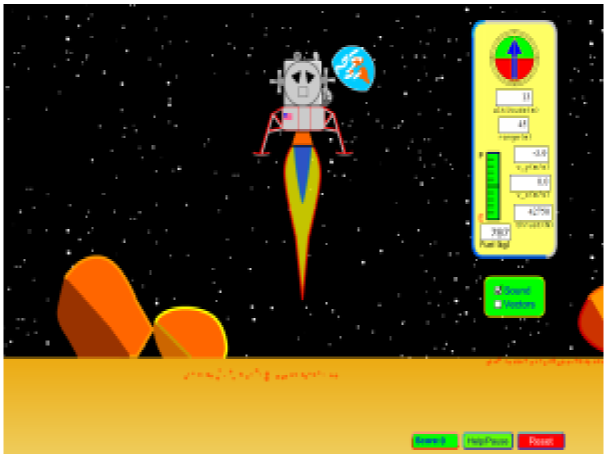
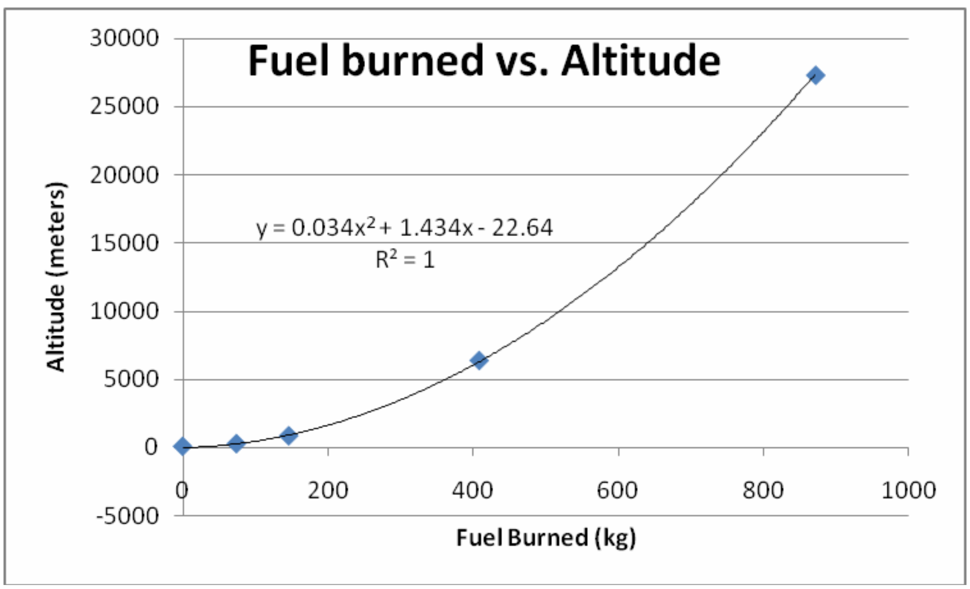
Introduction:

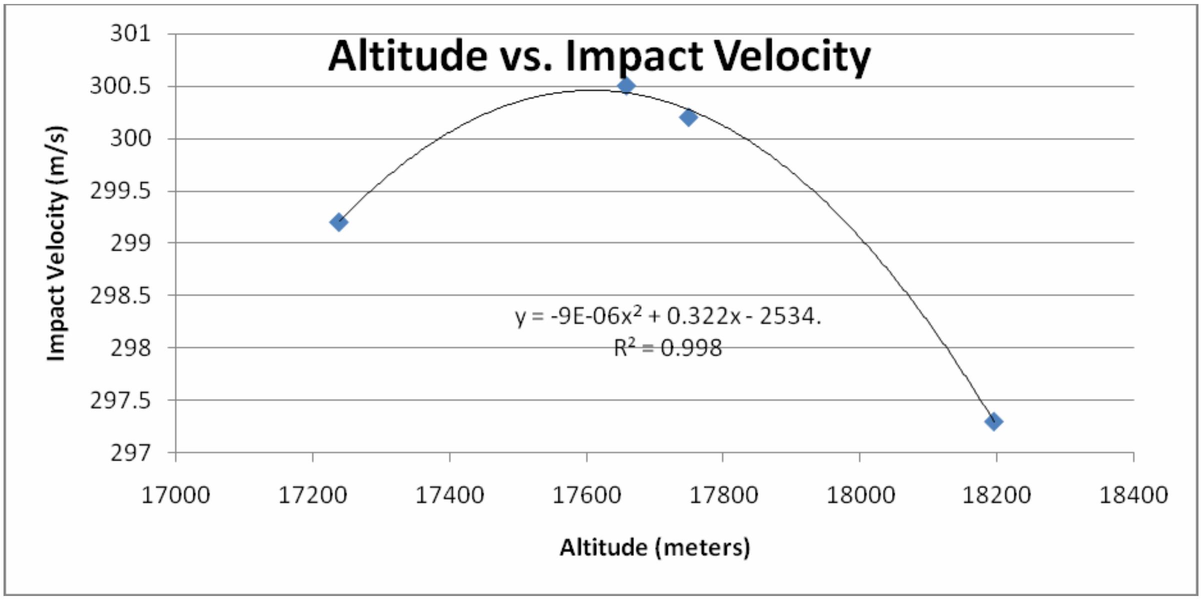
The laws of gravity states that everything that goes up must come down, and this is exactly what I exploited in this experiment. So, when a Lunar Lander module is accelerated into space away from the lunar surface eventually it will come back down if it hasn't broken out of its orbit. When it does come back down, it can either free fall or be accelerated even faster into the lunar surface with what fuel remains in the tank.





