Team Notebook

NSU_NoAC

October 7, 2022

Contents

1 src **2**

1.1 -Starters- . . . 2
- 1.1.1 C++ Include GNU PBDS [NK] . . . 2
- 1.1.2 C++ Starter debug[MB] . . . 2
- 1.1.3 C++ Starter [MB] . . . 2
- 1.1.4 C++ Starter [NK] . . . 2
- 1.1.5 C++ Starter [SK] . . . 2
- 1.1.6 Unordered Map [MB] . . . 3

1.2 Algebra . . . 3
- 1.2.1 Combinatrics [MB] . . . 3
- 1.2.2 Extended GCD [NK] . . . 4
- 1.2.3 Fraction-Functions [SK] . . . 4
- 1.2.4 Fraction[MB] . . . 4
- 1.2.5 Miller-Rabin-for-prime-checking [SK] . . . 4
- 1.2.6 Modular Binary Exponentiation (Power) [NK] . . . 4
- 1.2.7 Modular Int [MB] . . . 5
- 1.2.8 Modular inverse [NK] . . . 5
- 1.2.9 nCrp-O(1) [SK] . . . 5
- 1.2.10 Prime Phi Sieve [MB] . . . 5
- 1.2.11 Prime Sieve [MB] . . . 6

1.3 Brute-force . . . 7
- 1.3.1 Power Set [NK] . . . 7

1.4 Data Structures . . . 7
- 1.4.1 BIT [MB] . . . 7
- 1.4.2 DSU [MB] . . . 7
- 1.4.3 DSU [NK] . . . 8
- 1.4.4 Lazy Segment Tree [MB] . . . 8
- 1.4.5 Lazy Segment Tree [SK] . . . 9
- 1.4.6 LCA [MB] . . . 10
- 1.4.7 Mos Algorithm [MB] . . . 10
- 1.4.8 Segment Tree [SK] . . . 11
- 1.4.9 Segment Tree[MB] . . . 12
- 1.4.10 SparseTable[MB] . . . 12
- 1.4.11 Treap[MB] . . . 13

1.5 Graph . . . 13
- 1.5.1 Edge Remove CC [MB] . . . 13
- 1.5.2 Kruskal's [NK] . . . 14
- 1.5.3 Tree Rooting [MB] . . . 14

1.6 String . . . 15
- 1.6.1 Hashing [MB] . . . 15
- 1.6.2 Hashing [NK] . . . 16
- 1.6.3 Hashing [SK] . . . 17
- 1.6.4 Z-Function [MB] . . . 18

1 src

1.1 -Starters-

1.1.1 C++ Include GNU PBDS [NK]

```
#include <ext/pb_ds/assoc_container.hpp>
#include <ext/pb_ds/tree_policy.hpp>
namespace pbds = __gnu_pbds;

template <class T>
using ordered_set = pbds::tree<T, pbds::null_type, std::less
    <T>,
                           pbds::rb_tree_tag,
                           pbds::
                                tree_order_statistics_node_update
                                >;
template <class K, class V>
using hash_map = pbds::gp_hash_table<K, V>;
```

1.1.2 C++ Starter debug[MB]

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

using namespace std;

template <typename T, typename C = typename T::value_type>
typename enable_if<!is_same<T, string>::value, ostream &>::
    type operator<<(ostream &out, const T &c)
{
 for (auto it = c.begin(); it != c.end(); it++)
  out << (it == c.begin() ? "{" : ",") << *it;
 return out << (c.empty() ? "{" : "") << "}";
}

template <typename T, typename S>
ostream &operator<<(ostream &out, const pair<T, S> &p)
{
 return out << "{" << p.first << ", " << p.second << "}";
}

#define dbg(...) _dbg_print(#__VA_ARGS__, __VA_ARGS__);

template <typename Arg1>
void _dbg_print(const char *name, Arg1 &&arg1)
{
 if (name[0] == ' ')
  name++;
 cout << "[" << name << ": " << arg1 << "]"
  << "\n";
}

template <typename Arg1, typename... Args>
void _dbg_print(const char *names, Arg1 &&arg1, Args &&...
    args)
{
 const char *comma = strchr(names + 1, ',');
 cout << "[";
 cout.write(names, comma - names) << ": " << arg1 << "] ";
 _dbg_print(comma + 1, args...);
}
```

1.1.3 C++ Starter [MB]

```
#if defined LOCAL && !defined ONLINE_JUDGE
#include "debug.cpp"
#else
#include <bits/stdc++.h>
using namespace std;
#define dbg(...) ;
#endif

typedef long long ll;
typedef pair<int, int> pii;
typedef pair<ll, ll> pll;

#define mem(x, n) memset(x, n, sizeof(x))
#define all(x) x.begin(), x.end()
#define sz(x) ((int)(x).size())
#define vec vector

inline bool read(auto &...a) { return (((cin >> a) ? true :
    false) && ...); }

inline void print(const auto &...a) { ((cout << a), ...); }
inline void println(const auto &...a) { print(a..., '\n'); }

void run_case([[maybe_unused]] const int &TC)
{

}

int main()
{
 ios_base::sync_with_stdio(false), cin.tie(0);

 int tt = 1;
 read(tt);

 for (int tc = 1; tc <= tt; tc++)
  run_case(tc);

 return 0;
}
```

1.1.4 C++ Starter [NK]

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

constexpr double eps = 1e-9;
constexpr int inf = 1 << 30;
constexpr int mod = 1e9 + 7;
constexpr int nmax = 1e6;

void runcase(int casen) {

    // cout << "Case " << casen << ": " << '\n';
}

int main() {
    ios_base::sync_with_stdio(false);
    cin.tie(nullptr);

    int ncases = 1;
    cin >> ncases; // Comment out for single-case tests
    for (int casen = 1; casen <= ncases; ++casen) {
        runcase(casen);
    }

    return 0;
}
```

1.1.5 C++ Starter [SK]

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

typedef long long ll;
typedef unsigned long long ull;
#define endl "\n"
#define pi 3.142
const double eps = 1e-10;
int dx[] = {1,0,-1,0};
int dy[] = {0,1,0,-1};
```

```
const ll M = (ll)(1e9) + 7;
const ll inf = (ll)1e17;
const int N = (ll)(1e6 + 10);


int main()
{

    cin.tie(0);
    cout.tie(0);
    ios_base::sync_with_stdio(false);

    //freopen("two.in", "r", stdin);
    //freopen("out.txt", "w", stdout);



}

/*

*/
```

1.1.6 Unordered Map [MB]

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

// For gp_hash_table
#include <ext/pb_ds/assoc_container.hpp>

using namespace __gnu_pbds;

using namespace std;

struct custom_hash
{
 static uint64_t splitmix64(uint64_t x)
 {
  // http://xorshift.di.unimi.it/splitmix64.c
  x += 0x9e3779b97f4a7c15;
  x = (x ^ (x >> 30)) * 0xbf58476d1ce4e5b9;
  x = (x ^ (x >> 27)) * 0x94d049bb133111eb;
  return x ^ (x >> 31);
 }

 size_t operator()(uint64_t x) const
 {
  static const uint64_t FIXED_RANDOM = chrono::steady_clock
      ::now().time_since_epoch().count();
  return splitmix64(x + FIXED_RANDOM);
 }
};

// Example Use
unordered_map<int, int, custom_hash> mp;

// Faster
gp_hash_table<int, int, custom_hash> mp;
```

1.2 Algebra

1.2.1 Combinatrics [MB]

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

using namespace std;

typedef long long ll;

struct Combinatrics
{
 vector<ll> fact, fact_inv, inv;
 ll mod, nl;

