Experiment 3: Periscope, Telescope and Microscope PHY 431

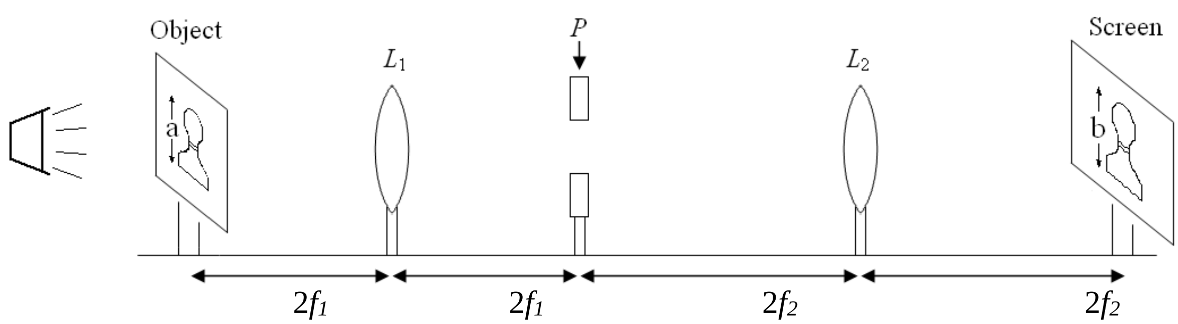
In this experiment you will examine two basic optical systems out of two converging lenses: 1) a periscope/telescope and 2) a refraction microscope. Periscope is a device that allows to inspect objects without inversion, while possibly circumventing geometric obstacles to the viewing. Telescope is used for viewing far-away objects in the line of view. The microscope will be used here to examine the resolution of the characters produced by a laser printer.

In experimenting, you will examine the practice of object magnification and the impacts of stops and pupils limiting some rays and thus improving image quality and practical angular magnification that can be reached. Until optical components become specialized for the particular use, the boundaries between differently named optical systems are blurry, as with small changes the same components can be exploited for alternate purposes.

Procedure:

Periscope/Telescope

A. Set up the following system using two lenses of equal diameters, but not necessarily equal focal lengths. You may find it convenient to replace the screen with a reticle (a glass plate with an inscribed length scale). Construct a bright object by backlighting tracing paper with a halogen lamp. Define the object to have a diameter of just 1-2 mm with masking tape. You will probably need an iris between the lamp and the object to prevent stray light from lamp impinging on the rest of the system. Note that light rays are also limited by the finite diameter of the lenses. Hence, L_1 plays both the roles of aperture stop and entrance pupil.



B. Use Eq. (1) of the Appendix (i) to find the magnification of the periscope M = b/a. Measure the object and image sizes to find M (including uncertainty). Compare the calculation and measurement.

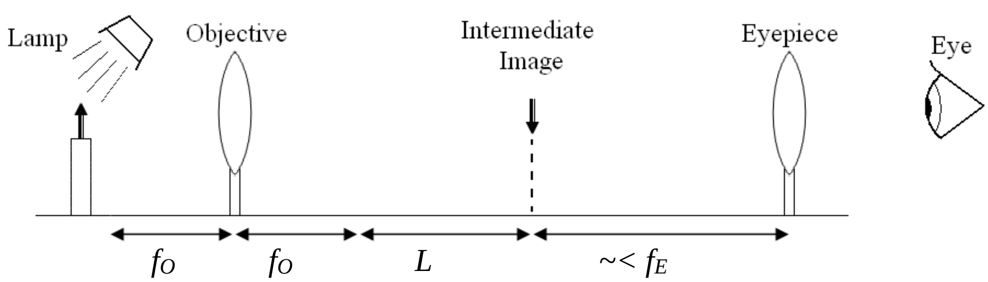
C. Put a field stop at point P aiming to sharpen the image. (Note: The stop there nominally represents a geometric obstacle to image projection.)
Q1. What is the source of the original image fogginess or blurring? (Hint: The lens system may be used to create images of other objects in the vicinity, even including one of the lens L_1. Through where do the rays for other images pass and where do they end up?)