Fuel Burned/Altitude

0	50
74	244
146	823
408	6351
871	27309



Altitude	Impact Velocity
17238	299.2
18195	297.3
17749	300.2
17658	300.5

Phet Activity 1: Lunar Lander

Objectives: In this experiment we set out to find exactly how fast we could make the Lunar Lander module crash into the lunar surface. To do so we needed to write two equations, one for height vs. fuel used and one for altitude vs. impact velocity. The graphs for the two equations can be seen above. Since altitude and fuel used are directly related either could be used to plot against impact velocity, but I chose to use altitude because it is clearer.

<u>Procedure</u>:

1.) Open Lunar Lander Phet simulation.
2.) Familiarize yourself with the controls of the Lunar Lander lab, find how much fuel you have, find how high you are (altitude), find what your current velocity is and how your main thruster affects that. What makes your velocity positive or negative?
3.) Conduct four experiments resetting the game after each one. In these experiments you need to find how high you can go in relation to fuel. You do not need to burn all of your fuel to achieve the desired graph. For our experiment we only burned 74 kg of fuel for the first test.
4.) For these experiments press the space bar once to turn the fuel all the way on and press it once more to turn it all the way off. Be sure to note how much fuel is in the tank at the beginning of the run and then subtract how much is left when you stop thrusting to determine the fuel burned.

5.) Create a graph using the data gathered in step three. Add a trendline to the data (polynomial is the best fit because the fuel and altitude are directly related). You will need to use this graph on your calculator further on in the lab.
6.) Run four tests in which you use up more than half of your fuel, and then let the Lander coast (even though you will not be able to see it, it will still be going up). Turn the Lander around so that it is facing straight down, when your velocity turns negative. Then use your main thruster to boost the Lander towards the ground. Try to use up all of your fuel right before you hit the ground as this will yield the maximum speed.
7.) Once you have completed these four experiments plot a graph of the four points and add a polynomial trendline. You can use the fourth calc feature to find a maximum point on the parabola. This point will be your optimum altitude for the most speed. When you find this point go back to the graph you created in step four and find out how much fuel you need to burn to achieve this altitude.
8.) Run a series of three tests while trying to obtain the optimum altitude and fuel level using the same technique as step five. This should yield the maximum impact speed of the Lunar Lander module.
9.) (**NOTE:** You must burn your fuel in one continuous stream or else the data will be inconsistent.)

<u>Analysis:</u>

This Phet simulation is a wonderful tool for learning because all of its values will inevitably come out as whole numbers and are quite easy to work with because all of the variables are at the controls of the physicist. It is also quite pleasing to find that you can mathematically produce a maximum crashing speed for a piece of machinery. By creating a table on a graphing calculator with the values that you find for altitude and impact speed you can create a parabola. The top of this parabola is the theoretical value of the fastest impact speed. You can also use the calculator to find this, by hitting second CALC and then MAXIMUM. Then arrow over on the graph to the left bound side and then the right bound side and you can get a maximum. This equation was the key to the experiment because it led me to find exactly how fast we could make the lander hit the surface of the moon.

Errors: Although this Phet simulation is designed to minimize variables, and allows the user to control what is left, there are certain things in the simulation that cannot be controlled well enough to make the experiments entirely reproducible. For example I noticed that there were slight variations in the impact speed from test to test, even while I was trying to duplicate my previous results. When the Lander is on the way back down towards the moon and you need to hit the gas to accelerate it into the surface even faster, you cannot always hit the gas at the same time. For each experiment I tried to hit the gas around 3,000 meters and noticed that the closer you were to the ground when you used up your fuel, the higher your impact speed would be; however if you did not use up all of your fuel then you would not reach your max speed, and this is one of the errors. Since there is no sure way to fire the main thruster at the same time in each experiment, the test as a whole has a minor flaw; however it is almost an insignificant change.