9      cyc.push_back(v);
10     while (true) {
11         v = pre[v];
12         if (v == 0) break;
13         cyc.push_back(v);
14         if (v == u) break;
15     }
16     reverse(cyc.begin(), cyc.end());
17     resp.push_back(cyc);
18 }
19 // edge
20 void get_cyc(int u, int v, int id) {

```

```

21     if (!rese.empty()) return;
22     vector<int> cyc;
23     cyc.push_back(id);
24     while (true) {
25         if (pre[v] == 0) break;
26         cyc.push_back(pre_edg[v]);
27         v = pre[v];
28         if (v == u) break;
29     }
30     reverse(cyc.begin(), cyc.end());
31     rese.push_back(cyc);
32 }
33 void dfs(int u, int edg) {
34     col[u] = 1;
35     for (auto [v, id] : G[u]) if (id != edg) {
36         if (col[v] == 1) {
37             get_cyc(v, u);
38             get_cyc(v, u, id);
39         } else if (col[v] == 0) {
40             pre[v] = u;
41             pre_edg[v] = id;
42             dfs(v, id);
43         }
44     }
45     col[u] = 2;
46 }
47 void MAIN() {
48     cin >> n >> m;
49     for (int i = 1; i <= m; i++) {
50         int u, v; cin >> u >> v;
51         // G[u].push_back({v, i});
52         // G[v].push_back({u, i});
53     }
54     for (int i = 1; i <= n; i++) if (!col[i]) dfs(i, -1);
55 }

```

2.2. SPFA

```

1  mt19937_64 rng(chrono::steady_clock::now().time_since_epoch().count());
2
3  const int mod = 998244353;
4  const int N = 5e5 + 5;
5  const ll inf = 1e17;
6  int n, m, s, t, q[N], ql, qr;
7  int vis[N], fr[N];
8  ll dis[N];
9  vector<pii> G[N];
10 void MAIN() {
11     cin >> n >> m >> s >> t;
12     for (int i = 1; i <= m; i++) {
13         int u, v, w;

```

```

14     cin >> u >> v >> w;
15     G[u].push_back({v, w});
16 }
17 for (int i = 0; i <= n; i++) dis[i] = inf;
18 dis[s] = 0; q[qr] = s; vis[s] = 1;
19 while (ql <= qr) {
20     if (rng() % (qr - ql + 1) == 0) sort(q + ql, q + qr + 1, [](int
x, int y) {
21         return dis[x] < dis[y];
22     });
23     int u = q[ql++];
24     vis[u] = 0;
25     for (auto [v, w] : G[u]) {
26         if (dis[u] + w < dis[v]) {
27             dis[v] = dis[u] + w;
28             fr[v] = u;
29             if (!vis[v]) {
30                 if (ql > 0) q[--ql] = v;
31                 else q[++qr] = v;
32                 vis[v] = 1;
33             }
34         }
35     }
36 }
37 if (dis[t] == inf) {
38     cout << "-1\n";
39     return;
40 }
41 cout << dis[t] << ' ';
42 vector<pii> stk;
43 while (t != s) {
44     stk.push_back({fr[t], t});
45     t = fr[t];
46 }
47 reverse(stk.begin(), stk.end());
48 cout << stk.size() << '\n';
49 for (auto [u, v] : stk) cout << u << ' ' << v << '\n';
50 }

```

2.3. 连通分量

2.3.1. 有向图强连通分量

```

1 const int N = 5e5 + 5;
2 int n, m, dfc, dfn[N], low[N], stk[N], top, idx[N], in_stk[N], scc_cnt;
3 vector<int> G[N];
4
5 void tarjan(int u) {
6     low[u] = dfn[u] = ++dfc;
7     stk[++top] = u;
8     in_stk[u] = 1;

```

```

9     for (int v : G[u]) {
10         if (!dfn[v]) {
11             tarjan(v);
12             low[u] = min(low[u], low[v]);
13         } else if (in_stk[v]) low[u] = min(dfn[v], low[u]);
14     }
15     if (low[u] == dfn[u]) {
16         int x;
17         scc_cnt++;
18         do {
19             x = stk[top--];
20             idx[x] = scc_cnt;
21             in_stk[x] = 0;
22         } while (x != u);
23     }
24 }
25
26 void MAIN() {
27     for (int i = 1; i <= n; i++) low[i] = dfn[i] = idx[i] = in_stk[i] =
0;
28     dfc = scc_cnt = top = 0;
29     cin >> n >> m;
30     for (int i = 1; i <= n; i++) if (!dfn[i]) tarjan(i);
31 }

```

2.3.2. 强连通分量(incremental)

edge[3] 保存了每条边的两个点在同一个强连通分量的时间。调用的时候右端点时间要大一位，因为可能有些边到最后也不能在一个强连通分量中。

```

1 int n, m, Q, s[N];
2 vector<array<int, 4>> edge;
3 vector<int> G[N];
4 struct DSU {
5     int fa[N], dep[N], top;
6     pii stk[N];
7     void init(int n) {
8         top = 0;
9         iota(fa, fa + n + 1, 0);
10        fill(dep, dep + n + 1, 1);
11    }
12    int find(int u) {
13        return u == fa[u] ? u : find(fa[u]);
14    }
15    void merge(int u, int v) {
16        u = find(u), v = find(v);
17        if (u == v) return;
18        if (dep[u] > dep[v]) swap(u, v);
19        stk[++top] = {u, (dep[u] == dep[v] ? v : -1)};
20        fa[u] = v;
21        dep[v] += (dep[u] == dep[v]);

```

```

22     }
23     void rev(int tim) {
24         while (tim < top) {
25             auto [u, v] = stk[top--];
26             fa[u] = u;
27             if (v != -1) dep[v]--;
28         }
29     }
30 } D;
31 int stk[N], top, dfc, dfn[N], low[N], in_stk[N];
32 void tarjan(int u) {
33     low[u] = dfn[u] = ++dfc;
34     stk[++top] = u;
35     in_stk[u] = 1;
36     for (int v : G[u]) {
37         if (!dfn[v]) {
38             tarjan(v);
39             low[u] = min(low[u], low[v]);
40         } else if (in_stk[v]) low[u] = min(dfn[v], low[u]);
41     }
42     if (low[u] == dfn[u]) {
43         int x;
44         do {
45             x = stk[top--];
46             D.merge(x, u);
47             in_stk[x] = 0;
48         } while (x != u);
49     }
50 }
51
52 void solve(int l, int r, int a, int b) {
53     if (l == r) {
54         for (int i = a; i <= b; i++) edge[i][3] = l;
55         return;
56     }
57     int mid = (l + r) >> 1;
58     vector<int> node;
59     for (int i = a; i <= b; i++) if (edge[i][0] <= mid) {
60         int u = D.find(edge[i][1]), v = D.find(edge[i][2]);
61         if (u != v) node.push_back(u), node.push_back(v),
62         G[u].push_back(v);
63     }
64     int otp = D.top;
65     for (int x : node) if (!dfn[x]) tarjan(x);
66     vector<array<int, 4>> e1, e2;
67     for (int i = a; i <= b; i++) {
68         int u = D.find(edge[i][1]), v = D.find(edge[i][2]);
69         if (edge[i][0] > mid || u != v) e2.push_back(edge[i]);
70         else e1.push_back(edge[i]);
71     }
72     int s1 = e1.size(), s2 = e2.size();
73     for (int i = a; i < a + s1; i++) edge[i] = e1[i - a];

```



```

73     for (int i = a + s1; i <= b; i++) edge[i] = e2[i - a - s1];
74     dfc = 0;
75     for (int x : node) dfn[x] = low[x] = 0, vector<int>().swap(G[x]);
76     vector<int>().swap(node);
77     vector<array<int, 4>>().swap(e1);
78     vector<array<int, 4>>().swap(e2);
79     solve(mid + 1, r, a + s1, b);
80     D.rev(otp);
81     solve(l, mid, a, a + s1 - 1);
82 }

```

2.3.3. 割点和桥

```

1  int dfn[N], low[N], dfs_clock;
2  bool iscut[N], vis[N];
3  void dfs(int u, int fa) {
4      dfn[u] = low[u] = ++dfs_clock;
5      vis[u] = 1;
6      int child = 0;
7      for (int v : e[u]) {
8          if (v == fa) continue;
9          if (!dfn[v]) {
10             dfs(v, u);
11             low[u] = min(low[u], low[v]);
12             child++;
13             if (low[v] >= dfn[u]) iscut[u] = 1;
14             } else if (dfn[u] > dfn[v] && v != fa) low[u] = min(low[u],
15             dfn[v]);
16             if (fa == 0 && child == 1) iscut[u] = 0;
17         }
18     }

```

2.3.4. 点双

```

1  #include <cstdio>
2  #include <vector>
3  using namespace std;
4  const int N = 5e5 + 5, M = 2e6 + 5;
5  int n, m;
6
7  struct edge {
8      int to, nt;
9  } e[M << 1];
10
11 int hd[N], tot = 1;
12
13 void add(int u, int v) { e[++tot] = (edge){v, hd[u]}, hd[u] = tot; }
14
15 void uadd(int u, int v) { add(u, v), add(v, u); }
16

```

```

17 int ans;
18 int dfn[N], low[N], bcc_cnt;
19 int sta[N], top, cnt;
20 bool cut[N];
21 vector<int> dcc[N];
22 int root;
23
24 void tarjan(int u) {
25     dfn[u] = low[u] = ++bcc_cnt, sta[++top] = u;
26     if (u == root && hd[u] == 0) {
27         dcc[++cnt].push_back(u);
28         return;
29     }
30     int f = 0;
31     for (int i = hd[u]; i; i = e[i].nt) {
32         int v = e[i].to;
33         if (!dfn[v]) {
34             tarjan(v);
35             low[u] = min(low[u], low[v]);
36             if (low[v] >= dfn[u]) {
37                 if (++f > 1 || u != root) cut[u] = true;
38                 cnt++;
39                 do dcc[cnt].push_back(sta[top--]);
40                 while (sta[top + 1] != v);
41                 dcc[cnt].push_back(u);
42             }
43         } else
44             low[u] = min(low[u], dfn[v]);
45     }
46 }
47
48 int main() {
49     scanf("%d%d", &n, &m);
50     int u, v;
51     for (int i = 1; i <= m; i++) {
52         scanf("%d%d", &u, &v);
53         if (u != v) uadd(u, v);
54     }
55     for (int i = 1; i <= n; i++)
56         if (!dfn[i]) root = i, tarjan(i);
57     printf("%d\n", cnt);
58     for (int i = 1; i <= cnt; i++) {
59         printf("%llu ", dcc[i].size());
60         for (int j = 0; j < dcc[i].size(); j++) printf("%d ", dcc[i][j]);
61         printf("\n");
62     }
63     return 0;
64 }

```

2.3.5. 边双

