Modeling and Simulation -

Lab Assignment 3

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Problem 1

(Modeling Influenza) Implement the SIR model of Influenza and obtain Fig. 6.2.3

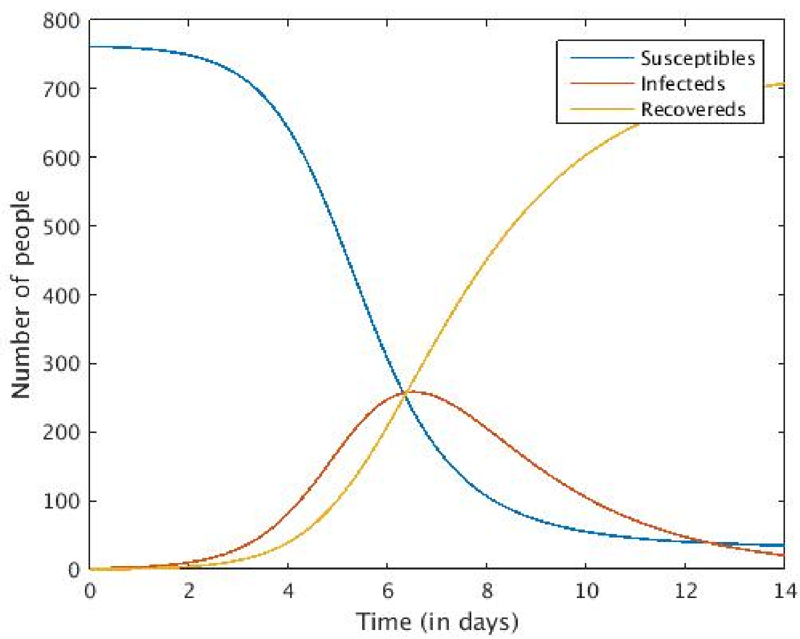

Figure 1

The number of susceptibles decreases slowly at first before experiencing a rapid decrease due to increase in number of infecteds. The curve of recovereds behaves to the logistic curve. When the number of susceptibles decreases sharply, the infecteds increase to their maximum. Afterwards, as the number of infecteds decreases, the number of recovereds rises.

Part A:

From the projects section implement problem 1.

Immunization occurs immediately from the beginning here. We have assumed that vaccination occurs only once in a day. Hence number of vaccinated remains constant throughout the day after vaccination and so we will see step increase behaviour in vaccinated and similar to step decrease behaviour in susceptibles.

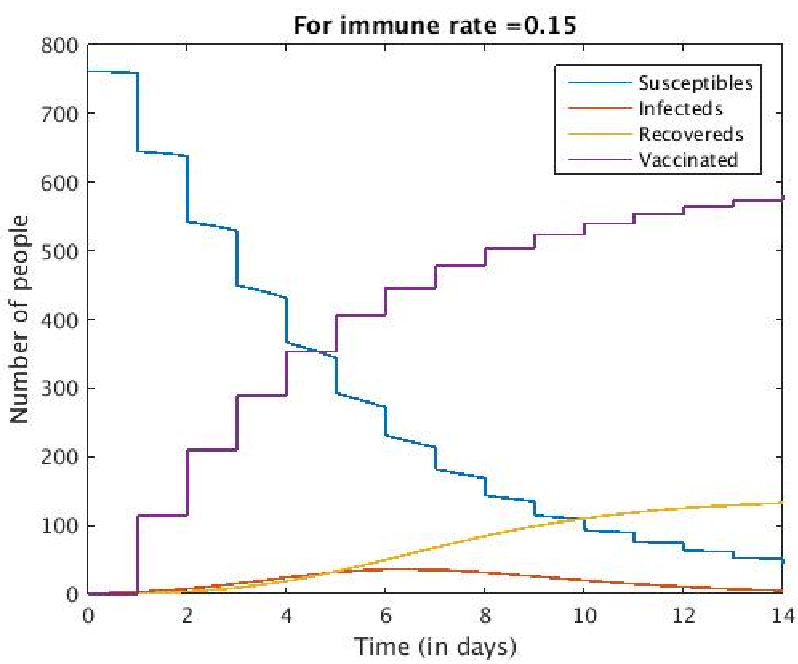

Figure 2

Susceptible decreases as some get infected and some get vaccinated. Hence number of people vaccinated increases as time passes. Behaviour of infected and recovered is same as the case without the vaccination, the only difference is that number of infected is less here as most of susceptible are vaccinated here.

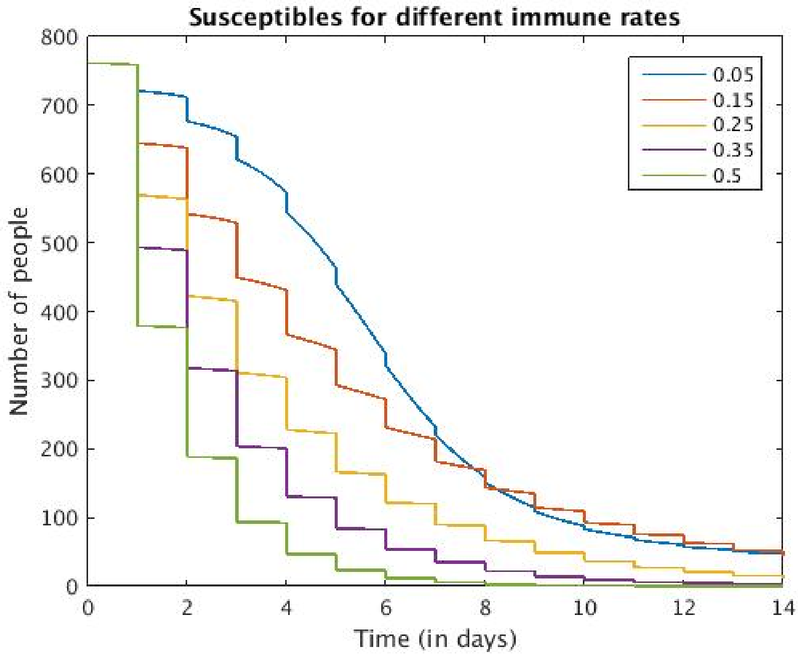

Figure 3

As the immune rate increases, decrease in number of susceptibles occurs faster as more portion of susceptible get vaccinated each day.

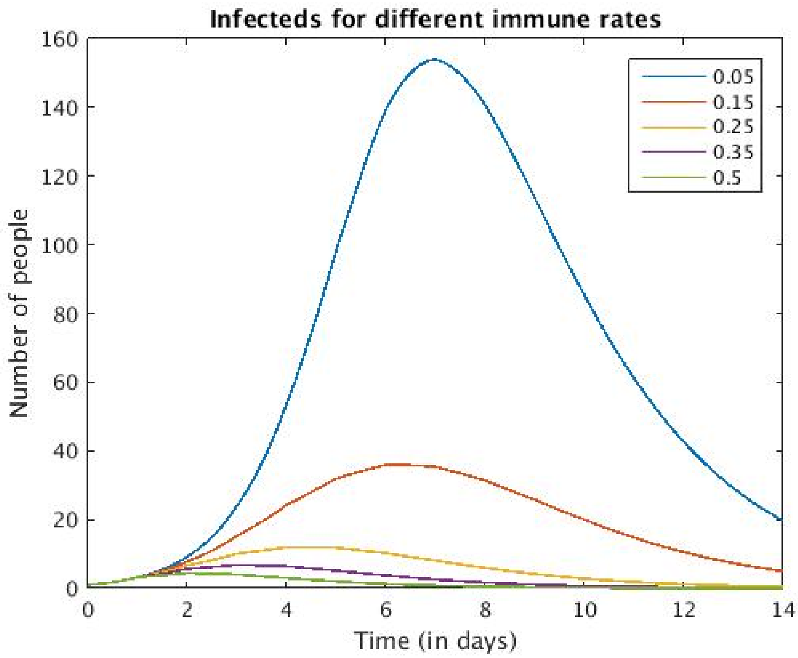

Figure 4

As the immune rate increases, the maximum value infected reaches decreases as more portion of susceptible get vaccinated with each day passing. Also it can be seen from the plot that the maximum value in infected is achieved faster with increase in immune rate.

