Chapter 23

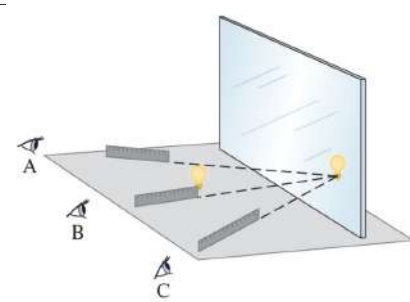
Mirrors and Lenses

23.1 Plane Mirrors

OALG 23.1.1 Observe and explain

Equipment: a mirror positioned perpendicular to the desk surface, a short battery-operated candle or another small bright object, a meter stick.

To do this experiment alone you need to be creative. First, prop up a plane mirror so it is perpendicular to the desk's surface. Place a small lightbulb or a candle about 10-15 cm in front of the plane mirror. Then use a meter stick to level your eyes with the desk and point the meter stick in the direction in which you see the image of the candle in the mirror (being precise is very important here). Draw a line on the desk along which you position the meterstick to point at the candle. Then repeat at least 2 more times to get 3 or more lines as shown in the figure below (the dashed lines indicate the orientations of the meter sticks).

Extend the dashed lines behind the mirror to locate the image of the candle relative to the mirror. When your eye is at points A, B, and C, light seems to be coming from that image location.	
Suggest a rule that explains the location of the image that a plane mirror forms of an object (for example, the flame of the candle).	

OALG 23.1.2 Explain

Use two arbitrary rays to explain why the image of the candle in Activity 23.1.1 is at the same distance behind the mirror as the candle is in front of the mirror.

a. Draw two rays starting from a point on the candle and moving toward the mirror.

b. Draw the same rays after reflection from the mirror. Do the reflected rays that you drew in part **a.** ever meet? If not, how does the mirror form an image?

c. Explain why we see an image of the candle behind the mirror.

d. Extend the reflected rays back behind the mirror to find the image of the candle. Use geometry to prove that the image is the same distance behind the mirror as the candle is in front.

OALG 23.1.3 Test your idea (1)

Equipment: plane mirror, candle, cardboard, other materials if needed.

Justin and Isabel are investigating the location of the image of a candle produced by a plane mirror. Justin says that the image is on the surface of the mirror. Test his idea by designing an experiment whose outcome contradicts the prediction based on Justin's idea.

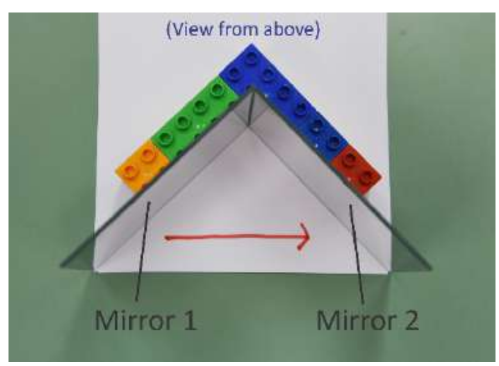
a. Describe an experiment to test Justin's idea.

b. Predict the outcome of the experiment based on Justin's idea.

c. Perform the experiment and record the outcome.

d. Discuss whether the experiment disproves the idea that the image is on the surface of the mirror.

OALG 23.1.4 Test your idea (2)



a. You have vertical mirrors on a flat surface so that their faces make a right angle as shown on the right. You draw an arrow as shown in the figure. What will you see in the mirrors?

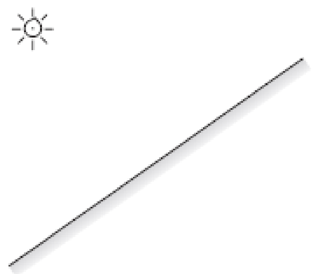
b. Use a ray diagram to make a prediction. Oce you are done, compare your prediction to the outcome of the experiment https://youtu.be/HcAH0ajRZ8M. Explain which part of the arrow is the result of reflection from mirror 1 and which one is the result of reflection from mirror 2.

c. Now watch the following experiment https://youtu.be/7zR9aCKVpCc and compare the outcome to your explanation in part **b**. Explain the discrepancies.