```

1  #include <algorithm>
2  #include <cstdio>
3  #include <vector>
4
5  using namespace std;
6  const int N = 5e5 + 5, M = 2e6 + 5;
7  int n, m, ans;
8  int tot = 1, hd[N];
9
10 struct edge {
11     int to, nt;
12 } e[M << 1];
13
14 void add(int u, int v) { e[++tot].to = v, e[tot].nt = hd[u], hd[u] = tot; }
15
16 void uadd(int u, int v) { add(u, v), add(v, u); }
17
18 bool bz[M << 1];
19 int bcc_cnt, dfn[N], low[N], vis_bcc[N];
20 vector<vector<int>> bcc;
21
22 void tarjan(int x, int in) {
23     dfn[x] = low[x] = ++bcc_cnt;
24     for (int i = hd[x]; i; i = e[i].nt) {
25         int v = e[i].to;
26         if (dfn[v] == 0) {
27             tarjan(v, i);
28             if (dfn[x] < low[v]) bz[i] = bz[i ^ 1] = 1;
29             low[x] = min(low[x], low[v]);
30         } else if (i != (in ^ 1))
31             low[x] = min(low[x], dfn[v]);
32     }
33 }
34
35 void dfs(int x, int id) {
36     vis_bcc[x] = id, bcc[id - 1].push_back(x);
37     for (int i = hd[x]; i; i = e[i].nt) {
38         int v = e[i].to;
39         if (vis_bcc[v] || bz[i]) continue;
40         dfs(v, id);
41     }
42 }
43
44 int main() {
45     scanf("%d%d", &n, &m);
46     int u, v;
47     for (int i = 1; i <= m; i++) {
48         scanf("%d%d", &u, &v);
49         if (u == v) continue;
50         uadd(u, v);

```

```

51     }
52     for (int i = 1; i <= n; i++)
53         if (dfn[i] == 0) tarjan(i, 0);
54     for (int i = 1; i <= n; i++)
55         if (vis_bcc[i] == 0) {
56             bcc.push_back(vector<int>());
57             dfs(i, ++ans);
58         }
59     printf("%d\n", ans);
60     for (int i = 0; i < ans; i++) {
61         printf("%llu", bcc[i].size());
62         for (int j = 0; j < bcc[i].size(); j++) printf(" %d", bcc[i][j]);
63         printf("\n");
64     }
65     return 0;
66 }

```

2.4. 二分图匹配

2.4.1. 匈牙利算法

mch 记录的是右部点匹配的左部点

```

1  int mch[maxn], vis[maxn];
2  std::vector<int> e[maxn];
3  bool dfs(const int u, const int tag) {
4      for (auto v : e[u]) {
5          if (vis[v] == tag) continue;
6          vis[v] = tag;
7          if (!mch[v] || dfs(mch[v], tag)) return mch[v] = u, 1;
8      }
9      return 0;
10 }
11 int main() {
12     int ans = 0;
13     for (int i = 1; i <= n; ++i) if (dfs(i, i)) ++ans;
14 }

```

2.4.2. KM

2.5. 网络流

2.5.1. 网络最大流

```

1  int head[N], cur[N], ecnt, d[N];
2  struct Edge {
3      int nxt, v, flow, cap;
4  }e[];
5  void add_edge(int u, int v, int flow, int cap) {
6      e[ecnt] = {head[u], v, flow, cap}; head[u] = ecnt++;
7      e[ecnt] = {head[v], u, flow, 0}; head[v] = ecnt++;

```

```

8 }
9 bool bfs() {
10     memset(vis, 0, sizeof vis);
11     std::queue<int> q;
12     q.push(s);
13     vis[s] = 1;
14     d[s] = 0;
15     while (!q.empty()) {
16         int u = q.front();
17         q.pop();
18         for (int i = head[u]; i != -1; i = e[i].nxt) {
19             int v = e[i].v;
20             if (vis[v] || e[i].flow >= e[i].cap) continue;
21             d[v] = d[u] + 1;
22             vis[v] = 1;
23             q.push(v);
24         }
25     }
26     return vis[t];
27 }
28 int dfs(int u, int a) {
29     if (u == t || !a) return a;
30     int flow = 0, f;
31     for (int& i = cur[u]; i != -1; i = e[i].nxt) {
32         int v = e[i].v;
33         if (d[u] + 1 == d[v] && (f = dfs(v, std::min(a, e[i].cap -
e[i].flow))) > 0) {
34             e[i].flow += f;
35             e[i ^ 1].flow -= f;
36             flow += f;
37             a -= f;
38             if (!a) break;
39         }
40     }
41     return flow;
42 }
43

```

2.5.2. 最小费用最大流

```

1 const int inf = 1e9;
2 int head[N], cur[N], ecnt, dis[N], s, t, n, m, mincost;
3 bool vis[N];
4 struct Edge {
5     int nxt, v, flow, cap, w;
6 }e[100002];
7 void add_edge(int u, int v, int flow, int cap, int w) {
8     e[ecnt] = {head[u], v, flow, cap, w}; head[u] = ecnt++;
9     e[ecnt] = {head[v], u, flow, 0, -w}; head[v] = ecnt++;
10 }
11 bool spfa(int s, int t) {

```

```

12     std::fill(vis + s, vis + t + 1, 0);
13     std::fill(dis + s, dis + t + 1, inf);
14     std::queue<int> q;
15     q.push(s);
16     dis[s] = 0;
17     vis[s] = 1;
18     while (!q.empty()) {
19         int u = q.front();
20         q.pop();
21         vis[u] = 0;
22         for (int i = head[u]; i != -1; i = e[i].nxt) {
23             int v = e[i].v;
24             if (e[i].flow < e[i].cap && dis[u] + e[i].w < dis[v]) {
25                 dis[v] = dis[u] + e[i].w;
26                 if (!vis[v]) vis[v] = 1, q.push(v);
27             }
28         }
29     }
30     return dis[t] != inf;
31 }
32 int dfs(int u, int a) {
33     if (vis[u]) return 0;
34     if (u == t || !a) return a;
35     vis[u] = 1;
36     int flow = 0, f;
37     for (int& i = cur[u]; i != -1; i = e[i].nxt) {
38         int v = e[i].v;
39         if (dis[u] + e[i].w == dis[v] && (f = dfs(v, std::min(a,
e[i].cap - e[i].flow))) > 0) {
40             e[i].flow += f;
41             e[i ^ 1].flow -= f;
42             flow += f;
43             mincost += e[i].w * f;
44             a -= f;
45             if (!a) break;
46         }
47     }
48     vis[u] = 0;
49     return flow;
50 }

```

2.6. 2-SAT

$2 * u$ 代表不选择, $2 * u + 1$ 代表选择。

2.6.1. 搜索

```

1 vector<int> G[N * 2];
2 bool mark[N * 2];
3 int stk[N], top;
4 void build_G() {
5     for (int i = 1; i <= n; i++) {

```

```

6         int u, v;
7         G[2 * u + 1].push_back(2 * v);
8         G[2 * v + 1].push_back(2 * u);
9     }
10 }
11 bool dfs(int u) {
12     if (mark[u ^ 1]) return false;
13     if (mark[u]) return true;
14     mark[u] = 1;
15     stk[++top] = u;
16     for (int v : G[u]) {
17         if (!dfs(v)) return false;
18     }
19     return true;
20 }
21 bool 2_sat() {
22     for (int i = 1; i <= n; i++) {
23         if (!mark[i * 2] && !mark[i * 2 + 1]) {
24             top = 0;
25             if (!dfs(2 * i)) {
26                 while (top) mark[stk[top--]] = 0;
27                 if (!dfs(2 * i + 1)) return 0;
28             }
29         }
30     }
31     return 1;
32 }

```

2.6.2. tarjan

如果对于一个 x $sccno$ 比它的反状态 $x^{\wedge}1$ 的 $sccno$ 要小, 那么我们用 x 这个状态当做答案, 否则用它的反状态当做答案。

2.7. 生成树

2.7.1. Prime

```

1 int n, m;
2 vector<pii> G[N];
3 ll dis[N];
4 int vis[N];
5 void MAIN() {
6     cin >> n >> m;
7     for (int i = 1; i <= m; i++) {
8         int u, v, w;
9         cin >> u >> v >> w;
10        G[u].push_back({v, w});
11        G[v].push_back({u, w});
12    }
13    for (int i = 1; i <= n; i++) dis[i] = 1e18, vis[i] = 0;
14    priority_queue<pair<ll, int>> q;
15    dis[1] = 0;

```

```

16     q.push({-dis[1], 1});
17     ll ans = 0;
18     while (!q.empty()) {
19         auto [val, u] = q.top(); q.pop();
20         if (vis[u]) continue;
21         vis[u] = 1;
22         ans -= val;
23         for (auto [v, w] : G[u]) if (dis[v] > w) {
24             dis[v] = w;
25             q.push({-w, v});
26         }
27     }
28     cout << ans << '\n';
29 }

```

2.8. 圆方树

记得开两倍空间。

