Topic 4.6
What are lenses and what are some of their applications?

Specific Expectations

- **E2.1** use appropriate terminology related to light and optics, including, but not limited to: *angle of incidence, angle of reflection, angle of refraction, centre of curvature, focal length, luminescence, magnification, principal axis, radius of curvature,* and *vertex*
- **E2.4** predict the qualitative characteristics of images formed by converging lenses, test their predictions through inquiry, and draw ray diagrams to record their observations
- **E2.7** construct an optical device that uses a variety of mirrors
- **E3.8** explain how the properties of light or colour are applied in the operation of an optical device

Skills

- formulate scientific questions
- select appropriate instruments and materials and use them safely
- select, organize, record, and interpret relevant information
- communicate ideas, plans, and procedures using appropriate language
- use appropriate numeric, symbolic, and graphic modes of communication

Materials

Please see the teaching notes for each activity for a list of the materials required. Please see pages TR-50 to TR-52 for a summary of the materials required in this topic.

Overview

In this topic, students will investigate properties and uses of converging lenses. Students will learn that lenses have at least one curved surface and refract light in predictable ways. Additionally, they will come to realize that lenses can be used to produce different types of images.

Common Misconceptions

- **Students are generally familiar with the use of converging lenses, such as hand lenses (magnifying glasses), but are unfamiliar with combinations of lenses used in, for example, telescopes and cameras.** Provide many opportunities for students to see optical instruments at work.
- **Many students do not believe it is possible to capture images with only a converging lens.** Demonstrate that it is possible by holding a piece of paper at the appropriate distance from a magnifying glass to capture an image.

Background Knowledge

Lenses transmit and bend rays of light to enable images to form. Many lenses are made of highly polished glass or transparent plastic that has nearly perfect axial symmetry. Lenses are rarely found singly in optical devices. Rather, they are found in combinations of lenses and are usually referred to as compound lenses.

Converging lenses have the ability to focus rays from a beam of light through a focal point. By contrast, diverging lenses disperse rays as if they all originated from a single focal point. Combinations of converging and diverging lenses are used to correct vision, produce sharp images in optical equipment, and focus light on distant objects.

Diverging lenses are presented only to contrast the characteristics of converging lenses. There is no requirement in the curriculum for students to understand the properties of diverging lenses.

Literacy Strategies

Before Reading

- Review the key terms with students. Have students examine Figure 4.43 on page 346 of the student textbook to see how converging lenses and diverging lenses differ.
- Ask students to answer the topic question in their own words and save their answer to reflect on during and after reading. You could create a concept map about lenses with students, and add to it after reading the topic.

During Reading

- As students read this topic, ask them to work with a classmate and use sticky notes to highlight sections that they do not understand.
- As students read, encourage them to make connections between items in the margins (for example, key terms, diagrams, and captions) and the main text. Ask how these items are connected or related to one another.

After Reading

- Ask students to summarize two things they learned in this topic and one thing they still do not understand.
- Ask students to work together to describe how the key points in the topic connect to daily life. This could be a think-pair-share activity.

Assessment FOR Learning

Tool	Evidence of Learning	Supporting Learners
Activity 4.21, page 349 Learning Check, page 349	Students draw a ray diagram to show formation of an image for a converging lens and interpret the ray diagram to draw conclusions about converging lenses.	• Model the drawing process using the steps in Table 4.6 on page 348, and then provide alternative examples. • Consider enlisting the help of a peer tutor, perhaps from a senior physics class, to provide additional help for students. • Students can use **BLM 4-20 Converging Lens Template** to draw their ray diagrams.
Learning Check, page 350 Investigation 4C, page 353	Students create and describe images with different characteristics formed by objects at differing distances from converging lenses.	• Provide explicit instructions for the observation table students create in Investigation 4C. They should include columns for image size, orientation, distance from lens, and type (real or virtual). • Demonstrate image formation for objects at different distances using an interactive white board or chalkboard. Students can practise creating ray diagrams for images of objects at different distances by placing a small object on a copy of **BLM 4-20 Converging Lens Template** and placing stir sticks on the diagram to represent light rays.

