Question 2 a:

Flow Diagram and Equations.

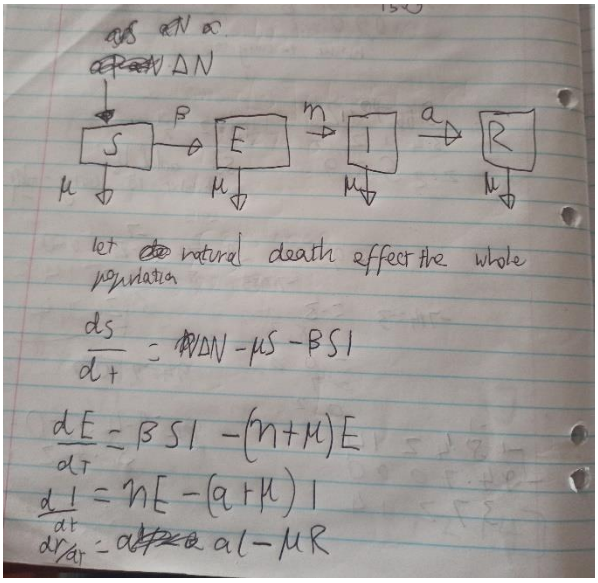


Figure 1: S E I R diagrams.

The formulation of this equation is derived from the fact that all the population will be able to re produce, so N is updated and the population changes accordingly. The rest of the parameters vary according to their change parameters, then the death will affect all of the different variables.

Some analysis we can look at is with the initial values here. What we find is that the death rate and the birth rate have a relationship, because births effect the whole population, that being, Delta*N, we find that if they are the same we will essentially get that the population stays the same and everything will even out (figure 2).

There are then two other options, that the death rate is greater than the birth rate, In which we see the population decrease towards 0, and the birth rate is greater than the death rate, in which we see the population go towards infinity.

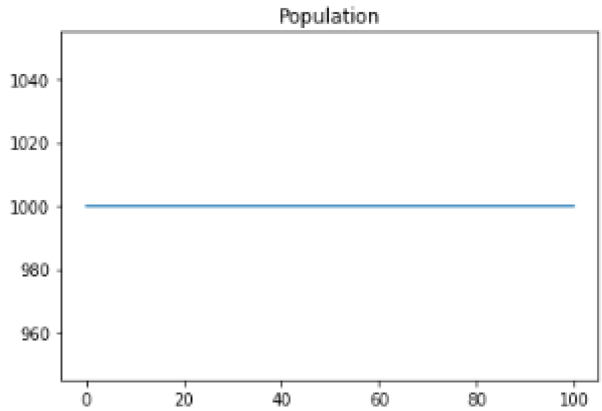


Figure 2: When the death and birth rate is set as the same value.

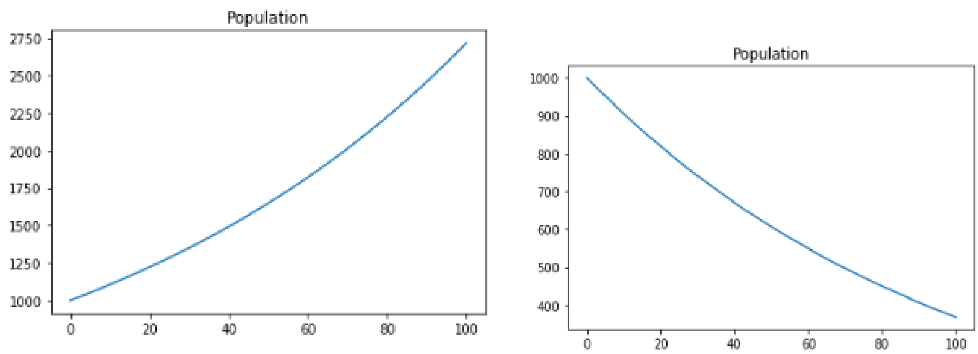


Figure 3: population for the other two birth/death rates.

Qualitative Analysis:

We will use the same initial values of S=999, I=1 and the others as 0.

We will analyse the problem in which the birth rate and the death rate is the same.

