MATHS COMPETITON FROM UNIVERSITY OF MELBOURNE

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Contents

The Problem

The question I have answered is question 7, just to recall the question is:

In a certain city, with a population of 1,000,000 people. 17 people have been infected with a disease. Five of these people are super spreaders. Super spreaders do not get sick, but will always be infected

Out of the remaining infected people, 50% do not get sick, and do not isolate, but will spread the disease for a week and then will no longer be infected. 35% will self-isolate and get better. The remaining 15% get sick and are admitted to hospital. Within a week, a super spreader will infect 0.1% of the population. A spreader is only infected for a week but will infect 0.01% of the population. Everyone in self-isolation will recover within a week. 50% of people in hospital will die, while the other 50% make a full recovery.

a) Following this trend, what happens to the population over time?

b) You are allowed to implement one city wide lockdown, which can last a maximum of 3 weeks. During the lockdown, a super spreader will infect 0,001% of the population. A spreader will not infect anyone within the population. 25% of people in hospital will die, while the other 75% make a full recovery. When would be the best time to introduce the lockdown? How will this alter the current trend?

c) A vaccination takes at least 20 weeks to produce. Given that one is produced, and 2.5% of the population can be vaccinated in 1 week, when will be the best time to begin vaccinating the population?

Two notes that we were provided are:

Note 1 - You cannot vaccinate the population while in lockdown.

Note 2-The disease is continually evolving and as a consequence can infect the same person multiple times.

Solution

So, lets break down the question. There is a certain city with 1 million people. In this city there are 17 people with a certain type of disease that has newly evolved. There are 5 super spreaders in these 17. The super spreaders do not get sick, they will not isolate and also, they will always be infected. From the remaining 12 people, 50% do not get sick, they don not isolate, they also spread the disease but unlike the super spreader they are only infected and only spread the disease for 1 week and 35% self-isolate meaning they isolate, they will get better in a matter of 1 week. The remaining 15% are sick and will be admitted to hospital.

Out of this 15% that are admitted to hospital 50% of them recover in a matter of 1 week whilst the other 50% will unfortunately pass away.

Other important information we must take note of is that the super spreader will infect 0.1% of the population in one week. For example, if there is 1000 people living the super spreader in that case will affect 1 person. A spreader who is only infected for one week will infect 0.01% of the population. Everyone who is self-isolating will fortunately recover within a week.

Subsequently, after breaking down the main part of the question lets start with the first question in the question, question (a). It says 'Following this trend, what happens to the population over time? Obviously, we know that the population will decrease, but by how much, when and why will it decrease. The first calculation we need to do is about how many people the super spreader will affect, if there are 1 million people living or the population is 1 million (1000000), then out of this the super spreader will only affect 0.1% of it. So, we do

$$1000000 \times 0.1\% = 1000$$

This means that in the first week the super spreader will affect 1000 people. Now for the spreader. They affect only 0.01% of the population. In this case the population is still 1 million people so then you have to do

$$1000000 \times 0.01\% = 100$$

This shows that the spreader in a matter of one week will only affect 100 people. But there is a way that the number of infected can actually decrease. The people who went into self-isolation will also recover decreasing the number of infected people. The people who isolate are only 35% so the calculation we have to do here is

$$17 - 5 = 12,\ 12 \times 0.35 = 4.2,$$
$$4.2\ \textit{rounded is equal to}\ 4$$

This means that there are 4 people that have isolated and recovered. This 4 people will decrease the number of infected people. Also, there is 15% admitted to hospital, half of which survive and the other half die. So, to make the calculation system easier we can say 7.5% of the 12 people survive in the hospital whilst the remaining 7.5% of 12 people die in the hospital. The calculation we do to calculate the number of survivors and dead is

$$12 \times 0.075 = 0.9,$$
$$0.9\ \textit{can be rounded of to}\ 1$$

This means there is 1 survivor in the hospital and 1 dead in the hospital. When we add up all the people, we will get a certain number these are the number of active cases for the next day.

