Journal of Interdisciplinary Science Topics

The Monkey King's Somersault

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25/03/2014

Abstract
The Monkey King is a famous fictional character from ancient Chinese literature. A famous saying is that he can travel a distance of 54,000km on a somersault. Such a distance requires a jump height of 13,500km. This feat is inefficient on the Earth, which has dimensions smaller than the jump and as a result, may only be helpful in the Heavenly Kingdom with unknown properties and parameters.

Introduction

The Monkey King, also known as Sun Wukong (or Wukong), is the main character of the novel "*Journey to the West*", one of the Four Great Classical Novels in ancient China. He is a monkey that was born from a stone and acquired magical powers. One of his more famous powers is the ability to move 108,000 li (里), a distance of 54,000 km, in one somersault. This paper aims to calculate the height, force and duration of such a somersault.

The somersault

The properties of human jump have been of interest to researchers for a long time. Current formulas are very inaccurate and made to fit the data points. A somersault is different from a jump and may be harder to model. As such, for this paper, an easier model is to assume that Sun Wukong moves like a projectile over even ground without air resistance.

Using various equations Sun Wukong's velocity can be found. A projectile travels the farthest when launched at $45°$ [1]. The distance is $54{,}000\ km$ and the gravitational constant is $9.81\ m/s^2$. Putting in the information into the range formula [1], where d is the distance travelled by the projectile, v is the initial velocity, g is the gravitational acceleration and θ is the launch angle:

$$d = \frac{v^2 \sin(2\theta)}{g}$$

$$5.4 \times 10^7 m = \frac{v^2 \sin(90)}{9.81 m/s^2}$$

$$v = 23016\ m/s$$

After finding the velocity, the duration of the jump can be calculated using the formula below:

$$x(t) = vt\cos(\theta),$$

where $x(t)$ is the horizontal distance travelled in a given time and t is time. The total horizontal distance is $5.4 \times 10^7 m$, the velocity is $23016\ m/s$ and the angle is $45°$. From the above formula, rearranging for time, t, gives:

$$t = \frac{x(t)}{v\cos(\theta)}$$

$$t = \frac{5.4 \times 10^7 m}{23016\frac{m}{s} \times \frac{\sqrt{2}}{2}}$$
$$t = 3318s$$

The maximum height achieved can be calculated by differentiating the vertical displacement equation and equating it to 0:

$$y(t) = vt\sin(\theta) - \frac{1}{2}gt^2$$
$$\frac{dy}{dt} = v\sin(\theta) - gt = 0$$
$$23016\frac{m}{s} \times \frac{\sqrt{2}}{2} - 9.81\frac{m}{s^2}t = 0$$
$$t = 1659s$$

The highest point is reached after $1659\ s$, which is a height of:

$$y(t) = vt\sin(\theta) - \frac{1}{2}gt^2$$
$$y(1659) = \left(23016\frac{m}{s} \times 1659s \times \frac{\sqrt{2}}{2}\right) - \left(\frac{1}{2} \times\ 9.81\frac{m}{s^2} \times 2752281s^2\right)$$
$$y(1659) = 1.35 \times 10^7 m$$

The force can be calculated by finding acceleration. In this scenario, Sun Wukong accelerated from $0\ m/s$ to $23016 m/s$. The acceleration is instantaneous, but since it's not quantitative, we assume the time taken for this acceleration to be 1s. Thus the acceleration will be $23016\ m/s^2$. The mass of Wukong is not known, thus we can only make assumptions. With a mass of 60kg, the Force will be:

$$F = ma$$
$$F = (60kg)\left(23016\frac{m}{s^2}\right)$$
$$F = 1.38 \times 10^6 N$$

Conclusion

The Journey to the West is said to have happened on Earth in ancient china. The earth has a circumference of 40,075km [2] and an atmospheric height of 10,000km (exosphere) [3]. Although Sun Wukong's somersault is enough to go around the earth once and would be enough to move outside the Earth's atmosphere, the formula did not take into account that the surface is round and neglected air resistance. The force produced is more than 66% of that produced by a space shuttle main engine during lift-off [4]. With such strength, the journey to the east would have been over in just one somersault. One explanation for such feat might be that he only achieved such a distance in the Heavenly Kingdom, assuming that it is much larger than the Earth and has lower gravity, while less force would be needed to travel the same distance, the travel time will be longer.

References

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