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# Executive Summary

## Introduction: Problem B

Now that Japan successfully landed two probes on the asteroid Ryugu, we are in search of a new asteroid on which to land the probes to continue the research on these rocky celestial bodies. We must determine a range of dimensions for the smallest possible asteroid chosen. Once we find an asteroid that meets our criteria, we must find a method to land the small probe. The final position of the probe must be as close to the predetermined point as possible using the least number of bounces to avoid damaging the probe. We also need to develop a way for the probe to move to a predetermined point without using a device that creates thrust.

## Methods

We determined that the smallest possible asteroid we can land the probe on must have a gravitational pull that is strong enough so that the probe won't gain enough velocity after its initial bounce to escape the asteroid's gravitational pull. We used the information given in the articles about the Japanese mission to determine a point of reference for gravity. The mass of the probe was 1.1 kg. The gravity of reference was 0.0001483 $m/s^2$. We assume this point to be the maximum point of gravity needed to hold the probe within the new asteroid's gravitational force field. To determine the dimensions of the asteroid, we used the gravitational force equation shown below.

$F = G((m_1 m_2)/r^2)$
F – gravitational force acting between 2 objects
G – Universal gravitational constant $6.674*10^{-11}$ $N*M^2*kg^{-2}$
$m_1$ – mass of object 1 (1.1 kg for our probe)
$m_2$ – mass of object 2 (desired asteroid to land on)
r – distance between the center of masses of the 2 objects

Assuming we know the mass of the asteroid, we determined the radius needed to produce the needed gravitational force. We assumed that the mass of the probe and that the distance from which it was dropped remained constant. The equation showed a proportional relationship between the mass and the radius of the asteroid. The range of dimensions depended on the mass of the asteroid. Meaning that the smaller the radius, the bigger the mass needed to be to keep the probe within the asteroid's gravitational field after the probe's initial bounce.

To land the probe, we used the conservation of energy equation shown below.

$mgH = (1/2)mv^2 \longrightarrow v = sqrt(2gH)$
m – mass of probe
g – gravity of asteroid
H – height of which probe is dropped from
$v_1$ – velocity that the probe is falling at

We assume the initial velocity of the probe to be zero. The equation above allows us to find the velocity of the probe before the first bounce. We then use this velocity and the coefficient of restitution to determine the velocity of the probe after the first bounce.

$V_2 = -ev_1$
$v_2$ – velocity of the probe going up after first bounce
e – coefficient of restitution
$v_1$ – velocity of probe just before impact

After finding the second velocity we used the conservation of energy formula once again to determine the height to which the probe would bounce. The height of the bounce needed to be low enough to reduce the damage to the probe after each additional bounce.

$H_2 = v_2^2/2g$

To move the probe to a predetermined point we used the springs on the feet of the probe. Each foot had its own spring so that they could adjust to the different forces and counter them, thus controlling the movement of the probe. This way the probe could maintain its path and reach the predetermined point. The force on each spring was calculated by the formula:

$F = -kx$
F – force exerted by the spring
k – the spring constant
x – the measure of the displacement of the spring from its uncompressed position to its compressed position.