```

1 void tarjan(int u) {
2     stk[++top] = u;
3     low[u] = dfn[u] = ++dfc;
4     for (int v : G[u]) {
5         if (!dfn[v]) {
6             tarjan(v);
7             low[u] = min(low[u], low[v]);
8             if (low[v] == dfn[u]) {
9                 cnt++;
10                for (int x = 0; x != v; --top) {
11                    x = stk[top];
12                    T[cnt].push_back(x);
13                    T[x].push_back(cnt);
14                    val[cnt]++;
15                }
16                T[cnt].push_back(u);
17                T[u].push_back(cnt);
18                val[cnt]++;
19            }
20        } else low[u] = min(low[u], dfn[v]);
21    }
22 }
23 // 调用
24 cnt = n;
25 for (int i = 1; i <= n; i++) if (!dfn[i]) {
26     tarjan(i);
27     --top;
28 }

```

- 静态仙人掌最短路。边权设置为到点双顶点的最短距离。


```

1 void tarjan(int u) {
2     stk[++top] = u;
3     dfn[u] = low[u] = ++dfc;
4     for (auto [v, w] : G[u]) if (!dfn[v]) {
5         dis[v] = dis[u] + w;
6         tarjan(v);
7         low[u] = min(low[u], low[v]);
8         if (low[v] == dfn[u]) {
9             ++cnt;
10            val[cnt] = cyc[stk[top]] + dis[stk[top]] - dis[u];
11            for (int x = 0; x != v; --top) {
12                x = stk[top];
13                //assert(val[cnt] >= (dis[x] - dis[u]));
14                int w = min(dis[x] - dis[u], val[cnt] - (dis[x] -
dis[u]));
15                T[cnt].push_back({x, w});
16                T[x].push_back({cnt, w});
17            }
18            T[cnt].push_back({u, 0});
19            T[u].push_back({cnt, 0});
20        }
21    } else if (dfn[v] < dfn[u]) {
22        cyc[u] = w;
23        low[u] = min(low[u], dfn[v]);
24    }
25 }
26
27 void dfs(int u, int fa) {
28     faz[0][u] = fa;
29     for (int k = 1; k < M; k++) faz[k][u] = faz[k - 1][faz[k - 1][u]];
30     for (auto [v, w] : T[u]) if (v != fa) {
31         dep[v] = dep[u] + 1;
32         ff[v] = ff[u] + w;
33         dfs(v, u);
34     }
35 }
36
37 int dist(int u, int v) {
38     int tu = u, tv = v;
39     if (dep[u] < dep[v]) swap(u, v);
40     int det = dep[u] - dep[v];
41     for (int k = 0; k < M; k++) if ((det >> k) & 1) u = faz[k][u];
42     int lca;
43     if (u == v) lca = u;
44     else {
45         for (int k = M - 1; k >= 0; k--) if (faz[k][u] != faz[k][v]) {
46             u = faz[k][u]; v = faz[k][v];
47         }
48         lca = faz[0][u];
49     }
50     if (lca <= n) return ff[tu] + ff[tv] - ff[lca] * 2;
51     int tm = min(abs(dis[u] - dis[v]), val[lca] - abs(dis[u] - dis[v]));
52     return ff[tu] - ff[u] + ff[tv] - ff[v] + tm;

```

52 }

- 圆方树上 dp

以单源最短路为例，原点记录该点出发是否返回的最长路，方点记录顶点出发经过环上所能走到的最长路。

```

1 void dfs(int u, int fa) {
2     for (int v : T[u]) if (v != fa) dfs(v, u);
3     if (u <= n) {
4         int mx = 0;
5         /*
6         这里必须设为 0 而不是 -inf，或者在平凡方点转移的时候要 max(dp[0],
dp[1])
7         hack: 4 4
8         1 2
9         2 3
10        3 4
11        4 2
12        */
13        for (int v : T[u]) if (v != fa) {
14            dp[u][1] += dp[v][1];
15            mx = max(mx, dp[v][0] - dp[v][1]);
16            dp[u][0] += dp[v][1];
17        }
18        dp[u][0] += mx;
19    } else {
20        int sum = 1;
21        dp[u][1] = 1;
22        for (int v : T[u]) if (v != fa) {
23            dp[u][1] += dp[v][1] + 1;
24            dp[u][0] = max(dp[u][0], sum + dp[v][0]);
25            sum += dp[v][1] + 1;
26        }
27        sum = 1;
28        reverse(T[u].begin(), T[u].end());
29        for (int v : T[u]) if (v != fa) {
30            dp[u][0] = max(dp[u][0], sum + dp[v][0]);
31            sum += dp[v][1] + 1;
32        }
33        if (val[u] == 2) dp[u][1] = 0;
34    }
35 }

```

2.9. 欧拉回路

- 有向图

```

1 void dfs(int u) {
2     for (int &i = hd[u]; i < G[u].size(); ) dfs(G[u][i++]);

```

```

3     stk.push_back(u);
4 }
5 int check() {
6     int mo = 0, le = 0, st = 1;
7     for (int i = 1; i <= n; i++) {
8         if (abs(in[i] - out[i]) > 1) return -1;
9         if (in[i] > out[i]) le++;
10        if (in[i] < out[i]) mo++, st = i;
11    }
12    if (mo > 1 || le > 1 || mo + le == 1) return -1;
13    return st;
14 }
15
16 void MAIN() {
17     cin >> n >> m;
18     for (int i = 1; i <= m; i++) {
19         int u, v;
20         cin >> u >> v;
21         in[v]++; out[u]++;
22         G[u].push_back(v);
23     }
24     for (int i = 1; i <= n; i++) sort(G[i].begin(), G[i].end());
25     int tmp = check();
26     if (tmp == -1) cout << "No\n";
27     else {
28         dfs(tmp);
29         copy(stk.rbegin(), stk.rend(), ostream_iterator<int>(cout, "
"));
30         cout << '\n';
31     }
32 }

```

• 无向图

```

1 void dfs(int u) {
2     for (int &i = hd[u]; i < G[u].size(); ) {
3         while (i < G[u].size() && cnt[u][G[u][i]] == 0) ++i;
4         if (i == G[u].size()) break;
5         cnt[u][G[u][i]]--;
6         cnt[G[u][i]][u]--;
7         dfs(G[u][i++]);
8     }
9     stk.push_back(u);
10 }
11 int check() {
12     int odd = 0, st = -1;
13     for (int i = 1; i <= n; i++) {
14         if (deg[i] == 0) continue;
15         if (st == -1) st = i;
16         if (deg[i] & 1) {
17             ++odd;

```

```

18         if (odd == 1) st = i;
19     }
20 }
21 if (odd > 2) return -1;
22 return st;
23 }
24
25 void MAIN() {
26     n = 500;
27     cin >> m;
28     for (int i = 1; i <= m; i++) {
29         int u, v;
30         cin >> u >> v;
31         ++deg[u]; ++deg[v];
32         G[u].push_back(v);
33         G[v].push_back(u);
34         ++cnt[u][v];
35         ++cnt[v][u];
36     }
37     for (int i = 1; i <= n; i++) sort(G[i].begin(), G[i].end());
38     int tmp = check();
39     if (tmp == -1) cout << "No\n";
40     else {
41         dfs(tmp);
42         copy(stk.rbegin(), stk.rend(), ostream_iterator<int>(cout,
43             "\n"));
44     }
45 }

```

2.10. 无向图三/四元环计数

• 三元环

```

1 int vis[N];
2 vector<int> G[N];
3 ll main() {
4     ll cnt = 0;
5     for (int i = 0; i < m; i++) {
6         if (deg[ed[i].fi] == deg[ed[i].se] && ed[i].fi > ed[i].se)
7             swap(ed[i].fi, ed[i].se);
8         if (deg[ed[i].fi] > deg[ed[i].se]) swap(ed[i].fi, ed[i].se);
9         G[ed[i].fi].push_back(ed[i].se);
10    }
11    for (int u = 1; u <= n; u++) {
12        for (int v : G[u]) vis[v] = 1;
13        for (int v : G[u]) for (int w : G[v]) if (vis[w]) ++cnt;
14        for (int v : G[u]) vis[v] = 0;
15    }
16    return cnt;
17 }

```

• 四元环

统计 $c?b \rightarrow a \leftarrow d?c$ 的数目，因为最大度数点 a 不同，所以不会算重。

```

1 int n, m, deg[N], cnt[N];
2 bool bigger(int a, int b) {
3     return deg[a] > deg[b] || (deg[a] == deg[b] && a > b);
4 }
5 void MAIN() {
6     cin >> n >> m;
7     for (int i = 1; i <= m; i++) {
8         int u, v;
9         cin >> u >> v;
10        ed.push_back({u, v});
11        G[u].push_back(v);
12        G[v].push_back(u);
13        ++deg[u]; ++deg[v];
14    }
15    for (auto [u, v] : ed) {
16        if (bigger(v, u)) swap(u, v);
17        T[u].push_back(v);
18    }
19    ll ans = 0;
20    for (int a = 1; a <= n; a++) {
21        for (int b : T[a]) {
22            for (int c : G[b]) {
23                if (c == a || bigger(c, a)) continue;
24                ans += cnt[c];
25                ++cnt[c];
26            }
27        }
28        for (int b : T[a]) for (int c : G[b]) cnt[c] = 0;
29    }
30    cout << ans << '\n';
31 }

```

2.11. 虚树

需要保证 $LCA(0, u) = 0$

```

1 int solve(vector<int>po) {
2     sort(po.begin(), po.end(), [](int x, int y) {
3         return dfn[x] < dfn[y];
4     });
5     int ans = 0;
6     top = 0;
7     stk[++top] = 0;
8     for (int u : po) {
9         int lca = LCA(u, stk[top]);
10        if (lca == stk[top]) stk[++top] = u;
11        else {
12            for (int i = top; i >= 2 && dep[stk[i - 1]] >= dep[lca];
i--) {

```

