LESSON **22**

Combining Lenses

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How does a telescope work? Can you make one?

INTRODUCTION

A simple magnifier has only one lens. Do all optical devices that magnify objects have just one lens? Do microscopes or telescopes contain only one lens? If not, why do they contain more than one lens? How are these lenses selected, and how do they work together inside the device? In this lesson, you will investigate these questions as you select and use lenses to design and construct a simple telescope.

OBJECTIVES FOR THIS LESSON

Investigate a number of lenses and determine their type and approximate focal length.

Design and construct a simple telescope.

Discuss the role of the components of a telescope.

Getting Started

1. One member of your group should collect the plastic box of materials. Divide the materials between the pairs in your group. Each pair should have four different lenses.

2. Use your knowledge of lenses to determine the type and the approximate focal lengths of these lenses. Be prepared to share your conclusions with the class.

MATERIALS FOR LESSON 22

For you and your lab partner

4 lenses
1 meterstick
1 ball of clay
1 paper towel

SAFETY TIP

Never look at the Sun through your telescope. Doing so can permanently damage your eyes.

Inquiry 22.1
Making a Simple Telescope

PROCEDURE

1. Can a simple telescope be made using some of the lenses you have been given? Experiment with the lenses and determine whether they can be combined in some way so that they magnify a distant object.

2. When you have the lenses arranged, determine how you could use only the lenses, clay, and the meterstick to build a simple telescope.

3. Construct your telescope. Adjust it to obtain the clearest enlarged image you can of the distant object your teacher identifies. In your science notebook, draw a labeled diagram of your telescope. Also provide information on the type, focal length, and position of each lens in your telescope.

4. Examine the telescope made by another pair of students. Compare their design with yours. Here are some points to consider:

Have they used the same order, position, and combination of lenses?

Does their telescope work as well as yours?

Can you improve on your design?

5. Explain the construction of your telescope to the class. Your explanation should include information on the order, position, and focal length of the lenses you used.

6. Your teacher will ask you to view another object, closer than the one you looked at first. Adjust your telescope so that you can see the object clearly. Be prepared to discuss the following questions with the class.

   What adjustments did you have to make to get the object in focus?

   How are these adjustments made using a commercially made telescope or a pair of binoculars?

REFLECTING ON WHAT YOU'VE DONE

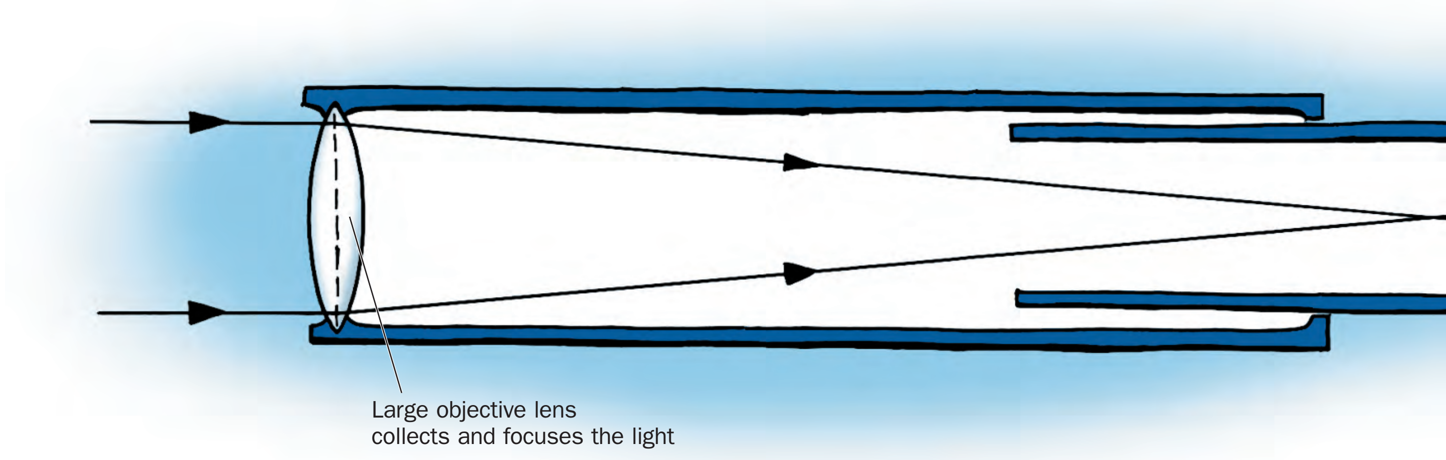
1. In your notebook, draw a diagram of a cross-section of your telescope. Include in your diagram the light rays from a distant object entering the lens of the telescope and their approximate paths from one lens to the other and to the observer's eye.

