

# Q1

Q1.1)

adajcency matrix

```
[[0. 1. 0. 1. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 1. 0. 1. 0. 0. 0. 1. 0. 1.]
 [1. 0. 1. 0. 0. 1. 1. 1. 1. 0. 0. 0. 1. 0. 0. 0. 1. 1. 1. 1. 1. 0.]
 [0. 1. 0. 1. 1. 1. 1. 0. 1. 1. 1. 0. 0. 0. 0. 1. 0. 1. 0. 1. 0. 0.]
 [1. 0. 1. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 1. 0. 1. 0. 1.]
 [0. 0. 1. 0. 0. 0. 1. 0. 0. 0. 0. 1. 1. 1. 1. 1. 1. 0. 0. 1. 0. 1.]
 [0. 1. 1. 0. 0. 0. 0. 0. 0. 1. 0. 0. 1. 0. 1. 0. 1. 0. 0. 1. 0. 0.]
 [0. 1. 1. 1. 1. 0. 0. 0. 1. 0. 1. 0. 1. 0. 1. 1. 1. 1. 0. 0. 0.]
 [0. 1. 0. 0. 0. 0. 0. 0. 0. 1. 1. 0. 0. 0. 1. 1. 0. 1. 0. 1. 0. 1.]
 [0. 1. 1. 0. 0. 0. 0. 1. 0. 0. 0. 1. 1. 1. 1. 1. 1. 1. 0. 0. 1. 0.]
 [0. 1. 1. 0. 0. 0. 1. 0. 0. 1. 1. 1. 1. 1. 1. 1. 1. 1. 0. 0. 1. 1.]
 [0. 0. 1. 0. 0. 1. 0. 1. 0. 1. 1. 1. 1. 1. 1. 1. 1. 1. 0. 0. 1. 1.]
 [0. 0. 1. 0. 0. 1. 1. 0. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 0. 0. 1. 1.]
 [1. 0. 1. 0. 1. 0. 0. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 0. 0. 0. 1.]
 [0. 1. 0. 0. 1. 0. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 0. 0. 0. 1.]
 [0. 1. 0. 0. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 0. 0. 0. 1.]
 [0. 0. 0. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 0. 0. 0. 1.]
 [0. 1. 1. 0. 1. 0. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 0. 0. 0. 1.]
 [0. 1. 0. 1. 0. 0. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 0. 0. 0. 1.]
 [1. 1. 1. 0. 0. 1. 1. 1. 1. 0. 1. 1. 0. 0. 0. 1. 1. 0. 0. 0. 1. 0.]
 [0. 1. 0. 1. 1. 0. 0. 0. 1. 1. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0.]
 [1. 0. 0. 1. 0. 0. 0. 1. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0.]
 [node_id: 6
closeness centrality: 0.59375 rank: 2 /20
degree centrality: 0.3684210526315789 rank: 3 /20
```

Q1.2)