Topic 4.6 (Student textbook pages 344–355)

Using the Topic Opener

- One of the big ideas for this unit is the wide range of technologies that utilize the properties of light. Many of these technologies use lenses. Have students brainstorm a list of technologies that use lenses with a classmate, then share their ideas with the class. Students can also share experiences they have had with lenses, for example, trying to focus binoculars or looking through a telescope. Students wearing corrective eyewear may wish to share their experiences and feelings with the class.
- Ask students to use what they already know about light to explain why the image seen through the lens on page 345 is upside down.

Starting Point Activity (Student textbook page 345)

Pedagogical Purpose

Students will see that a single drop of water can demonstrate properties of a converging lens.

Planning	
Materials	Per group: 10 cm × 10 cm piece of waxed paper half a sheet of newspaper medicine dropper water
Time	10 min in class 10 min preparation

Activity Notes and Troubleshooting

- Students should conduct this activity in pairs or groups of three. Each student could have his or her own materials, and the group could compare observations and support one another.
- As students are working, focus their attention on the bending of light as it enters and exits the drop of water.

Additional Support

- Students may also wish to look at a sample of their own writing or a drawing through the drop of water.
- Students with visual challenges may find this activity difficult. Have a classmate with excellent communication skills describe the process to them.
- Have a labelled ray diagram showing refraction on display for students to refer to as they respond to the What Did You Find Out? questions.

Starting Point Activity Answers

1. The single drop of water provided a magnified view of the chosen letter.
2. The larger drop of water was able to collect more rays of light and expand the field of view, and may have affected the magnification of the image.
3. For water drops of different shapes, the air-water interface will be at a different angle, and the light rays passing through it will refract in a different direction.

Instructional Strategies for Topic 4.6

Student textbook pages 346–349

- Demonstrate the properties of converging and diverging lenses by attempting to focus rays to a single point and also to capture an image. This will be possible with a converging lens but not so with a diverging lens. Pairs or groups of students could experiment with both types of lenses to become familiar with their properties.
- Use a large diagram of a converging lens to demonstrate the three rules for drawing rays to find images, as shown on page 347.
- In Table 4.6 on page 348, point out that rays are simplified in ray diagrams. Although we know they change direction at the interface between air and lens, they are drawn to change direction at the centre of the lens.
- Make liberal reference to key terms, especially *incident ray, medium,* and *refracted ray,* to provide students with the means to describe the optical phenomena that they are investigating.

Student textbook pages 350–352

- Lenses enable formation of images, both real and virtual; ensure that students have an opportunity to experience both types. To experience virtual images, students will need to place the object between the focal point and the lens. Table 4.7 on page 351 shows how to draw a ray diagram for a virtual image. Have students categorize the images they see using lenses such as magnifying lenses, cameras, and the lenses in their eyes as real or virtual.

Learning Check Answers (Student textbook page 347)

1. Lenses have one focal point on each side.
2. Venn diagrams should contain the following points.
   Converging lenses: rays of light come together
   Diverging lenses: rays of light spread apart
   Both: refract light, have two focal points, are made of transparent material, have at least one curved side
3. A ray passing through a lens at the principal axis will strike the lens with an angle of incidence of zero and therefore will not refract or change direction.

Activity 4.21 Drawing and Analyzing Ray Diagrams for Converging Lenses (Student textbook page 349)

Pedagogical Purpose

Students will draw ray diagrams to show formation of images in converging lenses and predict the qualitative characteristics of the images formed.

Planning	
Materials	Per student: paper pencil ruler **BLM 4-20 Converging Lens Template** (optional) **BLM G-9 Data Tables** (optional)
Time	25 min in class 5 min preparation

Skills Focus

- record information in tables and in ray diagrams
- interpret observations and draw conclusions

Activity Notes and Troubleshooting

- Consider inviting a peer helper, preferably a senior physics student, to assist with students requiring support.
- Before students begin, model drawing a ray diagram using a chalkboard or interactive white board and the steps in Table 4.6.
- Discuss students' predictions in What Did You Find Out? question 2. Encourage students to justify their predictions based on their observations.

