Graphs level 1

Data Structures

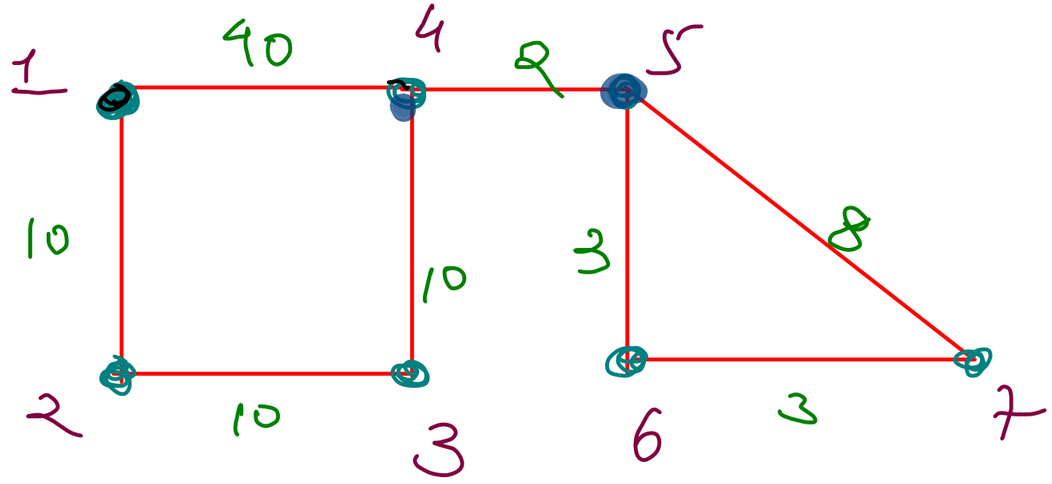
- → Arrays & Strings
- → Array list
- → Stack
- → Queue
- → Linked list
- → Generic Tree
- → Binary Tree
- → Binary Search Tree
- → Hashmap
- → Heap

Graphy

- → graph algorithms
- → graph application

Terminologies

1. Node / vertices
2. Edges
3. Undirected / directed
   - undirected → bidirectional
   - directed → unidirectional
4. weighted / unweighted
5. Incoming Edge / Outgoing Edge



Applications

1. Google maps → Shortest distance / Mincost to connect all dist
2. Social Media
3. Airline Management

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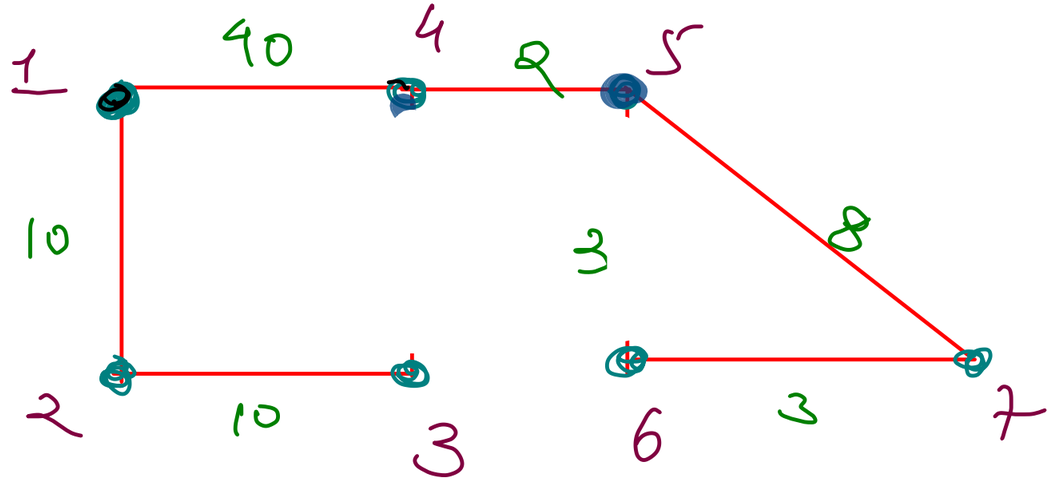

Applications

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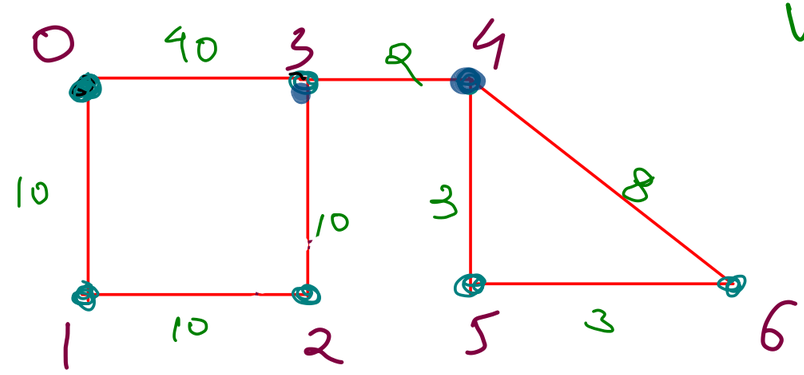
Implementation

