CS F211
Data Structures and Algorithms
Assignment - 10

Graphs, Non-Binary Trees

Allowed Languages: **C, C++**

April 3, 2024

General Tips

- Try to use functions as much as possible in your code. Functions increase reusability and the pass-by-value feature provides a significant help sometimes. Modularizing your code also helps you to debug efficiently.
- Use `scanf` to read characters/strings from STDIN. Avoid using `getchar`, `getc` or `gets`. Try to read up about character suppression in `scanf` as it will be very helpful in some of the problems.
- Use `printf` instead of `putc`, `putchar` or `puts` to print character/string output on STDOUT.
- Indent your code appropriately and use proper variable names. These increase readability and writability of the code. Also, Use comments wherever necessary.
- Use a proper IDEs like Sublime Text or VSCode as they help to run and test your code on multiple test-cases easily.
- **Note:** Kindly try to do all of these questions by yourself at least once. Spend some time thinking about it, or trying to code it instead of directly asking help of your friends or searching it up online. This helps you understand the question, allowing you to solve further questions which are not in the scope of this Assignment yourself.
- 0 or 1, whichever is the smallest value is the root node in tree problems, unless specified otherwise.

A: Nom is Old

As time passed by, having not had enough Peanut Butter in his life, Nom started to grow old and weak. He decided to send one of his juniors to gather all the Peanut Butter jars from just the longest path between any two nodes. Each node has a jar. The tree was not binary anymore, it also grew more branches as Nom grew older.

Help Nom have as many Peanut Butter jars as he can during his last times.

Input

The first line contains a single integer n ($1 \leq n \leq 10^6$) - number of edges in the tree.
The next n lines contain two integers each, specifying the edge between two nodes.

Output

A single integer - the maximum number of jars Nom can have.

```
input
12
0 1
0 2
0 3
1 4
1 5
1 6
3 7
3 8
6 9
6 10
7 11
9 12

output
8
```

B: Kira goes ICPC

Kira has gone to UP to give his ICPC Continentals, so Nom has to make this Assignment in loneliness. Thus, Nom decided to steal all of Kira's prize money to go visit new cities which he had never been to. Assume that Kira's prize money never ends. Not all cities are connected together.

Now, Nom gets the news the Kira damaged all these roads through which he was planning to travel, to get his money back. Nom called up the Road Department and they told him that it will take a few years to get the roads back up again, unless..., he paid them some amount per road. Nom reluctantly agreed. Now, they gave him roads and the cost to rebuild them. Help Nom find the minimum cost to rebuild the roads such that he can go to all cities.

Input

The first line contains a single integer n ($1 \leq n \leq 2 * 10^3$) - number of roads.
The next n lines contain three integers each, specifying the two cities connected by a road and the cost to rebuild it.

Output

A single integer - minimum cost to rebuild the roads to connect all cities.

```
input
7
1 2 1
1 3 2
1 4 3
1 5 4
2 3 5
2 5 7
3 4 6

output
10
```

C: Kira goes ICPC 2

Kira practiced a lot of trees but was still scared during his ICPCs in case a tree problem came. There was a problem he did in binary trees in which he had to find the sum of depths of all subtree nodes in a given binary tree. But in ICPC it came as a general tree instead of a binary one. Even the example they gave was not of a general tree. Help Kira solve this problem for a general tree.

Input

The first line contains a single integer n ($1 \leq n \leq 10^6$) - number of edges in the tree.
The next n lines contain two integers each, specifying the edge between two nodes.

Output

A single integer - sum of depths of all subtree nodes in the tree.

---

input
```
8
1 2
1 3
2 4
2 5
3 6
3 7
4 8
4 9
```

output
```
26
```

---

input
```
4
1 2
1 3
1 4
3 5
```

output
```
6
```

D: Graphs are Nice

Tans got full in all 8 Labs. So she decided to leave DSA Assignments and do CodeLeet instead. There she encountered an interesting daily problem which was very much different than what we set in Assignments till now. The problem is as follows:

Given an unweighted, undirected graph of V nodes and E edges, a source node S, and a destination node D, find the shortest path from S to D in the graph.

Help Tans solve this problems so that she can maintain her CodeLeet streak.

Input

The first line contains 4 integers V, E, S and D ($1 \leq S, D \leq V \leq 10^5$; $1 \leq E \leq 10^5$) - number of vertices, edges, source node and destination node respectively.
The next E lines contain two integers each, specifying the edge between two nodes.

Output

Shortest Path from S to D.

```
input
8 10 0 7
0 1
1 2
0 3
3 4
4 7
3 7
6 7
4 5
4 6
5 6

output
0 3 7
```

E: DisCo, DSA, DAA...

