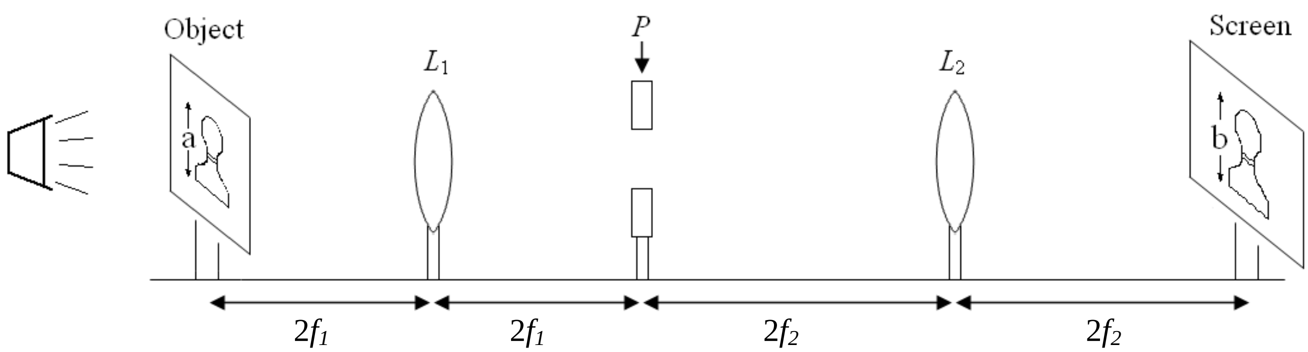
Experiment 3: Periscope, Telescope and Microscope Phys 431

In this experiment you will examine two optical systems: 1) a periscope, which can also be operated as a telescope, and you will be asked to compare the observer's perceptions of the magnification of these two modes. 2) a reflection microscope which you will use to examine the sharpness of the lines drawn by our printer. A major theme is that not every light ray emanating from an object completes the journey to the final image – stops and pupils limit or block many of these rays.

Procedure:

Periscope/Telescope

A. Set up the following system using two lenses of equal diameter, but not necessarily equal focal lengths. You may find it convenient to replace the screen with a reticle. Construct a bright object by backlighting tracing paper with a halogen lamp. Define the object to have a diameter of 1-2 mm using masking tape. You will probably need an iris between the lamp and the object to prevent stray light rays from interfering with the rest of the system. Note that in this simple system the light rays are limited by the diameter of the lenses. Hence, L_1 plays the role of both the aperture stop and entrance pupil.



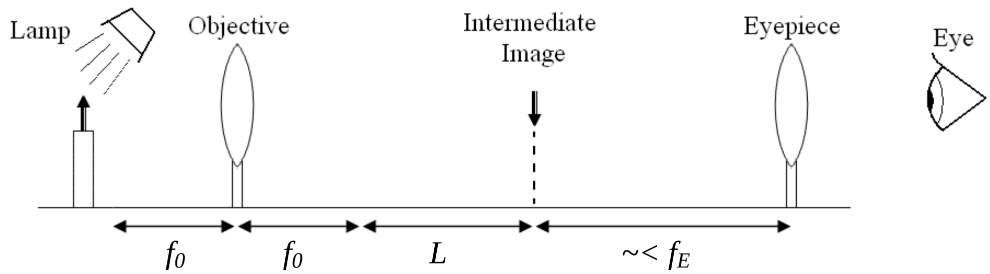
B. Use equation (1) of the appendix to predict the magnification of the periscope M=b/a. Measure the object and image sizes to find your measured M (including uncertainty). Does it agree with your expectation?

C. Put a field stop at point P. Does this eliminate a blurred portion of the image? **Q1** What was the source of the blurring? (Hint: if you placed an object at the position of either lens, would it be in focus on your screen?) **Q2** Assuming that the blurring is related to the edges of the lenses, can you determine which lens is the culprit? Try putting the field stop at a position other than P. **Q3** Does it work as effectively? Can you explain why or why not?

D. The system can now be used as a telescope by turning off the lamp and replacing the screen with your eye. You will find that you cannot immediately focus on the image. Move L_2 towards the object until you are able to see it clearly through the telescope. **Q4** Why is it necessary to shift L_2? 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? **Q5** Can you explain the discrepancy?

Microscope

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



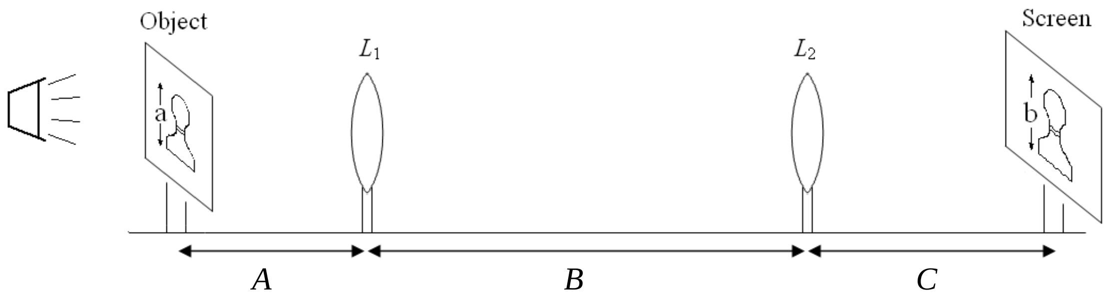
F. In the sketch above, the object is 1.25 f_o away from the objective lens. Draw a ray diagram for this case. Next draw a ray diagram for an object distance of 1.75 f_o, adjusting the placement of the eyepiece accordingly. **Q6** Is the magnification greater or less for the 1.75 f_o distance?

G. Set the object distance to about 1.5 f_o 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. This may seem surprising; remember that for the periscope we needed to use a field stop to obtain a sharp border. **Q8** Why is this not necessary in this case?

H. Situate the camera in the place of your eye to take a picture, taking care to get the image in focus (feel free to adjust the position of the eyepiece if necessary). Please include the picture in your write-up. Now that the character is greatly enlarged, you can comment on the precision of our printer. Note that the lines and curves do not look perfectly sharp. **Q9** Are the imperfections consistent with the printer's resolution of 1600 dots per inch? If not, please speculate as to the origin of the less-than-ideal characters.

Appendix

Here is a description of the general system.



The image produced by the first lens L_1 is at a position $s_1^{'}$ and is given by

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

The object is at $B-s_1^{'}$ for the second lens L_2 and the final image is at C so that

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

The magnification $m_1=\dfrac{-s_1^{'}}{A}$ and the magnification $m_2=\dfrac{-C}{B-s_1^{'}}$, so that the total magnification $M=m_1m_2$ is given by

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