Section 12.1 Characteristics of Lenses

(Student textbook pages 487 to 493)

Specific Expectations

- **E1.1** analyse a technological device or procedure related to human perception of light, and evaluate its effectiveness
- **E2.1** use appropriate terminology related to light and optics, including, but not limited to: *angle of incidence, angle of reflection, angle of refraction, focal point, luminescence, magnification, mirage,* and *virtual image*
- **E3.4** explain the conditions required for partial reflection/refraction and for total internal reflection in lenses, and describe the reflection/refraction using labelled ray diagrams
- **E3.5** describe the characteristics and positions of images formed by converging lenses, with the aid of ray diagrams

In this section, students will learn about the different types of lenses, the characteristics of the image formed by each of those lenses, and some of the practical difficulties in making those types of lenses. They will learn about aberration, which occurs when the rays of light do not completely focus at the same point, and the reasons different types of aberration exist.

Common Misconceptions

- Students may believe that the three principal rays of light (shown as red, green, and blue in ray diagrams in Chapter 10) are the only rays of light passing through the air. You can test this by asking students what would happen if they covered half of a lens with a piece of paper. A common answer is that half of the image would disappear. The correct answer is the light rays would be focussed from the half of the lens that light still passes through, so the image would be as clear, merely fainter. The three primary rays of light are chosen for ray diagrams only to simplify the process. If you have sufficient time, you could create a ray diagram with many random rays of light from an object, merely by noticing the angle at which each ray intersects the lens, and by using the index of refraction to accurately draw the path of the light ray.
- Students may think that refraction occurs at the axis of symmetry of a lens. The misconception may be due to the misinterpretation of ray diagrams such as Figure 12.6, which show a line of symmetry drawn through the middle of a lens. In reality, light rays refract at the boundary between media, so refraction occurs at both the front and back surfaces of a lens (as shown in Figure 12.7). Point out that this approximation is used to simplify the drawing of ray diagrams, and that students should think about how and where refraction actually occurs.

Background Knowledge

The study of mirrors, presented in Chapter 10, is the foundation for the study of lenses. Much of the terminology is the same. Curved mirrors can be classified as converging or diverging, depending on how light acts when it reflects off them. A concave mirror is a converging mirror because the reflected rays converge (come together at the focal point in front of the mirror). A convex mirror is a diverging mirror because the reflected rays diverge (spread out).

The mathematics of lenses is identical to the mathematics of mirrors except that a converging lens is one with convex surfaces, and a diverging lens is one with concave surfaces. A concave lens acts like a convex mirror: it produces a virtual image that is smaller than the object and upright. A convex lens acts like a concave mirror: when the object is close, the image is larger than the object, upright, and virtual; when the object is farther away, the image is inverted and real.

Lenses are made in a wide variety of shapes, and because some have both convex and concave surfaces, it may not be clear whether the lens is a diverging or converging lens. The simplest way for students to tell the difference is to check whether the edges of the lens come together to form a point, in which case you have a converging lens, or whether the edges are thicker than the middle, in which case you have a diverging lens. In practical terms, the difference is related to the amount of curvature on the two surfaces but students at this level can use a more intuitive approach.

Literacy Support

Using the Text

- ELL To help English language learners in particular, have students share their current knowledge of lenses, based on whether they wear glasses or contact lenses or know someone who does. Ask how lenses are commonly described.

Before Reading

- Have students preview the text features, looking for headings and highlighted words. In pairs, have them predict what the main ideas of the section will be.

During Reading

- Have students make connections to prior knowledge. Students may be familiar with some of the topics and it is a good idea to encourage them to identify what they already know about the material in the section.

After Reading

- Have students look for similarities between the text in this section and the text about curved mirrors in Chapter 10 sections 10.3 and 10.4. In pairs students can make a list of the similarities they notice.
- Point out the Study Toolkit for "Word Families" in the margin on page 489. Have students compare the words *converging* and *diverging*.