2. Read "How Telescopes Work."

3. Check your telescope design. Does it suffer from chromatic aberrations? What causes these aberrations, and which telescope design avoids them?

4. Before returning the lenses to the plastic box, use the paper towel to wipe off any fingerprints.

How Telescopes Work



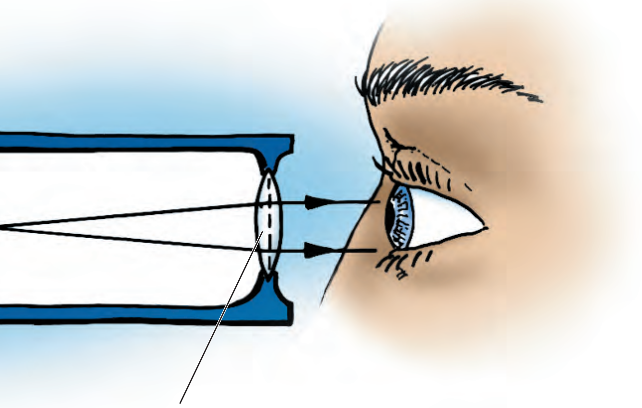
The components of a simple refracting telescope. This type of telescope is often referred to as a Keplerian telescope because it was used by the famous astronomer Johannes Kepler (1571–1630). Is the image produced by this telescope upright or inverted?

In 1608, a Dutch optician invented a device that altered our entire view of the universe. His name was Hans Lippershey (1570–1619). His invention arose from the simple observation that when two convex lenses were aligned at the correct distance from each other, they made distant objects look closer. By putting the lenses into a tube, Lippershey constructed what is believed to be the world's first telescope.

All telescopes collect electromagnetic radiation and focus it in some way. But not all telescopes are the same. Some, such as radio telescopes, do not use lenses at all. They don't collect visible light, but instead look for objects (for example, pulsars that emit radio waves) by using concave reflectors to focus invisible radio waves coming from the objects. Optical telescopes collect visible light. They come in two main forms: refracting telescopes, which use only lenses, and reflecting telescopes, which use mirrors and lenses.

Hans Lippershey's telescope was a refracting telescope. Refracting telescopes contain at least two lenses. The lens at one end of the tube of a refracting telescope collects light from a distant object. This lens is called the objective lens, and its job is to focus a real image of the object. The objective lens is usually large and has a long focal length. A second lens close to the eye—one with a shorter focal length—magnifies this real image. This lens is called the eyepiece. Lippershey's new invention was a boon to sailors and it spread rapidly along trade routes. Within a year of its invention, telescopes could be purchased in many parts of Europe. The telescope soon became popular with astronomers.

The Italian scientist Galileo (1564–1642) used the telescope to revolutionize astronomy. He modified Lippershey's earlier design by making the eyepiece a concave, rather than a convex, lens. One advantage of this design was

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Isaac Newton made this telescope. He has been credited with the construction of the first reflecting telescope. For this reason, these telescopes are sometimes called Newtonian reflectors.

