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P1_1 Resting On The Shoulders Of Giants

S. Davis, P. Relton, A. Ramsden, C. Clark

Department of Physics and Astronomy, University of Leicester, Leicester, LE1 7RH

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Abstract

This paper investigates the concept of a 'World Turtle' as imagined in Terry Pratchett's Discworld series. The giant astronomical elephants which stand upon the turtle's shell support the Discworld. By assuming that the elephants have the same anatomy as terrestrial elephants, the dimensions of these animals is found. Each of the elephants would have to be $3.6 \times 10^6 m$ tall to be able to support the mass of the disk. It was also found that the size of the elephants to support a model based on 'Flat Earth theory' would be $6.7 \times 10^6 m$ tall. A relationship between the radius of a disk and the height of the elephant was also found.

Introduction

The concept of a 'World Turtle' goes back to ancient Hindu and Native American mythology, but more recently popularised in the Terry Pratchett book series 'Discworld'. The belief was that the Earth is a flat disk resting on the back of four huge elephants, all of which are standing on the shell of an even larger turtle as it swims through space.

Theory

We modelled two different disks carried by the four elephants. The first is the disk as described in the Terry Pratchett novels: a disk with a diameter of 10,000 miles ($1.6 \times 10^7 m$) [2]. The second model that we investigated uses a disk as described by the concept of a 'Flat Earth': a disk with a diameter of 24,900 miles ($4.0 \times 10^7 m$) [1]. By assuming that the disk can be modelled as a shallow cylinder, the total volumes were calculated using Eq. 1:

$$V = \pi r^2 h \quad (1)$$

where V is the volume, r is the radius of the disk, and h is the depth. It can be assumed that both disks have the same proportions as the Earth's crust. As oceanic and continental crusts have a different depths, they have different values for h . So an average depth was calculated. The calculated volumes were converted to masses using Eq. 2:

$$M = \rho V \quad (2)$$

where M is the mass of the disk, ρ is the average density of the Earth's crust ($2700 kg m^{-3}$) and V is the total volume of the disk.

An adult African elephant can carry 25% of its own weight on its back [6]. As there are four elephants this means that for them to carry the disk between them, each of the elephants would have the same mass as the disk. On average, terrestrial elephants grow up to 4.0m tall and weight up to 6000kg [5].

For both of the disks it is assumed that 60% of the crust is oceanic which is approximately 10km thick and 40% is continental crust which is approximately 40km thick, just as it is on the Earth

[3]. This means that the actual total volume of each of the disks is given by Eq. 3:

$$V_T = V_O + V_C \quad (3)$$

In this equation, V_T is the total volume of the disk, V_O is the portion of that volume consisting of the oceanic crust, and V_C is the proportion of the volume consisting of continental crust. Eq. 3 can be simplified to give Eq. 4 by calculating each of the volumes independently and combining them, which eventually simplifies down to Eq. 4. These values were found by using the values of their typical thickness and multiplying it by a factor of 0.6 and 0.4 respectively:

$$V_T = 0.6 \times 10,000\pi r^2 + 0.4 \times 40,000\pi r^2 \quad (4)$$

$$= 6,000\pi r^2 + 16,000\pi r^2 = 22000\pi r^2 \quad (5)$$

where r is the radius of the disk.

Using this relation, Eq. 2 can be adapted to give the mass of the disk related to the radius of the disk, as shown in Eq. 6:

$$M = \rho V = 2700V = 5.94 \times 10^7 \pi r^2 \quad (6)$$

here M is the total mass of the disk, ρ is the average density of the crust (2700kgm^{-3}) [4] and r is the radius of the disk.

Assuming that an elephant is roughly cubic and its density is roughly the same as a human (therefore the same as water, 1000kgm^{-3}), Eq. 7 shows the general relationship between the height of each elephant and the radius supported disk.

$$h = \left(\frac{M}{\rho_w}\right)^{\frac{1}{3}} = \left(\frac{5.94 \times 10^7 \pi}{\rho_w}\right)^{\frac{1}{3}} r^{\frac{2}{3}} \quad (7)$$

Results

Discworld: Using a diameter of $1.6 \times 10^7\text{m}$ for the disk and Eq. 6, we found that the disk would have a theoretical mass of $4.8 \times 10^{22}\text{kg}$.

Using Eq. 7 the height of each elephant supporting the Discworld was calculated as $3.6 \times 10^6\text{m}$.

A Flat Earth: Using a diameter of $4.0 \times 10^7\text{m}$ for the disk and Eq. 6, we calculated that the

mass of disk would be $3.0 \times 10^{23}\text{kg}$. Using Eq. 7 the height of each elephant supporting a flat Earth was calculated as $6.7 \times 10^6\text{m}$.

By using this scale four terrestrial African elephants of height 4.0m would be able to support a disk of diameter 0.019m with the same thickness and density of crust.

Conclusion

In conclusion we have calculated that the heights of each of the Discworld and flat Earth's elephants would have to have heights of $3.6 \times 10^6\text{m}$ and $6.7 \times 10^6\text{m}$ respectively. Considering these values it can be surmised that artists impressions of these worlds are plausible.

To improve these results fewer assumptions could be made by investigating a direct relation for mass to the height of an elephant. Another method of reducing the error is to investigate the precise weight that elephants can carry by including the changes in bone strength as the elephants change in size. This method could investigate how the weight affects each bone and joint as the elephant supports the load.

References

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