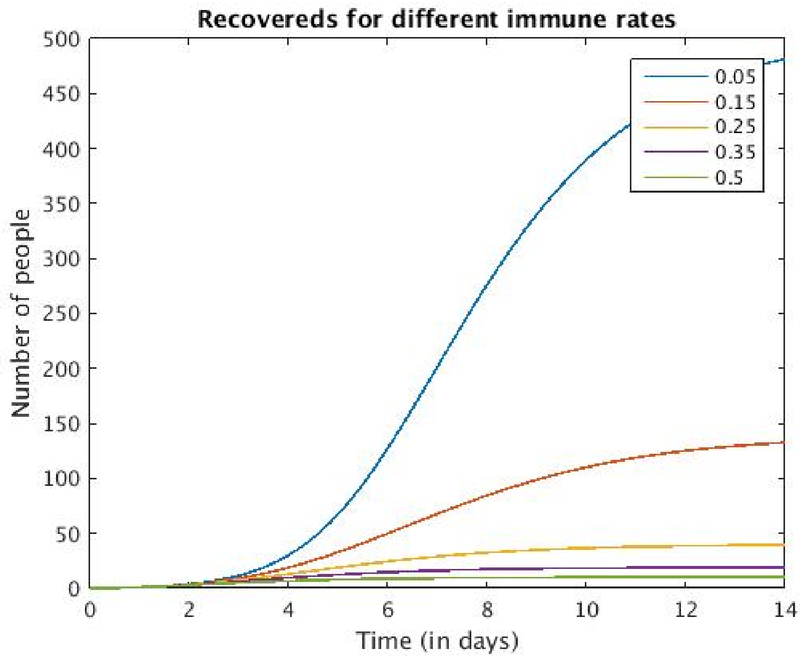

Figure 5

The behaviour of recovered depends just on infected. Hence here also the maximum value of recovered is less with increase in infected rate.

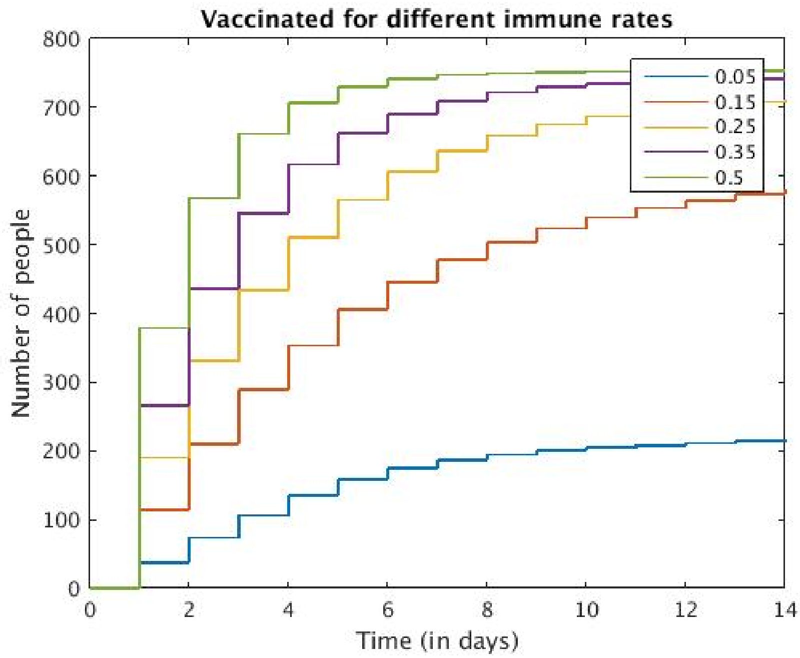

Figure 6

Part B:

For problem 2 in the project section first obtain the differential equations and then implement and comment.

The difference in this problem from Part A is that there is no vaccination system available for 1st 3 days as it takes time for people to know about the spread of disease and hence no vaccination system available for initial stage.

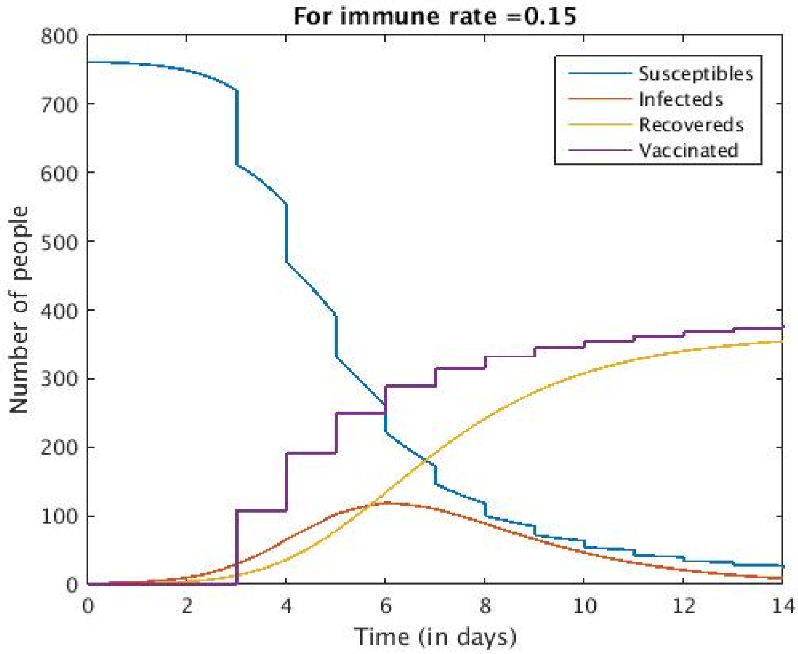

Figure 7

Vaccinated people increases from 0 after 3 days and then there is a step increase in people. After 3 days behaviour of all people are similar to Part A case. Here the maximum value reached in infected and hence recovered is higher for same immune rate as compared to Part A because vaccination occurs late in this case. So people getting infected in first 3 days plays role here.

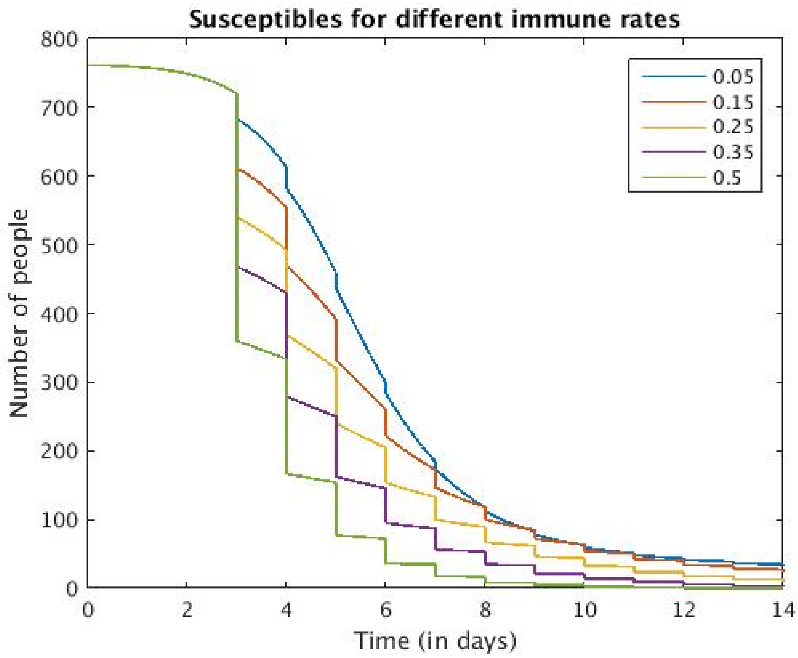

Figure 8

Initial behaviour for 3 days is same as that of case without vaccination. Then behaviour almost same as Part A.

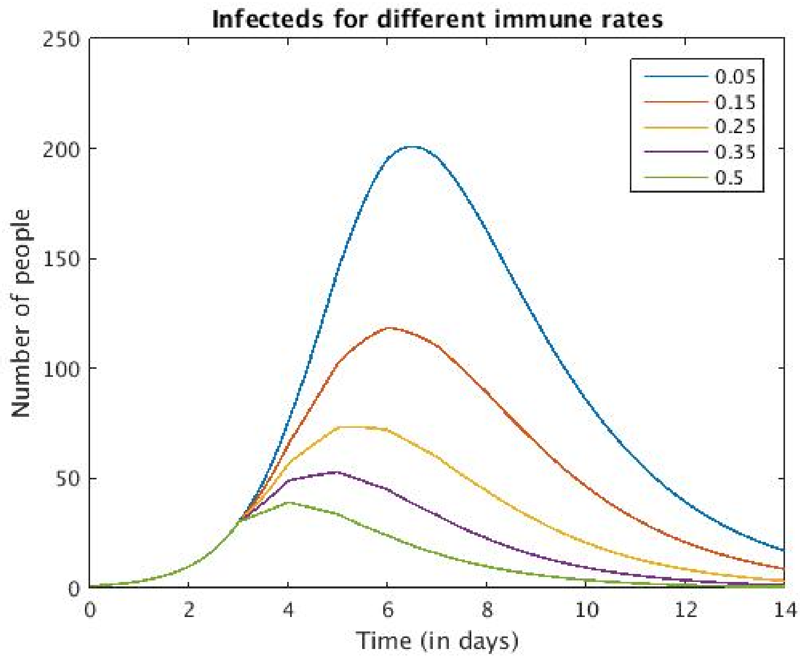

Figure 9

Here the curve is almost same as in Part A with only change being that maximum value reached for same value of immune rate is increased due to late vaccination.

