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| [**VISUAL PHYSICS ONLINE**](http://www.physics.usyd.edu.au/teach_res/hsp/sp/spHome.htm)  [**DOING PHYSICS WITH MATLAB**](http://www.physics.usyd.edu.au/teach_res/mp/mphome.htm)  **A NUMERICAL MODEL FOR THE TIME**  **EVOLUTION OF COVID19 VIRUS**  Description: Description: Description: Description: Description: Image result for IMAGE COVID19 VIRUS  Ian Cooper  Any comments, suggestions or corrections, please email me at  [matlabvisualphysics@gmail.com](mailto:matlabvisualphysics@gmail.com)  Data for the infection spreading around the globe is from the excellent website  <https://www.worldometers.info/coronavirus/>  **Revised / Updated 23 March 2020** |

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| **WORLD PREDICTIONS**  Total infections 540 K Deaths 44 K Peak 26 March 330 K      The crosses are for the actual data and the solid lines, the model predictions. |

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| **CHINA PREDICTIONS**  Total infections 81 K Deaths 4 K Peak 16 February March 58 K        The number of infections peaked about 18 February and the number of infections is now slowly decreasing. **The decrease only occurs when the susceptible population numbers decrease and this decrease in susceptible numbers only occurred through the drastic actions taken by the Chinese government is limiting the movement of people**. |

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| **USA PREDICTIONS**  Total infections 54 K Deaths 6 K Peak 25 March 50 K |

