

Indian Institute of Information Technology, Nagpur

Team Blank

I/O

```

import sys,math,cmath,random,os,
psutil
from heapq import heappush,heappop
from bisect import bisect_right,
bisect_left
from collections import Counter,
deque, defaultdict
from itertools import permutations,
combinations
from io import BytesIO, IOBase
from decimal import Decimal,
getcontext
process = psutil.Process(os.getpid())
BUFSIZE = 8192
class FastIO(IOBase):
    newlines = 0
    def __init__(self, file):
        self._file = file
        self._fd = file.fileno()
        self.buffer = BytesIO()
        self.writable = "x" in file.mode or "r" not in file.mode
        self.write = self.buffer.write
        if self.writable else None
    def read(self):
        while True:
            b = os.read(self._fd, max(
                os.fstat(self._fd).st_size, BUFSIZE))
            if not b:
                break
            ptr = self.buffer.tell()
            self.buffer.seek(0, 2),
            self.buffer.write(b),
            self.buffer.seek(ptr)
        self.newlines = 0
        return self.buffer.read()
    def readline(self):
        while self.newlines == 0:
            b = os.read(self._fd, max(
                os.fstat(self._fd).st_size, BUFSIZE))
            self.newlines = b.count(b"\n") + (not b)
            ptr = self.buffer.tell()
            self.buffer.seek(0, 2),
            self.buffer.write(b),
            self.buffer.seek(ptr)
        self.newlines -= 1
        return self.buffer.readline()
    def flush(self):

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if self.writable:
    os.write(self._fd, self.
buffer.getvalue())
    self.buffer.truncate(0),
    self.buffer.seek(0)
class IOWrapper(IOBase):
    def __init__(self, file):
        self.buffer = FastIO(file)
        self.flush = self.buffer.flush
        self.writable = self.buffer.
writable
        self.write = lambda s: self.
buffer.write(s.encode("ascii"
"))
        self.read = lambda: self.
buffer.read().decode("ascii"
")
        self.readline = lambda: self.
buffer.readline().decode("ascii"
")
sys.stdin, sys.stdout = IOWrapper(
    sys.stdin), IOWrapper(sys.stdout)
MOD = 10**9 + 7
RANDOM = random.randrange(1, 2**62)
def gcd(a,b):
    while b:a,b = b,a%b;return a
def lcm(a,b):return a//gcd(a,b)*b
II = lambda : int(sys.stdin.readline().
strip())
LII = lambda : list(map(int, sys.
stdin.readline().split()))
SI = lambda : sys.stdin.readline().
strip()
LII_1 = lambda : list(map(lambda x:
int(x)-1, sys.stdin.readline().
split()))
if True:
    base = os.path.dirname(os.path.
abspath(__file__))
    sys.stdin = open(os.path.join(
        base, "input.txt"), "r")
    sys.stdout = open(os.path.join(
        base, "output.txt"), "w")
    sys.stderr = open(os.path.join(
        base, "error.txt"), "w")
def solve():
    return
solve()

```

Number Theory

```

def miller_is_prime(n):
    if n < 5 or n & 1 == 0 or n % 3
        == 0: return 2 <= n <= 3

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s = ((n - 1) & (1 - n)).
bit_length() - 1
d = n >> s
for a in [2, 325, 9375, 28178,
450775, 9780504, 1795265022]:
    p = pow(a, d, n)
    if p == 1 or p == n - 1 or a %
        n == 0: continue
    for _ in range(s):
        p = (p * p) % n
        if p == n - 1: break
    else: return False
return True
def is_prime(n):
    if n <= 1: return False
    if n <= 3: return True
    if n % 2 == 0 or n % 3 == 0:
        return False
    i = 5
    while i * i <= n:
        if n % i == 0 or n % (i + 2)
            == 0: return False
        i += 6
    return True

```

```

def sieve(n):
    primes = [];isp = [1] * (n+1)
    isp[0] = isp[1] = 0
    for i in range(2,n+1):
        if isp[i]:
            primes.append(i)
            for j in range(i*i,n+1,i):
                isp[j] = 0
    return primes
def sieve_unique(N):
    mini = [i for i in range(N)]
    for i in range(2,N):
        if mini[i]==i:
            for j in range(2*i,N,i):
                mini[j] = i
    return mini
MAX_N = 10**6+1
Lmini = sieve_unique(MAX_N)
def prime_factors(k,typ=0):
    if typ==0:ans = Counter()
    elif typ==1:ans = set()
    else:ans = []
    while k!=1:
        if typ==0:ans[Lmini[k]] += 1
        elif typ==1:ans.add(Lmini[k])
        else:ans.append(Lmini[k])
        k //= Lmini[k]
    return ans
def all_factors(x):

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L = list(prime_factors(x).items())
st = [1]
for i in range(len(L)):
    for j in range(len(st)):
        -1, -1, -1):
        k = L[i][0]
        for l in range(L[i][1]):
            st.append(st[j]*k)
            k *= L[i][0]
return st

```

```

def memodict(f):
    class memodict(dict):
        def __missing__(self, key):
            ret = self[key] = f(key)
            return ret
    return memodict().__getitem__
def pollard_rho(n):
    if n & 1 == 0:
        return 2
    if n % 3 == 0:
        return 3
    s = ((n - 1) & (1 - n)).bit_length() - 1
    d = n >> s
    for a in [2, 325, 9375, 28178,
              450775, 9780504, 1795265022]:
        p = pow(a, d, n)
        if p == 1 or p == n - 1 or a % n == 0:
            continue
        for i in range(s):
            prev = p
            p = (p * p) % n
            if p == 1:
                return gcd(prev - 1, n)
            if p == n - 1:
                break
        else:
            for i in range(2, n):
                x, y = i, (i * i + 1) % n
                f = gcd(abs(x - y), n)
                while f == 1:
                    x, y = (x * x + 1) % n, (y * y + 1) % n
                    f = gcd(abs(x - y), n)
                if f != n:
                    return f
    return n
@memodict
def prime_factors(n):

```

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# returns prime factor in n^(1/4)
# but is probabilistic
if n <= 1:
    return Counter()
f = pollard_rho(n)
return Counter([n]) if f == n
else prime_factors_large(f) +
prime_factors_large(n // f)
def extended_gcd(a, b):
# returns gcd(a, b), s, r s.t. a
# * s + b * r == gcd(a, b)
s, old_s = 0, 1
r, old_r = b, a
while r:
    q = old_r // r
    old_r, r = r, old_r - q * r
    old_s, s = s, old_s - q * s
return old_r, old_s, (old_r -
old_s * a) // b if b else 0
def composite_crt(b, m):
# returns x s.t. x = b[i] (mod m[i])
# for all i
x, m_prod = 0, 1
for bi, mi in zip(b, m):
    g, s, _ = extended_gcd(m_prod,
                           mi)
    if ((bi - x) % mi) % g:
        return None
    x += m_prod * (s * ((bi - x) %
                         mi) // g)
    m_prod = (m_prod * mi) // gcd(
        m_prod, mi)
return x % m_prod
def phi(n):
    ph = [i if i & 1 else i // 2 for
          i in range(n + 1)]
    for i in range(3, n + 1, 2):
        if ph[i] == i:
            for j in range(i, n + 1, i):
                ph[j] = (ph[j] // i) * (i - 1)
    return ph

```

Combinatorics

```

class Factorial:
    def __init__(self, N, mod):
        N += 1; self.mod = mod
        self.f = [1 for _ in range(N)]
        self.g = [1 for _ in range(N)]
        for i in range(1, N): self.f[i] =
            self.f[i - 1] * i % self.mod

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self.g[-1] = pow(self.f[-1],
                  mod - 2, mod)
for i in range(N - 2, -1, -1):
    self.g[i] = self.g[i + 1] *
    (i + 1) % self.mod
def fac(self, n): return self.f[n]
def fac_inv(self, n): return self.
g[n]
def combi(self, n, m):
    if m == 0: return 1
    if n < m or m < 0 or n < 0:
        return 0
    return self.f[n] * self.g[m] %
    self.mod * self.g[n - m] %
    self.mod
def permu(self, n, m):
    if n < m or m < 0 or n < 0:
        return 0
    return self.f[n] * self.g[n -
    m] % self.mod
def catalan(self, n): return (self.
    .combi(2 * n, n) - self.combi(2
    * n, n - 1)) % self.mod
def inv(self, n): return self.f[n -
    1] * self.g[n] % self.mod

```

Ways to partition n into k or fewer parts of size 1 or greater

```

@memoize
def partition(n, k):
    if n < 0: return 0
    if n == 0: return 1
    if k < 1: return 0
    return 1 if n == 1 else partition(
        n, k - 1) + partition(n - k, k)

```

Number of ways to partition n elements into k non-empty subsets

```

stirling_2 = lambda n, k: sum((((-1)
    **(k - j)) * nCr(k, j) * (j**n))
    for j in range(k + 1)) // math.
factorial(k)

```

Number of permutations of n objects where no object appears in its original position

```

derangements = lambda n: int(math.
    factorial(n) / math.e + 0.5)

```

Geometry

```

## here onwards, it is for
intersection only, even the point
class is different
class Point:
    def __init__(self, x, y):
        self.x = x; self.y = y
    def onSegment(p, q, r):
        return ((q.x <= max(p.x, r.x)) and
                (q.x >= min(p.x, r.x)) and
                (q.y <= max(p.y, r.y)) and (q.y
                >= min(p.y, r.y)))
    def orientation(p, q, r):
        # to find the orientation of an
        # ordered triplet (p,q,r)
        # 0:Collinear points,1:Clockwise
        # points,2:Counterclockwise
        val = ((q.y - p.y) * (r.x - q.x))
        - ((q.x - p.x) * (r.y - q.y))
        if (val > 0):return 1
        elif (val < 0):return 2
        else:return 0
    def doIntersect(p1,q1,p2,q2):
        o1 = orientation(p1, q1, p2);o2 =
            orientation(p1, q1, q2)
        o3 = orientation(p2, q2, p1);o4 =
            orientation(p2, q2, q1)
        if ((o1 != o2) and (o3 != o4)):
            return True
        if ((o1 == 0) and onSegment(p1,
            p2, q1)):return True
        if ((o2 == 0) and onSegment(p1,
            q2, q1)):return True
        if ((o3 == 0) and onSegment(p2,
            p1, q2)):return True
        if ((o4 == 0) and onSegment(p2,
            q1, q2)):return True
        return False
## lines
# 2d line: ax + by + c = 0 is (a, b,
# c)
# ax + by + c = 0 ((a, b, c),
# 3d line: dx + ez + f = 0 is (d, e,
# f),
# gy + hz + i = 0 (g, h, i))
def get_2dline(p1, p2):
    if p1 == p2: return (0, 0, 0)
    p1, p2 = min(p1, p2), max(p1,
    p2)
    a, b, c = p2[1] - p1[1], p1[0] -
    p2[0], p1[1] * p2[0] -
    p1[0] * p2[1]
    g = gcd(gcd(a, b), c)

```

```

        return (a // g, b // g, c // g)
    dist = lambda p1, p2: sum((a - b) *
        (a - b) for a, b in zip(p1, p2)) *
        **0.5
    get_line = lambda p1, p2: map(
        get_2dline, combinations(p1, 2),
        combinations(p2, 2))
    is_parallel = lambda l1, l2: l1[0] *
        l2[1] == l2[0] * l1[1]
    is_same = lambda l1, l2: is_parallel
        (l1, l2) and (l1[1] * l2[2] == l2
        [1] * l1[2])
    collinear = lambda p1, p2, p3:
        is_same(get_2dline(p1, p2),
            get_2dline(p2, p3))
    intersect = (lambda l1, l2: None if
        is_parallel(l1, l2) else (
            (l2[1] * l1[2] - l1[1] * l2[2]) /
            (l2[0] * l1[1] - l1[0] * l2
            [1]),
            (l1[0] * l2[2] - l1[2] * l2[0]) /
            (l2[0] * l1[1] - l1[0] * l2
            [1]),
            ))
    rotate = lambda p, theta, origin=(0,
        0): (
        origin[0] + (p[0] - origin[0]) *
        math.cos(theta) - (p[1] -
        origin[1]) * math.sin(theta),
        origin[1] + (p[0] - origin[0]) *
        math.sin(theta) + (p[1] -
        origin[1]) * math.cos(theta),
        )
    ## polygons
    dist = lambda p1, p2: sum((a - b) *
        (a - b) for a, b in zip(p1, p2)) *
        **0.5
    perimeter = lambda p: sum(dist(i, j)
        for i, j in zip(p, p[1:] + p
        [:1]))
    area = lambda p: abs(sum(i[0] * j
        [1] - j[0] * i[1] for i, j in zip(
        p, p[1:] + p[:1]))) / 2
    is_in_circle = lambda p, c, r: sum(i
        * i - j * j for i, j in zip(p, c))
        < r * r
    incircle_radius = lambda a, b, c:
        area(a, b, c) / (perimeter(a, b, c
        ) / 2)
    circumcircle_radius = lambda a, b, c
        : (dist(a, b) * dist(b, c) * dist(
        c, a)) / (4 * area(a, b, c))
    ##

```

Linear Algebra

