LANDING ON TARGET

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Problem B, Adjustment 1

INITIAL MODEL

Our goal was to land a 1kg probe on an asteroid using springs as landing and movement devices in place of thrusters. The size of the probe is based upon the Japanese *Huyabusa* mission’s probe specifications.

Our probe uses a spring damper system upon impact with the asteroid in order to achieve landing. After landing, the spring is reoriented and used to launch the probe in a desired direction.

We determined the smallest possible asteroid upon which our proposed lander could reasonably function.

SUMMARY OF MECHANISM

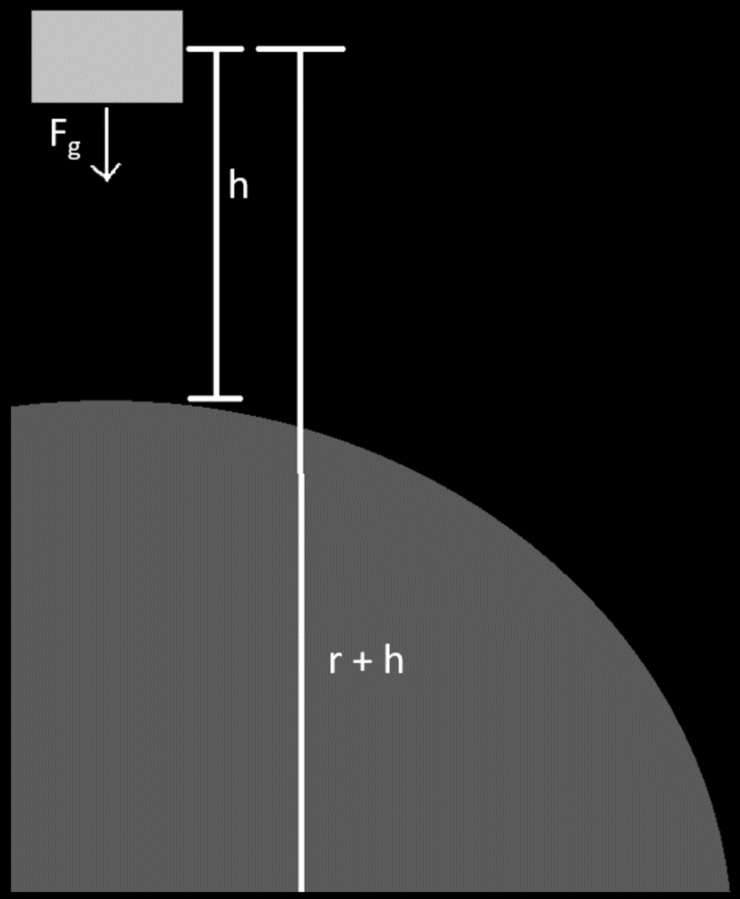
1. A probe is carried in a satellite.
2. Satellite expels probe so that the probe's velocity is 0m/s.
3. Probe drops to the surface of the asteroid.
4. A spring is used to dampen the force of the fall.
5. Solar panels attached to a capacitor powers a piston to compresses the spring.
6. Spring is oriented and decompressed, launching the probe.
7. A spring-suspension system dampens the force of landing of the jump.
8. Steps 5-7 are repeated in direction of the predetermined location.

STEP 1-3

1. A probe is carried in a satellite.
2. Satellite expels probe so that the probe's velocity is 0m/s.
3. Probe drops to the surface of the asteroid.

$$v_e = \sqrt{\frac{2GM}{r}} = \sqrt{2G\rho\left(\frac{4\pi}{3}\right)r^2}, \qquad \rho = 2000\ \text{kg}/m^3$$

$$\frac{r}{946} = v_e = v \sin \theta$$



CONTINUED MATH

$$\frac{r}{946 \sin \Theta} = v, \quad r=3441m$$

v=5.14m/s

$$\frac{1}{2}k_{movement}x^2 = \frac{1}{2}mv^2, \qquad \frac{r}{946 \sin \Theta} = v$$

$k_{movement}$=29400N/m, $x_{movement}$=.03m, Θ=45

r=3441m

$$v_{escape} = \sqrt{\frac{2Gm_a}{r}},\ v=5.14m/s,\ r=3441m$$

m_a= 6.83x$10^{14}kg$

$v^2 = 2a$h, a= .003m/s^3, v=5.14m/s

h=520.2m

Our asteroid needed to be large enough that it had a reasonably high escape velocity so that our probe would not leave the asteroid every time it jumped.

STEP 4

$$m\frac{d^2x}{dt^2} + \sigma\frac{dx}{dt} + kx = 0$$

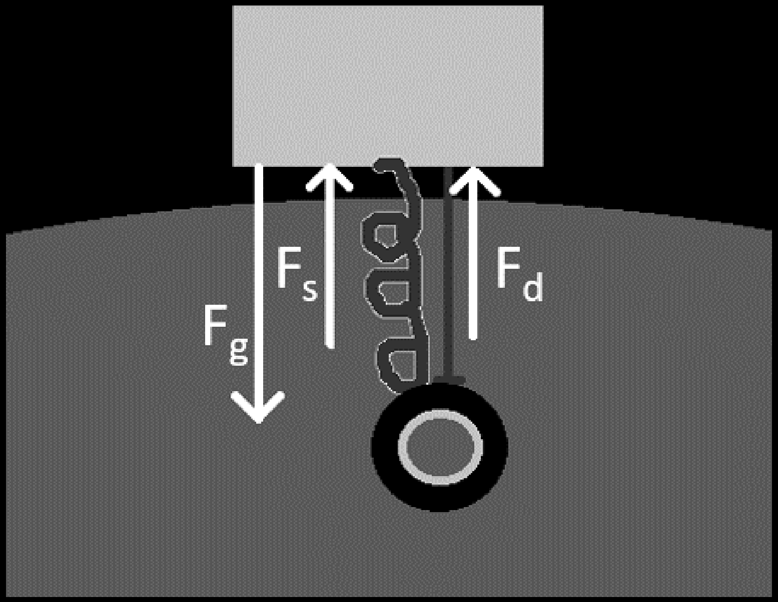
This differential equation was used to model the dampening of the initial landing.