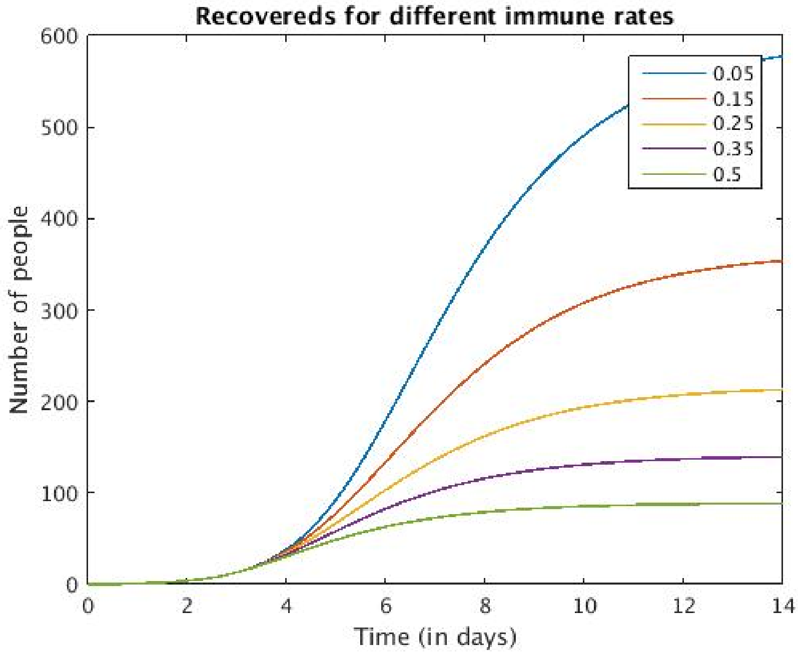

Figure 10

Here the curve is almost same as in Part A with only change being that maximum value reached for same value of immune rate is increased due to late vaccination.

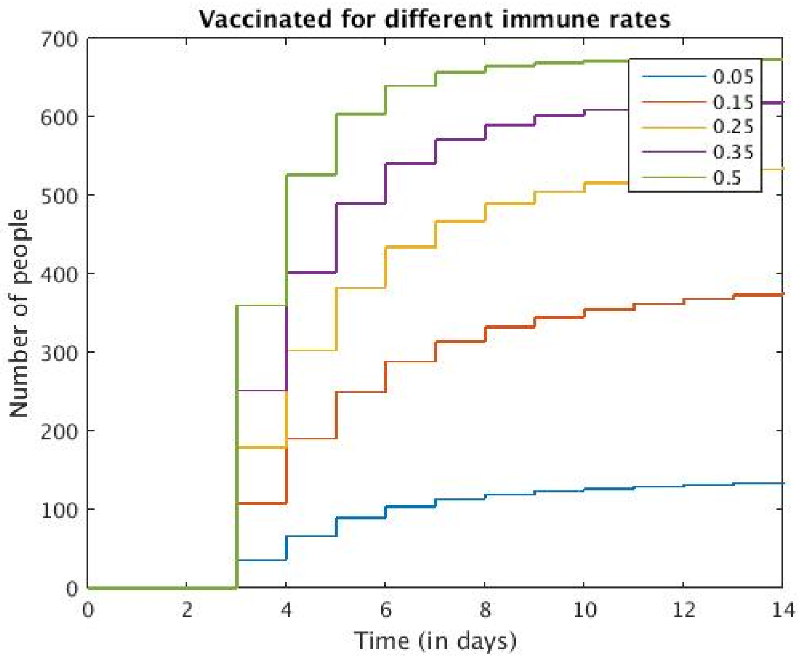

Figure 11

Here the curve is almost same as in Part A with only change being that maximum value reached for same value of immune rate is decreased due to late vaccination.

Problem 2

(Modeling SARS) Read the SARS model and using Fig. 6.2.4 obtain the set of differential equations.

Project Question : 5

Complete the Lipsitch SARS model introduced in the text. Have the model evaluate R. Produce graphs and a table of appropriate populations, including susceptible, ***recovered_immune*****, SARS_death, and the total of the five categories of infecteds. Employ the following parameters: k=10/day;**

b=0.06;

p=0.2;

v=0.04;

m=0.0975;

w=0.0625;

u=0.1;

n=10000000;

Discuss the results of changing the value of q.

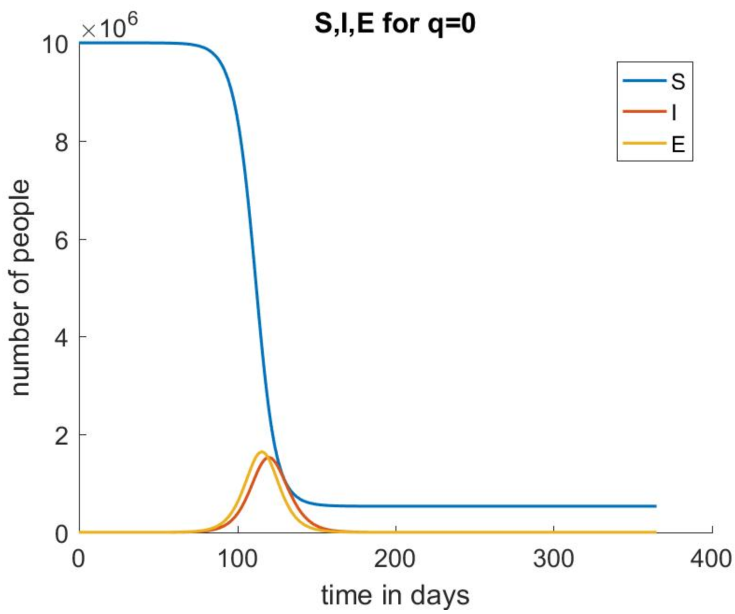

Figure 12

Here we can see that, for q=0, there is no quarantine happening, So all the exposed will be exposed who do not know about the disease. They will definitely become infected soo after that and will infect other susceptibles.