The way we calculate this is by the final formula before putting this into an excel sheet to make life easier is

$$1000 + 100 + 17 = 1117$$
$$1117 - 4 - 1 - 1 = 1111$$

This means that for the next week there will be 1111 active cases, there will be 5 super spreaders, 553 spreaders, 387 isolators, 83 people who survive in the hospital and 83 people who die in the hospital. We can put this into a excel spreadsheet with the following formula:

	A	B	C	D	E	F
1	Week No.	Current Population	Total Infected	Non-Infected	Super spreader (SS) 0.1%	SS added infection following week
2	0	1000000	17	=B2-C2	5	=D2*0.1%
3	1	=B2-K2	=(C2-I2-J2-K2)+F2+H2	=B3-C3	5	=D3*0.1%
4	2	=B3-K3	=(C3-I3-J3-K3)+F3+H3	=B4-C4	5	=D4*0.1%
5	3	=B4-K4	=(C4-I4-J4-K4)+F4+H4	=B5-C5	5	=D5*0.1%
6	4	=B5-K5	=(C5-I5-J5-K5)+F5+H5	=B6-C6	5	=D6*0.1%
7	5	=B6-K6	=(C6-I6-J6-K6)+F6+H6	=B7-C7	5	=D7*0.1%
8	6	=B7-K7	=(C7-I7-J7-K7)+F7+H7	=B8-C8	5	=D8*0.1%
9	7	=B8-K8	=(C8-I8-J8-K8)+F8+H8	=B9-C9	5	=D9*0.1%

G	H	I	J	K
Spreader (SP) 0.01%	Sp infection following week	Infected & Isolated 0.35%	Hospitalised and will recover 50%	Hospital but will die 50%
=(C2-E2)/2	=D2*0.01%	=(C2-E2)*0.35	=((C2-E2)*0.15)/2	=C2-E2-G2-I2-J2
=(C3-E3)/2	=D3*0.01%	=(C3-E3)*0.35	=((C3-E3)*0.15)/2	=C3-E3-G3-I3-J3
=(C4-E4)/2	=D4*0.01%	=(C4-E4)*0.35	=((C4-E4)*0.15)/2	=C4-E4-G4-I4-J4
=(C5-E5)/2	=D5*0.01%	=(C5-E5)*0.35	=((C5-E5)*0.15)/2	=C5-E5-G5-I5-J5
=(C6-E6)/2	=D6*0.01%	=(C6-E6)*0.35	=((C6-E6)*0.15)/2	=C6-E6-G6-I6-J6
=(C7-E7)/2	=D7*0.01%	=(C7-E7)*0.35	=((C7-E7)*0.15)/2	=C7-E7-G7-I7-J7
=(C8-E8)/2	=D8*0.01%	=(C8-E8)*0.35	=((C8-E8)*0.15)/2	=C8-E8-G8-I8-J8
=(C9-E9)/2	=D9*0.01%	=(C9-E9)*0.35	=((C9-E9)*0.15)/2	=C9-E9-G9-I9-J9

So, the answer for the first question is (Question A) is that the trend of the number of cases has rapidly increased then they gradually at a slow pace start to decrease as the infection rates are increasing. This can be seen in the graphs below.

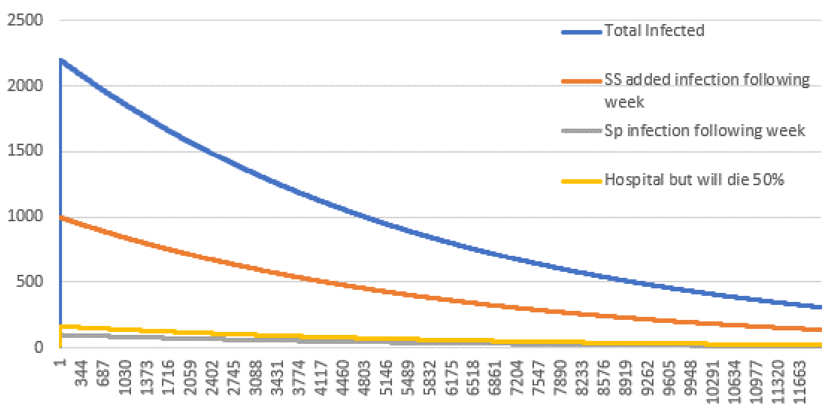

Figure 1: This is a graph for nearly 215 years

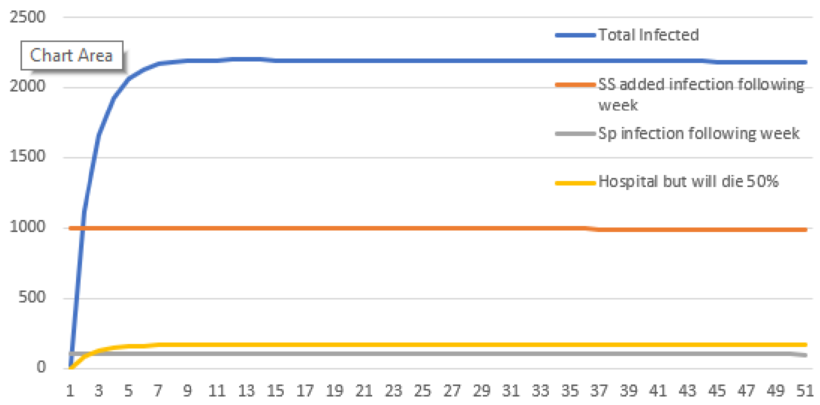

Figure 2: This is a graph for 1 year

The next question is as follows ‘You are allowed to implement one city wide lockdown, which can last a maximum of 3 weeks. During the lockdown, a super spreader will infect 0,001% of the population. A spreader will not infect anyone within the population. 25% of people in hospital will die, while the other 75% make a full recovery. When would be the best time to introduce the lockdown? How will this alter the current trend?’