```

def max_xor(A, flag=True):
    base = []; how = {}; reduced_base =
        {}
    for i in range(len(A)):
        a = A[i]; tmp = 0
        while a:
            b = a.bit_length() - 1
            if b in reduced_base:
                a ^= reduced_base[b]; tmp =
                    how[b]
            else:
                reduced_base[b] = a
                how[b] = tmp | (1 << len
                    (base))
                base.append(i)
                break
    x = 0; tmp = 0
    for j in sorted(reduced_base,
        reverse=True):
        if not x & (1 << j):
            x ^= reduced_base[j]
            tmp ^= how[j]
    if flag:
        # elements whose combination
        # returns all possible subset
        # xors
        return list(reduced_base.
            values())
    # elements whose xor is maximum
    return [base[j] for j in range(
        len(base)) if tmp & (1 << j)]
def matmul(L, B, MOD=(10**9 + 7)):
    ans = [[0 for i in range(len(B
        [0]))] for j in range(len(L))]]
    for i in range(len(L)):
        for j in range(len(B[0])):
            for k in range(len(B)):
                ans[i][j] = (ans[i][j]+L
                    [i][k]*B[k][j])%MOD
    return ans
def matpow(M, power):
    size = len(M)
    result = [[1 if i == j else 0 for
        j in range(size)] for i in
        range(size)]
    while power:
        if power % 2 == 1: result =
            matmul(result, M)
        M = matmul(M, M); power //=
            2
    return result

```

```

def gauss(A, mod=MOD):
    m, n = len(A), len(A[0])-1
    rank = 0; L = [-1]*n
    for col in range(n):
        for row in range(rank, m):
            if A[row][col]:
                A[rank], A[row] = A[row], A[rank]
                break
            else:
                continue
        k = pow(A[rank][col], -1, mod)
        for j in range(col, n+1):
            A[rank][j] = A[rank][j]*k % mod
        for row in range(m):
            if row!=rank and A[row][col]:
                factor = A[row][col]
                for j in range(col, n+1):
                    A[row][j] -= factor*A[rank][j]
                    A[row][j] %= mod
        L[col] = rank
        rank += 1
    for row in range(rank, m):
        if A[row][n]:
            return None
    return [A[L[i]][n] if L[i]!=-1 else 0 for i in range(len(L))]

class DiophantineEquations:
    """
        used for solving equations of
        the form  $a*x + b*y = c$ ,
        solnll takes the lower limit
        as well
    """
    def __init__(self): pass
    def euclidean_gcd(self, a, b):
        """
            euclidean gcd , returns x
            and y such that
             $a*x + b*y = \text{gcd}(a,b)$ 
        """
        if b == 0:
            return a, 1, 0
        g, x1, y1 = self.euclidean_gcd(b, a % b)
        x = y1
        y = x1-(a/b)*y1
        return g, x, y
    def soln(self, a, b, c, t=10**18, t1=10**18):
        """
    
```

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        return m and n such that  $a*$ 
         $m + b*n = c$  and  $0 \leq m \leq t$ 
        and  $0 \leq n \leq t_1$ 
        don't input t,t1 for any
        possible value
    """
    g = gcd(a, b)
    if c%g!=0:
        return -1, -1
    _, x, y = self.euclidean_gcd(a, b)
    k3 = x*(c//g)
    n1 = y*(c//g)
    k1 = max(math.ceil(-k3*g/b),
              math.ceil((n1-t1)/(a/g)))
    kmaxi = min(math.floor((t-k3)/(b/g)), math.floor(n1/(a/g)))
    if k1<=kmaxi:
        k = k1
        m = k3+k*(b//g)
        n = n1-k*(a//g)
        return m, n
    else:
        return -1, -1
    def solnll(self, a, b, c, t, t1,
               m_lower, n_lower):
        """
            return m and n such that  $a*$ 
             $m + b*n = c$  and
             $m_{\text{lower}} \leq m \leq t$  and
             $n_{\text{lower}} \leq n \leq t_1$ 
        """
        g = gcd(a, b)
        if c % g != 0:
            return -1, -1
        _, x, y = self.euclidean_gcd(a, b)
        k3 = x * (c // g)
        n1 = y * (c // g)
        k1 = max(math.ceil((m_lower - k3 * g) / b), math.ceil((n1 - t1) / (a / g)))
        kmaxi = min(math.floor((t - k3) / (b / g)), math.floor((n1 - n_lower) / (a / g)))
        if k1 <= kmaxi:
            k = k1
            m = k3 + k * (b // g)
            n = n1 - k * (a // g)
            if m_lower <= m <= t and n_lower <= n <= t1:
                return m, n
            else:
                return -1, -1
        else:
    
```

```

            return -1, -1
    Leq = DiophantineEquations()

```

Data Structures

Disjoint Set Union

```

class DisjointSetUnion:
    def __init__(self, n):
        self.parent = list(range(n))
        # self.s = set(self.parent)
        self.size = [1] * n
    def find(self, a):
        acopy = a
        while a != self.parent[a]:
            a = self.parent[a]
        while acopy != a:
            self.parent[acopy], acopy =
                a, self.parent[acopy]
        return a
    def union(self, a, b):
        a, b = self.find(a), self.find(b)
        if a != b:
            if self.size[a] < self.size[b]:
                a, b = b, a
            self.s.remove(b)
            self.parent[b] = a
            self.size[a] += self.size[b]
    def set_size(self, a):
        return self.size[self.find(a)]
    def __len__(self):
        return len(self.s)
    def notfind(self, a):
        k = self.find(a)
        for j in self.s:
            if j!=k:
                return j
        return -1

```

Persistent DSU

```

class PersistentDSU:
    def __init__(self, n):
        self.parent = list(range(n))
        self.size = [1]*n
        self.time = [float('inf')]*n
    def find(self, node, version):
        # returns root at given
        # version
        while not (self.parent[node]==
                   node or self.time[node]>
                   version):
    
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        node = self.parent[node]
    return node
def union(self,a,b,time):
# merges a and b
a = self.find(a,time)
b = self.find(b,time)
if a==b:
    return False
if self.size[a]>self.size[b]:
    a,b = b,a
self.parent[a] = b
self.time[a] = time
self.size[b] += self.size[a]
return True
def isconnected(self,a,b,time):
    return self.find(a,time)==self
    .find(b,time)

```

Fenwick Tree

```

class BIT:
#Faster than segment tree so use
# if possible
    def __init__(self, x):
        self.bit = x
        for i in range(len(x)):
            j = i | (i + 1)
            if j < len(x):
                x[j] += x[i]
    def update(self, idx, x):
        """updates bit[idx] += x"""
        while idx < len(self.bit):
            self.bit[idx] += x
            idx |= idx + 1
    def query(self, end):
        """calc sum(bit[:end])"""
#gives sum of element before
#end
        x = 0
        while end:
            x += self.bit[end - 1]
            end &= end - 1
        return x
    def findkth(self, k):
        """Find largest idx such that
        sum(bit[:idx]) <= k"""
        idx = -1
        for d in reversed(range(len(
            self.bit).bit_length())):
            right_idx = idx + (1 << d)
            if right_idx < len(self.bit)
            ) and k >= self.bit[
                right_idx]:
                idx = right_idx

```

```

        k -= self.bit[idx]
    return idx + 1

```

2-D Fenwick Tree

```

class BIT2D:
    def __init__(self, arr):
        self.n = len(arr)
        self.m = len(arr[0]) if self.n
        > 0 else 0
        # self.bit = [row[:] for row
        # in arr]
        self.bit = arr # assuming that
        arr is not used after this
    for i in range(self.n):
        for j in range(self.m):
            ni = i | (i + 1)
            if ni < self.n:
                self.bit[ni][j] +=
                    self.bit[i][j]
    for i in range(self.n):
        for j in range(self.m):
            nj = j | (j + 1)
            if nj < self.m:
                self.bit[i][nj] +=
                    self.bit[i][j]
    def add(self, x, y, delta):
        # 0-based in log n * log m
        i = x
        while i < self.n:
            j = y
            while j < self.m:
                self.bit[i][j] += delta
                j |= j + 1
            i |= i + 1
    def sum(self, x, y):
        # sum from 0,0 to x,y
        # inclusive in log n * log m
        if not (0<=x<self.n) or not
        (0<=y<self.m):
            return 0
        res = 0
        i = x
        while i >= 0:
            j = y
            while j >= 0:
                res += self.bit[i][j]
                j = (j & (j + 1)) - 1
            i = (i & (i + 1)) - 1
        return res
    def query(self, x1, y1, x2, y2):
        # sum of L[x1:x2+1][y1:y2+1]
        return (self.sum(x2, y2)-self.
            sum(x1-1, y2)-self.sum(x2, y1)
            -1)+(self.sum(x1-1, y1-1)))

```

Bucket Sorted List

```

from typing import Generic, Iterable,
    Iterator, List, Tuple, TypeVar,
    Optional
T = TypeVar('T')
class SortedList(Generic[T]):
    BUCKET_RATIO = 16
    SPLIT_RATIO = 24
    def __init__(self, a: Iterable[T]
    = []):
        a = list(a)
        n = self.size = len(a)
        if any(a[i] > a[i + 1] for i
        in range(n - 1)):
            a.sort()
        num_bucket = int(math.ceil(
            math.sqrt(n / self.
            BUCKET_RATIO)))
        self.a = [a[n * i //
        num_bucket : n * (i + 1) //(
        num_bucket)] for i in range(
        num_bucket)]
    def __iter__(self) -> Iterator[T]:
        for i in self.a:
            for j in i: yield j
    def __reversed__(self) ->
        Iterator[T]:
        for i in reversed(self.a):
            for j in reversed(i): yield
            j
    def __eq__(self, other) -> bool:
        return list(self) == list(other)
    def __len__(self) -> int:
        return self.size
    def __repr__(self) -> str:
        "SortedMultiset" + str(self.a)
    def __str__(self) -> str:
        s = str(list(self))
        return "{" + s[1 : len(s) - 1]
        + "}"
    def position(self, x: T) ->
        Tuple[List[T], int, int]:
        for i, a in enumerate(self.a):
            if x <= a[-1]: break
        return (a, i, bisect_left(a, x))
    def __contains__(self, x: T) ->
        bool:
            if self.size == 0: return
            False

```

```

    a, _, i = self._position(x) == ||
    return i != len(a) and a[i] == x
def count(self, x: T) -> int:
    return self.index_right(x) - self.index(x)
def add(self, x): return self.
    insert(x)
def insert(self, x: T) -> None:
    if self.size == 0:
        self.a = [[x]]
        self.size = 1
        return
    a, b, i = self._position(x)
    a.insert(i, x)
    self.size += 1
    if len(a) > len(self.a) * self.
        .SPLIT_RATIO:
        mid = len(a) // 2
        self.a[b:b+1] = [a[:mid], a
            [mid:]]
def _pop(self, a: List[T], b: int
, i: int) -> T:
    ans = a.pop(i)
    self.size -= 1
    if not a: del self.a[b]
    return ans
def remove(self, x: T) -> bool:
    if self.size == 0: return
        False
    a, b, i = self._position(x)
    if i == len(a) or a[i] != x:
        return False
    self._pop(a, b, i)
    return True
def lt(self, x: T) -> Optional[T]:
    for a in reversed(self.a):
        if a[0] < x:
            return a[bisect_left(a,
                x) - 1]
def le(self, x: T) -> Optional[T]:
    for a in reversed(self.a):
        if a[0] <= x:
            return a[bisect_right(a,
                x) - 1]
def gt(self, x: T) -> Optional[T]:
    for a in self.a:
        if a[-1] > x:
            return a[bisect_right(a,
                x)]
def ge(self, x: T) -> Optional[T]:

