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A6_3 It's a Flat World!

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Abstract

Lorentz-FitzGerald Contraction occurs when a moving object is measured to be shorter than its proper length from the reference frame of a stationary observer. The aim of this paper was to determine the minimum velocity required to perceive the Earth as being flat. With the use of Lorentz transformations, a minimum velocity greater than 0.99 times the speed of light was obtained, assuming the observed width of the Earth was 40 km (the thickness of its crust).

Introduction

When two objects approach each other at a combined velocity which is a fraction of the speed of light, the length of Object A measured from the reference frame of Object B is shorter than the length of Object A measured from its own reference frame (also known as the Proper Length), and vice versa. This phenomenon is known as Lorentz-FitzGerald Contraction, and was postulated in the late 19th century by physicists Hendrik Lorentz and George FitzGerald to explain the results of the 1887 Michelson-Morley experiment [1]. The experiment unexpectedly measured the speed of light to be constant throughout, and would eventually disprove the "Aether Wind" theory. In 1905, Einstein published his theory of Special Relativity which ultimately linked length contraction to time dilation (as the speed of light is a constant) [2]. Although it has been known since the classical era (circa 6th Century BC) [3] that the Earth is an oblate spheroid, the theory for a flat Earth is still in existence [4]. The purpose of this paper is, therefore, to determine how fast an astronaut would have to travel in order to view the Earth as being flat using the theory of Lorentz transformations in relativity. Newton's Law of gravity is also used to determine the approaching speed of the Earth.

Theory

To improve the accuracy of the required velocity, the approaching velocity of the Earth will first be calculated. This can be calculated using the following equation (derived from Newton's law of Gravity)[5]:

$$v_e^2 = (GM_S)/r \tag{1}$$

where v_e is the Earth's orbital velocity, $G = 6.67 \times 10^{-11}\ \mathrm{N\,m^2\,kg^{-2}}$ (gravitational constant), M_S is the mass of the Sun (1.989×10^{30} kg)[6], and r is the distance between the Sun and the Earth (mean distance of 15×10^{10} m) [7]. This results in a velocity of $2.97 \times 10^4\ \mathrm{m\,s^{-1}}$. As this is a radial velocity, it is assumed that this velocity is taken to be along the same axis as the approaching astronaut. The length contraction is calculated via the Lorentz transformation equations, one of which is shown below [5]:

$$x'_2 - x'_1 = \gamma(x_2 - x_1) \tag{2}$$

The points x'_1 and x'_2 represent the length of the Earth in its own reference frame, and can be rewritten as L_P, which is the proper length. Points x_1 and x_2 represent the length of the Earth as perceived in the approaching astronaut's reference frame, and can be represented as length L. γ is the Lorentz-Factor which is given by [5]:

$$\gamma = 1/[1 - (v^2/c^2)]^{1/2} \quad (3)$$

where c is the speed of light (taken to be 3×10^8 m s^{-1}) and v is the velocity of the astronaut as measured from Earth's reference frame, also known as the relative velocity. Inserting Eq. (2) into Eq. (3) the latter can be rearranged to make relative velocity v the subject, which gives:

$$v^2 = c^2[1 - (L/L_P)^2] \quad (4)$$

In this case $L_P = 12742000$ m (Earth's diameter) [8] and for Earth to be observed flat, $L = 40000$ m (average thickness of Earth's crust) [9]. This provides a combined velocity of 299998521.8 m s^{-1}. To calculate the minimum velocity for the astronaut, the Einstein addition rule is used. The equation has been rearranged to make v_a, the astronaut's velocity, the subject [5]:

$$v_a = (v - v_e)/(1 - vv_e/c^2) \quad (5)$$

As calculated before, v_e is the Earth's velocity (2.97×10^4 m s^{-1}), which makes v_a = 299998521.5 m s^{-1}, or greater than 0.99 c.

Conclusion

In conclusion, using the concept of Lorentz-FitzGerald contraction in special relativity, it is determined that an astronaut would have to travel greater than 0.99 times the speed of light in order to observe the Earth as flat within their own reference frame, assuming the Earth is considered "flat" when its thickness 40 km (the average thickness of its crust).

References

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