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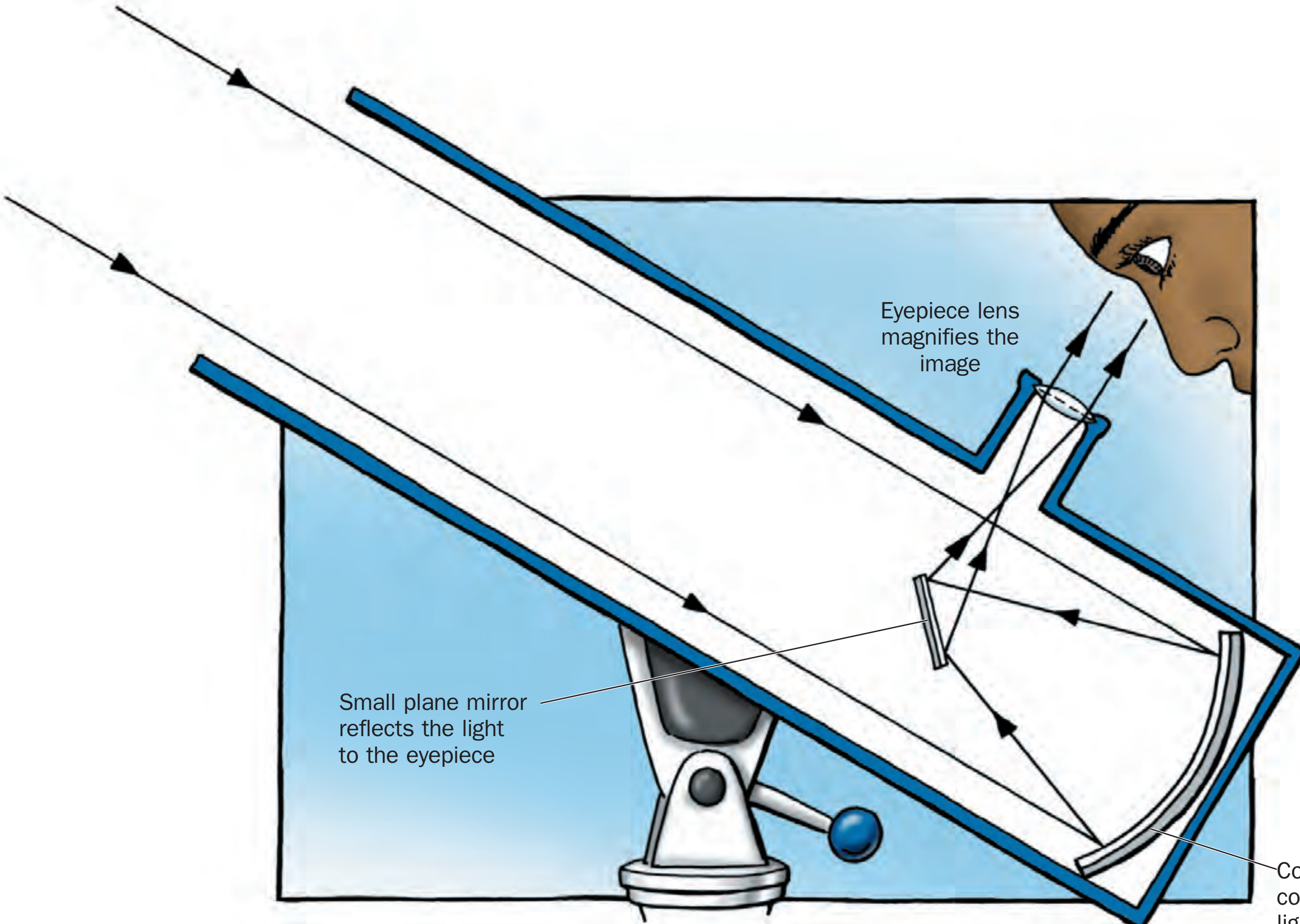
An early telescope being used for astronomical observation



