Experiment 15: Telescope

Required Equipment from Basic Optics System

Bench

2 Convex Lenses (+100 mm and +200 mm)

Screen

Paper grid pattern (see page 57), or a 14 × 16 grid of 1 cm squares

+250 mm and -150 mm lenses (optional, for further study)

Purpose

In this experiment, you will construct a telescope and determine its magnification.

Theory

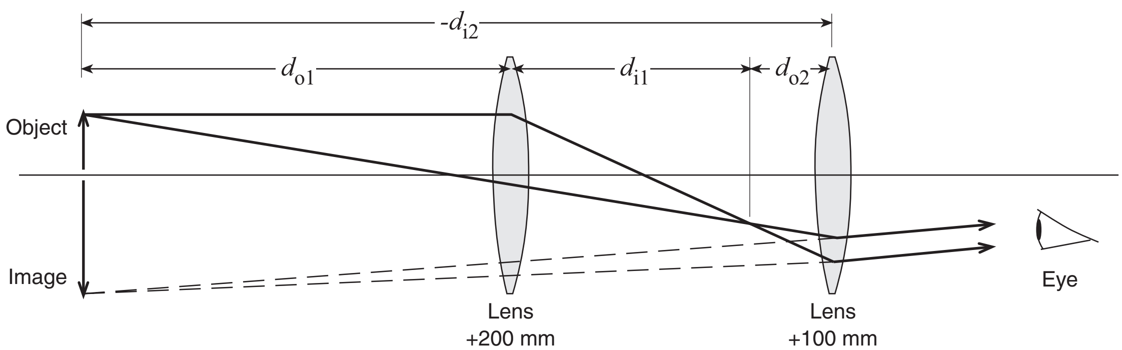

Figure 15.1

An astronomical telescope consists of two convex lenses. The astronomical telescope in this experiment will form an image in the same place as the object (see Figure 15.1).

The lenses are thin compared to the other distances involved, which allows the Thin Lens Formula to be used:

(eq. 15.1)

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

where f is focal length, d_o is the distance between the object and the lens, and d_i is the distance between the image and the lens.

The magnification, M, of a two-lens system is equal to the product of the magnifications of the individual lenses:

(eq. 15.2)

$$M = M_1 M_2 = \left(\frac{-d_{i1}}{d_{o1}}\right)\left(\frac{-d_{i2}}{d_{o2}}\right)$$

Set Up

1. Tape the paper grid pattern to the screen to serve as the object.

2. The +200 mm lens is the objective lens (the one closer to the object). The +100 mm lens is the eyepiece lens (the one closer to the eye). Place the lenses near one

end of the optics bench and place the screen on the other end (see Figure 15.2). Their exact positions do not matter yet.

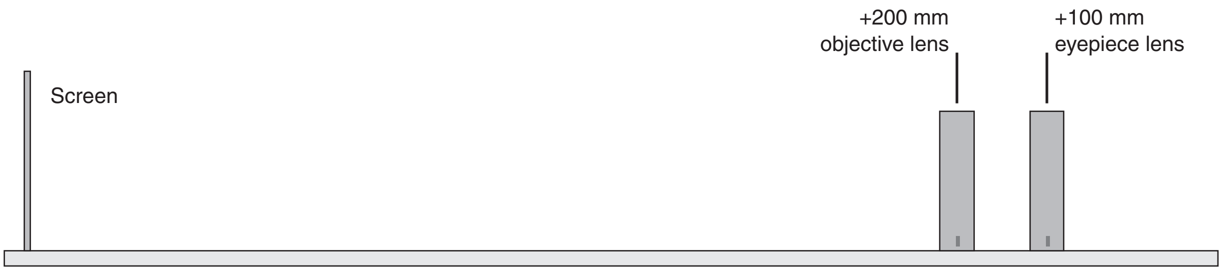

Figure 15.2

Procedure

1. Put your eye close to the eyepiece lens and look through both lenses at the grid pattern on the screen. Move the objective lens to bring the image into focus.

