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## A5_3 Sliding in Space

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**Abstract**

This paper is based on a thought experiment in which a perfectly rigid slide with zero friction connects the surface of the Moon to the surface of the Earth at the closest points. By using Newton's Law of Gravity and programming in R, as well as modelling the Earth and Moon as two stationary points in space, we calculated the time it would take for a person launched from a cannon on the Moon to reach the Earth. The time was calculated to be 92 hours.

### Introduction

Ever since men took their first steps on the Moon in 1969 [1], colonising the Moon has been an area of strong interest in the world of science. The time taken to slide from the Moon to the Earth has been investigated based on a hypothetical scenario where people travel from the Moon to the Earth by being launched onto a slide that would force them to move on a certain path to prevent them entering into an orbit. This would effectively cause the person to slide from the Moon to the Earth.

### Theory and Results

To simplify this scenario, the Moon and the Earth have been modelled as two stationary points, and we have made the assumption that there is no air resistance or friction acting against the person when travelling down the slide. The initial step was to find the distance between the Earth and the Moon, $r_g$, at which the net gravitational force was zero with respect to the centre of the Moon. This was done using Eq. (1) [2], equating the gravitational forces from the Moon and the Earth as shown in Eq. (2): $G = 6.67$ x $10^{-11}$ $\mathrm{m^3\ kg^{-1} s^{-2}}$ (the universal gravitational constant), $M_m = 7.35$ x $10^{22}$ kg (the mass of the Moon), $M_e = 5.97$ x $10^{24}$ kg (the mass of the Earth), $m = 60$ kg (the mass of the person) [2] and $r_e$ being the distance from the surface of the Earth to the point at which net gravitational force is zero.

$$F = \frac{GMm}{r^2} \tag{1}$$

$$\frac{GM_m m}{r_g^2} = \frac{GM_e m}{r_e^2} \tag{2}$$

$$\frac{r_e^2}{r_g^2} = \frac{M_e}{M_m} \tag{3}$$

$$r_e + r_g = R_{total} \tag{4}$$

Rearranging Eq.(2) for Eq.(3) and substituting in $r_e$ from Eq.(4), where $R_{total} = 384400$ km is the distance between the centre of the Earth and centre of the Moon, resulted with a value of $r_g = 3.8$ x $10^7$ m, as measured from the centre of the Moon. This value is required in order to calculate the minimum velocity needed to get from the Moon's surface to the point at which no gravity is acting on the person.

The difference in potential energy between the surface of the Moon and $r_g$ was calculated using Eq. (5), where $r$ is a radius. The energy required to travel from the Moon's surface, $r = 1737$ km to $r = r_g$ was calculated to be 162000 kJ.

$$U = \frac{-GM_m m}{r} \tag{5}$$

The kinetic energy equation, Eq. (6), was then used to calculate the minimum initial velocity, where $v$ is velocity, which came to be 2320 $\mathrm{ms}^{-1}$.

$$E = \frac{1}{2}mv^2 \tag{6}$$

To calculate the time taken for the person to travel from the surface of the Moon to the surface of the Earth, the acceleration was required. To find the duration of the journey Eq. (7) would be integrated and rearranged for $t$;

$$\frac{dv}{dt} = \frac{-GM_e}{R^2} + \frac{GM_m}{(R_{total} - R)^2} = a \tag{7}$$

where $R$ is the distance of the person from the Moon and $a$ is the acceleration of the person.

As the values of both $r$ and $a$ change with respect to time, the integral became too complex to solve. As a result, computational methods in R were used to plot graphical representations of the scenario (see Figure 1).

Figure 1 therefore shows the total travel time down the slide to be roughly 92 hours.

## Analysuis and Conclusion

Despite this thought experiment not being possible to physically conduct as producing a frictionless slide between the Earth and Moon is impossible, the total travel time of 92 hours seems plausible. This is based on the time taken for the Apollo 11 crew to reach the Moon's orbit: approximately 76 hours [4].

To take this experiment further and acquire more accurate results, the integral of Eq. (7) could be solved mathematically rather than calculated computationally. This would improve

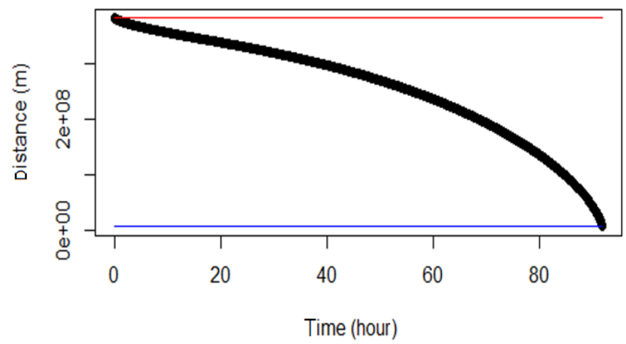


Figure 1: Graph of the relationship between the person's distance from the Earth and their travel time. The red and blue lines are the location of the Moons and Earths surface respectively.

accuracy as the computer model only applies deceleration every 5 seconds which would result in a lower velocity change than expected during acceleration and deceleration, meaning a higher initial velocity would need to be used to give the same journey time of 92 hours. The spins and orbits of the Moon and the Earth could also be accounted for, and therefore have more forces involved such as the Coriolis effect [5] and friction, which would change the initial velocity needed and alter the time taken to reach the Earth.

## References


[1] Tipler, P. and Mosca, G. *Physics for Scientists and Engineers* 6th ed, (2007)

[2] `https://nssdc.gsfc.nasa.gov/planetary/factsheet/moonfact.html` [Accessed 12 October 2017]

[3] `http://www.nasa.gov/audience/forstudents/k-4/stories/first-person-on-moon.html` [Accessed 2 November 2017]

[4] `https://www.space.com/18145-how-far-is-the-moon.html/` [Accessed 12 October 2017]

[5] `https://www.nationalgeographic.org/encyclopedia/coriolis-effect/` [Accessed 12 October 2017]