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P6_4 Tee Off Into Space

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Abstract

Our aim in this paper is to explore the possibility of hitting a golf ball into orbit around various objects in our solar system by using the orbital velocity equation. We found this to be possible around four moons, six dwarf planet candidates and a trojan of Jupiter (See Table 1).

Introduction

The gravity and atmosphere on Earth limits the distance a golf ball can be hit. If instead a golfer was placed on a small moon with almost no atmosphere, could they theoretically hit a golf ball so fast so that it would enter orbit?. In this paper, we will review notable solar system objects in order to identify which ones are suitable to attempt this ambitious shot.

Theory

In 1974, astronaut Alan Shepard played golf on the Moon during the Apollo 14 mission. The reduced gravitational strength and vacuum should have massively helped Shepard but he estimated his shot only travelled approximately 180 m [1]. His relatively short drive was probably due to the limited movement that Shepard experienced in his space suit.

If we want to explore how fast a ball needs to be travelling to enter orbit we need to use the orbital velocity equation. This can be derived by setting the gravitational force acting on an object equal to its centripetal force:

$$F_g = \frac{GMm}{r^2} \quad (1)$$

$$F_c = \frac{mv_o^2}{r} \quad (2)$$

Where G is the gravitational constant, M is the mass of the body, m is the golf ball mass, r is the orbital radius and v_o is the ball's orbital velocity. We can rearrange for v_o so that:

$$v_o = \sqrt{\frac{GM}{r}} \quad (3)$$

We can set the minimum radius of the orbit to equal the radius of a body to calculate the minimum orbital velocity. For the Moon, $M = 7.346\times10^{22}$ kg and $r = 1737m$ [2]. the Moon's v_o is $1680ms^{-1}$. For comparison, the current world record golf ball speed is only $97.1ms^{-1}$ [3].

If an orbital shot on the Moon is not possible, we can use equation 3 to determine v_o for other objects in the solar system. An orbital shot around a solar system object is possible so long as $v_0 < 97.1ms^{-1}$. This assumes that the golfer would be able to hit the golf ball at the maximum speed despite the harsh environment, and that the shot has no inclination.

Results

A list of known solar system objects to the Gigagram range of was used [2]. All planets, moons, dwarf planets or notable objects that had a lower radius than the Moon were included. Objects with $r < 100km$ were not included due to their insignificant size and because many of their masses are only rough estimates. Asteroids and un-named objects were not considered which significantly simplified the final list.

This meant that the orbital velocities were calculated for a total of 46 objects. The list consists of 23 moons, 5 dwarf planets and 18 objects yet to be fully classified.

Body	r (km)	M (10^{18} kg)	v_o (ms^{-1})
Hiiaka	160	20	91.3
Actaea	140	18.6	94.1
Hyperion	205	5.58	42.6
Sila	125	11	76.6
Chariklo	124	9	69.6
Chiron	116	7	63.4
Hektor	113	10	60.0
Ceto	112	5.4	56.7
Phoebe	107	8.29	72.1
Deucalion	105	3.14	44.7
Bienor	104	3.15	44.9

Table 1: Notable solar system objects that were found to have a $v_o < 97.1ms^{-1}$.

We found that an orbital golf ball shot was possible around 4 moons, 6 dwarf planet candidates and Hektor, an L4 Trojan of Jupiter. A Trojan is is an object that orbits at the Lagrange point of another gravitational body.

A golfer would have more than one reason to visit some of these objects. The dwarf planets Chariklo and Chiron both have rings, Hiiaka orbits the egg shaped dwarf planet Haumea, which also has rings. The moons Hyperion and Phoebe would offer stunning views of the Gas Giants.

Discussion

One assumption we make is that the solar system objects were spherical. In reality an irregular shaped object would lead to gravitational perturbations in the golf balls orbit, which could make it unstable. However a ball with sufficient velocity would be able to complete one orbit around all of the objects listed.

Furthermore a ball hit on the surface of a body closer to its centre of mass would require higher velocity or a precise inclination to stop it hitting the surface. Many low mass solar system objects have irregular shapes, this was accounted for where possible by using the maximum radii for the calculations.

Another assumption is that the golfer would not experience the limited movement while wearing a space suit. The reason this was not considered was because there was no quantifiable way to calculate it's effect on the orbital velocity. While this is a concern, many of the calculated orbital velocities are significantly below the world record speed. Furthermore, future improvements to space suit design could make swinging a golf club easier.

If a body had an atmosphere this would also mean a higher orbital velocity is required. It is understood that the atmospheres of smaller objects in the solar system are generally extremely thin so they would not effect the ball. The Moon has an atmosphere 2×10^{14} times thinner than Earth's, it was assumed that small objects would have similarly thin atmospheres [4].

Conclusion

Hitting a golf ball into orbit might seem impossible here from Earth, but we have successfully shown that there are a large variety of moons, dwarf planets and asteroids that such shots are possible from. Future space exploration might lead the sport of golf to new frontiers.

References

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