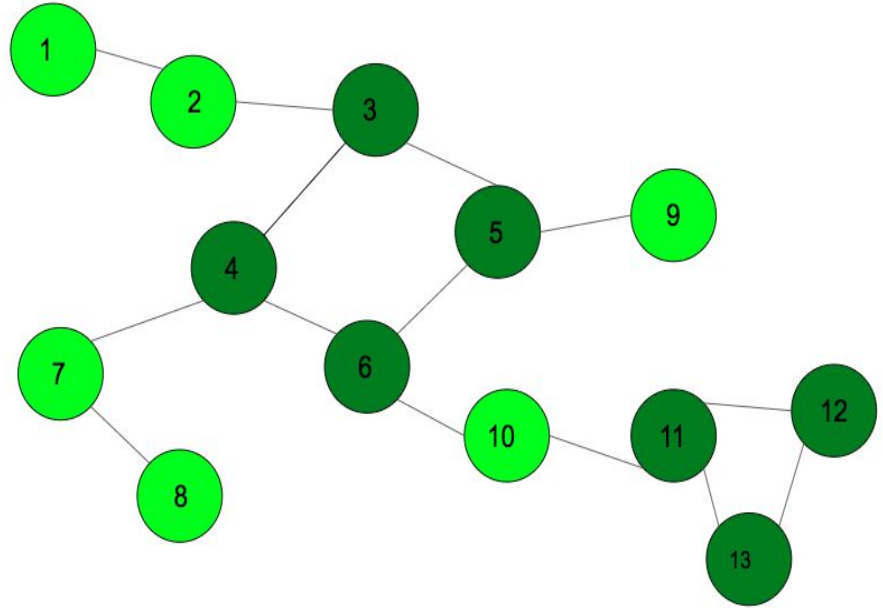


GRAPH AND TREES

GRAPHS???

Graphs are non-linear data structures that are used to represent the relationships between various entities.



REAL LIFE EXAMPLES.....

- **Geography of the country:** A country has various cities connected by roads. This type of information can be represented by graphs.
- **Network topology:** The information like how computers are connected in a network, and how should the data be transferred between two computers can be represented by graphs.

FORMAL DEFINITION

A graph G can be defined as a pair (V, E) , where V is a set of vertices, and E is a set of edges between the vertices $E \subseteq \{(u, v) \mid u, v \in V\}$.

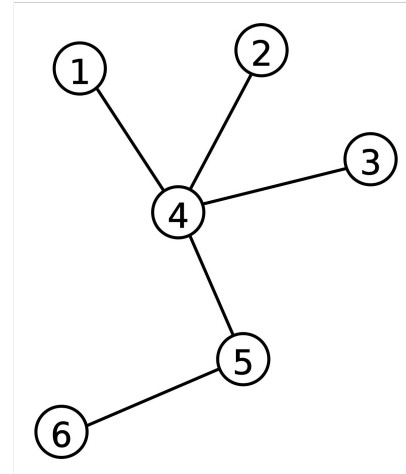
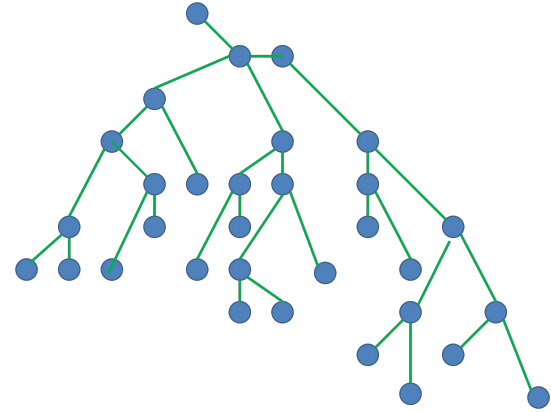
TYPES???

- CONNECTED/UNCONNECTED GRAPH
- CYCLIC/ACYCLIC GRAPH
- DIRECTED/UNDIRECTED GRAPH
- WEIGHTED/UNWEIGHTED GRAPH
- BIPARTITE GRAPH
- SIMPLE GRAPH
- DENSE/SPARSE GRAPH

TREES???

Trees are nothing but acyclic connected graphs. Some of the properties of trees include:

- There are $N-1$ edges on a tree if the number of nodes = N .
- A tree is acyclic
- It is connected.



GRAPH AND TREES IN CODE??

The most trivial way to represent graphs is using an array/vector of edges (pair of nodes which it connects). This type of representation is mostly used to give input in CP sites.

CODE

BASIC ALGORITHMS

DFS

Depth-first search (DFS) is an algorithm for traversing or searching tree or graph data structures. The algorithm starts at the root node (selecting some arbitrary node as the root node in the case of a graph) and explores as far as possible along each branch before backtracking.

Stacks are used for DFS.

CODE

BFS

The algorithm can be visualized as a fire originating from some node and spreading throughout the graph using the edges.

Queues are used for the same.

CODE

QUESTIONS...