 Combinatrics() {}

 Combinatrics(ll n, ll _mod)
 {
  this->nl = n;
  this->mod = _mod;
  fact.resize(n + 1, 1), fact_inv.resize(n + 1, 1), inv.
      resize(n + 1, 1);
  init();
 }

 void init()
 {
  fact[0] = 1;

  for (int i = 1; i <= nl; i++)
  {
   fact[i] = (fact[i - 1] * i) % mod;
  }

  inv[0] = inv[1] = 1;
  for (int i = 2; i <= nl; i++)
   inv[i] = inv[mod % i] * (mod - mod / i) % mod;

 fact_inv[0] = fact_inv[1] = 1;

 for (int i = 2; i <= nl; i++)
  fact_inv[i] = (inv[i] * fact_inv[i - 1]) % mod;
}

ll ncr(ll n, ll r)
{
 if(n < r){
  return 0;
 }

 if (n > nl)
  return ncr(n, r, mod);
 return (((fact[n] * 1LL * fact_inv[r]) % mod) * 1LL *
      fact_inv[n - r]) % mod;
}

ll npr(ll n, ll r)
{
 if(n < r){
  return 0;
 }

 if (n > nl)
  return npr(n, r, mod);
 return (fact[n] * 1LL * fact_inv[n - r]) % mod;
}

ll big_mod(ll a, ll p, ll m = -1)
{
 m = (m == -1 ? mod : m);
 ll res = 1 % m, x = a % m;
 while (p > 0)
  res = ((p & 1) ? ((res * x) % m) : res), x = ((x * x) % m
       ), p >>= 1;
 return res;
}

ll mod_inv(ll a, ll p)
{
 return big_mod(a, p - 2, p);
}

ll ncr(ll n, ll r, ll p)
{
 if (n < r)
  return 0;
```

```
  if (r == 0)
   return 1;
  return (((fact[n] * mod_inv(fact[r], p)) % p) * mod_inv(
      fact[n - r], p)) % p;
 }

 ll npr(ll n, ll r, ll p)
 {
  if (n < r)
   return 0;
  if (r == 0)
   return 1;
  return (fact[n] * mod_inv(fact[n - r], p)) % p;
 }
};

const int N = 1e6, MOD = 998244353;

Combinatrics comb(N, MOD);
```

1.2.2 Extended GCD [NK]

```
template <class Z>
constexpr Z extended_gcd(Z a, Z b, Z& x_ref, Z& y_ref) {
    x_ref = 1, y_ref = 0;
    Z x1 = 0, y1 = 1, tmp = 0, q = 0;
    while (b > 0) {
        q = a / b;
        tmp = a, a = b, b = tmp - (q * b);
        tmp = x_ref, x_ref = x1, x1 = tmp - (q * x1);
        tmp = y_ref, y_ref = y1, y1 = tmp - (q * y1);
    }
    return a;
}
```

1.2.3 Fraction-Functions [SK]

```
pair<ll,ll> frac_add(pair<ll,ll> a,pair<ll,ll> b)
{
    ll g = a.second*b.second;
    pair<ll,ll> x;
    x.second = g;
    x.first = a.first * (b.second) + b.first * (a.second);
    ll y = __gcd(x.first,x.second);
    x.first/=y;
    x.second/=y;
    return x;
}
pair<ll,ll> frac_mult(pair<ll,ll> a,pair<ll,ll> b)
{

    pair<ll,ll> x;

    x.first = a.first * b.first;
    x.second = a.second * b.second;
    ll y = __gcd(x.first,x.second);
    x.first/=y;
    x.second/=y;
    return x;
}
```

1.2.4 Fraction[MB]

```
struct Fraction {
    int p, q;

    Fraction (int _p, int _q) : p(_p), q(_q) {
    }

    std::strong_ordering operator<=> (const Fraction &oth)
        const {
        return p * oth.q <=> q * oth.p;
    }
};
```

1.2.5 Miller-Rabin-for-prime-checking [SK]

```
typedef long long ll;

ll mulmod(ll a, ll b, ll c) {
  ll x = 0, y = a % c;
  while (b) {
    if (b & 1) x = (x + y) % c;
    y = (y << 1) % c;
    b >>= 1;
  }
  return x % c;
}

ll fastPow(ll x, ll n, ll MOD) {
  ll ret = 1;
  while (n) {
    if (n & 1) ret = mulmod(ret, x, MOD);
    x = mulmod(x, x, MOD);
    n >>= 1;
  }
  return ret;
}

bool isPrime(ll n) {
  ll d = n - 1;
  int s = 0;
  while (d % 2 == 0) {
    s++;
    d >>= 1;
  }

  // It's guranteed that these values will work for any
      number smaller than 3*10**18 (3 and 18 zeros)
  int a[9] = { 2, 3, 5, 7, 11, 13, 17, 19, 23 };
  for(int i = 0; i < 9; i++) {
    bool comp = fastPow(a[i], d, n) != 1;
    if(comp) for(int j = 0; j < s; j++) {
      ll fp = fastPow(a[i], (1LL << (ll)j)*d, n);
      if (fp == n - 1) {
        comp = false;
        break;
      }
    }
    if(comp) return false;
  }
  return true;
}
```

1.2.6 Modular Binary Exponentiation (Power) [NK]

```
template <class B, class E, class M>
constexpr B power(B base, E expo, M mod = 0) {
    assert(expo >= 0);
    if (mod == 1) return 0;
    if (base == 0 || base == 1) return base;
    B res = 1;
    if (!mod) {
        while (expo) {
            if (expo & 1) res *= base;
            base *= base;
            expo >>= 1;
        }
    } else {
        assert(mod > 0);
        base %= mod;
        if (base <= 1) return base;
        while (expo) {
```

```
            if (expo & 1) res = (res * base) % mod;
            base = (base * base) % mod;
            expo >>= 1;
        }
    }
    return res;
}
```

1.2.7 Modular Int [MB]

```
#include <bits/stdc++.h>
// Tested By Ac
// submission : https://atcoder.jp/contests/abc238/
    submissions/29247261
// problem : https://atcoder.jp/contests/abc238/tasks/
    abc238_c

template <const int MOD>
struct ModInt
{
 int val;
 ModInt() { val = 0; }
 ModInt(long long v) { v += (v < 0 ? MOD : 0), val = (int)(v
      % MOD); }
 ModInt &operator+=(const ModInt &rhs)
 {
  val += rhs.val, val -= (val >= MOD ? MOD : 0);
  return *this;
 }
 ModInt &operator-=(const ModInt &rhs)
 {
  val -= rhs.val, val += (val < 0 ? MOD : 0);
  return *this;
 }
 ModInt &operator*=(const ModInt &rhs)
 {
  val = (int)((val * 1ULL * rhs.val) % MOD);
  return *this;
 }
 ModInt pow(long long n) const
 {
  ModInt x = *this, r = 1;
  while (n)
   r = ((n & 1) ? r * x : r), x = (x * x), n >>= 1;
  return r;
 }
 ModInt inv() const { return this->pow(MOD - 2); }
 ModInt &operator/=(const ModInt &rhs) { return *this = *
     this * rhs.inv(); }
 friend ModInt operator+(const ModInt &lhs, const ModInt &
     rhs) { return ModInt(lhs) += rhs; }
 friend ModInt operator-(const ModInt &lhs, const ModInt &
     rhs) { return ModInt(lhs) -= rhs; }
 friend ModInt operator*(const ModInt &lhs, const ModInt &
     rhs) { return ModInt(lhs) *= rhs; }
 friend ModInt operator/(const ModInt &lhs, const ModInt &
     rhs) { return ModInt(lhs) /= rhs; }
 friend bool operator==(const ModInt &lhs, const ModInt &rhs
     ) { return lhs.val == rhs.val; }
 friend bool operator!=(const ModInt &lhs, const ModInt &rhs
     ) { return lhs.val != rhs.val; }
 friend std::ostream &operator<<(std::ostream &out, const
     ModInt &m) { return out << m.val; }
 friend std::istream &operator>>(std::istream &in, ModInt &m
     ) { return in >> m.val; }
 operator int() const { return val; }
};

const int MOD = 1e9 + 7;
using mint = ModInt<MOD>;
```

1.2.8 Modular inverse [NK]