adajcency matrix

```
[[0. 1. 0. 1. 0. 0. 0. 0. 0. 0. 0. 1. 0. 1. 0. 0. 0. 0. 1. 0. 1. 0. 1.]
 [1. 0. 1. 0. 0. 1. 1. 1. 1. 0. 0. 0. 1. 0. 0. 0. 1. 1. 1. 1. 1. 0.]
 [0. 1. 0. 1. 1. 1. 1. 0. 1. 1. 1. 0. 0. 0. 0. 1. 0. 1. 0. 1. 0. 0.]
 [1. 0. 1. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 1. 0. 1. 1.]
 [0. 0. 1. 0. 0. 0. 1. 0. 0. 0. 0. 0. 1. 1. 1. 1. 1. 0. 0. 0. 1. 0.]
 [0. 1. 1. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 1. 0. 1. 0. 0. 1. 0. 0. 0.]
 [0. 1. 1. 1. 1. 0. 0. 0. 1. 0. 1. 0. 1. 0. 1. 0. 1. 1. 1. 0. 0. 0.]
 [0. 1. 0. 0. 0. 0. 0. 0. 1. 0. 0. 1. 0. 1. 0. 1. 0. 1. 1. 1. 0. 0.]
 [0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 1. 1. 0. 0. 0. 0. 0. 0. 0. 1. 0. 1.]
 [0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 1. 1. 1. 1. 1. 1. 1. 0. 0. 1. 0. 1.]
 [0. 1. 1. 0. 0. 0. 1. 0. 0. 1. 1. 1. 1. 1. 1. 1. 1. 0. 0. 1. 0. 1.]
 [0. 1. 1. 0. 0. 0. 1. 1. 0. 0. 1. 1. 1. 1. 1. 1. 1. 0. 0. 1. 0. 1.]
 [0. 0. 1. 0. 0. 1. 0. 0. 1. 0. 1. 1. 1. 1. 1. 1. 1. 0. 0. 0. 1. 1.]
 [0. 0. 1. 0. 0. 0. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 0. 0. 0. 1. 1.]
 [0. 0. 1. 0. 0. 0. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 0. 0. 0. 1. 1.]
 [1. 0. 1. 0. 1. 0. 0. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 0. 0. 0. 1. 0.]
 [0. 1. 0. 0. 1. 1. 1. 0. 1. 1. 1. 1. 0. 0. 1. 0. 0. 0. 0. 0. 0. 1.]
 [1. 0. 0. 0. 1. 0. 0. 0. 1. 1. 1. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0.]
 [0. 0. 0. 1. 1. 1. 1. 1. 1. 1. 1. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0.]
 [0. 1. 1. 0. 1. 0. 1. 1. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0.]
 [0. 1. 0. 1. 0. 0. 1. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [1. 1. 1. 0. 0. 1. 1. 1. 1. 0. 1. 1. 0. 0. 0. 0. 1. 1. 0. 0. 0. 1.]
 [0. 1. 0. 1. 1. 0. 0. 0. 1. 1. 0. 1. 0. 0. 0. 0. 0. 0. 0. 1. 0. 1.]
 [1. 0. 0. 1. 0. 0. 0. 1. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0.]
 [node_id: 8
betweenness centrality: 0.005360623781676412 rank: 1 /10
degree centrality: 0.3157894736842105 rank: 2 /10
```

Q1.3)

adajcency matrix

```
[[0. 1. 0. 0. 1. 1. 1. 0. 0. 1. 1. 0. 1. 0. 1. 1. 0. 1. 0. 0. 0.]
 [1. 0. 1. 0. 0. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 0. 0.]
 [0. 1. 0. 0. 0. 1. 1. 0. 0. 0. 1. 0. 0. 1. 0. 0. 0. 0. 0. 0. 1.]
 [1. 0. 1. 0. 1. 0. 0. 0. 1. 1. 0. 0. 0. 1. 1. 1. 1. 1. 0. 0. 0.]
 [1. 1. 0. 0. 0. 0. 0. 1. 0. 0. 0. 1. 1. 0. 0. 1. 0. 0. 1. 0. 0. 0.]
 [0. 0. 0. 0. 1. 0. 1. 0. 0. 1. 0. 1. 1. 1. 0. 0. 0. 0. 1. 1. 1.]
 [1. 0. 0. 0. 0. 0. 0. 1. 0. 0. 1. 1. 1. 0. 1. 1. 1. 0. 1. 1. 1.]
 [0. 1. 1. 0. 1. 1. 1. 0. 0. 1. 1. 1. 1. 1. 0. 0. 1. 0. 0. 1. 1. 1.]
 [1. 0. 1. 0. 0. 0. 1. 0. 0. 0. 1. 0. 1. 0. 1. 0. 1. 0. 1. 1. 0. 0.]
 [0. 1. 0. 1. 0. 0. 1. 1. 1. 0. 0. 1. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0.]
 [1. 1. 1. 0. 1. 1. 1. 0. 1. 1. 0. 1. 0. 0. 1. 1. 1. 0. 0. 1. 1. 1.]
 [1. 0. 0. 0. 1. 0. 0. 1. 0. 0. 0. 1. 0. 1. 0. 1. 0. 1. 0. 1. 1. 0.]
 [1. 1. 0. 0. 0. 0. 1. 0. 1. 1. 1. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0.]
 [1. 1. 1. 0. 0. 0. 1. 1. 1. 0. 1. 1. 0. 0. 0. 1. 1. 1. 0. 0. 0. 1.]
 [1. 0. 0. 0. 1. 0. 0. 1. 0. 1. 0. 0. 0. 1. 1. 1. 0. 0. 0. 0. 0. 1.]
 [1. 1. 1. 0. 0. 0. 1. 1. 1. 0. 1. 1. 0. 0. 0. 1. 1. 1. 0. 0. 0. 1.]
 [0. 1. 0. 0. 0. 1. 1. 1. 1. 0. 0. 1. 1. 1. 0. 0. 0. 0. 0. 1. 1. 1.]
 [1. 0. 1. 1. 0. 1. 0. 1. 0. 0. 1. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 1.]
 [1. 0. 0. 1. 0. 1. 0. 1. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 1. 1. 0.]
 [1. 1. 1. 0. 0. 0. 0. 1. 1. 0. 1. 1. 0. 0. 0. 0. 0. 1. 0. 0. 0. 1.]]
```