Additional Support

- DI Pair students who have strong logical-mathematical skills with those who require support.
- ELL You may wish to pair English language learners with classmates who have strong English communication skills.
- If students require support creating data tables, they can refer to Science Skill 8, Creating Data Tables, on page 390, and create their table using **BLM G-9 Data Tables.**
- Students could use **BLM 4-20 Converging Lens Template** for their drawings.

Activity 4.21 Answers

1. **a)** smaller
   b) larger
2. The object and image heights will be the same.

Learning Check Answers (Student textbook page 349)

1. It will be directed through the focus on the opposite side of the lens.
2. The third ray is a check to make sure that you have located the image correctly.

Learning Check Answers (Student textbook page 350)

1. A converging lens can produce real inverted images if the object is farther from the lens than the focal point. The same converging lens can produce upright virtual images if the object is between the focal point and the lens.
2. Table 4.7 shows formation of a virtual image. The light rays spread out when the object is between the focal point and the lens. The image is the path of light that your eye interprets.
3. upright, virtual, farther from lens, and larger than the object

Activity 4.20 Finding the Focal Length of a Converging Lens

(Student textbook page 352)

Pedagogical Purpose

Students will use an investigative approach to determine the focal length of a converging lens and make inferences about the effect of thickness on focal length.

Planning		
Materials	Per group: 3 or more converging lenses of different focal lengths (roughly similar in diameter)	sheet of paper metric ruler metre stick (optional)
Time	20 min in class	
Safety	Caution students not to look at the Sun directly or through a lens.	

Skills Focus

- analyze and interpret quantitative data
- draw conclusions based on observations

Activity Notes and Troubleshooting

- A bright window is an excellent source of light. On overcast days use an intense lamp situated at a distance from students.
- Students can share lenses. Label each lens to help students identify them.
- Groups of three are ideal for this activity: one to hold the lens, one to hold the screen, and one to take measurements. Students should take a turn with each role.
- Stress careful measurement of the focal length and tell students the number of decimal places that they should use to record their observations.
- Students can place a metre stick on a flat surface, then hold the lens at one end of it. When they find a focussed image of the light source on their screen, it will be easy to measure its distance from the lens.

Additional Support

- DI Pair students who have strong logical-mathematical skills with those who require support to activate their pattern-recognition abilities.
- Students with visual challenges will find this activity difficult; have a classmate with strong communication skills describe the process to them.
- DI Allow bodily-kinesthetic learners to move around the room, or extend the activity outdoors if weather conditions permit and if adequate supervision is available.
- ELL You may wish to pair English language learners with classmates who have good communication skills. A quick demonstration of what to do should help all students understand the instructions.

Activity 4.20 Answers

Answers may vary depending on the focal lengths of the lenses. For example:

Description of Lens	Maximum Thickness of Lens (mm)	Focal Length (cm)
Transparent, slightly thickened glass	5.5	15.0
Transparent, moderately thickened plastic	9.0	10.0
Transparent, extremely biconcave plastic	12.5	8.0

What Did You Find Out?

1. The thicker the converging lens is, the smaller its focal length is.

Investigation 4C Investigating Converging Lenses

(Student textbook page 353)

Pedagogical Purpose

Students will use an investigative approach to determine the characteristics of images produced with a converging lens placed at fixed distances from the screen.

Planning		
Materials	Per group: converging lens lens holder metre stick four strips of masking tape	blank sheet of paper as a screen small light source such as a burning candle or battery operated lamp for an object **BLM 4-21 Investigation 4C** (optional)
Time	55 min in class 15 min preparation	
Safety	Caution students about safe behaviour around open flames.	

Background

Converging lenses produce images with characteristics that depend on the distance by which an object and the lens are separated. The following diagrams help to illustrate the point.

A The object is between the focal point and the converging lens.