```

13         // ans += ff[stk[i]] - ff[stk[i - 1]] - (vis[stk[i]] ?
    val[stk[i]]: 0);
14         // cout << stk[i] << ' ' << stk[i - 1] << ' ' <<
    ff[stk[i]] - ff[stk[i - 1]] - (vis[stk[i]] ? val[stk[i]]: 0) << '\n';
15         add_edge(stk[i], stk[i - 1]);
16         --top;
17     }
18     if (stk[top] != lca) {
19         // cout << lca << ' ' << stk[top] << ' ' << ff[stk[top]]
    - ff[lca] - (vis[stk[top]] ? val[stk[top]] : 0) << '\n';
20         // ans += ff[stk[top]] - ff[lca] - (vis[stk[top]] ?
    val[stk[top]] : 0);
21         add_edge(stk[top], lca);
22         stk[top] = lca;
23     }
24     stk[++top] = u;
25 }
26 }
27 for (int i = 2; i < top; i++) {
28     // cout << stk[i + 1] << ' ' << stk[i] << ' ' << ff[stk[i + 1]] -
    ff[stk[i]] - (vis[stk[i + 1]] ? val[stk[i + 1]] : 0) << '\n';
29     // ans += ff[stk[i + 1]] - ff[stk[i]] - (vis[stk[i + 1]] ?
    val[stk[i + 1]] : 0);
30     add_edge(stk[i + 1], stk[i]);
31 }
32 //ans += (vis[stk[2]] ? 0 : val[stk[2]]);
33 return ans;
34 }

```

2.12. 最近公共祖先

```

1 // 倍增
2 int faz[N][20], dep[N];
3 void dfs(int u, int fa) {
4     faz[u][0] = fa;
5     dep[u] = dep[fa] + 1;
6     for (int i = 1; i < 20; i++) faz[u][i] = faz[faz[u][i - 1]][i - 1];
7     for (int v : G[u]) if (v != fa) {
8         dfs(v, u);
9     }
10 }
11 int LCA(int u, int v) {
12     if (dep[u] < dep[v]) swap(u, v);
13     int d = dep[u] - dep[v];
14     for (int i = 0; i < 20; i++) if ((d >> i) & 1) u = faz[u][i];
15     if (v == u) return u;
16     for (int i = 19; i >= 0; i--) if (faz[u][i] != faz[v][i])
17         u = faz[u][i], v = faz[v][i];
18     return faz[u][0];
19 }
20

```

```

21 //树剖
22 int dfc, dfn[N], rnk[N], siz[N], top[N], dep[N], son[N], faz[N];
23 void dfs1(int u, int fa) {
24     dep[u] = dep[fa] + 1;
25     siz[u] = 1;
26     son[u] = -1;
27     faz[u] = fa;
28     for (int v : G[u]) {
29         if (v == fa) continue;
30         dfs1(v, u);
31         siz[u] += siz[v];
32         if (son[u] == -1 || siz[son[u]] < siz[v]) son[u] = v;
33     }
34 }
35 void dfs2(int u, int fa, int tp) {
36     dfn[u] = ++dfc;
37     rnk[dfc] = u;
38     top[u] = tp;
39     if (son[u] != -1) dfs2(son[u], u, tp);
40     for (int v : G[u]) {
41         if (v == fa || v == son[u]) continue;
42         dfs2(v, u, v);
43     }
44 }
45 int LCA(int u, int v) {
46     while (top[u] != top[v]) {
47         if (dep[top[u]] > dep[top[v]])
48             u = faz[top[u]];
49         else
50             v = faz[top[v]];
51     }
52     return dep[u] > dep[v] ? v : u;
53 }
54
55 // O(1) query
56
57 int dfn[N], faz[N], dep[N], rnk[N], dfc, st[N][20];
58 void dfs(int u, int fa) {
59     dfn[u] = ++dfc; faz[u] = fa; dep[u] = dep[fa] + 1; rnk[dfc] = u;
60     for (auto [v, w] : G[u]) if (v != fa) dfs(v, u);
61 }
62 int LCA(int u, int v) {
63     if (u == v) return u;
64     if (dfn[u] > dfn[v]) swap(u, v);
65     int l = dfn[u] + 1, r = dfn[v];
66     int k = __lg(r - l + 1);
67     return dep[st[l][k]] < dep[st[r - (1 << k) + 1][k]] ? faz[st[l]
[k]] : faz[st[r - (1 << k) + 1][k]];
68 }
69
70 int main() {
71     dfs(1, 0);

```

```

72     dep[0] = n + 1;
73     for (int i = 1; i <= n; i++) st[i][0] = rnk[i];
74     for (int j = 1; j < 20; j++) {
75         for (int i = 1; i <= n; i++) {
76             st[i][j] = dep[st[i][j - 1]] <= dep[st[min(n, i + (1 << (j -
1))))][j - 1]] ? st[i][j - 1] : st[min(n, i + (1 << (j - 1))))][j - 1];
77         }
78     }
79 }

```

3. 数学

3.1. 子集卷积

高维前缀和

```

1 for (int k = 0; k < 20; k++) {
2     for (int i = 0; i < (1 << 20); i++) if ((i >> k) & 1) {
3         f[i] = f[i] + f[i ^ (1 << k)];
4     }
5 }

```

高维后缀和

```

1 for (int k = 0; k < 20; k++) {
2     for (int i = 0; i < (1 << 20); i++) if ((i >> k) & 1) {
3         f[i] = f[i] + f[i ^ (1 << k)];
4     }
5 }

```

高维差分

```

1 for (int k = 0; k < 20; k++) {
2     for (int i = 0; i < (1 << 20); i++) if ((i >> k) & 1) {
3         f[i] = f[i] - f[i ^ (1 << k)];
4     }
5 }

```

3.2. 线性基

```

1 struct LinerBasis {
2     int a[20], pos[20];
3     void add(int v, int p) {
4         for (int i = 19; i >= 0; i--) if ((v >> i) & 1) {
5             if (a[i]) {
6                 if (p > pos[i]) {
7                     swap(p, pos[i]);
8                     swap(a[i], v);

```



```

9         }
10        v ^= a[i];
11    } else {
12        a[i] = v;
13        pos[i] = p;
14        return;
15    }
16    }
17    }
18 } b[N];
19
20 LinerBasis operator + (LinerBasis a, LinerBasis b) {
21     for (int i = 19; i >= 0; i--) {
22         if (b.a[i]) a.add(b.a[i], b.pos[i]);
23     }
24     return a;
25 }

```

3.3. 高斯消元

```

1 namespace Gauss {
2     bitset<258> a[256 + 256 + 5];
3     int n;
4     void push(const bitset<258>& x) {
5         a[++n] = x;
6     }
7     bool solve(int m) {
8         int k = 1;
9         for (int i = 1; i <= m; i++) {
10             if (k > n) break;
11             for (int j = k + 1; j <= n; j++) if (a[j][i] > 0) {
12                 swap(a[k], a[j]);
13                 break;
14             }
15             if (a[k][i] == 0) break;
16             for (int j = 1; j <= n; j++) if (j != k && a[j][i]) {
17                 a[j] ^= a[k];
18             }
19             ++k;
20         }
21         for (int i = k; i <= n; i++) if (a[i][m + 1]) return false;
22         return true;
23     }
24 }

```

4. 多项式

4.1. NTT

这个板子很慢

```

1  #include <bits/stdc++.h>
2  using namespace std;
3
4  typedef vector<int> poly;
5  const int mod = 998244353;
6  const int N = 4000000 + 5;
7
8  int rf[32][N];
9  int fpow(int a, int b) {
10     int res = 1;
11     for (; b >= 1, a = a * 1ll * a % mod) if (b & 1)
12         res = res * 1ll * a % mod;
13     return res;
14 }
15 void init(int n) {
16     assert(n < N);
17     int lg = __lg(n);
18     static vector<bool> bt(32, 0);
19     if (bt[lg] == 1) return;
20     bt[lg] = 1;
21     for (int i = 0; i < n; i++) rf[lg][i] = (rf[lg][i >> 1] >> 1) + ((i
22         & 1) ? (n >> 1) : 0);
23 }
24 void ntt(poly &x, int lim, int op) {
25     int lg = __lg(lim), gn, g, tmp;
26     for (int i = 0; i < lim; i++) if (i < rf[lg][i]) swap(x[i], x[rf[lg]
27         [i]]);
28     for (int len = 2; len <= lim; len <= 1) {
29         int k = (len >> 1);
30         gn = fpow(3, (mod - 1) / len);
31         for (int i = 0; i < lim; i += len) {
32             g = 1;
33             for (int j = 0; j < k; j++, g = gn * 1ll * g % mod) {
34                 tmp = x[i + j + k] * 1ll * g % mod;
35                 x[i + j + k] = (x[i + j] - tmp + mod) % mod;
36                 x[i + j] = (x[i + j] + tmp) % mod;
37             }
38         }
39     }
40     if (op == -1) {
41         reverse(x.begin() + 1, x.begin() + lim);
42         int inv = fpow(lim, mod - 2);
43         for (int i = 0; i < lim; i++) x[i] = x[i] * 1ll * inv % mod;
44     }
45 }
46 poly multiply(const poly &a, const poly &b) {
47     assert(!a.empty() && !b.empty());
48     int lim = 1;
49     while (lim + 1 < int(a.size() + b.size())) lim <= 1;
50     init(lim);
51     poly pa = a, pb = b;
52     while (pa.size() < lim) pa.push_back(0);

```

```

51     while (pb.size() < lim) pb.push_back(0);
52     ntt(pa, lim, 1); ntt(pb, lim, 1);
53     for (int i = 0; i < lim; i++) pa[i] = pa[i] * 1ll * pb[i] % mod;
54     ntt(pa, lim, -1);
55     while (int(pa.size()) + 1 > int(a.size() + b.size())) pa.pop_back();
56     return pa;
57 }
58 poly prod_poly(const vector<poly>& vec) { // init vector, too slow
59     int n = vec.size();
60     auto calc = [&](const auto &self, int l, int r) -> poly {
61         if (l == r) return vec[l];
62         int mid = (l + r) >> 1;
63         return multiply(self(self, l, mid), self(self, mid + 1, r));
64     };
65     return calc(calc, 0, n - 1);
66 }
67
68 // Semi-Online-Convolution
69 poly semi_online_convolution(const poly& g, int n, int op = 0) {
70     assert(n == g.size());
71     poly f(n, 0);
72     f[0] = 1;
73     auto CDQ = [&](const auto &self, int l, int r) -> void {
74         if (l == r) {
75             // exp
76             if (op == 1 && l > 0) f[l] = f[l] * 1ll * fpow(l, mod - 2) %
mod;
77             return;
78         }
79         int mid = (l + r) >> 1;
80         self(self, l, mid);
81         poly a, b;
82         for (int i = l; i <= mid; i++) a.push_back(f[i]);
83         for (int i = 0; i <= r - l - 1; i++) b.push_back(g[i + 1]);
84         a = multiply(a, b);
85         for (int i = mid + 1; i <= r; i++) f[i] = (f[i] + a[i - l - 1])
% mod;
86         self(self, mid + 1, r);
87     };
88     CDQ(CDQ, 0, n - 1);
89     return f;
90 }
91
92 poly getinv(const poly &a) {
93     assert(!a.empty());
94     poly res = {fpow(a[0], mod - 2)}, na = {a[0]};
95     int lim = 1;
96     while (lim < int(a.size())) lim <= 1;
97     for (int len = 2; len <= lim; len <= 1) {
98         while (na.size() < len) {
99             int tmp = na.size();
100             if (tmp < a.size()) na.push_back(a[tmp]);

```