② Adjacency matrix

	0	1	2	3	4	5	6
0	-1	10	-1	40	-1	-1	-1
1	10	-1	10	-1	-1	-1	-1
2	-1	10	-1	10	-1	-1	-1
3	40	-1	10	-1	2	-1	-1
4	-1	-1	-1	2	-1	3	8
5	-1	-1	-1	-1	3	-1	3
6	-1	-1	-1	-1	8	3	-1



$O(n)$

Vertices → n

Edges → $^nC_2$

$= \frac{n*(n-1)}{2}$

$O(n^2)$

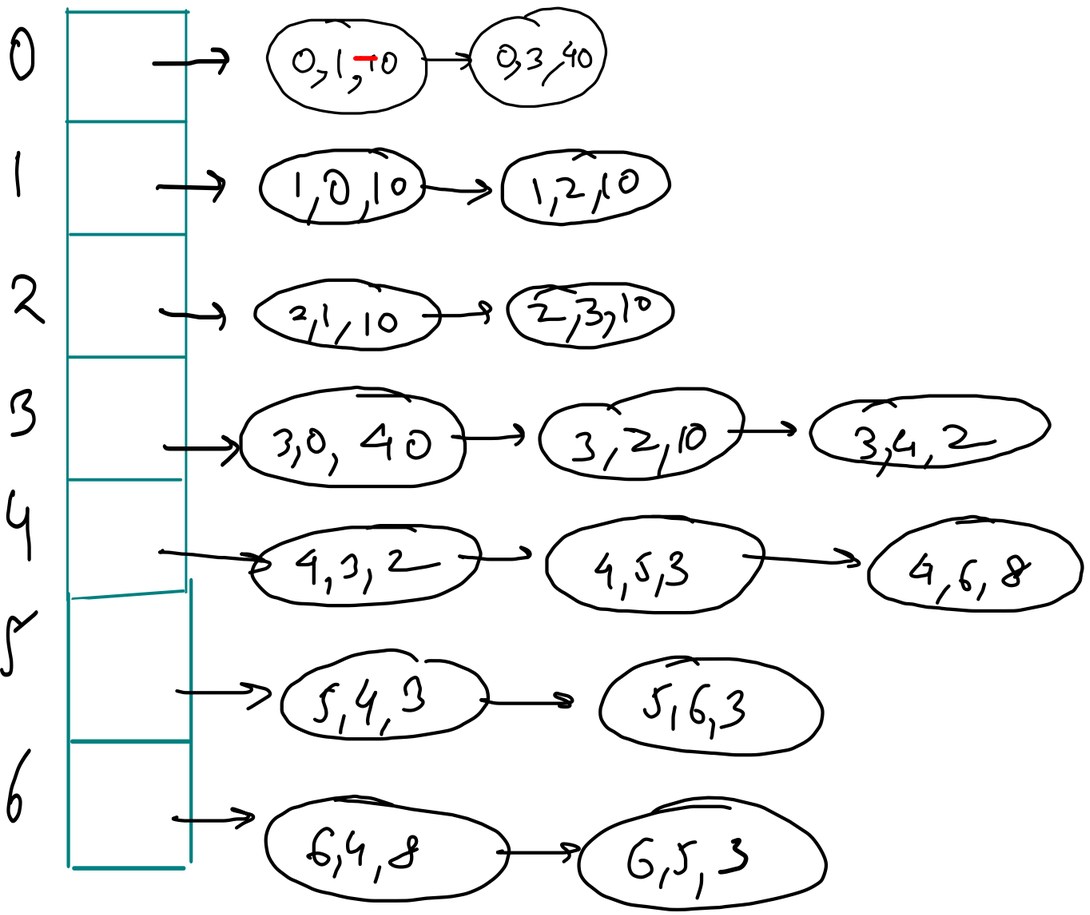
① Edge list

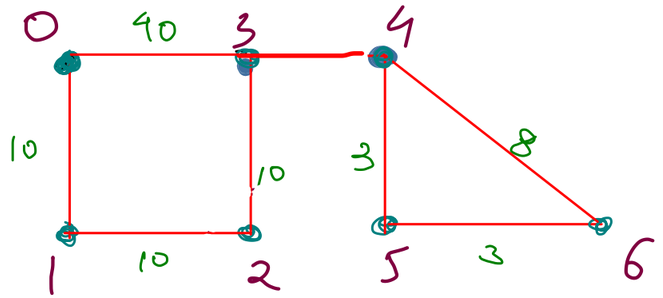
{ 0,3,40}, { 0,1,10}, { 1,2,10},

{ 2,3,10}, { 3,4,2}, { 4,5,3},

{ 5,6,3} , { 4,6,8}

③ Adjacency list






```java
static class Edge {
    int src;
    int nbr;
    int wt;
    Edge(int src, int nbr){ }
    Edge(int src, int nbr, int wt){ }
}
```

Edge class

```java
ArrayList<Edge>[] graph = new ArrayList[vts];
for(int i=0; i<vts; i++){
    graph[i] = new ArrayList<>();