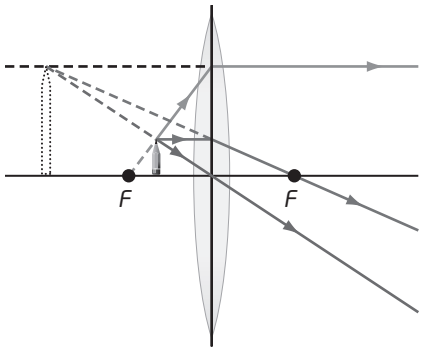


Image Characteristics:
- farther from lens than object
- upright
- larger than object
- virtual

B The object is between one and two focal lengths from the converging lens.

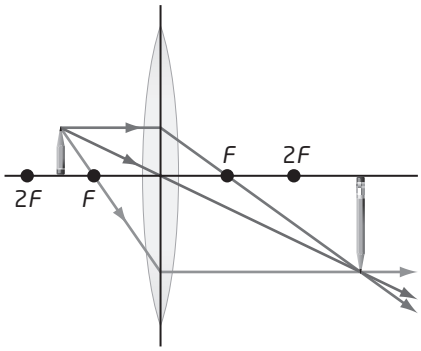


Image Characteristics:
- farther from lens than object
- inverted
- larger than object
- real

C The object is beyond two focal lengths from the converging lens.

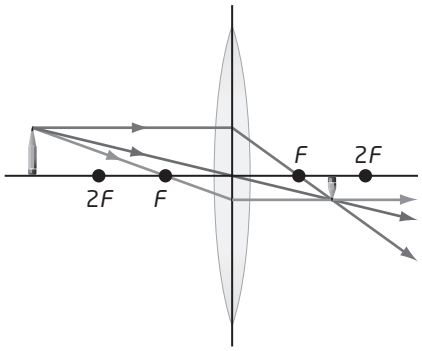


Image Characteristics:
- closer to lens than object
- inverted
- smaller than object
- real

A When the object is between the focal point and the converging lens, the virtual image is larger and farther from the lens than the object is. **B** When the object is between one and two focal lengths from the converging lens, the real image is larger and farther away from the lens than the object is. **C** When the object is farther than two focal lengths from the lens, the real image is smaller and closer to the lens than the object is.

It should also be noted that when an object is placed exactly two focal lengths from the lens (i.e., at 2F), the real, inverted image is exactly the same size as the object and is located at exactly the same distance from the lens. If an object is placed exactly one focal length from the lens, then no image will form because the refracted rays will exit the lens as a parallel beam. Hence, they will not converge to form an image.

Skills Focus

- conduct an inquiry controlling some variables
- use standard equipment and materials safely and effectively
- collect, analyze, and interpret qualitative data
- draw conclusions based on observations and inquiry results

Activity Notes and Troubleshooting

- Students need to move around to find focal lengths in this activity. Review safe behaviour around candles with them. Ensure that each group has adequate space around them.
- Consider inviting a peer helper, preferably a senior physics student, to assist with management of this activity and to help ensure safety.
- When the object is located less than one focal length from the lens, students will have to look into the lens from the side opposite the object to observe the virtual image. Draw students' attention to the note in the investigation following What to Do step 6.
- Students are investigating to collect qualitative, not quantitative, data. Remind them that they do not have to collect measurements.
- Supply students with **BLM 4-21 Investigation 4C.**

Additional Support

- DI Pair students who have strong logical-mathematical skills with those who require support to activate their pattern-recognition abilities.
- Students with visual challenges will find this activity difficult; have a classmate with excellent communication skills describe the process to them.
- DI Bodily-kinesthetic learners may benefit from moving around the room as they observe images. Ensure that adequate supervision is available.
- ELL You may wish to pair English language learners with classmates who have strong English communication skills.

Investigation 4C Answers

What Did You Find Out?

1. Real images are produced for all object distances beyond F.

2. Virtual images are produced for object distances less than F.

3. Images are larger than the object when located between F and 2F and less than F.

4. a) Real images are upside down.

b) Virtual images are right side up.

