1 STL Useful Tips

1.1 Common libraries

1.2 I/O

1.3 Useful constant

1.4 Space waster

1.5 Tricks in cmath

1.6 Initialize array with predefined value

1.7 Modifying sequence operations

1.8 Merge

1.9 String

1.10 Heap

1.11 Sort

1.12 Permutations

1.13 Searching

1.14 Random algorithm

2 Number Theory

2.1 Prime number under 100

2.5 If prime number

2.6 Prime factorization

2.7 Leap year

2.8 Binary exponential

2.10 Factorial mod

2.11 Generate combinations

2.12 10-ary to m-ary

2.13 m-ary to 10-ary

2.14 Binomial coefficient

2.15 Catalan numbers

2.16 Eulerian numbers

2.17 Karatsuba algorithm in Java

2.18 Euler’s totient function

2.19 Split plane

3 Searching Algorithms

3.1 Find rank k in array

3.2 KMP Algorithm

4 Dynamic Programming

4.1 0/1 Knapsack problems

4.2 Complete Knapsack problems

4.3 Longest common subsequence (LCS)

4.4 Longest increasing common sequence (LICS)

4.5 Longest Increasing Subsequence (LIS) 4.6 Maximum submatrix

4.7 Partitions of integers

4.8 Partitions of sets

5 Trees

5.1 Tree traversal

5.2 Depth and width of tree

6 Graph Theory 19

6.1 Graph representation

6.2 Flood fill algorithm

6.3 SPFA — shortest path

6.4 Floyd-Warshall algorithm – shortest path of all pairs

6.5 Prim — minimum spanning tree

6.6 Eulerian circuit

6.7 Topological sort

7 Individual Templates

7.1 Template by Rakib

7.2 Template by Faisal

7.3 Template by Rizu

**1 STL Useful Tips**

1.1 Common libraries

/\*\*\* Functions \*\*\*/

#include<algorithm>

#include<functional> // for hash

#include<climits> // all useful constants

#include<cmath>

#include<cstdio>

#include<cstdlib> // random

#include<ctime>

#include<iostream>

#include<sstream>

#include<iomanip> // right justifying std::right and std::setw(width)

/\*\*\* Data Structure \*\*\*/

#include<deque> // double ended queue

#include<list>

#include<queue> // including priority\_queue

#include<stack>

#include<string>

#include<vector>

**1.2 I/O**

// iostream and cstdio are both using I/O streams

// However, they have different behavior,

// pay attention on them if you’re using them together.

// cin does not concern with ’\n’ at end of each line

// however scanf or getline does concern with ’\n’ at end of each line

// ’\n’ will be ignored when you use cin to read char.

// when you use getline(cin, str) to read a whole line of input

// please add an extra getline before inputing if previous inputs are numbers

cin >> n;

getline(cin, str) // wasted getline

getline(cin, str) // real input string

1.3 Useful constant

INT\_MIN

INT\_MAX

LONG\_MIN

LONG\_MAX

LLONG\_MIN

LLONG\_MAX

(~0u) // infinity (for long and long long)

// use (~0u)>>2 for int.

**1.4 Space waster**

// consider to redefine data types to void data range problem

#define int long long // make everyone long long

#define double long double // make everyone long double

// function definitions

#undef int // main must return int

int main(void)

#define int long long // redefine int

// rest of program

1.5 Tricks in cmath

// when the number is too large. use powl instead of pow.

// will provide you more accuracy.

powl(a, b)

(int)round(p, (1.0/n)) // nth root of p

1.6 Initialize array with predefined value

// for 1d array, use STL fill\_n or fill to initialize array

fill(a, a+size\_of\_a, value)

fill\_n(a, size\_of\_a, value)

// for 2d array, if want to fill in 0 or -1

memset(a, 0, sizeof(a));

// otherwise, use a loop of fill or fill\_n through every a[i]

fill(a[i], a[i]+size\_of\_ai, value) // from 0 to number of row.

1.7 Modifying sequence operations

void copy(first, last, result);

void swap(a,b);

void swap(first1, last1, first2); // swap range

void replace(first, last, old\_value, new\_value); // replace in range

void replace\_if(first, last, pred, new\_value); // replace in conditions

// pred can be represented in function

// e.x. bool IsOdd (int i) { return ((i%2)==1); }

void reverse(first, last); // reverse a range of elements

void reverse\_copy(first, last, result); // copy a reverse of range of elements

void random\_shuffle(first, last); // using built-in random generator to shuffle array

1.8 Merge

// merge sorted ranges

void merge(first1, last1, first2, last2, result, comp);

// union of two sorted ranges

void set\_union(first1, last1, first2, last2, result, comp);

// intersection of two sorted ranges

void set\_interaction(first1, last1, first2, last2, result, comp);

// difference of two sorted ranges

void set\_difference((first1, last1, first2, last2, result, comp);

1.9 String

// Searching

unsigned int find(const string &s2, unsigned int pos1 = 0);

unsigned int rfind(const string &s2, unsigned int pos1 = end);

unsigned int find\_first\_of(const string &s2, unsigned int pos1 = 0);

unsigned int find\_last\_of(const string &s2, unsigned int pos1 = end);

unsigned int find\_first\_not\_of(const string &s2, unsigned int pos1 = 0);

unsigned int find\_last\_not\_of(const string &s2, unsigned int pos1 = end);

// Insert, Erase, Replace

string& insert(unsigned int pos1, const string &s2);

string& insert(unsigned int pos1, unsigned int repetitions, char c);

string& erase(unsigned int pos = 0, unsigned int len = npos);

string& replace(unsigned int pos1, unsigned int len1, const string &s2);

string& replace(unsigned int pos1, unsigned int len1, unsigned int repetitions, char c);

// String streams

stringstream s1;

int i = 22;

s1 << "Hello world! " << i;

cout << s1.str() << endl;

1.10 Heap

template <class RandomAccessIterator>

void push\_heap (RandomAccessIterator first, RandomAccessIterator last);

template <class RandomAccessIterator, class Compare>

void push\_heap (RandomAccessIterator first, RandomAccessIterator last,

                                    Compare comp);

                    template <class RandomAccessIterator>

                    void pop\_heap (RandomAccessIterator first, RandomAccessIterator last);

                    template <class RandomAccessIterator, class Compare>

                    void pop\_heap (RandomAccessIterator first, RandomAccessIterator last,

                                   Compare comp);

                    template <class RandomAccessIterator>

                    void make\_heap (RandomAccessIterator first, RandomAccessIterator last);

                    template <class RandomAccessIterator, class Compare>

                    void make\_heap (RandomAccessIterator first, RandomAccessIterator last,

                                    Compare comp );

                    template <class RandomAccessIterator>

                    void sort\_heap (RandomAccessIterator first, RandomAccessIterator last);

                    template <class RandomAccessIterator, class Compare>

                    void sort\_heap (RandomAccessIterator first, RandomAccessIterator last,

                                    Compare comp);

                    template <class RandomAccessIterator>

                    RandomAccessIterator is\_heap\_until (RandomAccessIterator first,

                            RandomAccessIterator last);

                    template <class RandomAccessIterator, class Compare>

                    RandomAccessIterator is\_heap\_until (RandomAccessIterator first,

                            RandomAccessIterator last

                            Compare comp);

                    1.11 Sort

                    void sort(iterator first, iterator last);

                    void sort(iterator first, iterator last, LessThanFunction comp);

                    void stable\_sort(iterator first, iterator last);

                    void stable\_sort(iterator first, iterator last, LessThanFunction comp);

                    void partial\_sort(iterator first, iterator middle, iterator last);

                    void partial\_sort(iterator first, iterator middle, iterator last, LessThanFunction comp);

                    bool is\_sorted(iterator first, iterator last);

                    bool is\_sorted(iterator first, iterator last, LessThanOrEqualFunction comp);

// example for sort, if have array x, start\_index, end\_index;

                    sort(x+start\_index, x+end\_index);

                    /\*\* sort a map \*\*/

// You cannot directly sort a map<key type, mapped data type>

// if you only want to sort in key type

// you can use insert method to copy map into another map

// b.insert(make\_pair(it->first, it->second) /\* it is a map iterator \*/

// this will result a map which sorts key type in increasing order

// if you want to sort key type in decreasing order, then declare your map as

// something like:

// map<char, int, greater<char> >

// if you want to sort based on key, you need to copy the data to a vector

// where elements of vector are pair.

// you can define a PAIR type by using:

                    typedef pair<char, int> PAIR;

// suppose this is the map

                    map<char, int> a;

// sort vector in decreasing order

                    bool cmp\_by\_value(const PAIR& lhs, const PAIR& rhs)

{

    return lhs.second > rhs.second;

}

// sort key in increasing order

bool cmp\_by\_char(const PAIR& lhs, const PAIR& rhs)

{

    return lhs.first < rhs.first;

}

// copy map data to vector

vector<PAIR> b(a.begin(), a.end());

// sort data

sort(b.begin(), b.end(), cmp\_by\_value);

// you can still call your data by b[i].first and b[i].second.

// THE ABOVE CODES ARE EXAMPLE FOR SORTING A MAP.

// PLEASE USE IT FOR YOUR OWN DEMANDS.