```
template <class Z>
constexpr Z inverse(Z num, Z mod) {
    assert(mod > 1);
    if (!(0 <= num && num < mod)) {
        num %= mod;
        if (num < 0) num += mod;
    }
    Z res = 1, tmp = 0;
    assert(extended_gcd(num, mod, res, tmp) == 1);
    if (res < 0) res += mod;
    return res;
}
```

1.2.9 nCrp-O(1) [SK]

```
// array to store inverse of 1 to N
ll factorialNumInverse[N + 1];

// array to precompute inverse of 1! to N!
ll naturalNumInverse[N + 1];

// array to store factorial of first N numbers
ll fact[N + 1];

// Function to precompute inverse of numbers
void InverseofNumber(ll p)
{
    naturalNumInverse[0] = naturalNumInverse[1] = 1;
    for (int i = 2; i <= N; i++)
        naturalNumInverse[i] = naturalNumInverse[p % i] * (p
            - p / i) % p;
}
// Function to precompute inverse of factorials
void InverseofFactorial(ll p)
{
    factorialNumInverse[0] = factorialNumInverse[1] = 1;

    // precompute inverse of natural numbers
    for (int i = 2; i <= N; i++)
        factorialNumInverse[i] = (naturalNumInverse[i] *
            factorialNumInverse[i - 1]) % p;
}

// Function to calculate factorial of 1 to N
void factorial(ll p)
{
    fact[0] = 1;

    // precompute factorials
    for (int i = 1; i <= N; i++) {
        fact[i] = (fact[i - 1] * i) % p;
    }
}

// Function to return nCr % p in O(1) time
ll Binomial(ll N, ll R, ll p)
{
    // n C r = n!*inverse(r!)*inverse((n-r)!)
    ll ans = ((fact[N] * factorialNumInverse[R])
              % p * factorialNumInverse[N - R])
             % p;
    return ans;
}
```

1.2.10 Prime Phi Sieve [MB]

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

using namespace std;

typedef long long ll;
typedef pair<int, int> pii;
typedef pair<ll, ll> pll;
```

```
struct PrimePhiSieve
{
private:
 ll n;
 vector<ll> primes, phi;
 vector<bool> is_prime;

public:
 PrimePhiSieve() {}

 PrimePhiSieve(ll n)
 {
  this->n = n, is_prime.resize(n + 5, true), phi.resize(n +
      5, 1);
  phi_sieve();
 }
 void phi_sieve()
 {
  is_prime[0] = is_prime[1] = false;

  for (ll i = 1; i <= n; i++)
   phi[i] = i;

  for (ll i = 1; i <= n; i++)
   if (is_prime[i])
   {
    primes.push_back(i);
    phi[i] *= (i - 1), phi[i] /= i;

    for (ll j = i + i; j <= n; j += i)
     is_prime[j] = false, phi[j] /= i, phi[j] *= (i - 1);
   }
 }

 ll get_divisors_count(int number, int divisor)
 {
  return phi[number / divisor];
 }

 vector<pll> factorize(ll num)
 {
  vector<pll> a;
  for (int i = 0; i < (int)primes.size() && primes[i] * 1LL
       * primes[i] <= num; i++)
   if (num % primes[i] == 0)
   {
    int cnt = 0;
    while (num % primes[i] == 0)
     cnt++, num /= primes[i];
    a.push_back({primes[i], cnt});
   }

  if (num != 1)
   a.push_back({num, 1});
  return a;
 }

 ll get_phi(int n)
 {
  return phi[n];
 }
 // (n/p) * (p-1) => n- (n/p);
 void segmented_phi_sieve(ll l, ll r)
 {
  vector<ll> current_phi(r - l + 1);
  vector<ll> left_over_prime(r - l + 1);

  for (ll i = l; i <= r; i++)
   current_phi[i - l] = i, left_over_prime[i - l] = i;

  for (ll p : primes)
  {
   ll to = ((l + p - 1) / p) * p;

   if (to == p)
    to += p;

   for (ll i = to; i <= r; i += p)
   {
    while (left_over_prime[i - l] % p == 0)
     left_over_prime[i - l] /= p;
    current_phi[i - l] -= current_phi[i - l] / p;
   }
  }

  for (ll i = l; i <= r; i++)
  {
   if (left_over_prime[i - l] > 1)
    current_phi[i - l] -= current_phi[i - l] /
         left_over_prime[i - l];
   cout << current_phi[i - l] << endl;
  }
 }

 ll phi_sqrt(ll n)
 {
  ll res = n;

  for (ll i = 1; i * i <= n; i++)
  {
   if (n % i == 0)
   {
    res /= i;
    res *= (i - 1);

    while (n % i == 0)
     n /= i;
   }
  }

  if (n > 1)
   res /= n, res *= (n - 1);
  return res;
 }
};
```

1.2.11 Prime Sieve [MB]

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

using namespace std;

typedef long long ll;
typedef pair<int, int> pii;
typedef pair<ll, ll> pll;

struct PrimeSieve
{
public:
 vector<int> primes;
 vector<bool> isprime;
 int n;

 PrimeSieve() {}

 PrimeSieve(int _n)
 {
  this->n = _n, isprime.resize(_n + 5, true), primes.clear()
       ;
  sieve();
 }

 void sieve()
 {
  isprime[0] = isprime[1] = false;

  primes.push_back(2);
  for (int i = 4; i <= n; i += 2)
```

```
  isprime[i] = false;

 for (int i = 3; 1LL * i * i <= n; i += 2)
  if (isprime[i])
   for (int j = i * i; j <= n; j += 2 * i)
    isprime[j] = false;

 for (int i = 3; i <= n; i += 2)
  if (isprime[i])
   primes.push_back(i);
}

vector<pll> factorize(ll num)
{
 vector<pll> a;
 for (int i = 0; i < (int)primes.size() && primes[i] * 1LL
      * primes[i] <= num; i++)
  if (num % primes[i] == 0)
  {
   int cnt = 0;
   while (num % primes[i] == 0)
    cnt++, num /= primes[i];
   a.push_back({primes[i], cnt});
  }

 if (num != 1)
  a.push_back({num, 1});
 return a;
}

vector<ll> segemented_sieve(ll l, ll r)
{
 vector<ll> seg_primes;
 vector<bool> current_primes(r - l + 1, true);
 for (ll p : primes)
 {
  ll to = (l / p) * p;
  if (to < l)
   to += p;
  if (to == p)
   to += p;
  for (ll i = to; i <= r; i += p)
  {
   current_primes[i - l] = false;
  }
 }

 for (ll i = l; i <= r; i++)
 {
  if (i < 2)
   continue;
  if (current_primes[i - l])
  {

   seg_primes.push_back(i);
  }
 }
 return seg_primes;
}
};
```

1.3 Brute-force

1.3.1 Power Set [NK]

```
template <class T>
vector<vector<T>> power_set(const vector<T>& vec) {
    vector<vector<T>> res;
    list<T> buf;
    function<void(int)> recurse = [&](int i) -> void {
        if (i == vec.size()) {
            res.emplace_back(buf.begin(), buf.end());
            return;
        }
        recurse(i + 1);
        buf.push_back(vec[i]), recurse(i + 1), buf.pop_back()
            ;
    };
    recurse(0);
    return res;
}
```

1.4 Data Structures

1.4.1 BIT [MB]