```

```

    for a in self.a:
        if a[-1] >= x:
            return a[bisect_left(a,
                x)]
def __getitem__(self, i: int) ->
T:
    if i < 0:
        for a in reversed(self.a):
            i += len(a)
            if i >= 0: return a[i]
    else:
        for a in self.a:
            if i < len(a): return a[
                i]
            i -= len(a)
    raise IndexError
def pop(self, i: int = -1) -> T:
    if i < 0:
        for b, a in enumerate(
            reversed(self.a)):
            i += len(a)
            if i >= 0: return self.
                _pop(a, ~b, i)
    else:
        for b, a in enumerate(self.
            a):
            if i < len(a): return
                self._pop(a, b, i)
            i -= len(a)
    raise IndexError
def bisect_left(self, x): return
    self.index(x)
def index(self, x: T) -> int:
    ans = 0
    for a in self.a:
        if a[-1] >= x:
            return ans + bisect_left(
                a, x)
        ans += len(a)
    return ans
def bisect_right(self, x): return
    self.index_right(x)
def index_right(self, x: T) ->
int:
    ans = 0
    for a in self.a:
        if a[-1] > x:
            return ans +
                bisect_right(a, x)
        ans += len(a)
    return ans
def find_closest(self, k: T) ->
Optional[T]:
    if self.size == 0: return None
    ltk = self.le(k); gtk = self.ge(
        k)

```

```

        (k)
        if ltk is None: return gtk
        if gtk is None: return ltk
        return ltk if abs(k-ltk) <= abs(
            k-gtk) else gtk

```

Lazy Segment Tree

```

class SegmentTree:
    @staticmethod
    def func(a, b):
        return a+b
    def __init__(self, data, default
=0, mode='s'):
        self.mode = mode
        self._default = default
        self.n = len(data)
        self.size = 1 << (self.n - 1).
            bit_length()
        self.tree = [default] * (2 *
            self.size)
        self._size = [0] * (2 * self.
            size)
        self._size[self.size:] = [1] *
            self.size
    for i in range(self.size - 1,
        0, -1):
        self._size[i] = self._size[
            i << 1] + self._size[i <<
            1 | 1]
    self.lazy_add = 0 if self.mode
        == 's' else 0
    self.lazy_set = None
    self.lazy_add = [0] * self.
        size
    self.lazy_set = [None] * self.
        size
    for i in range(self.n):
        self.tree[self.size + i] =
            data[i]
    for i in range(self.size - 1,
        0, -1):
        self.tree[i] = self.func(
            self.tree[i << 1], self.
            tree[i << 1 | 1])
    def _apply_set(self, pos, value):
        if self.mode == 's':
            self.tree[pos] = value *
                self._size[pos]
        else:
            self.tree[pos] = value
            if pos < self.size:
                self.lazy_set[pos] = value
                self.lazy_add[pos] = 0
    def _apply_add(self, pos, value):

```

```

if self.mode == 's':
    self.tree[pos] += value *
        self._size[pos]
else:
    self.tree[pos] += value
if pos < self.size:
    if self.lazy_set[pos] is
        not None:
        self.lazy_set[pos] +=
            value
    else:
        self.lazy_add[pos] +=
            value
def _build(self, pos):
    while pos > 1:
        pos >>= 1
        self.tree[pos] = self.func(
            self.tree[pos << 1], self.
            tree[pos << 1 | 1])
    if self.lazy_set[pos] is
        not None:
        if self.mode == 's':
            self.tree[pos] = self.
                lazy_set[pos] *
                    self._size[pos]
        else:
            self.tree[pos] = self.
                lazy_set[pos]
    if self.lazy_add[pos] != 0:
        if self.mode == 's':
            self.tree[pos] +=
                self.lazy_add[pos] *
                    self._size[pos]
        else:
            self.tree[pos] +=
                self.lazy_add[pos]
def _push(self, pos):
    for shift in range(self.size.
        bit_length() - 1, 0, -1):
        i = pos >> shift
        set_val = self.lazy_set[i]
        if set_val is not None:
            self._apply_set(i << 1,
                set_val)
            self._apply_set(i << 1 |
                1, set_val)
            self.lazy_set[i] = None
        add_val = self.lazy_add[i]
        if add_val != 0:
            self._apply_add(i << 1,
                add_val)
            self._apply_add(i << 1 |
                1, add_val)
        self.lazy_add[i] = 0

```

```

def range_update(self, left,
    right, value, flag=True):
    # Range Update in [L,R] if
    # flag, then add
    if flag:
        l = left + self.size
        r = right + self.size
        l0, r0 = l, r
        self._push(l0)
        self._push(r0)
        while l <= r:
            if l & 1: self.
                _apply_add(l, value);
                l += 1
            if not r & 1: self.
                _apply_add(r, value);
                r -= 1
            l >>= 1; r >>= 1
            self._build(l0)
            self._build(r0)
        else:
            l = left + self.size
            r = right + self.size
            l0, r0 = l, r
            self._push(l0)
            self._push(r0)
            while l <= r:
                if l & 1: self.
                    _apply_set(l, value);
                    l += 1
                if not r & 1: self.
                    _apply_set(r, value);
                    r -= 1
                l >>= 1; r >>= 1
                self._build(l0)
                self._build(r0)
def range_query(self, left, right):
    # Range Query in [L,R]
    l = left + self.size
    r = right + self.size
    self._push(l)
    self._push(r)
    res = self._default
    while l <= r:
        if l & 1: res = self.func(
            res, self.tree[l]); l +=
            1
        if not r & 1: res = self.
            func(res, self.tree[r]);
            r -= 1
        l >>= 1; r >>= 1
    return res
def __repr__(self):
    return f"SegmentTree({[self.

```

```

range_query(i, i) for i in
range(self.n)]})"

```

Lazy Segment Tree 2

```

class SegmentTree:
    def __init__(self, data, default
        =0, func=max):
        # don't forget to change func
        here
        # default is the value given
        to it by default
        self._default = default
        self._func = func
        self._len = len(data)
        self._size = _size = 1 << (
            self._len - 1).bit_length()
        self._lazy = [0] * (2 * _size)
        self.data = [default] * (2 *
            _size)
        self.data[_size:_size + self.
            _len] = data
        for i in reversed(range(_size)):
            self.data[i] = func(self.
                data[i + i], self.data[i +
                i + 1])
    def __len__(self):
        return self._len
    def __push(self, idx):
        q, self._lazy[idx] = self.
            _lazy[idx], 0
        self._lazy[2 * idx] += q
        self._lazy[2 * idx + 1] += q
        self.data[2 * idx] += q
        self.data[2 * idx + 1] += q
    def __update(self, idx):
        for i in reversed(range(1, idx
            .bit_length())):
            self._push(idx >> i)
    def __build(self, idx):
        idx >= 1
        while idx:
            self.data[idx] = self._func
                (self.data[2 * idx], self.
                    data[2 * idx + 1]) +
                self._lazy[idx]
            idx >>= 1
    def add(self, start, stop, value):
        # lazily add value to [start,
            stop]

```

```

start = start_copy = start +
        self._size
stop = stop_copy = stop + self
        ._size
while start < stop:
    if start & 1:
        self._lazy[start] += value
        self.data[start] += value
    start += 1
    if stop & 1:
        stop -= 1
        self._lazy[stop] += value
        self.data[stop] += value
    start >>= 1
    stop >>= 1
    self._build(start_copy)
    self._build(stop_copy - 1)
def query(self, start, stop,
default=float('inf')):
    # func of data[start, stop)
    # don't forget to update the
        default
    start += self._size
    stop += self._size
    self._update(start)
    self._update(stop - 1)
    res = default
    while start < stop:
        if start & 1:
            res = self._func(res,
                               self.data[start])
            start += 1
        if stop & 1:
            stop -= 1
            res = self._func(res,
                               self.data[stop])
            start >>= 1
            stop >>= 1
    return res
def __repr__(self):
    return "LazySegmentTree({0})".format(self.data)

```

Trie

```
class Trie:
    def __init__(self):
        self.root = {}
    def add(self, word):
        current_dict = self.root
        for letter in word:
            current_dict = current_dict.setdefault(letter, {})
```

```

current_dict[0] = True

convex Hull

class ConvexHull:
    def __init__(self, n=100000):
        # put n equal to max value of
        # ai , bi , you may need to do
        # coordinate compression in
        # case it is upto 10**9
        # works for value which are
        # not increasing as well
        self.n = n
        self.seg = [Line(0, float('inf'))] * (4 * n)
        self.lo = [0] * (4 * n)
        self.hi = [0] * (4 * n)
        self.build(1, 1, n)
    def build(self, i, l, r):
        stack = [(i, l, r)]
        while stack:
            idx, left, right = stack.pop()
            self.lo[idx] = left
            self.hi[idx] = right
            self.seg[idx] = Line(0,
                float('inf'))
            if left == right:
                continue
            mid = (left + right) // 2
            stack.append((2 * idx + 1,
                mid + 1, right))
            stack.append((2 * idx, left,
                mid))
    def insert(self, L):
        pos = 1
        while True:
            l, r = self.lo[pos], self.
                hi[pos]
            if l == r:
                if L(l) < self.seg[pos]:
                    l:
                        self.seg[pos] = L
                break
            m = (l + r) // 2
            if self.seg[pos].m < L.m:
                self.seg[pos], L = L,
                    self.seg[pos]
            if self.seg[pos].m > L(m):
                self.seg[pos], L = L,
                    self.seg[pos]
            pos = 2 * pos
        else:
            pos = 2 * pos + 1
    def query(self, x):

```

```

res = f(self.line, x) if self. ||
    line is not None else ||
    -10**18
if self.lo == self.hi:
    return res
if x <= self.m and self.left
    is not None:
        res = max(res, self.left.
            query(x))
elif x > self.m and self.right
    is not None:
        res = max(res, self.right.
            query(x))
return res
class Line:
    def __init__(self, m, b, c=0):
        # c is an identifier for the
        # line
        self.m = m; self.b = b; self.c =
        c
    def __call__(self, x):
        return self.m * x + self.b

```

Heavy Light Decomposition

```

class HLD:
    def __init__(self, adj, values,
                 root=0, func=max, unit=float('-
inf')):
        self.adj = adj
        self.values = values
        self.parent = [-1] * len(adj)
        self.depth = [0] * len(adj)
        self.size = [0] * len(adj)
        self.heavy = [-1] * len(adj)
        self.head = [0] * len(adj)
        self.pos = [0] * len(adj)
        self.flat = [0] * len(adj)
        self.unit = unit
        self.func = func
        self._dfs(root)
        self._decompose(root)
        self(seg = SegmentTree([self.
            values[self.flat[i]] for i
            in range(len(self.adj))],
            func, unit))
    def _dfs(self, start=0):
        visited = [False] * len(self.
            adj)
        stack = [start]
        while stack:
            start = stack[-1]
            if not visited[start]:
                visited[start] = True
                for child in self.adj[

```

```

                    start]:
                        if not visited[child]:
                            self.parent[child] =
                                start
                            self.depth[child] =
                                self.depth[
                                    start]+1
                            stack.append(child)
                        else:
                            self.size[stack.pop()] =
                                1
                            k = 0
                            for child in self.adj[
                                start]:
                                if self.parent[start] !=
                                    child:
                                    self.size[start] +=
                                        self.size[
                                            child]
                                if self.size[child] >k:
                                    k = self.size[
                                        child]
                                    self.heavy[
                                        start] =
                                        child
                    return visited
    def _decompose(self, root):
        stack = [(root, root)]
        time = 0
        while stack:
            u, h = stack.pop()
            self.head[u] = h
            self.flat[time] = u
            self.pos[u] = time
            time += 1
            for v in reversed(self.adj[
                u]):
                if v!=self.parent[u] and
                    v!=self.heavy[u]:
                    stack.append((v, v))
            if self.heavy[u] != -1:
                stack.append((self.heavy[
                    u], h))
    def query(self, u, v):
        res = self.unit
        while self.head[u] != self.
            head[v]:
            if self.depth[self.head[u]] <
                self.depth[self.head[v]]:
                u, v = v, u
        res = self.func(res, self.