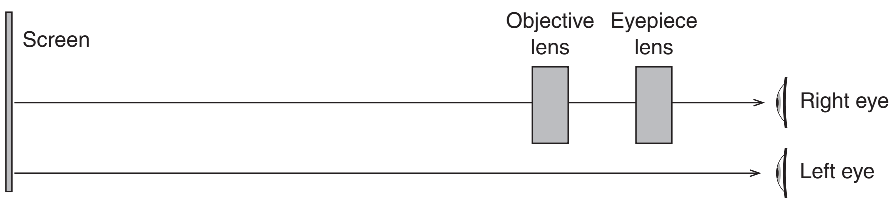

Figure 15.3

2. In this step, you will adjust your telescope to make the image occur in the same place as the object. To do this, you will look at both image and object at the same time and judge their relative positions by moving your head side to side. If the image and object are not in the same place, then they will appear to move relative to each other. This effect is known as parallax.

Open both eyes. Look with one eye through the lenses at the image and with the other eye past the lenses at the object (see Figure 15.3). The lines of the image (solid lines shown in Figure 15.4) will be superimposed on the lines of the object (shown as dotted lines in Figure 15.4). Move your head left and right or up and down by about a centimeter. As you move your head, the lines of the image may move relative to the lines of the object due to the parallax. Adjust the eyepiece lens to eliminate parallax. Do not move the objective lens. When there is no parallax, the lines in the center of the lens appear to be stuck to the object lines.

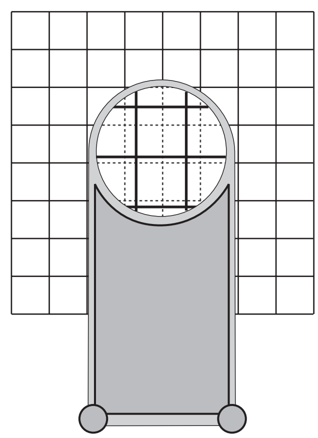

Figure 15.4

Note: You will probably have to adjust the eyepiece lens by no more than a few centimeters.

3. Record the positions of the lenses and screen in Table 15.1.

4. Estimate the magnification of your telescope by counting the number of object squares that lie along one side of one image square. To do this, you must view the image through the telescope with one eye while looking directly at the object with the other eye. Remember that magnification is negative for an inverted image. Record the observed magnification in Table 15.1.

Analysis

To calculate the magnification, complete the following steps and record the results in Table 15.1:

1. Measure d_{o1}, the distance from the object (paper pattern on screen) to the objective lens.

2. Determine d_{i2}, the distance from the eyepiece lens to the image. Since the image is in the plane of the object, this is equal to the distance between the eyepiece lens and the object (screen). Remember that the image distance for a virtual image is negative.

3. Calculate d_{i1} using d_{o1} and the focal length of the objective lens in the Thin Lens Formula (Equation 15.1).

4. Calculate d_{o2} by subtracting d_{i1} from the distance between the lenses.

5. Calculate the magnification using Equation 15.2.

6. Calculate the percent difference between the calculated magnification and the observed value.

Table 15.1: Results

Position of Objective Lens	
Position of Eyepiece Lens	
Position of Screen	
Observed magnification	
d_{o1}	
d_{i2}	
d_{i1}	
d_{o2}	
Calculated Magnification	
Percent Difference	

Questions

1. Is the image inverted or upright?

2. Is the image that you see through the telescope real or virtual?

Further Study

Image Formed by the Objective Lens

Where is the image formed by the objective lens? Is it real or virtual? Use a desk lamp to brightly illuminate the paper grid (or replace the screen with the light source's crossed-arrow object). Hold a sheet of paper vertically where you think the image is. Do you see the image? Is it inverted or upright? Remove the sheet of paper and hold a pencil in the same place. Look through eyepiece lens; you will see two images, one of the pencil and one of the grid pattern. Are both images inverted? Use parallax to determine the location of the pencil image.

Object at Infinity

Remove the screen and look through the lenses at a distant object. Adjust the distance between the lenses to focus the telescope with your eye relaxed. Estimate the observed magnification. Now calculate the magnification by taking the ratio of the focal lengths of the lenses. Compare the calculated magnification to the observed magnification.

How is the distance between the lenses related to their focal lengths?

Galilean Telescope

Make a new telescope using the -150 mm lens as the eyepiece and the +250 mm lens as the objective lens. Look through it at a distant object. Adjust the distance between the lenses to focus the telescope with your eye relaxed. How is the distance between the lenses related to their focal lengths?

How does the image viewed through this telescope differ from that of the previous telescope? Is the magnification positive or negative?