```

101         else na.push_back(0);
102     }
103     auto tmp = multiply(na, res);
104     for (auto &x : tmp) x = (x > 0 ? mod - x : x);
105     tmp[0] = ((tmp[0] + 2) >= mod) && (tmp[0] -= mod);
106     tmp = multiply(res, tmp);
107     while (tmp.size() > len) tmp.pop_back();
108     res = tmp;
109 }
110 while (res.size() > a.size()) res.pop_back();
111 return res;
112 }
113 poly exp(const poly &g) {
114     int n = g.size();
115     poly b(n, 0);
116     for (int i = 1; i < n; i++) b[i] = i * 1ll * g[i] % mod;
117     return semi_online_convolution(b, n, 1);
118 }
119 poly ln(const poly &A) {
120     int n = A.size();
121     auto C = getinv(A);
122     poly A1(n, 0);
123     for (int i = 0; i < n - 1; i++) A1[i] = (i + 1) * 1ll * A[i + 1] %
mod;
124     C = multiply(C, A1);
125     for (int i = n - 1; i > 0; i--) C[i] = C[i - 1] * 1ll * fpow(i, mod
- 2) % mod;
126     C[0] = 0;
127     while (C.size() > n) C.pop_back();
128     return C;
129 }
130 poly quick_pow(poly &a, int k, int k_mod_phi, bool is_k_bigger_than_mod
= false) {
131     assert(!a.empty());
132     int n = a.size(), t = -1, b;
133     for (int i = 0; i < n; i++) if (a[i]) {
134         t = i, b = a[i];
135         break;
136     }
137     if (t == -1 || t && is_k_bigger_than_mod || k * 1ll * t >= n) return
poly(n, 0);
138     poly f;
139     for (int i = 0; i < n; i++) {
140         if (i + t < n) f.push_back(a[i + t] * 1ll * fpow(b, mod - 2) %
mod);
141         else f.push_back(0);
142     }
143     f = ln(f);
144     for (auto &x : f) x = x * 1ll * k % mod;
145     f = exp(f);
146     poly res;
147     for (int i = 0; i < k * t; i++) res.push_back(0);

```

```

148     int fb = fpow(b, k_mod_phi);
149     for (int i = k * t; i < n; i++) res.push_back(f[i - k * t] * 1ll *
fb % mod);
150     return res;
151 }
152
153 int main() {
154     ios::sync_with_stdio(0); cin.tie(0);
155     int n, k = 0, k_mod_phi = 0, isb = 0;
156     string s;
157     cin >> n >> s;
158     for (auto ch : s) {
159         if ((ch - '0') + k * 10ll >= mod) isb = 1;
160         k = ((ch - '0') + k * 10ll) % mod;
161         k_mod_phi = ((ch - '0') + k_mod_phi * 10ll) % 998244352;
162     }
163     poly a(n);
164     for (auto &x : a) cin >> x;
165     a = quick_pow(a, k, k_mod_phi, isb);
166     while (a.size() > n) a.pop_back();
167     for (auto x : a) cout << x << ' ';
168     return 0;
169 }

```

4.2. 任意模数 NTT

模数小于 10^9

```

1  #include <bits/stdc++.h>
2  using namespace std;
3
4  typedef complex<double> cp;
5  typedef vector<cp> poly;
6  typedef long long ll;
7
8  const int N = 4000000 + 5;
9  const double pi = acos(-1);
10
11 int rf[26][N];
12 void init(int n) {
13     assert(n < N);
14     int lg = __lg(n);
15     static vector<bool> bt(26, 0);
16     if (bt[lg] == 1) return;
17     bt[lg] = 1;
18     for (int i = 0; i < n; i++) rf[lg][i] = (rf[lg][i >> 1] >> 1) + ((i
& 1) ? (n >> 1) : 0);
19 }
20 void fft(poly &x, int lim, int op) {
21     int lg = __lg(lim);

```

```

22     for (int i = 0; i < lim; i++) if (i < rf[lg][i]) swap(x[i], x[rf[lg]
[i]]);
23     for (int len = 2; len <= lim; len <= 1) {
24         int k = (len >> 1);
25         for (int i = 0; i < lim; i += len) {
26             for (int j = 0; j < k; j++) {
27                 cp w(cos(pi * j / k), op * sin(pi * j / k));
28                 cp tmp = w * x[i + j + k];
29                 x[i + j + k] = x[i + j] - tmp;
30                 x[i + j] = x[i + j] + tmp;
31             }
32         }
33     }
34     if (op == -1) for (int i = 0; i < lim; i++) x[i] /= lim;
35 }
36 poly multiply(const poly &a, const poly &b) {
37     assert(!a.empty() && !b.empty());
38     int lim = 1;
39     while (lim + 1 < int(a.size() + b.size())) lim <= 1;
40     init(lim);
41     poly pa = a, pb = b;
42     pa.resize(lim);
43     pb.resize(lim);
44     for (int i = 0; i < lim; i++) pa[i] = (cp){pa[i].real(),
pb[i].real()};
45     fft(pa, lim, 1);
46     pb[0] = conj(pa[0]);
47     for (int i = 1; i < lim; i++) pb[lim - i] = conj(pa[i]);
48     for (int i = 0; i < lim; i++) {
49         pa[i] = (pa[i] + pb[i]) * (pa[i] - pb[i]) / cp({0, 4});
50     }
51     fft(pa, lim, -1);
52     pa.resize(int(a.size() + b.size()) - 1);
53     return pa;
54 }
55 vector<int> MTT(const vector<int> &a, const vector<int> &b, const int
mod) {
56     const int B = (1 << 15) - 1, M = (1 << 15);
57     int lim = 1;
58     while (lim + 1 < int(a.size() + b.size())) lim <= 1;
59     init(lim);
60     poly pa(lim), pb(lim);
61     auto get = [](const vector<int>& v, int pos) -> int {
62         if (pos >= v.size()) return 0;
63         else return v[pos];
64     };
65     for (int i = 0; i < lim; i++) pa[i] = (cp){get(a, i) >> 15, get(a,
i) & B};
66     fft(pa, lim, 1);
67     pb[0] = conj(pa[0]);
68     for (int i = 1; i < lim; i++) pb[lim - i] = conj(pa[i]);
69     poly A0(lim), A1(lim);

```

```

70     for (int i = 0; i < lim; i++) {
71         A0[i] = (pa[i] + pb[i]) / (cp){2, 0};
72         A1[i] = (pa[i] - pb[i]) / (cp){0, 2};
73     }
74     for (int i = 0; i < lim; i++) pa[i] = (cp){get(b, i) >> 15, get(b,
i) & B};
75     fft(pa, lim, 1);
76     pb[0] = conj(pa[0]);
77     for (int i = 1; i < lim; i++) pb[lim - i] = conj(pa[i]);
78     poly B0(lim), B1(lim);
79     for (int i = 0; i < lim; i++) {
80         B0[i] = (pa[i] + pb[i]) / (cp){2, 0};
81         B1[i] = (pa[i] - pb[i]) / (cp){0, 2};
82     }
83     for (int i = 0; i < lim; i++) {
84         pa[i] = A0[i] * B0[i];
85         pb[i] = A0[i] * B1[i];
86         A0[i] = pa[i];
87         pa[i] = A1[i] * B1[i];
88         B1[i] = pb[i];
89         B0[i] = A1[i] * B0[i];
90         A1[i] = pa[i];
91         pa[i] = A0[i] + (cp){0, 1} * A1[i];
92         pb[i] = B0[i] + (cp){0, 1} * B1[i];
93     }
94     fft(pa, lim, -1); fft(pb, lim, -1);
95     vector<int> res(int(a.size() + b.size()) - 1);
96     const int M2 = M * 1ll * M % mod;
97     for (int i = 0; i < res.size(); i++) {
98         ll a0 = round(pa[i].real()), a1 = round(pa[i].imag()), b0 =
round(pb[i].real()), b1 = round(pb[i].imag());
99         a0 %= mod; a1 %= mod; b0 %= mod; b1 %= mod;
100        res[i] = (a0 * 1ll * M2 % mod + a1 + (b0 + b1) % mod * 1ll * M %
mod) % mod;
101    }
102    return res;
103 }
104
105 int main() {
106 #ifdef LOCAL
107     freopen("miku.in", "r", stdin);
108     freopen("miku.out", "w", stdout);
109 #endif
110     ios::sync_with_stdio(0); cin.tie(0);
111     int n, m, p;
112     cin >> n >> m >> p;
113     vector<int> a(n + 1), b(m + 1);
114     for (auto &x : a) cin >> x;
115     for (auto &x : b) cin >> x;
116     auto res = MTT(a, b, p);
117     for (auto x : res) cout << x << ' ';
118 }

```

5. 数据结构

5.1. 李超树

