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P5 5 Investigating the feasibility of Dr. Stone's sweat-lens

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Abstract

In this paper we look at a scene in the popular anime Dr. Stone, where a convex lens made of sweat and glass is used to ignite a leather cloth with sunlight. We have assumed that the radius of the lens $r = 2.5cm$, the Solar Intensity $I_0 = 1366W/m^2$ and the temperature that the leather ignites at is 300 °C on a sunny day. Our results show that rather than taking 60 seconds to ignite like it did in the show, this process in real life would take 154 seconds. This suggests that the scene in Dr. Stone is inaccurate.

Introduction

In one episode of Dr. Stone's anime, a scenario is presented where a convex lens is used to focus sunlight into a single spot on a piece of cloth, causing ignition after a full minute. The convex lens used is not any ordinary convex lens; it is a concave lens that is turned into a convex lens by the curvature of a drop of sweat sitting in the lens. In every situation, a concave lens diverges any incoming light. However, when it curved with the lens, this will be completely opposite. As sweat curving with the lens, both the thickness and the focal length are altered, from the light traveling in the air-glass-air boundary to the air-water-glass-air boundary. The increasing thickness of the lens turns the focal length from negative to positive, as well as gaining a focus point, which then enables light to focus on one point .

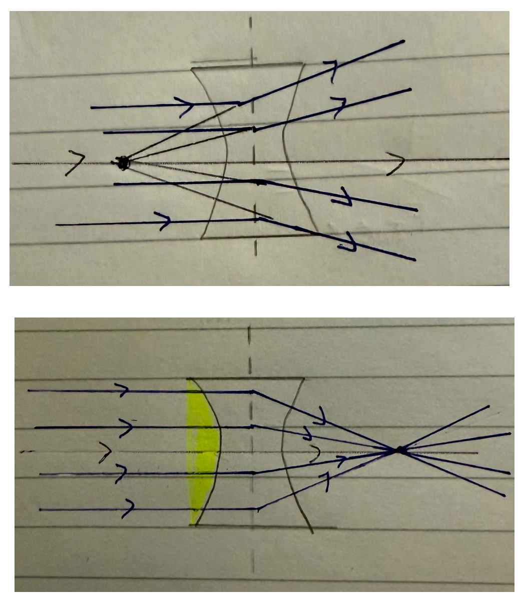

Figure 1: Diagrams of light travel through concave lens without and with curving sweat (water) as well as changed of focal length (lines of intersect).

Method

To determine the time it takes for a cloth to ignite, several equations are required for explanation. The first step is to find the value of the total Lens power P_{Total} with unit in diopters, where this is the inverse of the focal length,f:

$$f = \frac{1}{P_{\text{Total}}} = \frac{1}{P_{\text{Lens}} + P_{\text{Sweat}}} \tag{1}$$

Where P_{Lens} is the Lens power of the lens ; P_{Sweat} is the Lens Power of the sweat, both applying the same equation :

$$P = \left(\frac{n_{\text{inner}}}{n_{\text{medium}}} - 1\right)\frac{2}{r} \tag{2}$$

Where n_{Medium} is the refractive index of the medium of light, in terms of P_{Lens}, it is the refractive index of the lens, $n_{\text{lens}} = 1.5$ divided by the refractive index of the air, $n_{\text{air}} = 1.0$; in terms of P_{Sweat}, it is the refractive index of lens divided by the refractive index of the sweat, $n_{\text{sweat}} = 1.33$. r is the radius of the lens , 2.5 cm ($2.5 \times 10^{-2}m$). However, according to Tipler[1], the applied equation should be

$$P = \left(\frac{n_{\text{inner}}}{n_{\text{air}}} - 1\right)\frac{2}{r}$$

The reason why this is not applied is that this situation involves multiple layers instead of a single layer.

To determine the distance between the leather cloth and the lens, using the thin lens equation:

$$\frac{1}{f} = \frac{1}{s} + \frac{1}{s'} \tag{3}$$

Where f, in units of meters, is the focal length of the convex lens ; s and s', in units of meters, represent the distance and the distance from the image, respectively. However, since the distance from the sun to Earth is approximately $1.5 \times 10^{11}m$ (1AU) [2],

The next step is to calculate the total power of the sun. This requires information on the intensity of the sun (power per unit area) as well as the area of the lens (square meters), both will be called I_0 and A, respectively:

$$P_{\text{sun}} = I_0 A \tag{4}$$

The last step is to acquire the thermal energy required to ignite the cloth , using the specific heat capacity:

$$Q = mc\Delta T \tag{5}$$

Where the specific heat capacity of the leather is ($c = 1500J/kg.K$)taking the assumption that the mass be $1 \times 10^{-3}kg$ and ΔT is the temperature difference of the leather to ignite from room temperature to 300 °C [3]. Due to the definition of power,

$$P = \frac{\mathrm{d}E}{\mathrm{d}t} = \frac{\mathrm{d}Q}{\mathrm{d}t}$$

Integral for both sides gives :

$$Q = P_{\text{sun}}t \quad \Rightarrow \quad t = \frac{Q}{P_{\text{sun}}} \tag{6}$$

Results

Using (2) followed by a substitute to (1),

$$P_{\text{Sweat}} = 0.4D, \quad P_{\text{Lens}} = 0.102D$$

$$P_{\text{Total}} = 0.502D \quad \Rightarrow \quad f = 0.123m = 12.3cm$$

For (3) :

$$\frac{1}{s} \to 0 \quad \Rightarrow \quad s' = f = 0.123m$$

For (4) ,The power of the Sun is :

$$P_{\text{sun}} \approx 2.68W$$

For (5), The thermal energy to be :

$$Q = 414J$$

For (6), the time taken to be :

$$t \approx 154s$$

Conclusion

The results show that Dr. Stone's sweat-lens would take $154s$ to ignite a small patch of leather cloth, which is much longer than the $60s$ shown in the anime. Although it is physically possible to turn a concave lens into a converging system with a water droplet and use that lens to ignite a cloth, the issue in anime is that the intensity of the sun is assumed to be constant $1366W/m^2$. The anime miscalculates the time needed due to simplified assumptions about solar intensity, heat loss, and material properties.

References

[1] P. A. Tipler and G. Mosca, *Physics for Scientists and Engineers*, 6th ed. (W. H. Freeman, 2004) (Page1105, 1112, 1115).

[2] NASA Science, "Earth-Sun Distance", `https://science.nasa.gov/learning-resources/how-big-is-the-solar-system/` [Accessed 19 October 2025]

[3] Engineering ToolBox, "Specific Heat", `https://www.engineeringtoolbox.com/specific-heat-capacity-d_391.html` [Accessed 19 October 2025]