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Landing on an Asteroid

- **Introduction**

Our team has been tasked with landing our probe, Star5, on the asteroid, Roculus, and collecting samples for further research on Earth, similar to how when the Japan Aerospace Exploration Agency (JAXA) collected samples from the asteroid, Ryugu, with their Hayabusa2 Spacecraft. In order to do this, we must overcome the challenges associated with a low gravity environment, as well as landing on the assumed rugged surface of an asteroid, riddled with grooves and cliffs.

- **Problem Statement**

Due to the unideal condition of the surface, slight bouncing on impact is inevitable. We are to create a function that enables us minimize the damage done to the probe by bouncing, as well as ensure that Star5 does not hit the asteroid with such a force that will launch it right back into orbit. Once our probe is safely landed and at rest, we must also develop a way to make it hop in various directions using a spring, while also considering its limitations in different conditions.

- **Assumptions and Derivations**

Since the scenario given to us was based off JAXA's Hayabusa2, we gave ourselves similar numbers for our constants to keep it as realistic as possible for the calculations.

G = gravitational constant = 6.67*10^-11

M1 = Mass of Space5 probe = 610kg

M2 = Mass of Asteroid = 8*10^11kg

R = Distance of Space5 from center of asteroid = 25,000 m

r = Radius of Roculus, the asteroid = 1,500 m

h = distance from probe to the surface of the asteroid.

a = acceleration

v = velocity

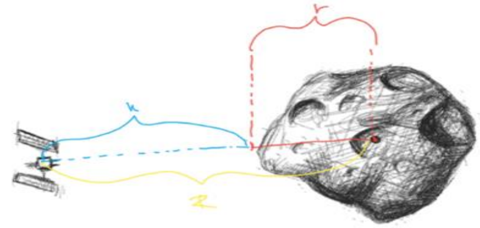
$F = (G * M1 * M2)/(r)^2$ and $F = Ma$ ➡ $M1a = (G * M1 * M2)/(r)^2$ ➡

$$\boldsymbol{a = (G * M2)/(r)^2}$$

$$PE = mgh$$

$$KE = 1/2mv^2$$

$$F = -kx$$

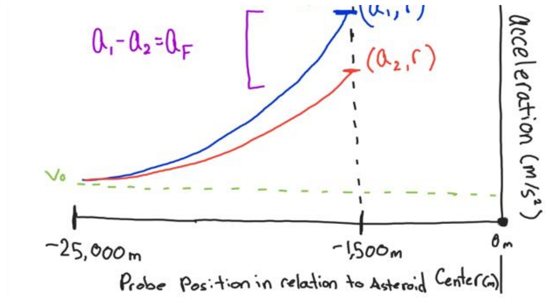


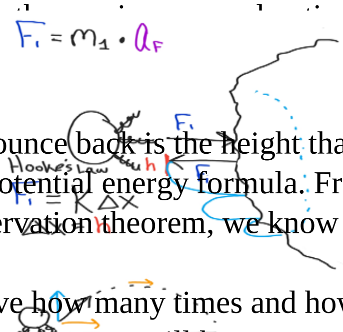
- **Method**

❖ a(max) = maximum acceleration Space5 probe can reach, because it is the acceleration it would reach right at the surface of the asteroid

❖ Goal: Reach an acceleration just below this max acceleration, so we do not crash into the surface and hit it with too much force.

❖ This goal can be reached by using the Euler method. By using the derived acceleration formula from above as the differential function. After running the Matlab code, we are giv , as well as an a ue.





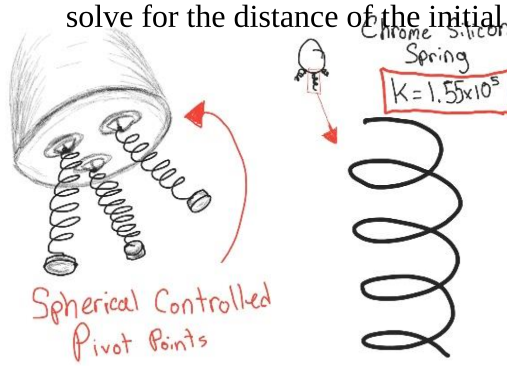
❖ The initial bounce back is the height that can be used in the potential energy formula. From the energy conservation theorem, we know that PE=KE.

❖ Once we solve how many times and how far Space5 can bounce, we will know our radial margin of error.

❖ To hop from place to place, we have designed our probe to have Spherical Controlled Pivot Points for each of the springs that can rotate and compress the springs, depending on the desired direction.

❖ The final acceleration is given by subtracting a2 from a1. From that, you can solve for the total force Star5 strikes the asteroid with using Newton's 2nd law.

❖ Once force is known, Hooke's Spring Law comes into play. We first determined qualities necessary for our spring to endure harsh conditions, then calculated the spring constant. From that, we can solve for the distance of the initial bounce-back.



- **Analysis and Conclusion**

We met the conditions and limitations of the challenge by accounting for low-gravity, hazardous conditions, and other unforeseen circumstances. Through the use of differential equation, we are able to determine all the necessary data needed to complete the mission successfully with minimal error.

Work Cited

- Wall,Mike, “Japanese Spacecraft Successfully Snags Sample of Asteroid Ryugu,” space.com, 22 February 2019, https://www.space.com/japanese-asteroid-probe-lands-ryugu.html . Accessed November 2019.