}
```

Initialization

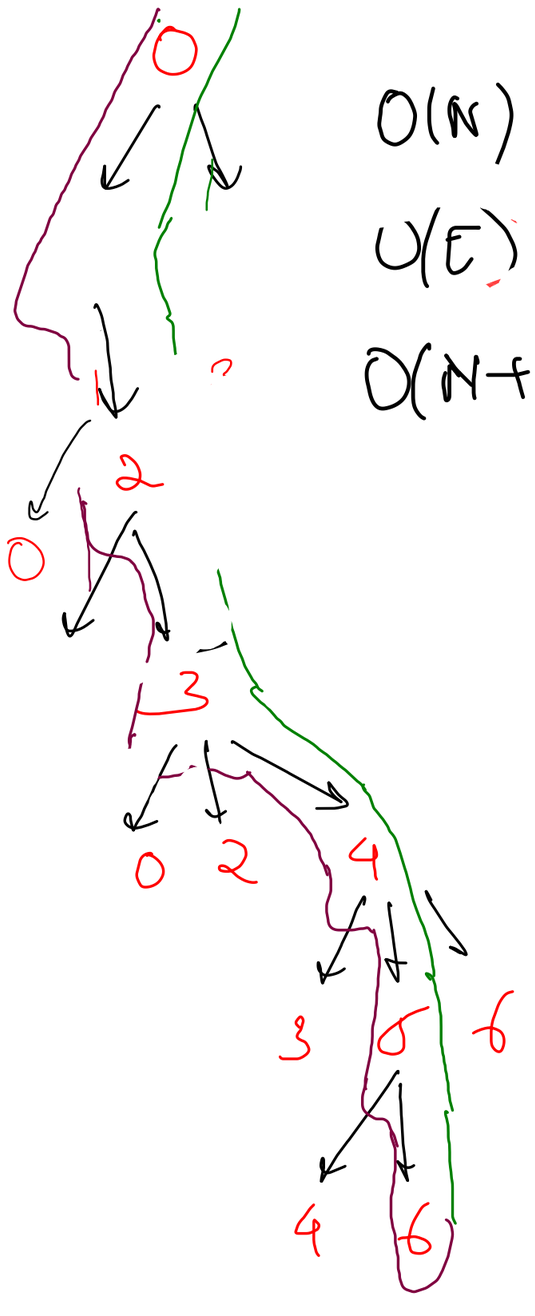
```java
int edges = scn.nextInt();

for(int i=0; i<edges; i++){
    int v1 = scn.nextInt();
    int v2 = scn.nextInt();
    int wt = scn.nextInt();

    graph[v1].add(new Edge(v1, v2, wt));
    graph[v2].add(new Edge(v2, v1, wt));
}
```

Construct

```java
for(int i=0; i<vts; i++){

    System.out.print(i + ": ");

    // Adjacency List of Vertex i
    for(Edge e: graph[i]){
        System.out.print("{ " + e.src + ", " + e.nbr + " @ " + e.wt + "}, ");
    }

    System.out.println();
}
```

display

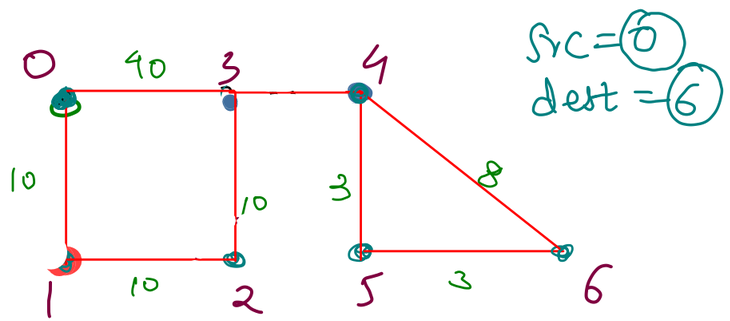
has Path

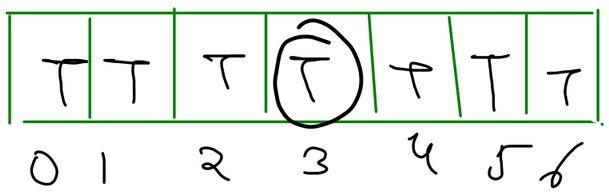


O(N)

O(E)

O(N+E)





2f 2f 3p

...