1.12 Permutations

bool next\_permutation(iterator first, iterator last);

bool next\_permutation(iterator first, iterator last, LessThanOrEqualFunction comp);

bool prev\_permutation(iterator first, iterator last);

bool prev\_permutation(iterator first, iterator last, LessThanOrEqualFunction comp);

1.13 Searching

// will return address of iterator, call result as \*iterator;

iterator find(iterator first, iterator last, const T &value);

iterator find\_if(iterator first, iterator last, const T &value, TestFunction test);

bool binary\_search(iterator first, iterator last, const T &value);

bool binary\_search(iterator first, iterator last, const T &value, LessThanOrEqualFunction comp);

1.14 Random algorithm

srand(time(NULL));

// generate random numbers between [a,b)

rand() % (b - a) + a;

// generate random numbers between [0,b)

rand() % b;

// generate random permutations

random\_permutation(anArray, anArray + 10);

random\_permutation(aVector, aVector + 10);

**2 Number Theory**

**2.1 Prime number under 100**

// there are 25 numbers

2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31, 37,

41, 43, 47, 53, 59, 61, 67, 71, 73, 79, 83, 89, 97

**2.5 If prime number**

bool prime(int n)

{

    if (n<2) return false;

    if (n<=3) return true;

    if (!(n%2) || !(n%3)) return false;

    for (int i=5; i\*i<=n; i+=6)

        if (!(n%i) || !(n%(i+2))) return false;

    return true;

}

2.6 Prime factorization

// smallest prime factor of a number.

function factor(int n)

{

    int a;

    if (n%2==0)

        return 2;

    for (a=3; a<=sqrt(n); a++++)

    {

        if (n%a==0)

            return a;

    }

    return n;

}

// complete factorization

int r;

while (n>1)

{

r = factor(n);

    printf("%d", r);

    n /= r;

}

**2.7 Leap year**

bool isLeap(int n)

{

    if (n%100==0)

        if (n%400==0) return true;

        else return false;

    if (n%4==0) return true;

    else return false;

}

**2.8 Binary exponiential**

int binpow (int a, int n)

{

    int res = 1;

    while (n)

        if (n & 1)

        {

            res \*= a;

            --n;

        }

        else

        {

            a \*= a;

            n >>= 1;

        }

    return res;

}

**2.9 a**

**b mod p**

long powmod(long base, long exp, long modulus)

{

    base %= modulus;

    long result = 1;

    while (exp > 0)

    {

        if (exp & 1) result = (result \* base) % modulus;

        base = (base \* base) % modulus;

        exp >>= 1;

    }

    return result;

}

**2.10 Factorial mod**

**//n! mod p**

int factmod (int n, int p)

{

    long long res = 1;

    while (n > 1)

    {

        res = (res \* powmod (p-1, n/p, p)) % p;

        for (int i=2; i<=n%p; ++i)

            res=(res\*i) %p;

        n /= p;

    }

    return int (res % p);

}

**2.11 Generate combinations**

// n>=m, choose M numbers from 1 to N.

void combination(int n, int m)

{

    if (n<m) return ;

    int a[50]= {0};

    int k=0;

    for (int i=1; i<=m; i++) a[i]=i;

    while (true)

    {

        for (int i=1; i<=m; i++)

            cout << a[i] << " ";

        cout << endl;

        k=m;

        while ((k>0) && (n-a[k]==m-k)) k--;

        if (k==0) break;

        a[k]++;

        for (int i=k+1; i<=m; i++)

            a[i]=a[i-1]+1;

    }

}

2.12 10-ary to m-ary

char a[16]= {’0’,’1’,’2’,’3’,’4’,’5’,’6’,’7’,’8’,’9’,

             ’A’,’B’,’C’,’D’,’E’,’F’

            };

            string tenToM(int n, int m)

{

    int temp=n;

    string result="";

    while (temp!=0)

    {

        result=a[temp%m]+result;

        temp/=m;

    }

    return result;

}

**2.13 m-ary to 10-ary**

string num="0123456789ABCDE";

           int mToTen(string n, int m)

{

    int multi=1;

    int result=0;

    for (int i=n.size()-1; i>=0; i--)

    {

        result+=num.find(n[i])\*multi;

        multi\*=m;

    }

    return result;

}

**2.14 Binomial coefficient**

#define MAXN 100 // largest n or m

long binomial\_coefficient(n,m) // compute n choose m

int n,m;

{

    int i,j;

    long bc[MAXN][MAXN];

    for (i=0; i<=n; i++) bc[i][0] = 1;

    for (j=0; j<=n; j++) bc[j][j] = 1;

    for (i=1; i<=n; i++)

        for (j=1; j<i; j++)

            bc[i][j] = bc[i-1][j-1] + bc[i-1][j];

    return bc[n][m];

}

2.15 Catalan numbers

Cn =

    nX−1

    k=0

      CkCn−1−k =

          1

          n + 1

          n

          k

          (1)

          The first terms of this sequence are 2, 5, 14, 42, 132, 429, 1430 when C0 = 1. This is the number of ways to build a balanced

                  formula from n sets of left and right parentheses. It is also the number of triangulations of a convex polygon, the number of

    rooted binary tress on n + 1 leaves and the number of paths across a lattice which do not rise above the main diagonal.

        2.16 Eulerian numbers

        n

        k

        = k

          n − 1

          k

          + (n − k + 1)

          n − 1

          k − 1

          (2)

// This is the number of permutations of length n with exactly k ascending sequences or runs.

// Basis: k=0 has value 1

#define MAXN 100 // largest n or k

          long eularian(n,k)

          int n,m;

{

    int i,j;

    long e[MAXN][MAXN];

    for (i=0; i<=n; i++) e[i][0] = 1;

    for (j=0; j<=n; j++) e[0][j] = 0;

    for (i=1; i<=n; i++)

        for (j=1; j<i; j++)

            e[i][j] = k\*e[i-1][j] + (i-j+1)\*e[i-1][j-1];

    return e[n][k];

}

**2.17 Karatsuba algorithm in Java**

// fast algorithm to find multiplication of two big numbers.

import java.math.BigInteger;

import java.util.Random;

class Karatsuba

{

    private final static BigInteger ZERO = new BigInteger("0");

    public static BigInteger karatsuba(BigInteger x, BigInteger y)

    {

        int N = Math.max(x.bitLength(), y.bitLength());

        if (N <= 2000) return x.multiply(y);

        N=(N/2)+(N %2);

        BigInteger b = x.shiftRight(N);

        BigInteger a = x.subtract(b.shiftLeft(N));

        BigInteger d = y.shiftRight(N);

        BigInteger c = y.subtract(d.shiftLeft(N));

        BigInteger ac = karatsuba(a, c);

        BigInteger bd = karatsuba(b, d);

        BigInteger abcd = karatsuba(a.add(b), c.add(d));

        return ac.add(abcd.subtract(ac).subtract(bd).shiftLeft(N)).add(bd.shiftLeft(2\*N));

    }

    public static void main(String[] args)

    {

        long start, stop, elapsed;

        Random random = new Random();

        int N = Integer.parseInt(args[0]);

        BigInteger a = new BigInteger(N, random);

        BigInteger b = new BigInteger(N, random);

        start = System.currentTimeMillis();

        BigInteger c = karatsuba(a, b);

        stop = System.currentTimeMillis();

        System.out.println(stop - start);

        start = System.currentTimeMillis();

        BigInteger d = a.multiply(b);

        stop = System.currentTimeMillis();

        System.out.println(stop - start);

        System.out.println((c.equals(d)));

    }

}

2.18 Euler’s totient function

// the positive integers less than or equal to n that are relatively prime to n.

int phi (int n)

{

    int result = n;

    for (int i=2; i\*i<=n; ++i)

        if(n %i==0)

        {

            while(n %i==0)

                n /= i;

            result -= result / i;

        }

    if (n > 1)

        result -= result / n;

    return result;

}

**2.19 Split plane**

n lines can split a plane in (n+1)n

2 + 1 sub-regions.

