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P1_6 Moon Shoes on the Moon

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Abstract

Moon shoes are a children's toy described as 'mini trampolines for your feet'. By assuming that the rubber bands in these shoes obey Hooke's law, we have investigated how these shoes would work when used on the moon and compared this to how they work on Earth. We found that if the bands were stretched by just 0.04m, an astronaut on the moon could bounce up to 14.7m.

Introduction

Moon shoes are hollow cuboids of rigid plastic, with rubber bands stretched across one of the long sides. By strapping your own shoes to the moon shoes, you should theoretically be able to bounce higher than you can jump. By assuming that the rubber band obeys Hooke's law when it is stretched (this validity of this is discussed in the results section), we used this relation and Young's modulus to find the potential energy stored in each rubber band when it is stretched. By converting this elastic potential energy to gravitational potential energy, we found the height of a single bounce using the moon shoes.

Method

We assumed that the rubber band stretched across the moon shoe consists of one wide strip of rubber. The average male shoe size in the US is 10.5 [1] which is equivalent to 0.273m long and 0.11m wide [2]. In order to accommodate the bulky spacesuit boots that the astronauts were wearing, we assumed each rubber strip was 0.3m long and 0.12m wide. Young's modulus gives the ratio of the stress applied to a material, and the strain it undergoes due to this pressure:

$$Y = \frac{stress}{strain} = \frac{Fx}{A\Delta x} \tag{1}$$

where F is the applied force in N, x is the length of the material, Δx is the change in this length and A is the surface area of the material, in a direction perpendicular to the direction of the force [3]. For small strain rubber, Y has a value of 0.1 GPa [4]. Hooke's law is given in Eq.(2):

$$F = k\Delta x \tag{2}$$

where k is the spring constant [5]. By rearranging Eq.(1) and substituting this into Eq.(2) you get an equation for k in terms of Young's modulus:

$$k = \frac{F}{\Delta x} = \frac{YA}{x}. \tag{3}$$

Substituting this into the equation for elastic potential energy [6] gives:

$$U = \frac{1}{2}k\Delta x^2 = \frac{1}{2}\frac{YA}{x}\Delta x^2 \tag{4}$$

As this is the potential energy produced by one shoe, the total potential energy is twice this. If no energy is lost in the form of heat, all this elastic potential energy is converted to kinetic energy used to move the astronaut vertically in the air.

By assuming that there is no air resistance, we found the maximum height of a bounce by equating the two types of potential energy [6] and rearranged this equation to find h (the height of the vertical bounce):

$$h = \frac{2U}{mg_0} = \frac{YA}{mx}\frac{\Delta x^2}{g_0} \tag{5}$$

where m is the total mass of the astronaut (161 kg). To find this, we used the average mass of a man [7] and the mass of the Apollo A7L suit [8]. g_0 is the gravitational acceleration on the moon (0.166 times that of the gravitational acceleration on the Earth) [9].

Results and Discussion

Fig. 1 shows values for h, the maximum height of a bounce, calculated using Eq.(5), for a range of different Δx values. For comparison, we also included values for how the moon shoes would work on Mars (where gravitational acceleration is 0.377 times stronger than on Earth) [9].

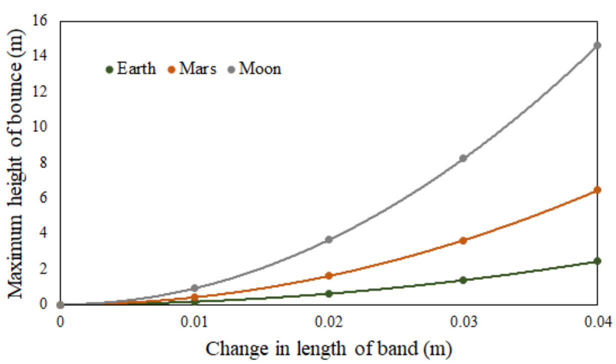

Figure 1: Showing the maximum bounce height for a range of changes in length, on the Earth, Moon and Mars.

As expected, there is a quadratic relationship between the height of bounce and the initial stretch of the rubber bands. On the Moon, this means that with a Δx of just 0.04m, the astronaut can bounce up to 14.7m. This is approximately 6 times the height of a bounce on Earth. This is an over estimate as, in reality, rubber bands do not obey Hooke's law. As they relax after being stretched, some of the stored potential energy is converted to heat. On the Moon and Mars, where the atmosphere is very thin, air resistance would have little effect. But on Earth, where the atmosphere is thicker, air resistance would have to be taken into account to produce a more accurate result.

Conclusion

To conclude, we have shown that moon shoes would work successfully on the moon. However, the exact value of the maximum bounce height possible is likely to be inaccurate as we have neglected the loss of energy through heating. We have also assumed that the astronaut starts their bounce from a stationary position with two feet on the ground. Bouncing from one foot to the other is likely to increase the height of the bounce because this would increase the value of Δx as the total mass of the astronaut would be pushing down onto one shoe.

References

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