= O(E)

```java
public static boolean dfs(ArrayList<Edge>[] graph, int src, int dest, boolean[] vis){
    if(src == dest){
        return true;
    }

    vis[src] = true;

    for(Edge e: graph[src]){
        if(vis[e.nbr] == false){ // already visited
            boolean res = dfs(graph, e.nbr, dest, vis);
            if(res == true) return true;
        }
    }

    return false;
}
```

1. Time Complexity of DFS (Single Choice) *

30/30 (100%) answered

A Has Path - O(N + E), Print All Paths - O(N + E) (14/30) 47%

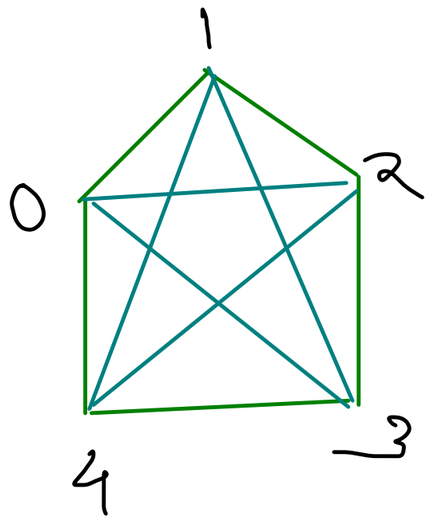
B Has path - O(N + E), Print All Paths - Exponential (14/30) 47%

C Has Path - Exponential, Print All Paths - Exponential (2/30) 7%

Backtracking ⇒ ~~polynomial~~ Exponential

Recursion

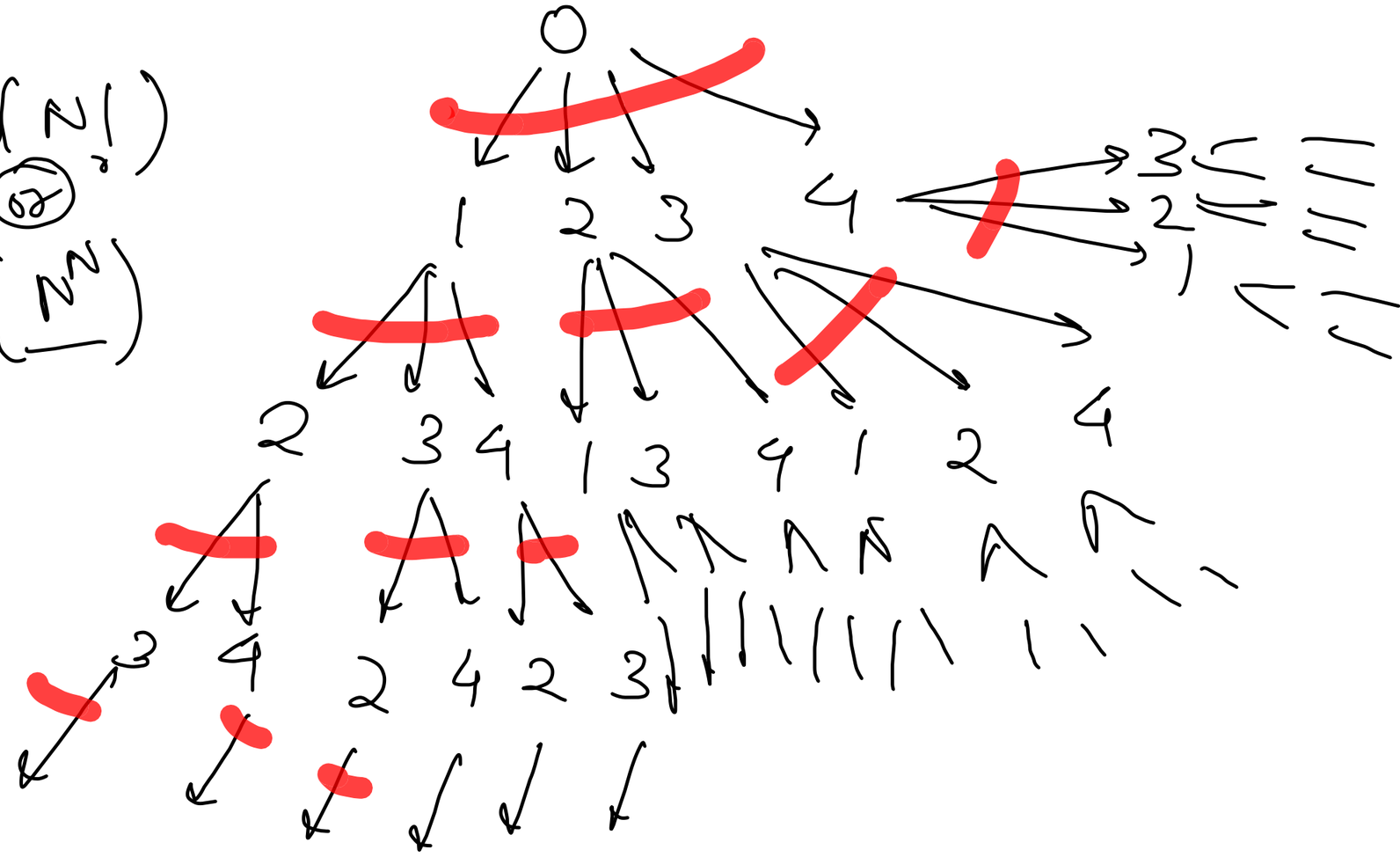
$(\text{calls})^{\text{height}} = \left(\frac{E}{N}\right)^{N} = \left(\frac{N^2}{N}\right)^{N} = O(N^N)$