3 Searching Algorithms

**3.1 Find rank k in array**

int find(int l, int r, int k)

{

    int i=0,j=0,x=0,t=0;

    if (l==r) return a[l];

    x=a[(l+r)/2];

    t=a[x];

    a[x]=a[r];

    a[r]=t;

    i=l-1;

    for (int j=l; j<=r-1; j++)

        if (a[j]<=a[r])

        {

            i++;

            t=a[i];

            a[i]=a[j];

            a[j]=t;

        }

    i++;

    t=a[i];

    a[i]=a[r];

    a[r]=t;

    if (i==k) return a[i];

    if (i<k) return find(i+1, r,k);

    return find(l, i-1, k);

}

**3.2 KMP Algorithm**

#include <iostream>

#include <string>

#include <vector>

using namespace std;

typedef vector<int> VI;

void buildTable(string& w, VI& t)

{

    t = VI(w.length());

    int i = 2, j = 0;

    t[0] = -1;

    t[1] = 0;

    while(i < w.length())

    {

        if(w[i-1] == w[j])

        {

            t[i] = j+1;

            i++;

            j++;

        }

        else if(j > 0) j = t[j];

        else

        {

            t[i] = 0;

            i++;

        }

    }

}

int KMP(string& s, string& w)

{

    int m = 0, i = 0;

    VI t;

    buildTable(w, t);

    while(m+i < s.length())

    {

        if(w[i] == s[m+i])

        {

            i++;

            if(i == w.length()) return m;

        }

        else

        {

            m += i-t[i];

            if(i > 0) i = t[i];

        }

    }

    return s.length();

}

int main(void)

{

    string a = (string) "The example above illustrates the general technique for assembling "+

               "the table with a minimum of fuss. The principle is that of the overall search: "+

               "most of the work was already done in getting to the current position, so very "+

               "little needs to be done in leaving it. The only minor complication is that the "+

               "logic which is correct late in the string erroneously gives non-proper "+

               "substrings at the beginning. This necessitates some initialization code.";

    string b = "table";

    int p = KMP(a, b);

    cout << p << ": " << a.substr(p, b.length()) << " " << b << endl;

    return 0;

}

4 Dynamic Programming

4.1 0/1 Knapsack problems

#include<iostream>

using namespace std;

int f[1000]= {0};

             int n=0, m=0;

             int main(void)

{

    cin >> n >> m;

    for (int i=1; i<=n; i++)

    {

        int price=0, value=0;

        cin >> price >> value;

        for (int j=m; j>=price; j--)

            if (f[j-price]+value>f[j])

                f[j]=f[j-price]+value;

    }

    cout << f[m] << endl;

    return 0;

}

**4.2 Complete Knapsack problems**

#include<iostream>

using namespace std;

int f[1000]= {0};

             int n=0, m=0;

             int main(void)

{

    cin >> n >> m;

    for (int i=1; i<=n; i++)

    {

        int price=0, value=0;

        cin >> price >> value;

        for (int j=price; j<=m; j++)

            if (f[j-price]+value>f[j])

                f[j]=f[j-price]+value;

    }

    cout << f[m] << endl;

    return 0;

}

**4.3 Longest common subsequence (LCS)**

int dp[1001][1001];

int lcs(const string &s, const string &t)

{

    int m = s.size(), n = t.size();

    if (m == 0 || n == 0) return 0;

    for (int i=0; i<=m; ++i)

        dp[i][0] = 0;

    for (int j=1; j<=n; ++j)

        dp[0][j] = 0;

    for (int i=0; i<m; ++i)

        for (int j=0; j<n; ++j)

            if (s[i] == t[j])

                dp[i+1][j+1] = dp[i][j]+1;

            else

                dp[i+1][j+1] = max(dp[i+1][j], dp[i][j+1]);

    return dp[m][n];

}

**4.4 Longest increasing common sequence (LICS)**

#include<iostream>

using namespace std;

int a[100]= {0};

            int b[100]= {0};

            int f[100]= {0};

            int n=0, m=0;

            int main(void)

{

    cin >> n;

    for (int i=1; i<=n; i++) cin >> a[i];

    cin >> m;

    for (int i=1; i<=m; i++) cin >> b[i];

    for (int i=1; i<=n; i++)

    {

        int k=0;

        for (int j=1; j<=m; j++)

        {

            if (a[i]>b[j] && f[j]>k) k=f[j];

            else if (a[i]==b[j] && k+1>f[j]) f[j]=k+1;

        }

    }

    int ans=0;

    for (int i=1; i<=m; i++)

        if (f[i]>ans) ans=f[i];

    cout << ans << endl;

    return 0;

}

**4.5 Longest Increasing Subsequence (LIS)**

#include<iostream>

using namespace std;

int n=0;

      int a[100]= {0}, f[100]= {0}, x[100]= {0};

      int main(void)

{

    cin >> n;

    for (int i=1; i<=n; i++)

    {

        cin >> a[i];

        x[i]=INT\_MAX;

    }

    f[0]=0;

    int ans=0;

    for(int i=1; i<=n; i++)

    {

        int l=0, r=i;

        while (l+1<r)

        {

            int m=(l+r)/2;

            if (x[m]<a[i]) l=m;

            else r=m;

// change to x[m]<=a[i] for non-decreasing case

        }

        f[i]=l+1;

        x[l+1]=a[i];

        if (f[i]>ans) ans=f[i];

    }

    cout << ans << endl;

    return 0;

}

**4.6 Maximum submatrix**

// URAL 1146 Maximum Sum

#include<iostream>

using namespace std;

int a[150][150]= {0};

                 int c[200]= {0};

                 int maxarray(int n)

{

    int b=0, sum=-100000000;

    for (int i=1; i<=n; i++)

    {

        if (b>0) b+=c[i];

        else b=c[i];

        if (b>sum) sum=b;

    }

    return sum;

}

int maxmatrix(int n)

{

    int sum=-100000000, max=0;

    for (int i=1; i<=n; i++)

    {

        for (int j=1; j<=n; j++)

            c[j]=0;

        for (int j=i; j<=n; j++)

        {

            for (int k=1; k<=n; k++)

                c[k]+=a[j][k];

            max=maxarray(n);

            if (max>sum) sum=max;

        }

    }

    return sum;

}

int main(void)

{

    int n=0;

    cin >> n;

    for (int i=1; i<=n; i++)

        for (int j=1; j<=n; j++)

            cin >> a[i][j];

    cout << maxmatrix(n);

    return 0;

}

**4.7 Partitions of integers**

#define MAXN 100 // largest n or m

long int\_coefficient(n,k) // compute f(n,k)

int n,m;

{

    int i,j;

    long f[[MAXN][MAXN];

                 f [1][1] = 1;

                 for (i=0; i<=n; i++) f[i][0] = 0;

                 for (i=1; i<=n; i++)

                 for (j=1; j<i; j++)

                 if (i-j <= 0)

                 f[i][j] = f[i][k-1];

                 else

                 f[i][j] = f[i-j][k]+f[i][k-1];

                 return f[n][k];

      }

      4.8 Partitions of sets

      Number of ways to partition n + 1 items into k sets.

      n

      k

          = k

            n − 1

            k

            +

            n − 1

            k − 1

            (3)

      where

      n

      1

      =

          n

          n

          = 1 (4)

            5 Trees

            5.1 Tree traversal

            int L[100]= {0};

int R[100]= {0};

            void DLR(int m)

{

    cout << m << " ";

    if (L[m]!=0) DLR(L[m]);

    if (R[m]!=0) DLR(R[m]);

}

void LDR(int m)

{

    if (L[m]!=0) LDR(L[m]);

    cout << m << " ";

    if (R[m]!=0) LDR(R[m]);

}

void LRD(int m)

{

    if (L[m]!=0) LRD(L[m]);

    if (R[m]!=0) LRD(R[m]);

    cout << m << " ";

}

int main(void)

{

    cin >> n;

    for (int i=1; i<=n; i++)

        cin >> L[i] >> R[i];

    DLR(1);

    cout << endl;

    LDR(1);

    cout << endl;

    LRD(1);

    cout << endl;

    return 0;

}

**5.2 Depth and width of tree**

#include <iostream>

#include <queue>

#include <stack>

using namespace std;

int l[100]= {0};

            int r[100]= {0};

            stack<int> mystack;

            int n=0;

            int w=0;

            int d=0;

            int depth(int n)

{

    if (l[n]==0 && r[n]==0)

        return 1;

    int depthl=depth(l[n]);

    int depthr=depth(r[n]);

    int dep=depthl>depthr ? depthl:depthr;

    return dep+1;

}

void width(int n)

{

    if (n<=d)

    {

        int t=0,x;

        stack<int> tmpstack;

        while (!mystack.empty())

        {

            x=mystack.top();

            mystack.pop();

            if (x!=0)

            {

                t++;

                tmpstack.push(l[x]);

                tmpstack.push(r[x]);

            }

        }

        w=w>t?w:t;

        mystack=tmpstack;

        width(n+1);

    }

}

int main(void)

{

    cin >> n;

    for (int i=1; i<=n; i++)

        cin >> l[i] >> r[i];

    d=depth(1);

    mystack.push(1);

    width(1);

    cout << w << " " << d << endl;

    return 0;

}

***6 Graph Theory***

**6.1 Graph representation**

// The most common way to define graph is to use adjacency matrix

// example:

// (1) (2) (3) (4) (5)

// (1) 2 0 5 0 0

// (2) 4 2 0 0 1

// (3) 3 0 0 1 4

// (4) 6 9 0 0 0

// (5) 1 1 1 1 5

// it’s always a square matrix.

// suppose a graph has n nodes, if given exactly adjacency matrix

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

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

{

    cin << a[i][j] << endl;

    }

// Usually will go like this representation in data

// start\_node end\_node weight

// suppose m lines

for (int i=1; i<=m; i++)

{

int x=0, y=0, t=0;

cin >> x >> y >> t;

a[x][y]=t;

// if undirected graph

    a[y][x]=t;

}

// another variant: on the ith line, has data as

// end\_node weight

// when you read data, you can assign matrix as

a[i][x]=t;

// if undirected graph

        a[x][i]=t;

// Initialization of graph !!!IMPORTANT

// Depends on usage, normally initialize as 0 for all elements in matrix.

// so that 0 means no connection, non-0 means connection

// (for problem without weight, use weight as 1)

// If weights are important in this context (especially searching for path)

// Initialize graph as infinity for all elements in matrix.