```

```

            seg.query(self.pos[self.
                head[u]], self.pos[u] +
                1))
        u = self.parent[self.head[u]]
        if self.depth[u] > self.depth[
            v]:
            u, v = v, u
        return self.func(res, self.seg.
            query(self.pos[u], self.pos[
                v] + 1))
    def update(self, u, value):
        self.seg.update(self.pos[u],
            value)
    def update_path(self, u, v, value
    ):
        while self.head[u] != self.
            head[v]:
            if self.depth[self.head[u]] <
                self.depth[self.head[v]]:
                u, v = v, u
            self.seg.range_update(self.
                pos[self.head[u]], self.
                pos[u], value)
        u = self.parent[self.head[u]]
        if self.depth[u] > self.depth[
            v]:
            u, v = v, u
        self.seg.range_update(self.pos[
            u], self.pos[v], value)
    def add_to_subtree(self, u, value
    ):
        self.seg.range_update(self.pos[
            u], self.pos[u] + self.size[
            u] - 1, value)

```

Mono Deque

```

from typing import Callable, TypeVar
T = TypeVar('T')
class MonoStack(Generic[T]):
    def __init__(self, op: Callable[[
        T, T], T], e: Callable[[], T]):
        self.s: List[T] = []
        self.sMono: List[T] = []
        self.op = op
        self.e = e
    def push(self, x: T):
        self.s.append(x)
        if not self.sMono:
            self.sMono.append(x)
        else:
            self.sMono.append(self.op(

```

```

        self.sMono[-1], x))
def pop(self) -> T:
    if not self.s:
        return self.e()
    self.sMono.pop()
    return self.s.pop()
def get(self) -> T:
    return self.sMono[-1] if self.
        sMono else self.e()
def empty(self) -> bool:
    return not self.s
class MonoDeque(Generic[T]):
    def __init__(self, op: Callable[[T, T], T] = lambda a, b: max(a, b),
                 e: Callable[[], T] = lambda : -float('inf')):
        # e is the unit value in form
        # of lambda : 0
        # The Function op must be
        # associative, f(a,b)==f(b,a)
        self.op = op
        self.e = e
        self.front = MonoStack(op, e)
        self.back = MonoStack(op, e)
    def push_back(self, x: T):
        self.back.push(x)
    def pop_front(self):
        if self.front.empty():
            while not self.back.empty():
                self.front.push(self.
                    back.pop())
        self.front.pop()
    def get(self) -> T:
        # returns the function op of
        # the elements present in the
        # deque
        return self.op(self.front.get(),
                       self.back.get())

```

Merge Sort Tree

```

class MergeSortTree:
    def merge(L, L1):
        L2 = []
        L = list(L); L1 = list(L1)
        i = j = 0
        while j < len(L) and i < len(L1):
            if L[j] < L1[i]:
                L2.append(L[j])
                j += 1
            else:
                L2.append(L1[i])
                i += 1
        L2.extend(L[j:] + L1[i:])

```

```

        return L2
    def __init__(self, data):
        self.n = len(data)
        self.tree = [SortedList() for
                    _ in range(2 * self.n)]
        self.build(data)
    def build(self, data):
        for i in range(self.n):
            self.tree[self.n + i].
                insert(data[i])
        for i in range(self.n - 1, 0,
                      -1):
            self.tree[i] = SortedList(
                MergeSortTree.merge(self.
                    tree[i << 1], self.tree[i
                        << 1 | 1]))
    def query(self, left, right, l, r):
        res = 0
        left += self.n
        right += self.n
        while left < right:
            if left & 1:
                res += self.func(self.
                    tree[left], l, r); left
                += 1
            if right & 1:
                right -= 1; res += self.
                    func(self.tree[right],
                          l, r)
            left >>= 1; right >>= 1
        return res
    def func(self, L, l, r):
        return L.bisect_right(r) - L.
            bisect_left(l)
    def update(self, pos, value):
        pos += self.n; old_val = self.
            tree[pos][0]
        self.tree[pos].remove(old_val)
        self.tree[pos].add(value)
        while pos:
            pos >>= 1
            self.tree[pos].remove(
                old_val)
            self.tree[pos].add(value)

```

Persistent Segment Tree

```

class PersistentSegmentTree:
    class Node:
        def __init__(self, value=0,
                     left=None, right=None):
            self.value = value
            self.left = left
            self.right = right

```

```

@staticmethod
def func(a, b):
    return a+b
def __init__(self, data):
    self.n = len(data)
    self.versions = []
    self.versions.append(self.
        _build(data))
def _build(self, data):
    stack = [(0, self.n - 1, False
              )]
    nodes = {}
    while stack:
        left, right, visited =
            stack.pop()
        if left == right:
            nodes[(left, right)] =
                self.Node(data[left])
        else:
            if visited:
                mid = (left + right)
                // 2
                left_child = nodes[(left,
                                     mid)]
                right_child = nodes[(mid + 1,
                                      right)]
                nodes[(left, right)] =
                    self.Node(self.
                        func(left_child.
                            value, right_child.
                            value), left_child,
                            right_child)
            else:
                stack.append((left,
                              right, True))
                mid = (left + right)
                // 2
                stack.append((mid +
                              1, right, False))
                stack.append((left,
                              mid, False))
    return nodes[(0, self.n - 1)]
def update(self, version, pos,
           value):
    old_root = self.versions[
        version]
    stack, path = [(old_root, 0,
                   self.n - 1)], []
    while stack:
        node, left, right = stack.
            pop()
        path.append((node, left,
                     right))

```

```

if left == right:
    break
mid = (left + right) // 2
if pos <= mid:
    stack.append((node.left,
                  left, mid))
else:
    stack.append((node.right
                  , mid + 1, right))

new_nodes = {}
for node, left, right in
reversed(path):
    if left == right:
        k = value
        # k = self.func(node.
        # value,value) # if i
        # want to update
        new_nodes[(left, right)] =
            self.Node(k)
    else:
        mid = (left + right) //
        2
        left_child = new_nodes.
            get((left, mid), node.
            left)
        right_child = new_nodes.
            get((mid + 1, right),
            node.right)
        new_nodes[(left, right)] =
            self.Node(self.func(
                left_child.value,
                right_child.value),
                left_child,
                right_child)
return new_nodes[(0, self.n -
1)]

def create_version(self, version,
pos, value):
    new_root = self.update(version
                           , pos, value)
    self.versions.append(new_root)
    return len(self.versions) - 1

def query(self, version, ql, qr):
    node, left, right = self.
        versions[version], 0, self.n -
        1
    stack = [(node, left, right)]
    result = 0 # change this
    depending on the problem
    while stack:
        node, left, right = stack.
            pop()

```

```

if ql > right or qr < left:
    continue
if ql <= left and right <=
qr:
    result = self.func(
        result, node.value)
else:
    mid = (left + right) //
    2
    stack.append((node.left,
                  left, mid))
    stack.append((node.right
                  , mid + 1, right))
return result

```

Suffix Automaton

```

class State:
    def __init__(self):
        self.next = {}
        self.link = -1
        self.len = 0
        self.first_pos = -1
        self.occurrence = 0

class SuffixAutomaton:
    def __init__(self, s):
        self.s = s
        self.states = [State()]
        self.size = 1
        self.last = 0
        for ch in s:
            self.add(ch)
        self._prepare_occurrences() # comment out if taking time
        self._count_substrings()

    def add(self, ch):
        p = self.last
        cur = self.size
        self.states.append(State())
        self.size += 1
        self.states[cur].len = self.
            states[p].len + 1
        self.states[cur].first_pos =
            self.states[cur].len - 1
        self.states[cur].occurrence =
            1
        while p != -1 and ch not in
            self.states[p].next:
            self.states[p].next[ch] =
                cur
            p = self.states[p].link
        if p == -1:
            self.states[cur].link = 0
        else:
            q = self.states[p].next[ch]

```

```

if self.states[p].len + 1
    == self.states[q].len:
        self.states[cur].link =
            q
    else:
        clone = self.size
        self.states.append(State
            ())
        self.size += 1
        self.states[clone].len =
            self.states[p].len +
            1
        self.states[clone].next =
            self.states[q].next.
            copy()
        self.states[clone].link =
            self.states[q].link
        self.states[clone].
            first_pos = self.
            states[q].first_pos
        while p != -1 and self.
            states[p].next[ch] ==
            q:
            self.states[p].next[
                ch] = clone
            p = self.states[p].
                link
        self.states[q].link =
            self.states[cur].link
            = clone
        self.last = cur
def _prepare_occurrences(self):
    order = sorted(range(self.size
        ), key=lambda x: -self.
        states[x].len)
    for i in order:
        if self.states[i].link !=
            -1:
            self.states[self.states[
                i].link].occurrence +=
                self.states[i].
                    occurrence
def _count_substrings(self):
    self.dp = [0] * self.size
    for i in range(self.size):
        self.dp[i] = 1
    order = sorted(range(self.size
        ), key=lambda x: self.states[
            x].len)
    for u in reversed(order):
        for v in self.states[u].
            next.values():
            self.dp[u] += self.dp[v]
def is_substring(self, s):
    current = 0

```

```

for ch in s:
    if ch not in self.states[
        current].next:
        return False
    current = self.states[
        current].next[ch]
return True
def count_occurrences(self, s):
    current = 0
    for ch in s:
        if ch not in self.states[
            current].next:
            return 0
        current = self.states[
            current].next[ch]
    return self.states[current].occurrence
def count_distinct_substrings(
    self):
    return sum(self.states[i].len
               - self.states[self.states[i].link].len for i in range(
                   1, self.size))
def kth_lex_substring(self, k):
    # kth distinct substring
    result = []
    current = 0
    while k:
        for ch in sorted(self.
                          states[current].next):
            next_state = self.states[
                current].next[ch]
            if self.dp[next_state] <
                k:
                k -= self.dp[
                    next_state]
            else:
                result.append(ch)
                k -= 1
                current = next_state
                break
    return ''.join(result)
def enumerate_all_substrings(self):
    result = []
    def dfs(state, path):
        for ch in sorted(self.
                          states[state].next):
            next_state = self.states[
                state].next[ch]
            result.append(path + ch)
            dfs(next_state, path +
                 ch)
    dfs(0, "")
    return result
def longest_common_substring(self)

```

```

    t):
    v = 0; l = 0; best = 0; bestpos =
    0
    for i in range(len(t)):
        while v and t[i] not in
            self.states[v].next:
            v = self.states[v].link
            l = self.states[v].len
        if t[i] in self.states[v].next:
            v = self.states[v].next[
                t[i]]
            l += 1
        if l > best:
            best = l
            bestpos = i
    return t[bestpos - best + 1:
             bestpos + 1]
def all_occurrences(self, s):
    current = 0
    for ch in s:
        if ch not in self.states[
            current].next:
            return []
        current = self.states[
            current].next[ch]
    positions = []
    def collect(state):
        if self.states[state].occurrence:
            pos = self.states[state].
                first_pos - len(s) +
            1
            positions.append(pos)
        for v in self.states[state].
            next.values():
            collect(v)
    collect(current)
    return sorted(set(positions))
def missing_sub(self):
    visited = set()
    q = deque([(0, "")])
    while q:
        state, path = q.popleft()
        for c in map(chr, range(97,
                               123)):
            if c not in self.states[
                state].next:
                return path + c
            next_state = self.states[
                state].next[c]
            if (next_state, path + c)
                not in visited:
                visited.add((
                    next_state, path +

```

```

                    c))
                q.append((next_state,
                           path + c))
    return None