node\_id: 13

eigenvector centrality: 0.1645387514108087 rank: 3 /20

degree centrality: 1.0 rank: 6 /20

Q1.4)

adajcency matrix

```
[[0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0.]
 [0. 0. 1. 0. 0. 0. 0. 1. 1. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 1. 0. 0. 0. 0. 0. 1. 1. 1. 0. 1. 0. 0. 1. 0. 0. 0. 0. 1. 0.]
 [0. 0. 0. 1. 1. 1. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 1.]
 [0. 0. 0. 1. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0.]
 [0. 0. 0. 1. 0. 0. 0. 0. 0. 1. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 1.]
 [0. 0. 0. 1. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 1.]
 [0. 0. 0. 1. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 1.]
 [0. 1. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 1. 0.]
 [0. 1. 1. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 1. 0. 0.]
 [1. 1. 1. 0. 0. 1. 1. 0. 0. 0. 1. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 1. 1. 0. 0. 0. 0. 0. 1. 0. 1. 0.]
 [0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0.]
 [0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 1.]
 [0. 1. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 1.]
 [0. 1. 1. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 1. 0. 0.]
 [1. 1. 1. 0. 0. 1. 1. 0. 0. 0. 1. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 1. 1. 0. 0. 0. 0. 1. 0. 1. 0.]
 [0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0.]
 [0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 1.]
 [0. 0. 0. 0. 0. 1. 1. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 1. 1. 0. 0. 0. 0. 0. 0.]
 [1. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1.]
 [0. 0. 0. 1. 0. 1. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1.]]
```

node\_id: 10

degree centrality: 0.10526315789473684 rank: 1 /20

closeness centrality: 0.40425531914893614 rank: 2 /20

Q1.5)  
adjacency matrix

```
[[0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0.]  
[0. 0. 1. 0. 0. 0. 0. 0. 1. 1. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]  
[0. 1. 0. 0. 0. 0. 0. 0. 1. 1. 1. 0. 0. 1. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 1. 0.]  
[0. 0. 0. 0. 1. 1. 1. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1.]  
[0. 0. 0. 1. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0.]  
[0. 0. 0. 1. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1.]  
[0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1.]  
[0. 1. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 1.]  
[0. 1. 1. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0.]  
[1. 1. 1. 0. 0. 0. 1. 1. 0. 0. 0. 0. 1. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]  
[0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]  
[0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 1. 1. 0. 0. 0. 0. 0. 1. 0. 0. 1. 0. 1. 1. 0. 0.]  
[0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0. 1. 0. 0.]  
[0. 0. 0. 1. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]  
[0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0.]  
[0. 0. 0. 0. 0. 0. 0. 1. 1. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]  
[0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]  
[0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]  
[1. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]  
[0. 0. 0. 1. 0. 1. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1.]]
```

node\_id: 10  
betweenness centrality: 0.0 rank: 1 / 20  
closeness centrality: 0.40425531914893614 rank: 2 / 20