// Another way to store graph is Adjacency list

// No space advantage if using array (unknown maximum number for in-degree).

// Big space advantage if using dynamic data structure (like list, vector).

// each row represent a node and its connectivity.

// we don’t need it so much due to it’s search efficiency.

// let’s define a node as

        struct Node

{

    int id; // node id

    int w; // weight

};

// suppose n nodes and m lines of inputs as

// start\_node end\_node weight

// assume using <vector> in this example

// g is a vector, and each element of g is also a vector of Node

for (int i=1; i<=m; i++)

{

int x=0, y=0, t=0;

cin >> x >> y >> t;

Node temp;

temp.id=y;

temp.w=t;

g[x].push\_back(temp);

// if undirected

    temp.id=x;

    g[y].push\_back(temp);

}

// Note that you don’t need this node structure if graph has only connectivity information.

/\*\*\*\* Special Structure \*\*\*\*/

// Special structure here is usually not a typical graph, like city-blocks, triangles

// They are represented in 2-d array and shows weights on nodes instead of edges.

// Note that in this case travel through edge has no cost, but visit node has cost.

// Triangles: Read data like this

// 1

// 1 2

// 4 2 7

// 7 3 1 5

// 6 2 9 4 6

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

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

    cin >> a[i][j];

// Simple city-blocks: it’s just like first form of adjacency matrix, but this time

// represents weights on nodes, may not be square matrix.

// 1 2 4 5 6

// 2 4 5 1 3

// 4 5 2 3 6

        for (int i=1; i<=n; i++)

            for (int j=1; <=m; j++)

                cin >> a[i][j];

// More complex data structures: typical city-block structure may has some constraints on

// questions, but it has no boundaries. However, some questions requires to form a maze.

// In these cases, data structures can be very flexible, it totally depends on how the question

// presents the data. A usual way is to record it’s adjacent blocks information:

                struct Block

        {

            bool l[4]; // if has 8 neighbors then use bool l[8];

// label them as your favor, e.x.

// 1 1 2 3

// 4 x 2 8 x 4

// 3 7 6 5

// true if there is path, false if there is boundary

// other informations (optional)

                int weight;

                int component\_id;

// etc.

            };

// Note that usually we use array from index 1 instead of 0 because sometimes

// you need index 0 as your boundary, and start from index 1 will give you

// advantage on locating nodes or positions

**6.2 Flood fill algorithm**

//component(i) denotes the

//component that node i is in

void flood\_fill(new\_component)

do

    num\_visited = 0

                  for all nodes i

                  if component(i) = -2

                                        num\_visited = num\_visited + 1

                                                component(i) = new\_component

                                                        for all neighbors j of node i

                                                            if component(j) = nil

                                                                        component(j) = -2

                                                                                until num\_visited = 0

                                                                                        void find\_components()

                                                                                        num\_components = 0

                                                                                                for all nodes i

                                                                                                    component(node i) = nil

                                                                                                            for all nodes i

                                                                                                                if component(node i) is nil

                                                                                                                    num\_components = num\_components + 1

                                                                                                                            component(i) = -2

                                                                                                                                    flood\_fill(component num\_components)

**6.3 SPFA — shortest path**

                                                                                                                                    int q[3001]= {0}; // queue for node

                                          int d[1001]= {0}; // record shortest path from start to ith node

                                          bool f[1001]= {0};

                                          int a[1001][1001]= {0}; // adjacency list

                                          int w[1001][1001]= {0}; // adjacency matrix

                                          int main(void)

                        {

                            int n=0, m=0;

                            cin >> n >> m;

                            for (int i=1; i<=m; i++)

                                {

                                    int x=0, y=0, z=0;

                                    cin >> x >> y >> z; // node x to node y has weight z

                                    a[x][0]++;

                                    a[x][a[x][0]]=y;

                                    w[x][y]=z;

                                    /\*

                                    // for undirected graph

                                    a[x][0]++;

                                    a[y][a[y][0]]=x;

                                    w[y][x]=z;

                                    \*/

                                }

                                int s=0, e=0;

                                cin >> s >> e; // s: start, e: end

                                SPFA(s);

                                cout << d[e] << endl;

                                return 0;

                            }

void SPFA(int v0)

{

    int t,h,u,v;

    for (int i=0; i<1001; i++) d[i]=INT\_MAX;

    for (int i=0; i<1001; i++) f[i]=false;

    d[v0]=0;

    h=0;

    t=1;

    q[1]=v0;

    f[v0]=true;

    while (h!=t)

    {

        h++;

        if (h>3000) h=1;

        u=q[h];

        for (int j=1; j<=a[u][0]; j++)

        {

            v=a[u][j];

            if (d[u]+w[u][v]<d[v]) // change to > if calculating longest path

            {

                d[v]=d[u]+w[u][v];

                if (!f[v])

                {

                    t++;

                    if (t>3000) t=1;

                    q[t]=v;

                    f[v]=true;

                }

            }

        }

        f[u]=false;

    }

}

**6.4 Floyd-Warshall algorithm – shortest path of all pairs**

// map[i][j]=infinity at start

void floyd()

{

    for (int k=1; k<=n; k++)

        for (int i=1; i<=n; i++)

            for (int j=1; j<=n; j++)

                if (i!=j && j!=k && i!=k)

                    if (map[i][k]+map[k][j]<map[i][j])

                        map[i][j]=map[i][k]+map[k][j];

}

6.5 Prim — minimum spanning tree

int d[1001]= {0};

             bool v[1001]= {0};

             int a[1001][1001]= {0};

             int main(void)

{

    int n=0;

    cin >> n;

    for (int i=1; i<=n; i++)

    {

        int x=0, y=0, z=0;

        cin >> x >> y >> z;

        a[x][y]=z;

    }

    for (int i=1; i<=n; i++)

        for (int j=1; j<=n; j++)

            if (a[i][j]==0) a[i][j]=INT\_MAX;

    cout << prim(1,n) << endl;

}

int prim(int u, int n)

{

    int mst=0,k;

    for (int i=0; i<d.length; i++) d[i]=INT\_MAX;

    for (int i=0; i<v.length; i++) v[i]=false;

    d[u]=0;

    int i=u;

    while (i!=0)

    {

        v[i]=true;

        k=0;

        mst+=d[i];

        for (int j=1; j<=n; j++)

            if (!v[j])

            {

                if (a[i][j]<d[j]) d[j]=a[i][j];

                if (d[j]<d[k]) k=j;

            }

        i=k;

    }

    return mst;

}

**6.6 Eulerian circuit**

// USACO Fence

#include<iostream>

using namespace std;

int f[100]= {0}, ans[100]= {0};

            bool g[100][100]= {0}, v[100]= {0};

            int n=0, m=0, c=0;

            void dfs(int k)

{

    for (int i=1; i<=n; i++)

        if (g[k][i])

        {

            g[k][i]=false;

            g[i][k]=false;

            dfs(i);

        }

    m++;

    ans[m]=k;

}

int main(void)

{

    cin >> n >> m;

    for (int i=1; i<=m; i++)

    {

        int x=0, y=0;

        g[x][y]=true;

        g[y][x]=true;

        f[x]++;

        f[y]++;

    }

    m=0;

    int k1=0;

    for (int i=1; i<=n; i++)

    {

        if (f[i]%2==1) k1++;

        if (k1>2)

        {

            cout << "error" << endl;

            return 0;

        }

        if (f[i]%2 && c==0) c=i;

    }

    if (c==0) c=1;

    dfs(x);

    for (int i=m; i>=1; i--) cout << ans[i] << endl;

    return 0;

}

**6.7 Topological sort**

// Find any solution of topological sort.

#include<iostream>

using namespace std;

int f[100]= {0}, ans[100]= {0};

            bool g[100][100]= {0}, v[100]= {0};

            int n=0, m=0;

            void dfs(int k)

{

    int i=0;

    v[k]=true;

    for (int i=1; i<=n; i++)

        if (g[k][i] && !v[i]) dfs(i);

    m++;

    ans[m]=k;

}

int main(void)

{

    cin >> n >> m;

    for (int i=1; i<=m; i++)

    {

        int x=0, y=0;

        cin >> x >> y;

        g[y][x]=true;

    }

    m=0;

    for (int i=1; i<=n; i++)

        if (!v[i]) dfs(i);

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

    return 0;

}

**// Find the order of topological sort is dictionary minimum**

#include<iostream>

using namespace std;

int f[100]= {0}, ans[100]= {0};

            bool g[100][100]= {0}, v[100]= {0};

            int n=0, m=0;

            int main(void)

{

    cin >> n >> m;

    for (int i=1; i<=m; i++)

    {

        int x=0, y=0;

        cin >> x >> y;

        g[x][y]=true;

        f[y]++;

    }

    for (int i=1; i<=n; i++)

    {

        for (int j=1; j<=n; j++)

        {

            if (f[j]==0 && !v[j]) break;

            if (f[j]!=0)

            {

                cout << "error" << endl;

                return 0;

            }

            ans[i]=j;

            v[j]=true;

            for (int k=1; k<=n; k++)

                if (g[j][k]) f[k]--;

        }

    }

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

    return 0;

}

**7 Individual Templates**

***7.1 Template by Rakib***

#pragma GCC optimize ("Ofast")

#include"bits/stdc++.h"

using namespace std;

#include <ext/pb\_ds/assoc\_container.hpp>

#include <ext/pb\_ds/tree\_policy.hpp>

using namespace \_\_gnu\_pbds;

///order\_of\_key (k) : Number of items strictly smaller than k .