As you know that you need to complete DisCo to do DSA and DSA to do DAA, similarly, you have n courses and m requirements given to you of the form "a should be completed before b". You have to find in which order to do the courses such that you complete all of them.

Input

The first line contains two integers n and m ($1 \leq n \leq 10^5$; $1 \leq m \leq 2 * 10^5$) - number of courses numbered 1 to n and number of requirements respectively.
Next m lines contain two integers a and b, where course a has to be completed before course b.

Output

Order in which you complete all the courses, otherwise "IMPOSSIBLE".

---

input
5 3
1 2
3 1
4 5

output
3 4 1 5 2

---

input
5 5
1 2
2 3
3 4
4 5
5 1

output
IMPOSSIBLE

F: Centroid

Kira is in train and still wants to bully the kids. So he sends the toughest problems for the Assignment even Nom couldn't solve. One of the problems are as follows:

Given a tree with n nodes, find the centroid of the tree such that when the centroid is appointed as the root node, each subtree has at most $\lfloor n/2 \rfloor$ nodes.

Input

The first line contains a single integer n ($1 \leq n \leq 10^6$) - number of nodes in the tree.
The next $n-1$ lines contain two integers each, specifying the edge between two nodes.

Output

A single node - centroid of the tree with the minimum node value.

```
input
5
1 2
2 3
3 4
3 5

output
3
```

```
input
11
1 2
1 4
2 5
2 9
3 9
4 6
4 7
4 8
9 10
9 11

output
2
```

G: Flights

There are n countries and m flight connections such that every country is somehow connected to every other country. Find the lengths of the shortest routes from country 1 to every country.

Input

The first line contains n and m ($1 \leq n \leq 10^5$; $1 \leq m \leq 2 * 10^5$) - number of countries and number of flights respectively.
Next m lines contain the flight connections. Each line has three integers a, b and c: a flight begins at city a, ends at city b, and its length is c ($1 \leq c \leq 10^9$). Each flight is a one-way flight.

Output

n space-separated integers with the lengths of shortest routes from 1 to all countries.

```
input
5 6
1 2 10
1 3 5
1 4 2
4 2 3
3 5 4
2 5 1

output
0 5 5 2 6
```

```
input
3 4
1 2 6
1 3 2
3 2 3
1 3 4

output
0 5 2
```

H: Nom hates Negative Cycles

Nom was doing a project on directed graphs and he found out lots of negative cycles in it. Irritated by it, he decided to find out which cycles among the graphs are negative cycles. It is guaranteed that there will only be one negative cycle. If there exists one, give the cycle order.

A negative cycle is one where the sum of all the edges of the cycle is negative.

Input

The first line contains n and m ($1 \leq n \leq 2500$; $1 \leq m \leq 5000$) - number of nodes and edges respectively.
Next m lines contain the edges. Each line has three integers a, b and c: there is an edge from a to b, and its length is c ($-10^9 \leq c \leq 10^9$).

Output

"YES" with the cycle order if a negative cycle exists, otherwise "NO".

```
input
4 5
1 2 1
2 4 1
3 1 1
4 1 -3
4 3 -2

output
YES
1 2 4 1
```

```
input
3 4
1 2 6
1 3 2
3 2 3
1 3 4

output
NO
```

I: An Easy Problem

All of you must've heard about a $m * n$ grid which represents the map of 1's (land) and 0's (water). Your task is to find out the total number of islands present in the map such that Nom can go and dig them up to find new variants of Peanut Butter.

An island is surrounded by water and is connected to other land units either horizontally or vertically. All edges of the map are surrounded by water.

Input

The first line contains two integers m and n ($1 \leq m, n \leq 500$) - the dimensions of the map.
Next m lines contain n bits each representing the map.

Output

A single integer - number of islands.

```
input
4 5
0 1 1 0 1
1 1 0 0 0
0 0 0 0 1
0 0 1 1 1

output
3
```

```
input
7 4
1 1 1 0
1 0 0 1
0 0 0 1
1 0 1 1
0 0 0 0
1 1 1 1
0 1 0 0

output
4
```

J: Number of Connected Components

You're given n nodes in an undirected graph numbered 1 to n. The graph has m edges. Calculate the number of connected components in the graph.

A connected component is a set is a set of vertices in a graph that are linked to each other by paths.

Input

The first line contains two integers n and m ($1 \leq n \leq 10^5$; $1 \leq m \leq 2 * 10^5$).
Next m lines contain two integers each, specifying the edge between two nodes.

Output

A single integer - number of connected components.

```
input
8 5
1 2
2 3
2 4
3 5
6 7

output
3
```

```
input
4 2
1 3
2 4

output
2
```
