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P5_2 Causing a Mass Extinction Event with a Single Bullet

H. Clear, D. Evan, G. McGilvray, E. Turner

Department of Physics and Astronomy, University of Leicester, Leicester, LE1 7RH

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Abstract

In this paper, we explore the feasibility of using a bullet and a cannon shell to cause significant damage to the Earth, and calculated that they would need an impact velocity exceeding 99.999 919% the speed of light to do so.

Introduction

Throughout Earth's history, there have been numerous mass extinction events, many of which are accredited to high-energy impacts caused by asteroids measuring several kilometres across colliding with the Earth at speeds of over 11 km s^{-1} [1]. In this paper, we investigate how fast the world's largest bullet, and the world's largest cannon shell would have to travel in order to cause a mass extinction event, as well as the more extreme case of destroying the Earth.

Theory

The most well known extinction event caused by an asteroid impact is that of the Chicxulub impact, more commonly known as the extinction of the dinosaurs. Various estimates exist for the energy involved in this impact [2, 3], but for the purposes of this investigation we will approximate it to be 5×10^{23} J [4, 5].

As for 'Destroying the Earth', this is a somewhat ambiguous phrase, so in this investigation we assume it to mean launching all of Earth's matter on an escape trajectory away from its centre. The estimation of the energy involved then simply becomes the gravitational binding energy of the Earth (i.e. the work done in moving all of Earth's matter from infinity to its current position), approximately 1.711×10^{32} J for a variable density model [6].

For simplicity, we will assume that the energies involved in these events arise directly from the impactors' kinetic energies, and neglect the effects of the atmosphere as well as the complex dynamics of planetary collisions. We will also assume that, given the extraordinarily high energies and the relatively low mass of the impactors, Newtonian mechanics will be insufficient for analysing these scenarios. As such, we will use the relativistic equation for the kinetic energy of a particle of rest mass m_0 travelling at velocity v, given by

$$K = m_0 c^2 \left(\frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} - 1 \right) \tag{1}$$

where c is the speed of light in a vacuum [7]. Rearranging this to give velocity as a fraction of the speed of light yields the following equation.

$$\frac{v}{c} = \sqrt{1 - \left(\frac{K}{m_0 c^2} + 1 \right)^{-2}} \tag{2}$$

The most massive projectiles ever fired from a firearm are the 226.8 g solid bronze bullets used by rare 2-bore hunting rifles [8, 9], and the most massive cannon shells ever fired were the 7100 kg armour-piercing shells of the German Schwerer Gustav railway gun [10].

Results and Discussion

Substituting the impact energies and projectile rest masses into equation 2, we find that the bronze bullets would need to travel at approximately $8.31 \times 10^{-14}\%$ slower than the speed of light to have enough energy to cause a mass extinction event, and just $7.10 \times 10^{-31}\%$ slower than the speed of light to have enough energy to completely destroy the Earth. The cannon shells, having a much higher mass, only need to travel at $8.12 \times 10^{-5}\%$ and $6.95 \times 10^{-22}\%$ slower than the speed of light respectively to achieve these energies. It should also be noted that the Chicxulub impact evidently did not wipe out all life on Earth [11], meaning even greater speeds still would be needed to achieve total extinction.

Conclusion

Causing significant damage to the Earth with projectiles of this size requires them to be travelling at incredibly high fractions of the speed of light. Such a weapon would require so much energy and resources to build and operate that it becomes clearly impractical. A more realistic method would be to slightly alter the trajectories of much higher mass asteroids and minor bodies to direct them at Earth, however this would be much less immediate than a near-light-speed space cannon.

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