///find\_by\_order(k) : K-th element in a set (counting from zero).

struct \_ { ios\_base::Init i; \_() { cin.sync\_with\_stdio(0); cin.tie(0); cout << fixed << setprecision(10); } } \_\_\_;

#define trace(...) \_\_f(#\_\_VA\_ARGS\_\_, \_\_VA\_ARGS\_\_)

template <typename Arg1>

void \_\_f(const char\* name, Arg1&& arg1) {

    cerr << name << " : " << arg1 << endl;

}

template <typename Arg1, typename... Args>

void \_\_f(const char\* names, Arg1&& arg1, Args&&... args) {

    const char\* comma = strchr(names + 1, ',');

    cerr.write(names, comma - names) << " : " << arg1 << "  ";

    \_\_f(comma + 1, args...);

}

#define ll long long

#define pii pair<int,int>

#define ff first

#define ss second

#define endll '\n'

#define rep(i,n) for(int i=0;i++<n;)

#define scl(i) scanf("%lld",&i)

#define int long long int

#define all(n) n.begin(),n.end()

#define mem(n,i) memset(n,i,sizeof n)

#define em(a) emplace\_back(a)

#define pb(a) push\_back(a)

#define srep(it,vv) for(auto &it : vv)

#define prep(it,vv) for(auto it : vv)

#define b\_s(a,b) binary\_search(a.begin(),a.end(),b)

#define l\_b(a,b) lower\_bound(a.begin(),a.end(),b)

#define u\_b(a,b) upper\_bound(a.begin(),a.end(),b)

#define uniq(x) sort(x.begin(),x.end());x.erase(unique(x.begin(),x.end()),x.end())

//vector<vector<int>>arr(n + 5, vector<int>(m + 5,0));

#define oset tree<int, null\_type,less<int>, rb\_tree\_tag,tree\_order\_statistics\_node\_update>

typedef vector<int> vii;

typedef vector<string> vss;

// merge(tree[2\*node].begin(), tree[2\*n].end(), tree[2\*node+1].begin(),tree[2\*node+1].end(),back\_inserter(tree[node]));

#ifndef ONLINE\_JUDGE

freopen("input.txt", "r", stdin);

freopen("output.txt", "w", stdout);

#endif

**//PRIME FACTORIZATION**

vector <int> prime; // Stores generated primes

char sieve[SIZE]; // 0 means prime

void primeSieve ( int n ) {

    sieve[0] = sieve[1] = 1; // 0 and 1 are not prime

    prime.push\_back(2); // Only Even Prime

    for ( int i = 4; i <= n; i += 2 ) sieve[i] = 1; // Remove multiples of 2

    int sqrtn = sqrt ( n );

    for ( int i = 3; i <= sqrtn; i += 2 ) {

        if ( sieve[i] == 0 ) {

            for ( int j = i \* i; j <= n; j += 2 \* i ) sieve[j] = 1;

        }

    }

    for ( int i = 3; i <= n; i += 2 ) if ( sieve[i] == 0 ) prime.push\_back(i);

}

/\*

prime divisor -> p1,p2,p3

p1^a\*p2^b\*p3^c

NOD : (a+1)(b+1)(c+1)

SOD 1: (p1^0+P1^1+..+p1^a)(p2^0+P2^1+..+p2^b)(p3^0+P3^1+..+p3^c)

SOD 2: ((p1^(a+1)-1)/(a-1)) ((p2^(b+1)-1)/(b-1)) ((p3^(c+1)-1)/(c-1))

\*/

int Set(int N, int pos) { return N = N | (1 << pos); }

int reset(int N, int pos){ return N = N & ~ (1 << pos); }

bool check(int N, int pos){ return (bool) (N & (1 << pos)); }

\*/

**//DSU**

#include<bits/stdc++.h>

using namespace std;

int par[100];

//eta parent find korar jonno

int find(int u){

    if(u==par[u]) return u;

    else{

        return par[u]=find(par[u]);

    }

}

//eta duitar parent chack kore join kore

void join(int u,int v){

    int pu=find(u);

    int pv=find(v);

    if(pu!=pv){

        par[pu]=par[pv];//v er parent er parent value update korsi ekhane

    }

}

int main()

{

    int n;

    cin>>n;

    for(int i=1;i<=n;i++) par[i]=i;

    int m;

    cin>>m;

    for(int i=0;i<m;i++){

        int u,v;

        cin>>u>>v;

        join(u,v);

    }

    //shobar parent check korlam

    for(int i=1;i<=n;i++){

        cout<<find(i)<<endl;

    }

}

**///SEGMENT TREE**

/// first u have to build

const int N = 3e5 + 10;

int tree[N << 2];

int arr[N];

void build(int u, int i, int j)

{

if (i == j) /// leap node

{

tree[u] = arr[i];

return;

}

int mid = (i + j) >> 1;

build(2 \* u, i, mid); /// left child

build(2 \* u + 1, mid + 1, j); /// right child

tree[u] = tree[2 \* u] ^ tree[2 \* u + 1]; /// build as per required

}

void update(int u, int i, int j, int idx, int x)

{

if (i == j)

{

tree[u] ^= x; /// here is update as per required

return;

}

int mid = (i + j) >> 1;

if (idx <= mid) update(2 \* u, i, mid, idx, x);

else update(2 \* u + 1, mid + 1, j, idx, x);

tree[u] = tree[2 \* u] ^ tree[2 \* u + 1]; /// ja change hoise , se jonno range gulao update korte hocche

}

int query(int u, int i, int j, int b, int e)

{

if (e < i or j < b) return 0; /// out of required range

if (i >= b and j <= e) return tree[u]; /// range is full inside in required range

int mid = (i + j) >> 1;

int left = query(2 \* u, i, mid, b, e);

int right = query(2 \* u + 1, mid + 1, j, b, e);

return  left ^ right; /// here is operation as per require

}

/// BINARY EXPO MOD

int bin\_expo\_mod(int a,int n,int p)

{

    int res = 1;

    while(n)

    {

        if(n&1) res = (res\*a)%p,n--;

        else a = (a\*a)%p,n>>=1;

    }

    return res;

}

///BINARY STRING TO LONG LONG INT

string s = "1001";

long long int xx = stoll(s,0,2)

////

/// PRIME DIVISOR/FACTOR FACTORIZATION

int prime\_divisor\_factorization(int n)

{

    /// 12 = (2^2)\*(3^1) ,so 12's divisor is = (2+1)\*(1+1) = 6;

    vector<int>dd(n + 50, 0);

    dd[1] = 1;

    for (int i = 2; i \* i <= n + 5; i++)

    {

        if (dd[i]) continue;

        for (int j = i + i; j <= n + 5; j += i)

        {

            if (!dd[j]) dd[j] = i; /// inserting into dd[j] j's very first prime divisor;

        }

    }

    rep(i, n + 5) if (!dd[i]) dd[i] = i;///those are not yet fill is prime and prime's first prime divisor is itself;

    int sum = 0;

    for (int i = 1; i <= n; i++)

    {

        int xx = i;

        int d = 1;

        while (xx > 1)

        {

            int yy = dd[xx];///yy is very first prime divisor of xx;

            int ff = 0;

            while (xx % yy == 0) xx /= yy, ff++;

            d \*= (ff + 1);

        }

        sum += i \* d;

    }

    return sum;

}

/// NLOGN DIVISOR COUNT

vector<int>arr(10000005)

for (int i = 1; i < n + 2; i++)

        for (int j = i; j < n + 2; j += i)

            arr[j]++;

///

///DIF 1D

#include <bits/stdc++.h>

using namespace std;

const int N = 1e6 + 100;

int D[N], a[N];

int main() {

    // freopen("in.txt", "r", stdin);

    ios::sync\_with\_stdio(0);

    cin.tie(0);

    int n, q;

    cin >> n >> q;

    while(q--) {

        int l, r;

        cin >> l >> r;

        D[l]++, D[r+1]--;

    }

    for(int i = 1; i <= n; i++) {

        a[i] = a[i-1] + D[i];

    }

    return 0;

}

**/// DIF 2D**

#include <bits/stdc++.h>

using namespace std;

const int N = 2005;

int D[N][N], a[N][N];

int main() {

    int n, m, q;

    cin >> n >> m >> q;

    while(q--) {

        int x1, y1, x2, y2;

        cin >> x1 >> y1 >> x2 >> y2;

        D[x1][y1]++;

        D[x2+1][y2+1]++;

        D[x1][y2+1]--;

        D[x2+1][y1]--;

    }

    for(int x = 1; x <= n; x++) {

        for(int y = 1; y <= m; y++) {

            a[x][y] = a[x][y-1] + a[x-1][y] - a[x-1][y-1] + D[x][y];

        }

    }

    return 0;

}

**/// PREFIX SUM 1D**

#include <bits/stdc++.h>

using namespace std;

const int N = 1e6+100;

int a[N], pref[N];

int main() {

    int n;

    cin >> n;

    for(int i = 1; i <= n; i++) cin >> a[i];

    for(int i = 1; i <= n; i++) {

        pref[i] = pref[i-1] + a[i];