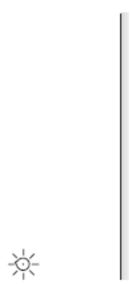
OALG 23.1.5 Represent and reason

A candle burns in front of a plane mirror, as shown in the figures below. Consider the flame to be a point-like source of light. For each case, locate the flame's image by drawing any two rays on the illustration. (Rays can extend in any direction that strikes the mirror.)

a.



b.



Then, devise a rule that can be used to locate plane-mirror images without using rays.

OALG 23.1.6 Represent and reason

Draw ray diagrams to answer the following questions:

a. How does the size of an image produced by a plane mirror change (does it increase, decrease or remain the same) when the object is moved away from the plane mirror? How does the size change when the object is moved toward the plane mirror? Notice that to locate an image of each point of an object you need at least two rays.

b. An object moves away from the mirror. How does the speed of the object compare to the speed of the image? A mirror moves away from the object, which is resting on the table. How does the speed of the image compare to the speed of the mirror for an observer who is standing still next to the table?

c. Watch the following video https://youtu.be/jCuN-bEt5-I and compare the outcome of the experiment to your prediction in part b. If needed, revise the reasoning that led you to the prediction.

OALG 23.1.7 Test your ideas

Imagine that you stand in front of a plane mirror to look at your image.

a. Draw a ray diagram to determine the minimum size of a mirror in which you can see your entire body.

b. Predict where you should put the top of that mirror relative to the top of your head.

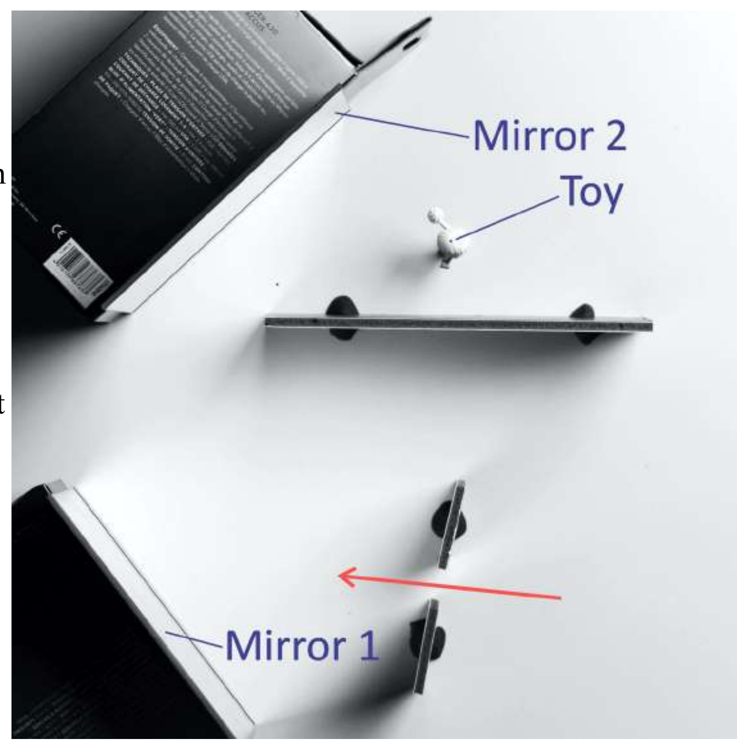
c. Does it matter where you stand with respect to the mirror? Support your answer with a ray diagram. If you have an appropriate mirror at home, do the experiment and compare the outcome to your prediction.

d. Compare your answers to parts **a-c** to the answers in Conceptual Exercise 23.2 in the textbook.

OALG 23.1.8 Apply

Equipment: a protractor and a ruler.

a. In the photo on the right you see a top view of an arrangement of two mirrors and a toy (a girl holding ice cream in her right hand) in front of mirror 2 and a red arrow in front of mirror 1. The red arrow indicates the direction in which the camera is pointed. Will the camera see the toy? If it does see the toy, will the girl that the camera sees hold ice cream in her right or her left hand? Use a ruler and a protractor to answer these questions.



b. Check out the video taken by the camera pointed in the direction of the red arrow https://youtu.be/F8gCHBcRgps. Did your prediction match the outcome of the experiment?