Q1.7)

adajcency matrix

```
[[0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0.]
 [0. 0. 1. 0. 0. 0. 0. 1. 1. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 1. 0. 0. 0. 0. 0. 1. 1. 1. 0. 1. 0. 0. 1. 0. 0. 0. 0. 1. 0. 0.]
 [0. 0. 0. 0. 1. 1. 1. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 1.]
 [0. 0. 0. 1. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0.]
 [0. 0. 0. 1. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0.]
 [0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 1. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 1.]
 [0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1.]
 [0. 1. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 1. 0.]
 [0. 1. 1. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 1. 0. 0.]
 [0. 1. 1. 0. 1. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 1. 0. 0. 0.]
 [1. 1. 1. 0. 0. 1. 1. 0. 0. 0. 1. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 1. 0. 0. 0. 0. 0. 0. 1. 1. 0. 0. 0. 0. 1. 0. 1. 1. 0. 0.]
 [0. 0. 0. 0. 1. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 1. 0. 1. 0.]
 [0. 0. 1. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 1. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0. 1. 1. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0.]
 [0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0.]
 [0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [1. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 1. 0. 1. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1.]
 [0. 0. 0. 1. 0. 1. 1. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]]
```

node\_id: 0

closeness centrality: 0.3877551020408163 rank: 1 /20

betweenness centrality: 0.004873294346978557 rank: 2 /20

Q1.8)

adajcency matrix

```
[[0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0.]
 [0. 0. 1. 0. 0. 0. 0. 1. 1. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 1. 0. 0. 0. 0. 0. 1. 1. 1. 0. 1. 0. 0. 0. 1. 0. 0. 0. 0. 0. 1. 0.]
 [0. 0. 0. 0. 1. 1. 1. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 1.]
 [0. 0. 0. 1. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0.]
 [0. 0. 0. 1. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0.]
 [0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 1. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 1.]
 [0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1.]
 [0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1.]
 [0. 1. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 1. 0.]
 [0. 1. 1. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 1. 1. 0. 0. 0. 0. 1. 0. 1. 1. 0. 0. 0.]
 [0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 1. 0. 1. 0.]
 [0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0.]
 [0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 1. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 1. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1.]
 [1. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1.]
 [0. 0. 0. 1. 0. 0. 1. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]]
```

node\_id: 0

degree centrality: 0.10526315789473684 rank: 1 /20

eigenvector centrality: 0.12185043367972846 rank: 3 /20

```

Q1.9)
adajcency matrix
[[0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0.]
 [0. 0. 1. 0. 0. 0. 0. 1. 1. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 1. 0. 0. 0. 0. 0. 1. 1. 1. 0. 1. 0. 0. 1. 0. 0. 0. 0. 1. 0.]
 [0. 0. 0. 0. 1. 1. 1. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 1.]
 [0. 0. 0. 1. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 1. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0.]
 [0. 0. 0. 1. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1.]
 [0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 1. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 1. 0.]
 [0. 1. 1. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0.]
 [1. 1. 1. 0. 0. 1. 1. 0. 0. 0. 1. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 1. 1. 0. 0. 0. 0. 1. 0. 1. 1. 0. 0.]
 [0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 1. 0. 0.]
 [0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0. 1. 1. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [1. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1.]
 [0. 0. 0. 1. 0. 1. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1.]]
node_id: 0
closeness centrality: 0.3877551020408163 rank: 1 /20
eigenvector centrality: 0.12185043367972846 rank: 3 /20