5. When used as a magnifying glass, the object was less than one focal length from the lens.

Investigation 4D Options for an Optical Device

(Student textbook page 354)

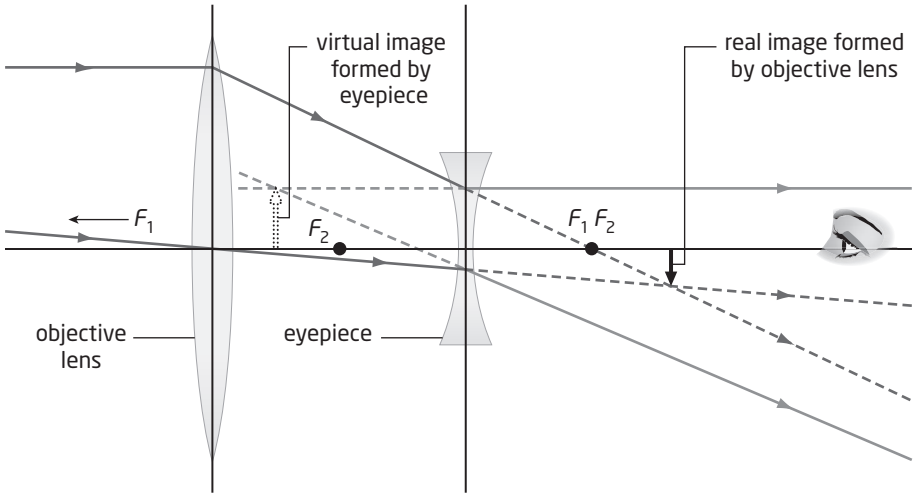
Pedagogical Purpose

Students will experiment with a variety of available lenses to design and construct an optical device that will magnify objects.

Planning	
Materials	Per group: convex lens (with a large curve) convex lens (with a small curve) cardboard scissors tape ruler **BLM 4-22 Investigation 4D** (optional)
Time	30 min in class 15 min preparation
Safety	Caution students to work safely with scissors.

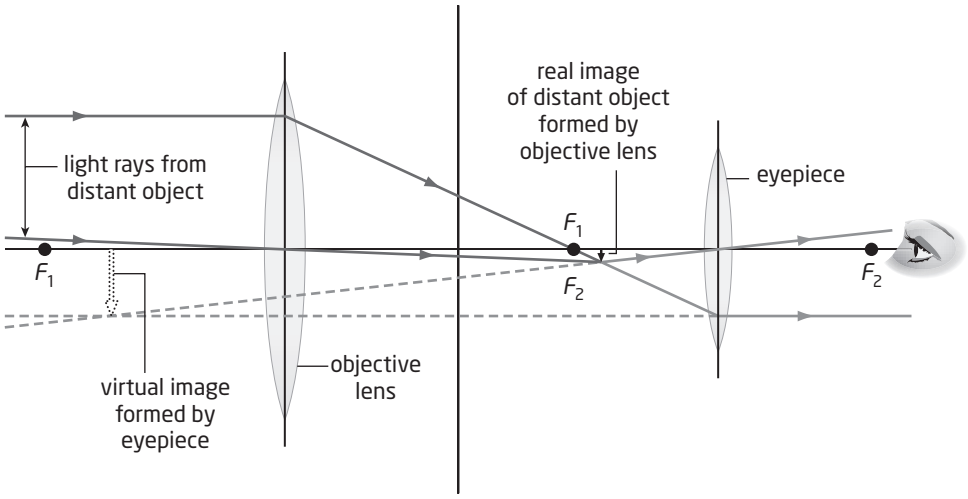
Background

Optical devices take advantage of the properties of lenses to perform a function. For example, Galileo combined a diverging eyepiece lens with a converging objective lens to produce a magnified upright image (seen below).