    }

    int q;

    cin >> q;

    while(q--) {

        int l, r;

        cin >> l >> r; // a[l]+a[l+1]+...+a[r]

        cout << pref[r] - pref[l-1] << "\n";

    }

    return 0;

}

**/// PREFIX SUM 2D**

#include <bits/stdc++.h>

using namespace std;

const int N = 2005;

int a[N][N], pref[N][N];

int main() {

    int n, m;

    cin >> n >> m;

    for(int i = 1; i <= n; i++) {

        for(int j = 1; j <= m; j++) {

            cin >> a[i][j];

        }

    }

    // precal

    for(int x = 1; x <= n; x++) {

        for(int y = 1; y <= m; y++) {

            pref[x][y] = a[x][y] + pref[x][y-1] + pref[x-1][y] - pref[x-1][y-1];

        }

    }

    int q;

    cin >> q;

    while(q--) {

        int x1, y1, x2, y2;

        cin >> x1 >> y1 >> x2 >> y2;

        int sum = pref[x2][y2] - pref[x1-1][y2] - pref[x2][y1-1] + pref[x1-1][y1-1];

        cout << sum << "\n";

    }

    return 0;

}

**///HASHING**

#include <bits/stdc++.h>

#define ff first

#define ss second

#define mp make\_pair

using namespace std;

typedef long long LL;

typedef pair<LL, LL> PLL;

const PLL M=mp(1e9+7, 1e9+9);   ///Should be large primes

const LL base=347;              ///Should be a prime larger than highest value

const int N = 1e6+7;            ///Highest length of string

ostream& operator<<(ostream& os, PLL hash) {

    return os<<"("<<hash.ff<<", "<<hash.ss<<")";

}

PLL operator+ (PLL a, LL x)     {return mp(a.ff + x, a.ss + x);}

PLL operator- (PLL a, LL x)     {return mp(a.ff - x, a.ss - x);}

PLL operator\* (PLL a, LL x)     {return mp(a.ff \* x, a.ss \* x);}

PLL operator+ (PLL a, PLL x)    {return mp(a.ff + x.ff, a.ss + x.ss);}

PLL operator- (PLL a, PLL x)    {return mp(a.ff - x.ff, a.ss - x.ss);}

PLL operator\* (PLL a, PLL x)    {return mp(a.ff \* x.ff, a.ss \* x.ss);}

PLL operator% (PLL a, PLL m)    {return mp(a.ff % m.ff, a.ss % m.ss);}

PLL power (PLL a, LL p) {

    if (p==0)   return mp(1,1);

    PLL ans = power(a, p/2);

    ans = (ans \* ans)%M;

    if (p%2)    ans = (ans\*a)%M;

    return ans;

}

///Magic!!!!!!!

PLL inverse(PLL a)  {

    return power(a, (M.ff-1)\*(M.ss-1)-1);

}

PLL pb[N];      ///powers of base mod M

PLL invb;

///Call pre before everything

void hashPre() {

    pb[0] = mp(1,1);

    for (int i=1; i<N; i++)

        pb[i] = (pb[i-1] \* base)%M;

    invb = inverse(pb[1]);

}

///Calculates Hash of a string

PLL Hash (string s) {

    PLL ans = mp(0,0);

    for (int i=0; i<s.size(); i++)

        ans=(ans\*base + s[i])%M;

    return ans;

}

///appends c to string

PLL append(PLL cur, char c) {

    return (cur\*base + c)%M;

}

///prepends c to string with size k

PLL prepend(PLL cur, int k, char c) {

    return (pb[k]\*c + cur)%M;

}

///replaces the i-th (0-indexed) character from right from a to b;

PLL replace(PLL cur, int i, char a, char b) {

    cur = (cur + pb[i] \* (b-a))%M;

    return (cur + M)%M;

}

///Erases c from the back of the string

PLL pop\_back(PLL hash, char c) {

    return (((hash-c)\*invb)%M+M)%M;

}

///Erases c from front of the string with size len

PLL pop\_front(PLL hash, int len, char c) {

    return ((hash - pb[len-1]\*c)%M+M)%M;

}

///concatenates two strings where length of the right is k

PLL concat(PLL left, PLL right, int k) {

    return (left\*pb[k] + right)%M;

}

///Calculates hash of string with size len repeated cnt times

///This is O(log n). For O(1), pre-calculate inverses

PLL repeat(PLL hash, int len, LL cnt) {

    PLL mul = (pb[len\*cnt] - 1) \* inverse(pb[len]-1);

    mul = (mul%M+M)%M;

    PLL ans = (hash\*mul)%M;

    if (pb[len].ff == 1)    ans.ff = hash.ff\*cnt;

    if (pb[len].ss == 1)    ans.ss = hash.ss\*cnt;

    return ans;

}

///Calculates hashes of all prefixes of s including empty prefix

vector<PLL> hashList(string s) {

    int n = s.size();

    vector<PLL> ans(n+1);

    ans[0] = mp(0,0);

    for (int i=1; i<=n; i++)

        ans[i] = (ans[i-1] \* base + s[i-1])%M;

    return ans;

}

///Calculates hash of substring s[l..r] (1 indexed)

PLL substringHash(const vector<PLL> &hashlist, int l, int r) {

    int len = (r-l+1);

    return ((hashlist[r] - hashlist[l-1]\*pb[len])%M+M)%M;

}

///Solves LightOJ 1255-Substring Frequency

///You are given two strings A and B. You have to find

///the number of times B occurs as a substring of A.

char buffer[N];

int main()

{

    hashPre();

    int t;

    scanf("%d", &t);

    for (int cs=1; cs<=t; ++cs)

    {

        string a, b;

        scanf("%s", buffer); a = buffer;

        scanf("%s", buffer); b = buffer;

        int na = a.size(), nb = b.size();

        PLL hb = Hash(b);

        vector<PLL> ha = hashList(a);

        int ans = 0;

        for (int i=1; i+nb-1<=na; i++)

            if (substringHash(ha, i, i+nb-1) == hb)  ans++;

        printf("Case %d: %d\n", cs, ans);

    }

}

**/// TRIE**

const int N = 1e6 + 100;

int tot\_node = 1;

int to[N][26];

int add(string &s) {

    int cur = 1; // root node

    for(int i = 0; i < s.size(); i++) {

        int c = s[i]-'a';

        if(!to[cur][c]) to[cur][c] = ++tot\_node;

        cur = to[cur][c];

    }

    return cur; // leaf node where this string ends

}

///

/// KMP PI TABLE (FUCKING MATERIALS)

vector<int> prefix\_function(string s) /// this will  return kmp pi table

{

    int n = s.size();

    vector<int> pi(n);/// pi[0] = 0, as per kmp condition

    for (int i = 1; i < n; i++)

    {   /// j = prefix length and end at j-1

        int j = pi[i - 1]; /// max prefix matched at i-1

        while (j > 0 and s[i] != s[j]) j = pi[j - 1];

        if (s[i] == s[j]) ++j;

        pi[i] = j;

    }

    return pi;

}

**/// DIGIT DP**

//  How many numbers x are there in the range a to b, where the digit d occurs exactly k times in x?

int a, b, d, k;

vii digit;

int n;

int dp[30][30][3];

/// DP[p][c][f] = Number of valid numbers <= b from this state

/// p = current position from left side (zero based)

/// c = number of times we have placed the digit d so far

/// f = the number we are building has already become smaller than b? [0 = no, 1 = yes]

int call(int idx, int cnt, int f)

{

    if (cnt > k) return 0;

    if (idx >= n) return cnt == k;

    if (dp[idx][cnt][f] != -1) return dp[idx][cnt][f];

    int limit;

    if (!f) limit = digit[idx];

    /// Digits we placed so far matches with the prefix of b

    /// So if we place any digit > num[pos] in the current position, then the number will become greater than b

    else limit = 9;

    /// The number has already become smaller than b. We can place any digit now.

    int xx = 0;

    /// Try to place all the valid digits such that the number doesn't exceed b

    for (int i = 0; i <= limit; i++)

    {

        int cnt1 = 0;

        int ff = f;

        if (!f and i < limit) ff = 1;/// The number is getting smaller at this position

        if (i == d) cnt1 = 1;

        xx += call(idx + 1, cnt + cnt1, ff);

    }

    return dp[idx][cnt][f] = xx;

}

int solve(int x)

{

    mem(dp, -1);

    digit.clear();

    while (x)

    {

        digit.em(x % 10);

        x /= 10;

    }

    reverse(all(digit));

    /// Stored all the digits of x in num for simplicity

    n = digit.size();

    return call(0, 0, 0);

}

signed main()

{

#ifndef ONLINE\_JUDGE

    freopen("input.txt", "r", stdin);

    freopen("output.txt", "w", stdout);

#endif

    cin >> a >> b >> d >> k;

    cout << solve(b) - solve(a - 1) << endll;

}

/////

/// SEGMENT TREE LAZY

const int N = 1e5 + 100;

int tree[N << 2], lz[N << 2];

void propagate(int u, int st, int en)

{

if (!lz[u]) return;

tree[u] += lz[u] \* (en - st + 1);

if (st != en)

