PHYS 265 Lab 1 Report

- I Introduction

In this lab, we will use Python and given known values for mass, distance, etc, of the Earth, the Moon, and the Saturn V rocket stage 1. Using these values, we will define functions and create plots using oriented programming graphing to show different characteristics and solve for certain values of gravitational Earth and moon systems and specifications of the Saturn V rocket.

- II The gravitational potential of the Earth-Moon system

The gravitational potential energy is the energy between a mass and a certain point a distance r from that mass. That energy is equivalent to the kinetic energy the point would have if it starts moving towards the mass. The energy is given by the equation -G*M/r where G is the gravitational potential energy (6.67e-11 m^3/kg/s^2).

To graph the gravitational potential from -1.5 to 1.5, the earth's distance to the moon of an earth and moon system, we must define a function for the gravitational potential energy and make it return the equation described above. We can now use the command pcolormesh for Python to make a color plot where we can see the magnitude of the potential is very high at Earth, and we also see an increase in potential energy where the moon is located.

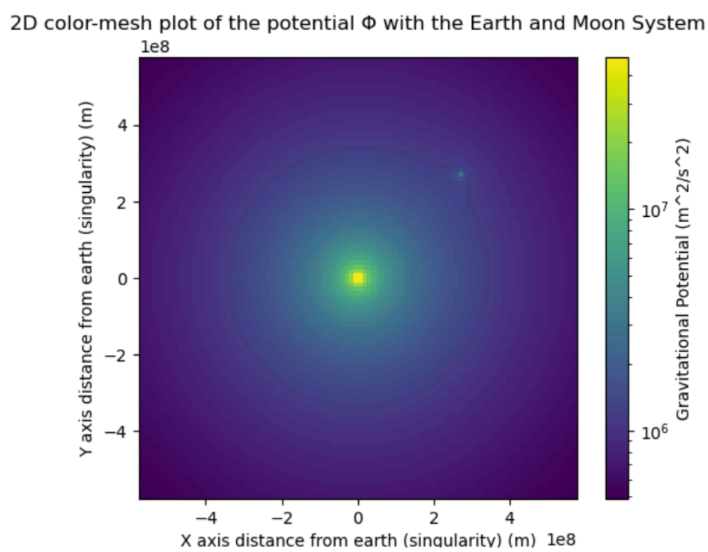

Figure 1: As we can see, the further away we go from a mass, the lower the magnitude of gravitational potential.

In this scenario, we are assuming the Earth and the moon are point masses, to make our calculations simpler. Another important thing to note is that all of the x and y coordinates in the figures in the report have been scaled logarithmically to make the graphs easier to see and analyze. This means that the x and y positions are the natural logarithm of the x and y values, this makes the graph spread out more, and it's easier to see the change in potential.

A similar graph is a contour plot that also shows the same data, we can see it shown below.

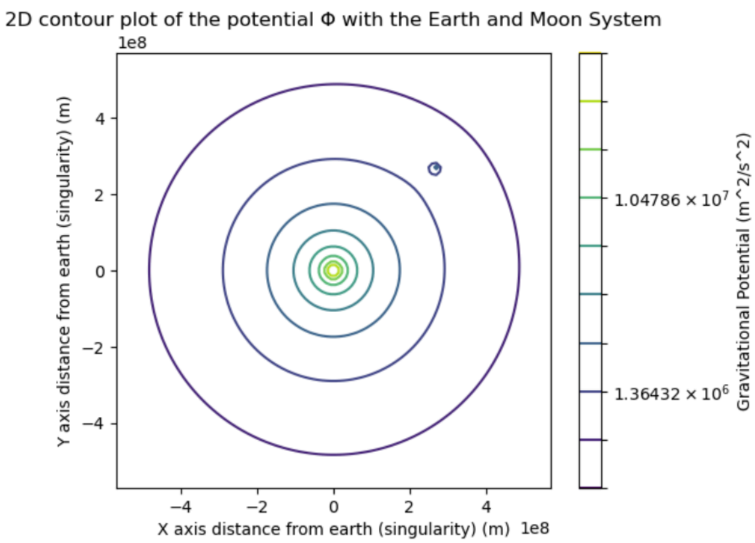

Figure 2: As we can see, this graph also shows the further away we go from a mass, the lower the magnitude of gravitational potential as shown by the color bar and the difference in distance between each contour line.

- III The gravitational force of the Earth-Moon system

Similarly to the potential energy, we will also define the gravitational force equation for it to give us the x and y components of the force. The gravitational force is given by -GMm/r^2, where M and m are the masses and r is the distance between them. After defining the equation, we will use our meshgrid and known values for each of the masses in the system to calculate the force on the Saturn V rocket from both the Earth and the Moon. To create a streamplot of the forces, we will use the function "streamplot" and plug in the x and y grid coordinates, the x and y forces. This will show a plot of where the force is going at different paths in the plot. These x and y values have also been scaled logarithmically. Here we can see the streamlines.