```

Segment Tree

```

class SegmentTree:
    @staticmethod
    def func(a, b):
        # Change this function
        # depending upon needs
        return max(a, b)
    def __init__(self, data):
        self.n = len(data)
        self.tree = [0] * (self.n<<1)
        self.build(data)
    def build(self, data):
        for i in range(self.n):
            self.tree[self.n + i] =
                data[i]
        for i in range(self.n - 1, 0,
                       -1):
            self.tree[i] = self.func(
                self.tree[i<<1], self.
                tree[(i<<1) + 1])
    def update(self, pos, value):
        # Update the value at the leaf
        # node
        pos += self.n
        # For updating
        self.tree[pos] = value
        # self.tree[pos] += value
        # If you want to add rather
        # than update
        while pos > 1:
            pos >>= 1
            self.tree[pos] = self.func(
                self.tree[pos<<1], self.
                tree[(pos<<1) + 1])
    def query(self, left, right):
        # Query the maximum value in
        # the range [left, right)
        left += self.n
        right += self.n
        # Change the initializer
        # depending upon the self.func
        max_val = float('-inf')
        ##
        while left < right:
            if left&1:
                max_val = self.func(
                    max_val, self.tree[
                        left])
            left += 1

```

```

if right&1:
    right -= 1
    max_val = self.func(
        max_val, self.tree[
            right])
left >>= 1
right >>= 1
return max_val
def __repr__(self):
    values = [str(self.query(i, i + 1)) for i in range(self.n)]
    return f"Seg[{''.join(values)}]"

```

Sparse Table

```

class SparseTable:
    @staticmethod
    def func(a, b):
        # func(a, a) should be a
        return gcd(a, b)
    def __init__(self, arr):
        self.n = len(arr)
        self.table = [[0 for i in range(int((math.log(self.n, 2)+1)))]] for j in range(self.n)]
        self.build(arr)
    def build(self, arr):
        for i in range(0, self.n):
            self.table[i][0] = arr[i]
        j = 1
        while (1 << j) <= self.n:
            i = 0
            while i <= self.n - (1 << j):
                self.table[i][j] = self.
                    func(self.table[i][j - 1], self.table[i + (1 << (j - 1))][j - 1])
                i += 1
            j += 1
    def query(self, L, R):
        # query from [L,R]
        j = int(math.log2(R - L + 1))
        return self.func(self.table[L][j], self.table[R - (1 << j) + 1][j])

```

BitArray

```

class BitSet:
    ADDRESS_BITS_PER_WORD = 12

```

```

BITS_PER_WORD = 1 <<
    ADDRESS_BITS_PER_WORD
WORD_MASK = -1
def __init__(self, sz):
    self.sz = sz
    self.words = [0] * (self.
        _wordIndex(sz - 1) + 1)
def __wordIndex(self, bitIndex):
    if bitIndex >= self.sz:
        raise ValueError("out of
            bound index", bitIndex)
    return bitIndex >> BitSet.
        ADDRESS_BITS_PER_WORD
def flip(self, bitIndex):
    wordIndex = self._wordIndex(
        bitIndex)
    self.words[wordIndex] ^= 1 <<
        (bitIndex % BitSet.
            BITS_PER_WORD)
def flip_range(self, l, r):
    startWordIndex = self.
        _wordIndex(l)
    endWordIndex = self._wordIndex(
        r)
    firstWordMask = BitSet.
        WORD_MASK << (l % BitSet.
            BITS_PER_WORD)
    rem = (r+1) % BitSet.
        BITS_PER_WORD
    lastWordMask = BitSet.
        WORD_MASK if rem == 0 else
            ~(BitSet.WORD_MASK << rem)
    if startWordIndex ==
        endWordIndex:
        self.words[startWordIndex]
            ^= (firstWordMask &
                lastWordMask)
    else:
        self.words[startWordIndex]
            ^= firstWordMask
        for i in range(
            startWordIndex + 1,
            endWordIndex):
            self.words[i] ^= BitSet.
                WORD_MASK
        self.words[endWordIndex] ^
            lastWordMask
def __setitem__(self, bitIndex,
    value):
    wordIndex = self._wordIndex(
        bitIndex)
    if value:
        self.words[wordIndex] |= 1
            << (bitIndex % BitSet.
                BITS_PER_WORD)
else:
    self.words[wordIndex] &=
        ~(1 << (bitIndex % BitSet.
            BITS_PER_WORD))
def __getitem__(self, bitIndex):
    wordIndex = self._wordIndex(
        bitIndex)
    return self.words[wordIndex] &
        (1 << (bitIndex % BitSet.
            BITS_PER_WORD)) != 0
def nextSetBit(self, fromIndex):
    wordIndex = self._wordIndex(
        fromIndex)
    word = self.words[wordIndex] &
        (BitSet.WORD_MASK << (
            fromIndex % BitSet.
            BITS_PER_WORD))
    while True:
        if word != 0:
            return wordIndex *
                BitSet.BITS_PER_WORD +
                (word & -word).
                bit_length() - 1
        wordIndex += 1
        if wordIndex > len(self.
            words) - 1:
            return -1
        word = self.words[wordIndex]
def nextClearBit(self, fromIndex):
    wordIndex = self._wordIndex(
        fromIndex)
    word = ~self.words[wordIndex] &
        (BitSet.WORD_MASK << (
            fromIndex % BitSet.
            BITS_PER_WORD))
    while True:
        if word != 0:
            index = wordIndex *
                BitSet.BITS_PER_WORD +
                (word & -word).
                bit_length() - 1
            return index if index <
                self.sz else -1
        wordIndex += 1
        if wordIndex > len(self.
            words) - 1:
            return -1
        word = ~self.words[
            wordIndex]
def lastSetBit(self):
    wordIndex = len(self.words) -
        1

```

```

word = self.words[wordIndex]
while wordIndex >= 0:
    if word != 0:
        return wordIndex *
            BitSet.BITS_PER_WORD +
            (word.bit_length() -
             1 if word > 0 else
             BitSet.BITS_PER_WORD -
             1)
    wordIndex -= 1
    word = self.words[wordIndex]
return -1
def __str__(self):
    res = []
    st = 0
    while True:
        i = self.nextSetBit(st)
        if i != -1:
            res += [0] * (i - st)
            j = self.nextClearBit(i)
            if j != -1:
                res += [1] * (j-i)
                st = j
            else:
                res += [1] * (self.sz -
                               i)
                break
        else:
            res += [0] * (self.sz -
                           st)
            break
    return "".join(str(v) for v in
                  res)
def __repr__(self):
    return "Bitset(%s)" % str(self)
def __iter__(self):
    for i in self[:]:
        yield i
def __len__(self):
    return self.sz
def __or__(self, other):
    if self.sz != other.sz:
        raise ValueError("BitSets
                          must be of equal size")
    res = BitSet(self.sz)
    res.words = [a | b for a, b in
                zip(self.words, other.words
                    )]
    return res
def __add__(self, other):
    if self.sz != other.sz:

```

```

raise ValueError("BitSets
    must be of equal size")
res = BitSet(self.sz)
carry = 0
for i in range(len(self.words)):
    total = self.words[i] +
        other.words[i] + carry
    res.words[i] = total &
        BitSet.WORD_MASK
    carry = total >> BitSet.
        BITS_PER_WORD
return res
def __and__(self, other):
    if self.sz != other.sz:
        raise ValueError("BitSets
                          must be of equal size")
    res = BitSet(self.sz)
    res.words = [a & b for a, b in
                zip(self.words, other.words
                    )]
    return res
def __xor__(self, other):
    if self.sz != other.sz:
        raise ValueError("BitSets
                          must be of equal size")
    res = BitSet(self.sz)
    res.words = [a ^ b for a, b in
                zip(self.words, other.words
                    )]
    return res
def __invert__(self):
    res = BitSet(self.sz)
    res.words = [~a & BitSet.
        WORD_MASK for a in self.
        words]
    return res
def add(self, val):
    self.flip_range(val, self.
        nextClearBit(val))
def rem(self, val):
    self.flip_range(val, self.
        nextSetBit(val))

```

```

start = stack[-1]
if not visited[start]:
    visited[start] = True
    for child in d[start]:
        if not visited[child]:
            stack.append(child)
else:
    stack.pop()
dp[start] += 1
for child in d[start]:
    if finished[child]:
        dp[start] += dp[child]
finished[start] = True
return dp
def dijkstra(d, start=0):
    n = len(d)
    dist = [float("inf")] * n
    # parents = [-1] * n
    dist[start] = 0
    queue = [(0, start)]
    while queue:
        path_len, v = heappop(queue)
        if path_len == dist[v]:
            for w, edge_len in d[v]:
                new_dist = edge_len +
                    path_len
                if new_dist < dist[w]:
                    dist[w] = new_dist
                    # parents[w] = v
                    heappush(queue, (
                        new_dist, w))
    return dist

```

Others

```

def euler_path(d):
    start = [1]
    ans = []
    while start:
        cur = start[-1]
        if len(d[cur]) == 0:
            ans.append(start.pop())
            continue
        k1 = d[cur].pop()
        d[k1].remove(cur) # if
                           undirected
        start.append(k1)
    return ans
def floyd_marshall(n, edges):
    dist = [[0 if i == j else float(
        "inf") for i in range(n)] for j
        in range(n)]

```

Graphs

Basics

```

def dfs(d, start=0):
    n = len(d)
    visited = [False] * n
    dp = [0] * n
    finished = [False] * n
    stack = [start]
    while stack:

```

```

pred = [[None] * n for _ in range(n)]
for u, v, d in edges:
    dist[u][v] = d
    pred[u][v] = u
for k in range(n):
    for i in range(n):
        for j in range(n):
            if dist[i][k] + dist[k][j] < dist[i][j]:
                dist[i][j] = dist[i][k] + dist[k][j]
                pred[i][j] = pred[k][j]
return dist, pred

def toposort(graph):
    res, found = [], [0] * len(graph)
    stack = list(range(len(graph)))
    while stack:
        node = stack.pop()
        if node < 0:
            res.append(~node)
        elif not found[node]:
            found[node] = 1
            stack.append(~node)
            stack += graph[node]
    for node in res:
        if any(found[nei] for nei in graph[node]):
            return None
    found[node] = 0
    return res[::-1]

```

Advance

```

INF = float("inf")
class Dinic:
    def __init__(self, n):
        self.lvl = [0] * n
        self.ptr = [0] * n
        self.q = [0] * n
        self.adj = [[] for _ in range(n)]
    def add_edge(self, a, b, c, rcap=0):
        self.adj[a].append([b, len(self.adj[b]), c, 0])
        self.adj[b].append([a, len(self.adj[a]) - 1, rcap, 0])
    def dfs(self, v, t, f):
        if v == t or not f:
            return f
        for i in range(self.ptr[v], len(self.adj[v])):

