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P4_3 Walking on Wolf-Biederman

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Abstract
In the 1998 blockbuster ‘Deep Impact’ a crew of astronauts land on the surface a comet named Wolf-Biederman. The film leads the audience to believe that the force of gravity at the surface of the comet is strong enough to keep the astronauts gravitationally bound to the surface. This paper investigates the validity of this depiction, based on information given in the film. It is found that the local gravitational constant at the surface of the comet, 1.4×10^{-3}ms^{-2}, would be just sufficient to allow motion along the surface by walking and jumping as the film depicts, and that the astronauts would not be at risk of drifting into space in spite of the comets low escape velocity of 3.9 ms^{-1}.

Introduction

In the 1998 blockbuster ‘Deep Impact’ an amateur astronomer identifies a comet which is on a collision course with Earth. It is determined that if the comet collided with the Earth it would be an Extinction Level Event, extinguishing the majority of life on Earth. A crew of astronauts is sent to land on the surface of the comet in order to deploy thermonuclear weapons in the hope of destroying it. While on the surface of the comet the astronauts are able to move as though they are under the influence of a substantial gravitational field, a field strong enough to prevent them from floating out into space while they walk and run on the surface. The feasibility of this is explored by considering the strength of gravity at the surface of the comet and the comets escape velocity.

Analysis

In the film the comet is 7 miles across at its widest point [1]. For the purposes of this discussion the comet is modelled as a sphere, taking the diameter to be 7 miles. The composition of the comet is assumed to be 100% ice with a density of 920 kgm^{-3}. Using the equation for the volume of a sphere,

$$V = \frac{4}{3}\pi R^3, \qquad (1)$$

in which V is the volume of the comet and R is the radius of the comet which is equal to 5600 m, the volume is found to be 7.35×10^{11} m^3. The mass M of the comet can then be calculated by rearranging the average density equation [2];

$$\rho = \frac{M}{V}. \qquad (2)$$

This gives a comet mass of 6.76×10^{14} kg.

Escape velocity can be defined as being when the kinetic energy of an object is equal in magnitude to its gravitational potential energy [3], or;

$$\frac{1}{2}mv^2 = mgh, \qquad (3)$$

in which m is the mass of the escaping object, v is the velocity of the escaping object, g is the local gravitational constant and h is the altitude. Hence, the escape velocity of the comet can be calculated if its local gravitational constant is known.

The local gravitational constant at the surface of the comet can be calculated by equating Newton's law of gravitation [4] and Newton's 2nd law [5];

$$ma = \frac{GMm}{\mathrm{r}^2}, \qquad (4)$$

in which G is the gravitational constant equal to 6.67×10^{-11} $m^3kg^{-1}s^{-2}$, M is the mass of the comet, m is the mass of an astronaut, r is the distance between the centres of the two masses and approximately equal to the radius of the comet R, and a is the local gravitational constant at the surface of the comet, know as g from here on. Substituting the given values into (4) and solving for g gives a local gravitational constant of 1.4×10^{-3} ms^{-2} at the surface of the comet.

Solving equation (3) for v;

$$v = \sqrt{2gr}\,, \qquad (5)$$

and substituting g gives an escape velocity v of 3.9 ms^{-1}.

This velocity can be put into context by considering the jumping motion of a human on the surface of the earth. The second equation of motion under constant acceleration is [6];

$$v^2 = u^2 + 2as, \qquad (6)$$

in which v is the final velocity, u is the initial velocity, a is acceleration and s is displacement. Rearranging for s and substituting the escape velocity as u, v as zero (the point at which the downward acceleration has brought the human to rest instantaneously), and a as 9.81 ms^{-2}, s comes out as 0.77 m.

Conclusion

An escape velocity of 3.9 ms^{-1} is extremely low relative to those of the earth and moon which are 11.2 kms^{-1} and 2.4 kms^{-1} respectively (attained by substitution into (5)). However, the fact that the astronauts would need to jump with an initial velocity of 3.9 ms^{-1} in the vertical means that it is quite unlikely that they would drift into space while on the surface of the comet. On earth, a human jumping with an initial velocity of 3.9 ms^{-1} would attain a height of 0.77 m, and in reality, this just isn't achievable. Hence, jumping with an initial vertical velocity of 3.9 ms^{-1} while on the surface of the comet would be extremely difficult to achieve wearing an EVA suit.

It is therefore concluded that the astronauts would remain gravitationally bound to the surface of the comet, as the film Deep Impact depicts.

References

[1] *Deep Impact*, Paramount Pictures, DreamWorks, 1998.
[2] P. A. Tipler, G. Mosca, *Physics for Scientists and Engineers, 6th Edition* (W. H. Freeman and Company, New York, 2008) p424.
[3] http://hyperphysics.phy-astr.gsu.edu/hbase/vesc.html#ves (26/10/11).
[4] P. A. Tipler, G. Mosca, *Physics for Scientists and Engineers, 6th Edition* (W. H. Freeman and Company, New York, 2008) p367.
[5] P. A. Tipler, G. Mosca, *Physics for Scientists and Engineers, 6th Edition* (W. H. Freeman and Company, New York, 2008) p97.
[6] http://www.antonine-education.co.uk/Physics_AS/Module_2/Topic_1/equations_of_motion.htm (1/11/11).