This means that when is the best time for you to start a city-wide lockdown to lower the number of cases. In my opinion we should start the lockdown in around week 18-20. This is because the lockdown will finish and the vaccine will be released but this will be further discussed in the next question. In the formula written in the spreadsheet above should be changed as follows, in the 6th column 0.1% should be changed to 0.001 and the 8th column 0.01% should be changed to 0%. This isn’t for all the rows only for row 20, 21 and 22 or week 18,19 and 20.

20	18	997366	2195	995171	5	10	1095	0	767	246	82
21	19	997284	1110	996174	5	10	552	0	387	124	41
22	20	997242	567	996675	5	10	281	0	197	63	21

This will affect the number of cases in the city for the lockdown period majorly. The graph below will explain this.

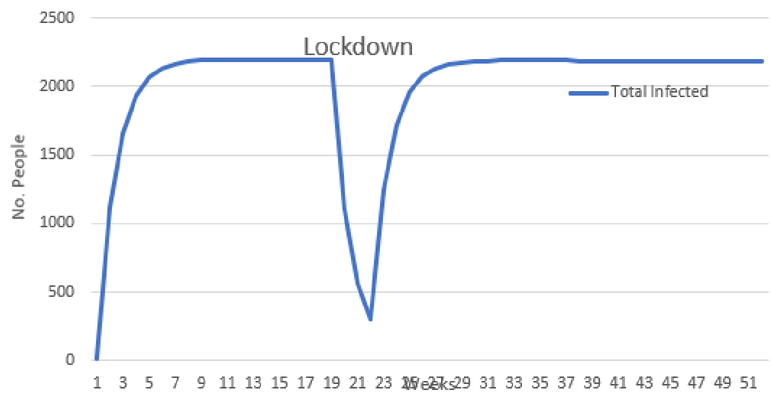

Figure 3: This is a graph for 1 year.

This final question is ‘A vaccination takes at least 20 weeks to produce. Given that one is produced, and 2.5% of the population can be vaccinated in 1 week, when will be the best time to begin vaccinating the population?’ The best time to start producing the vaccine is the first week from when the virus was detected and the vaccine should be released to the public by week 21.

The main reason for this choice is that if the number of cases is already low then the vaccine will result in the cases to go even low. This means that the number of cases will start to go near 0 and so will the infection rate. The graph below will show how the vaccine will affect the cases with the lockdown in place and without the lockdown in place.

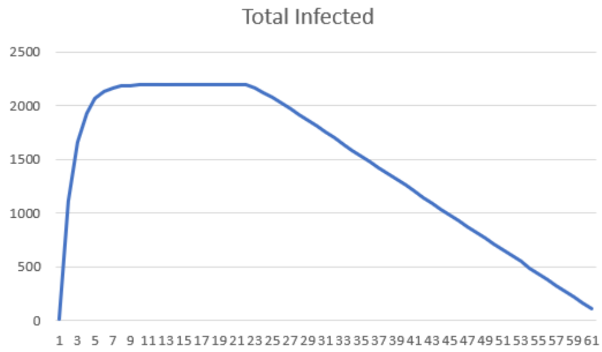

Figure 4: Without lockdown

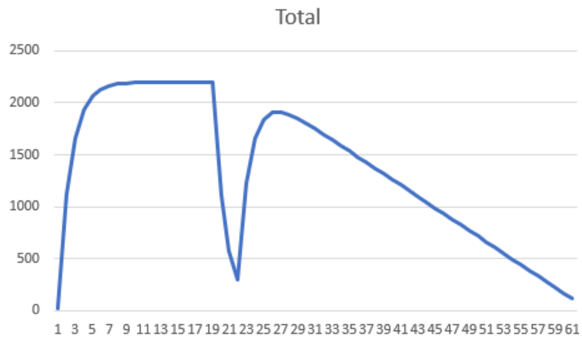

Figure 5: With lockdown

The trend in theses may look similar but there is a smaller number of people dying and getting infected, and lives are more important than the overall cases of a disease.