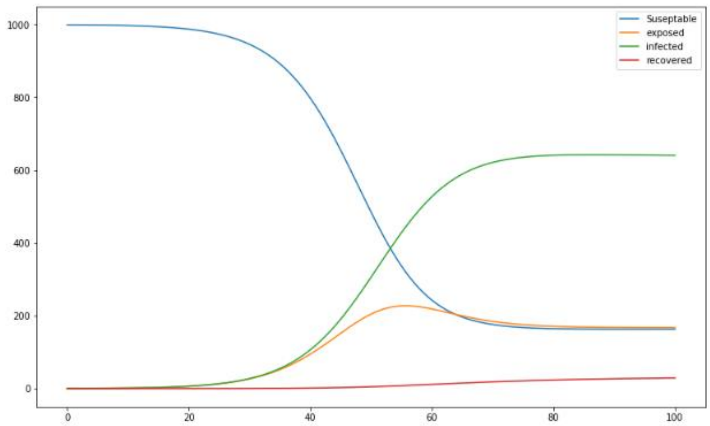
mu = 0.05, death rate

delta = 0.05, increase in N

beta = 0.0004, Transmission rate

alpha = 0.0025, recovery rate

n=0.2



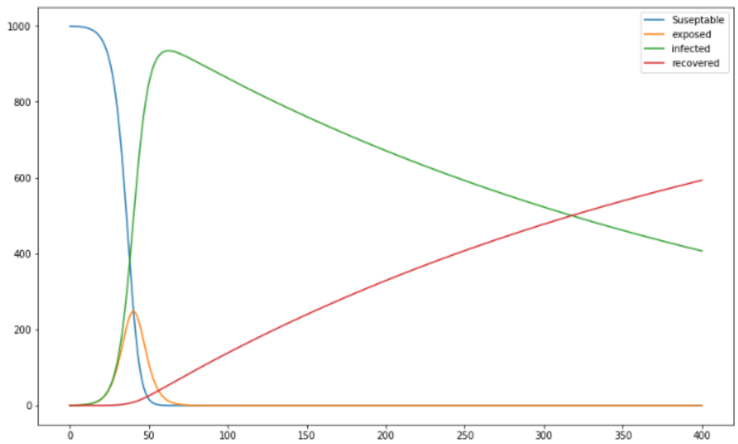


Figure 4: with death rate (left), without on the right.

We can see from figure 4, that the variation does appear very similar initially (note the axis on the left is 100 and the right is 400). As time continues what does seem to occur however is in the non-death model on the right balances through the infected and recovered, and the population will remain at 50, with the population seeming to all approach recovered. We see however in the model containing death and birth, because the birth rate and death rate is the same, the populations begin to level out. If the birth/death rates varied, we would see the population again either all dying, or the populations would begin to approach infinity. We also notice in this case that there is always a susceptible population, hence the virus can never leave, whereas in the other case it should technically eventually leave in an asymptomatic fashion.