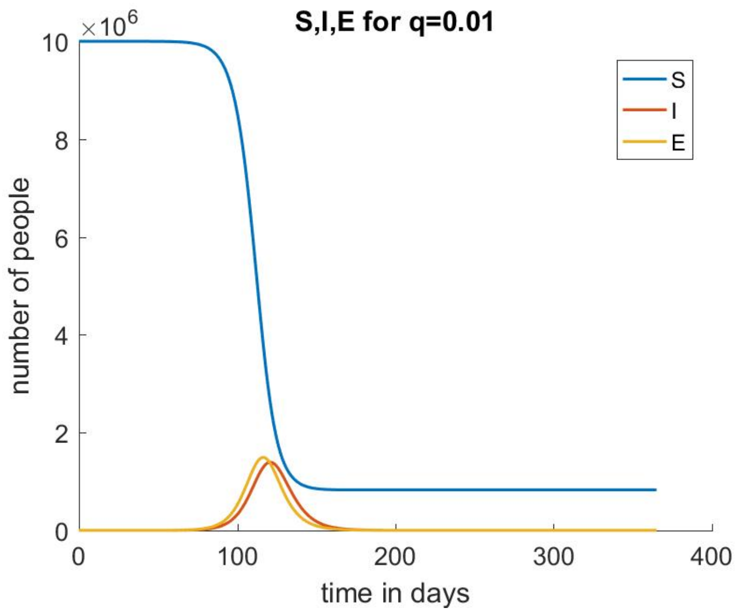

Figure 13

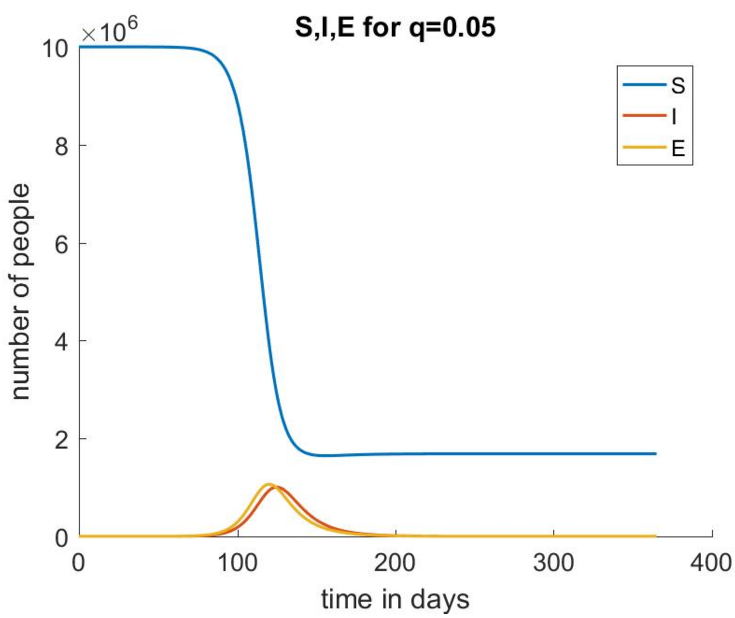

Figure 14

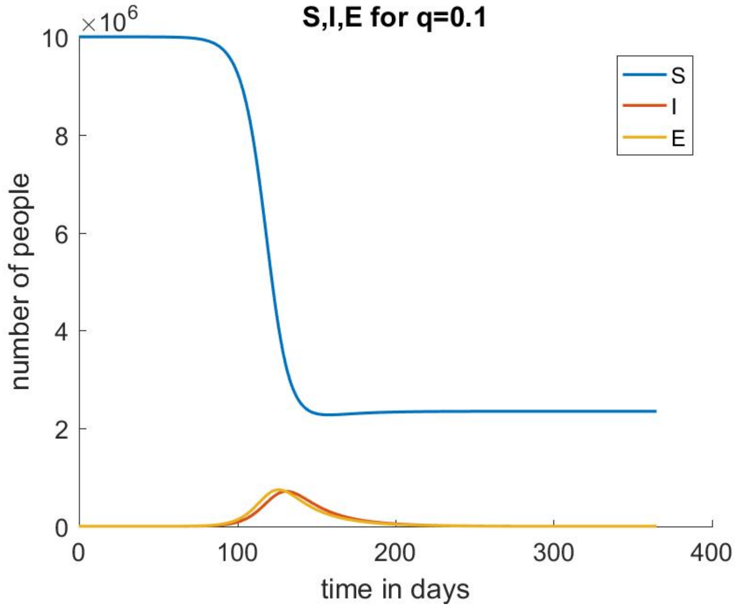

Figure 15

As the value of q increases, the maximum number of infecteds will become smaller and smaller. There will be a q value for which the value of R_0 will become less than 1 initially and then no spreading will happen at all.

$$R_0 = \frac{k(1-q)b}{v+m+w}$$

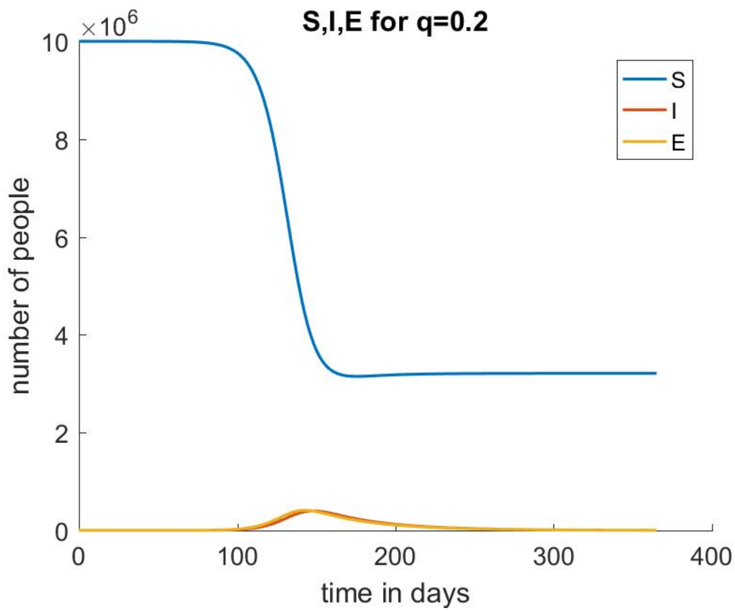

Figure 16

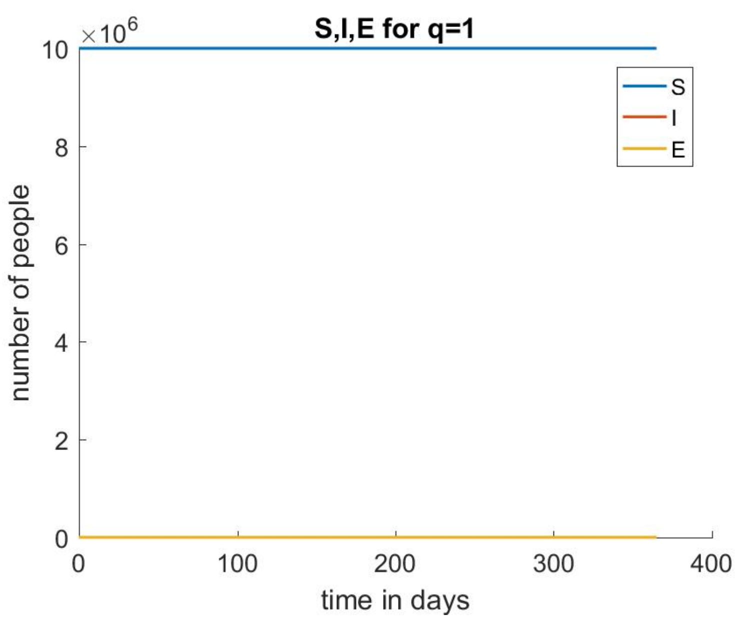

Figure 17

Q=1 is an extreme case where no infected will be unaware of the disease and no epidemic can happen at all. This is very hypothetical scenario where all the susceptibles will be quarantined as they get exposed.

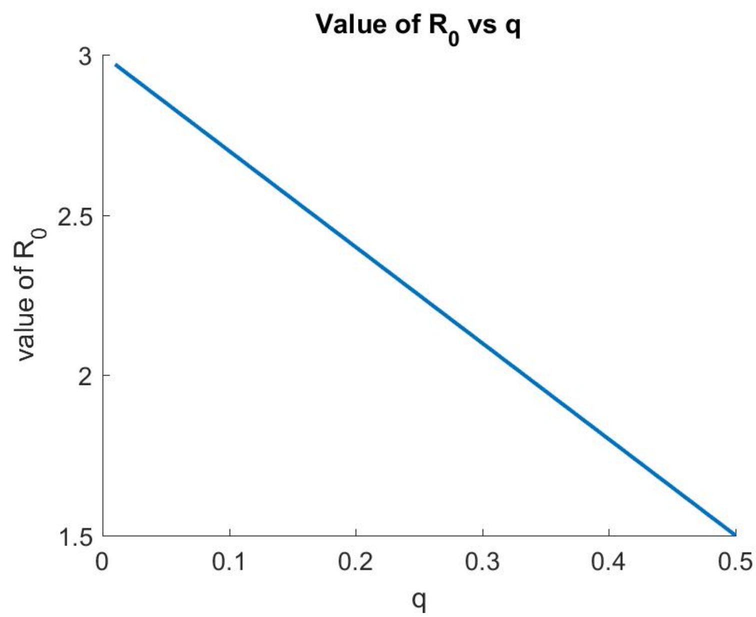

Figure 18

Project Question : 6

After developing the model of Project 5, with a fixed value of q, test other ranges of k from 5 to 20 per day. Discuss the results.

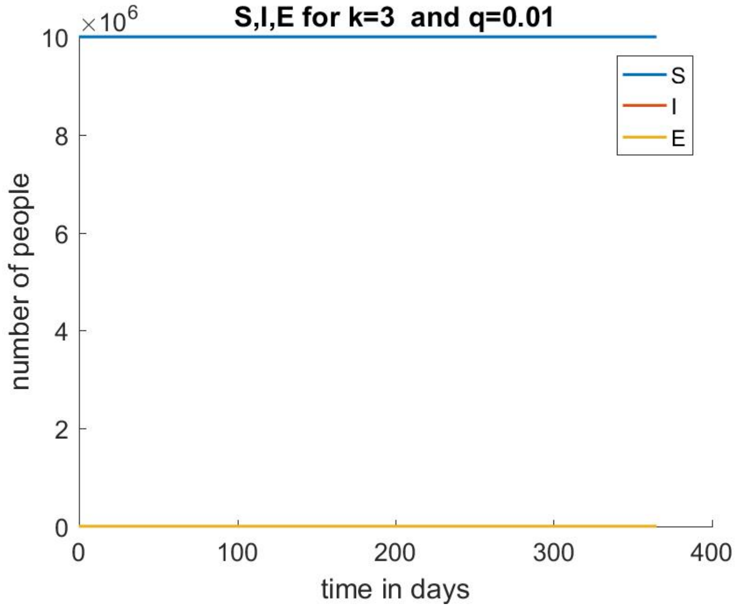

Figure 19

$$R_0 = \frac{k(1-q)b}{v+m+w}$$

In the above equation we can see that $R_0 \propto k$, so for lesser value of k the value of R will be less.

$$R_0 = 0.8910$$

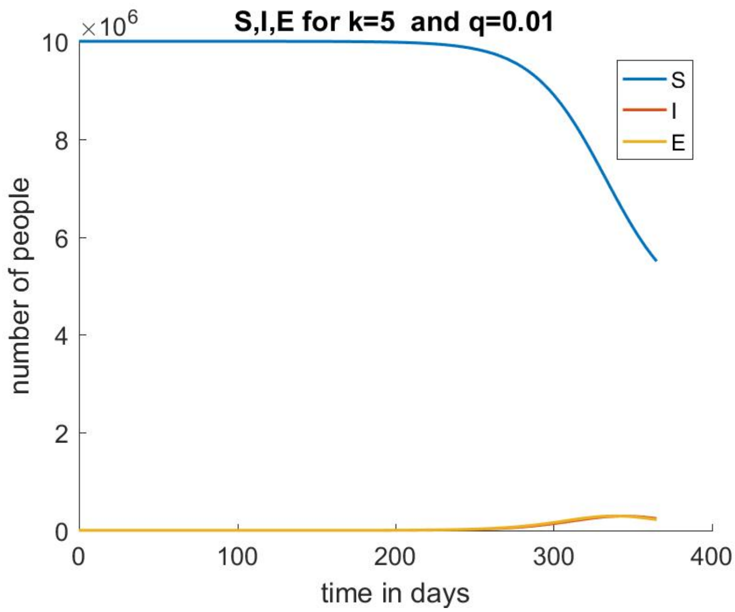

Figure 20

For $k = 4$ and $k = 5$ the value of R_0 becomes greater than 1.

$$R_0 = 1.4850$$

In the above graph the epidemic spread is happening but it is not to its full potential.

