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P4_6 Horses make the world go round

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Abstract

The aim of this paper was to determine the feasibility of some factors of the Helios mythology, and to find the force that would be required to accelerate Earth from rest to its current angular velocity. We found that the force required to achieve this in a single day, is 1.39×10^{22} N which is extremely large considering Helios is only using four winged horses. This combined with there being no practical way to apply this force to the Earth, led to us concluding that it was not feasible.

Introduction

In ancient Greek mythology it was believed that the god Helios would cause the Sun to rise and set by pulling the Sun from east to west every day with a chariot drawn by winged horses [1]. Of course, there are a range of fairly obvious scientific inaccuracies here.

Firstly, the rising and setting of the Sun is the result of the Earth's rotation around its own axis. Hence if there was a mythological individual causing the day and night cycle, they would be causing the rotation of the Earth and not the movement of the Sun. This begs the question, if the Earth's rotation was caused by Helios what sort of forces would be involved?

Theory

For the purposes of this paper, we will make a number of assumptions. The first being that initially the Earth has no initial rotational velocity around its axis and hence the day and night cycle is caused entirely by Helios. The second being that the Earth is a uniform solid sphere. The third being that through his mythological nature, any pull created by Helios' chariot will work entirely as torque on the Earth. The fourth and final being that any friction forces between the Earth and any materials in space is ignored.

To start the calculations, we must find the moment of inertia of the Earth. As the Earth is being treated as a solid sphere the equation for moment of inertia is,

$$I = \frac{2}{5}MR^2, \tag{1}$$

where M is the mass of the Earth, 5.9722×10^{24} kg and R is the volumetric mean radius of the Earth, 6371 km [2].

This gives a moment of inertia for the Earth of 9.70×10^{37} kgm^2, which can be used in the equation,

$$\tau = I\alpha, \tag{2}$$

with α, being the angular acceleration of Earth, to find the required torque.

Assuming that the time taken for the acceleration is 24 h or 86400 s we can find the angular acceleration using the angular velocity of Earth, 7.9221×10^{-5} rad/s. This gives an angular acceleration of 9.17×10^{-10} rad/s^2. Substituting our values into equation (2) produces a torque of 8.89×10^{28} Nm. An alternate equation for torque is

$$\tau = rF \sin \theta. \tag{3}$$

where r is the position vector of the applied force, F is the force is applied and θ is the angle of the vector applied. Assuming that the force is applied tangentially, and that r is the Earth's radius, 6.38×10^{6} m, the force given is 1.39×10^{22} N.

Results and Discussion

Typical depictions of Helios tend to show his chariot being pulled by 4 winged horses. This would mean each winged horse produces around 3.48×10^{21} N of force or 2.22×10^{28} Nm of torque.

Figure 1: This is a depiction of Helios and his chariot being pulled from the 5th century BC [1].

Now that we have a result it may be useful to check the validity of our assumptions. To test the solid sphere model our moment of inertia factor, $\frac{2}{5}$ can be compared to the actual value of 0.3307 [4]. This means our calculated moment of inertia should be approximately 20.96 % higher than the actual value. Hence the true force requirements would be lower.

However, the real issue is that there would be no realistic way to take the force from the chariot and apply it to the Earth's rotation.

Conclusion

We made use of a solid sphere model to find approximate values for the Earth's moment of inertia, 9.70×10^{37} kgm^2, and the force required to rotate a stationary Earth to its current rotational velocity in 24 hours, 1.39×10^{22} N. While these values are approximately 20.96 % higher than the true values, even with this considered the required output of each of the 4 winged horses is still absurdly high.

This could be accounted for by increasing the acceleration time. However, this would not rectify the issues with applying the force without any way of providing propulsion. As such, even after changing some of the key points of the myths of Helios to improve accuracy. It can be concluded that it would not be possible to cause the Earth to rotate using this method.

References

[1] `https://www.theoi.com/Titan/Helios.html` [Accessed 1 November 2022]

[2] `https://nssdc.gsfc.nasa.gov/planetary/factsheet/earthfact.html` [Accessed 1 November 2022]

[3] `https://www.universetoday.com/89406/angular-velocity-of-earth/` [Accessed 1 November 2022]

[4] `https://en.wikipedia.org/wiki/Moment_of_inertia_factor` [Accessed 1 November 2022]