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A2 4 Welcome to the World of Tomorrow!

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Abstract

The following paper imagines a rocket capable of transporting its passengers to the year 3000 in a time span of only 10 years from the perspective of its passengers. Using some generous assumptions, we found that the rocket would need to burn 75,000,000 tons of fuel.

Introduction

Life in 2025 can be difficult. With the growing desire to escape the humdrum and struggles of daily life, the idea of time travel continues to capture the human imagination. Although journeys to the past remain controversial among many physicists, with many dismissing it as impossible, special relativity suggests that time travel to the future is achievable via time dilation.

For this paper, we evaluate the plausibility of using a relativistic rocket to travel to the year 3000 in a time frame of 10 years (for a passenger on the rocket ship).

Theory

In this paper, we are assuming that the rocket orbits the Earth at a far enough distance such that gravity from Earth and its other satellites are negligible. This rocket is composed of a module where the passenger (or passengers) will live during the travel time and the rocket fuel composing the rest of the rocket ship. We have assumed that the module (M_f) is equivalent to the mass of the International Space Station (420 tons) [1]. We will also generously assume that the rocket reaches its velocity instantaneously. According to Hobson, M. P. et al. (2006) [2], time dilation can be described by the following formula:

$$t = \frac{t'}{[1 - \frac{v^2}{c^2}]^{\frac{1}{2}}}. \quad (1)$$

Where t will be the time in the Earth's frame of reference, t' will be the time in the passenger's frame, and v is the velocity of the rocket. Due to the relativistic nature of this scenario, we unfortunately can't describe the rocket using the Tsiolkovsky rocket equation [3]:

$$v = u \ln\left(\frac{M_i}{M_f}\right). \quad (2)$$

Where u is the exhaust velocity and $\frac{M_i}{M_f}$ is the ratio of the initial mass of the rocket to the final mass of the rocket. Instead, it is necessary to make relativistic corrections to Equation (2). For this paper, we used a relativistic equation derived by [4]:

$$\frac{M_i}{M_f} = \left(\frac{1 + \frac{v}{c}}{1 - \frac{v}{c}}\right)^{\frac{c}{2u}}. \quad (3)$$

According to [4], the maximum exhaust velocity for a relativistic rocket was derived as follows:

$$u_{max} = c[e(2 - e)]^{\frac{1}{2}}, \quad (4)$$

where e is the fraction of mass converted into kinetic energy. From now on, $u = u_{max}$ and e is assumed to be 0.1.

Calculations

In order to travel to the year 3000 from the current year of 2025, time t will become 975 years and t' will have to be 10 years. We can rearrange Equation (1) to find the rocket velocity v:

$$v = c\sqrt{1 - \frac{t'^2}{t^2}}. \qquad (5)$$

From Equation (5), we find $v = 0.999947$ c. By using Equation (4) and setting $e = 0.1$, we find $u_{max} = 0.436c$. Using u_{max}, v, and the relativistic rocket (3), we can then obtain a value for the ratio $\frac{M_i}{M_f}$. The ratio was found to be $179,000$. We then used this ratio to determine $M_i = 75,000,000$ tons.

Since $M_f << M_i$, $M_i \approx M_{fuel}$. Thus, from Equation (3), we found that the rocket would need to have a fuel mass M_{fuel} of 75,000,000 tons.

Discussion

The aim of the paper was to determine properties of a relativistic rocket. In the theory section, we mentioned that the usual equation for a rocket (the Tsiolkovsky equation) would not be applicable to a relativistic rocket. By referring to Figure 1, it should be clear that Equation (2) and Equation (3) closely match each other for $v/c < 0.5$. However, at higher v/c the two equations diverge significantly as $v/c \to 1$.

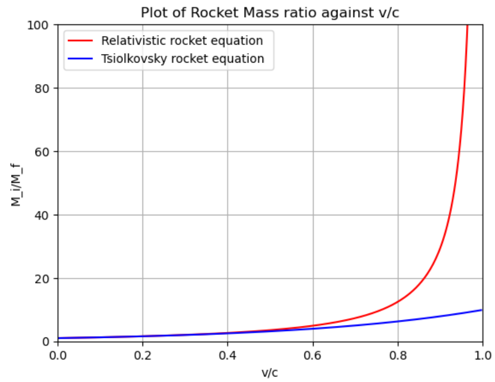

Figure 1: Plot of Equation (2) and Equation (3), where $u_{max} = 0.436$ c.

At $v/c = 0.999947$, Equation (2) would give a value of 9.80 for the mass ratio. This is around 8 million times less than the mass ratio for the relativistic equation.

It is also important to note that the answer is likely a lower-bound estimate for the $\frac{M_i}{M_f}$. This is due to the fact that we had used the maximum possible exhaust velocity u_{max} in our calculations.

Furthermore, we have also assumed that the rocket reaches its velocity instantaneously. This is a highly generous assumption and may not be applicable to real life.

Conclusion

In summary, we have determined that it is possible to travel to the year 3000 using a relativistic rocket (at least theoretically). While we found that $75,000,000$ tons would be sufficient to allow time travel to the year 3000, we caution that these are likely lower-bound estimates (see discussion).

References

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