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A5 4 It's Raining Tiplers

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Abstract

This paper calculates the number of falling Tiplers that are required to break apart the Earth and the Moon, assuming that all the kinetic energy of the books is absorbed by the Earth and the Moon upon impact. We find that 1.98×10^{29} falling Tiplers are required to break apart the Earth, and 4.37×10^{23} falling Tiplers are required to break apart the Moon, which are many orders of magnitude greater than the number of books published, making these situations astronomically implausible.

Introduction

The undergraduate physics textbook "Physics for Scientists and Engineers with Modern Physics' by Paul A. Tipler and Gene Mosca, commonly referred to as "Tipler", has earned a notorious reputation amongst undergraduate physics students at the University of Leicester, for whom the textbook is required reading for their degree course, in part due to its cumbersome size. In this paper, we calculate the number of falling Tiplers that are required to break apart the Earth and the Moon, if we assume that all the kinetic energy of the books is absorbed by the Earth and the Moon upon impact.

Breaking apart the Earth

The eBay product listing for the hardback sixth edition of Tipler gives its weight as 3604 g, its height as 285 mm, and its width as 239 mm. Using this information, we calculate the mass m_T of Tipler to be equal to 3.604 kg and the area of the front face A_T of Tipler to be equal to $0.285 \times 0.239 = 0.068115$ m^2 [1]. The terminal velocity v_T of Tipler can be calculated using the equation:

$$v_T = \sqrt{\frac{2mg}{\rho_a A_T C_d}} \tag{1}$$

where the gravitational acceleration $g = 9.81$ m s^{-2}, the density of air $\rho_a = 1.293$ kg m^{-3} [2], and, if we model Tipler as a rectangular flat plate falling perpendicular to the air flow, the drag coefficient $C_d = 1.28$ [3]. Substituting these values into Equation 1, we calculate the terminal velocity of Tipler to be 25.04 m s^{-1}. We can use the calculated terminal velocity value to calculate the energy K_T of a falling Tipler using the kinetic energy equation:

$$U_T = K_T = 0.5 m_T v_T^2 \tag{2}$$

Substituting the values of the mass and terminal velocities into Equation 2, we calculate the kinetic energy of a Tipler falling at terminal velocity to be equal to 1130 J. The equation for the gravitational binding energy U_B for a spherical body of uniform density is given by the equation:

$$U_B = -\frac{3GM^2}{5R} \tag{3}$$

If we model the Earth as a spherical body of uniform density, then by substituting the gravitational constant $G = 6.673 \times 10^{-11}$ N m^2 kg^{-2} the mass of Earth $M_E = 5.972 \times 10^{24}$ kg, and the radius of Earth $R_E = 6.370 \times 10^6$ m into Equation 3, we calculate the gravitational binding energy of Earth to be equal to 2.24×10^{32} J. This means that 2.24×10^{32} J of energy needs to be transferred to the Earth to break it apart. If we assume that all the kinetic energy from a Tipler falling at terminal velocity is transferred to the Earth upon impact, the number of Tiplers required to break apart the Earth n_T can be calculated using the equation:

$$n_T = \frac{U_B}{U_T} \tag{4}$$

which gives a value of $n_T = 1.98 \times 10^{29}$ Tiplers.

Breaking apart the Moon

We now calculate the number of Tiplers required to break apart the Moon. The Moon has no atmosphere, so the Tiplers do not reach terminal velocity. We assume that the Tiplers are dropped at rest from the altitude of the Earth-Moon L1 Lagrange point at $r = 6.135 \times 10^7$ m, with their gravitational potential energy turning into kinetic energy as they accelerate down towards the Moon. We can calculate the energy of a Tipler falling towards the Moon using the equation for gravitational potential energy U_T in a nonuniform field:

$$U_T = \frac{GM_M m_T}{r} \tag{5}$$

where the mass of the Moon $M_M = 7.436 \times 10^{22}$ kg [4]. Calculating U using Equation 3 gives a value of 2.915×10^5 J. We can then calculate the gravitational binding energy of the Moon U_M using Equation 3 as being equal to 1.2745×10^{29} J, with the radius of the Moon $R_M = 1.737 \times 10^6$ m [4]. Substituting these values into Equation 4, we can calculate that 4.37×10^{23} falling Tiplers are required to break apart the Moon.

Conclusion

We have calculated that 1.98×10^{29} falling Tiplers are required to break apart the Earth, and 4.38×10^{23} falling Tiplers are required to break apart the Moon. Both these numbers are incredibly large, many orders of magnitude greater than the estimated number of published books, which in 2010 was estimated as being 1.30×10^7 [5]. In addition, the total mass of the Tiplers required to break apart Earth adds up to $m_T n_T = 7.14 \times 10^{29}$ kg, which is 120 thousand times the mass of the Earth and 36% of the mass of the Sun, and the total mass of the Tiplers required to break apart the Moon adds up to $m_T n_T = 1.58 \times 10^{24}$ kg, which is 21 times the mass of the Moon and 26% the mass of the Earth, making these situations astronomically implausible as entire planets' worth of Tiplers would be required to destroy the Earth and/or the Moon.

References

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