OALG 23.1.9 Read and interrogate

Read and interrogate Section 23.1 in the textbook and answer Review Question 23.1.

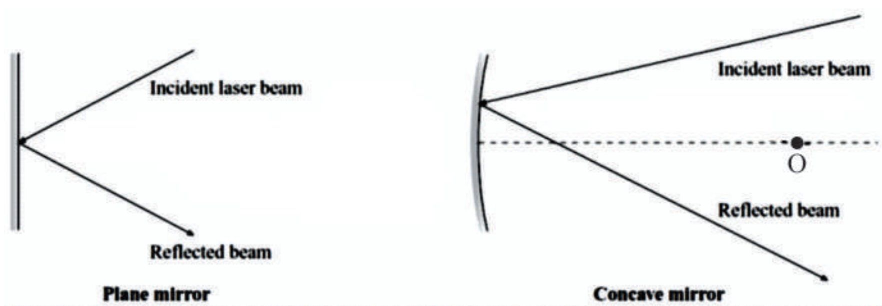
OALG 23.1.10 Practice

Answer Questions 1-3 on page 745 and solve Problems 4 and 5 on page 746 in the textbook.

23.2 Qualitative analysis of curved mirrors

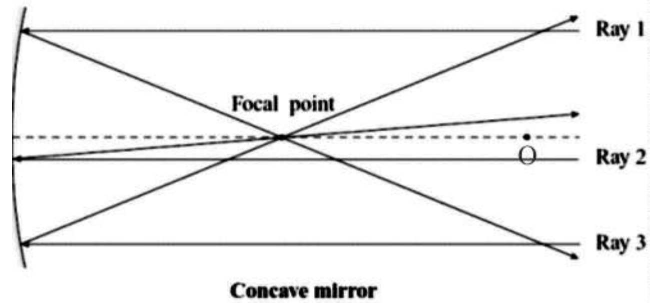
OALG 23.2.1 Observe and explain

Figures below show what happens to an incident beam of light when shone on a plane mirror and a curved (concave) mirror. Explain the behavior in terms of the law of reflection. *Note:* The dashed line perpendicular to the curved mirror's surface in the figure passes through the center O of the sphere from which the mirror was cut.



OALG 23.2.2 Observe and explain

If you point the beams of the lasers parallel to the main axis of the mirror (a horizontal axis through the center of the mirror), as shown in the figure below, after reflection, the rays all pass through the same point exactly in the middle between the mirror and the center of the sphere from which the mirror was cut. This point is called the *focal point*—the point through which rays parallel to the axis of the concave mirror pass after reflection from the mirror. Use the law of reflection to explain this observation.



OALG 23.2.3 Apply

a. Draw a ray diagram to predict what will happen if you aim the beams of the lasers so that they both pass through the focal point before hitting the mirror.

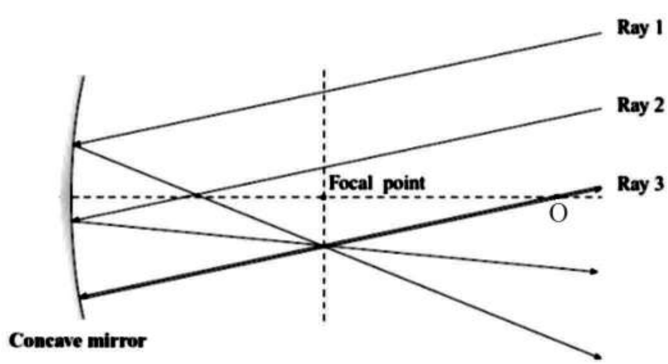
b. Compare and contrast this situation with the experiment in Activity 22.2.3.