Q2. Assuming that any lack of sharpness is tied to the edges of the lenses, try to determine whether one lens can be blamed more as a culprit than the other. For this, try to put the field stop at positions other than *P* and see whether these closer to L_1 have more impact than those closer to L_2. (Note: If the focal lengths are similar, you may not see a difference in testing out the two lenses as culprits.)
Q3. How effective are the alternate positions for the stop in arriving at sharpness compared to *P*? Can you explain the findings?

D. The system can now be used as a Keplerian refracting telescope by dimming the lamp and replacing the screen with your eye at location slightly above. Move your eye back and forth to get the clearest view.
Q4. Now estimate the apparent magnification of the object from your current point of view. In other words, compare the angle subtended by the image θ_i to the angle subtended by the distant object θ_o. How does θ_i/θ_o compare to *M*? Can you explain any discrepancy, if there? (Hint: Different types of magnification are employed in optics. What types of magnification are at play here?)
Q5. Finally experiment shifting L_2 along the line to the object. What goal can you achieve this way for the telescope?

Microscope

E. Use the same lenses to set up the following system



As an object use selected location on the paper covered with text printed using the lab's printer.

F. In the sketch above, the object is 1.25 f_O away from the objective lens. Draw a ray diagram for this case. Next draw a ray diagram for an object distance of 1.75 f_O, adjusting the placement of the eyepiece accordingly.
Q6. Is the magnification greater or less for the 1.75 f_O distance?

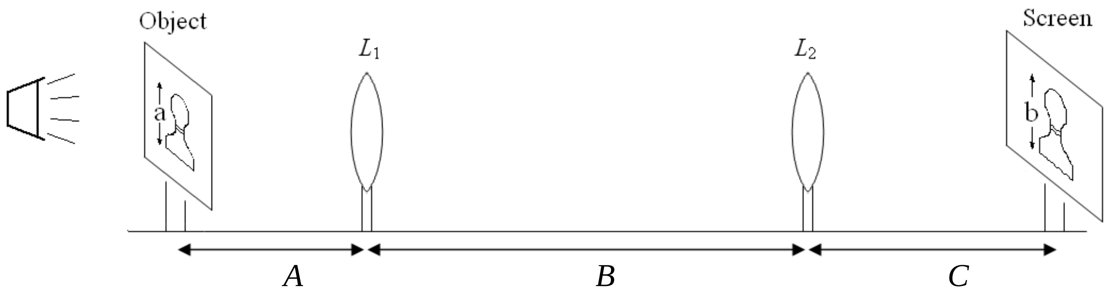
G. Set the object distance to about 1.5 f_O from the objective and focus the microscope.
Q7. Can you obtain a better image by reducing the magnification? If so, how can you explain this? You should find that the border of the field of view is fairly well-defined. If this seems surprising; note that for the periscope a field stop gave a sharp border.
Q8. Why is the field stop not needed in this case?

H. Situate a camera at the place of your eye to take a picture. Make sure to get the image in focus (you may adjust the position of the eyepiece if necessary). Please include the picture in your report. Now that the characters are greatly enlarged, comment on the precision of the printer. Note that the lines and curves do not look perfectly sharp.

Q9. Are the imperfections consistent with the printer resolution of 1600 dots per inch, claimed by the manufacturer? If not, what do you think is the origin of the less-than-ideal characters?

Appendix: Two-Lens System

Here is a description of the general to-lens system.



The image produced by the first lens L_1 is at position s_1' that can be found from the thin lens equation

$$\frac{1}{A}+\frac{1}{s_1'}=\frac{1}{f_1}, \quad \text{so that} \quad s_1'=\frac{Af_1}{A-f_1}.$$

The object for L_2 is at the distance $B-s_1'$ from L_2 and the final image is at the distance C that can be found from

$$\frac{1}{C}+\frac{1}{B-s_1'}=\frac{1}{f_2}\ , \quad \text{so that} \quad C=\left[\frac{1}{f_2}-\frac{1}{B-\dfrac{Af_1}{A-f_1}}\right]^{-1}.$$

The magnifications are $m_1=\frac{-s_1'}{A}$ and $m_2=\frac{-C}{B-s_1'}$, respectively, and the net magnification $M=m_1m_2$ is then given by

$$M=\frac{f_1}{A-f_1}\frac{C-f_2}{f_2} \qquad (1)$$