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| **What has physics to do with the spread of the covid19 virus (novel coronavirus)?**  One can apply scientific principles to create a model for the spread of the disease. Then, we can use the model to gain better understanding of how the virus spreads around the globe. We can also make predictions of the number of infections and deaths that may occur in the future and the model can provide us an insight to how we might lessen the impact of the virus.  If our political leaders had a better understanding of the scientific principles which determine the spread of the disease, their decision may have been very different. Unfortunately, political decisions have been made which are not based upon the science. Government officials in Wuhan ignored the scientific evidence. They did not want to upset their political leaders higher up the ladder. Our leaders of state governments and our federal government have not been any better. They have made political decisions to “please the public” and not made decisions based upon the scientific principles governing the spread of the disease. In China, less than 500 hundred individuals who were initially infected from an unknown source will led to about 90 000 individuals being infected and in the order of 4000 deaths.  **MODELING THE SPREAD OF THE VCOVID19 VIRUS**  **How does a physicist approach a problem?**  The real world is very complicated. For example, how the virus spreads depends upon many factors. So, to gain an understanding of the phenomenon, it is necessary to make a set of simplification and approximations.  We will consider different subsets (groups) of the population which change with time:   * **Susceptible individuals** who are not infected but could become infected. The number of susceptible individuals is represented by the variable  which is a function of time *t*. * **Infected individuals** that have the virus and can transmit it to those individuals who are susceptible. The number of active cases (those that are currently infected) is represented by the variable . * **Recovered individuals** that have recovered from the virus and are assumed to be immune from being infected again. The number of individuals who have recovered is represented by the variable . * **Dead individuals** that have died from the infection. The number of individuals who have died as a result of the infection is represented by the variable .   It is assumed that the time scale is short enough that births and deaths (other than deaths from the virus) can be neglected and the number of deaths from the virus is small compared with the living population.  In some time interval , the numbers in each in each group will change   * A susceptible individual may become infected or remain susceptible      * An infected individual may recover, die or remain infected     In our model, we assume that in the time interval  the changes in the group populations are described by the equation       (1)         Description: Description: Description: Description: Description: Description: Description: Description: Description: Description: Description: Description: Description: Description: http://www.physics.usyd.edu.au/teach_res/mp/doc/sird19B_files/image025.png       (2)                (3)         Description: Description: Description: Description: Description: Description: Description: Description: Description: Description: Description: Description: Description: Description: http://www.physics.usyd.edu.au/teach_res/mp/doc/sird19B_files/image029.png       (4)         Description: Description: Description: Description: Description: Description: Description: Description: Description: Description: Description: Description: Description: Description: http://www.physics.usyd.edu.au/teach_res/mp/doc/sird19B_files/image031.png       (5)          Description: Description: Description: Description: Description: Description: Description: Description: Description: Description: Description: Description: Description: Description: http://www.physics.usyd.edu.au/teach_res/mp/doc/sird19B_files/image033.png  As the virus spreads from its source, many more individuals will become infected, so the susceptible population will increase for a period of time. This increase is the susceptible population is governed by the surge factor *s* as given by equation 6. During the surge period, the susceptible population *S* is increased by  where  (6)  During a surge period, instead of the number of susceptible individuals decreasing, it increases. This results in significant increases in the infected population.  But, this increase in infected numbers produces a further increase in the susceptible numbers. This gives rise to a positive feedback loop leading to a very rapid rise in the number of active infected cases.  The changes in the populations of each group are determined by the positive constants *a*, *b* *d* and *s*. The model parameters are adjusted to best fit the model predictions with the published data.  The most significant equation is the relationship given by equation 2.      An understanding of this equation explains the staggering increase in the infection rate around the world as of 23 March 2020 and provides an insight into way in which the spread of the infection can be controlled.  If *S* = constant then the rate of increase of the infection is given by    This means that the change in the number of infected individuals is proportional to the number of infected individuals and so the number of infected individuals increase, then the rate of increase of infections also increases. This leads to an exponential increase in the number of infections. Often our medical experts and senior government officials talk about the infected population increasing **exponentially**. But this is ***wrong***. The situation is even worse than a population increasing exponentially whenever the number of susceptible individuals is also increasing. This is because the **rate of infection is proportional to both the number of infected individuals and the number of susceptible individuals**.    Look at the plot for the USA. The number of infections went from 994 to 24207 in 11 days.  For China, the initial number of infections in the model was 362, but only after 25 days the number of infections reached the staggering number of nearly 60 000.    Fig. 1. The number of current infected individuals who contacted the virus in China from 22 January to 27 February. The data for China may not be very reliable, but you use see that our model prediction is in excellent agreement with the actual recorded infections.  Statements made by politicians and their so called expert advisors have made statements such as “ … our number of infections is low now. Therefore, we do not need drastic measures now”. View the plots for the number of infections and the only conclusions to be drawn using scientific principles is that drastic action needs to be taken as early as possible. If you start with only a small number of infections, the number of infections will at first grow slowly and then **grow faster than exponentially**.  In figure 1, the number of infections in China reaches a peak after 25 days. The reason that the number of infections starts to decline is because the number of susceptible individuals decreases. If the number of susceptible individuals does not decrease then the number of infections just gets bigger, bigger, bigger, . . . , very rapidly.  Figure 2 shows the model prediction for number of susceptible individuals over 200 days for China. In China, drastic measures were taken to prevent the movement of infected individuals from spreading the disease and to restrict the movement of healthy individuals so that they did not become part of the susceptible population.    Fig. 2. The time evolution of the susceptible population from the 22 January. The maximum susceptible population is scaled to one.  There is no vaccine or “magic pill” for the virus. **The only way to reduce the number of infections is to reduce the number of individuals that are susceptible**. **The rate of infection only tends to zero if the susceptible population also goes to zero**.  Our political leaders have only now passed a law that all people arriving in Australia from overseas must be placed into quarantine for 14 days (15 March). This should have been done much early. Since mid-February, most of the people who are infected came to Australia from overseas and were already infected. We know that the more infected people, the greater the rate of increase in infections. More importantly than this is the fact that as these individuals move about, they dramatically increase the susceptible population and this increases the rate of increase in the number of infections since    Our Prime Minister has made many irresponsible statements (Thursday 12 March), “ .. I am going to the football”. In large gatherings, what you are doing is increasing the number of susceptible people. We now know from, this is just about the worst possible thing you can do. Only now (15 March) is the federal government starting to introduce drastic measures to limit contact between people. One leading Professor of Medicine who is advising our governments stated that there is no need for drastic actions to be taken yet, as the numbers of infected individuals is low. This is completely incorrect, to control the spread of the virus successfully, you need drastic action when the numbers are low, otherwise it is too late since the rate of infection is proportional to both the numbers infected *I* and susceptible *S*. This Professor of Medicine had little understanding of basic mathematics and physical principles.  You can ask, why are Australian schools still open (19 March)? In terms of the science, schools should have been closed a few weeks ago. Schools of China have been closed since Chinese New Year and schooling is taking place online. Why could not Australian governments make sensible decisions? How many extra people have been put at risk? A South Australian politician said the safest strategy is for students to keep going to school. His next statement was amount mass gatherings – the worst thing you can do is to have lots of people together is a static situation for long periods of time. But, this what school students are doing five days per week. Also, by closing schools you have less people moving about and travelling on public transport. In Norway (I think) schools are operated by a skeleton staff for students of emergence (essential) workers. A sensible idea. Why can’t our government make more sensible decisions?  The simplified model discussed does explain the staggering increase in infections and the only way to prevent a dramatic increase in infections is to reduce the susceptible population.  The model parameters as adjusted as new data is added. So far, the model predictions agree with the present data. But, what about the future? The model predictions into the future will greatly underestimate the total number of infections and deaths. This is because new epicentres of the infection are appearing throughout the world. The numbers that we will see in the future are most likely to be very scary.  How good are the predictions?  Only time will tell. But his is what science is about. Scientists propose a model and test it. A model is rejected when its findings do not match experimental results. If model seems OK, more evidence can be gathered to support the model. The model can be improved and complexities added to get a better agreement between the model predictions and the experimental results.  Even if our model predictions for numbers are “way-out”, the conclusions drawn from the mathematics are irrevocable. To prevent a truly world-wide catastrophe, then the number of susceptible individuals must be reduced since to a good approximation |

