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P1_3 Sort It Out, Scotty!

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Abstract

In this paper, we calculated a length contraction of 290 m (2 s.f) to 250 m (2 s.f) and a time dilation of 4000 s (2 s.f) to 4600 s (2 s.f) for the starship, the USS Enterprise (NCC-1701). The starship is from the original 1960s Star Trek series and modelled to be travelling at half the speed of light from Jupiter back to Earth. The observer is standing on Mars and is watching the starship moving towards Earth for repairs.

Introduction

Due to a catastrophic failure in the warp drive the USS-Enterprise (NCC-1701) is currently travelling back to Earth with a fraction of its speed capabilities. In this paper we explore the affects the Enterprise's speed will have when observed from Mars as it travels to Earth for repairs.

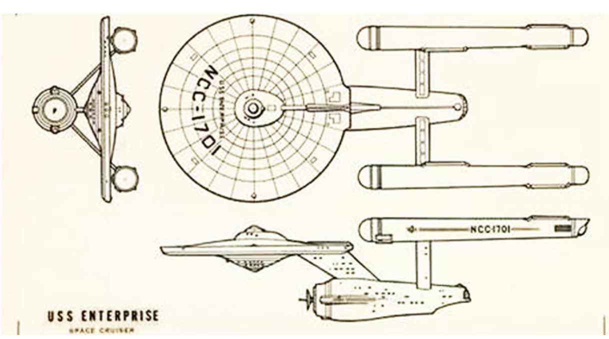

Figure 1: Schematic of the starship, the USS Enterprise, as seen in the original 1960's series, Star Trek [1].

Albert Einstein first published his Special Theory of Relativity in 1905, providing an explanation of how speed affects mass, time and space. We expect the star ship to behave accordingly to this theory and experience length contraction and time dilation as it travels towards Earth.

Theory

Length contraction is the phenomenon in which the length of a moving object (l') is shorter than the proper length (l). The difference between the contracted length and the proper length can be calculated using the Lorentz Transformations. The length of the object is at maximum in the frame where the object is at rest [2]. The length contraction can be calculated using,

$$l' = l\sqrt{1 - (v^2/c^2)} \tag{1}$$

Time dilation occurs when there is a difference in experienced time between one observer and another based on their relative motion [3]. At high speeds, time experienced by the observer appears to move faster than experienced by the party in motion. The "speeding up" of the time experienced by the observer is a relativistic effect.

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

Where v is the speed of the party in motion, and c is the speed of light, 3.0 x 10^8 m/s (2 s.f), for Equation 1 and 2.

In this paper we assume the USS-Enterprise is travelling at half the speed of light, 1.5 x 10^8 m/s (2 s.f). The length of the USS-Enterprise is 290 m (2 s.f) [4].

Results

Substituting a rest length value of 290 m and a velocity of 1.5 x 10^8 m/s into Equation 1 yields a length measured by the observer of 250 m. To find the corresponding time dilation value we first needed to find a value for the proper time, the time as measured by the ship. By taking the distance between Earth and Jupiter to be 590 million km (2 s.f) [5] and dividing this by the ship's velocity of 0.5 c we calculated a travel time of 4000 s (2 s.f). Substituting this value and the ship's velocity into Equation 2 yields a time experienced by the observer of 4600 s (2 s.f) or around 77 minutes (2 s.f).

Discussion

As expected the USS-Enterprise appears to contract in length from the point of view of the Martian observer as it travels towards Earth. This will affect the calculations needed to successfully complete manoeuvres such as docking secondary vehicles with the Enterprise. Our calculations show the crew experience time slower than for the observer. This has implications for the practicality of space travel as, while the journey may pass in a matter of minutes for the crew of the Enterprise, for their loved ones and colleagues on Earth the time dilation effects will add up causing them to age days or years faster than the crew, depending on the length of the journey.

Conclusion

In this investigation, we found that the length contracted from a rest length of 290 m to 250 m. This would need to be taken into account when vehicles outside of the reference frame wish to dock with the Enterprise. The time was shown to dilate from 4000 s (2 s.f) in the ship's frame of reference to 4600 s (2 s.f) in the observer's. This demonstrates that the faster an object moves the slower time passes in it's reference frame. This tells us the crew of the Enterprise will age slower relative to their Earthly counterparts. Extended time spent travelling in space may start to cause significant age discrepancies between crew members and their loved ones which could discourage potential applicants from joining Starfleet.

References

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[4] Robinson, B., Riley, M. and Okuda, M., 2010. USS Enterprise Owners Manual. [Accessed 7th October 2022]

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