SIMPLE LENSES AND TELESCOPES

6

OBJECTIVES

After completing this exercise the student will be able to:

1. use an optical bench to find the focal length of a lens.
2. find the focal length of a lens when an object is placed at infinity.
3. calculate a telescope's resolving power, focal ratio, and magnification.

STUDENT MATERIALS

pencil
calculator

LAB MATERIALS

Each setup requires:

2 different lenses with different focal lengths
1 illuminated light source and/or object
1 screen and screen holder
1 lens holder
examples of several different types of telescopes should be set up around the lab room (one example of each type)

STUDENT REQUIREMENTS

This lab is to be done with a lab partner during the data collection period. You are to make calculations individually and to answer questions using your own words. After completing the lab, turn in answer sheets for **Parts A** and **B**.

INTRODUCTION

In the last lab you learned about the Laws of Refraction and Reflection. These basic laws of optics guide the construction of optical instruments that use lenses and mirrors. Lenses are used in many forms, from eyeglasses to microscopes to binoculars to telescopes. As parallel light passes through a convex lens, the light bends so that all the rays intersect at one point in space, called the focus (**Fig. 1**). The distance from the center of the lens to the focus is the

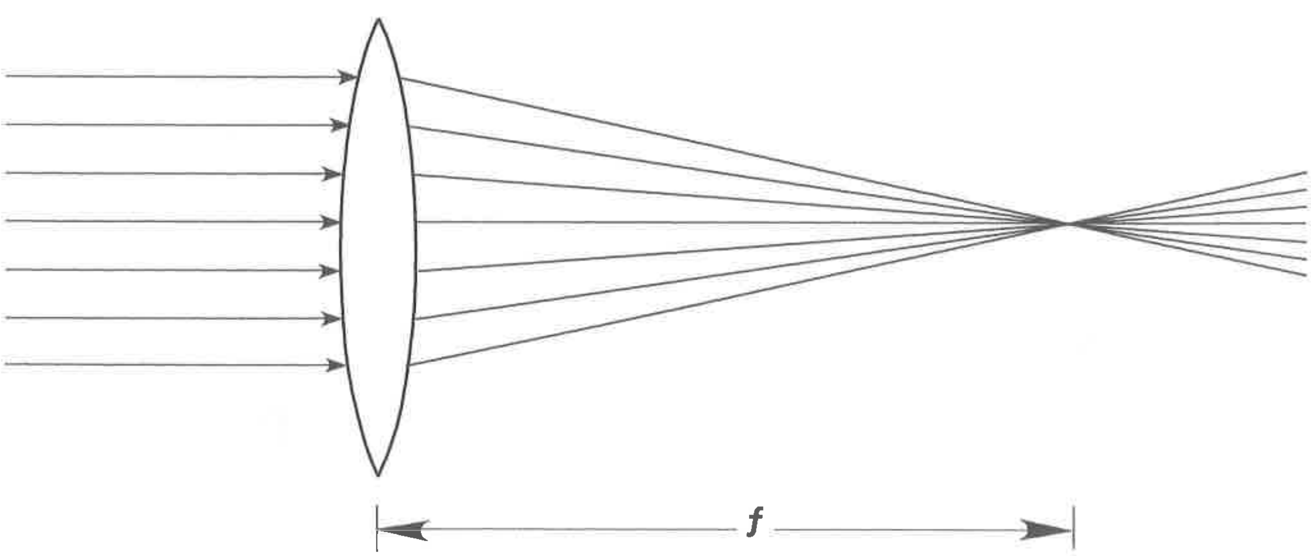

Fig. 1: Simple converging lens.

focal length. The focal length of a lens is constant and is determined by the lens's shape and material (glass, plastic, etc.).

Parallel light means that the light source is a point an infinite distance away from us. We can assume this is the case for stars. We cannot assume this for sources of light which are close to us (such as light bulbs). A finite-sized light source (like a light bulb) a finite distance away (like 30 centimeters) will emit light in all directions, not just parallel to the axis of the lens. In this case, **Fig. 1** does not show the correct situation. To find the focal length we must use the simple lens equation:

$$f = \frac{(S \times I)}{(I + S)}$$

where

f = focal length of the lens

I = image distance = distance from the lens to the image

S = object distance = distance from the source to the lens.

This equation says that:

focal length = image distance times object distance all divided by the sum of the image distance and object distance.

PROCEDURE

A. Measuring the Focal Length of Lenses

1. Set up your optical bench as shown in **Fig. 2**. The arrow is your source. The screen will hold your image. Note that the ruler in the bench is movable. Place the 0 cm mark so that the arrowed source is at 0 cm.
2. Be careful to touch only the edge of any lens. Carefully place the lens with orange paint on its edge, in the lens holder. Move the screen until you see a sharp image of the arrow. Record the object distance, **S**, and the image distance, **I**, on your lab report.
3. Move the lens on the optical bench to a new location and refocus. Again record **S** and **I**. Repeat this procedure a third time. You have now mea-sured the numbers you need to determine the focal length of this lens.
4. Calculate the focal length using the simple lens equation for each position of the lens. Record your answers to a tenth of a centimeter. Calculate the average focal length and record the result.
5. Use the lens with blue paint on its edge. Repeat steps 2, 3, and 4.