```
struct BIT
{
private:
 std::vector<long long> mArray;

public:
 BIT(int sz) // Max size of the array
 {
  mArray.resize(sz + 1, 0);
 }

 void build(const std::vector<long long> &list)
 {
  for (int i = 1; i <= list.size(); i++)
  {
   mArray[i] = list[i];
  }

  for (int ind = 1; ind <= mArray.size(); ind++)
  {
   int ind2 = ind + (ind & -ind);
   if (ind2 <= mArray.size())
   {
    mArray[ind2] += mArray[ind];
   }
  }
 }

 long long prefix_query(int ind)
 {
  int res = 0;
  for (; ind > 0; ind -= (ind & -ind))
  {
   res += mArray[ind];
  }
  return res;
 }

 long long range_query(int from, int to)
 {
  return prefix_query(to) - prefix_query(from - 1);
 }

 void add(int ind, long long add)
 {
  for (; ind < mArray.size(); ind += (ind & -ind))
  {
   mArray[ind] += add;
  }
 }
};
```

1.4.2 DSU [MB]

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

// 0 based
class DSU
{
 std::vector<int> p, csz;
```

```
public:
 DSU() {}
 // Max size
 DSU(int dsz)
 {
  //Default empty
  p.resize(dsz + 5, 0), csz.resize(dsz + 5, 0);

  init(dsz);
 }

 void init(int n)
 {
  // n = size
  for (int i = 0; i <= n; i++)
  {
   p[i] = i, csz[i] = 1;
  }
 }

 //Return parent Recursively
 int get(int x)
 {
  if (p[x] != x)
   p[x] = get(p[x]);

  return p[x];
 }

 // Return Size
 int get_comp_size(int component) { return csz[get(component
     )]; }
 // Return if Union created Succesffully or false if they
     are already in Union
 bool merge(int x, int y)
 {
  x = get(x), y = get(y);
  if (x == y)
   return false;

  if (csz[x] > csz[y])
   std::swap(x, y);

  p[x] = y;
  csz[y] += csz[x];

  return true;
 }
};
```

1.4.3 DSU [NK]

```
struct DSU {
    int n_nodes = 0;
    int n_components = 0;
    vector<int> component_size;
    vector<int> component_root;

    DSU(int n_nodes, bool make_all_nodes = false)
        : n_nodes(n_nodes),
          component_root(n_nodes, -1),
          component_size(n_nodes, 0) {
        if (make_all_nodes) {
            for (int i = 0; i < n_nodes; ++i) {
                make_node(i);
            }
        }
    }

    void make_node(int v) {
        if (component_root[v] == -1) {
            component_root[v] = v;
            component_size[v] = 1;
            ++n_components;
        }
    }

    int root(int v) {
        auto res = v;
        while (component_root[res] != res) {
            res = component_root[res];
        }
        while (v != res) {
            auto u = component_root[v];
            component_root[v] = res;
            v = u;
        }
        return res;
    }

    int connect(int u, int v) {
        u = root(u), v = root(v);
        if (u == v) return u;
        if (component_size[u] < component_size[v]) {
            swap(u, v);
        }
        component_root[v] = u;
        component_size[u] += component_size[v];
        --n_components;
    }
};
```

1.4.4 Lazy Segment Tree [MB]

```
template <typename T, typename F, T(*op)(T, T), F(*
    lazy_to_lazy)(F, F), T(*lazy_to_seg)(T, F, int, int)>
struct LazySegTree
{
private:
 std::vector<T> segt;
 std::vector<F> lazy;
 int n;
 T neutral;
 F lazyE;
 int left(int si) { return si * 2; }
 int right(int si) { return si * 2 + 1; }
 int midpoint(int ss, int se) { return (ss + (se - ss) / 2);
     }
 T query(int ss, int se, int si, int qs, int qe)
 {
  // **** //
  if (lazy[si] != lazyE)
  {
   F curr = lazy[si];
   lazy[si] = lazyE;
   segt[si] = lazy_to_seg(segt[si], curr, ss, se);
   if (ss != se)
   {
    lazy[left(si)] = lazy_to_lazy(lazy[left(si)], curr);
    lazy[right(si)] = lazy_to_lazy(lazy[right(si)], curr);
   }
  }
  if (se < qs || qe < ss)
   return neutral;
  if (qs <= ss && qe >= se)
   return segt[si];
  int mid = midpoint(ss, se);
  return op(query(ss, mid, left(si), qs, qe), query(mid + 1,
      se, right(si), qs, qe));
 }

 void update(int ss, int se, int si, int qs, int qe, F val)
 {
  // **** //
  if (lazy[si] != lazyE)
  {
   F curr = lazy[si];
   lazy[si] = lazyE;
   segt[si] = lazy_to_seg(segt[si], curr, ss, se);
```

```
  if (ss != se)
  {
   lazy[left(si)] = lazy_to_lazy(lazy[left(si)], curr);
   lazy[right(si)] = lazy_to_lazy(lazy[right(si)], curr);
  }
 }
 if (se < qs || qe < ss)
  return;
 if (qs <= ss && qe >= se)
 {
  // **** //
  segt[si] = lazy_to_seg(segt[si], val, ss, se);

  if (ss != se)
  {
   lazy[left(si)] = lazy_to_lazy(lazy[left(si)], val);
   lazy[right(si)] = lazy_to_lazy(lazy[right(si)], val);
  }
  return;
 }

 int mid = midpoint(ss, se);

 update(mid + 1, se, si * 2 + 1, qs, qe, val);
 update(ss, mid, left(si), qs, qe, val);

 segt[si] = op(segt[left(si)], segt[right(si)]);
}
void build(const std::vector<T> &a, int si, int ss, int se)
{
 if (ss == se)
 {
  segt[si] = a[ss];
  return;
 }
 int mid = midpoint(ss, se);
 build(a, left(si), ss, mid);
 build(a, right(si), mid + 1, se);
 segt[si] = op(segt[left(si)], segt[right(si)]);
}
public:
 LazySegTree() : n(0) {}
 LazySegTree(int sz, T ini, T _neutral, F _lazyE)
 {
  this->n = sz + 1;
  this->neutral = _neutral;
  this->lazyE = _lazyE;
  segt.resize(n * 4 + 5, ini);
  lazy.resize(n * 4 + 5, _lazyE);
 }
 LazySegTree(const std::vector<T> &arr, T ini, T _neutral, F
       _lazyE) : LazySegTree((int)arr.size(), ini, _neutral,
      _lazyE)
 {
  init(arr);
 }
 void init(const std::vector<T> &arr) { this->n = (int)arr.
      size(); build(arr, 1, 0, n - 1); }
 T get(int qs, int qe) { return query(0, n - 1, 1, qs, qe);
      }
 void set(int from, int to, F val) { update(0, n - 1, 1,
      from, to, val); }
};

int op(int a, int b)
{
 return a + b;
}

int lazy_to_seg(int seg, int lazy_v, int l, int r)
{
 return seg + (lazy_v * (r - l + 1));
}

int lazy_to_lazy(int curr_lazy, int input_lazy)
{
 return curr_lazy + input_lazy;
}
```

1.4.5 Lazy Segment Tree [SK]

```
ll v[4*N];
ll add[4*N];
int arr[N];

void push(int cur)
{
    add[cur*2] += add[cur];
    add[cur*2 + 1] += add[cur];
    add[cur] = 0;
}

/*
void build(int cur,int l,int r)
{
    if(l==r)
    {
        v[cur] = arr[l];
        return;
    }

    int mid = l + (r-l)/2;

    build(cur*2,l,mid);
    build(cur*2 + 1,mid+1,r);

    v[cur]= v[cur*2] + v[cur*2 + 1];

    return;
}
*/

ll query(int cur,int l,int r,int x,int y)
{

    if(x>r || y<l)
    {
        return 0;
    }

    if(l==r)
    {
        return v[cur] + add[cur];
    }

    if(l==x && r==y)
    {
        return v[cur] + add[cur]*(r-l+1);
    }

    int mid = l + (r-l)/2;

    v[cur] += add[cur]*(r-l+1);
    push(cur);

    ll left = query(cur*2,l,mid,x,min(mid,y));
    ll right = query(cur*2 + 1,mid+1,r,max(mid+1,x),y);

    ll res = 0;

    res = left + right ;


    return res;
}


void update(int cur,int l,int r,int s,int e,int val)
{
```

```
    if(l==s && r==e)
    {
        add[cur] += val;
        return;
    }

    if(s>r || e<l)
    {
        return;
    }

    int mid = l + (r-l)/2;

    push(cur);

    update(cur*2,l,mid,s,min(e,mid),val);
    update(cur*2 + 1,mid+1,r,max(s,mid+1),e,val);

    v[cur] = (v[cur*2] + add[cur*2]*(mid-l+1)) + (v[cur*2 +
         1] + add[cur*2 + 1]*(r-mid));

    return;
}
```

