## Section 12.2 Images Formed by Lenses

(Student textbook pages 494 to 501)

In this section, students will predict the location and characteristics of images formed by converging lenses and diverging lenses, using ray diagrams and algebraic equations (the thin lens equation and the magnification equation).

### Common Misconceptions

Students may think that the three rays used to create a ray diagram are just representative and happen to be easy to trace. If you had the time and patience, you could trace rays in any direction toward the lens, accurately calculate the angles of refraction at both surfaces, and locate the image. Only two rays are needed to determine the intersection point. The third ray serves as a check. If the rays do not converge at exactly one point, either the work or the lens contains errors.

### Background Knowledge

The images formed by lenses are very similar to those formed by mirrors. Converging. lenses and converging mirrors act in a fashion comparable to each other, as do diverging lenses and diverging mirrors. The main difference, of course, is that you look through a lens, whereas light is reflected from a mirror. One consequence of this is that virtual images are visible to us as real images. Because we are looking through the lens, our eyes will focus the light rays for us, and thus, if we are looking at a virtual image, it can be focussed by our eyes on our retinas. This is why glasses can be used to help people see objects in the distance clearly, when those glasses are made with diverging lenses.

### Literacy Support

#### Using the Text

- Most tables contain only text or numbers. However, Table 12.1 is unusual in that it shows ray diagrams and text describing how to make the ray diagram and how to use it to solve problems involving optics. Review with students how the technical writing (used in this case to illustrate a process to develop skill) differs from text that delivers data only.

**Before Reading**

- Discuss the meaning of *diverging* with respect to rays of light (i.e., light rays that spread apart from the source).
- Discuss the meaning of *converging* with respect to rays of light (i.e., light rays that come together to focus at a specific point).

**During Reading**

- Emphasize that students are seeing the same thing described in two or three different ways. A ray diagram, the verbal description of characteristics, and the equations are all ways of predicting where the image will appear.
- Have students compile a list of questions as they read the text. This will help focus their reading and will serve as an organizer for information they still need to learn.

**After Reading**

- DI Bodily-kinesthetic learners might find it easier to solve the lens equation by physically setting up lenses as described in the question, observing the image, creating a ray diagram, and then retroactively performing the calculations.

#### Specific Expectations

- **E3** demonstrate an understanding of various characteristics and properties of light, particularly with respect to reflection in mirrors and reflection and refraction in lenses.
- **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*
- **E2.3** predict the qualitative characteristics of images formed by plane and curved mirrors, test their predictions through inquiry, and summarize their findings
- **E2.5** predict, using ray diagrams and algebraic equations, the position and characteristics of an image produced by a converging lens, and test their predictions through inquiry
- **E3.5** describe the characteristics and positions of images formed by converging lenses, with the aid of ray diagrams

### Using the Images

- For Figure 12.11, have the students explain why they think a smaller image is described as being further away. What possible uses could there be for either of these sorts of lenses?
- When drawing ray diagrams, as shown in Figure 12.12 and described in Tables 12.1 and 12.2, students can use a different colour for each ray. This benefits most students because it helps them to connect and remember the instructions and the procedure. You can model this by using three different colours of chalk on the board, or three different colours of marker on a white board. Use the same colour for writing the rule as for drawing the ray in a ray diagram.
- For Figure 12.13, it would be useful for students to reproduce this in their notes, because it relates the variables to the letters that represent them and their physical representations. You might ask students to use the diagram to help answer the following question: Are all images formed by converging lenses inverted? (Answer: No. Whether or not the image is inverted depends on where the object is in relation to F.)
- Gravitational lenses, the subject of Figure 12.14, were predicted by Einstein's theory of relativity. Even today they are used to test this theory. The mass of the nearby galaxy operates like a lens on space-time itself, allowing light to be focussed from a more distant galaxy. Depending on the exact geometry, between one and 16 different images of the distant galaxy will be formed. The number of images can and has actually been used to test different theories of relativity. In Figure 12.14B, the blue ring is sometimes referred to as Einstein's ring.

**Assessment FOR Learning**

| Tool | Evidence of Student Understanding | Supporting Learners |
|---|---|---|
| Learning Check questions, page 498 | Ray diagrams show light rays meet at a focus point to indicate formation of an image. Four characteristics are stated for each image. | Review the meaning of the coloured rays used in Table 12.1 and 12.2 to confirm sequence. Have students use **BLM G-45 Spider Map** to create a spider map summarizing the qualities of images made by each type of lens. |
| Section 12.2 Review questions, page 501 | Students use the thin lens equation to calculate height, orientation, and location of image. | Have students complete **BLM 12-7 Using the Thin Lens and Magnification Equations for Converging Lenses** which provides scaffolding for the questions. |

## Instructional Strategies

- Some students might find it helpful to remember the four characteristics of images by using the acronym LOST (Location, Orientation, Size, and Type). The characteristics of images formed by lenses are the same as those formed by mirrors.
- When working on questions involving the use of algebra, encourage students to list all the information first before they use the equations to calculate the unknowns (e.g., For Practice Problem 1: $f = 12.0$ cm, $h_o = 63.0$ cm, $d_o = 54.0$ cm, $d_i = ?$, $h_i = ?$). Then, students should check their solution by drawing a ray diagram similar to the appropriate one in Figure 12.12.
- There is no lab activity in this section, however Inquiry Investigation 12–A Image Characteristics of a Converging Lens, applies well here if it was not already done.
- Lead students through the sample problem "Using the Thin Lens and Magnification Equations for Converging Lenses" on page 499 in the student textbook. Then, have them work through the Practice Problems on page 500 individually or in pairs. Have students check each others' work and address any common difficulties to the class as a whole. You may wish to provide **BLM 12-7 Using the Thin Lens and Magnification Equations for Converging Lenses** which scaffolds the process.