23.2.4 Observe and explain

Observe the following experiment:
http://islephysics.net/pt3/experiment.php?topicid=12&exptid=185.

a. Use a ruler to draw a line through all the points where the reflected rays intersect for each position of the mirror. Where is this line with respect to the mirror? Notice that in this experiment the incident laser beams are parallel to each other but not parallel to the main axis of the mirror. Explain your observation using the law of reflection.

b. In the figure below you see the paths of 3 rays. One of the rays (Ray 3) passes through the center of the sphere from which the mirror was cut (point O*)*. This ray reflects back along the same path. After reflection, the other two rays pass through the point where the center-passing ray crosses the focal plane of the mirror. Use the law of reflection to explain this observation.



c. Compare your explanations to the analysis of experiments in Observational Experiment Table 23.3 and the explanatory text on page 717 in the textbook. Notice that the concept of a *focal plane* is crucial for understanding how images are formed in curved mirrors.

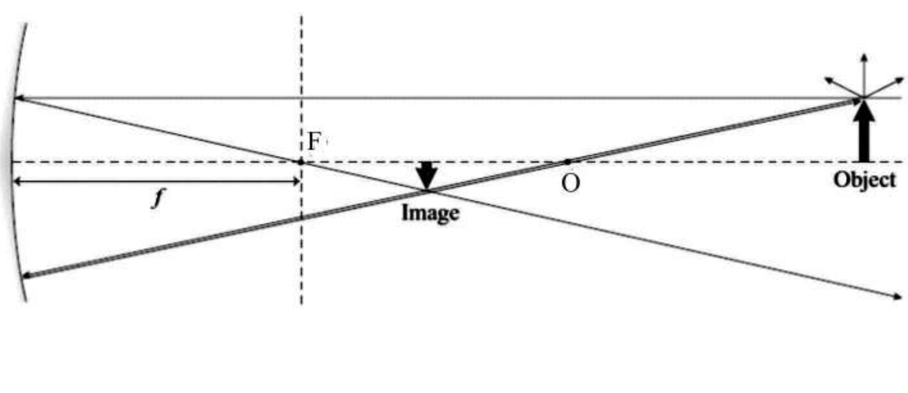
OALG 23.2.5 Represent and reason

Draw a ray diagram showing the path of each of the rays described below after reflection from a concave mirror. Remember that you can locate the image of an object formed by a concave mirror by using any two of these four rays:

a. A ray that is parallel to the main axis of the mirror.	**b.** A ray that passes though the focal point of the mirror.	**c.** A ray that passes through the center of the sphere from which the mirror was cut.	**d.** A ray that is parallel to the ray in part **c.**

OALG 23.2.6 Represent and reason

A small, shining object is placed above the main axis of a concave mirror at a distance $s > R$ from the mirror. Two rays are used to find the image of the top of the object. Point O is the center of curvature of the mirror—that is, the center of the sphere from which the mirror was cut. The focal point is indicated by F, and the focal length is f.



a. Explain the path of each ray in the figure.

b. What assumptions were made in the diagram?

c. After you have learned how to locate the image of an object produced by a concave mirror, use available materials to check whether you can see the image where the ray diagram predicts when you recreate the situation in the ray diagram with real equipment.

OALG 23.2.7 Represent and reason

a. Imagine placing a small, shining object at a distance $s\ (s > R)$ from a concave mirror. Draw two rays to represent the situation — one parallel to the main axis and one going through the focal point. Draw the reflected rays and find the location of the image of the object. Describe the image using adjectives: upright/inverted, real/virtual, enlarged/reduced.

b. Imagine placing a small, shining object at a distance $s\ (f < s < R)$ from a concave mirror. Draw two rays to represent the situation — one parallel to the main axis and one going through the focal point. Draw the reflected rays and find the location of the image of the object. Describe the image using adjectives: upright/inverted, real/virtual, enlarged/reduced .

c. Imagine placing a small, shining object at a distance $s\ (s < f)$ from a concave mirror. Draw two rays to represent the situation — one parallel to the main axis and one reflected from the center of the mirror. Draw the reflected rays and find the location of the image of the object. Describe the image using adjectives: upright/inverted, real/virtual, enlarged/reduced.

OALG 23.2.8 Represent and reason

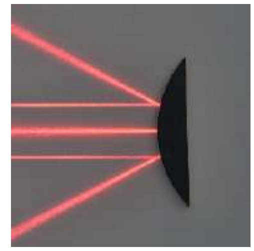
Use ray diagrams to determine how the size of an image changes (increases or decreases) when the object is moved away from a concave mirror.