mu = 0.05, death rate

delta = 0.05, increase in N

beta = 0.01, Transmission rate

alpha = 0.08, recovery rate

n=0.2

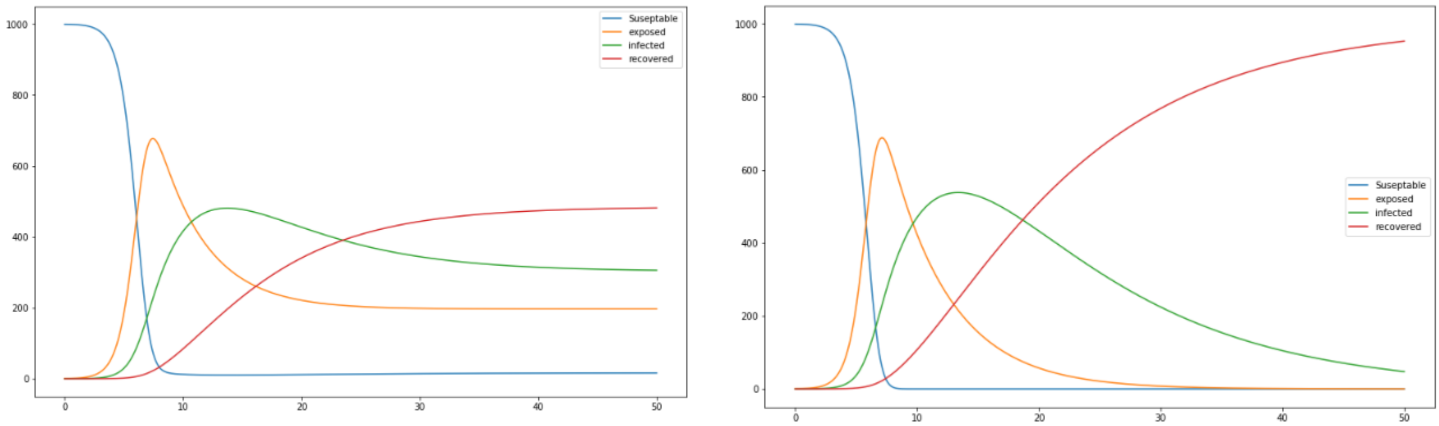
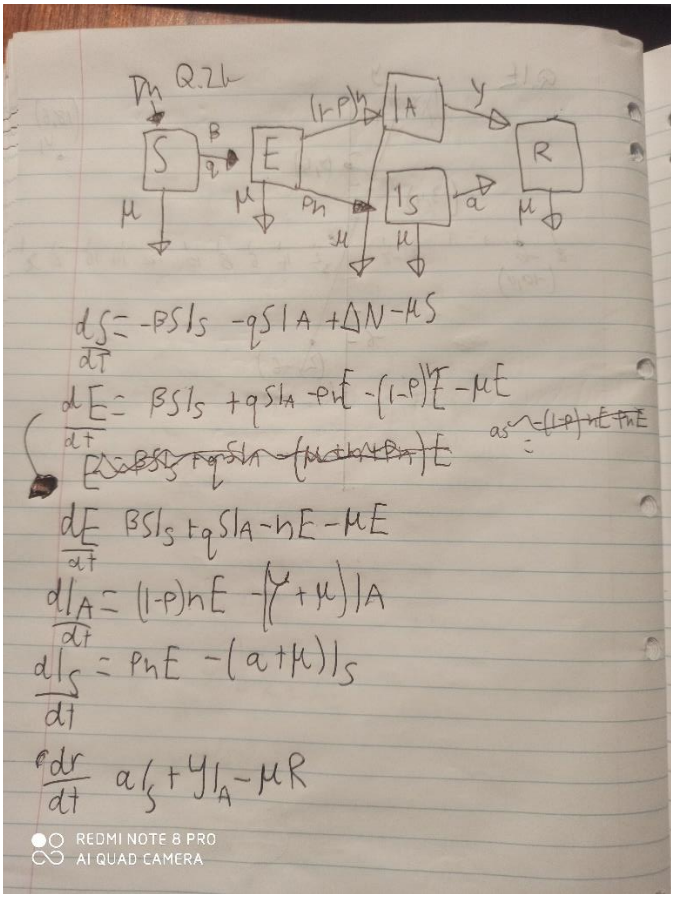


Figure 5: demography model (left), normal is right.

As we change two variables here, we see on the left, the susceptible population goes to a low number and the variables remain at a moderate level, however in the other model, the recovered again approaches the whole population and the recovered goes to 0. This suggests if we have a changing population, it becomes more complex to completely remove the virus from society.

Question 2 b:

The diagram is below. In this case the infection now effects Is and Ia, we also add the different recovery rates and infection rates. The P will affect a multiple of n, so it should sum to -nE in De/dt.



Qualitative Analysis:

delta = 0.05, increase in N

beta = 0.05, Transmission rate

alpha = 0.08, recovery rate

n=0.2

p = 0.6, prop to symptomatic

q = 0.02, transmission rate asymptomatic

y = 0.13, recovery rate asymptomatic

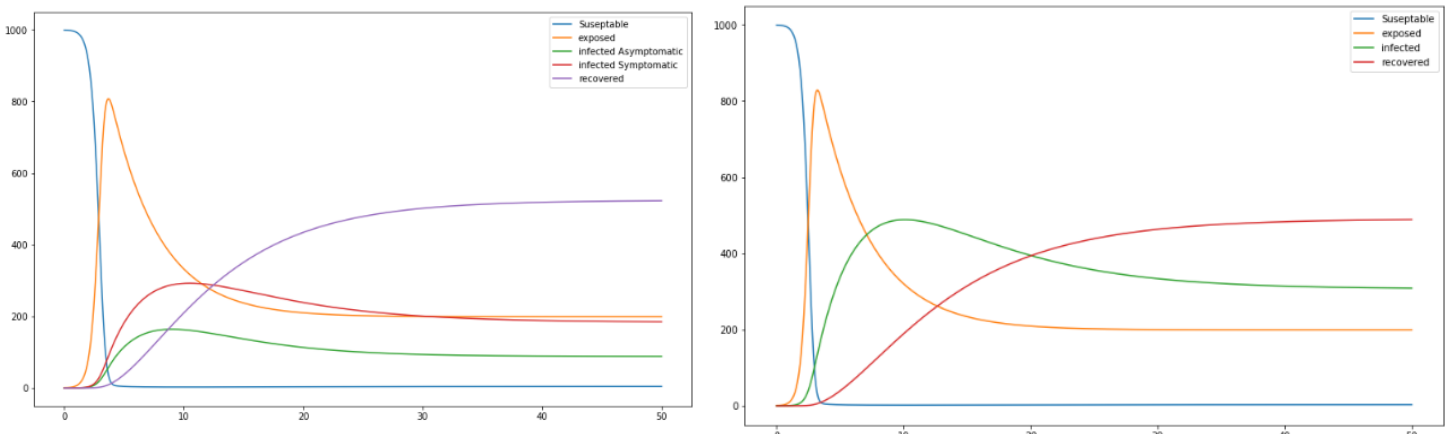


Figure 6: asymptomatic model (left), regular model (right)

From figure 6 initially it does appear that they follow a similar trend, in this case we see the value for susceptible, recovered and exposed to follow a similar pattern, the inclusion of the asymptomatic and non-asymptomatic appear to follow a similar trend as the infected for the 2 a model, as though the sum of the two would essentially reach the same value. Here we see again them following the same long-term trend, both appearing to reaching somewhat of a steady state where nothing is changing because the values of death and birth are essentially the same. Varying the value of p and q will essentially just change the rate at which the asymptomatic and symptomatic variables change the p value to a higher value of 0.8 we get the graphic as per below.

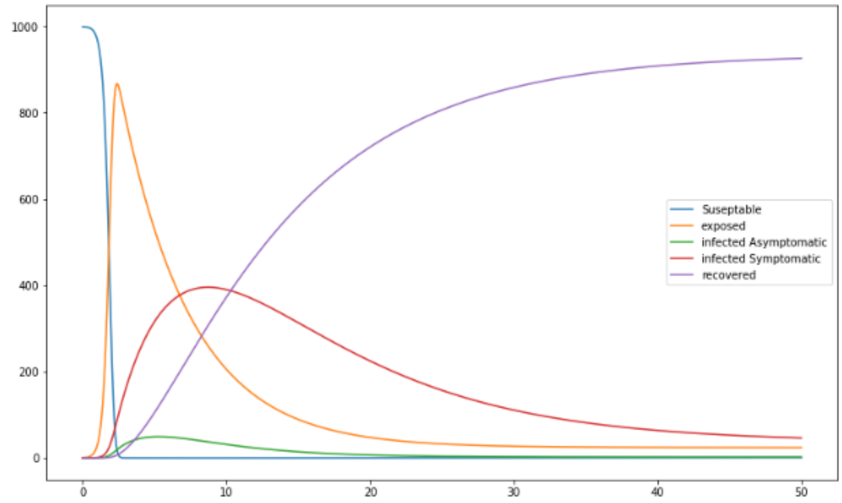


Figure 7: A much higher symptomatic infection rate, also makes the population approach closer to no transmission of the virus.

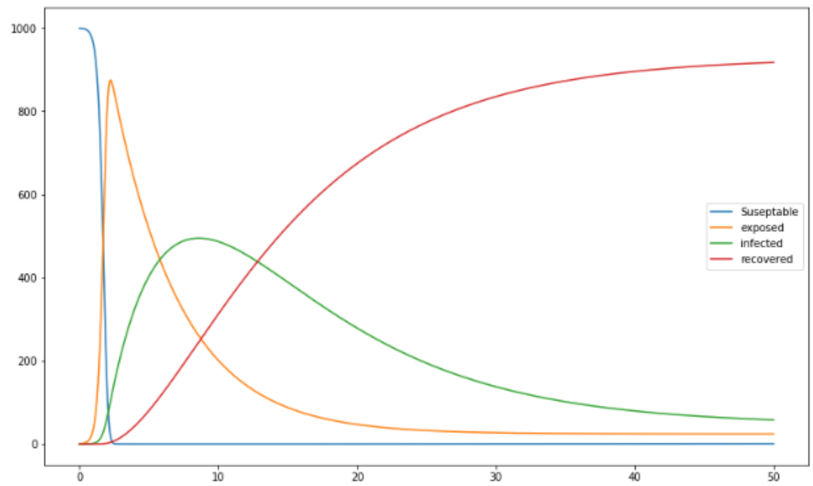


Figure 8: Again in this case with a slight variation to regular infection and recovery rates we see the infection rates drop significantly.

Overall the models appear to follow similar trends overall with the only slight difference being that one has asymptomatic transmission which varies the model slightly, but still remains relatively similar in the cases above.