```

```

e = self.adj[v][i]
if self.lvl[e[0]] == self.lvl[v] + 1:
    p = self.dfs(e[0], t, min(f, e[2] - e[3]))
    if p:
        self.adj[v][i][3] += p
        self.adj[e[0]][e[1]][3] -= p
        return p
    self.ptr[v] += 1
return 0
def calc(self, s, t):
    flow, self.q[0] = 0, s
    for l in range(31): # l = 30
        maybe faster for random data
        while True:
            self.lvl, self.ptr = [0] * len(self.q), [0] * len(self.q)
            qi, qe, self.lvl[s] = 0, 1, 1
            while qi < qe and not self.lvl[t]:
                v = self.q[qi]
                qi += 1
                for e in self.adj[v]:
                    if not self.lvl[e[0]] and (e[2] - e[3]) >> (30 - l):
                        self.q[qe] = e
                        qe += 1
                        self.lvl[e[0]] = self.lvl[v] + 1
            p = self.dfs(s, t, INF)
            while p:
                flow += p
                p = self.dfs(s, t, INF)
                if not self.lvl[t]:
                    break
            return flow
class AuxiliaryTree:
    def __init__(self, edge, root = 0):
        self.n = len(edge)
        self.order = [-1] * self.n
        self.path = [-1] * (self.n - 1)
        self.depth = [0] * self.n
        if self.n == 1: return
        parent = [-1] * self.n
        que = [root]
        t = -1
        while que:
            u = que.pop()
            self.path[t] = parent[u]
            t += 1
            self.order[u] = t
            for v in edge[u]:
                if self.order[v] == -1:
                    que.append(v)
                    parent[v] = u
                    self.depth[v] = self.depth[u] + 1
        self.n -= 1
        self.h = self.n.bit_length()
        self.data = [0] * (self.n * self.h)
        self.data[:self.n] = [self.order[u] for u in self.path]
        for i in range(1, self.h):
            for j in range(self.n - (1 << i) + 1):
                self.data[i * self.n + j] = min(self.data[(i - 1) * self.n + j], self.data[(i - 1) * self.n + j + (1 << (i - 1))])
        def lca(self, u, v):
            if u == v: return u
            l = self.order[u]
            r = self.order[v]
            if l > r:
                l, r = r, l
            level = (r - 1).bit_length() - 1
            return self.path[min(self.data[level * self.n + l], self.data[level * self.n + r - (1 << level))])
        def dis(self, u, v):
            if u == v: return 0
            l = self.order[u]
            r = self.order[v]
            if l > r:
                l, r = r, l
            level = (r - 1).bit_length() - 1
            p = self.path[min(self.data[level * self.n + l], self.data[level * self.n + r - (1 << level))])
            return self.depth[u] + self.depth[v] - 2 * self.depth[p]

```

```

def make(self, vs):
    k = len(vs)
    vs.sort(key = self.order.
             __getitem__)
    par = dict()
    edge = dict()
    edge[vs[0]] = []
    st = [vs[0]]
    for i in range(k - 1):
        l = self.order[vs[i]]
        r = self.order[vs[i+1]]
        level = (r - l).bit_length()
        w = self.path[min(self.data.
                           [level * self.n + 1], self.
                           data[level * self.n + r
                                 -(1 << level))])
        if w != vs[i]:
            p = st.pop()
            while st and self.depth[w] < self.depth[st[-1]]:
                par[p] = st[-1]
                edge[st[-1]].append(p)
                p = st.pop()
            if not st or st[-1] != w:
                st.append(w)
                edge[w] = [p]
            else:
                edge[w].append(p)
                par[p] = w
            st.append(vs[i+1])
            edge[vs[i+1]] = []
    for i in range(len(st) - 1):
        edge[st[i]].append(st[i+1])
        par[st[i+1]] = st[i]
    par[st[0]] = -1
    return st[0], edge, par

class binary_lift:
    def __init__(self, graph, f=max,
                 root=0, flag=False):
        n = len(graph)
        parent = [-1] * (n + 1)
        depth = self.depth = [-1] * n
        bfs = [root]
        depth[root] = 0
        data = [0]*n
        for node in bfs:

```

```

# for nei,w in graph[node]:
for nei in graph[node]:
    if depth[nei] == -1:
        # data[nei] = w
        parent[nei] = node
        depth[nei] = depth[
            node] + 1
        bfs.append(nei)
parent = self.parent = [parent]
self.f = f
if flag:
    data = self.data = [data]
    for _ in range(max(depth).
                   bit_length()):
        old_data = data[-1]
        old_parent = parent[-1]
        data.append([f(val,
                       old_data[p]) for val,p
                       in zip(old_data,
                              old_parent)])
        parent.append([
            old_parent[p] for p in
            old_parent])
else:
    for _ in range(max(depth).
                   bit_length()):
        old_parent = parent[-1]
        parent.append([
            old_parent[p] for p in
            old_parent])
def lca(self, a, b):
    depth = self.depth
    parent = self.parent
    if depth[a] < depth[b]:
        a,b = b,a
    d = depth[a] - depth[b]
    for i in range(d.bit_length()):
        if (d >> i) & 1:
            a = parent[i][a]
    for i in range(depth[a].
                   bit_length())[::-1]:
        if parent[i][a] != parent[i][b]:
            a = parent[i][a]
            b = parent[i][b]
    if a != b:
        return parent[0][a]
    else:
        return a
def distance(self, a, b):
    return self.depth[a] + self.
        depth[b] - 2 * self.depth[
            self.lca(a,b)]

```

```

def kth_ancestor(self, a, k):
    parent = self.parent
    if self.depth[a] < k:
        return -1
    for i in range(k.bit_length()):
        if (k >> i) & 1:
            a = parent[i][a]
    return a
def __call__(self, a, b, c=0):
    depth = self.depth
    parent = self.parent
    data = self.data
    f = self.f
    c = self.lca(a, b)
    val = c
    for x,d in (a, depth[a] -
                depth[c]), (b, depth[b] -
                depth[c]):
        for i in range(d.bit_length()):
            if (d >> i) & 1:
                val = f(val, data[i][x])
                x = parent[i][x]
    return val

```

Graph-Flatten

```

def dfs(graph):
    starttime = [[0, 0] for i in range(
        len(graph))]
    time = 0
    stack = [(0, -1, 0)]
    while stack:
        cur, prev, state = stack.pop()
        if state == 0:
            starttime[cur][0] = time
            time += 1
            stack.append((cur, prev, 1))
        for neighbor in graph[cur]:
            if neighbor == prev:
                continue
            stack.append((neighbor,
                          cur, 0))
    elif state == 1:
        starttime[cur][1] = time
    return starttime

```

2-sat

```

def find_SCC(graph):
    SCC, S, P = [], [], []
    depth = [0] * len(graph)
    stack = list(range(len(graph)))

```

```

while stack:
    node = stack.pop()
    if node < 0:
        d = depth[~node] - 1
        if P[-1] > d:
            SCC.append(S[d:])
            del S[d:], P[-1]
            for node in SCC[-1]:
                depth[node] = -1
    elif depth[node] > 0:
        while P[-1] > depth[node]:
            P.pop()
    elif depth[node] == 0:
        S.append(node)
        P.append(len(S))
        depth[node] = len(S)
        stack.append(~node)
        stack += graph[node]
return SCC[::-1]

class TwoSat:
    def __init__(self, n):
        self.n = n
        self.graph = [[] for _ in range(2 * n)]
    def negate(self, x):
        return x + self.n if x < self.n else x - self.n
    def _imply(self, x, y):
        # agar x hoga, toh y hoga
        self.graph[x].append(y)
        self.graph[self.negate(y)].append(self.negate(x))
    def either(self, x, y):
        # koi ek true ho sakta hain ya dono bhi
        self._imply(self.negate(x), y)
        self._imply(self.negate(y), x)
    def set(self, x):
        self._imply(self.negate(x), x)
    def solve(self):
        SCC = find_SCC(self.graph)
        order = [0] * (2 * self.n)
        for i, comp in enumerate(SCC):
            for x in comp:
                order[x] = i
        for i in range(self.n):
            if order[i] == order[self.negate(i)]:
                return False, None
        return True, [+order[i] > order[self.negate(i)]] for i in range(self.n)

```

```

def find_bridges(adj):
    # returns all bridges
    bridges = []
    n = len(adj)
    timer = 0
    visited = [False] * n
    tin = [-1] * n
    low = [-1] * n
    for start in range(n):
        if visited[start]:
            continue
        stack = [(start, -1, 0, False)]
        visited[start] = True
        tin[start] = low[start] = timer
        timer += 1
        while stack:
            v, parent, idx, backtrack = stack.pop()
            if backtrack:
                to = adj[v][idx]
                low[v] = min(low[v], low[to])
                if low[to] > tin[v]:
                    bridges.append((v, to))
            continue
            if idx < len(adj[v]):
                to = adj[v][idx]
                stack.append((v, parent, idx + 1, False))
            if to == parent:
                continue
            if visited[to]:
                low[v] = min(low[v], tin[to])
            else:
                visited[to] = True
                tin[to] = low[to] = timer
                timer += 1
                stack.append((v, parent, idx, True))
                stack.append((to, v, 0, False))
        return bridges

def bridges_on_path(adj):
    # returns all bridges on path
    # from 1 to n
    n = len(adj)
    timer = 0
    visited = [False] * n

```

```

tin = [-1] * n
low = [-1] * n
bridges = []
for start in range(n):
    if visited[start]:
        continue
    stack = [(start, -1, 0, False)]
    visited[start] = True
    tin[start] = low[start] = timer
    timer += 1
    while stack:
        v, parent, idx, backtrack = stack.pop()
        if backtrack:
            to = adj[v][idx]
            low[v] = min(low[v], low[to])
            if low[to] > tin[v]:
                bridges.append((v, to))
        continue
        if idx < len(adj[v]):
            to = adj[v][idx]
            stack.append((v, parent, idx + 1, False))
        if to == parent:
            continue
        if visited[to]:
            low[v] = min(low[v], tin[to])
        else:
            visited[to] = True
            tin[to] = low[to] = timer
            timer += 1
            stack.append((v, parent, idx, True))
            stack.append((to, v, 0, False))
    comp_id = [-1] * n
    comp = 0
    bridge_set = set(bridges)
    for i in range(n):
        if comp_id[i] != -1:
            continue
        stack = [i]
        comp_id[i] = comp
        while stack:
            v = stack.pop()
            for to in adj[v]:
                if comp_id[to] == -1 and (v, to) not in

```

```

        bridge_set and (to, v) ||
        not in bridge_set: ||
        comp_id[to] = comp ||
        stack.append(to) ||
        comp += 1
tree = [[] for _ in range(comp)]
for u, v in bridges:
    cu, cv = comp_id[u], comp_id[v]
    tree[cu].append((cv, (u, v)))
    tree=cv.append((cu, (u, v)))
c1, cN = comp_id[0], comp_id[n-1]
if c1 == cN:
    return []
parent = {c1: None}
edge_used = {c1: None}
stack = [c1]
while stack:
    u = stack.pop()
    for v, e in tree[u]:
        if v not in parent:
            parent[v] = u
            edge_used[v] = e
            stack.append(v)
path_bridges = []
cur = cN
while cur != c1:
    path_bridges.append(edge_used[cur])
    cur = parent[cur]
return [(u, v) for u, v in path_bridges]

def lowlink(edge):
    n = len(edge)
    parent = [-1] * n
    visited = [False] * n
    for s in range(n):
        if not visited[s]:
            que = [s]
            while que:
                now = que.pop()
                if visited[now]:
                    continue
                visited[now] = True
                for nxt in edge[now]:
                    if not visited[nxt]:
                        parent[nxt] = now
                        que.append(nxt)
    order = [-1] * n
    low = [-1] * n
    is_articulation = [False] * n
    articulation = []
    bridge = []

```

```

def dfs(s):
    idx = 0
    cnt = 0
    que = [~s, s]
    while que:
        now = que.pop()
        if now >= 0:
            order[now] = low[now] = idx
            idx += 1
        for nxt in edge[now]:
            if parent[nxt] == now:
                que.append(~nxt)
                que.append(nxt)
            elif parent[now] != nxt and order[nxt] != -1:
                low[now] = min(low[now], order[nxt])
            else:
                now = ~now
                par = parent[now]
                if par == s: cnt += 1
                if now == s:
                    is_articulation[now] |= (cnt >= 2)
                if is_articulation[now]:
                    articulation.append(now)
                return
            if is_articulation[now]:
                articulation.append(now)
            if now != parent[par]:
                low[par] = min(low[par], low[now])
            is_articulation[par] |= (par != s and order[par] <= low[now])
            if order[par] < low[now]:
                bridge.append((par, now))
    for i in range(n):
        if parent[i] == -1:
            dfs(i)
    return articulation, bridge

def find_2ecc(edges, d):
    # returns a new graph, in which
    # two nodes are connected
    # if and only if they are part of

```

```

    same cycle.
    _, bridges = lowlink(d)
    newd = [[] for _ in range(len(d))]
    bridges = set((w(i[0]), w(i[1])))
    for i in bridges:
        for u, v in edges:
            if (w(u), w(v)) not in bridges
                and (w(v), w(u)) not in
                bridges:
                newd[u].append(v)
                newd[v].append(u)
    return newd