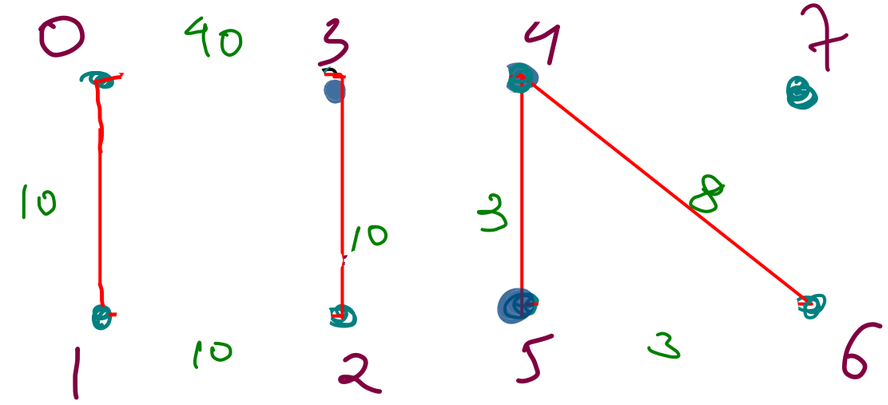
$O(N!)$

or

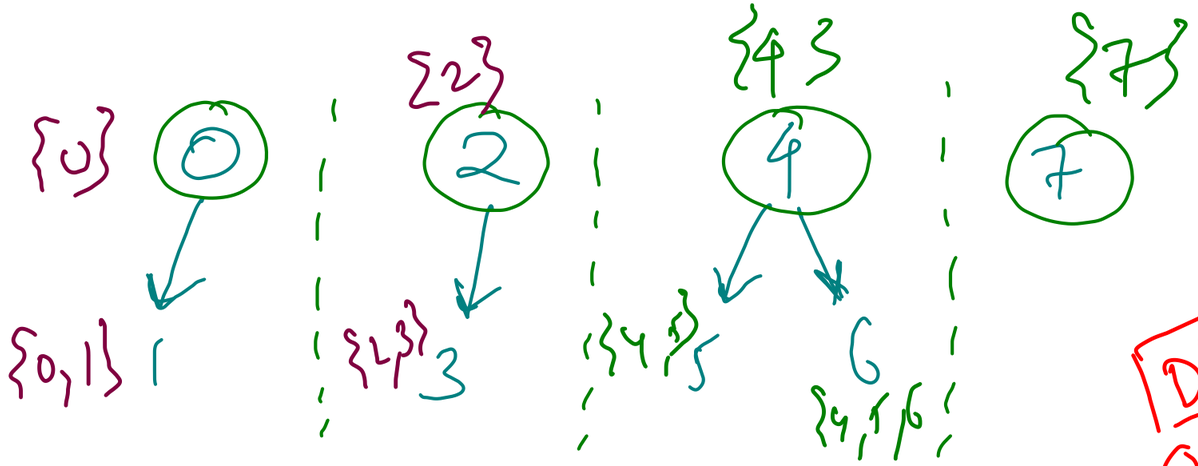
$O(N^N)$

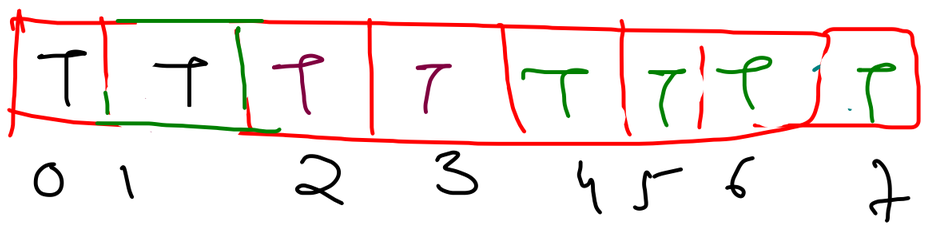


connected components {undirected}



{{0,1}, {2,3}, {4,5,6}, {7}}





DFS
O(N+E)

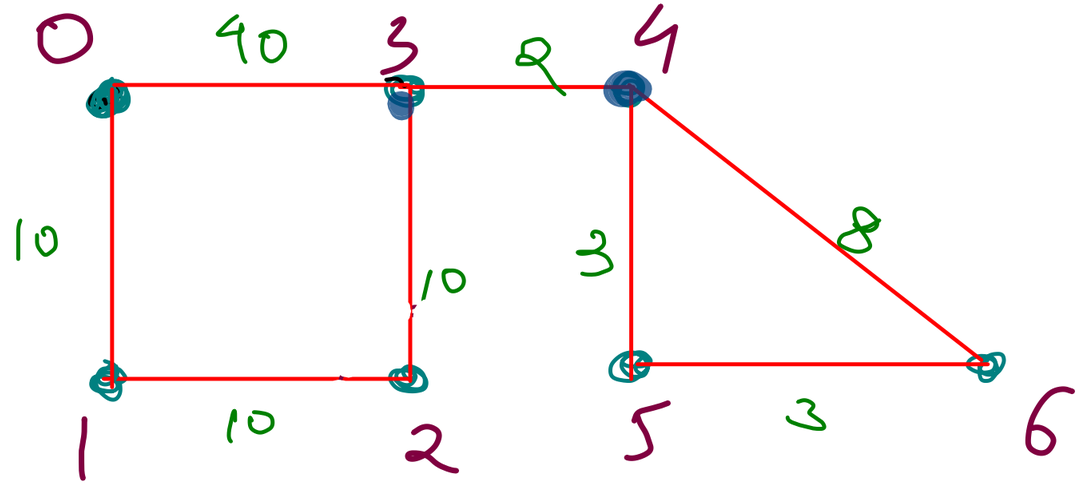
```java
public static void dfs(ArrayList<Edge>[] graph,
        int src, ArrayList<Integer> comp, boolean[] vis){
    vis[src] = true;
    comp.add(src);

    for(Edge e: graph[src]){
        if(vis[e.nbr] == false){ // already visited