1.4.6 LCA [MB]

```
struct LCA
{
private:
 int n, lg;
 std::vector<int> depth;
 std::vector<std::vector<int>> up;
 std::vector<std::vector<int>> g;

public:
 LCA() : n(0), lg(0) {}

 LCA(int _n)
 {
  this->n = _n;
  lg = (int)log2(n) + 2;
  depth.resize(n + 5, 0);
  up.resize(n + 5, std::vector<int>(lg, 0));
  g.resize(n + 1);
 }

 LCA(std::vector<std::vector<int>> &graph) : LCA((int)graph.
     size())
 {
  for (int i = 0; i < (int)graph.size(); i++)
   g[i] = graph[i];

  dfs(1, 0);
 }

 void dfs(int curr, int p)
 {
  up[curr][0] = p;
  for (int next : g[curr])
  {
   if (next == p)
    continue;
   depth[next] = depth[curr] + 1;
   up[next][0] = curr;
   for (int j = 1; j < lg; j++)
    up[next][j] = up[up[next][j - 1]][j - 1];
   dfs(next, curr);
  }
 }

 void clear_v(int a)
 {
  g[a].clear();
 }

 void clear(int n_ = -1)
 {
  if (n_ == -1)
   n_ = ((int)(g.size())) - 1;

  for (int i = 0; i <= n_; i++)
  {
   g[i].clear();
  }
 }

 void add(int a, int b)
 {
  g[a].push_back(b);
 }

 int par(int a)
 {
  return up[a][0];
 }

 int get_lca(int a, int b)
 {
  if (depth[a] < depth[b])
   std::swap(a, b);

  int k = depth[a] - depth[b];
  for (int j = lg - 1; j >= 0; j--)
  {
   if (k & (1 << j))
    a = up[a][j];
  }

  if (a == b)
   return a;

  for (int j = lg - 1; j >= 0; j--)
   if (up[a][j] != up[b][j])
   {
    a = up[a][j];
    b = up[b][j];
   }

  return up[a][0];
 }

 int get_dist(int a, int b)
 {
  return depth[a] + depth[b] - 2 * depth[get_lca(a, b)];
 }
};
```

1.4.7 Mos Algorithm [MB]

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

using namespace std;

const int N = 3e4 + 5;
const int blck = sqrt(N) + 1;

struct Query
{
 int l, r, i;
 bool operator<(const Query q) const
 {
  if (this->l / blck == q.l / blck)
   return this->r < q.r;
  return this->l / blck < q.l / blck;
 }
};
```

```
vector<int> mos_alogorithm(vector<Query> &queries, vector<
    int> &a)
{
 vector<int> answers(queries.size());
 sort(queries.begin(), queries.end());

 int sza = 1e6 + 5;
 vector<int> freq(sza);

 int cnt = 0;

 auto add = [&](int x) -> void
 {
  freq[x]++;
  if (freq[x] == 1)
   cnt++;
 };

 auto remove = [&](int x) -> void
 {
  freq[x]--;
  if (freq[x] == 0)
   cnt--;
 };

 int l = 0;
 int r = -1;
 for (Query q : queries)
 {
  while (l > q.l)
  {
   l--;
   add(a[l]);
  }
  while (r < q.r)
  {
   r++;
   add(a[r]);
  }
  while (l < q.l)
  {
   remove(a[l]);
   l++;
  }
  while (r > q.r)
  {
   remove(a[r]);
   r--;
  }
  answers[q.i] = cnt;
 }
 return answers;
}

int main()
{
 int n;
 cin >> n;

 vector<int> a(n);
 for (int i = 0; i < n; i++)
  cin >> a[i];

 int q;
 cin >> q;

 vector<Query> qr(q);

 for (int i = 0; i < q; i++)
 {
  int l, r;
  cin >> l >> r;

  l--, r--;
  qr[i].l = l, qr[i].r = r, qr[i].i = i;
 }

 vector<int> res = mos_alogorithm(qr, a);

 for (int i = 0; i < q; i++)
  cout << res[i] << endl;

 return 0;
}
```

1.4.8 Segment Tree [SK]

```
pair<int,int>v[4*N];
int arr[N];

void build(int cur,int l,int r)
{
    if(l==r)
    {
        pair<int,int> tmp = {0,0};
        if(arr[l]==0)
        {
            tmp.second++;
        }
        else if(arr[l]<0)
        {
            tmp.first++;
        }
        v[cur] = tmp;
        return;
    }

    int mid = l + (r-l)/2;

    build(cur*2,l,mid);
    build(cur*2 + 1,mid+1,r);

    v[cur].first = v[cur*2].first + v[cur*2 + 1].first;
    v[cur].second = v[cur*2].second + v[cur*2 + 1].second;
    return;
}

pair<int,int>query(int cur,int l,int r,int x,int y)
{
    if(l==x && r==y)
    {
        return v[cur];
    }

    if(x>r || y<l)
    {
        return {-1,-1};
    }
    int mid = l + (r-l)/2;
    pair<int,int> left = query(cur*2,l,mid,x,min(mid,y));
    pair<int,int> right = query(cur*2 + 1,mid+1,r,max(mid+1,x
        ),y);

    pair<int,int> res = {0,0};
    res.first = ((left.first!=-1)?left.first:0) + ((right.
        first!=-1)?right.first:0);
    res.second = ((left.second!=-1)?left.second:0) + ((right.
        second!=-1)?right.second:0);

    return res;
}


void update(int cur,int l,int r,int pos,int val)
{
    if(l==r)
    {
        arr[l] = val;
        pair<int,int> tmp = {0,0};
```

```
        if(arr[l]==0)
        {
            tmp.second++;
        }
        else if(arr[l]<0)
        {
            tmp.first++;
        }
        v[cur] = tmp;
        return;
    }

    int mid = l + (r-l)/2;

    if(pos<=mid)
    {
        update(cur*2,l,mid,pos,val);
    }
    else
    {
        update(cur*2 + 1,mid+1,r,pos,val);
    }


    v[cur].first = v[cur*2].first + v[cur*2 + 1].first;
    v[cur].second = v[cur*2].second + v[cur*2 + 1].second;
    return;
}
```

1.4.9 Segment Tree[MB]