Using the Images

- For Figure 12.1, have students discuss challenges in making a lens that is only a few millimeters in size. Some possible challenges associated with a very small scale include gathering enough light to make an image, and any small irregularity becomes significant compared to the size of the lens. Conversely, you may wish to discuss challenges associated with a very large scale. The largest telescopes are reflector telescopes (with mirrors) and not refractor (with lenses), because the lens will start to bend under its own weight after it reaches about 2 m in radius. In real telescopes, the lenses have electronic currents that adjust their surface to compensate for the refraction in the atmosphere in much the same way that this tiny lens does.
- For Figure 12.2, have students try to read something using reading stones. You can purchase some glass beads at a craft store to serve as smaller versions of reading stones. Ask students to read some type such as in the textbook with these, and try to determine what they see.
- The middle lens in Figure 12.3A and the rightmost lens in Figure 12.3B look very similar because they both have a convex surface and a concave surface. Ask students to describe two major differences. One is that the curvature of the converging lens is greater on the convex side then on the concave side, and vice versa for the diverging lens, so one side dominates. Another difference is that the diverging lens will always be thicker on the edges than in the centre, but in the converging lens this is the opposite.
- Students will produce a diagram similar to Figure12.4 if they did Activity *11.2 Investigating Properties of Light* in the last chapter.
- Figure 12.6 shows the focal point for a converging lens and a diverging lens. To help students visualize the situation, explain: If you physically had a lens, you could find the focal point of the converging lens quite easily, because that is where light converges to a single point.

- Referring to Figure 12.7, students could investigate how an increasing curvature affects both the operation in the magnification potential or other properties of lenses. The greater the curvature of the lens, the smaller the radius of curvature will be, and therefore the closer the focal point will be. Students may be able to see this from Figure 12.7. They should be able to make predictions about how a lens with more curvature will affect image properties such as magnification, location of the image, and so forth.
- Referring to Figure 12.8 (the fisheye lens) point out that the distortion is comparable to what students would have seen in the picture for the chapter opener in Chapter 11, where this aspect of refraction was discussed. (The light for a straight overhead in the photo of the scuba divers was fairly undistorted, but the distortions grew increasingly large near the edges, because of refraction.)
- Figure 12.9 shows two different types of aberration (spherical and cylindrical) but it may not be clear to students which one is which. Explain that if the lens was shaped like a parabola, there would be no aberration. However, in practical terms it is easier to manufacture cylinders or spheres and cut lenses and mirrors from those shapes. Because neither a cylinder nor a sphere is parabolic in shape, the light rays will not always meet exactly at the focus. This results in spherical aberration, as illustrated in Figure 12.9A, where the light rays do not come together (focus) exactly. In Figure 12.9B chromatic aberration is caused not only by the effect above, but also by the fact that different colours of light have a somewhat different index of refraction, so the same lens will bend different colours by different amounts. You can see both types of aberration in Figure 12.9C: the letters near the edge are stretched out due to spherical aberration and split into rainbow colours due to chromatic aberration.

Assessment FOR Learning		
Tool	**Evidence of Student Understanding**	**Supporting Learners**
Learning Check questions, page 489	Students describe and/or draw ray diagrams of converging and diverging lenses.	Have students complete **BLM 12-5 Drawing Ray Diagrams for Converging Lenses** and **BLM 12-6 Drawing Ray Diagrams for Diverging Lenses** which scaffold the process of drawing ray diagrams as shown in Tables 12.1 and 12.2.
Section 12.1 Review questions, page 493	Students locate focal points of converging and diverging lenses (questions 5 and 6) and explain aberrations (questions 7 to 9).	Give students a description of what a lens should do, then have them draw an appropriate lens shape. Or, ask students to compare the images that would be formed by a given lens. Select alternative or remedial questions from **BLM 12-4 Section 12.1 Review (Alternative Format).**
Activity 12-2 Hocus Focus, page 491	Students determine image characteristics and focal lengths of different converging lenses.	To help students describe the characteristics of images formed by converging lenses (e.g., orientation, size, type), have them sketch ray diagrams using **BLM 12-5 Drawing Ray Diagrams for Converging Lenses.**

Instructional Strategies

- DI This unit focuses on students who have well-developed intelligences in either linguistic, logical-mathematical, or spatial learning.
- To engage interest, have students carry out Inquiry Investigation 12-A Image Characteristics of a Converging Lens. See page TR-4-68 of this Teacher's Resource for notes on using this investigation.
- Have students complete Activity 12-2 Hocus Focus. See page TR-4-57 of this Teacher's Resource for notes on conducting this activity.