```

1 \begin{lstlisting}
2 struct Line {
3     ll k, b;
4 } lin[N];
5 int lcnt;
6 int add_line(ll k, ll b) {
7     lin[++lcnt] = {k, b};
8     return lcnt;
9 }
10 struct node {
11     int ls, rs, u;
12 } tr[N << 2];
13 int tot;
14 ll calc(int u, ll x) {
15     return lin[u].k * x + lin[u].b;
16 }
17 bool cmp(int u, int v, ll x) {
18     return calc(u, x) <= calc(v, x); // 如果要求最大值，只需要修改为大于等于
19 }
20 void pushdown(int &p, int l, int r, int v) {
21     if (!p) p = ++tot;
22     if (l == r) return;
23     int mid = (l + r) >> 1;
24     int &u = tr[p].u, b = cmp(v, u, mid);
25     if (b) swap(u, v);
26     int bl = cmp(v, u, l), br = cmp(v, u, r);
27     if (bl) pushdown(tr[p].ls, l, mid, v);
28     if (br) pushdown(tr[p].rs, mid + 1, r, v);
29 }
30 void update(int &p, int l, int r, int L, int R, int v) {
31     if (l > R || r < L) return;
32     if (!p) p = ++tot;
33     int mid = (l + r) >> 1;
34     if (l >= L && r <= R) return pushdown(p, l, r, v), void();
35     update(tr[p].ls, l, mid, L, R, v);
36     update(tr[p].rs, mid + 1, r, L, R, v);
37 }
38 ll query(int p, int l, int r, ll pos) {
39     if (!p) return le16;
40     ll res = calc(tr[p].u, pos);
41     int mid = (l + r) >> 1;
42     if (l == r) return res;
43     if (pos <= mid) {
44         res = min(res, query(tr[p].ls, l, mid, pos));
45     } else res = min(res, query(tr[p].rs, mid + 1, r, pos));
46     return res;
47 }
48

```



```

49 int main() {
50     lin[0].b = 1e16;
51     return 0;
52 }

```

5.2. 兔队线段树

求有多少个严格前缀最大值。

线段树保存每个区间为子问题时右部分的答案 res （可以不需要信息可减），和区间的最大值 mx 。

calc 考虑一段区间之前有 x 大的数时，区间此时前缀最大数的树目。

1. $x \geq val[lson], ans = calc(rson)$
2. $x < val[lson], ans = calc(lson) + res[p]$

```

1  #include <bits/stdc++.h>
2  using namespace std;
3  using ll = long long;
4
5  const int N = 1e5 + 5;
6  #define lson (p << 1)
7  #define rson ((p << 1) | 1)
8  #define mid ((l + r) >> 1)
9  int n, m;
10 struct node {
11     int s, a, b;
12 } tr[N << 2];
13 bool cmp(int a, int b, int c, int d) {
14     if (d == 0 && b == 0) return 0;
15     if (d == 0 && a == 0) return 0;
16     if (d == 0) return 1;
17     return a * 1ll * d > c * 1ll * b;
18 }
19 int calc(int p, int l, int r, int c, int d) {
20     if (l == r)
21         return cmp(tr[p].a, tr[p].b, c, d);
22     if (cmp(tr[lson].a, tr[lson].b, c, d)) {
23         return calc(lson, l, mid, c, d) + tr[p].s;
24     }
25     return calc(rson, mid + 1, r, c, d);
26 }
27 void modify(int p, int l, int r, int pos, int v) {
28     if (l == r) {
29         tr[p] = {0, v, pos};
30         return;
31     }
32     if (pos <= mid) modify(lson, l, mid, pos, v);
33     else modify(rson, mid + 1, r, pos, v);
34     if (cmp(tr[lson].a, tr[lson].b, tr[rson].a, tr[rson].b)) {

```

```

35     tr[p] = tr[lson];
36 } else tr[p] = tr[rson];
37 tr[p].s = calc(rson, mid + 1, r, tr[lson].a, tr[lson].b);
38 }
39
40 int main() {
41     scanf("%d %d", &n, &m);
42     while (m--) {
43         int x, y;
44         scanf("%d %d", &x, &y);
45         modify(1, 1, n, x, y);
46         printf("%d\n", calc(1, 1, n, 0, 0));
47     }
48     return 0;

```

5.3. 平衡树

```

1  #include <bits/stdc++.h>
2  using namespace std;
3  using ll = long long;
4
5  #define rank abcdefg
6  const int mod = 998244353;
7  const int N = 1e5 + 5;
8
9  int tot, fa[N], tr[N][2], sz[N], cnt[N], val[N], rt;
10
11 void maintain(int x) {
12     sz[x] = sz[tr[x][0]] + sz[tr[x][1]] + cnt[x];
13 }
14 int getdir(int x) {
15     return tr[fa[x]][1] == x;
16 }
17 void clear(int x) {
18     fa[x] = sz[x] = cnt[x] = tr[x][0] = tr[x][1] = val[x] = 0;
19 }
20 int create(int v) {
21     ++tot;
22     val[tot] = v;
23     sz[tot] = cnt[tot] = 1;
24     return tot;
25 }
26 void rotate(int x) {
27     if (x == rt) return;
28     int y = fa[x], z = fa[y], d = getdir(x);
29     tr[y][d] = tr[x][d ^ 1];
30     if (tr[x][d ^ 1]) fa[tr[x][d ^ 1]] = y;
31     fa[y] = x;
32     tr[x][d ^ 1] = y;
33     fa[x] = z;
34     if (z) tr[z][y == tr[z][1]] = x;

```

```

35     maintain(y);
36     maintain(x);
37 }
38 void splay(int x) {
39     for (int f = fa[x]; f = fa[x], f; rotate(x)) {
40         if (fa[f]) rotate(getdir(f) == getdir(x) ? f : x);
41     }
42     rt = x;
43 }
44 void insert(int v) {
45     if (!rt) {
46         rt = create(v);
47         return;
48     }
49     int u = rt, f = 0;
50     while (true) {
51         if (val[u] == v) {
52             cnt[u]++;
53             maintain(u);
54             maintain(f);
55             splay(u);
56             return;
57         }
58         f = u, u = tr[u][v > val[u]];
59         if (u == 0) {
60             int id;
61             fa[id = create(v)] = f;
62             tr[f][v > val[f]] = id;
63             maintain(f);
64             splay(id);
65             return;
66         }
67     }
68 }
69
70 int rank(int v) {
71     int rk = 0;
72     int u = rt;
73     while (u) {
74         if (val[u] == v) {
75             rk += sz[tr[u][0]];
76             splay(u);
77             return rk + 1;
78         }
79         if (v < val[u]) {
80             u = tr[u][0];
81         } else {
82             rk += sz[tr[u][0]] + cnt[u];
83             u = tr[u][1];
84         }
85     }
86     return -1;

```

```

87 }
88
89 int kth(int x) {
90     int u = rt;
91     while (u) {
92         if (sz[tr[u][0]] + cnt[u] >= x && sz[tr[u][0]] < x) return
val[u];
93         if (x <= sz[tr[u][0]]) {
94             u = tr[u][0];
95         } else {
96             x -= sz[tr[u][0]] + cnt[u];
97             u = tr[u][1];
98         }
99     }
100     return u ? val[u] : -1;
101 }
102 int pre() {
103     int u = tr[rt][0];
104     if (!u) return val[rt];
105     while (true) {
106         if (tr[u][1] == 0) return splay(u), val[u];
107         u = tr[u][1];
108     }
109     return 233;
110 }
111 int suf() {
112     int u = tr[rt][1];
113     if (!u) return val[rt];
114     while (true) {
115         if (tr[u][0] == 0) return splay(u), val[u];
116         u = tr[u][0];
117     }
118     return 233;
119 }
120 void del(int v) {
121     if (rank(v) == -1) return;
122     if (cnt[rt] > 1) {
123         cnt[rt]--;
124         return;
125     }
126     if (!tr[rt][1] && !tr[rt][0]) {
127         clear(rt), rt = 0;
128     } else if (!tr[rt][0]) {
129         int x = rt;
130         rt = tr[x][1];
131         fa[rt] = 0;
132         clear(x);
133     } else if (!tr[rt][1]) {
134         int x = rt;
135         rt = tr[x][0];
136         fa[rt] = 0;
137         clear(x);

```

```

138     } else {
139         int cur = rt, y = tr[cur][1];
140         pre();
141         tr[rt][1] = y;
142         fa[y] = rt;
143         clear(cur);
144         maintain(rt);
145     }
146 }
147
148 int main() {
149     int n, opt, x;
150
151     for (scanf("%d", &n); n; --n) {
152         scanf("%d%d", &opt, &x);
153
154         if (opt == 1)
155             insert(x);
156         else if (opt == 2)
157             del(x);
158         else if (opt == 3)
159             printf("%d\n", rank(x));
160         else if (opt == 4)
161             printf("%d\n", kth(x));
162         else if (opt == 5)
163             insert(x), printf("%d\n", pre()), del(x);
164         else
165             insert(x), printf("%d\n", suf()), del(x);
166     }
167
168     return 0;
169 }

```

5.4. 文艺平衡树

```

1  # include<iostream>
2  # include<cstdio>
3  # include<cstring>
4  # include<cstdlib>
5  using namespace std;
6  const int MAX=1e5+1;
7  int n,m,tot,rt;
8  struct Treap{
9      int pos[MAX],siz[MAX],w[MAX];
10     int son[MAX][2];
11     bool fl[MAX];
12     void pus(int x)
13     {
14         siz[x]=siz[son[x][0]]+siz[son[x][1]]+1;
15     }
16     int build(int x)

```

```

17     {
18         w[++tot]=x,siz[tot]=1,pos[tot]=rand();
19         return tot;
20     }
21     void down(int x)
22     {
23         swap(son[x][0],son[x][1]);
24         if(son[x][0]) fl[son[x][0]]^=1;
25         if(son[x][1]) fl[son[x][1]]^=1;
26         fl[x]=0;
27     }
28     int merge(int x,int y)
29     {
30         if(!x||!y) return x+y;
31         if(pos[x]<pos[y])
32         {
33             if(fl[x]) down(x);
34             son[x][1]=merge(son[x][1],y);
35             pus(x);
36             return x;
37         }
38         if(fl[y]) down(y);
39         son[y][0]=merge(x,son[y][0]);
40         pus(y);
41         return y;
42     }
43     void split(int i,int k,int &x,int &y)
44     {
45         if(!i)
46         {
47             x=y=0;
48             return;
49         }
50         if(fl[i]) down(i);
51         if(siz[son[i][0]]<k)
52             x=i,split(son[i][1],k-siz[son[i][0]]-1,son[i][1],y);
53         else
54             y=i,split(son[i][0],k,x,son[i][0]);
55         pus(i);
56     }
57     void coutt(int i)
58     {
59         if(!i) return;
60         if(fl[i]) down(i);
61         coutt(son[i][0]);
62         printf("%d ",w[i]);
63         coutt(son[i][1]);
64     }
65 }Tree;
66 int main()
67 {
68     scanf("%d%d",&n,&m);

```