```
template <typename T, T(*op)(T, T)>
struct SegTree
{
private:
 std::vector<T> segt;
 int n;
 T e;
 int left(int si) { return si * 2; }
 int right(int si) { return si * 2 + 1; }
 int midpoint(int ss, int se) { return (ss + (se - ss) / 2);
      }
 T query(int ss, int se, int qs, int qe, int si)
 {
  if (se < qs || qe < ss)
   return e;
  if (qs <= ss && qe >= se)
   return segt[si];
  int mid = midpoint(ss, se);
  return op(query(ss, mid, qs, qe, left(si)), query(mid + 1,
       se, qs, qe, right(si)));
 }
 void update(int ss, int se, int key, int si, T val)
 {
  if (ss == se)
  {
   segt[si] = val;
   return;
  }
  int mid = midpoint(ss, se);
  if (key > mid)
   update(mid + 1, se, key, right(si), val);
  else
   update(ss, mid, key, left(si), val);
  segt[si] = op(segt[left(si)], segt[right(si)]);
 }
 void build(const std::vector<T> &a, int si, int ss, int se)
 {
  if (ss == se)
  {
   segt[si] = a[ss];
   return;
  }
  int mid = midpoint(ss, se);
  build(a, left(si), ss, mid);
  build(a, right(si), mid + 1, se);
  segt[si] = op(segt[left(si)], segt[right(si)]);
 }
public:
 SegTree() : n(0) {}
 SegTree(int sz, T _e)
 {
  this->e = _e;
  this->n = sz;
  segt.resize(n * 4 + 5, _e);
 }
 SegTree(const std::vector<T> &arr, T _e) : SegTree((int)arr
      .size(), _e) { init(arr); }
 void init(const std::vector<T> &arr) { this->n = (int)(arr.
      size());build(arr, 1, 0, n - 1); }
 T get(int qs, int qe) { return query(0, n - 1, qs, qe, 1);
      }
 void set(int key, T val) { update(0, n - 1, key, 1, val); }
};

int op(int a, int b)
{
 return min(a, b);
}
```

1.4.10 SparseTable[MB]

```
template <typename T, T (*op)(T, T)>
struct SparseTable
{
private:
 std::vector<std::vector<T>> st;
 int n, lg;
 std::vector<int> logs;
 T e;

public:
 SparseTable() : n(0) {}

 SparseTable(int _n)
 {
  this->n = _n;
  int bit = 0;
  while ((1 << bit) <= n)
   bit++;
  this->lg = bit;

  st.resize(n, std::vector<T>(lg));
  logs.resize(n + 1, 0);
  logs[1] = 0;
  for (int i = 2; i <= n; i++)
  {
   logs[i] = logs[i / 2] + 1;
  }
 }

 SparseTable(const std::vector<T> &a) : SparseTable((int)a.
      size())
 {
  init(a);
 }

 void init(const std::vector<T> &a)
 {
  this->n = (int)a.size();

  for (int i = 0; i < n; i++)
  {
   st[i][0] = a[i];
  }

  for (int j = 1; j <= lg; j++)
  {
   for (int i = 0; i + (1 << j) <= n; i++)
   {
```

```
    st[i][j] = op(st[i][j - 1], st[std::min(i + (1 << (j - 1)
        ), n - 1)][j - 1]);
   }
  }
 }

 T get(int l, int r)
 {
  int j = logs[r - l + 1];
  return op(st[l][j], st[r - (1 << j) + 1][j]);
 }
};

int min(int a, int b)
{
 return std::min(a, b);
}
```

1.4.11 Treap[MB]

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

#define mem(x, n) memset(x, n, sizeof(x))
#define all(x) x.begin(), x.end()
#define endl "\n"

#include <ext/pb_ds/assoc_container.hpp> // Common file

// using namespace __gnu_pbds;

// https://codeforces.com/blog/entry/11080
//cout<<*X.find_by_order(4)<<endl; // 16
// cout<<(end(X)==X.find_by_order(6))<<endl; // true
// cout<<X.order_of_key(-5)<<endl; // 0
template <typename T, typename order = std::less<T>>
using ordered_set = __gnu_pbds::tree<T, __gnu_pbds::
    null_type, order, __gnu_pbds::rb_tree_tag, __gnu_pbds::
    tree_order_statistics_node_update>;

int main()
{
 ordered_set<int> X;

 std::cout << *X.find_by_order(4) << endl;          // 16
 std::cout << (std::end(X) == X.find_by_order(6)) << endl;
     // true
 std::cout << X.order_of_key(-5) << endl;          // 0

 return 0;
}
```

1.5 Graph

1.5.1 Edge Remove CC [MB]

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

using namespace std;

typedef long long ll;

#define var(...) " [" << #__VA_ARGS__ ": " << (__VA_ARGS__)
    << "] "
#define mem(x, n) memset(x, n, sizeof(x))
#define all(x) x.begin(), x.end()
#define sz(x) ((int)x.size())
#define vec vector
#define endl "\n"

class DSU
{
 std::vector<int> p, csz;

public:
 DSU() {}

 DSU(int dsz) // Max size
 {
  //Default empty
  p.resize(dsz + 5, 0), csz.resize(dsz + 5, 0);

  init(dsz);
 }

 void init(int n)
 {
  // n = size
  for (int i = 0; i <= n; i++)
  {
   p[i] = i, csz[i] = 1;
  }
 }

 //Return parent Recursively
 int get(int x)
 {
  if (p[x] != x)
   p[x] = get(p[x]);
  return p[x];
 }

 // Return Size
 int getSize(int x) { return csz[get(x)]; }
 // Return if Union created Succesffully or false if they
     are already in Union
 bool merge(int x, int y)
 {
  x = get(x), y = get(y);
  if (x == y)
   return false;

  if (csz[x] > csz[y])
   std::swap(x, y);

  p[x] = y;
  csz[y] += csz[x];

  return true;
 }
};

void runCase([[maybe_unused]] const int &TC)
{
 int n, m;
 cin >> n >> m;

 auto g = vec(n + 1, set<int>());

 auto dsu = DSU(n + 1);

 for (int i = 0; i < m; i++)
 {
  int u, v;
  cin >> u >> v;

  g[u].insert(v);
  g[v].insert(u);
 }

 set<int> elligible;

 for (int i = 1; i <= n; i++)
 {
  elligible.insert(i);
 }

 int i = 1;
```

```
 int cnt = 0;

 while (sz(elligible))
 {
  cnt++;
  queue<int> q;
  q.push(*elligible.begin());
  elligible.erase(elligible.begin());

  while (sz(q))
  {
   int fr = q.front();
   q.pop();

   auto v = elligible.begin();

   while (v != elligible.end())
   {
    if (g[fr].find(*v) == g[fr].end())
    {
     q.push(*v);
     v = elligible.erase(v);
    }
    else
    {
     v++;
    }
   }
  }
 }

 cout << cnt - 1 << endl;
}

int main()
{
 ios_base::sync_with_stdio(false), cin.tie(0);

 int t = 1;
 //cin >> t;

 for (int tc = 1; tc <= t; tc++)
  runCase(tc);

 return 0;
}
```

1.5.2 Kruskal's [NK]

```
struct Edge {
    using weight_type = long long;
    static const weight_type bad_w; // Indicates non-existent
          edge

    int u = -1;          // Edge source (vertex id)
    int v = -1;          // Edge destination (vertex id)
    weight_type w = bad_w; // Edge weight

#define DEF_EDGE_OP(op)                                        \
    friend bool operator op(const Edge& lhs, const Edge& rhs)
          { \
        return make_pair(lhs.w, make_pair(lhs.u, lhs.v)) op \
           make_pair(rhs.w, make_pair(rhs.u, rhs.v));     \
    }

    DEF_EDGE_OP(==)
    DEF_EDGE_OP(!=)
    DEF_EDGE_OP(<)
    DEF_EDGE_OP(<=)
    DEF_EDGE_OP(>)
    DEF_EDGE_OP(>=)
};

constexpr Edge::weight_type Edge::bad_w = numeric_limits<
     Edge::weight_type>::max();

template <class EdgeCompare = less<Edge>>
constexpr vector<Edge> kruskal(const int n, vector<Edge>
     edges, EdgeCompare compare = EdgeCompare()) {
    // define dsu part and initlaize forests

    vector<int> parent(n);
    iota(parent.begin(), parent.end(), 0);
    vector<int> size(n, 1);
    auto root = [&](int x) {
        int r = x;
        while (parent[r] != r) {
            r = parent[r];
        }
        while (x != r) {
            int tmp_id = parent[x];
            parent[x] = r;
            x = tmp_id;
        }
        return r;
    };
    auto connect = [&](int u, int v) {
        u = root(u);
        v = root(v);
        if (size[u] > size[v]) {
            swap(u, v);
        }
        parent[v] = u;
        size[u] += size[v];
        size[v] = 0;
    };