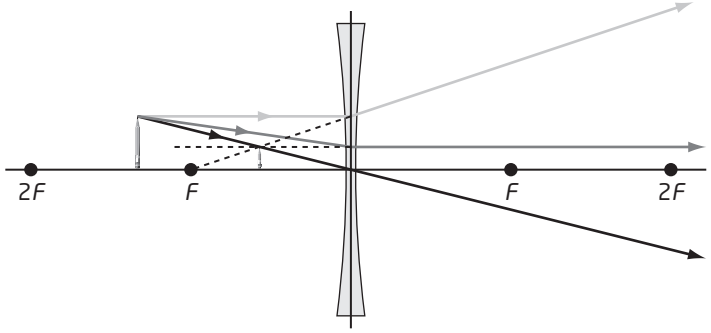
- To assess students' work on the Practice Problems, use **BLM A-17 Science-Math Connect Checklist.**
- Talk with the class about the Making a Difference feature, where the student has created a model. Point out that for every description of light we have made in this unit, all we have been able to describe is how light reacts under certain circumstances. Our best description of light is that it is a form of energy that can act like both a wave and a particle; in other words, it behaves like nothing else in our day-to-day world. Developing better models for light is an ongoing activity among physicists. Some students may find it interesting to realize that they have been studying a phenomenon for which nobody truly understands the details.
- Have students work on the Section 12.2 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 12-8 Section 12.2 Review (Alternative Format).**
- Encourage students to make links between their understanding of mirrors and lenses. They may notice, for example, that the thin lens equation is the same as the mirror equation from Chapter 10. They may also notice that a diverging lens has two concave surfaces, and that a converging lens has two convex surfaces.
- To help students differentiate between diverging and converging lenses, have them examine the edges. When the sides are closer together at the edges than at the middle, they converge. When the sides are farther apart at the edges, the lens diverges.

## Learning Check Answers (Student textbook page 498)

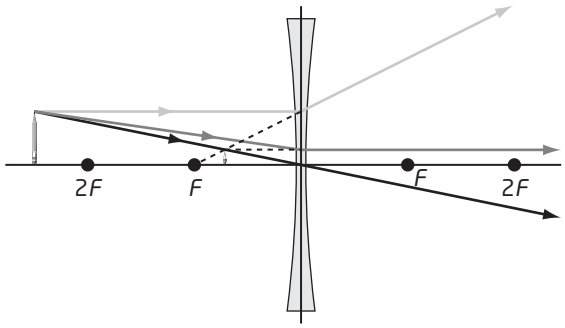
**1.** Image is inverted, real, larger than object, and farther from lens than object (past focal point, just past 3F). Diagrams should be similar to Figure 12.12B on student textbook page 496.

**2.** Image is inverted, real, smaller than object, and closer to lens than object (past focal point, almost as far as 2F). Diagrams should be similar to Figure 12.12C on student textbook page 496.

**3.** Image is upright, virtual, smaller than object, and between lens and focal point.




**4.** Image is upright, virtual, smaller than object, and between lens and focal point.



## Section 12.2 Review Answers (Student textbook page 501)

Please also see **BLM 12-8 Section 12.2 Review (Alternative Format).**

1. **a.** through F on the other side of the lens; All rays travelling parallel to the principal axis leave the lens in a direction that goes through the focal point.
   **b.** continues in the same direction after passing through the lens; The centre of the lens acts like a flat piece of glass. All rays passing through flat glass continue in the same direction.
   **c.** leaves the lens parallel to the principal axis; All rays entering a converging lens from a focal point, leave the lens and travel parallel to the principal axis.
2. When parallel rays pass through a converging lens, they converge. If the incident rays are not parallel they must be extended backward to find the image. As a result, there are no actual rays meeting at the image and the image is virtual.
3. **a.** converging lens
   **b.** between one and two focal lengths
4. The image is smaller than the object and is upright. A diverging lens formed the image.
5. $d_i = 80$ cm; $h_i = -5.50$ cm
6. Diagrams should be similar to the one on page 501, with the three rays drawn using the process described in Table 12.2. Image characteristics: closer to the lens than the object and on the same side of the lens, upright, smaller than the object, and virtual.
7. Diagrams will be similar to Figure 12.12B. $d_i = 18.7$ cm; $h_i = -4.0$ cm (inverted).
8. A gravitational lens is a large galaxy that causes light to bend toward it, making objects behind it visible.