            dfs(graph, e.nbr, comp, vis);
        }
    }
}
```

```java
for(int i=0; i<vtces; i++){
    if(vis[i] == false){
        ArrayList<Integer> comp = new ArrayList<>();
        dfs(graph, i, comp, vis);
        comps.add(comp);
    }
}
```

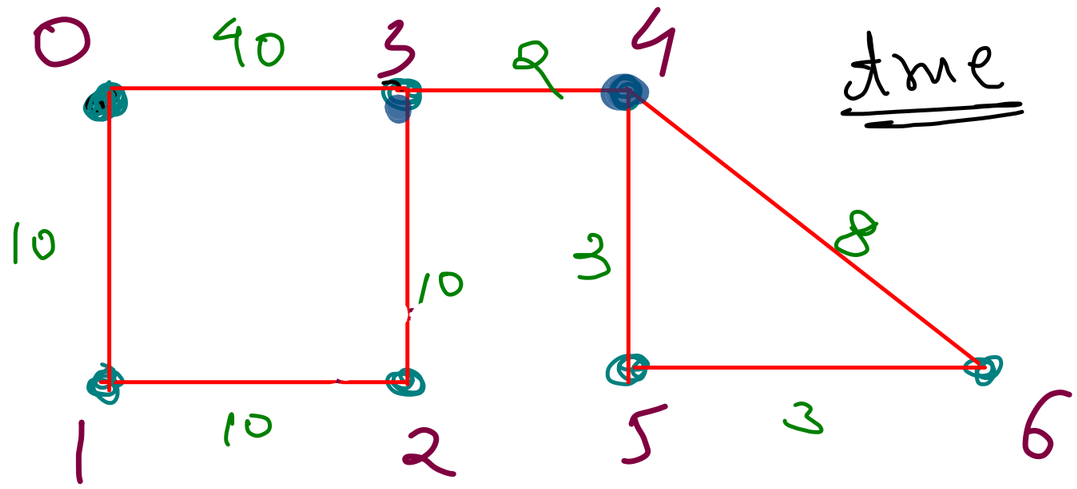
Today's Questions

- Multisolver - Smallest, Longest, Ceil, Floor, Kthlargest Path
- Is Graph Connected
- Number Of Islands
- Perfect Friends
- ~~Hamiltonian Path And Cycle~~

