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University Examinations 2023/2024

THIRD YEAR SECOND SEMESTER EXAMINATION FOR THE DEGREE OF BACHELOR
OF SCIENCE DATA SCIENCE

CDS 3354: COMPLEX NETWORK ANALYSIS

DATE: APRIL 2024

TIME: 2 HOURS

INSTRUCTIONS: Answer question *one* and any other *two* questions

QUESTION ONE (30 MARKS)

- a) Complex networks exhibit several distinct topological features that help characterize their structure and behavior. With appropriate mathematical formulas and/or illustrations, define each of the following;
- i. Degree (2 Marks)
 - ii. Degree Distribution (2 Marks)
 - iii. Clustering coefficient (2 Marks)
 - iv. Network Diameter (2 Marks)
- b) Discuss each of the following Stochastic models of Complex Networks;
- i. Erdos-Renyi Network Model (3 Marks)



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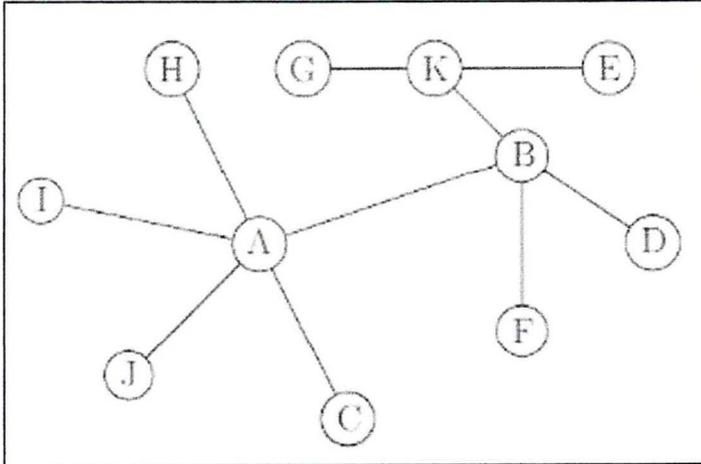


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ii. Watts-Strogatz Network Model (3 Marks)

iii. Barabasi-Albert Network Model (3 Marks)

c) Consider the network below which was constructed by the algorithm intended to generate a Barabasi-Albert network to answer the questions that follow;



i. Calculate the degree distribution of the network (4 Marks)

ii. Represent the degree distribution of in (i) above using a graph (4 Marks)

iii. Supposedly a new node is inserted in the network that will be attached to exactly one other node using the preferential attachment-rule. For the nodes A, B and C compute the probability that the new node will connect to each of them respectively. (Justify your answer) (5 Marks)

QUESTION TWO (20 MARKS)

a) A study seeks to establish the reason why Complex Network analysis is important to data scientists. As a graduate of Data Science, you are mandated to outline some of the reasons why it is important. Highlight at least four of the many reasons you would present in your report (8 Marks)

b) A data science student at Meru University of Science and Technology developed the following algorithmic sequence of steps to generate a random network. Using Python programming language, write code that would successfully implement his algorithm.



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Algorithm: Random_Network

Input: Maximum number of Nodes, N; Probability of connectivity, P

Output: Graph, G with randomly connected nodes N

Step 1: Define the number of nodes, N (can be obtained from the user)

Step 2: Define the probability, P (can be obtained from the user)

Step 3: Create a graph, G with N nodes without any edges.

Step 4: Add the edges to the graph randomly, take a pair of nodes, and get a random number R.

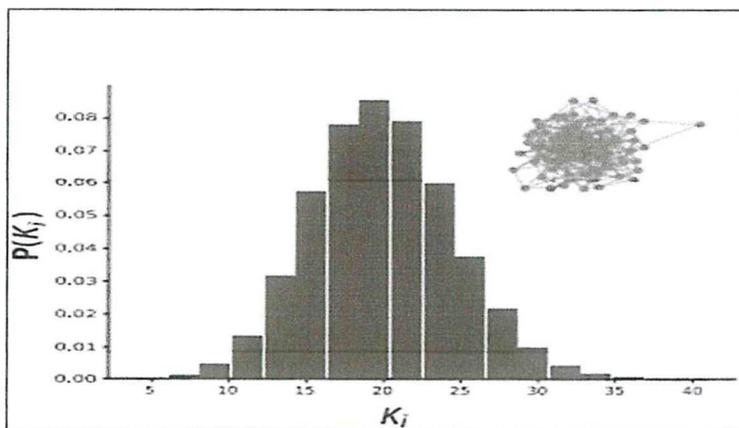
If $R < P$ (probability), add an edge. Repeat steps 5 and 6 for all possible pairs of nodes and then display the whole social network (graph) formed

Step 5: Display the Graph

Step 6: Perform analysis on need basis.

QUESTION THREE (20 MARKS)

- a) A student was working on working on his project using complex networks. Using her datasets, she plotted the degree distribution of the network and obtained the figure below;



- i. Describe the type of distribution exhibited in the figure (3 Marks)
 - ii. In your opinion, explain to the student the probable type of network model the data is modeled (3 Marks)
 - iii. Highlight the expected characterization of the network with regard to clustering coefficient, accidental failure of nodes and formation/disintegration of a giant component (5 Marks)
- b) Using appropriate examples; describe each of the following concepts as applied in complex networks;
- i. Resilience and robustness (3 Marks)
 - ii. Avalanche and failure cascades (3 Marks)
 - iii. Search and diffusion (3 Marks)

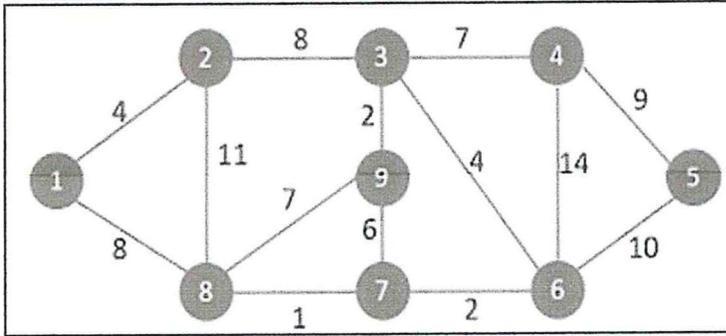
QUESTION FOUR (20 MARKS)

- a) Fill in the missing gaps in the following table; (8 Marks)

Type of network	Nodes/Vertices	Links/Edges
Communication network		
Biological networks		
Computer networks		
Neural networks		

- b) Using an example, describe the two common ways of representing complex networks (4 Marks)
- c) Represent the following network using the two ways describe in (b) above (8 Marks)





QUESTION FIVE (20 MARKS)

a) Consider the following rumour spreading process. There is a population of N individuals, one of whom initially knows a rumour. There are N independent Poisson processes, one associated with each individual. If individual i knows the rumour at an increment time of his Poisson process, then at this time he picks an individual uniformly at random from the population (including himself!), and informs this person of the rumour. This counts as one communication, even if the target (which could be himself) already knows the rumour. The choice of individual to contact at each step is independent of all past choices.

- i. How many communications does it take, on average, until all N individuals know the rumour? <Obtain a simple approximate expression for this quantity, for large N ; you may replace sums by integrals, or make other reasonable approximations, them> (6 Marks)
- ii. Obtain a simple approximation for the mean number of communications required until at least $n/2$ individuals know the rumour (6 Marks)
- iii. Represent this description as a complex temporal network for instances $t, t+2, t+4$ and $t+6$ (8 Marks)