QUESTION - 1

Given a tree with N nodes each node numbered from 0 to $N - 1$. It is rooted at node 0 . Each node has been assigned a value i.e., for node ' x ' value is $val[x]$. Can you find the depth of the node with value ' Y '?

BFS OR DFS??

CODE

QUESTION - 2

Count number of subgraphs in a disconnected graph?

CODE

LET'S MOVE TO A BIT
TOUGH QUESTION

QUESTION - 3

Detect cycle in an undirected **connected** graph?

Here, cycle is a path from a certain node X to itself, such that the path contains at least 1 edge and no edge is repeated in the path.

Do we really need an algorithm for
this question?

Now the graph need not be connected.....
Then??

Can we use the previous trick??

Now, the graph is directed and need not be connected.....

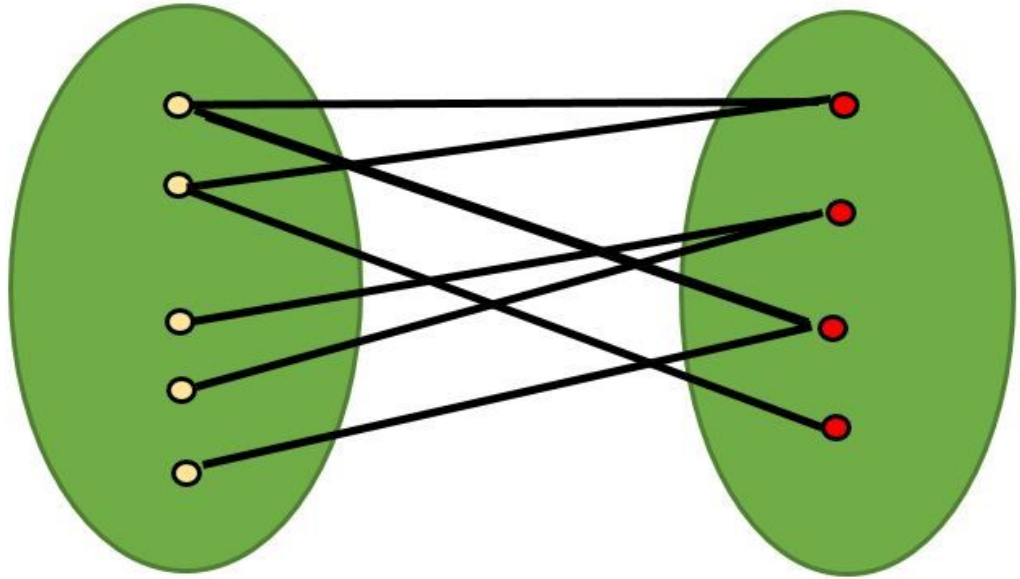
Solution: Topological sort or DFS with stack

Baad main padhenge.....

LET'S INCREASE
DIFFICULTY AGAIN

BIPARTITE GRAPH

A Bipartite Graph is a graph whose vertices can be divided into two independent sets, U and V such that every edge (u, v) either connects a vertex from U to V or a vertex from V to U .



HOW TO CHECK WHETHER A GRAPH IS BIPARTITE?

DFS?

CODE

QUESTION - 4

<https://codeforces.com/group/hUywLYmr80/contest/383005/problem/A>

CAUSE OF NETWORK ISSUE, HERE'S THE SS

A chess tournament is organized in MNNIT in which N players are registered. There will be M games and the schedule of the tournament is already released. You need to divide the players into two teams.

A Match is said to be a **deathmatch** if both the players of the match are from the same team. You need to divide the players into two teams so that the situation of deathmatch is delayed as much as possible.

Find the maximum number of games up to which the situation of deathmatch can be avoided.

Input

First line contains N ($1 \leq N \leq 10^5$), the number of Players.

Second line contains M ($1 \leq M \leq 5 * 10^5$), the number of matches.

Next M lines will contain two different integers ($1 \leq u, v \leq N$) representing the game between two players.

Output

Output Single integer, The maximum number of games up to which the situation of deathmatch can be avoided.

Examples

input	Copy
3 3 1 2 2 3 3 1	
output	Copy
2	

input	Copy
4 4 1 3 2 4 1 2 2 3	
output	Copy
3	

Note

For Test 1: We can divide players as:

- Player 1 and 3 in Team A
- Player 2 in Team B. (or vice versa)

Hence there will be 2 matches before the deathmatch and it can be shown that it is the most optimal answer.

For Test 2: We can divide players as:

- Player 1 and 4 in Team A
- Player 2 and 3 in Team B. (or vice versa)

Hence there will be 3 matches before the deathmatch and it can be shown that it is the most optimal answer.

Is your solution $O(N^2)$???

Constraints:

$1 \leq N \leq 1e5$

$1 \leq M \leq 1e5$

CODE

QUESTION - 5 (ASKED IN OA)

There are N people numbered from 0 to $N - 1$. You are given an array 'A' of pairs of size M . At i th second, $A[i].first$ and $A[i].second$ become friends.

If A and B are friends, B and C are friends, then A and C are also friends.

Determine the instant at which all the N people become friends.