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| **MATLAB**  The modeling was coded using Matlab.  [**MATLAB SCRIPTS**](http://www.physics.usyd.edu.au/teach_res/mp/mscripts/) **(download files)**  **svr19.m (World Data) svr19CHINA.m (China Data) svr19USA (USA Data)**  The Script allows one to model the time evolution of the infection caused by the **covid19 virus** (**novel coronavirus**) and compare the numerical predictions against the published data. The model parameters are adjusted to best match the actual data. The model can be updated as new data is available. Using the model, we can make predictions about the number of people who will contact the virus, recover and die in the future.  There has been a global outbreak of the virus since mid-February. To account for additional epicenters of the virus, I have included a **surge factor** *s* into the model. As the virus spreads, more people are susceptible to the virus. For a period of days (surge period), the number of susceptible people is increased in the iteration to compute the populations for susceptible S, infected I, recovered R and dead D individuals.  The model input parameters are adjusted in the INPUT section of the Script.  % \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*  % INPUTS: Model Parameters  % \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*    % Maximum number of days for model [200]  tMax = 200;  % Initial number of infections [0.004]  I = zeros(num,1);  I(1) = 0.004;  % Adjustable model parameters  % S --> I [0.38]  a = 0.38;  % I --> R [0.036]  b = 0.036;  % I --> D [0.0025]  d = 0.0032;    % Surge factor: New epicenters for virus [0.32]  s1 = 0.33;  s3 = 0.80;    tsd1 = [2020 02 20]; % start date  tsd2 = [2020 04 10]; % end data  tsd3 = [2020 03 16]; % extra surge  The initial population is set to one and the initial numbers of recoveries and deaths are zero.  The values from the model and the actual data for *I*, *R* and *D* are displayed graphically. The model parameters are adjusted manually to give a best fit between the model and data values. The model values for *I*, *R* and *D* are scaled to match the actual COVID19 data. The infected population peak is adjusted to equal the maximum number of infections using the  scaling variable f.  % \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*  % MODEL: Time Evolution  % \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*    for n = 1:num-1  dS = -a\*S(n)\*I(n)\*dt;  dI = -dS;  S(n+1) = S(n) + dS;  I(n+1) = I(n) + dI;  dR = b\*I(n)\*dt;  dD = d\*I(n)\*dt;  R(n+1) = R(n)+ dR;  D(n+1) = D(n) + dD;  I(n+1) = I(n+1) - dR - dD;    % Surge factors: new epicentres for spread of virus  s = 0;  if t(n+1) > ts1; s = s1; end  if t(n+1) > ts3; s = s3; end  if t(n+1) > ts2; s = 0; end  dS = s\*S(n+1)\*dt;  S(n+1) = S(n+1) + dS;  end    % Scaling I, R and D values at day specified by t\_index  % I(27) = Id(27)  t\_index = 27;  index = find(t > t\_index,1);  f = Id(t\_index)./ I(index);    % Scale populations  I = f.\*I;  R = f.\*R;  D = f\*D;  Imax = max(I);  Rmax = max(R);  Dmax = max(D);  % Model: total population that has been infected;  Itot = I + R + D;  **covid19.mat**  Data file for numbers of infections, recoveries and deaths. Data is updated daily as more numbers become available from  <https://www.worldometers.info/coronavirus/>  The variable **covid** has six columns. Each row has the data for a day, starting from 22 January 2020.  column 1 World Date: Active Infections (currently infected individuals)  column 2 World data: Recoveries (cumulative number of people who have recovered  and no longer susceptible)  column 3 World Data: Deaths (cumulative number of deaths due to the infection  from the virus)  Column 4 China Data: Total Infections (cumulative number of individuals that have  been infected by the virus)  Column 5 China Data: Active Infections  Column 6 China Data: Deaths  Column 7 USA Data: Total Infections (cumulative number of individuals that have  been infected by the virus)  Column 8 USA: Active Infections  Column 9 USA Data: Deaths  To load the data, type in the Command Window  load(‘covid19.mat’)  To update the array and save new data, type in the Command Window  save covid19.mat covid19 |