Movement of an object in Microgravity Enviroments

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Problem

We have been asked to answer 4 main questions

1. What are the smallest possible asteroids we could land on?
2. How do we land a probe as close to a predetermined location as possible?
3. How do we move to a predetermined location after landing?
4. How to deal with different kinds of terrain while moving across the asteroid?

Assumptions

- The rover has a mass of 1 kg.
- The rover stays close enough to the surface of the asteroid to assume gravity is constant.
- The rover must jump at a 45 degree angle with respect to the surface.
- The mothership from which the probe is released from is in geosynchronous orbit with the asteroid so that its position is static with respect to the target region.
- The landing zone is level with respect to the asteroids center of gravity.
- The probe free falls to the surface during deployment.
- The probe retains 20% of its energy everytime it bounces.

Assumptions

- The asteroid has a uniform density.
- There is no drag force acting upon the rover.
- The target landing region and shape of the asteroid allow us to approximate surface gravity by treating the asteroid as a spherical body .

Size of the Asteroid

Spring-based mode of transportation relies solely on gravity to return the probe back to the surface after each jump.

Maximum allowed vertical velocity is the escape velocity.

By assuming a constant angle for jumping, we can describe the maximum speed produced by the spring in terms of the potential energy of the spring ***u***.

$$V_{vertical,max} = \sqrt{u}$$

Size of the Asteroid *(cont.)*

Can compare the previous equation to the escape velocity to produce

$$\mathrm{V}_{vertical,max} \leq V_{escape} = \sqrt{2GM/R}$$

where G is the gravitational constant, M is the mass of the asteroid, and R is the mean radius of the asteroid.

Given a density ρ, we can write M in terms of R and vice versa. By doing so, we can write the minimum radius R in terms of the u (the potential energy of the spring).

$$\mathrm{R}_{min} = \gamma\sqrt{u}$$

$$\gamma = \sqrt{3/(8G\rho\pi^{1/3})}$$

Deployment

By assuming the mothership is in geosynchronous orbit with the asteroid so that it is static with respect to the target, we need to only concern ourselves with the impact velocity of the probe

$$\mathrm{V}_{impact} = \sqrt{2GM\left(1/R + 1/(R+d)\right)}$$

where *d* is the initial altitude of the drop. Since $\lim_{d \to \infty} V_{impact} = V_{escape}$ and the escape velocity will be much less than the velocity required to damage the probe, we do not need to worry about damage as a result of impact.

Therefore, we can choose *d* to minimize the bouncing due to impact, ensuring a gentle and accurate landing.

Traversal

Jumping a a constant 45 degree angle would mean that our maximum y-distance and x-distance are

$$\mathrm{x}_{max} = 2\lambda u^{3/2}$$
$$\mathrm{y}_{max} = \lambda u^{3/2}$$

where

$$\lambda = \gamma^2/(\sqrt{2}GM)$$

This maximum y-distance would be the maximum cliff we would be able to jump up to. This max x-distance would be the maximum distance we could travel along the surface of the asteroid without accounting for bouncing. When accounting for bouncing and assuming the probe retains 20 % of kinetic energy every bounce, this distance would increase by about 25 %.

Adaptation

A bigger asteroid would be easier to land on but would require more energy to move across. As the size of the asteroid increased your energy required to move larger distances would increase along with the gravitational pull of the asteroid.

The shape determines where you would land and how you would attempt to traverse surface.

As the size of the asteroid increased bouncing would become less of a factor due to acceleration of gravity increasing.

Conclusion

With the minimum radius depending on the maximum energy being generated by the probe there is virtually no limit to how small our asteroids could be. The only limit would be how small of an asteroid would be how small of an asteroid we could successfully orbit a probe around and onto. The shape of the asteroid would change how we approach landing and moving across the surface. The ability to move across the asteroid is only limited by the strength of our spring and the size of the asteroid.