```

69     for(int i=1;i<=n;i++)
70         rt=Tree.merge(rt,Tree.build(i));
71     for(int i=1;i<=m;i++)
72     {
73         int l,r,a,b,c;
74         scanf("%d%d",&l,&r);
75         Tree.split(rt,l-1,a,b);
76         Tree.split(b,r-l+1,b,c);
77         Tree.fl[b]^=1;
78         rt=Tree.merge(a,Tree.merge(b,c));
79     }
80     Tree.coutt(rt);
81     return 0;
82 }

```

6. 字符串

6.1. KMP

```

1  int n = strlen(s + 1);
2  for (int i = 2; i <= n; i++) {
3      int j = k[i - 1];
4      while (j != 0 && s[i] != s[j + 1]) j = k[j];
5      if (s[i] == s[j + 1]) k[i] = j + 1;
6      else k[i] = 0;
7  }

```

6.2. Z function

```

1  for (int i = 2, l = 0, r = 0; i <= n; i++) {
2      if (r >= i && r - i + 1 > z[i - l + 1]) {
3          z[i] = z[i - l + 1];
4      } else {
5          z[i] = max(0, r - i + 1);
6          while (z[i] < n - i + 1 && s[z[i] + 1] == s[i + z[i]]) ++z[i];
7      }
8      if (i + z[i] - 1 > r) l = i, r = i + z[i] - 1;
9  }

```

6.3. SA

```

1  int sa[N], ork[N], rk[N], cnt[N], id[N], h[N], M, n;
2  char s[N];
3  int mn[22][N];
4  int lcp(int a, int b) {
5      if (a == b) return n - a + 1;
6      if (rk[a] > rk[b]) swap(a, b);
7      int l = rk[a] + 1, r = rk[b];
8      int len = r - l + 1, k = __lg(len);

```

```

9     return min(mn[k][l], mn[k][r - (1 << k) + 1]);
10 }
11 void MAIN() {
12     scanf("%s", s + 1);
13     n = strlen(s + 1);
14     for (int i = 1; i <= n; i++) M = max(M, (int)s[i]);
15     for (int i = 1; i <= n; i++) if ((int)(s[i]) > M) M = (int)(s[i]);
16     for (int i = 1; i <= n; i++) cnt[rk[i] = s[i]]++;
17     for (int i = 0; i <= M; i++) cnt[i] += cnt[i - 1];
18     for (int i = n; i; i--) sa[cnt[rk[i]]--] = i;
19     for (int w = 1, p; w < n; w <= 1, M = p) {
20         p = 0;
21         for (int i = n; i > n - w; i--) id[++p] = i;
22         for (int i = 1; i <= n; i++) if (sa[i] > w) id[++p] = sa[i] - w;
23         for (int i = 0; i <= M; i++) cnt[i] = 0;
24         for (int i = 1; i <= n; i++) cnt[rk[i]]++;
25         for (int i = 1; i <= M; i++) cnt[i] += cnt[i - 1];
26         for (int i = n; i; i--) sa[cnt[rk[id[i]]]--] = id[i];
27         p = 0;
28         for (int i = 0; i <= n; i++) ork[i] = rk[i];
29         for (int i = 1; i <= n; i++) {
30             if (ork[sa[i]] == ork[sa[i - 1]] && ork[sa[i] + w] ==
ork[sa[i - 1] + w]) rk[sa[i]] = p;
31             else rk[sa[i]] = ++p;
32         }
33         if (p == n) break;
34     }
35     for (int i = 1, k = 0; i <= n; i++) {
36         if (rk[i] == 1) continue;
37         if (k) k--;
38         while (s[i + k] == s[sa[rk[i] - 1] + k]) k++;
39         h[rk[i]] = k;
40     }
41     for (int i = 1; i <= n; i++) mn[0][i] = h[i];
42     for (int j = 1; j < 22; j++) {
43         for (int i = 1; i <= n; i++) {
44             mn[j][i] = min(mn[j - 1][i], mn[j - 1][min(n, i + (1 << (j -
1))))]);
45         }
46     }
47 }

```

6.4. AC 自动机

```

1 int ch[N][26], tot, fail[N], e[N];
2 void insert(const char *s) {
3     int u = 0, n = strlen(s + 1);
4     for (int i = 1; i <= n; i++) {
5         if (!ch[u][s[i] - 'a']) ch[u][s[i] - 'a'] = ++tot;
6         u = ch[u][s[i] - 'a'];
7     }

```



```

8   e[u] += 1;
9 }
10 void build() {
11     queue<int> q;
12     for (int i = 0; i <= 25; i++) if (ch[0][i]) q.push(ch[0][i]);
13     while (!q.empty()) {
14         int now = q.front(); q.pop();
15         for (int i = 0; i < 26; i++) {
16             if (ch[now][i]) fail[ch[now][i]] = ch[fail[now]][i],
q.push(ch[now][i]);
17             else ch[now][i] = ch[fail[now]][i];
18         }
19     }
20 }
21 int query(const char *s) {
22     int u = 0, n = strlen(s + 1), res = 0;
23     for (int i = 1; i <= n; i++){
24         u = ch[u][s[i] - 'a'];
25         for (int j = u; j && e[j] != -1; j = fail[j]) {
26             res += e[j];
27             e[j] = -1;
28         }
29     }
30     return res;
31 }

```

6.5. Manacher

对于第 i 个字符为对称轴:

1. 如果回文串长为奇数, $\frac{d[2*i]}{2}$ 是半径加上自己的长度
2. 如果长为偶数, $\frac{d[2*i-1]}{2}$ 是半径的长度, 方向向右.

```

1 int n, d[N * 2];
2 char s[N];
3
4 for (int i = 1; i <= n; i++) t[i * 2] = s[i], t[i * 2 - 1] = '#';
5 t[n * 2 + 1] = '#';
6 m = n * 2 + 1;
7 for (int i = 1, l = 0, r = 0; i <= m; i++) {
8     int k = i <= r ? min(d[r - i + 1], r - i + 1) : 1;
9     while (i + k <= m && i - k >= 1 && t[i + k] == t[i - k]) k++;
10    d[i] = k--;
11    if (i + k > r) r = i + k, l = i - k;
12 }

```

7. 杂项

7.1. fastio

来自 oiwiki

```

1 // #define DEBUG 1 // 调试开关
2 struct IO {
3     #define MAXSIZE (1 << 20)
4     #define isdigit(x) (x >= '0' && x <= '9')
5     char buf[MAXSIZE], *p1, *p2;
6     char pbuf[MAXSIZE], *pp;
7     #if DEBUG
8     #else
9     IO() : p1(buf), p2(buf), pp(pbuf) {}
10
11     ~IO() { fwrite(pbuf, 1, pp - pbuf, stdout); }
12 #endif
13     char gc() {
14         #if DEBUG // 调试, 可显示字符
15             return getchar();
16         #endif
17         if (p1 == p2) p2 = (p1 = buf) + fread(buf, 1, MAXSIZE, stdin);
18         return p1 == p2 ? ' ' : *p1++;
19     }
20
21     bool blank(char ch) {
22         return ch == ' ' || ch == '\n' || ch == '\r' || ch == '\t';
23     }
24
25     template <class T>
26     void read(T &x) {
27         double tmp = 1;
28         bool sign = false;
29         x = 0;
30         char ch = gc();
31         for (; !isdigit(ch); ch = gc())
32             if (ch == '-') sign = 1;
33         for (; isdigit(ch); ch = gc()) x = x * 10 + (ch - '0');
34         if (ch == '.')
35             for (ch = gc(); isdigit(ch); ch = gc())
36                 tmp /= 10.0, x += tmp * (ch - '0');
37         if (sign) x = -x;
38     }
39
40     void read(char *s) {
41         char ch = gc();
42         for (; blank(ch); ch = gc());
43         for (; !blank(ch); ch = gc()) *s++ = ch;
44         *s = 0;
45     }
46
47     void read(char &c) { for (c = gc(); blank(c); c = gc()); }
48
49     void push(const char &c) {
50         #if DEBUG // 调试, 可显示字符
51             putchar(c);
52         #else

```

```

53     if (pp - pbuf == MAXSIZE) fwrite(pbuf, 1, MAXSIZE, stdout), pp =
        pbuf;
54     *pp++ = c;
55 #endif
56 }
57
58 template <class T>
59 void write(T x) {
60     if (x < 0) x = -x, push('-'); // 负数输出
61     static T sta[35];
62     T top = 0;
63     do {
64         sta[top++] = x % 10, x /= 10;
65     } while (x);
66     while (top) push(sta[--top] + '0');
67 }
68
69 template <class T>
70 void write(T x, char lastChar) {
71     write(x), push(lastChar);
72 }
73 } io;
74

```

7.2. 高精度

来自 oiwiki

```

1  constexpr int MAXN = 9999;
2  // MAXN 是一位中最大的数字
3  constexpr int MAXSIZE = 10024;
4  // MAXSIZE 是位数
5  constexpr int DLEN = 4;
6
7  // DLEN 记录压几位
8  struct Big {
9      int a[MAXSIZE], len;
10     bool flag; // 标记符号 '-'
11
12     Big() {
13         len = 1;
14         memset(a, 0, sizeof a);
15         flag = false;
16     }
17
18     Big(const int);
19     Big(const char*);
20     Big(const Big&);
21     Big& operator=(const Big&);
22     Big operator+(const Big&) const;
23     Big operator-(const Big&) const;

```