} ⇒ multisource DFS



Is Graph connected



component

=1 : connected

>1 : disconnected

=0 component {not possible} { atleast one vertex should be present in graph }

Number of Islands

Prerequisite :- Floodfill, Connected components.

O(r*c)

```
public static void dfs(int[][] arr, int srcRow, int srcCol){
    if(srcRow < 0 || srcRow >= arr.length || srcCol < 0
        || srcCol >= arr[0].length || arr[srcRow][srcCol] != 0){
        // invalid cell or already visited island cell or water cell
        return;
    }

    arr[srcRow][srcCol] = -1;

    dfs(arr, srcRow + 1, srcCol);
    dfs(arr, srcRow - 1, srcCol);
    dfs(arr, srcRow, srcCol + 1);
    dfs(arr, srcRow, srcCol - 1);
}
```

```
int islands = 0;
for(int i=0; i<m; i++){
    for(int j=0; j<n; j++){

        if(arr[i][j] != -1 && arr[i][j] != 1)
        {
            // unvisited island cell
            dfs(arr, i, j);
            islands++;
        }

    }
}
System.out.println(islands);
```

for each r*c cell

no of vertices

c

r

```
0 0 1 1 1 1 1 1 1
0 0 1 1 1 1 1 1 1
1 1 1 1 1 1 1 0
1 1 0 0 0 1 1 0
1 1 1 1 0 1 1 0
1 1 1 1 0 1 1 0
1 1 1 1 1 1 1 0
1 1 1 1 1 1 1 0
```

ϕ X 3

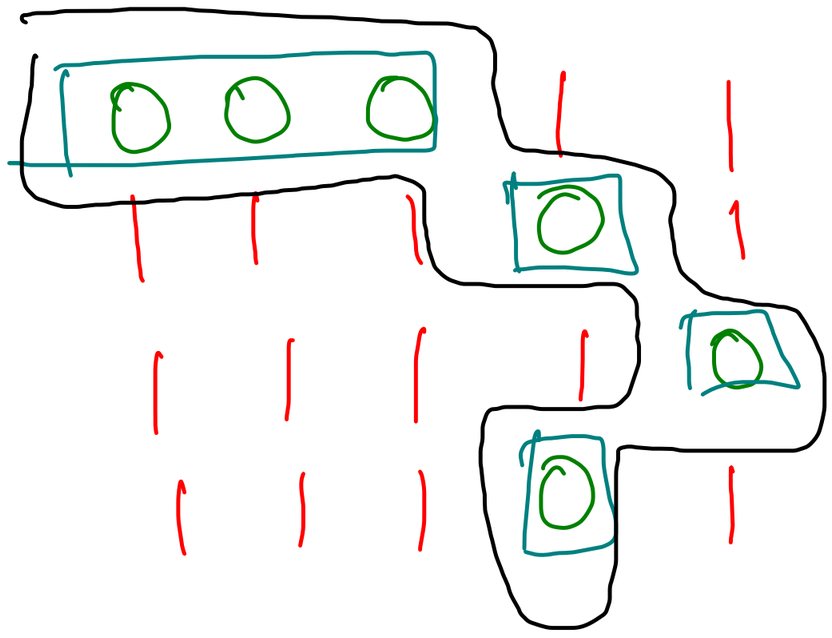
0 ⇒ island

1 ⇒ water

4 way connected

Note

↙ This matrix is not adjacency matrix.