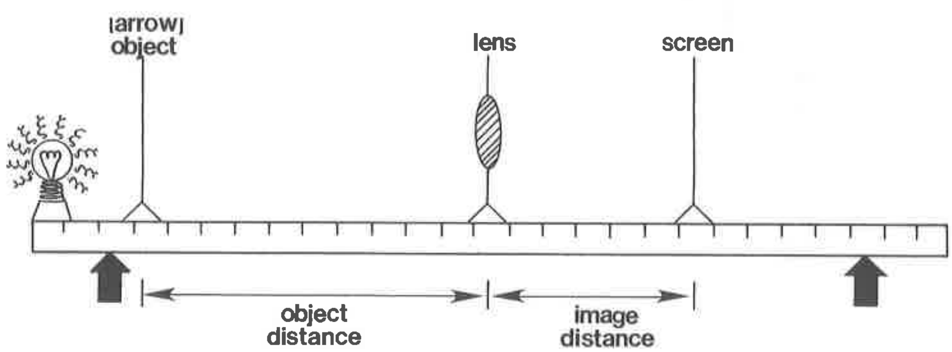

Fig. 2: Use this optical bench setup for the first part of this exercise.

6. Now carefully place both lenses together in the lens holder. Repeat steps 2, 3, and 4.

7. Carefully slide the light bulb (it is **HOT**) and arrowed object off the optical bench.

8. Place the orange lens in the lens holder. Aim the optical bench so that it points toward a window or down a long hallway. Adjust the screen until you see a sharp image of the scene. This image may be difficult to see. Record the image distance on your report form. (**Note:** There is no object distance because it is infinity.)

9. Move the lens to two more positions and measure the image distances.

10. Calculate the average value of **I**. How does this image distance compare to the average focal length for this lens, as obtained from the optical bench part? They should be about the same value.

11. Repeat steps 8 and 10 for the blue lens.

B. Telescopes

One or more telescopes have been set up around the room to be used for this part.

1. On each telescope is a card with the telescope's optical design, aperture, focal length, and eyepiece focal length. Record this information about each telescope on your answer sheet.

   While you are at each telescope, look at some scene outside the room. Notice the image's brightness, orientation and general quality.

   The steps below will reveal some important specifications about each telescope.

   Return to your seat for steps 2 through 5.

2. The focal ratio of a lens or telescope is an indicator of its photographic speed or image brightness. It can be calculated by dividing the telescope's focal length, f_o, by its aperture, D. Mathematically, this is written as

   $$\textbf{focal ratio} = \frac{f_o}{D}$$

   Since this is a ratio it is important that f_o and d be expressed in the same units. The larger the focal ratio is, the fainter the telescope's image will be. Thus a large ratio means a slower photographic speed.

   Calculate the focal ratio for each telescope set up in the lab room and record your answer in the space provided.

3. A telescope's angular resolution is its ability to see tiny angles. Usually, the resolution is expressed as an angle in seconds of arc or arcsec. For most optical telescopes the angular resolution can be calculated using

   $$\textbf{angular resolution} = \frac{11.6}{D}$$

   where D is the telescope's aperture in centimeters. The smaller the angular resolution, the smaller the details the telescope can see.

   Calculate the angular resolution of each telescope set up in the lab room and record your answers in the spaces provided.

4. One reason astronomers build large-aperture telescopes is to gather more light. You can catch more rainwater with a large bucket than with a small one. A telescope's light-gathering ability is directly proportional to the primary lens or mirror's surface area. Because most telescope optics have a circular lens or mirror the surface area is simply the area of a circle, which can be written as

   $$\textbf{telescope's surface area} = \pi \left(\frac{D}{2}\right)^2$$

   where $\pi = 3.14$ and D = telescope's aperture.

   Calculate the surface area of each telescope set up in the lab room. Record your answers in the spaces provided.

5. Magnification is simply the ratio of the telescope's focal length, f_o, to the eyepiece's focal

length, f_e. This can be written as

$$\textbf{magnification} = \frac{f_o}{f_e}$$

where f_o and f_e must be expressed in the same units. Notice that magnification is a ratio and therefore has no units. However, the symbol **×** is sometimes used to indicate how many ***times*** the object is enlarged. An example would be 150**×** for a magnification of 150 times.

Calculate the magnification of each telescope set up in the lab room. Record your answers in the spaces provided.

Please straighten up your lab area before you leave.

ANSWER SHEET

NAME: ______________________________

SECTION: ______________________________

PART A: Measuring the Focal Length of Lenses

Steps 1 to 6

Orange Lens

Trial No.	S in cm	I in cm	*f* in cm
1			
2			
3			

f_{ave} ____________

Blue Lens

Trial No.	S in cm	I in cm	*f* in cm
1			
2			
3			

f_{ave} ____________

Orange and Blue

Trial No.	S in cm	I in cm	*f* in cm
1			
2			
3			

f_{ave} ____________

Steps 7 to 11

Trial No.	I (orange)	I (blue)
1		
2		
3		

average I (orange) = ____________

average I (blue) = ____________

ANSWER SHEET

NAME: ______________________________

SECTION: ______________________________

PART B: Telescopes

1. Optical Design = ______________________________

   aperture = ______________________________

   focal length = ______________________________

   eyepiece focal length = ______________________________

   Calculate: focal ratio = ______________________________

   resolution = ______________________________

   surface area = ______________________________

   magnification = ______________________________

2. Optical Design = ______________________________

   aperture = ______________________________

   focal length = ______________________________

   eyepiece focal length = ______________________________

   Calculate: focal ratio = ______________________________

   resolution = ______________________________

   surface area = ______________________________

   magnification = ______________________________

3. Optical Design = ______________________________

   aperture = ______________________________

   focal length = ______________________________

   eyepiece focal length = ______________________________

   Calculate: focal ratio = ______________________________

   resolution = ______________________________

   surface area = ______________________________

   magnification = ______________________________