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P5_3 Whats cookin' good lookin'

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Abstract

Using magnifying glasses to set things on fire is an age-old pastime of curious children, we investigate in this paper whether it is possible to take this act to the extreme of focusing the Sun's power to cook an adult human. It was found that it is indeed possible with a suitably large magnifying glass of radius $2.4m$ that is held over a person for 1 hour.

Introduction

We investigate in this paper if using a magnifying glass to burn paper can be feasibly scaled up to cook an adult male using just the Sun's energy, and discuss whether it would be practical to create such a lens, in order to test the theory.

Theory and Results

In order to calculate the size of the magnifying glass, we first need to ascertain the energy required to cook a man. This can be achieved using the heat energy equation,

$$Q = mc\Delta T, \tag{1}$$

where Q is the thermal energy, m is mass of the man, c is specific heat capacity of human flesh, and ΔT is change in temperature of human flesh.

First of all we calculated the change in temperature we would need to cook a man. Pork and beef require to be cooked to approximately 63 °C [1] to be considered safe to eat and human flesh is roughly analogous to these two, the average resting temperature of a human is approximately 37 °C [2]. This gives us a value for ΔT of 26 °C, which is the same as 26 K. We substituted the following values into Equation 1: The average weight of an adult male in the UK, $m = 84$ kg [3], the average specific heat capacity of human flesh, $c = 3.5$ kJkg^{-1}K^{-1} [4], and our above calculated value for the change in temperature $\Delta T = 26$ K. This gives the total thermal energy required as $Q = 7.6$ MJ. This is the energy required to heat up the whole body, so we will assume that the magnifying glass is being moved over the human evenly, so the whole body is being heated.

A magnifying glass operates by focusing the light rays incident upon it to a point, therefore we have assumed that the magnifying glass is held above the human at a height that is equal to the focal length of the lens in the magnifying glass. The energy at the focus point can be described as,

$$E = IAt, \tag{2}$$

where E is the total energy, I is the solar intensity at the earth's surface, A is the area of the magnifying glass, and t is the time the magnifying glass is held over the human. Assuming the magnifying glass is circular the area can be rewritten as $A = \pi r^2$ where r is the radius, Substituting this into Equation 2 and rearranging for radius gives the following,

$$r = \sqrt{E/It\pi}. \tag{3}$$

We substituted into this equation: our previously calculated value of total thermal energy $E = 7.6$ MJ, the average solar intensity at the earth's surface $I = 1.1$ kWm^{-2} [5], and a time of exposure to the magnifying glass of 1 hour, $t = 3600$ s. This gave a radius of 0.8 m.

Discussion

A magnifying glass with a radius of 0.8 m is an extremely large lens. Comparatively the largest operating refracting telescope is in the Yerkes Observatory and has a radius of 0.5 m [6]. This poses several issues as in a lens this large, losses due to imperfections will be amplified, which would result in less energy being focused on the human as light can be reflected or absorbed and heat the lens [7]. Another limiting factor is cost. Large, high quality, lenses are extremely expensive and time consuming to make as the smallest of defects can have a profound impact on its functionality. For comparison the James Webb Telescope uses mirrors which are created in a similar way to lenses, its main mirror is 3.25 m in radius and has taken over 10 years of designing and building and costed millions of dollars [8].

Also the errors in our assumptions need to be taken into account, such as the fact that the magnifying glass focuses all the energy into one small point on the human so in order to cook the whole body the magnifying glass would have to be either constantly moved over the body, or positioned such that it was closer than the focal length and was focusing to a larger point. However both these methods would most probably result in energy being lost to the surroundings, meaning our lens size may be too small.

Conclusion

We conclude that although it is possible to cook an adult using a large magnifying glass, it would be incredibly impractical to maneuver a lens of that size over a person, and the cost and time involved in producing the lens make it very unlikely anyone will ever be able to test this. We can say with certainty that better methods for cooking a human exist, such as an oven, campfire, or microwave.

References

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