OALG 23.2.9 Apply

Use the following video https://youtu.be/uecngABE31Q to determine the focal distance of the concave mirror.
a. Explain your method using a ray diagram.

b. Record the data that you collect from the video and your calculations.

OALG 23.2.10 Observe and explain



Observe the light from a laser pointer incident and reflected off of a curved mirror, which is a section of a sphere of radius *R* (convex) (see photo on the right and the sketch below). Explain the behavior in terms of the law of reflection.

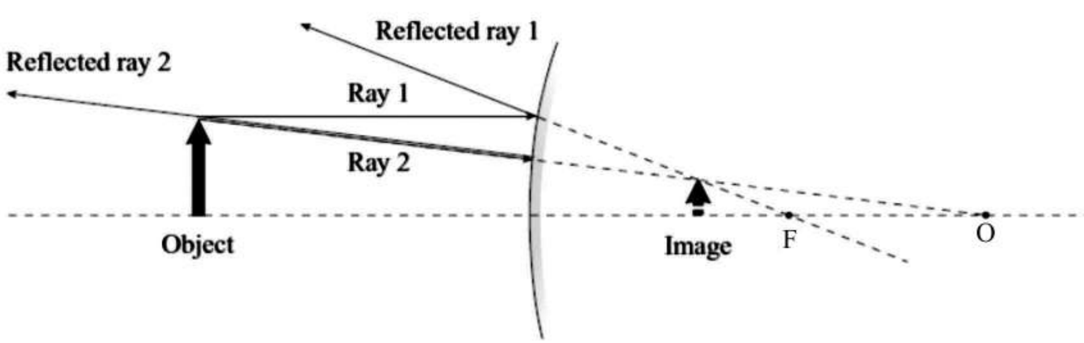
OALG 23.2.11 Test your idea

a. Read and interrogate Observational Experiment Table 23.4 and supporting text and Figure 23.9.

b. Use the concept of a virtual focal point and virtual focal plane to draw a ray diagram to predict what will happen in you shine several parallel beams of light on a convex mirror that is slowly rotated around the axis perpendicular to the beams. After you make your prediction, watch the following experiment http://islephysics.net/pt3/experiment.php?topicid=12&exptid=186 and compare your prediction to the outcome. Did they match? Explain.

OALG 23.2.12 Represent and reason

A ray diagram helps us understand how to find the image of an object produced by a convex mirror. Explain the path of each ray in the figure below and how we know where the image is located.



Why is the image in the figure above drawn with a dashed line? What assumptions were made in the diagram? For help, read and interrogate Physics Tool box 23.2 on page 720.

OALG 23.2.13 Represent and reason

Answer the following questions.

a. Place a small, shining object at a distance s $\left(R/2 < s < R\right)$ from a convex mirror. Use a ray diagram to find the location of the image. Describe the image using adjectives: upright/inverted, real/virtual, enlarged/reduced.

b. Place a small, shining object at a distance s $\left(s < R/2\right)$ from a convex mirror. Use a ray diagram to find the location of the image. Describe the image using adjectives: upright/inverted, real/virtual, enlarged/reduced.

OALG 23.2.14 Apply

Equipment: a tablespoon and a small object.

a. Take a tablespoon and a small object. Position the object in front of the spoon. Does the spoon work as a concave or a convex mirror? How do you know?

b. Find the side of the spoon that acts like a concave mirror and estimate its focal distance. Describe the experiment that you performed to do it and the data that you collected. Take photos of your experiment and post them for the class.

OALG 23.2.15 Read and Interrogate

Read and interrogate Section 23.2 in the textbook and answer Review Question 23.2.

