**Experiment #4: The Telescope and the Compound Microscope**

In this experiment, we are going to learn the basic principles of the telescope and the microscope that make it possible for us to observe very distant objects in the outer space and very tiny organisms that the naked eye is not capable of seeing.

**Part A: The Telescope**

**Equipment**
- Optics Bench
- 75 mm Focal Length Convex Lens
- 150 mm Focal Length Convex Lens
- Component Holders (2)

![Figure 1: Simple telescope set up](image)

**Introduction**
Telescopes are used to obtain magnified images of distant objects. The image of a distant object when viewed through a single converging lens will be focused nearly at the focal point of the lens. This image will be real, inverted, and reduced in size. In fact, the greater the distance of the object (with respect to \( f \)), the smaller the size of the image. However, this reduced image is useful. By viewing this image through a second converging lens—used as a magnifier—an enlarged image can be seen.
The figure shows the setup for a simple telescope. The objective lens, $L_1$, creates a real, inverted image. (You can barely see this image in the diagram. It's very small, just inside the focal point of lens $L_2$.) If the object is sufficiently far away, this image will be located approximately at $f_1$, the focal point of $L_1$. The eyepiece, $L_2$, then acts as a magnifier, creating a magnified, virtual image which can be viewed by the observer. For maximum magnification, $L_2$ is positioned so the virtual image is just slightly closer than its focal point, $f_2$. Therefore, the distance between the objective lens and the eyepiece of a telescope, when viewing distant objects, is approximately $f_1 + f_2$. The angular magnification for a telescope can be approximated by assuming the lenses are exactly $f_1 + f_2$ apart, as shown in Figure 2. The height of the object as seen with the naked eye is proportional to the angle $\theta_1$ in the lower diagram. If the distance from the object to the telescope is large—much larger than is shown in the diagram—$\theta_1 = \theta_1'$, to a good approximation. The ray shown in the upper diagram passes through the focal point of the objective lens, comes out parallel to the optical axis of the telescope, and is therefore refracted by the eyepiece through the focal point of the eyepiece. The angle $\theta_2$ is therefore proportional to $h_i$, the height of the image seen by the observer.

Procedure and Data Analysis

1- Using Figure 2, calculate $\tan \theta_1$ and $\tan \theta_2$ as a function of the height of the image, $h_i$, and the focal lengths of the two lenses, $f_1$ and $f_2$.

$$\tan \theta_1 = \tan \theta_1' = \frac{h_i}{f_1}$$

$$\tan \theta_2 = \frac{h_i}{f_2}$$

Assume that $\theta_1$ and $\theta_2$ are very small, and therefore equal to $\tan \theta_1$ and $\tan \theta_2$, respectively.

2- Calculate the angular magnification of the telescope.

Angular Magnification = $\theta_2/\theta_1 = \frac{h_i/f_2}{h_i/f_1}$
the object into sharp focus.
To measure the magnification, look with one eye through the telescope, and with the other eye look directly at the object. Compare the size of the two images. (If a meter stick is used as the object, fairly accurate measurements of magnification can be made.)

3- What is the magnification of the telescope when using the 75 mm lens as the eyepiece?

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Part B: The Compound Microscope

Equipment
- Optics Bench, Light Source
- 75 mm Focal Length Convex Lens
- 150 mm Focal Length Convex Lens
- Variable Aperture
- Component Holders (2)
- Viewing Screen

Figure 4: The compound microscope set up

Introduction
A compound microscope uses two lenses to provide greater magnification of near objects than is possible using a single lens as a magnifier. The setup is shown in Figure 4. The objective lens, \( L_1 \), functions as a projector. The object is placed just beyond the focal point of \( L_1 \) so a real, magnified, inverted image is formed. The eyepiece, \( L_2 \), functions as a magnifier. It forms an enlarged virtual image of the real image projected by \( L_1 \). The real image that is projected by \( L_1 \) is magnified by an amount \( m = -d_i / d_o \), as indicated by the Fundamental Lens Equation. That image is in turn magnified by the eyepiece by a factor of 25 cm/f. The combined magnification is, therefore: \( M = (-d_i / d_o)(25 \text{ cm/f}) \).
Procedure and Data Analysis

Set up the microscope as shown in Figure 4. Use the 75 mm focal length lens as the objective lens and the 150 mm focal length lens as the eyepiece. Begin with the objective lens approximately 150 mm away from the object (the Viewing Screen). Adjust the position of the eyepiece until you see a clearly focused image of the Viewing Screen scale.

1- Is the image magnified? How does the magnification compare to using the 75 mm focal length lens alone, as a simple magnifier?

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While looking through the eyepiece, slowly move the objective lens closer to the Viewing Screen. Adjust the position of the eyepiece as needed to retain the best possible focus.

2- Why does the magnification increase as the objective lens is moved closer to the object?

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3- What advantage would there be in using a 75 mm focal length lens as the eyepiece?

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