{

lz[2 \* u] += lz[u];

lz[2 \* u + 1] += lz[u];

}

lz[u] = 0;

}

void update(int u, int st, int en, int l, int r, int x)

{

propagate(u, st, en);

if (r < st or en < l) return;

else if (st >= l and en <= r)

{

lz[u] += x;

propagate(u, st, en);

}

else

{

int mid = (st + en) >> 1;

update(2 \* u, st, mid, l, r, x);

update(2 \* u + 1, mid + 1, en, l, r, x);

tree[u] = tree[2 \* u] + tree[2 \* u + 1];

}

}

int query(int u, int st, int en, int l, int r)

{

propagate(u, st, en);

if (r < st or en < l) return 0;

else if (st >= l and en <= r) return tree[u];

else

{

int mid = (st + en) >> 1;

int left = query(2 \* u, st, mid, l, r);

int right = query(2 \* u + 1, mid + 1, en, l, r);

return left + right;

}

}

**/// Dijkstra**

const int N = 1e5 + 100;

vector<pii> gra[N];

ll dis[N];

int par[N];

int main()

{

    int node, edge; cin >> node >> edge;

    rep(i, edge)

    {

        int a, b, w; cin >> a >> b >> w;

        gra[a].emplace\_back(b, w);

        gra[b].emplace\_back(a, w);

    }

    priority\_queue<pii> pq;

    rep(i, node) dis[i] = 1e18 + 100;

    int src = 1;

    dis[src] = 0;

    par[1] = -1;

    pq.push ({ -dis[src], src});

    while (pq.size() > 0)

    {

        auto t = pq.top();

        pq.pop();

        int u = t.ss, d = -t.ff;

        if (dis[u] < d) continue;

        for (auto it : gra[u])

        {

            int v = it.ff, w = it.ss;

            if (dis[v] > dis[u] + w)

            {

                dis[v] = dis[u] + w;

                pq.push({ -dis[v], v});

                par[v] = u;

            }

        }

    }

    vector<int>path;

    int xx = node;

    while (xx != -1)

    {

        path.em(xx);

        xx = par[xx];

        if (xx == 0)

        {

            cout << -1;

            return 0;

        }

    }

    reverse(all(path));

    for (int it : path) cout << it << ' ';

}

// dp print

int dp[60][1500];

int dir[60][1500];

int knap(int i,int now)

{

if(i>=cap)

return 0;

if(dp[i][now] != -1)

return dp[i][now];

int t1=0,t2=0;

if(now + arrw[i] <= n)

t1 = arrc[i] + knap(i+1,now+arrw[i]);

t2 = knap(i+1,now);

if(t1>t2)

dir[i][now] = 1;

else

dir[i][now] = 2;

return dp[i][now] = max(t1,t2);

}

vector <int> pri;

void print(int i,int now)

{

if(dir[i][now] == -1)

return;

if(dir[i][now] == 1)

{

pri.push\_back(i);

print(i+1,now+arrw[i]);

}

else

print(i+1,now);

}

***7.2 Template by Faisal***

// typedef long long int;

const int MX = 1e6+5;

#define pii pair<int, int>

template<typename T>

bool comp(T a, T b){//sort by descending

    return a > b;

}

**optimized Sieve(finds (n+1)th prime)**

vector<int> nth\_prime;

bitset<MX> visited;

void optimized\_prime(){

    nth\_prime.push\_back(2);

    for(int i=3; i<MX; i+=2){

            if(visited[i])

                continue;

            nth\_prime.push\_back(i);

            if(1ll\*i\*i > MX)

                continue;

            for(int j = i\*i; j< MX; j+= i+i)

                visited[j] = true;

    }

}

**stores smallest prime divisor of every num from 1 to x**

int spf[MX];

void sieve(){

    for(int i=1; i<MX; ++i)

        spf[i] = i;

    for(int i=2; i\*i<MX; ++i){

        if(spf[i] != i) continue;

        for(int j=i\*i; j<MX; j += i){

            if(spf[j]==j)

                spf[j] = i;

        }

    }

}

map<int, int> mp; **//prime factorization**

void factorize(int n)

{

    while(n != 1){

        mp[spf[n]]++;

        n /= spf[n];

    }

}

**when phi(1) to phi(n) is neeeded**

int phi[MX];

//bitset<MX> visited;// declared before in optimized SIEVE

void sieve\_phi(){

    for(int i=1; i<MX; ++i) phi[i] = i;

    visited[1] = 1;

    for(int i=2; i<MX; ++i){

        if(!visited[i]){

            for(int j = i; j<MX; j+=i){

                visited[j] = 1;

                phi[j] = phi[j]/i\*(i-1);

            }

        }

    }

}

**when only phi(n) is needed**

int phi(int n){ //O(sqrt(n))

    int res = n;

    for(int p=2; p\*p<=n; ++p){

        if(n%p== 0){

            while(n%p == 0)

                n /= p;

            res -= res/p;

        }

    }

    if(n>1) res -= res/n;

    return res;

}

**claculate nCR start**

typedef long long LL;

const LL MOD = 1e9+7;

const LL MAX = 2e5+5;

vector<LL> fact(MAX), inv(MAX);

void factorial(){

fact[0] = 1;

for(LL i=1; i<MAX; i++)

fact[i] = (i\*fact[i-1])%MOD;

}

LL bigmod(LL a, LL n, LL M=MOD){

LL res = 1;

while(n){

if(n&1) res = (res\*a)%M;

a = (a\*a)%M, n /= 2;

}

return res;

}

void inverse(){

for(int i=0; i<MAX; ++i)

inv[i] = bigmod(fact[i], MOD-2);

}

LL C(LL a, LL b){

if(a<b or a<0 or b<0) return 0;

LL de = (inv[b]\*inv[a-b])%MOD;

return (fact[a]\*de)%MOD;

}

//call factorial() and inverse() from main function

**// end nCR**

LL ModInv(int a, int M){    //M is prime

    return bigmod(a, M-2, M);

}

***7.3 Template by Rizu***

**Knight Moves**

int X[8]={2,1,-1,-2,-2,-1,1,2};

int Y[8]={1,2,2,1,-1,-2,-2,-1};

**//bit count in O(1)**

int BitCount(unsigned int u){

unsigned int uCount;

uCount = u - ((u >> 1) & 033333333333) - ((u >> 2) & 011111111111);

return ((uCount + (uCount >> 3)) & 030707070707) % 63;

}

**Matrix Exponentiation**

// A technique of computing a number raised to a square matrix in a fast and efficient manner.

// Uses properties of exponentiation and binary numbers for fast computation.

//

// Running time:

// O(m^3\*log(n)) where m is the size of the matrix and n is the power the matrix is being raised to.

//

// INPUT:

// - size of matrix m

// - the matrix A

// - the power n

// - modulo value mod

//

// OUTPUT:

// - the matrix A^n (all values mod m)

//

#include<bits/stdc++.h>

using namespace std;

typedef long long LL;

LL arr[60][60],res[60][60],tmp[60][60],m;

void matMul (LL a[][60], LL b[][60], LL mod)

{

for(int i=0; i<m; i++)

for(int j=0; j<m; j++)

{

tmp[i][j] = 0;

for(int k=0; k<m; k++)

{

tmp[i][j] += (a[i][k]\*b[k][j])%mod;

tmp[i][j] %= mod;

}

}

}

void power(LL n, LL mod)

{

for(int i=0; i<m; i++)

for(int j=0; j<m; j++)

if(i==j) res[i][j] = 1;

else res[i][j] = 0;

while(n)

{

if(n&1)

{

matMul(res,arr,mod);

for(int i=0; i<m; i++)

for(int j=0; j<m; j++) res[i][j] = tmp[i][j];

n--;

}

else

{

matMul(arr,arr,mod);

for(int i=0; i<m; i++)

for(int j=0; j<m; j++) arr[i][j] = tmp[i][j];

n/=2;

}

}

}

// BEGIN CUT

// The following code solves SPOJ problem #MPOW: Power of Matrix

int main()

{

ios\_base::sync\_with\_stdio(false); cin.tie(NULL); cout.tie(NULL);

//freopen("input.txt","r",stdin);freopen("output.txt","w",stdout);

LL t=1, n, mod=1e9+7; cin>>t;

while(t--)

{

cin>>m>>n;

for(int i=0; i<m; i++)

for(int j=0; j<m; j++) cin>>arr[i][j];

power(n,mod);

for(int i=0; i<m; i++)

{

for(int j=0; j<m; j++) cout<<res[i][j]<<" ";

cout<<"\n";

}

}

return 0;

}

// END CUT

**7.4** Given an undirected graph G with n nodes and m edges.We are required to find in it all the connected components,

i.e, several groups of vertices such that within a group each vertex can be reached from another and no path exists between different groups.