OALG 23.2.16 Practice

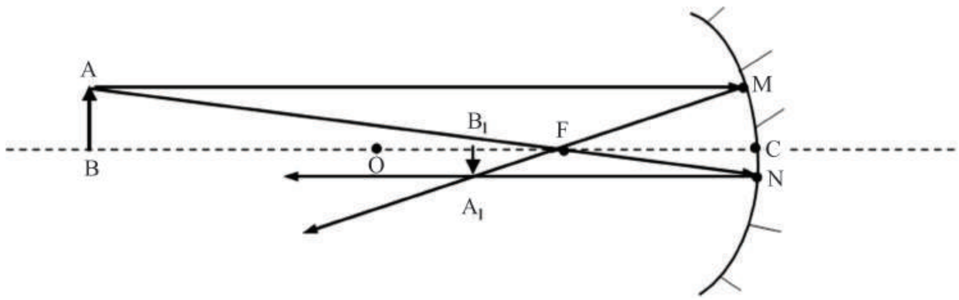
Answer Questions 4-6, 17, and 20 on page 745 and solve Problems 7 and 8 on page 746.

23.3 The mirror equation

OALG 23.3.1 Derive

The goal of this activity is to derive a mathematical relation that will allow you to predict where the image of an object placed in front of a concave mirror will be: in other words, to derive a mathematical relationship between the distance of the object from a mirror s, the distance of the image from the mirror s', and the focal distance of the mirror f.

Carefully examine the derivation, and evaluate the outcome using limiting-case analysis and your knowledge of how lenses form images of objects. *AB* in the figure below is a bright object; A_1B_1 is the image of the object.



- AM ≈ BC = s (the rays are close to the main axis of the mirror).
- $A_1N \approx B_1C = s'$; CM ≈ BA, and CN ≈ B_1A_1.
- ABF and CNF are similar triangles. Thus BF/CF = AB/A_1B_1 or $(s-f)/f = AB/A_1B_1$.
- A_1B_1F and MCF are similar triangles. Thus $CF/B_1F = CM/A_1B_1 = AB/A_1B_1 = f/(s'-f)$.
- From this we find

$$\frac{s-f}{f} = \frac{f}{s'-f}$$

or, after some algebra, we get a relationship that is called the *mirror equation*:

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$$

a. Does the relationship make sense when the object is infinitely far away? Support your answer with a ray diagram.

b. Does the relationship make sense if an object is placed right at the focal point? Support your answer with a ray diagram.

c. Does the relationship make sense when the object is between the mirror and the focal point? Support your answer with a ray diagram.

d. Describe carefully all the assumptions that we made deriving the relationship.

e. Compare your answers to the text in Section 23.3 in the textbook.

OALG 23.3.2 Apply

We videoed two experiments, both using the same concave mirror.

a. Describe what you observe in Experiment 1 https://youtu.be/x6oBXZtK5xk. Draw a ray diagram to explain why, when the screen and the source are at a particular distance from the mirror, you see a sharp inverted image of the candle.

b. Use the ray diagram to determine the focal distance of the mirror. What is the uncertainty in your value?

c. Describe what you observe in Experiment 2 https://youtu.be/uecngABE31Q . The light bulb (serving as a point-like source in this experiment) is positioned on the principal axis of the mirror. Explain why, when the point-like light source is at a certain distance from the mirror, there is a circle on the screen that matches the size of the mirror.

d. Use the ray diagram to determine the focal distance of the mirror. What is the uncertainty in your value?

e. Compare the values you found in parts **b** and **d.** Are they the same or different?

OALG 23.3.3 Represent and reason

Use ray diagrams and the mirror equation to locate the position, orientation, and type of image formed by an upright object held in front of a concave mirror of focal length $+20\text{ cm}$. The object distances are (a) 200 cm, (b) 40 cm, and (c) 10 cm.

OALG 23.3.4 Represent and reason

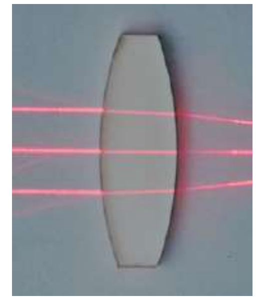
A large concave mirror of focal length $+3.0\text{ m}$ stands 20 m in front of you. Describe the changing appearance of your image as you move from 20 m to 1 m from the mirror. Indicate distances from the mirror where the change in appearance is dramatic.

