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P3_1Girl VS Chelyabinsk

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Abstract

We found that an average human woman of 5ft2, weighing 57kg, [3], would need a force of 8.5×10^{15} N, which is 7.1×10^{12} times higher than the average jumping force of a human, to have stopped the Chelyabinsk meteor and would have had to be travelling at 12 times the speed of light, hence crushing anyone's dreams of catching a meteorite- we will have to save that for NASA

Introduction

The Chelyabinsk Meteor is the largest recorded meteor to have fallen to Earth (to date). This paper investigates the velocity that an average weight 5ft2 female would have to travel at to stop the meteorite and hence what force she would need to jump at in order to accelerate fast enough to create the necessary velocity required. We can ignore air resistance because as the velocity of the woman approaches the speed of light, the relativistic mass becomes infinite. Air resistance is insignificant for heavy objects.

Theory

In order for the woman to stop the meteorite, the problem will be modelled as a perfect inelastic collision hence the two particles will stick together, so the maximum amount of kinetic energy in the system is transferred into other forms of energy. We model the problem in this way because we want to look at the situation as if the woman is catching the meteorite. Due to this we can make some assumptions. Assumption 1: The meteorite and the human will be modelled as if they are two particles. Assumption 2: Since the two particles are in a perfect inelastic collision,

the velocity after the collision is zero. Figure (1) is the basic model of the situation before the collision and after the collision.

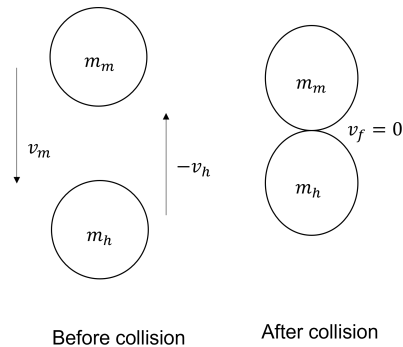


Figure 1: The inelastic collision of the two particles modelled before the collision and after the collision

The velocity the woman would need to be travelling for an inelastic collision can be worked out using Eq. (1) as in inelastic collisions the momentum is always conserved.

$$m_h(-v_h) + m_m v_m = (m_h + m_m)v_f \quad (1)$$

Where m_m is the mass of the meteorite and has a value of 11×10^6 kg, [1]. v_m is the velocity

of the meteorite and has a value 17980 ms^{-1} , [1]. m_h is the mass of the woman, which for an average 5ft2 woman is 57kg, [3]. v_f is zero as stated before. v_h is the velocity of the woman, which can be found from this equation.

The value of v_h is then used to work out the acceleration of the woman using Eq. (2)

$$v_h^2 = u^2 + 2aS \quad (2)$$

where the u is the initial velocity and as the woman starts of at rest, has a value of zero. S is the distance the meteorite and woman collide at above Earth's surface. The meteorite began to break apart at around 19-24km above the Earth's surface, [1], so the value of S is taken as 40km. a is the acceleration of the woman.

Once the acceleration is obtained, the force, f , at which the human would need to jump at can be worked out using Eq. (3)

$$f = ma \quad (3)$$

where m is mass of the woman.

Results

The velocity the woman would require to stop the meteorite would be $3.5 \times 10^9 \text{ ms}^{-1}$. They would need to accelerate at $1.5 \times 10^{14} \text{ ms}^{-2}$ which results in a jumping force of $8.5 \times 10^{15} \text{ N}$, [2].

Discussion

An important note is that one of the main reasons why it is impossible for the woman to reach a speed of $3.5 \times 10^9 \text{ ms}^{-1}$ is because it is impossible for a body to travel faster than the speed of light. Once an object reaches such high speeds, the mass of the body increases exponentially. This means that the mass becomes infinite and infinite energy would be required to move the body (woman). At such high speeds, the relativistic equations break down and no relativistic energies or masses can be calculated.

The force that is calculated from Eq.(3) does not take into the account that at such high speeds the relativistic mass of the woman can be considered. Eq. (4) can be used to calculate

the relativistic mass of a body.

$$m = m_o/\sqrt{1 - v^2/c^2} \quad (4)$$

where m is the relativistic mass, m_0 is the rest mass, v is the velocity of the woman and c is the speed of light. Since the woman is moving faster than the speed of light, the relativistic mass would be infinite hence the woman would need to jump at a force much greater than calculated. However, we can ignore relativistic effects for the purpose of this paper.

At high enough energies, the collision between the woman and the meteorite would produce enough kinetic energy to vaporise the meteorite. Eq. (5) is the equation for the relativistic energy, E . Since the speed of the woman is faster than the speed of light, a mathematical value for the relativistic energy cannot be obtained, however we can say with high certainty that the energy that the woman would theoretically reach, would vaporise the meteorite (and herself in the process).

$$E^2 = p^2c^2 + m_0^2c^4 \quad (5)$$

where p is the relativistic momentum.

Conclusion

In conclusion it would be physically impossible for a human to stop a meteorite by jumping to catch it as the speed needed to do so is $3.5 \times 10^9 \text{ ms}^{-1}$ which is 12 times the speed of light. The woman would need a jumping force of $8.5 \times 10^{15} \text{ N}$ to reach such a high velocity which is 7.1×10^{12} times higher than the average jumping force of a human, [2]. Hence there is no hope for any of us to catch a meteorite.

References

- [1] <https://www.space.com/33623-chelyabinsk-meteor-wake-up-call-for-earth.html> (accessed 12/10/2021)
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