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Phys 265

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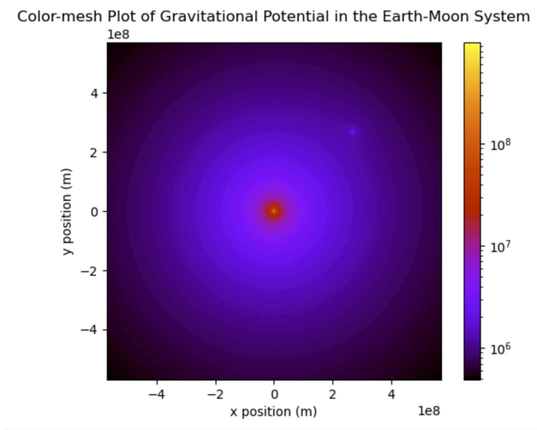
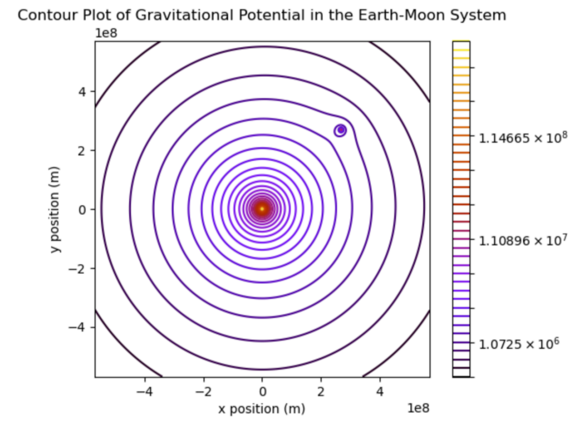
# Lab 1: The Apollo Missions

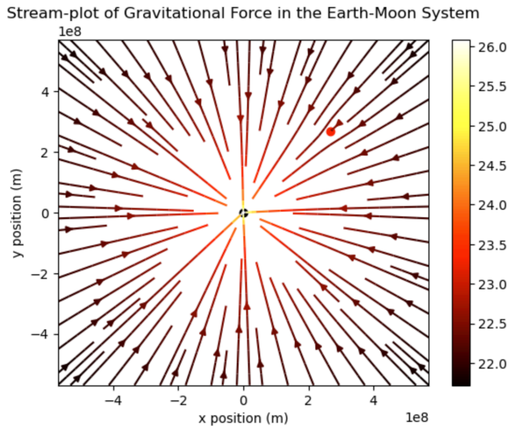
In this report, we will look at characteristics of the Earth-Moon System and the Saturn V rocket to illustrate the plan for the Apollo missions. In order to send astronauts to the Moon we need to understand the gravitational potential and force of the Earth-Moon system so that we can calculate the influence gravitational interactions will have on the necessary speed of the rocket for a mission to the moon. In this report we have calculated such fields as well as the height and time at which the projected fuel level for the rocket will run out. These calculations will help to determine the trajectory of the Saturn V rocket based on its projected specifications.

The gravitational potential of the Earth-Moon describes how much energy is necessary to move an object within a gravitational field. To determine the gravitational potential for the Earth-Moon system we coded a function that calculates the potential over a large distance and graphed it to illustrate this field. In order to do this the general function for gravitational potential given by $\phi(r) = -\frac{GM}{r}$ where G is the gravitational constant, M is the mass of the body of interest, and r is the distance from that mass to whatever point you are measuring the gravitational potential at. Using python we can use the def command to define a function that calculates the gravitational potential based on the variables mass of the object, in this scenario that is either the Earth or the Moon, the x and y coordinates of the object, and the x and y coordinates of the point you want to measure the potential at. By changing these input variables we can find the potential at thousands of points across the range of -1.5 times the distance from the Earth to the Moon to 1.5 times the same distance. By plotting the output with a color-mesh or a contour plot, which will give a different color to each value of potential, so we can see what the field of the gravitational potential for the Earth-Moon system looks like.




The gravitational force of the Earth-Moon system directly affects the velocity of the rocket with the Earth exerting more influence due to its significantly higher mass. This means that the force of gravity will be trying to move the rocket back towards Earth so the velocity of the rocket must be fast enough to account for this. To calculate this we need to use the formula for gravitational force given by $F_{21} = \; - G\frac{M_1 m_2}{\left|r_{21}\right|^2}$ multiplied by the direction vector for the distance which describes the force exerted on object 2 by object 1 and G is the gravitational constant, M1 and m2 are the masses of the objects and r is the vector of the distance between the two objects. Using python we can code a function similar to the one above that will calculate the gravitational force on the Saturn V rocket by the Earth-Moon system. This function will cover the same range as the previous one but instead of calculating the total force it will calculate the x and y components of the force. Then we can plot the output of this function using a streamplot which uses arrows to illustrate the direction of the force and colors corresponding to the value of the force.




The projected burnout height of the rocket shows us that the Saturn V rocket should actually make it to the moon based on its mass and fuel level. This height can be calculated using the equation $h = \int_0^T \Delta v(t)dt$ where $\Delta v(t)$ is the change in the rocket's velocity and T is the total burn time of the rocket. These functions were coded in python to calculate the projected burnout height which was 74.09 km.

The gravitational interactions between the Earth-Moon system and the Saturn V rocket as well as the projections for the performance of the Saturn V rocket detailed in this lab are necessary to plan the Apollo missions. There were a few approximations made in this lab specifically in representing the Earth and Moon as point sources and approximating the position of the Moon in relation to the Earth. We also neglected the effects of drag force on the height of the rocket. In the future changes would need to be made to account for drag force, and the sizes of these bodies and a more precise location of the Moon with respect to the Earth would need to be found. The first prototype of Saturn V burned for 160s and reached an altitude of 70 km, our calculations project the rocket would reach 74 km in 157s meaning our estimations were slightly over the actual burnout height which is likely due to the neglection of drag force in our equations on the rocket.