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P4_01, The Practicality of Ant Man's Shrinking

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Abstract

In this paper we calculate estimates for the density and ground pressure of a human when they are greatly reduced in size, while retaining their initial mass. We found that their density would increase to 3.64^9kg m^{-3} and would exert 8.4×10^8N m^{-2} of pressure on the ground. We also began to discuss how this decreased size would affect one's sight. Our calculation predict that as a result of having smaller eyes, the minimum angular resolution of one eye would be greatly increased to 0.0315rad.

Introduction

In the 2015 Marvel movie Ant Man, the concept of shrinking a person is introduced through the idea that the empty space between the nuclei and the orbiting electrons that construct their body can be reduced, conserving the mass of the person but greatly reducing the space in which they occupy. In this paper we consider the effects of undergoing such a process, assuming that the process itself is feasible.

Theory

The protagonist of the film, Scott Lang, stands about 6ft tall (1.8m) has a mass of about 190lbs (or 86kg) [1] and when he shrinks he retains all of his mass and strength, making him a formidable opponent in combat. While the size to which he can shrink varies, we'll take it to be about half an inch (12.7mm) [1] which means he is reduced to about 0.71% of his initial height.

Although Scott's mass is constant, his reduced volume means that he becomes much more dense. We assume that he shrinks to 0.71% of his initial dimensions, making his volume a factor of 3.58×10^{-7} smaller than normal. By taking the average volume of a human being to be $0.066m^3$ [2] an estimate for the density can be calculated using,

$$\rho = \frac{m}{V} \tag{1}$$

where ρ is the mass density, m is Scott's mass and V is his volume.

The typical area of a human foot is between 73 and 113cm^2 [4], we shall take 100cm^2 for simplicity. So by doubling it we estimate that the area Scott applies his weight to is about 200cm^2 (0.02m^2).The pressure he applies to the ground can also be calculated using

$$P = \frac{mg}{A} \tag{2}$$

where P is the pressure, g is the gravitational field strength on Earth (9.81m s^{-2}) and A is the area the weight is being applied.

To consider the effects Scott's small size would have on his vision we can estimate the minimum angular resolution of an aperture (pupil of the eye), which is given by the Rayleigh Criterion:

$$sin(\theta) = 1.22\frac{\lambda}{D} \quad (3)$$

where θ is the angular resolution, λ is the wavelength of the light and D is the diameter of the aperture.

Discussion

Using (1) Scott's initial density is approximately 1300kg m^{-3}. When shrunk his density becomes considerably higher, approximately 3.64×10^9kg m^{-3}.

Scott's new density is now multiple orders of magnitude greater than anything we encounter on earth (with the most dense metals only slightly exceeding 20,000 kg m^{-3})[3]. Not only is his density incredibly large but the pressure his shrunken feet will apply to whatever he may be standing on is also much larger.

Through (2) we can calculate and estimate that, at full size Scott exerts approximately $42,000$N m^{-2} and, if we assume the dimensions of Scott's feet decrease to be only 0.71% of their original value, similar to his height, the pressure he exerts when shrunk is about 8.4×10^8N m^{-2}.

This again is much larger than any pressure a person could normally exert and would be very impractical as Scott's legs would be applying more pressure than a high power water jet, which usually apply at most 6.2bar (620,000N m^{-2})[5] and would likely find himself sinking into the ground or breaking everything he stands on. His enormous weight compared to the things around him make it impossible for him to ride an ant as we see him do in the film as it would be similar to him applying 844N of weight onto the ant's back, which would obviously kill it.

Finally, if we take the diameter of the pupil to be 3mm and the wavelength of light to be 0.55μm [6]. Using (3), the angular resolution of the human eye is around 2.24×10^{-4}rad. However, if Scott's pupil now has a diameter 0.71% of 3mm, his minimum angular resolution would become 0.0315rad. Through basic trigonometry, it can be deduced his eye could not resolve two objects that were 15cm apart if they were only 5m away from him.

Conclusion

While at first consideration, the ability to shrink oneself and retain their mass sounds rather useful. However, as we have shown, the practicality of such an ability is rather limited as you'd be constantly exerting close to 10^9N m^{-2} of pressure on anything you touch. The estimates we have calculated demonstrate the enormous effect shrinking would have on density and ground pressure. Not only this but the experience would be very disorientating for Scott due to his increased minimum angular resolution of 0.0315rad.

References

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