- Have students work on the Section 12.1 Review questions during class so remediation can be given where necessary, either from a partner or you, the teacher. Additional or alternative questions could be selected from **BLM 12-4 Section 12.1 Review (Alternative Format).**
- As students read pages 507 to 509, have them add detail to the –opia word family table they created in the chapter opener (*myopia, hyperopia,* and *presbyopia*). Astigmatism also relates to vision trouble, but does not belong to the same word family. Have students suggest why (e.g., a quality problem rather than a shape problem).
- After reading page 489, have students create a word family table for *converging* and *diverging*. Refer students to the Word Study feature on page 489. They may also find **BLM G-40 Word Study** helpful.

Learning Check Answers (Student textbook page 489)

1. A lens must cause rays of light to diverge (spread out) or converge (come together).
2. **a.** A converging lens is thicker in the centre than it is on the edges. A diverging lens is thicker on the edges than it is in the centre.
   b. See right lens in Figure 12.3A and centre lens in Figure 12.3B on page 488.
3. Diagrams should look like Figure 12.5B on page 489, except that only half of each lens should be shown.
4. The inside of the contact lens must be concave, to fit on the eye. The outside must be convex.

Activity 12-2 Hocus Focus (Student textbook page 491)

Pedagogical Purpose

This activity gives students hands-on experience with the phenomenon that they have been describing. It also provides them with an opportunity for inquiry learning. Students practise these skills: performing and recording; analyzing and interpreting; communicating.

Planning	
Materials	Several different converging lenses Sheet of paper Metric ruler
Time	60 min
Safety	Remind students not to look at the Sun through a magnifying lens because they may burn out their retinas. If you are using outside light as a source for the image, ensure the converging lenses are not used to burn objects.

Background

This activity flows out of the textbook narrative on converging lenses. Because the lens in the human eye is convex, it is subject to all of the properties and difficulties inherent in convex lenses, including aberration and focussing the image exactly on the retina.

Activity Notes and Troubleshooting

- The biggest challenge in this lab is the light source. Blocking light from most windows makes this activity easier to perform. If you have a classroom with blackout blinds or one with no exterior windows, this activity can be done using a candle for a light source.
- Have students create the observation chart the day before (as homework), or distribute **BLM 12-2 Hocus Focus** which scaffolds this process.

- Students may have difficulty getting an image on the screen. The most likely reason for this is that they are holding the lens and the screen too close together, so that only a virtual image can form. To get an image, the screen must be more than one focal length away from the lens.
- To assess students' data collection, use **BLM A-35 Measuring and Reporting Rubric.**
- To assess students group work, use **BLM A-39 Co-operative Group Work Rubric.**

Additional Support

- Model the activity and what students should see. You may wish to write down a sample set of observations before letting students complete them on their own.
- You may want to practise with the lenses that students will be using to find the appropriate focal length and image position, so that you can coach students.

Answers

1. The image is smaller than the object and upside down.
2. The thicker the lens, the smaller its focal length.

Section 12.1 Review Answers (Student textbook page 493)

Please also see **BLM 12-4 Section 12.1 Review (Alternative Format).**

1. Lenses have two sides. Either side could be plane, concave, or convex.
2. A converging lens brings parallel light rays together. A diverging lens causes parallel rays to spread out. Students' diagrams should be similar to Figure 12.5.
3. A = converging; B = diverging; C = diverging; D = converging
4. Diagrams should be similar to Figure 12.6B. The focal point F is located by extending the exiting rays backwards and marking their intersection point.
5. Light can pass through a lens from either side, so there is a focal point on each side of the lens at the same distance from the centre of the lens.
6. The photo is fuzzy and shows extra colours at the edges of the structure. This occurs because the edges of the camera lenses disperse the light into colours.
7. Diagrams should be similar to Figure 12.9B. Chromatic aberration is the dispersion of light through a lens, especially at the edges of the lens. Light rays that pass through the lens near the principal axis meet at the focal point. For converging and diverging lenses, the rays that are farther from the principal axis do not pass through the focal point. The edges of converging and diverging lenses are like prisms, so the light gets separated into different colours. High-quality cameras combine many lenses to reduce chromatic aberration.
8. Spherical aberration is caused by the curvature of a mirror and both sides of a lens. Chromatic aberration is caused by the refraction that occurs when light passes from one medium to another, which occurs twice in a lens. (With mirrors, light is reflected and does not pass through a mirror.)