```

24  Big operator*(const Big&) const;
25  Big operator/(const int&) const;
26  // TODO: Big / Big;
27  Big operator^(const int&) const;
28  // TODO: Big ^ Big;
29
30  // TODO: Big 位运算;
31
32  int operator%(const int&) const;
33  // TODO: Big ^ Big;
34  bool operator<(const Big&) const;
35  bool operator<(const int& t) const;
36  void print() const;
37 };
38
39 Big::Big(const int b) {
40     int c, d = b;
41     len = 0;
42     // memset(a,0,sizeof a);
43     CLR(a);
44     while (d > MAXN) {
45         c = d - (d / (MAXN + 1) * (MAXN + 1));
46         d = d / (MAXN + 1);
47         a[len++] = c;
48     }
49     a[len++] = d;
50 }
51
52 Big::Big(const char* s) {
53     int t, k, index, l;
54     CLR(a);
55     l = strlen(s);
56     len = l / DLEN;
57     if (l % DLEN) ++len;
58     index = 0;
59     for (int i = l - 1; i >= 0; i -= DLEN) {
60         t = 0;
61         k = i - DLEN + 1;
62         if (k < 0) k = 0;
63         g(j, k, i) t = t * 10 + s[j] - '0';
64         a[index++] = t;
65     }
66 }
67
68 Big::Big(const Big& T) : len(T.len) {
69     CLR(a);
70     f(i, 0, len) a[i] = T.a[i];
71     // TODO:重载此处?
72 }
73
74 Big& Big::operator=(const Big& T) {
75     CLR(a);

```

```

76   len = T.len;
77   f(i, 0, len) a[i] = T.a[i];
78   return *this;
79 }
80
81 Big Big::operator+(const Big& T) const {
82   Big t(*this);
83   int big = len;
84   if (T.len > len) big = T.len;
85   f(i, 0, big) {
86     t.a[i] += T.a[i];
87     if (t.a[i] > MAXN) {
88       ++t.a[i + 1];
89       t.a[i] -= MAXN + 1;
90     }
91   }
92   if (t.a[big])
93     t.len = big + 1;
94   else
95     t.len = big;
96   return t;
97 }
98
99 Big Big::operator-(const Big& T) const {
100   int big;
101   bool ctf;
102   Big t1, t2;
103   if (*this < T) {
104     t1 = T;
105     t2 = *this;
106     ctf = true;
107   } else {
108     t1 = *this;
109     t2 = T;
110     ctf = false;
111   }
112   big = t1.len;
113   int j = 0;
114   f(i, 0, big) {
115     if (t1.a[i] < t2.a[i]) {
116       j = i + 1;
117       while (t1.a[j] == 0) ++j;
118       --t1.a[j--];
119       // WTF?
120       while (j > i) t1.a[j--] += MAXN;
121       t1.a[i] += MAXN + 1 - t2.a[i];
122     } else
123       t1.a[i] -= t2.a[i];
124   }
125   t1.len = big;
126   while (t1.len > 1 && t1.a[t1.len - 1] == 0) {
127     --t1.len;

```

```

128     --big;
129 }
130 if (ctf) t1.a[big - 1] = -t1.a[big - 1];
131 return t1;
132 }
133
134 Big Big::operator*(const Big& T) const {
135     Big res;
136     int up;
137     int te, tee;
138     f(i, 0, len) {
139         up = 0;
140         f(j, 0, T.len) {
141             te = a[i] * T.a[j] + res.a[i + j] + up;
142             if (te > MAXN) {
143                 tee = te - te / (MAXN + 1) * (MAXN + 1);
144                 up = te / (MAXN + 1);
145                 res.a[i + j] = tee;
146             } else {
147                 up = 0;
148                 res.a[i + j] = te;
149             }
150         }
151         if (up) res.a[i + T.len] = up;
152     }
153     res.len = len + T.len;
154     while (res.len > 1 && res.a[res.len - 1] == 0) --res.len;
155     return res;
156 }
157
158 Big Big::operator/(const int& b) const {
159     Big res;
160     int down = 0;
161     gd(i, len - 1, 0) {
162         res.a[i] = (a[i] + down * (MAXN + 1)) / b;
163         down = a[i] + down * (MAXN + 1) - res.a[i] * b;
164     }
165     res.len = len;
166     while (res.len > 1 && res.a[res.len - 1] == 0) --res.len;
167     return res;
168 }
169
170 int Big::operator%(const int& b) const {
171     int d = 0;
172     gd(i, len - 1, 0) d = (d * (MAXN + 1) % b + a[i]) % b;
173     return d;
174 }
175
176 Big Big::operator^(const int& n) const {
177     Big t(n), res(1);
178     int y = n;
179     while (y) {

```

```

180     if (y & 1) res = res * t;
181     t = t * t;
182     y >>= 1;
183 }
184 return res;
185 }
186
187 bool Big::operator<(const Big& T) const {
188     int ln;
189     if (len < T.len) return true;
190     if (len == T.len) {
191         ln = len - 1;
192         while (ln >= 0 && a[ln] == T.a[ln]) --ln;
193         if (ln >= 0 && a[ln] < T.a[ln]) return true;
194         return false;
195     }
196     return false;
197 }
198
199 bool Big::operator<(const int& t) const {
200     Big tee(t);
201     return *this < tee;
202 }
203
204 void Big::print() const {
205     printf("%d", a[len - 1]);
206     gd(i, len - 2, 0) { printf("%04d", a[i]); }
207 }
208
209 void print(const Big& s) {
210     int len = s.len;
211     printf("%d", s.a[len - 1]);
212     gd(i, len - 2, 0) { printf("%04d", s.a[i]); }
213 }

```

7.3. 手写 bitset

```

1 struct Bitset {
2     #define For(i,a,b) for(int i=a,i##end=b; i<=i##end; i++)
3     #define foR(i,a,b) for(int i=a,i##end=b; i>=i##end; i--)
4     using uint = unsigned int;
5     using ull = unsigned long long;
6     vector < ull > bit; int len;
7     Bitset(int x = n) {x = (x >> 6) + 1; bit.resize(x); len = x;}
8     void resize(int x) {bit.resize((x >> 6) + 1); len = (x >> 6) +
9 1;For(i, 0, len-1) bit[i] = 0;}
10    void set1(int x) {bit[x>>6] |= (1ull<<(x&63));}
11    void set0(int x) {bit[x>>6] &= ~(1ull<<(x&63));}
12    void flip(int x) {bit[x>>6] ^= (1ull<<(x&63));}
13    bool operator [] (int x) {return (bit[x>>6] >> (x&63)) & 1;}
14    bool any() {For(i, 0, len-1) if(bit[i]) return 1;return 0;}

```

```

14     Bitset operator ~ () const {Bitset res(len);For(i, 0, len-1)
    res.bit[i] = ~bit[i];return res;}
15     Bitset operator | (const Bitset &b) const {Bitset res(len); For(i,
    0, len-1) res.bit[i] = bit[i] | b.bit[i];return res;}
16     Bitset operator & (const Bitset &b) const {Bitset res(len); For(i,
    0, len-1) res.bit[i] = bit[i] & b.bit[i];return res;}
17     Bitset operator ^ (const Bitset &b) const {Bitset res(len); For(i,
    0, len-1) res.bit[i] = bit[i] ^ b.bit[i];return res;}
18     void operator &= (const Bitset &b) {For(i, 0, len-1) bit[i] &=
    b.bit[i];}
19     void operator |= (const Bitset &b) {For(i, 0, len-1) bit[i] |=
    b.bit[i];}
20     void operator ^= (const Bitset &b) {For(i, 0, len-1) bit[i] ^=
    b.bit[i];}
21     Bitset operator << (const int t) const {
22         Bitset res(len); int high = t >> 6, low = t & 63; ull lst = 0;
23         for(int i = 0; i + high < len; i++) {
24             res.bit[i + high] = (lst | (bit[i] << low));
25             if(low) lst = (bit[i] >> (64 - low));
26         }
27         return res;
28     }
29     Bitset operator >> (const int t) const {
30         Bitset res(len); int high = t >> 6, low = t & 63; ull lst = 0;
31         for(int i = len - 1; i >= high; i--) {
32             res.bit[i - high] = (lst | (bit[i] >> low));
33             if(low) lst = (bit[i] << (64 - low));
34         }
35         return res;
36     }
37     void operator <=< (const int t) {
38         int high = t >> 6, low = t & 63;
39         for(int i = len - high - 1; ~i; i--) {
40             bit[i + high] = (bit[i] << low);
41             if(low && i) bit[i + high] |= (bit[i - 1] >> (64 - low));
42         }
43         for(int i = 0; i < min(high, len - 1); i++) bit[i] = 0;
44     }
45     void operator >=> (const int t) {
46         int high = t >> 6, low = t & 63;
47         for(int i = high; i < len; i++) {
48             bit[i - high] = (bit[i] >> low);
49             if(low && i != len) bit[i - high] |= (bit[i + 1] << (64 -
    low));
50         }
51         for(int i = max(len - high, 0); i < len; i++) bit[i] = 0;
52     }
53     ull get(int x) {
54         int t = x >> 6, q = x & 63;
55         if (q == 63) return bit[t];
56         return bit[t] & ((1ull << (q + 1)) - 1);
57     }

```



```
58     ull get(int l, int r) {
59         int lt = (l >> 6), rt = (r >> 6);
60         if (lt == rt) {
61             if ((l & 63) == 0) return get(r);
62             return (get(r) - get(l - 1)) >> ((l & 63));
63         }
64         ull a = (l & 63) == 0 ? (bit[lt]) : ((bit[lt] - get(l - 1)) >>
        ((l & 63)));
65         return a + (get(r) << (64 - (l & 63)));
66     }
67 }
```

7.4. 对拍

```
1 #!/usr/bin/bash
2 g++ ./my.cpp -o my -std=c++17 -fsanitize=undefined
3 g++ ./std.cpp -o std -std=c++17 -fsanitize=undefined
4 g++ ./data.cpp -o data -std=c++17 -fsanitize=undefined
5 cnt=0;
6 while true; do
7     ./data > data.in
8     ./my < data.in > my.out
9     ./std < data.in > std.out
10    if diff my.out std.out; then
11        let cnt++;
12        echo "# $cnt AC";
13    else
14        echo "WA";
15        break;
16    fi
17 done
```