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P4_4 Ping Pong to Pluto

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Abstract

This paper discusses the energy required to hit a table tennis/ping pong ball out of the Earth's atmosphere, to Pluto and back. The findings of this paper concludes that the kinetic energy needed to get the ball out of Earth's atmosphere is 169kJ and 1.98kJ for the ball to leave Pluto's atmosphere. This is compared to the kinetic energy transferred into a ping pong ball when being used normally on Earth (1.40×10^{-3}kJ).

Introduction

The inspiration for this paper comes from the idea of two people playing ping pong but one person is on Earth and the other is on Pluto. Therefore, the energies needed to play this game of ping pong are to be investigated and the drag the ball would experience when exiting each atmosphere.

Method and Results

Firstly, the escape velocities for both Earth and Pluto needed to be calculated. This was done using the equation below:

$$v = \sqrt{\frac{2GM}{r}}, \tag{1}$$

where v is the escape velocity, G is the universal gravitational constant, M is the mass of the body being escaped (5.97×10^{24}kg for Earth and 1.31×10^{22}kg for Pluto), and r is the radius of the body being escaped (6370km for Earth and 1190km for Pluto). The escape velocity for Earth was calculated as 11200ms^{-1}. As the ball would not be hit from the surface of Earth the height of the person hitting the ball could be taken into account in the value of r for calculating the escape velocity. However, due to this being such a small amount it is negligible. The escape velocity of Pluto was found to be 1210ms^{-1}. The values obtained from Eq.(1) for both Earth and Pluto were then inputted into Eq.(2) to give the kinetic energy that would be required for the ball to leave each atmosphere. This is assuming all of the energy is transferred into the ball.

$$KE = \frac{1}{2}mv^2, \tag{2}$$

The kinetic energy needed to remove a ping pong ball (of mass 2.70×10^{-3}kg [2]) from the Earth's atmosphere was found to be 169kJ, and a value of kinetic energy to escape Pluto's orbit being 1.98kJ.

To play ping pong across the solar system, drag force can be considered when the ball exits and then enters the atmosphere. This would slow the ball down. The drag force for exiting each body was calculated from the following equation:

$$F_D = \frac{1}{2}\rho v^2 C_D A, \tag{3}$$

where F_D is the drag force experienced by the ball, ρ is the density of the atmosphere, v is the velocity the ball is exiting at, C_D is the drag coefficient and A is the cross-sectional area of the ball. To calculate the drag force, a couple more values had to be researched, these were: The cross-sectional area of the ping pong ball with a radius of 20.0mm [2] and, the drag coefficient of a smooth sphere being 0.10 [3]. The drag force for exiting Earth's atmosphere was found to be 9460N.

However, to find the drag force for exiting Pluto's atmosphere, the extra information of the density of Pluto's atmosphere had to also be calculated. This was done by assuming the atmosphere was made up of an ideal gas and the ideal gas law was used:

$$P = \rho RT. \tag{4}$$

Along with the knowledge that the surface temperature of Pluto is roughly 50.0K and the pressure is 1Pa [1], the density of Pluto's atmosphere was calculated as 2.41×10^{-3}kgm^{-3}. Thus, the drag force for exiting Pluto's orbit was calculated as 0.222N.

Discussion and Conclusion

The values of kinetic energy for both leaving the Earth's atmosphere and Pluto's are, as expected, significantly larger than the kinetic energy when hitting a ping pong ball normally on Earth. For comparison the average kinetic energy transferred into a ping pong ball when being used on Earth was found to be 1.40×10^{-3}kJ (using $v = 32.2$ms^{-1} [4]). This is due to the ball needing to go at much greater speeds to be able to escape the gravitational force of the body it is on. However, due to the high temperatures and pressures the ball would experience if it actually was to enter or exit one of these atmospheres, it would inevitably be destroyed.

Future research that could be done on this is the amount the ball slows down due to the drag force it experiences as it exits each atmosphere and how this would change the velocity it enters the next bodies atmosphere at. Another point could be made about the distance between the two bodies and the path/ trajectory the ball would take as it travels from one body to another and how this would effect the ball's velocity.

In conclusion, to exit the Earth's orbit a ping pong ball would have to have roughly 121000 times the kinetic energy transferred into it when in normal use. For Pluto, it would need 1420 times the kinetic energy transferred into it when in normal use.

References

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