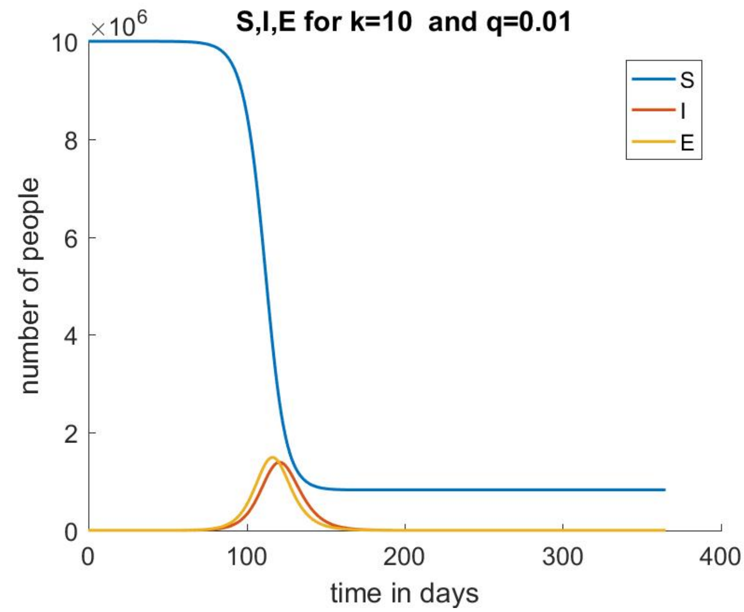

Figure 21

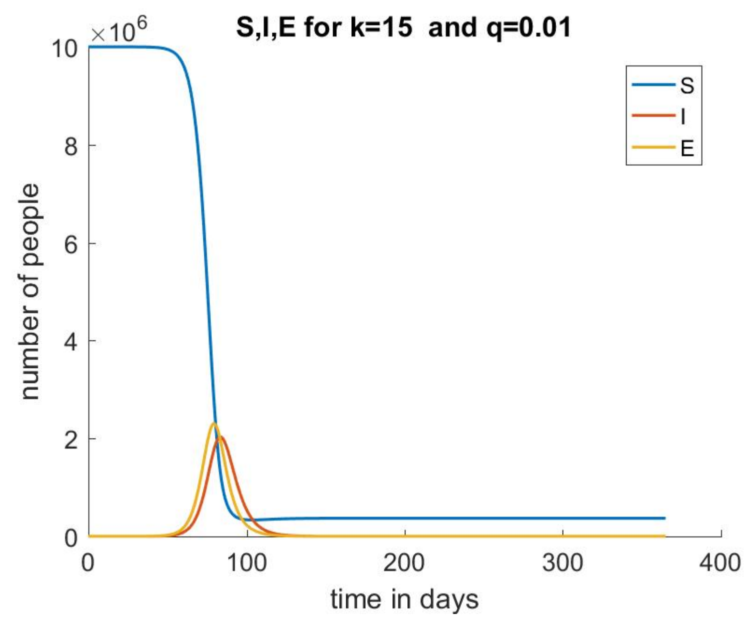

Figure 22

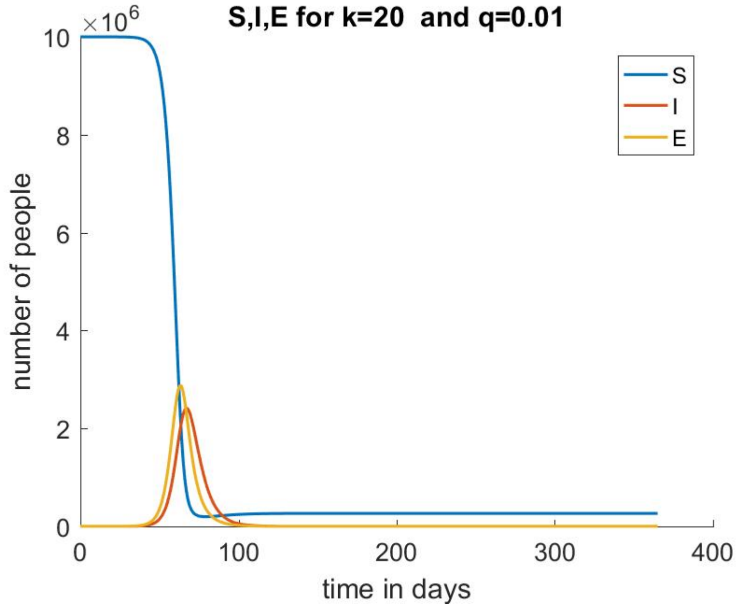

Figure 23

$R_0 = 5.94$

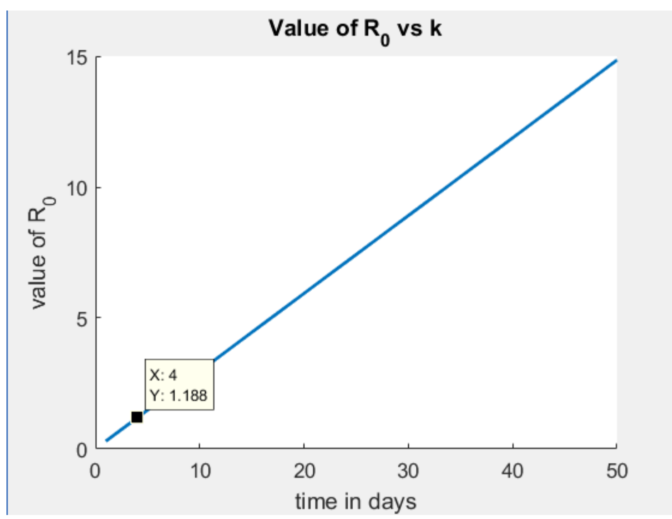

Figure 24

Relation between R and in days. We can see that the relation is obviously linear (from the equation).$R_0 > 1$ for k=4.

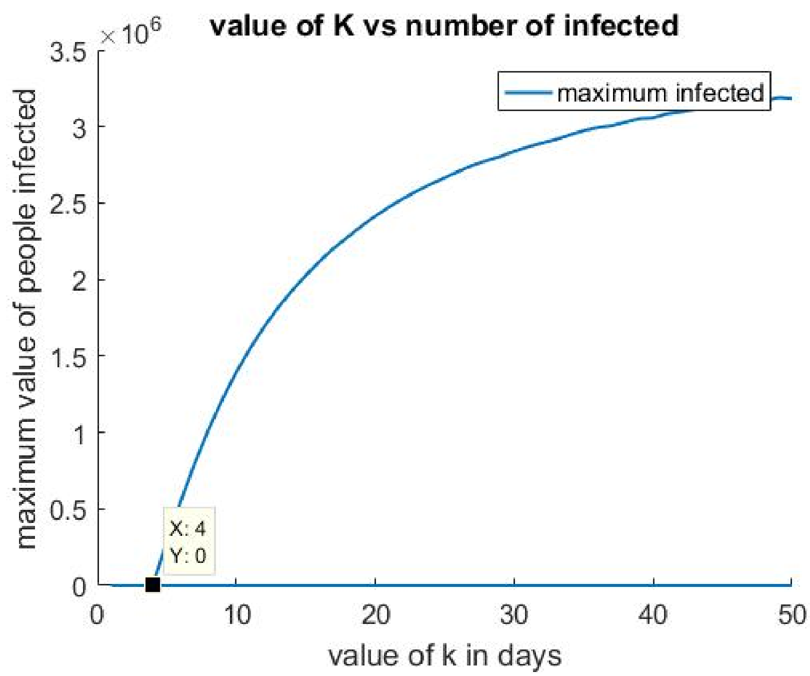

Figure 25

There is a discontinuity in maximum number of infecteds vs k because there are two parts $R_0 < 1$ vs $R_0 > 1$. Due to integer operations the maximum infecteds are zero for k=4, too.

Project Question : 7

After developing the model of Project 5, with a fixed value of q, test other ranges of 1/(v + m + w) from 1 to 5 days.