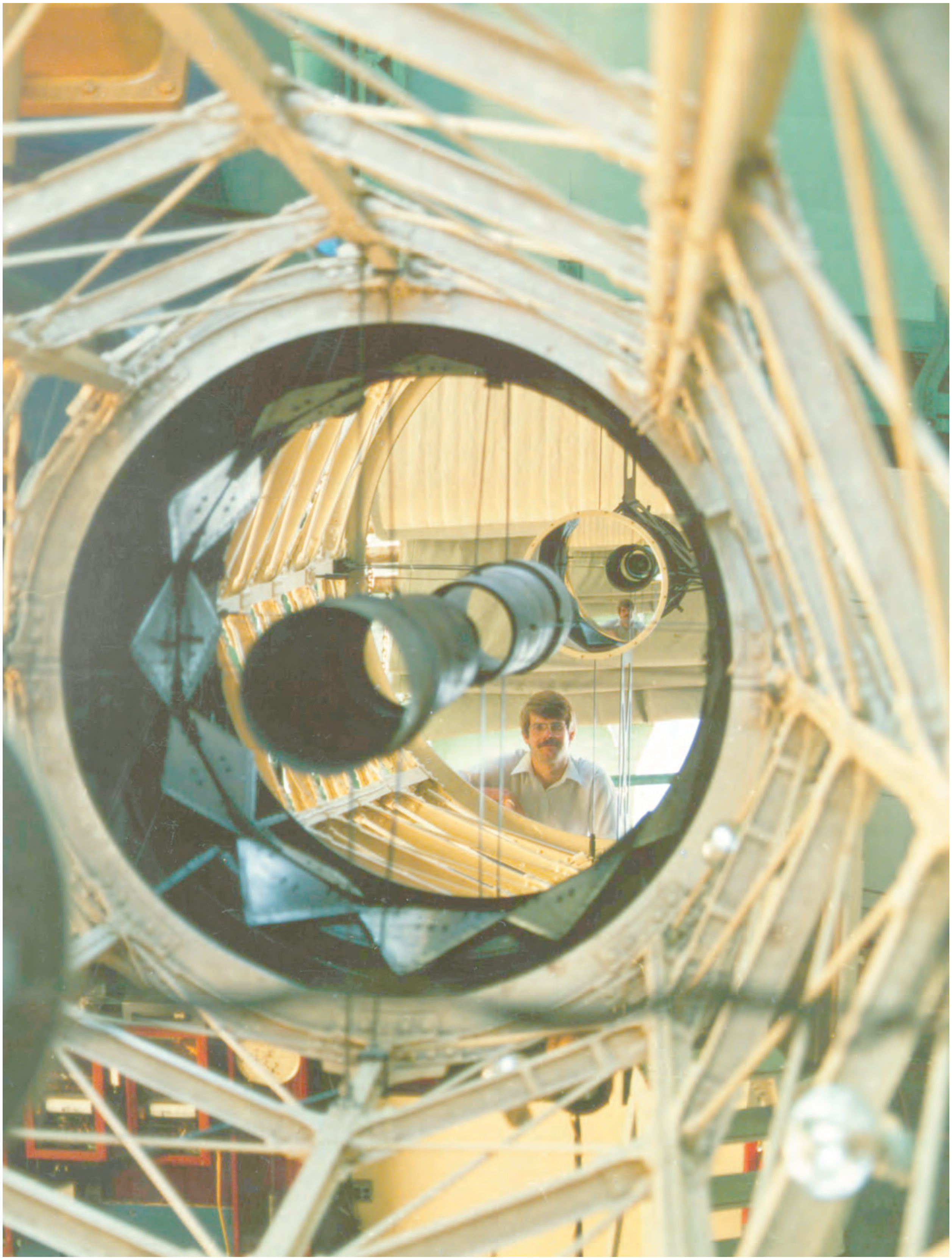
In a reflecting telescope, a concave mirror collects light, which is then directed by another mirror to the eyepiece.

that the final image was right-side up! However, the area of sky that could be observed with a Galilean telescope was smaller than the area that could be observed with Lippershey's design. Most modern refracting telescopes are closer to Lippershey's design but contain combinations of lenses to make the image upright.

But there is a problem with refracting telescopes. Their lenses can produce chromatic aberrations—a colored blur around the image you read about in Lesson 18. Modern telescopes contain achromatic lenses that reduce chromatic aberration to a minimum. Early astronomers built reflecting telescopes that solved the problem in a different manner. They used mirrors instead of lenses. It was probably Isaac Newton who built the first effective reflecting telescope. He followed a design suggested by Scottish astronomer James Gregory (1638–1675).

Light entering a reflecting telescope falls on a large concave mirror, usually at the bottom of a wide tube. The light is reflected onto another mirror, which diverts the image to an eyepiece on the side of the tube.

This basic design is still used, although sometimes the light is reflected back down through a hole in the mirror to an eyepiece. Because mirrors do not act as prisms, they don't split mixtures of different colored light and don't produce chromatic aberrations. Most big ground-based astronomical telescopes are reflecting telescopes. The Hubble Space Telescope you read about in Lesson 16 is also a reflecting telescope. □



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Which type of telescope is this? Reflecting or refracting?