Experiment 1

Lenses

The basic equation relating object distance s, image distance s', and focal length f of a lens is:

$$\frac{1}{f_2} = \frac{1}{s'} - \frac{1}{s} \tag{1.1}$$

The magnification M is given by:

$$M = -\frac{y'}{y} = -\frac{s'}{s} \tag{1.2}$$

Equations (1.1) and (1.2) are based on the following assumptions: negligible lens thickness, paraxial rays

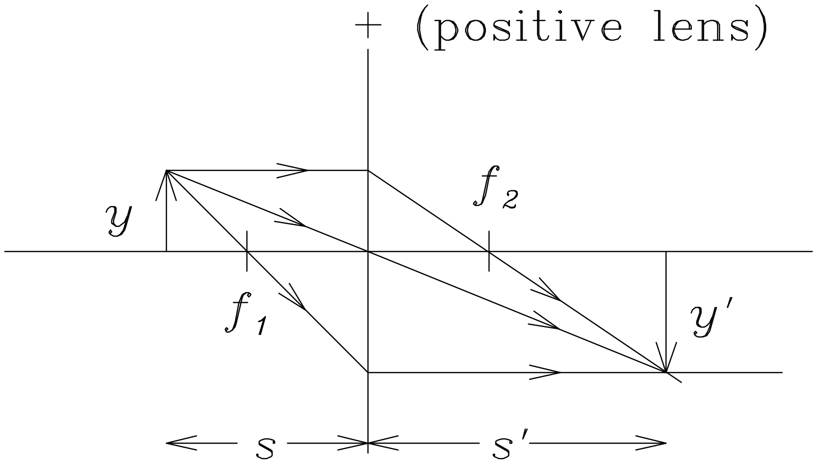

Figure 1.1: Ray diagram for a positive lens with $s > f_1$

and monochromatic light. The conventions for the signs of f_1, f_2, s, and s' are given in the textbook.

1.1 The Positive Lens

1.1.1 Determination of f for a positive lens

Mount the object (a transparent scale illuminated by a lamp) and the image screen on the optical bench, approximately 0.9 to 1.2 m apart. Mount the positive lens between the object and screen such that the object gives a magnified image on the screen. Call this postion "a". Use the centering pin to align the object, lens and image at the same height above the bench, and to measure the distances s_a and s'_a.

Calculate f_a (and its error measurement) from s_a and s'_a. Measure M_a, and compare it to $|s'_a/s_a|$. Screen off part of the lens surface with a mask, and observe its effect on the image quality. Next, slide the lens to a different position "b" so that a sharp, demagnified image is seen on the screen. Keep the distance between object and screen constant. Measure s_b, s'_b, and M_b and calculate f_b. What are the relations between f_a and f_b and between s_a, s'_a, s_b, and s'_b, M_a and M_b?

1.1.2 The Autocollimation Method

Use as an object, a narrow slit illuminated by the lamp. Position the slit approximately at the focal point of the lens. A parallel beam should emerge from the lens. Place a flat mirror nearly perpendicular to this beam, so that the light is directed back into the lens and an image of the slit is formed just adjacent to the slit. Adjust the postion of the lens until this image is sharp and exactly the same size as the slit itself. The slit is then exactly at the focal point of the lens. Change the position of the mirror. Does it influence the size or sharpness of the image? When the adjustments are satisfactory, measure f (with the centering pin) as the slit-lens distance.

Compare the accuracy of f determined by both methods. Include in your report, the ray diagrams for sections 1.1.1 and 1.1.2. Also include schematic ray diagrams for these cases: $2f_1 > s$, $f_1 > s > 2f_1$, $0 > s > f_1$, $f_2 > s > 0$, and $s > f_2$.

1.2 The Negative Lens

A negative lens always forms a virtual image ($s' < 0$) from a real object ($s > 0$). A virtual object can, however, under certain circumstances, give a real image through a negative lens. You will investigate this in the following section.

1.2.1 Determination of f

Form a real image from the real object (a transparent scale) through the positive lens used in section 1.1. Carefully determine the position of this image on the optical bench. Now use this real image as a virtual object for a negative lens by putting the negative lens somewhere to the left of the image. A (different) real image should be formed on the screen when it is placed approximately 1 to 1.5 m to the right of the negative lens. Adjust the position of the negative lens until this image is sharply focused. Determine s and s' for the negative lens, and calculate its focal length. Measure the overall magnification (from first object to final image) and compare it with the theoretical value.

Do a proper error analysis. Sketch ray diagrams for your set-ups. Also include in your report ray diagrams for image formation by a single negative lens for the cases: $f_2 > s$, $0 > s > f_2$, $f_1 > s > 0$, and $s > f_1$.