Changing v

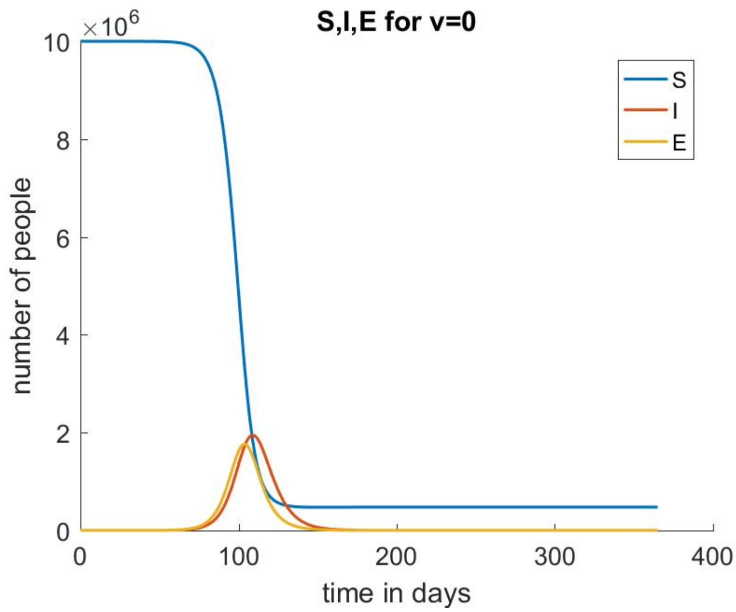

Figure 26

We will change the values of v, m and w. The effect is more or less same for infecteds. Because in our equation $v+m+w$ is in multiplication with number of infecteds.

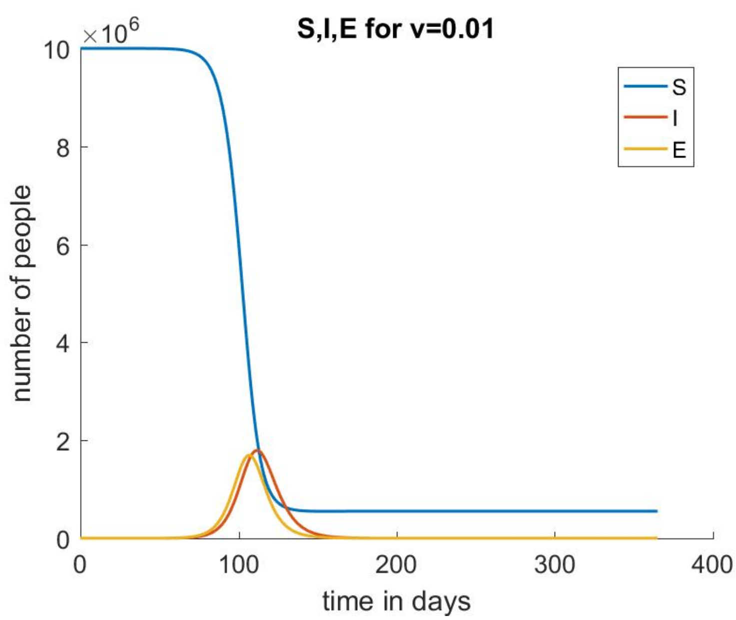

Figure 27

As v increases the maximum number of infecteds will decrease, because R_0 will decrease. In epidemic spread if we inhibit the infecteds at the begining, it will make a huge impact on the maximum number of infecteds.

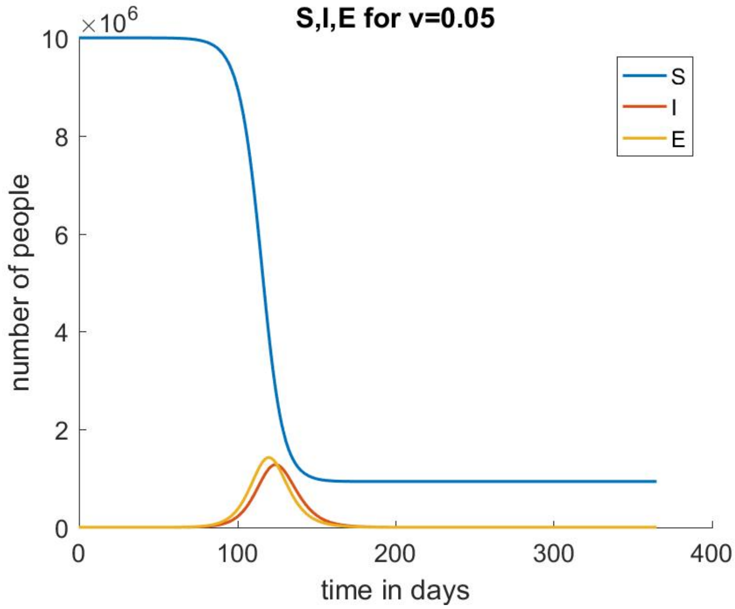

Figure 28

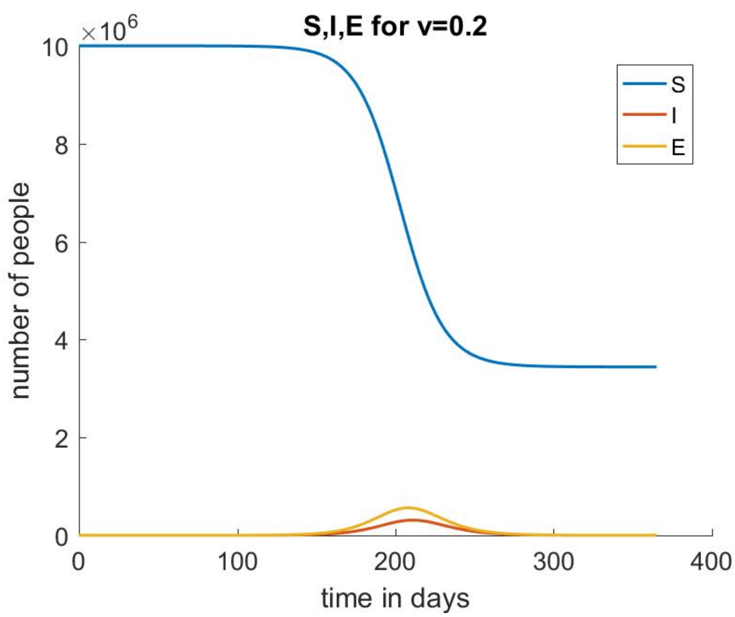

Figure 29

Changing w: Change of w or change of v or change of m or change of all the three parameters, the effect will be same.

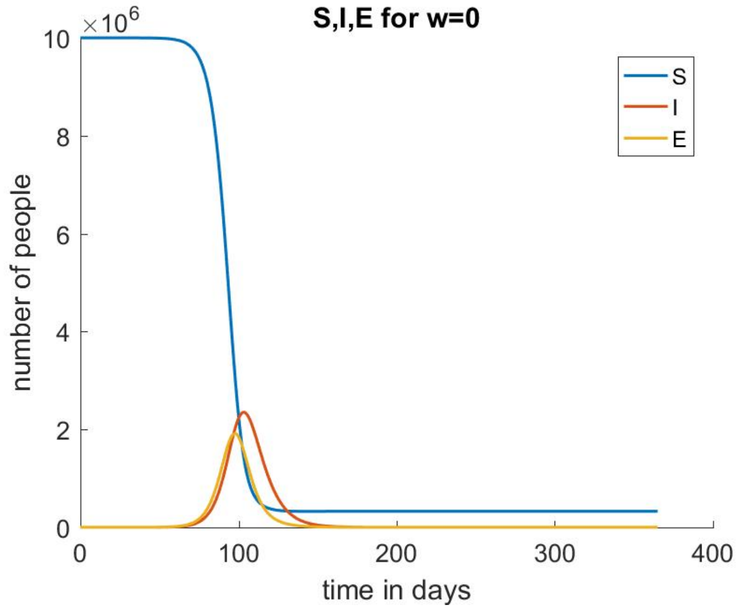

Figure 30

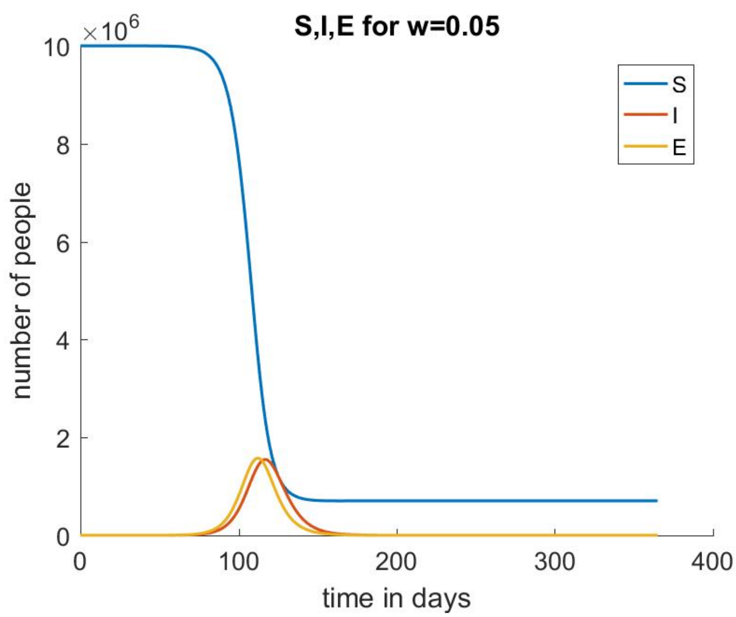

Figure 31

Changing m: Change of w or change of v or change of m or change of all the three parameters, the effect will be same.