// O(n+m)

int n;

vector<int> g[MAXN];

bool used[MAXN];

vector<int> comp;

void dfs(int v)

{

used[v] = true;

comp.push\_back(v);

for (size\_t i = 0; i < (int)g[v].size(); ++i)

{

int to = g[v][i];

if (!used[to])

dfs(to);

}

}

void find\_comps(){

for (int i = 0; i < n; ++i)

used[i] = false;

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

if (!used[i]){

comp.clear();

dfs(i);

cout << "Component:";

for (size\_t j = 0; j < comp.size(); ++j)

cout << ' ' << comp[j];

cout << endl;

}

}

}

**7.5 SCC**

const int N = 1002;

vector<int> adj[N], rev[N];

bitset<N> vis;

int n, m;

int comp[N]; // stores nth node is includedto which scc\_no

void DFS1(int node, stack<int> &TS){

vis[node] = true;

for (int child : adj[node])

if (!vis[child])

DFS1(child, TS);

TS.push(node);

}

void DFS2(int node, const int cc\_no, vector<int> &vec){

vis[node] = true;

comp[node] = cc\_no;

vec.push\_back(node);

for (int child : rev[node])

if (!vis[child])

DFS2(child, cc\_no,

vec);

}

auto SCC(){

vis.reset();

stack<int> TS;

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

if (!vis[i])

DFS1(i, TS);

// finding the SCCs using TopSort

vis.reset();

int cc\_no = 1;

vector<vector<int>> components;

while (!TS.empty())

{

int idx = TS.top();

TS.pop();

if (!vis[idx])

{

vector<int> vec;

DFS2(idx, cc\_no++, vec);

components.push\_back(vec);

}

}

return components;

}

signed main(){

cin >> n >> m;

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

int u, v;

cin >> u >> v;

// --u, --v;

adj[u].push\_back(v);

rev[v].push\_back(u);

}

auto res = SCC();

int sz = res.size(), scc\_no = 1;

cout << "No. of SCC: " << sz << '\n';

for (auto x : res)

{

cout << "SCC no." << scc\_no++ << " includes nodes : ";

for (auto y : x) cout<<y<<' ';

cout << '\n';

}

}

**no. of ways and min cost of connecting the sccs**

const int MOD = 1e9 + 7, N = 1e5 + 2, INF = 1e18 + 2;

int n, m, comp[N];

vector<int> adj[N], rev[N];

bitset<N> vis;

void DFS1(int u, stack<int> &TS){

vis[u] = true;

for (int v : adj[u])

if (!vis[v])

DFS1(v, TS);

TS.push(u);

}

void DFS2(int u, const int scc\_no, int &min\_cost, int &ways, vector<int> &cost){

vis[u] = true;

comp[u] = scc\_no;

for (int v : rev[u])

if (!vis[v])

{

if (min\_cost == cost[v])

++ways;

else if (min\_cost > cost[v])

{

ways = 1;

min\_cost = cost[v];

}

DFS2(v, scc\_no, min\_cost, ways,

cost);

}

}

signed main(){

FIO cin >> n;

vector<int> cost(n + 1);

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

cin >> cost[i];

cin >> m;

while (m--){

int u, v;

cin >> u >> v;

adj[u].push\_back(v);

rev[v].push\_back(u);

}

int tot = 0, ways = 1;

stack<int> TS;

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

if (!vis[i])

DFS1(i, TS);

vis.reset();

int scc\_no = 0;

while (!TS.empty()){

int u = TS.top();

TS.pop();

if (!vis[u]){

int tmp\_cst = cost[u], tmp\_ways = 1;

DFS2(u, ++scc\_no, tmp\_cst,

tmp\_ways, cost);

tot += tmp\_cst;

ways = (ways \* tmp\_ways) % MOD;

}

}

cout << tot << ' ' << ways;

}

**7.6 sqrt decomposition(MO’s Algo)**

// https://www.spoj.com/problems/DQUERY/

#include <bits/stdc++.h>

using namespace std;

const int SIZE\_1 = 1e6 + 10, SIZE\_2 = 3e4 + 10;

class query{

public:

int l, r, indx;

};

int block\_size, cnt = 0;

int frequency[SIZE\_1], a[SIZE\_2];

void add(int indx){

++frequency[a[indx]];

if (frequency[a[indx]] == 1)

++cnt;

}

void sub(int indx){

--frequency[a[indx]];

if (frequency[a[indx]] == 0)

--cnt;

}

bool comp(query a, query b){

if (a.l / block\_size == b.l / block\_size)

return a.r < b.r;

return a.l / block\_size < b.l / block\_size;

}

signed main(){

int n; cin >> n;

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

int q; cin >> q;

int ans[q] = {};

query Qur[q];

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

int l, r; cin>>l>>r;

Qur[i].l = l - 1;

Qur[i].r = r - 1;

Qur[i].indx = i;

}

block\_size = sqrt(n); // sqrt(q) dileo hobe, but n is more accurate

sort(Qur, Qur + q, comp);

int ML = 0, MR = -1;

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

int L = Qur[i].l;

int R = Qur[i].r;

// fixing right pointer

while (MR < R) add(++MR);

while (MR > R) sub(MR--);

// fixiing left pointer

while (ML < L) sub(ML++);

while (ML > L) add(--ML);

ans[Qur[i].indx] = cnt;

}

for (int i = 0; i < q; ++i)

cout << ans[i] << '\n';

}

**7.7 Meet in the middle**

#include <bits/stdc++.h>

using namespace std;

int les\_equal(vector<int> &s, int key){

int siz = s.size();

int lo = 0, hi = siz - 1, ans = 0;

while (hi >= lo){

int mid = lo + (hi - lo) / 2;

if (s[mid] <= key){

ans = max(ans, mid);

lo = mid + 1;

}

else hi = mid - 1;

}

return ans;

}

signed main(){

FIO int n, n1, n2, t;

cin >> n >> t;

n1 = (n + 1) / 2;

n2 = n / 2;

int a1[n1]; for(int &i: a1) cin>>i;

int a2[n2]; for(int &i: a2) cin>>i;

vector<int> set1, set2;

for(int mask=0; mask < (1<<n1); ++mask){

int temp\_sum = 0;

for (int i = 0; i < n1; ++i){

int f = 1 << i;

if (f & mask)

temp\_sum += a1[i];

}

set1.push\_back(temp\_sum);

}

for(int mask=0; mask < (1<<n2); ++mask){

int temp\_sum = 0;

for (int i = 0; i < n2; ++i){

int f = 1 << i;

if (f & mask)

temp\_sum += a2[i];

}

set2.push\_back(temp\_sum);

}

sort(set2.begin(), set2.end());

// for(auto itr: set2) cout<<itr<<' ';

// cout<<'\n';

// for(auto itr: set1) cout<<itr<<' ';

// cout<<'\n';

int ans = 0;

for (auto it : set1){

int left = t - it;

if (left < 0) continue;

int indx = les\_equal(set2, left);

int temp\_sum\_set2 = (indx != -1 ? (it + set2[indx]) : 0);

if (temp\_sum\_set2 <= t)

ans = max(ans, temp\_sum\_set2);

}

cout<<ans;

}

**7.8 PIE(inclusion - exclusion)**

#include <bits/stdc++.h>

using namespace std;

inline int LCM(int a, int b){

return a \* b / \_\_gcd(a, b);

}

int PIE(int div[], int n, int num){

int sum = 0;

for(int msk=1; msk < (1<<n); ++msk){

int bit\_cnt = 0;

int cur\_lcm = 1;

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

if (msk & (1 << i)){

++bit\_cnt;

cur\_lcm = LCM(cur\_lcm, div[i]);

}

}

int cur = num / cur\_lcm;

if (bit\_cnt & 1) sum += cur;

else sum -= cur;

}

return num - sum;

}

signed main(){

int n, m;

while (cin >> n >> m){

int a[m];

for(int &i : a)cin >> i;

cout << PIE(a, m, n) << '\n';

}

}

{

"cmd": ["g++.exe","-std=c++14", "${file}",

"-o", "${file\_base\_name}.exe", "&&" ,

"${file\_base\_name}.exe<inputf.in>outputf.i

n"],

"shell":true,

"working\_dir":"$file\_path",

"selector":"source.cpp"

}

**topic : Expected Value**

If the probability that your candidate will win is strictly greater than W%, print

GET A CRATE OF CHAMPAGNE FROM THE BASEMENT!

If your candidate has no chance of winning,

Print RECOUNT!

Otherwise, print PATIENCE, EVERYONE!

#include <bits/stdc++.h>

using namespace std;

#define err 1e-15

double dp[103][103]; // dp[confirmed votes][unknown votes]

signed main(){

dp[0][0] = 1.0;

for(int i = 1; i < 101; ++i){

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

dp[i][j] += 0.5 \* dp[i - 1][j];

// confirmed vote increased but the vote didn't go to my favour

dp[i][j + 1] += 0.5 \* dp[i - 1][j];

// confirmed vote increased and went to my favour

}

}

TC{

int n, a, b, w;

cin >> n >> a >> b >> w;

int un\_c = n - (a + b);

int flag = 101;

for(int i=0; i <= un\_c; ++i){

if(2\*a + 2\*i > n){

flag = i;

break;

}

}

double sum = 0;

for (int i = flag; i <= un\_c; ++i)

sum += dp[un\_c][i];

sum \*= 100;

sum -= err;

if (sum > w)

cout<<"GET A CRATE OF CHAMPAGNE FROM THE BASEMENT !\n";

else if(flag==101) cout<<"RECOUNT!\n";

else cout<<"PATIENCE,EVERYONE!\n";

}

}