    // connect components (trees) with edges in order from
         the sorted list

    sort(edges.begin(), edges.end(), compare);
    vector<Edge> edges_mst;
    int remaining = n - 1;
    for (const Edge& e : edges) {
        if (!remaining) break;
        const int u = root(e.u);
        const int v = root(e.v);
        if (u == v) continue;
        --remaining;
        edges_mst.push_back(e);
        connect(u, v);
    }

    return edges_mst;
}
```

1.5.3 Tree Rooting [MB]

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

using namespace std;

typedef long long ll;

const int N = 2e5 + 5;

vector<int> g[N];
ll sz[N], dist[N], sum[N];

void dfs(int s, int p)
{
 sz[s] = 1;
 dist[s] = 0;
 for (int nxt : g[s])
 {
  if (nxt == p)
   continue;
  dfs(nxt, s);
```

```
  sz[s] += sz[nxt];
  dist[s] += (dist[nxt] + sz[nxt]);
 }
}

void dfs1(int s, int p)
{

 if (p != 0)
 {
  ll my_size = sz[s];
  ll my_contrib = (dist[s] + sz[s]);

  sum[s] = sum[p] - my_contrib + sz[1] - sz[s] + dist[s];
 }
 for (int nxt : g[s])
 {
  if (nxt == p)
   continue;
  dfs1(nxt, s);
 }
}

// problem link: https://cses.fi/problemset/task/1133

int main()
{
 int n;
 cin >> n;

 for (int i = 1, u, v; i < n; i++)
  cin >> u >> v, g[u].push_back(v), g[v].push_back(u);

 dfs(1, 0);

 sum[1] = dist[1];

 dfs1(1, 0);

 for (int i = 1; i <= n; i++)
  cout << sum[i] << " ";
 cout << endl;

 return 0;
}
```

1.6 String

1.6.1 Hashing [MB]

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

using namespace std;

typedef long long ll;

const int PRIMES[] = {2147462393, 2147462419, 2147462587,
     2147462633, 2147462747, 2147463167, 2147463203,
     2147463569, 2147463727, 2147463863, 2147464211,
     2147464549, 2147464751, 2147465153, 2147465563,
     2147465599, 2147465743, 2147465953, 2147466457,
     2147466463, 2147466521, 2147466721, 2147467009,
     2147467057, 2147467067, 2147467261, 2147467379,
     2147467463, 2147467669, 2147467747, 2147468003,
     2147468317, 2147468591, 2147468651, 2147468779,
     2147468801, 2147469017, 2147469041, 2147469173,
     2147469229, 2147469593, 2147469881, 2147469983,
     2147470027, 2147470081, 2147470177, 2147470673,
     2147470823, 2147471057, 2147471327, 2147471581,
     2147472137, 2147472161, 2147472689, 2147472697,
     2147472863, 2147473151, 2147473369, 2147473733,
     2147473891, 2147473963, 2147474279, 2147474921,
     2147474929, 2147475107, 2147475221, 2147475347,
     2147475397, 2147475971, 2147476739, 2147476769,
     2147476789, 2147476927, 2147477063, 2147477107,
     2147477249, 2147477807, 2147477933, 2147478017,
     2147478521};

// ll base_pow,base_pow_1;
ll base1 = 43, base2 = 47, mod1 = 1e9 + 7, mod2 = 1e9 + 9;

// **** Enable this function for codeforces
void generateRandomBM()
{
 unsigned int seed = chrono::system_clock::now().
      time_since_epoch().count();
 srand(seed); /// to avoid getting hacked in CF, comment
      this line for easier debugging

 int q_len = (sizeof(PRIMES) / sizeof(PRIMES[0])) / 4;
 base1 = PRIMES[rand() % q_len];
 mod1 = PRIMES[rand() % q_len + q_len];
 base2 = PRIMES[rand() % q_len + 2 * q_len];
 mod2 = PRIMES[rand() % q_len + 3 * q_len];
}
```

```
struct Hash
{
public:
 vector<int> base_pow, f_hash, r_hash;
 ll base, mod;

 Hash() {}
 // Update it make it more dynamic like segTree class and
      DSU
 Hash(int mxSize, ll base, ll mod) // Max size
 {
  this->base = base;
  this->mod = mod;
  base_pow.resize(mxSize + 2, 1), f_hash.resize(mxSize + 2,
       0), r_hash.resize(mxSize + 2, 0);

  for (int i = 1; i <= mxSize; i++)
  {
   base_pow[i] = base_pow[i - 1] * base % mod;
  }
 }

 void init(string s)
 {
  int n = s.size();

  for (int i = 1; i <= n; i++)
  {
   f_hash[i] = (f_hash[i - 1] * base + int(s[i - 1])) % mod;
  }

  for (int i = n; i >= 1; i--)
  {
   r_hash[i] = (r_hash[i + 1] * base + int(s[i - 1])) % mod;
  }
 }

 int forward_hash(int l, int r)
 {
  int h = f_hash[r + 1] - (1LL * base_pow[r - l + 1] *
       f_hash[l]) % mod;
  return h < 0 ? mod + h : h;
 }

 int reverse_hash(int l, int r)
 {
  int h = r_hash[l + 1] - (1LL * base_pow[r - l + 1] *
       r_hash[r + 2]) % mod;
  return h < 0 ? mod + h : h;
 }
```

```
};

class DHash
{
public:
 Hash sh1, sh2;
 DHash() {}

 DHash(int mx_size)
 {
  sh1 = Hash(mx_size, base1, mod1);
  sh2 = Hash(mx_size, base2, mod2);
 }

 void init(string s)
 {
  sh1.init(s);
  sh2.init(s);
 }

 ll forward_hash(int l, int r)
 {
  return (ll(sh1.forward_hash(l, r)) << 32) | (sh2.
      forward_hash(l, r));
 }

 ll reverse_hash(int l, int r)
 {
  return ((ll(sh1.reverse_hash(l, r)) << 32) | (sh2.
      reverse_hash(l, r)));
 }
};
```

1.6.2 Hashing [NK]

```
// Primes suitable for use as the constant base in a
    polynomial rolling hash function.
constexpr std::array<int, 10>
    prime_bases = {257, 263, 269, 271, 277, 281, 283, 293,
        307, 311};
// Primes suitable for use as modulus.
constexpr std::array<int, 10>
    prime_moduli = {1000000007, 1000000009, 1000000021,
        1000000033, 1000000087,
                    1000000093, 1000000097, 1000000103,
                        1000000123, 1000000181};

/**
 * @brief A data structure for computing polynomial hashes
     of sequence keys.
 * For a given key defined as an integral sequence of n
     elements S[0], S[1], ...,
 * S[n - 1], this structure builds and stores for each
     prefix S[0...i] the hash value
 * H(i) = S[0] * B^i + S[1] * B^(i - 1) + ... + S[i] * B^0,
     modulo M.
 * @tparam Base The base B. Should be a prime to reduce
     chances of collision.
 * @tparam Modulus The modulus M. Should be a prime to
     reduce chances of collision.
 */
template <std::uint64_t Base, std::uint64_t Modulus>
class Polynomial_hasher {
public:
    using int_type = std::uint64_t;
    using value_type = int_type;
    using size_type = std::size_t;

    static constexpr int_type B = Base;
    static constexpr int_type M = Modulus;

protected:
    // Base power
    static std::vector<int_type> bpow_;
    // Prefix hash
    std::vector<int_type> pref_hash_;
    // Suffix hash
    std::vector<int_type> suff_hash_;
    // Flag for hashing bidirectionally
    bool bidir_ = false;

public:
    /**
     * @brief Default constructor
     */
    Polynomial_hasher() {}