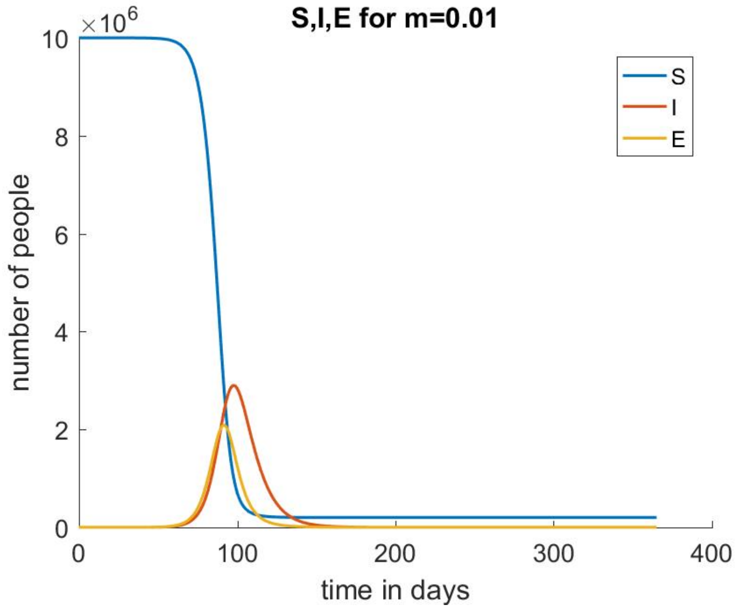

Figure 32

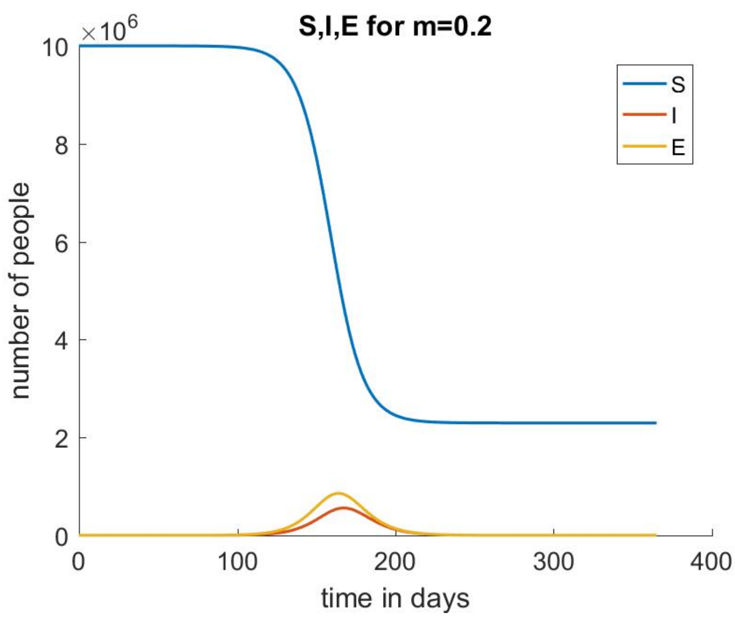

Figure 33

Project Question : 8

Adjust the model of Project 5 so that the simulation is allowed to run for a while before quarantine and isolation measures that reduce R to below 1 are instituted. Discuss the implications on the number of people quarantined and on the health care system of not taking aggressive measures initially.

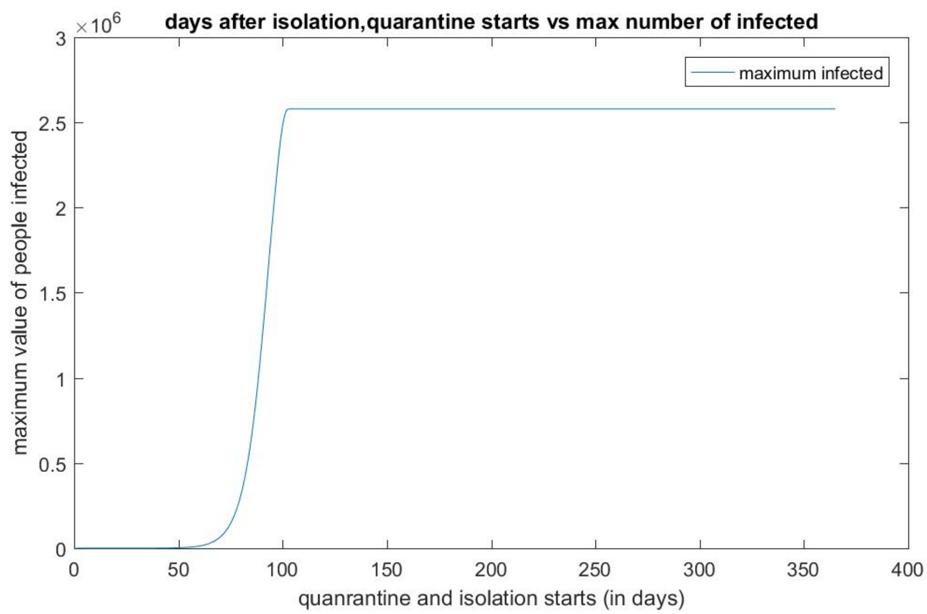

Figure 34

Here, we are introducing q and w, so they reduce the value of reproduction number to less than 1. Now after the simulation starts we can not compute value of R, but we can get intuition about reproduction number. Here we can see that after 103 days there is no point of introducing w and q. Because other factors make the value of R to less than 1 and there is no epidemic at all. So maximum value of infected do not effect after 103 days.

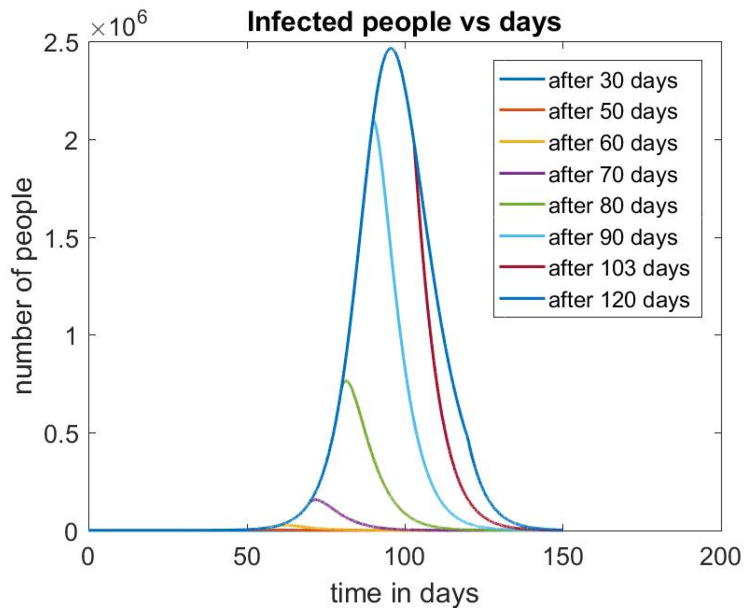

Figure 35

Here we can see that as we introduce the value of q and w and make R less than 1 the infecteds immediately starts decreasing. After 103 days the infecteds anyway starts to decrease.

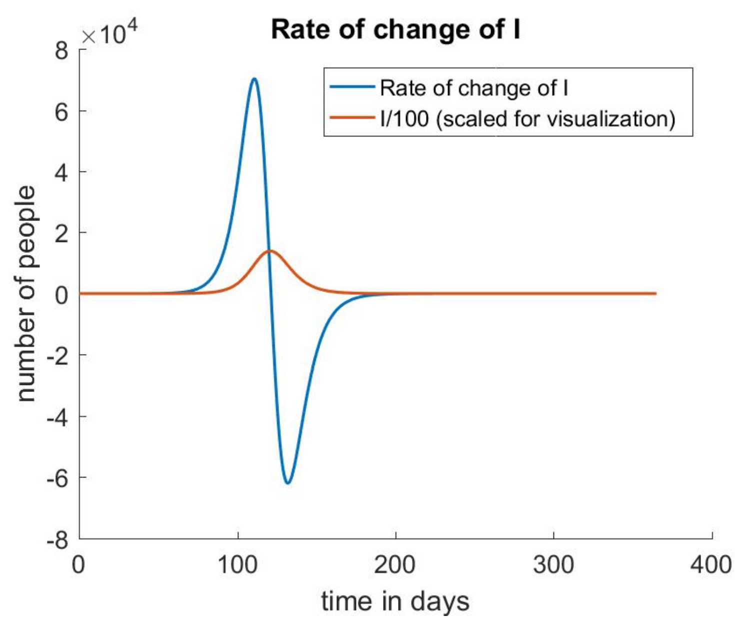

Figure 36

In the below graphs we can see the different behaviour as we intorduce quarantine and isolation in the system.