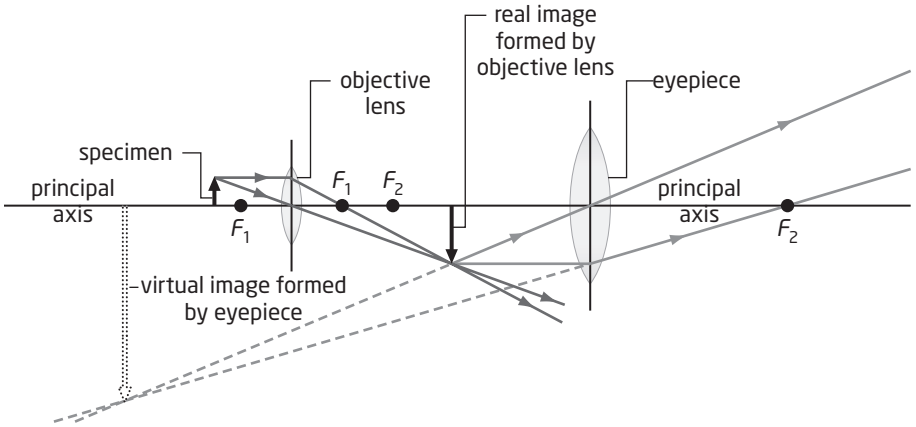
In Galileo's telescope, the objective lens alone would produce an inverted image. The eyepiece changes it into an upright image.

This was a real improvement on Kepler's telescope design (see below), which produced an inverted virtual image.



Kepler's telescope produces an inverted image.

Unlike telescopes, microscopes make use of two convex lenses to produce a magnified virtual image. In the following diagram, notice how the image produced by the objective lens becomes the object for the eyepiece.



It is likely that the outcome of student work in the present investigation will provide a result similar to the above diagram, and produce a magnified, virtual, inverted image.

Skills Focus

- build an optical instrument
- select appropriate instruments and materials and use them safely
- analyze qualitative data to adjust equipment and materials used
- communicate ideas, plans, and procedures using appropriate numeric, symbolic, and graphic modes of presentation

Activity Notes and Troubleshooting

- Remind students to exercise caution when using the lenses and materials when constructing their optical instrument.
- Consider inviting a peer helper, preferably a senior physics student, to assist with management of the activity, assisting students when required.
- Remind students that the image they produce will probably be virtual and they will need to look into the lens to see it.
- Remind students that they are working to build a device that actually produces a magnified image. Read the two criteria in What to Do step 2 aloud.
- To keep the investigation focussed, tell students how much time they will have for What to Do steps 1 and 2. Five to ten minutes should be adequate. Ten to fifteen more minutes should be needed for steps 3 and 4. After this time frame, ensure that students show you their plans, and then move on to step 5.
- After the activity, allow students to circulate to view other groups' devices.
- Supply students with **BLM 4-22 Investigation 4D.**

Additional Support

- DI Group students who have relatively strong logical-mathematical skills with those who require support.
- Students with visual challenges may find this investigation difficult. Have a classmate with strong communication skills work with them.
- DI Allow bodily-kinesthetic learners to move around the room, perhaps as observers of other groups' projects. Ensure that adequate supervision is available to ensure that groups remain on task.
- ELL Group English language learners with students who have strong English communication skills.

Investigation 4D Answers

Answers may vary.

What Did You Find Out?

1. Look for explanations that connect the outcome of the activity with stated learning expectations, for example, a virtual image was produced and located between the second and third convex lens.
2. Again, look for explanations that connect the outcome of the activity with stated learning expectations. To produce an upright image, a diverging lens is required. To increase magnification, the image produced by one lens must become the object for another lens, and be located less than one focal length from the lens.

Inquire Further

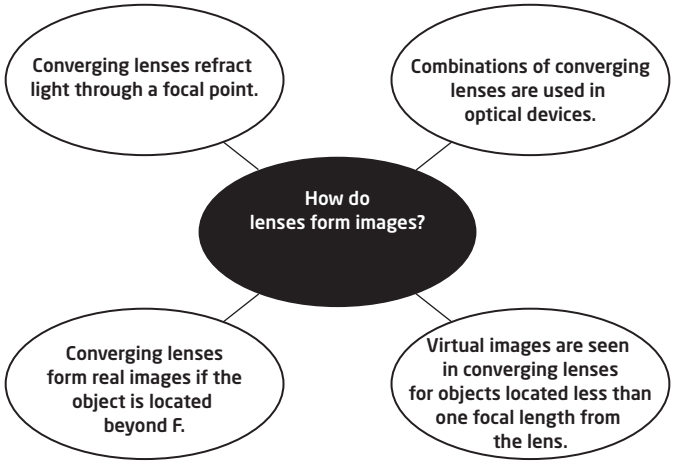
3. For the microscope described in the Background section students will need to add two plane mirrors to magnify an object behind them.