STEP 5-6
CRAFTING THE PROBE

- The dimensions of the probe were based on the *MINERVA* probes.
  - 12 cm in diameter
  - 10 cm in height
- The spring constants for the wider and thinner spring were based on the lower and upper limits, respectively, of the 4900N/m-29400N/m range of normal metallic springs.
- The decompressed thinner spring was placed below the center of mass of the probe through a hole at the bottom. It begins in the probe, extends 4 cm to ground level.
- There are pegs around the lower edge of the probe.
- There is a gyroscopic control that adjusts the orientation of the inner spring.
- Solar panels charge a capacitor to power a piston that compress a reoriented spring

STEP 7
FREE BODY DIAGRAM FOR PROBE

The sum of the force exerted by the spring and the damping force is equivalent to the force of gravity. The force of gravity and the spring force are conservative forces, however the damping force is not conserved which causes the system to dampen overtime.



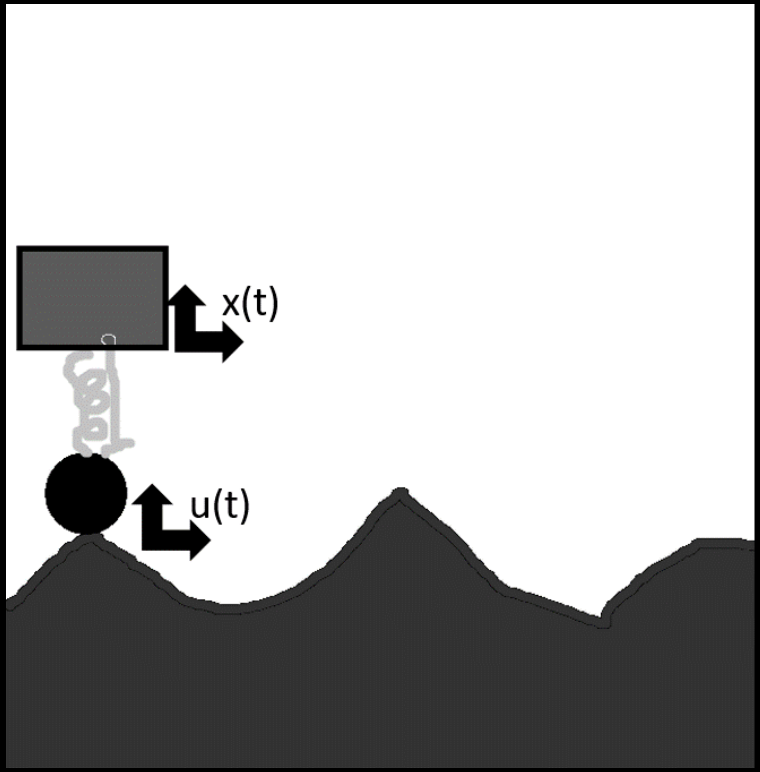
ADDITIONAL PROBLEM:

FOR THE ADDITIONAL PROBLEM OUR GOAL WAS TO MODEL A SUSPENSION SYSTEM THAT WOULD NEUTRALIZE BOUNCING DURING A ROLLING MOTION

$$F_s = k(l_0 - (x_0 + x - u))$$

$$F_d = \sigma\left(\frac{dx}{dt} - \frac{du}{dt}\right)$$

$$m\frac{d^2x}{dt^2} + \sigma\frac{dx}{dt} + kx = \sigma\frac{du}{dt} + ku$$



IMPLICATIONS

- Distance per jump: 1042m
- Maximum height: 260m
- Speed: (1042m/ the time it takes to charge a small capacitor)
- Maximum Aspect Ratio: 12.03

PARAMTERS

Method	Symbol	Measurement
Researched	m_s	609kg
Researched	m_p	1kg
Solved	m_a	6.83x$10^{14}kg$
Researched	ρ	2000kg/m^3
Solved	v_e	5.14m/s
Solved	r_a	3441m
Assumed	θ	45°
Researched	$k_{movement}$	29400N/m
Assumed	$x_{movement}$	0.03cm
Solved	h	520.2m
Solved	r_{max}	22761.4m
Researched	$k_{landing}$	4900N/m
Assumed	σ	150Ns/m
Solved	a	.003m/s^3

REAL EQUIVALENT

- Deimos: a moon of Mars
  - Mean radius: 6.20 km
  - Mass: 1.476 x 10^{15} kg
  - Mean Density: 1471 kg/m^3
  - Surface gravity: 0.003 m/s^2
  - Escape velocity: 5.56 m/s

  - All parameter are within 1 order of magnitude of our solved values.

CONCLUSIONS

Our model succeeds in modeling the landing of a probe using a spring given assumptions that the object is generally spherical.

Improvements:

Adapt equation to model asteroids with irregular aspect ratios

The model assumes stabilization probe so that it lands flat on the spring each time. An future adjustment could account for various landing terrain.

THANKS FOR LISTENING

Any questions?