```

Strings

String Hashing

```

HMOD = 2147483647
HBASE1 = random.randrange(HMOD)
HBASE2 = random.randrange(HMOD)
class Hashing:
    def __init__(self, s, mod=HMOD,
                 base1=HBASE1, base2=HBASE2):
        self.mod = mod
        self.base1 = base1
        self.base2 = base2
        self._len = _len = len(s)
        f_hash, f_pow = [0] * (_len + 1), [1] * (_len + 1)
        for i in range(_len):
            f_hash[i + 1] = (base1 *
                             f_hash[i] + s[i]) % mod
            f_pow[i + 1] = base1 *
                           f_pow[i] % mod
        self.f_hash, self.f_pow =
            f_hash, f_pow
    def hashed(self, start, stop):
        return (self.f_hash[stop] -
                self.f_pow[stop - start] *
                self.f_hash[start]) % self.mod

```

String Functions

```

def LCPArray(L, SA=None):
    # Longest Common prefix in
    # between S[i:] and S[i+1:]
    if not SA:
        SA = SuffArr(L)
    n = len(L)
    rank = [0] * n
    for i in range(n):
        rank[SA[i]] = i
    LCP = [0] * (n - 1)
    k = 0

```

```

for i in range(n):
    l = rank[i]
    if l==n-1:
        k = 0
        continue
    j = SA[l+1]
    while i+k<n and L[i+k] == L[j+k]:
        k += 1
    LCP[l] = k
    k -= k > 0
return LCP

def z_function(S):
    # return: the Z array, where Z[i] = length of the longest common prefix of S[i:] and S
    n = len(S)
    Z = [0] * n
    l = r = 0
    for i in range(1, n):
        z = Z[i - 1]
        if i + z >= r:
            z = max(r - i, 0)
            while i + z < n and S[z] == S[i + z]:
                z += 1
            l, r = i, i + z
        Z[i] = z
    Z[0] = n
    return Z

def manacher(s):
    # returns longest palindrome in s
    t = '#' + '#'.join(s) + '#'
    n = len(t)
    L = [0] * n
    c = r = 0
    ml = 0
    mc = 0
    for i in range(n):
        mirror = 2*c-i
        if i<r:
            L[i] = min(r-i, L[mirror])
        a = i+L[i]+1
        b = i-L[i]-1
        while a<n and b>=0 and t[a]==t[b]:
            L[i] += 1
            a += 1
            b -= 1
        if i+L[i]>r:
            c = i
            r = i+L[i]
        if L[i]>ml:

```

```

            ml = L[i]
            mc = i
            start = (mc-ml)//2
            return s[start:start+ml]

def SuffArray(s):
    # Starting position of ith suffix
    # in lexicographic order
    s += "$"
    n = len(s)
    k = 0
    rank = [ord(c) for c in s]
    tmp = [0] * n
    sa = list(range(n))
    def sort_key(i):
        return (rank[i], rank[i + (1 << k)] if i + (1 << k) < n
               else -1)
    while True:
        sa.sort(key=sort_key)
        tmp[sa[0]] = 0
        for i in range(1, n):
            tmp[sa[i]] = tmp[sa[i-1]] +
                         (sort_key(sa[i-1]) != sort_key(sa[i]))
        rank, tmp = tmp, rank
        k += 1
        if (1 << k) >= n:
            break
    return sa

```

FFT

FFT

```

class FastFFT:
    # This is a bit faster, one log n factor is less but it's accuracy is not 100%
    # use this when coefficient does not matter (set coefficient to 1 repeatedly)
    # or you could just risk it :(
    def __init__(self, MOD=998244353):
        FastFFT.MOD = MOD
        # g = self.
        primitive_root_constexpr()
        g = 3
        ig = pow(g, FastFFT.MOD - 2, FastFFT.MOD)
        FastFFT.W = [pow(g, (FastFFT.MOD - 1) >> i, FastFFT.MOD)
                    for i in range(30)]
        FastFFT.iW = [pow(ig, (FastFFT.

```

```

                .MOD - 1) >> i, FastFFT.MOD)
                for i in range(30)]
def primitive_root_constexpr(self):
    if FastFFT.MOD == 998244353:
        return 3
    elif FastFFT.MOD == 200003:
        return 2
    elif FastFFT.MOD == 167772161:
        return 3
    elif FastFFT.MOD == 469762049:
        return 3
    elif FastFFT.MOD == 754974721:
        return 11
    divs = [0] * 20
    divs[0] = 2
    cnt = 1
    x = (FastFFT.MOD - 1) // 2
    while x % 2 == 0:
        x //= 2
    i = 3
    while i * i <= x:
        if x % i == 0:
            divs[cnt] = i
            cnt += 1
        while x % i == 0:
            x /= i
        i += 2
    if x > 1:
        divs[cnt] = x
        cnt += 1
    g = 2
    while 1:
        ok = True
        for i in range(cnt):
            if pow(g, (FastFFT.MOD - 1) // divs[i], FastFFT.MOD) == 1:
                ok = False
                break
        if ok:
            return g
        g += 1
def fft(self, k, f):
    for l in range(k, 0, -1):
        d = 1 << l - 1
        U = [1]
        for i in range(d):
            U.append(U[-1] * FastFFT.W[l] % FastFFT.MOD)
        for i in range(1 << k - l):
            for j in range(d):
                s = i * 2 * d + j
                f[s], f[s + d] = (f[s] + f[s + d]) %

```

```

        FastFFT.MOD, U[j] * ||
        (f[s] - f[s + d]) ||

def ifft(self, k, f):
    for l in range(1, k + 1):
        d = 1 << l - 1
        for i in range(1 << k - l):
            u = 1
            for j in range(i * 2 * d,
                            (i * 2 + 1) * d):
                f[j+d] *= u
                f[j], f[j + d] = (f[j]
                                   + f[j + d]) % FastFFT.MOD,
                (f[j] - f[j + d]) % FastFFT.MOD
            u = u * FastFFT.iW[l]
            % FastFFT.MOD

def convolve(self, A, B):
    n0 = len(A) + len(B) - 1
    k = (n0).bit_length()
    n = 1 << k
    A += [0] * (n - len(A))
    B += [0] * (n - len(B))
    self.fft(k, A)
    self.fft(k, B)
    A = [a * b % FastFFT.MOD for a,
         b in zip(A, B)]
    self.ifft(k, A)
    inv = pow(n, FastFFT.MOD - 2,
              FastFFT.MOD)
    del A[n0:]
    for i in range(n0):
        A[i] = (A[i]*inv)%FastFFT.
        MOD
    return A

class FFT:
    def __init__(self, MOD=998244353,
                 MOD1=469762049):
        FFT.MOD = MOD
        FFT.MOD1 = MOD1
        FFT.MOD2 = pow(MOD, MOD1-2, MOD1)
        FFT.mod_inv = (self.XT_GCD(MOD,
                                     MOD1)[1])%MOD1
        # g = self.
        primitive_root_constexpr()
        g = 3
        ig = pow(g, FFT.MOD - 2, FFT.
                  MOD)
        ig1 = pow(g, FFT.MOD1 - 2, FFT.
                  MOD1)
        FFT.W = [pow(g, (FFT.MOD - 1)
                     >> i, FFT.MOD) for i in
                 range(30)]

```

```

FFT.W1 = [pow(g, (FFT.MOD1 -
                   1) >> i, FFT.MOD1) for i in
          range(30)]
FFT.iW = [pow(ig, (FFT.MOD -
                   1) >> i, FFT.MOD) for i in
          range(30)]
FFT.iW1 = [pow(ig1, (FFT.MOD1 -
                   1) >> i, FFT.MOD1) for i in
          range(30)]
def primitive_root_constexpr(self):
    if FFT.MOD == 998244353:
        return 3
    elif FFT.MOD == 200003:
        return 2
    elif FFT.MOD == 167772161:
        return 3
    elif FFT.MOD == 469762049:
        return 3
    elif FFT.MOD == 754974721:
        return 11
    divs = [0] * 20
    divs[0] = 2
    cnt = 1
    x = (FFT.MOD - 1) // 2
    while x % 2 == 0:
        x /= 2
    i = 3
    while i * i <= x:
        if x % i == 0:
            divs[cnt] = i
            cnt += 1
            while x % i == 0:
                x /= i
        i += 2
    if x > 1:
        divs[cnt] = x
        cnt += 1
    g = 2
    while 1:
        ok = True
        for i in range(cnt):
            if pow(g, (FFT.MOD - 1)
                   // divs[i], FFT.MOD)
                   == 1:
                ok = False
                break
        if ok:
            return g
        g += 1
def fft(self, k, f, f1):
    for l in range(k, 0, -1):
        d = 1 << l - 1
        U = [(1, 1)]
        for i in range(d):

```

```

U.append((U[-1][0] * FFT.
          .W[l] % FFT.MOD, U
          [-1][1] * FFT.W1[l] %
          FFT.MOD1))
for i in range(1 << k - 1):
    for j in range(d):
        s = i * 2 * d + j
        f[s], f[s + d] = (f[s]
                           + f[s + d]) % FFT.
                           MOD, U[j][0] * (f[s]
                                         - f[s + d]) %
                                         FFT.MOD
        f1[s], f1[s + d] = (f1[s]
                             + f1[s + d]) %
                             FFT.MOD1, U[j][1]
                             * (f1[s] - f1[s +
                                         d]) % FFT.MOD1
def ifft(self, k, f, f1):
    for l in range(1, k + 1):
        d = 1 << l - 1
        for i in range(1 << k - l):
            u = 1
            for j in range(i * 2 * d,
                            (i * 2 + 1) * d):
                f[j+d] *= u
                f[j], f[j + d] = (f[j]
                                   + f[j + d]) % FFT.MOD,
                (f[j] - f[j + d]) % FFT.MOD
            u = u * FFT.iW[l]
            % FFT.MOD

def XT_GCD(self, a, b):
    if b == 0:
        return a, 1, 0
    g, x1, y1 = self.XT_GCD(b, a % b)
    x = y1
    y = x1 - (a // b) * y1
    return g, x, y
def CRT(self, a, mod1, b, mod2):
    k = (a + (b-a)*self.mod_inv%mod2
         *mod1)%(mod1*mod2)
    return k
def convolve(self, A, B):
    n0 = len(A) + len(B) - 1
    k = (n0).bit_length()
    n = 1 << k

```

```

A += [0] * (n - len(A))
B += [0] * (n - len(B))
A1 = A[:]
B1 = B[:]
self.fft(k, A, A1)
self.fft(k, B, B1)
A = [a * b % FFT.MOD for a, b
      in zip(A, B)]
A1 = [a * b % FFT.MOD1 for a,
      b in zip(A1, B1)]
self.ifft(k, A, A1)
inv = pow(n, FFT.MOD - 2, FFT.
          MOD)
inv1 = pow(n, FFT.MOD1 - 2,
            FFT.MOD1)
del A[n0:]
for i in range(n0):
    A[i] = self.CRT(A[i]*inv,
                      FFT.MOD, A1[i]*inv1, FFT.
                      MOD1)
return A

```

FWHT

```

def fwht(a, invert=False):
    # In-place Fast Walsh Hadamard
    # Transform for XOR convolution.
    # invert: if True, computes
    # inverse transform
    n = len(a); step = 1
    while step < n:
        for i in range(0, n, step*2):
            for j in range(step):
                a[i+j], a[i+j+step] = a[i+j]
                           + j + a[i+j+step], a[i+j]
                           - a[i+j+step]
        step *= 2
    if invert:
        for i in range(n):
            a[i] /= n

def fwt_or(a, invert=False):
    n = len(a); step = 1
    while step < n:
        for i in range(0, n, step*2):
            for j in range(step):
                u = a[i+j]
                v = a[i+j+step]
                if not invert:
                    a[i+j+step] = u+v
                else:
                    a[i+j+step] = v-u
        step *= 2

def fwt_and(a, invert=False):
    n = len(a); step = 1

```

```

while step < n:
    for i in range(0, n, step*2):
        for j in range(step):
            u = a[i+j]
            v = a[i+j+step]
            if not invert:
                a[i+j] = u+v
            else:
                a[i+j] = u-v
        step *= 2

def convolution(A, B, fwt=fwht):
    # Computes XOR convolution of
    # arrays A and B using FWHT
    # res[i] = summation of A[j]*B[k]
    # such that j xor k = i
    n = 1; x = max(len(A), len(B))
    while n < x: n <<= 1
    n <<= 1
    fa = A + [0] * (n - len(A))
    fb = B + [0] * (n - len(B))
    fwt(fa)
    fwt(fb)
    for i in range(n):
        fa[i] *= fb[i]
    fwt(fa, invert=True)
    return fa

```

Miscellaneous

Bootstrap

```

from types import GeneratorType
def bootstrap(f, stack=[]):
    def wrappedfunc(*args, **kwargs):
        if stack:
            return f(*args, **kwargs)
        to = f(*args, **kwargs)
        while True:
            if type(to) is
                GeneratorType:
                stack.append(to)
                to = next(to)
            else:
                stack.pop()
                if not stack:
                    break
                to = stack[-1].send(to)
        return to
    return wrappedfunc

```

Utils

```

getcontext().prec = 50; sys.
setrecursionlimit(10**6)

```

```

sys.set_int_max_str_digits(10**5)
import builtins
globals()['print'] = lambda *args,
    **kwargs: builtins.print(*args,
                             flush=True, **kwargs)
interactive()

```

Definitions

Extended GCD Computes x, y s.t. $ax + by = \gcd(a, b)$.