    /**
     * @brief Constructors and builds the hash from a range (
         a "key").
     * @tparam InputIter Type of the iterator of the range
     * @param from Iterator pointing to the start of the
         range
     * @param until Iterator pointing to the end (one past
         the last element) of the range
     * @param bidir Flag for hashing bidirectionally
     */
    template <class InputIter>
    Polynomial_hasher(InputIter from, InputIter until, bool
         bidir = false) {
        build_hash(from, until, bidir);
    }

    /**
     * @brief Builds the hash from a range (a "key").
     * @tparam InputIter Type of the iterator of the range
     * @param from Iterator pointing to the start of the
         range
     * @param until Iterator pointing to the end (one past
         the last element) of
     * the range
     * @param bidir Flag for hashing bidirectionally
     */
    template <class InputIter>
    void build_hash(InputIter from, InputIter until, bool
         bidir = false) {
        const auto n = std::distance(from, until);
        while (bpow_.size() < n) {
            bpow_.push_back((bpow_.back() * B) % M);
        }
        // Build forward hash
        {
            pref_hash_.resize(n + 1);
            pref_hash_[0] = 0;
            auto it = from;
            for (size_type i = 0; i < n; ++i) {
                pref_hash_[i + 1] =
                    (((pref_hash_[i] * B) % M) + static_cast<
                        int_type>(*it)) % M;
                ++it;
            }
        }
        // Set and test flag, and build reverse hash
        bidir_ = bidir;
        if (bidir_) {
            suff_hash_.resize(n + 1);
            suff_hash_[n] = 0;
            auto it = prev(until);
            for (size_type i = n; i; --i) {
                suff_hash_[i - 1] =
                    (((suff_hash_[i] * B) % M) + static_cast<
                        int_type>(*it)) % M;
                --it;
            }
        }
    }

    /**
```

```
     * @brief Returns the polynomial hash value of the
         subsegment S[i], S[i + 1], ...,
     * S[i + n - 1], which is the value S[i] * B^(n - 1) + S[
         i + 1] * B^(n - 2) +
     * ... + S[i + n - 1] * B^0, modulo M.
     * @param i Starting index/position of the subsegment
     * @param n Length of the subsegment
     */
    value_type get(size_type i = 0,
                   size_type n = std::numeric_limits<size_type
                       >::max()) const {
        assert(i < pref_hash_.size());
        n = std::min(n, pref_hash_.size() - 1 - i);
        return (pref_hash_[i + n] - ((pref_hash_[i] * bpow_[n
            ]) % M) + M) % M;
    }

    /**
     * @brief Returns the polynomial hash value of the
         subsegment S[i], S[i + 1], ...,
     * S[i + n - 1] in reverse order, which is the value S[i]
          * B^i + S[i + 1] *
     * B^(i + 1) + ... + S[i + n - 1] * B^(i + n - 1), modulo
          M.
     * @param i Starting index/position of the subsegment
     * @param n Length of the subsegment
     */
    value_type get_rev(size_type i = 0,
                       size_type n = std::numeric_limits<
                           size_type>::max()) const {
        assert(bidir_);
        assert(i < suff_hash_.size());
        n = std::min(n, suff_hash_.size() - 1 - i);
        return (suff_hash_[i] - ((suff_hash_[i + n] * bpow_[n
            ]) % M) + M) % M;
    }

    /**
     * @brief Erases hash values of all prefixes (and
         suffixes if hashed
     * bidirectionally) calling `clear()` on the internal
         vector(s). Resets
     * bidirectional flag.
     */
    void clear() {
        pref_hash_.clear();
        suff_hash_.clear();
        bidir_ = false;
    }

    /**
     * @brief Number of elements in the hashed key.
     */
    size_type size() const { return pref_hash_.size() ?
        pref_hash_.size() - 1 : 0; }

    /**
     * @brief Returns true if no hash values are stored.
     */
    bool empty() const { return pref_hash_.empty(); }

    /**
     * @brief Returns true if the stored hash value is
         bidirectional (i.e., both
     * `hash` and `hash_rev` can be called).
     */
    bool bidirectional() const { return bidir_; }
};

template <std::uint64_t Base, std::uint64_t Modulus>
std::vector<std::uint64_t> Polynomial_hasher<Base, Modulus
    >::bpow_ = {1ULL};

using Hasher0 = Polynomial_hasher<prime_bases[0],
    prime_moduli[0]>;
using Hasher1 = Polynomial_hasher<prime_bases[1],
    prime_moduli[1]>;
```

1.6.3 Hashing [SK]

```
int powhash1[ 1000000+ 10]= {};
int powhash2[ 1000000+ 10]= {};
int f_prefhash1[1000000 + 10];
int f_prefhash2[1000000 + 10];
int r_prefhash1[1000000 + 10];
int r_prefhash2[1000000 + 10];

int add(ll x,ll y,ll mod)
{
    return (x+y>=mod)?(x+y-mod):(x+y);
}
int subtract(ll x,ll y,ll mod)
{
    return (x-y<0)?(x-y+mod):(x-y);
}

int multp(ll x,ll y,ll mod)
{
    return (x*y)%mod;
}


const int BASE1 = 125;
const int MOD1 = 1e9 + 9;

const int BASE2 = 250;
const int MOD2 = 1e9 + 7;

void f_prefhashcalc(string& s,int base,int mod,int*prefhash)
{
    ll sum = 0;
    int ns = s.size();

    for(int i=0; i<ns; i++)
    {

        sum = add(((ll)sum*base)%mod,s[i],mod);
        prefhash[i]=sum;
    }
}
void r_prefhashcalc(string& s,ll base,ll mod,int*prefhash)
{
    ll sum = 0;
    int ns = s.size();
    prefhash[ns]=0;

    for(int i=ns-1; i>=0; i--)
    {

        sum = add((sum*base)%mod,s[i],mod);
        prefhash[i]=sum;
    }
}



int f_strhash(string& s,int base,int mod)
{
    ll sum = 0;
    int ns = s.size();

    for(int i=0; i<ns; i++)
    {
        sum = add(((ll)sum*base)%mod,s[i],mod);
    }
    return sum;

}
int r_strhash(string& s,ll base,ll mod)
```

```
{
    ll sum = 0;
    int ns = s.size();

    for(int i=ns-1; i>=0; i--)
    {
        sum = add((sum*base)%mod,s[i],mod);
    }
    return sum;

}


void powhashfill(int base,int mod,int*powhash)
{
    for(int i=0; i<1000000 + 10; i++)
    {
        if(i==0)
        {
            powhash[0]=1;
            continue;
        }

        powhash[i] = multp(powhash[i-1],base,mod);
    }
}

int f_substrhash(int l,int r,ll mod,int*prefhash,int*powhash
    )
{

    ll x = subtract( prefhash[r], multp(prefhash[l-1],powhash
        [r-l+1],mod), mod );

    return x;
}
int r_substrhash(int l,int r,ll mod,int*prefhash,int*powhash
    )
{

    ll x = subtract( prefhash[l], multp(prefhash[r+1],powhash
        [r-l+1],mod), mod );

    return x;
}
```

1.6.4 Z-Function [MB]

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

/*
 tested by ac
 submission: https://codeforces.com/contest/432/submission
     /145953901
 problem: https://codeforces.com/contest/432/problem/D
*/
std::vector<int> z_function(const std::string &s)
{
 int n = (int)s.size();
 std::vector<int> z(n, 0);
 for (int i = 1, l = 0, r = 0; i < n; i++)
 {
  if (i <= r)
   z[i] = std::min(r - i + 1, z[i - l]);
  while (i + z[i] < n && s[z[i]] == s[i + z[i]])
   z[i]++;
  if (i + z[i] - 1 > r)
   l = i, r = i + z[i] - 1;
 }
 return z;
}
```