A5_7 A Relatively Fast Squirrel: How Much Energy?

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Abstract

In this paper we go about calculating the energy contained within a "Mach 6" energy drink from the 2006 film, "Over the Hedge". We did this by analysing the time dilation experienced by Hammy the squirrel after consuming the drink. Hammy was found to be travelling at approximately 99.983% of the speed of light, which correlated to the drink containing 9.7684×10^{17} J, or the equivalent of 2×10^{12} cans of Red Bull.

Introduction

In the animated movie "Over the Hedge", during one of the climactic scenes, the character Hammy, a hyperactive American Red Squirrel, drinks a "Mach 6" energy drink and time appears to slow down for him [1]. During this period of time dilation, Hammy accomplishes a number of tasks, allowing him to save himself and his friends. In this paper we went about calculating the energy contained within a "Mach 6" to allow Hammy to move fast enough to experience the time dilation depicted in the movie.

Method

To simplify the problem we needed to make some assumptions. Firstly, that Hammy does not interact with Earth's atmosphere whilst moving at relativistic speeds. Secondly, Hammy converts all the energy from the drink into kinetic energy. Thirdly, Hammy moves at a constant velocity throughout his journey. Finally, Hammy is able to withstand reaching relativistic speeds.

To go about calculating the energy of the "Mach 6" drink we first had to determine how fast Hammy was moving to experience the time dilation that he did. If we take Hammy's frame of reference to be frame S′ and the frame of an observer to be frame S, then the times experienced in each frame can related using Equation 1,

$$t = \frac{t'}{\left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}}} \tag{1}$$

where t is time experienced by an observer, t' is time experienced by Hammy, c is the speed of light in a vacuum and v is the velocity Hammy is travelling at. Equation 1 could then be rearranged for v to give Equation 2,

$$v = \left[c^2\left(1 - \left(\frac{t}{t'}\right)^2\right)\right] \tag{2}$$

From here we had to determine the energy stored in the "Mach 6" drink. As Hammy's kinetic energy was assumed to be equivalent to the energy stored in the drink, we could use Equation 3, the equation for relativistic kinetic energy to calculate it's value.

$$E = \frac{mc^2}{\left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}}} \qquad (3)$$

where E is the kinetic energy and m is Hammy's mass.

Results

For the calculation of v we used values of $c = 2.9979 \times 10^8$ ms^{-1}, $t = 1$ s and $t' = 55$ s. These time values were taken by timing the total screen time Hammy experiences the time dilation for and how long this time took for observers in the film scene [1]. This produced a value of $v = 2.9975 \times 10^8$ ms^{-1}, or $0.99983c$. Using this and the value $m = 0.2$ kg, the average mass of an adult American Red Squirrel [2], we calculated the relativistic kinetic energy and therefore the energy contained within a "Mach 6" drink to be $E = 9.7684 \times 10^{17}$ J.

Conclusion

To compare $E = 9.7684 \times 10^{17}$ J to the energy of other energy drinks, a 250 ml Red Bull can contains 115 kcal or 487.5×10^3 J [3] meaning that one "Mach 6" is equivalent to approximately 2×10^{12} cans of Red Bull.

Though this energy value is gargantuan, it is limited by the assumptions we made at the start of the paper. Our first assumption, that Hammy does not interact with the atmosphere, is a major simplification as his interaction with the atmosphere would cause molecules in the air to break down into an extremely hot plasma. The drag induced by this interaction would decrease his velocity, increasing the energy required to maintain Hammy's speed, and by extension the energy stored within the drink.

Our second assumption, Hammy converts 100% of the chemical energy stored in the drink into kinetic energy, which affects the total energy value needed to be contained within the drink. With an efficiency lower than 100%, the drink would need more energy than the kinetic energy Hammy needs to attain the stated velocity.

Our third assumption was that Hammy maintains a constant velocity during his journey. If true, from the S reference frame, Hammy should be seen covering a distance of 2.9975×10^8 m. The film clearly doesn't depict such travel distances meaning that Hammy likely accelerated and decelerated during his journey. Acceleration and deceleration would lead to a change in the velocity during the journey, which would greatly increase the energy needing to be contained within the drink.

Finally, our assumption that Hammy is able to withstand reaching relativistic speeds is inaccurate, such accelerations would likely prove fatal for an adult American Red Squirrel, or any lifeform for that matter.

In conclusion, the "Mach 6" energy drink presented in "Over the Hedge" contains a colossal amount of energy, however the value we calculated would be the minimum energy required to perform the feat Hammy achieves in the film.

References

[1] *Over the Hedge*. 2006. [Online] Directed by Tim Johnson and Karey Kirkpatrick. USA: Dreamworks Animation [Viewed 1 December 2020]. Available from Netflix.

[2] `https://animaldiversity.org/accounts/Tamiasciurus_hudsonicus/` [Accessed 1 December 2020]

[3] `https://www.sainsburys.co.uk/gol-ui/product/sports-energy-drinks/red-bull-energy-250ml` [Accessed 1 December 2020]