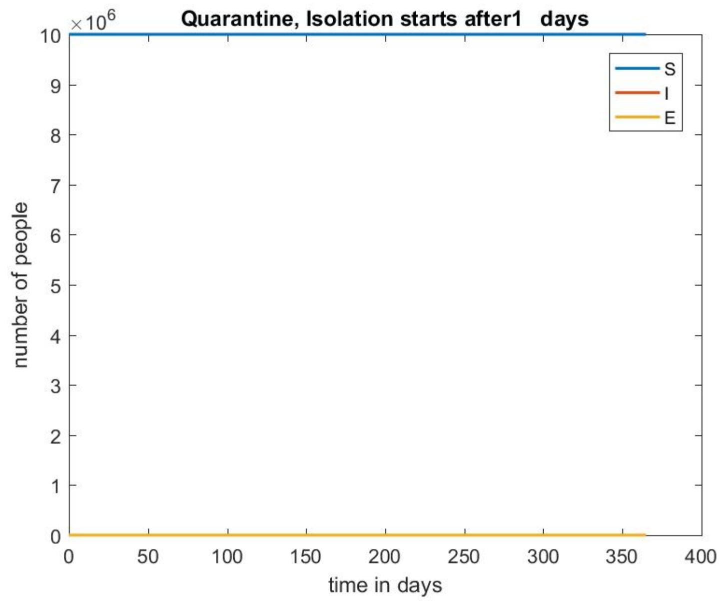

Figure 37

For the first few days, the epidemic spread won't happen at all because the value of q and w are such that the value of R will become less than 1.

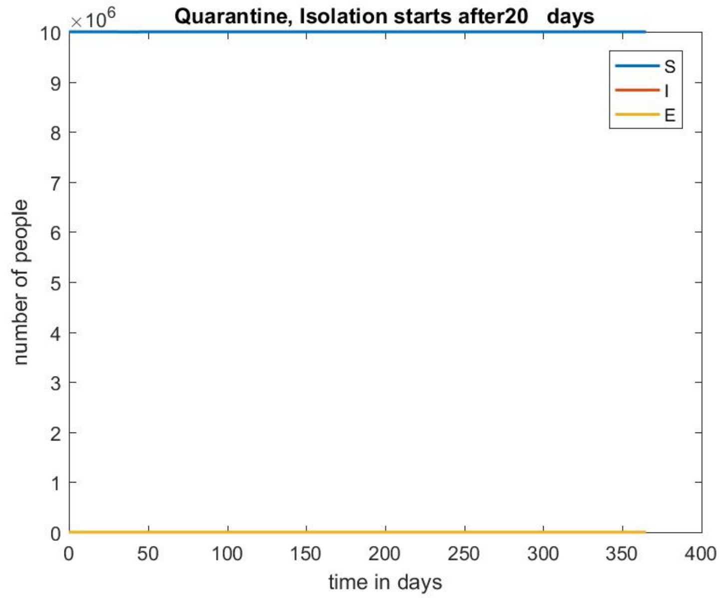

Figure 38

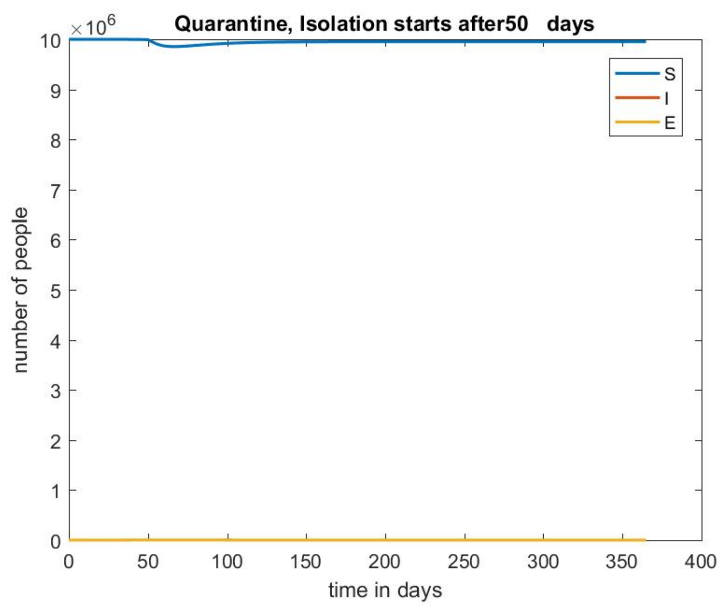

Figure 39

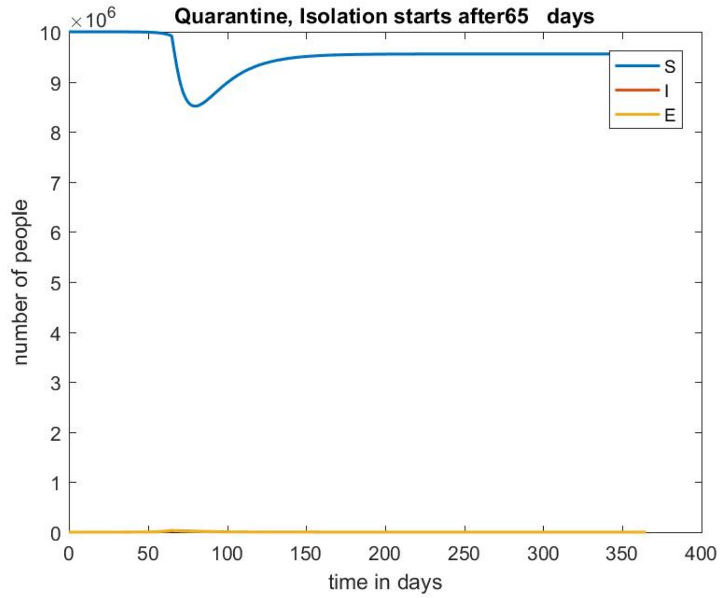

Figure 40

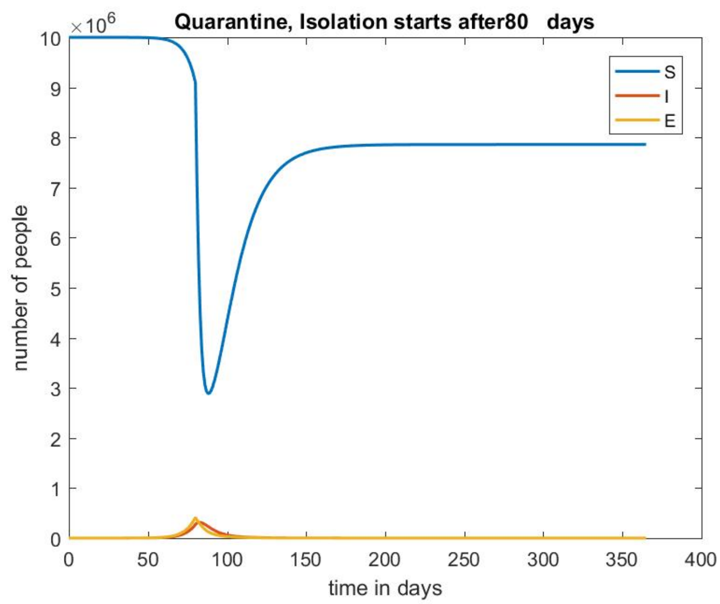

Figure 41

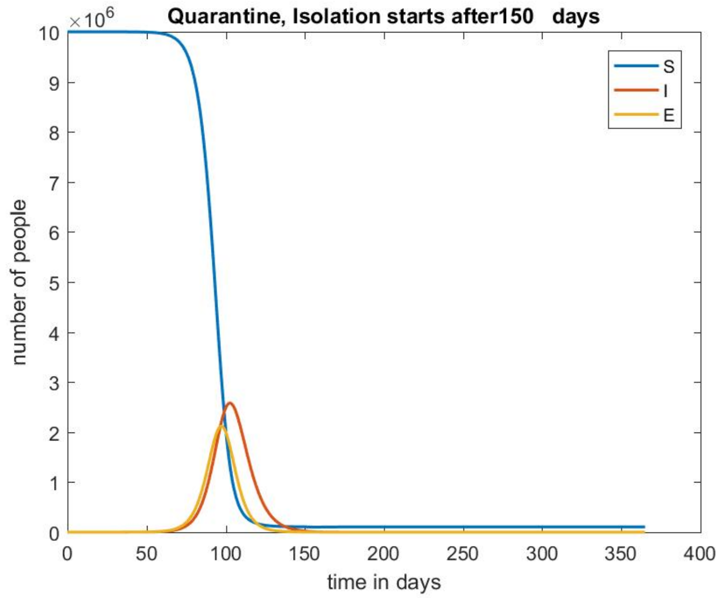

Figure 42

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