4 way connected != 4

8 way connected != 1

Perfect friends

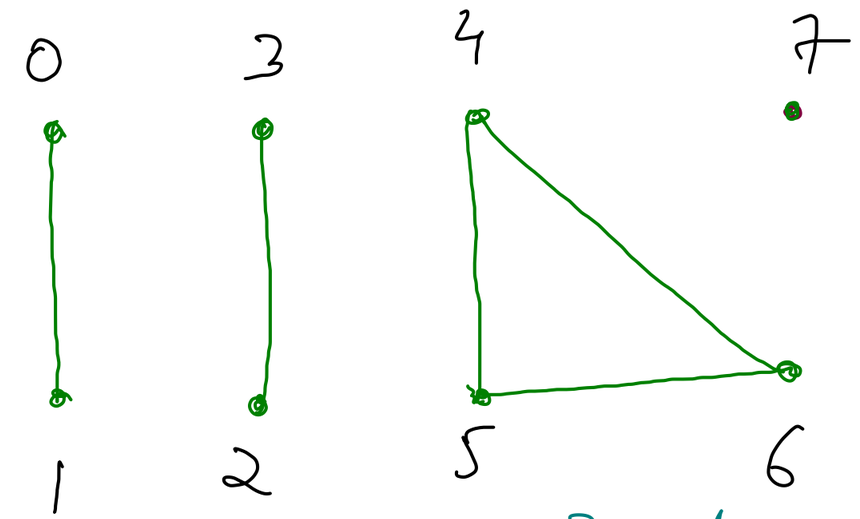
```
8
5
01
23
45
56
46
```

vl=0	vl=1
(0,2)	(1,2)
(0,3)	(1,3)
(0,4)	(1,4)
(0,5)	(1,5)
(0,6)	(1,6)
(0,7)	(1,7)

vl=2	vl=3
(2,4)	(3,4)
(2,5)	(3,5)
(2,6)	(3,6)
(2,7)	(3,7)

vl=4	vl=5	vl=6
(4,7)	(5,7)	(6,7)

vl=7 no pair



{ {0,1,3}, {2,4}, {5,6}, {7} }

2 * 6 + 2 * 4 + 3 * 1 + 1 * 0

= 12 + 8 + 3 + 0 = 23

Approach 1

```
int countWays = 0;
int remVtces = vtces;

for(int size: comps){
    remVtces -= size;
    countWays += remVtces * size;
}
System.out.println(countWays);
```

Approach 2

```
int countWays = 0;
for(int c1 = 0; c1 < comps.size(); c1++){
    for(int c2 = c1 + 1; c2 < comps.size(); c2++){
        countWays = countWays + comps.get(c1) * comps.get(c2);
    }
}
System.out.println(countWays);
```

Multisolver - Smallest, Longest, Ceil, Floor, Kthlargest Path

smallest :→ 0123456 @ 38

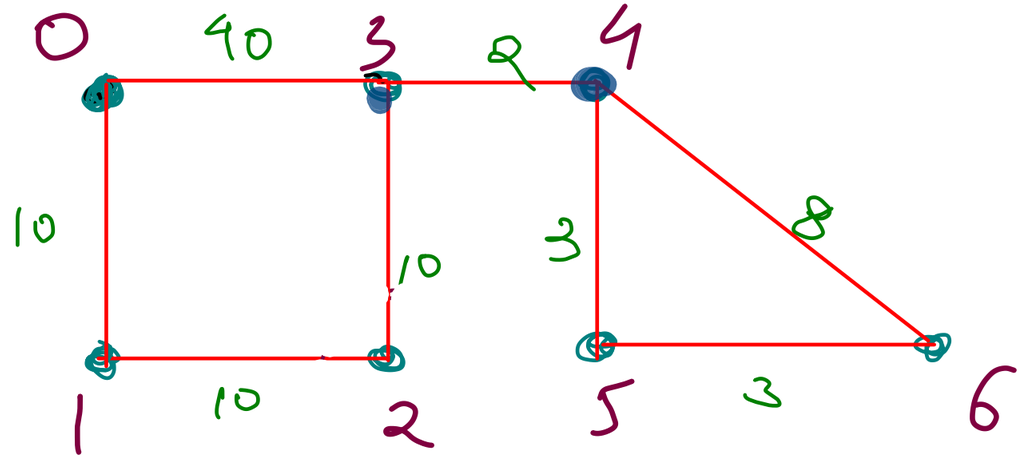
longest :→ 0346 @ 50

ceil(40) :→ 0345 @ 48

floor(40) :→ 012345 @ 38

kthlargest :
k = 3
012346 @ 40

src = 0, dest = 6
val = 40



0123456 :→ 38

01246 :→ 40

0346 :→ 48

0346 :→ 50

```java
public static void dfs(ArrayList<Edge>[] graph, int src, int dest,
        boolean[] vis, String pathSofar, int weightSofar){
    if(src == dest){ }

    vis[src] = true;

    for(Edge e: graph[src]){
        if(vis[e.nbr] == false){
            dfs(graph, e.nbr, dest, vis, pathSofar + e.nbr, weightSofar + e.wt);
        }
    }

    vis[src] = false;
}
```