CRT Finds smallest a satisfying $a \equiv b_i \pmod{m_i}$.

$\phi(n)$ Count of integers $< n$ coprime with n .

Suffix Array Starting indices of suffixes sorted lexicographically.

Euler Path Uses every edge exactly once.

Bridge Edge whose removal increases components.

Articulation Point Vertex whose removal increases components.

2ECC Maximal subgraph where every pair lies on a cycle.

C++ Notes

Use `get<i>(tuple)` for tuple access.
Custom sort: `[](auto& a, auto& b){return get<2>(a)<get<2>(b);}`
2D vector init: `vector<vector<int>> dp(n, vector<int>(m, 0));`
Prefer `emplace_back` for complex objects.
Min-heap: `priority_queue<pi, vector<pi>, greater<pi> pq;`

CP - C++

```

#include <bits/stdc++.h>
#include <ext/pb_ds/assoc_container.
    hpp>
#include <ext/pb_ds/tree_policy.hpp>
using namespace __gnu_pbds;
using namespace std;

#define int long long
#define INF LLONG_MAX
#define fastio ios::sync_with_stdio(
    false); cin.tie(0);

```

```

#define len(arr) arr.size()
#define f first
#define s second
#define pb push_back
using vi = vector<int>;
using vvi = vector<vector<int>>;
using pi = pair<int,int>;
#pragma GCC optimize("O3,unroll-loops")
#pragma GCC target("avx2,bmi,bmi2, lzcnt,popcnt")
template <typename T>
using ordered_multiset = tree<
    std::pair<T, int>,
    null_type,
    std::less<std::pair<T, int>>,
    rb_tree_tag,
    tree_order_statistics_node_update
>;
int II(){int a;cin>>a;return a;}
string SI(){string s;cin>>s;return s
;}
vi LII(int n){vi a(n);cin>>a;return a;}
void solve() {
}
int32_t main() {
    fastio
    int t=1;
    cin >> t;
    while (t--) solve();
    return 0;
}

```

Sorted List - C++

```

template <typename T>
class SortedList {
    ordered_multiset<T> os;
    int uid = 0;
public:
    void insert(T x) {
        os.insert({x, uid++});
    }
    void erase_one(T x) {
        auto it = os.lower_bound({x, 0});
        if (it != os.end() && it->first == x)
            os.erase(it);
    }
}

```

```

    }
    int index(T x) {
        return os.order_of_key({x, 0});
    }
    int count(T x) {
        return os.order_of_key({x, INT_MAX}) - os.order_of_key({x, 0});
    }
    T operator[](int k) {
        return os.find_by_order(k)->first;
    }
    int size() const {
        return os.size();
    }
    void print() {
        for (int i = 0; i < size(); i++)
            std::cout << (*this)[i]
            << " ";
        std::cout << "\n";
    }
};

```

Lazy Segment Tree - C++

```

class SegmentTree {
public:
    int n;
    vector<int> tree;
    vector<int> lazy_add;
    vector<int> lazy_set;
    int NO_ASSIGNMENT = LLONG_MIN;
    SegmentTree(vector<int>& arr) {
        n = arr.size();
        tree.assign(4 * n, 0);
        lazy_add.assign(4 * n, 0);
        lazy_set.assign(4 * n,
                        NO_ASSIGNMENT);
        build_tree(1, 0, n - 1, arr);
    }
    static int func(int a, int b) {
        return a + b;
    }
    void build_tree(int node, int start, int end, vector<int>& arr) {
        if (start == end) {
            tree[node] = arr[start];
        } else {
            int mid = start + (end - start) / 2;

```

```

            build_tree(2 * node, start,
                       mid, arr);
            build_tree(2 * node + 1,
                       mid + 1, end, arr);
            tree[node] = func(tree[2 * node],
                               tree[2 * node + 1]);
        }
    }
    void propagate_lazy(int node, int start, int end) {
        int current_range_size = (end - start + 1);
        if (lazy_set[node] != NO_ASSIGNMENT) {
            tree[node] = lazy_set[node]
                * current_range_size;
            if (start != end) {
                lazy_set[2 * node] =
                    lazy_set[node];
                lazy_set[2 * node + 1] =
                    lazy_set[node];
                lazy_add[2 * node] = 0;
                lazy_add[2 * node + 1] = 0;
            }
            lazy_set[node] =
                NO_ASSIGNMENT;
        }
        if (lazy_add[node] != 0) {
            tree[node] += lazy_add[node]
                * current_range_size;
            if (start != end) {
                lazy_add[2 * node] +=
                    lazy_add[node];
                lazy_add[2 * node + 1] +=
                    lazy_add[node];
            }
            lazy_add[node] = 0;
        }
    }
    void update(int node, int start, int end, int l, int r, int value, bool is_add) {
        propagate_lazy(node, start, end);
        if (start > r || end < l) {
            return;
        }
        if (start >= l && end <= r) {
            if (is_add) {
                tree[node] += value *
                    (end - start + 1);
                if (start != end) {

```

```

        lazy_add[2 * node] += ||
            value;
        lazy_add[2 * node +
            1] += value;
    } else {
        tree[node] = value * (
            end - start + 1);
        if (start != end) {
            lazy_set[2 * node] =
                value;
            lazy_set[2 * node +
                1] = value;
            lazy_add[2 * node] =
                0;
            lazy_add[2 * node +
                1] = 0;
        }
    }
    return;
}
int mid = start + (end - start) / 2;
update(2 * node, start, mid, l,
       r, value, is_add);
update(2 * node + 1, mid + 1,
       end, l, r, value, is_add);
tree[node] = func(tree[2 * node],
                   tree[2 * node + 1]);
}
int query(int node, int start,
          int end, int l, int r) {
    propagate_lazy(node, start,
                   end);
    if (start > r || end < l) {
        return 0;
    }
    if (start >= l && end <= r) {
        return tree[node];
    }
    int mid = start + (end - start) / 2;
    return func(query(2 * node,
                      start, mid, l, r),
                query(2 * node + 1, mid + 1, end, l,
                      r));
}
void range_update(int l, int r,
                  int value, bool is_add = true)
{
    update(1, 0, n - 1, l, r,
           value, is_add);
}
int range_query(int l, int r) {

```

```

        return query(1, 0, n - 1, l, r);
    }
    vector<int> to_list() {
        vector<int> result(n);
        for (int i = 0; i < n; ++i) {
            result[i] = range_query(i,
                                     i);
        }
        return result;
    }
}
```

FFT - C++

```

class FFT {
public:
    static const int MOD = 998244353;
    static const int MOD1 =
        469762049;
    int MOD2, mod_inv;
    vector<int> W, W1, iW, iW1;
    FFT() {
        MOD2 = power(MOD, MOD1 - 2,
                      MOD1);
        mod_inv = XT_GCD(MOD, MOD1).second %
            MOD1;
        int g = 3;
        int ig = power(g, MOD - 2, MOD);
        int ig1 = power(g, MOD1 - 2,
                         MOD1);
        W.resize(30); W1.resize(30);
        iW.resize(30); iW1.resize
            (30);
        for (int i = 0; i < 30; ++i) {
            W[i] = power(g, (MOD - 1)
                          >> i, MOD);
            W1[i] = power(g, (MOD1 - 1)
                           >> i, MOD1);
            iW[i] = power(ig, (MOD - 1)
                          >> i, MOD);
            iW1[i] = power(ig1, (MOD1 -
                1) >> i, MOD1);
        }
    }
    int power(int base, int exp, int
              mod) {
        int res = 1;
        while (exp) {
            if (exp % 2) res = res *
                base % mod;
            base = base * base % mod;
            exp /= 2;
        }
    }
}
```

```

    }
    return res;
}
pair<int, int> XT_GCD(int a, int
                      b) {
    if (b == 0) return {a, 1};
    pair<int, int> k9 = XT_GCD(b, a %
        b);
    int g = k9.first; int x1 = k9.
        second;
    return {g, x1 - (a / b) * x1};
}
int CRT(int a, int mod1, int b,
        int mod2) {
    return (a + (b - a) * mod_inv %
        mod2 * mod1) % (mod1 * mod2);
}
void fft(int k, vector<int>& f,
         vector<int>& f1) {
    for (int l = k; l > 0; --l) {
        int d = 1 << (l - 1);
        vector<pair<int, int>> U =
            {{1, 1}};
        for (int i = 0; i < d; ++i)
            U.emplace_back(U.back().first *
                            W[1] % MOD, U.
                            back().second * W1[1]
                            % MOD1);
        for (int i = 0; i < (1 << (k -
            l)); ++i) {
            for (int j = 0; j < d;
                 ++j) {
                int s = i * 2 * d + j;
                int tmp_f = f[s] - f[s +
                    d];
                int tmp_f1 = f1[s] -
                    f1[s + d];
                f[s] = (f[s] + f[s +
                    d]) % MOD;
                f[s + d] = U[j].first *
                    tmp_f % MOD;
                f1[s] = (f1[s] + f1[s +
                    d]) % MOD1;
                f1[s + d] = U[j].second *
                    tmp_f1 % MOD1;
            }
        }
    }
}
void ifft(int k, vector<int>& f,
          vector<int>& f1) {

```

```

for (int l = 1; l <= k; ++l) {
    int d = 1 << (l - 1);
    for (int i = 0; i < (1 << (k - l)); ++i) {
        int u = 1, u1 = 1;
        for (int j = i * 2 * d; j < (i * 2 + 1) * d; ++j) {
            f[j + d] = f[j + d] *
                u % MOD;
            f[j] = (f[j] + f[j + d]) % MOD;
            f[j + d] = (f[j] - f[j + d] + MOD) % MOD;
            u = u * iW[l] % MOD;
            f1[j + d] = f1[j + d] *
                u1 % MOD1;
            f1[j] = (f1[j] + f1[j + d]) % MOD1;
            f1[j + d] = (f1[j] - f1[j + d] + MOD1) % MOD1;
            u1 = u1 * iW1[l] %
                MOD1;
        }
    }
}
vector<int> convolve(vector<int> A, vector<int> B) {
    int n0 = A.size() + B.size() -
        1;
    int k = 0;
    while ((1 << k) < n0) ++k;
    int n = 1 << k;
    A.resize(n, 0);
    B.resize(n, 0);
    vector<int> A1 = A, B1 = B;
    fft(k, A, A1);
    fft(k, B, B1);
    for (int i = 0; i < n; ++i) {
        A[i] = A[i] * B[i] % MOD;
        A1[i] = A1[i] * B1[i] %
            MOD1;
    }
    ifft(k, A, A1);
    int inv = power(n, MOD - 2,
        MOD);
    int inv1 = power(n, MOD1 - 2,
        MOD1);
    A.resize(n0);
    for (int i = 0; i < n0; ++i) {
        A[i] = CRT(A[i] * inv % MOD
            , MOD, A1[i] * inv1 %

```