Journal of Physics Special Topics

P1_10 Moving the Earth

Matthew James, Sarah Botterill, Emma Comber, Daniel Spence

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

February 6, 2011

Abstract
Conservation of linear and angular momentum is used in this article to discuss whether human strength and power alone can move the Earth. It is found that the difference in mass between humans and the planet is far too large to have a significant effect.

Introduction

This article discusses whether the entire population of people is actually powerful enough to physically, and momentarily displace the Earth by the means of transferring momentum. It must be mentioned that the Earth and the people lie in a closed system where any displacement or alteration to the Earth's rotation can only be temporary.

Jumping

One way in which it might be possible to move the Earth using the strength of the entire population would be to place everyone in the same area and have them jump at the same time. This would give the people momentum away from the Earth which would be equal to the momentum of the Earth away from the people,

$$M_E v = N m_H u \qquad (1)$$

where v is the velocity of the Earth away from its original position, u is the average velocity of each person as they jump, M_E is the Earth's mass ($5.97\text{x}10^{24}$ kg [1]), N is the population (6,902,887,287 as of 03/01/2011 [2]) and m_H is the average human mass which will be assumed as 70kg for the purpose of this article.

Assuming that air resistance plays a negligible part, everybody has the same mass and jumps to the same height, the magnitude of u can be considered equivalent to the velocity which an object would reach when falling from a height h when it accelerates due to gravity, so

$$u^2 = 2gh \qquad (2)$$

where h is the height at which the average person can jump [3] (assumed to be 0.5m in this case) and g=9.8ms^{-2} [1].

The Earth can then be assumed to move in a similar manner in the opposite direction so that

$$v^2 = 2gs \qquad (3)$$

where s is the distance which Earth moves.

By substituting equations (2) and (3) into (1), s can be found as

$$s = \left(\frac{N m_H}{M_E}\right)^2 h \qquad (4)$$

which yields a result of $3.28\text{x}10^{-27}$m.

Running

Another possible way to move the Earth using human power would be for everyone to run along the equator. This would transfer a small amount of angular momentum from each person to the Earth thus altering the rate of rotation.

Angular momentum is expressed by

$$L = I\omega \qquad (5)$$

where L is the angular momentum [4], ω is the angular velocity and I is the moment of inertia expressed by

$$I = \sum m_i r_i^2 \quad (6)$$

for a system of *i* particles [5].

If the reference frame is considered where Earth and the population are stationary, the initial angular momentum L_I would be zero which, as momentum has to be conserved, would be equal to the total momentum when the people start running, L_F, so

$$L_I = L_F = L_E + L_H = 0 \quad (7)$$

where L_H is the Human component of angular momentum and L_E is Earths component of angular momentum.

Using equations (5), (6), and (7) we find that

$$\omega_H I_H = -\omega_E I_E \quad (8)$$

where

$$I_E = \frac{2}{5} M_E R_E^2 \quad (9)$$

if Earth is considered as a uniform sphere [6],

$$I_H = N m_H R_E^2 \quad (10)$$

and

$$\omega_H = \frac{u}{R_E} \quad (11)$$

where u, in this case, is the speed at which people run(assumed as $10ms^{-1}$), so

$$\omega_E = -\frac{5}{2}\frac{N m_H u}{M_E R_E} \quad (12)$$

where R_E is the Earth's radius (6371km [1]). If we now consider the rotating Earth, the new angular velocity would be expressed as

$$\Omega_F = \Omega_I \pm |\omega_E| \quad (13)$$

where Ω_I is the initial angular velocity of Earth(Earth rotates through 2π radians in 23h56m [7] = $7.29\text{x}10^{-5}$ rad s^{-1}, equivalent to one sidereal day).

Ω_F has two values which correspond to the direction in which the population run along the equator. If the population ran eastwards along the equator, the Earth's rotation would slow, while the opposite would be true if running westwards.

Substituting values into equation (11) gives the extra angular velocity of Earth as $3.18\text{x}10^{-19}$rad s^{-1}. This means that there would be one extra or one less rotation of the Earth every $6.29\text{x}10^{11}$ years depending on the direction which everybody runs along the equator.

Conclusion

If the entire human population was to jump on the same spot, or to run in the same direction along the equator, the Earth's motion would be affected by the transfer of momentum. The effect that both of these actions have would be minute in comparison to the scale of the Earth and its rotation rate.

This shows that human strength alone cannot actually move the Earth significantly as a whole due to the large differences in scale and the fact that, in the jumping case, the Earth would return to its original position as soon as everybody lands and in the running case, the Earth would resume its original rotation rate once the population stops running.

References

[1]http://nssdc.gsfc.nasa.gov/planetary/factsheet/jupiterfact.html(06/04/2011)
[2]http://www.census.gov/ipc/www/popclockworld.html (06/02/2011)
[3] P.A.Tipler, G.Mosca, *Physics For Scientists and Engineers,*(2007), p.39
[4] as [3] p.309
[5] as [3] p.293
[6] as [3] p.295
[7] Rene R.J.Rohr, *Sundials History, Theory and Practice*,(1996), p. 24