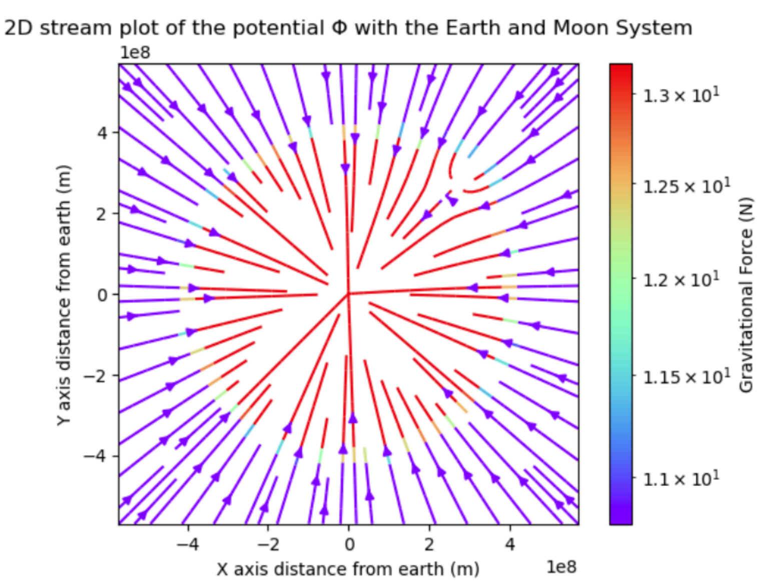

Figure 3: As we can see, the gravitational force is greatest the closer we get to a mass, and the path of the force near the moon gets redirected to attract towards the moon since the moon's mass has a greater gravitational force than the earth at that point.

- IV Projected performance of the Saturn V Stage 1

To analyze the performance of stage 1 of the Saturn V rocket we must use the equation: Change in velocity=ve ln(m0/m(t)) - gt, where t is time, ve is the velocity of the exhaust, m0 is the wet mass of the rocket, mt = m0-mdot * t where mdot is the amount of mass burnt at a specific rate, and g is the acceleration due to gravity. To find the time that the rocket is burning fuel, we can use the equation T=(m0-mf)/mdot, and from this we get that T=158 seconds. From this we define a function for the change in velocity and we can make a graph that looks like this.

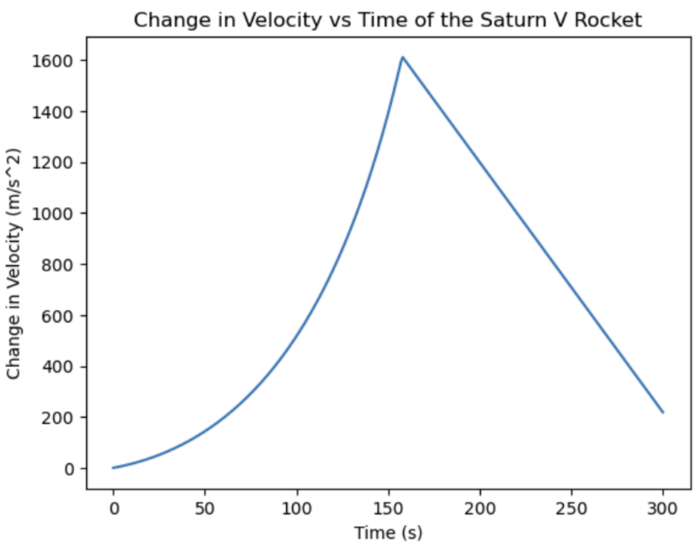

Figure 4: We can see how it's accelerating upward until around 160 seconds, and then its velocity falls back down afterwards since gravity is pulling back down.

From the past equation, we can use a function called "quad" to integrate the velocity over the time that the rocket is burning to find the height after the rocket stops burning. We get the height at the end of the burn is 74.1 km with an error of 6e-8 m.

- V Discussion and Future Work

Officially, NASA got the test results back from the first prototype of Saturn V. They found that it burned for about 160 seconds and lifted the system to an altitude of about 70km. The burn time calculated by NASA is only 2 seconds more than our calculations, and the altitude is 0.1 km less than our calculated value. Some approximations that could've affected these values are that we neglected drag, we also neglected that the Earth's force of gravity on the rocket decreases the further away the rocket goes, and that the rocket is not going to be perfectly wasting fuel at the same rate throughout the burn. All of these estimations can alter our values, which is why our calculations are different than NASA's results, however, it is important to note that our calculations are extremely close to NASA's, which can be assumed that we were very accurate in our calculations.