Journal of Physics Special Topics
An undergraduate physics journal

A3 1 The Riders of Rohan are approaching

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October 12, 2026

Abstract

In this paper, we investigate whether Legolas the Elf could resolve the width of a spear pole from 24 km away. At this distance, the pole subtends an angle of approximately 1.3 µrad. Using the Rayleigh criterion, we calculated that resolving the pole would require a pupil diameter of approximately 50 cm, far exceeding any pupil diameter recorded in an animal to date.

Introduction

Legolas the Elf is a fictional character in J.R.R. Tolkien's The Lord of the Rings. In The Two Towers, Chapter 2: The Riders of Rohan, Legolas observes 105 approaching Riders, describing their spears as bright, and stating they are no more than 5 leagues away [1]. Using these details, we investigate the plausibility of Legolas's eyesight by calculating whether he could resolve the width of a Rohan spear pole at this distance.

Theory

This paper considers two physical phenomena. The first is angular resolution, which describes the ability of an optical system to distinguish fine details in an object [2]. The Rayleigh criterion can be used to estimate the diffraction-limited angular resolution of an ideal optical system [3]

$$\theta_{\text{min}} = 1.22\frac{\lambda}{D}, \tag{1}$$

where λ is the wavelength of light and D the pupil diameter. The angle θ_{min}, expressed in radians, represents the minimum angular separation at which two fine features can be resolved. A smaller value of θ_{min} corresponds to a higher angular resolution, allowing finer details to be distinguished at the same distance.

The second phenomenon is angular size, which describes the angle subtended by an object when viewed from a distance [4]. This angle can be calculated using trigonometry. Since the angle is expected to be small, the small-angle approximation can be applied

$$\phi = \frac{W}{L}, \tag{2}$$

where ϕ is the angular size of the object, W is its width, and L is the distance between the object and the observer.

For the object's width to be resolved, its angular size must be at least equal to the minimum angular resolution, such that $\theta_{\text{min}} \leq \phi$. To determine the theoretical minimum pupil diameter required to satisfy this condition, equations (1) and (2) can be equated and rearranged to make D the subject, while keeping the other parameters constant

$$D' = \frac{1.22\lambda L}{W}. \tag{3}$$

Using the specified values of λ, W, and L, equation (3) gives the theoretical minimum pupil

diameter required for the object's width to be resolved. The notation D' is used to distinguish this calculated value from the original pupil diameter D.

Method

Before performing any calculations for the Legolas case, it should be clarified that the pole's width refers to its diameter rather than its length. Additionally, as Tolkien provides no information regarding Legolas's eye dimensions, the calculations will use human eye dimensions. This assumption is based on the film adaptations, in which Legolas is portrayed by a human actor, whose eyes have not been visibly altered.

Several assumptions are also made to simplify the calculations: Earth's curvature and atmospheric distortion are neglected, giving Legolas the best possible chance of resolving the pole's width. These assumptions simplify the model by eliminating the need to account for atmospheric effects and additional geometric considerations.

Furthermore, the Rayleigh criterion applies to two point sources. In this model, we are treating the two edges of the pole as features that must be distinguished to resolve its width, which represents a further approximation.

Results

For equation (1), a D value of 8 mm was used, representing the upper limit of the human pupil diameter [5]. This gives Legolas the greatest possible pupil diameter within the model, maximising his ability to resolve the pole's width. A value for λ of 550 nm was also assumed, corresponding approximately to the middle of the visible spectrum. Substituting these values into equation (1) gives a value for θ_{min} of approximately 84 µrad.

As The Lord of the Rings was written by English author J.R.R. Tolkien, an English land league was assumed, equivalent to approximately 4.8 km [6]. Therefore, a value for L of 24 km (5 leagues) was used. Assuming a pole diameter W of 3 cm, equation (2) gives a ϕ value of approximately 1.3 µrad.

Finally, equation (3) was used to calculate D', which was found to be approximately 50 cm.

Discussion

Under this model, Legolas could not resolve the pole's width from 5 leagues away with human eyes. The Colossal Squid has the largest eyes in the animal kingdom, but still only has a pupil diameter of approximately 9 cm [7]. This suggests that the required diameter is biologically unrealistic, although pupil size alone does not determine visual sharpness. Eagles however do have exceptional visual acuity, but resolving prey from 24 km away would remain highly challenging [8]. But again, this comparison is indirect, as eagle and human vision differ.

The model neglects atmospheric distortion and Earth's curvature. Despite these favourable assumptions, human eyes would be insufficient to resolve the spear's width. Furthermore, equation (1) describes an ideal optical system; real eyes have additional limitations that could further reduce resolution.

Changing the wavelength within the visible spectrum would not substantially alter this conclusion. However, Legolas's non-human vision is unknown, and sensitivity to shorter wavelengths could theoretically improve resolution.

Finally, Legolas comments on the spears' brightness rather than their width, suggesting he may have detected them without resolving their spatial details.

Conclusion

In conclusion, Legolas could not fully resolve the width of a Rohan spear pole from 5 leagues away if he had human eyes. Under this model, a minimum pupil diameter of approximately 50 cm would be required, far exceeding documented biological examples. However, Legolas does not describe the spears' spatial details in the books. He may therefore have detected them as spears without fully resolving their width.

References

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