Topic 4.6 Review (Student textbook page 355)

Please see also **BLM 4-23 Topic 4.6 Review (Alternative Format).**

Answers

1. Answers may vary. For example:



2. A converging lens focuses rays through a focal point on either side of the lens. A diverging lens causes light rays to separate, or diverge, as they travel away from the lens.

3. The focal length of a converging lens can be determined by holding a screen at various distances from the lens. Light from a distant bright object will appear as a bright spot when held at a distance from the lens, which is equal to the focal length.

4. The light ray will travel parallel to the principal axis.

5. The object would have to be located less than one focal length from a converging lens to produce a virtual image.

6. Light rays passing through a converging lens along the principal axis will pass through the lens without changing direction.

7.

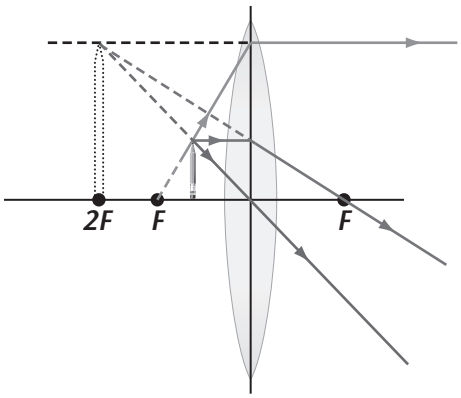


Image Characteristics

- farther from lens than object
- upright
- larger than object
- virtual

8. The object must be placed at a distance greater than 2F from the lens.

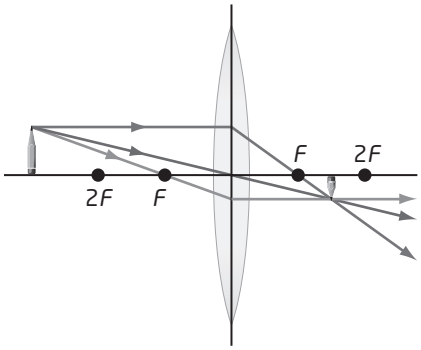


Image Characteristics

- closer to lens than object
- inverted
- smaller than object
- real

Using Science at Work (Student textbook pages 356–357)

Literacy Support

Before Reading

- Scan the first paragraph with students and review with students the meaning of the term "laserist." Draw attention to the job description given in the caption on page 356.
- Ask students to anticipate why this career was chosen for this topic. Guide them to make explicit connections with the properties of light studied in this topic.

During Reading

- Ask students to reflect on the reasons that Victor Tomei gives for his career choice. Do these reasons seem valid and relevant to the life choices a student now studying Grade 10 Science is likely to experience?
- Ask students to consider what makes a job challenging. Ask, "Why is any job a challenge?"

After Reading

- Encourage students to look for, and list, sentences in this section that present a practical application of the study of light and optics.
- In small groups, ask students to role play how a laserist might explain his or her knowledge of light and optics to a potential customer.

Instructional Strategies

- Give students the opportunity to discuss in pairs or small groups practical applications of laser technology. Each group should be prepared to describe one example to the class.
- English language learners may require additional support from a peer tutor. They may be able to conduct research in their first language, but require help formulating English responses.

Science at Work Answers

1. Possible questions include "Have you ever used a laser to blow up anything?" or "Do you have to like science to be a laserist?" or "What courses did you study in high school?"
2. Laser technology requires the laserist to direct light at specific targets. To do so, the laserist must know how light is affected by lenses and mirrors.
3. Answers will vary. Career profiles should include educational background, job satisfaction, job potential/prospects, future job availability, transferable skills, pay scales, and the requirement for scientific knowledge, manual dexterity, social skills, people skills, managerial skills, and business skills.