

CSC 539 Computational Epidemics
Summer 2022
Jackson State University
Exam 1
Instructor: Dr. Natarajan Meghanathan

Total Points: 125

Due: June 29th, 2022, 11.59 PM in Canvas

Q1: 17 pts) Consider an epidemic that spreads under the SI model with a transmission rate ($\langle k \rangle \beta$) of 1.2, where β is the probability an infected individual can infect a susceptible individual on any day. Note that the characteristic time for an epidemic under the SI model is the time it takes for the fraction of infected individuals to be ($1/e \sim 36\%$) of the entire population. Determine the *characteristic time* (in days) for the epidemic if the initial fraction (i_0) of the infected population is 0.001.

Q2: 30 pts) Consider an epidemic of $R_0 = 3$ that spreads under the SIS model with an initial fraction of infected nodes (i_0) being 0.0001. Let the fraction of infected nodes observed on the 10th day of its spread be 0.5.

- (a) Determine the transmission rate (term $\langle k \rangle \beta$) for the epidemic
- (b) Determine the average time (days) it takes for an infected person to recover and go back to the susceptible state.
- (c) Determine the fraction of infected nodes when the epidemic becomes an endemic.
- (d) Determine the time (# days) it takes for the fraction of infected nodes to become 99% of the fraction of infected nodes observed for (c): i.e., when the epidemic becomes an endemic.

Q3: 18 pts) Consider an epidemic (with $R_0 = 4$) that spreads under the SIR model in a city whose entire population is initially susceptible to the disease.

(a) Per the theoretical formulations we saw for the SIR model, what would be the maximum fraction of the population that would be infected at any time (i.e., the epidemic is said to have reached its peak)?

(b) Per the theoretical formulations we saw for the SIR model, what would be the fraction of the population that would have recovered from the epidemic by the time the epidemic reaches its peak?

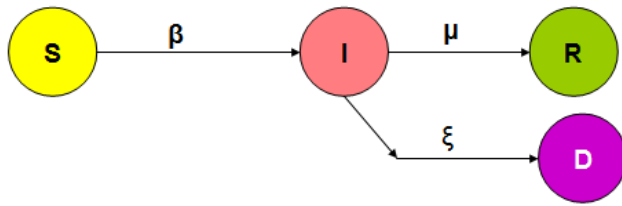
(c) If the population in the city is to be vaccinated a priori (i.e., before the onset of the epidemic) in order to achieve *herd immunity*, what is the minimum fraction of the population that needs to be vaccinated?

Q4: 30 pts) Consider an epidemic (with $R_0 = 4$) that spreads under the SIR model and lasts for an average of 14 days for an infected person. Assume 2% of the people in a city of 40,000 people get initially exposed to this epidemic and the rest of the population is susceptible to this epidemic.

- (a) Using Excel, simulate the spread of the epidemic and prepare a table that lists the number of infected people, number of susceptible people and the number of recovered people for days 1 to 100.
- (b) Per the simulation results of (a), determine the day when the maximum number of people will be infected. What is the maximum number of infected people on that day per your simulation?
- (c) Determine the day when less than 1% of the population remains infected with the epidemic.

Note: For (a), you can submit separate Excel spreadsheet, labeled with the question number and upload in Canvas.

Q5: 30 pts) Consider an extension of the SIR model, call it the SIRD model, as shown below (D - death).



Simulate the spread of an epidemic per the SIRD model in a population with $s_0 = 0.99$ and $i_0 = 0.01$. The values for the parameters β , μ and ξ are 0.8, 0.5 and 0.1 respectively. Let $\langle k \rangle$ be 1. Let the epidemic be considered to have reached an endemic state when the fraction of the people who are infected becomes less than 0.001.

- Present a table (generated using Excel) that features the fractions of susceptible, infected, recovered and died people from time instants 1 to 50.
- Present plots of the results (one plot per result) of (a) for each of the four states: susceptible, infected, recovered, died.
- What are the fractions of the susceptible, recovered and died people when the epidemic is considered to have reached an endemic state?

Note: For (a) and (b), you can either (i) submit the Excel file that also has the plots for each state, clearly labeled with the question number and upload in Canvas. (ii) or include the Excel table in the word document and include screenshots of the plots generated as well in the word document.