```

```

Q1.10)
adajcency matrix
[[0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0.]
 [0. 0. 1. 0. 0. 0. 0. 1. 1. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 1. 0. 0. 0. 0. 0. 1. 1. 1. 0. 1. 0. 0. 1. 0. 0. 0. 0. 0. 1. 0.]
 [0. 0. 0. 0. 1. 1. 1. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 1.]
 [0. 0. 0. 1. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0.]
 [0. 0. 0. 1. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0.]
 [0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 1.]
 [0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1.]
 [0. 1. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 1. 0. 1. 0.]
 [0. 1. 1. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 1. 0. 0. 0.]
 [1. 1. 1. 0. 0. 1. 1. 0. 0. 0. 1. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.]
 [0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 1. 1. 0. 0. 0. 0. 1. 0. 1. 1. 0. 0. 0.]
 [0. 0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1. 0.]
 [0. 0. 0. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1.]
 [0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1.]
 [0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1.]
 [0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1.]
 [1. 0. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1.]
 [0. 0. 0. 1. 0. 1. 1. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 1.]]
node_id: 0
betweeness centrality: 0.004873294346978557 rank: 2 /20
eigenvector centrality: 0.12185043367972846 rank: 3 /20

```

Q2

$$E(x^2)$$

$$= \int_{x_m}^{\infty} x^2 p(x) dx$$

$$= z \int_{x_m}^{\infty} x^{-\alpha+2} dx$$

$$= \frac{z}{3-\alpha} [x^{3-\alpha}]_{x_m}^{\infty}$$

$$= \frac{(a-1)x_m^{\alpha-1}}{3-\alpha} [\infty^{3-\alpha} - x_m^{3-\alpha}] \stackrel{\text{for } \alpha > 3}{=} \frac{\alpha-1}{\alpha-3} x_m^2$$

$$\therefore \text{Var}(x) = E(x^2) - [E(x)]^2 \quad \text{for } \alpha$$

$$= \begin{cases} \infty & \text{for } \alpha \leq 3 \end{cases}$$

$$\left( \frac{\alpha-1}{\alpha-3} x_m^2 - \left( \frac{\alpha-1}{\alpha-2} \right) x_m^2 \right) \text{ for } \alpha > 3$$

$$= \begin{cases} \infty & \text{for } \alpha \leq 3 \end{cases}$$

$$\left[ \frac{(\alpha-1)(\alpha^2-5\alpha+7)}{(\alpha-2)^2(\alpha-3)} x_m^2 \right] \text{ for } \alpha > 3$$

### Q3

3.1

$$q = \frac{1}{2} \quad A = \{e, f\}$$

$$\textcircled{1} \quad \{c\} : \quad p = \frac{2}{2} = 1 > \frac{1}{2}$$

$\therefore c$  will change to A.

$$A = \{c, e, f\}$$

$$\textcircled{2} \quad \{i\} : \quad p = \frac{2}{3} > \frac{1}{2}$$

$\therefore i$  will change to A.

$$A = \{c, e, f, i\}$$

$$\textcircled{3} \quad \{k\} : \quad p = \frac{1}{2} \text{ not } > \frac{1}{2}$$

$\therefore k$  will not change.

$$\textcircled{4} \quad \{g\} : \quad p = \frac{1}{3} \text{ not } > \frac{1}{2}$$

$\therefore g$  will not change.

No any node has neighbor with behavior A, spread stop.

$\therefore$  only i & C switch to A.

3.2

$$\textcircled{1} \quad S = \{e, f\} \quad G/S = \{c, i, k, g, j, d, h\}$$

$$p=0 \leq \frac{1}{2}$$

$$\textcircled{2} \quad S = \{e, c, f\} \quad G/S = \{i, k, g, j, d, h\}.$$

$$p=\frac{1}{3} \leq \frac{1}{2}$$

$$\textcircled{3} \quad S = \{e, c, f, i\} \quad G/S = \{k, g, j, d, h\}.$$

$$p=\frac{1}{2} \leq \frac{1}{2}$$

$$\textcircled{4} \quad S = \{e, c, f, i, k\} \quad G/S = \{g, j, d, h\}$$

$$p=\frac{2}{3} > \frac{1}{2}$$

$\therefore$  The cluster  ~~$\{g, j, d, h\}$~~  blocks behavior A from spreading to all nodes.