OALG 23.3.5 Practice

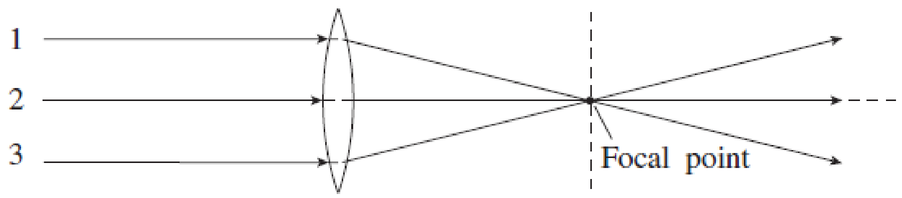
Solve Problems 12, 13, and 20 on page 746 in the textbook.

23.4 Qualitative analysis of lenses

OALG 23.4.1 Observe and explain



If you shine parallel beams of light from laser pointers on a thin convex lens made of glass (its surfaces are segments of a sphere) you will notice that refracted beams all pass through the same point on the main axis—called the *focal point.* http://islephysics.net/pt3/experiment.php?topicid=12&exptid=187

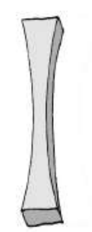


a. Explain qualitatively the path of each ray using the law of refraction — what happens at each glass–air interface to cause the net refraction of the rays shown in the figure above?

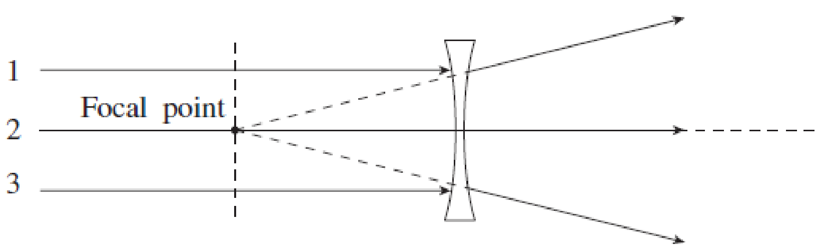
b. What would happen if you shone the laser pointers from the right side of the lens? How many focal points does this lens have?

c. Read and interrogate Observational Experiment Table 23.5 on page 725 in the textbook. What new patterns are described there?

OALG 23.4.2 Observe and explain



Observe what happens when you shine parallel beams of laser light onto a thin concave lens made of glass (its surfaces are segments of a sphere, as shown). http://islephysics.net/pt3/experiment.php?topicid=12&exptid=188



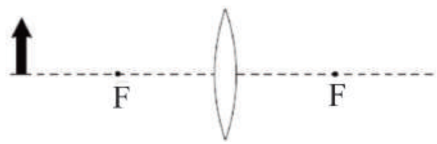
a. Explain qualitatively the path of each ray using the law of refraction—what happens at each glass–air interface to cause the net refraction of the rays shown in the figure above?

b. What would happen if you shone the laser pointers from the right side of the lens? How many focal points does this lens have?

OALG 23.4.3 Represent and reason

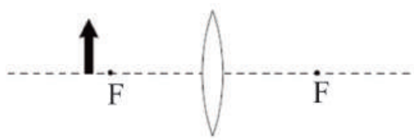
Read and interrogate Physics Tool Box 23.3 on Page 727. Then, draw in any two rays to construct images of the objects shown as arrows in the figures below. Confirm by drawing in a third ray. Describe the images using adjectives: upright/inverted, real/virtual, enlarged/reduced.

a.



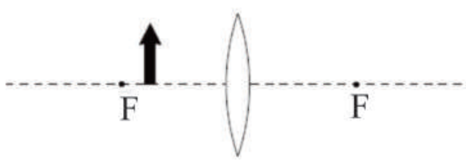
Description:

b.



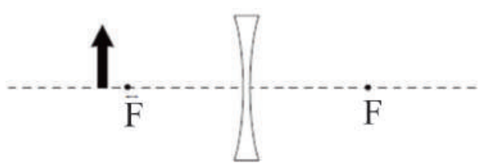
Description:

c.



Description:

d.



Description:

OALG 23.4.4 Evaluate

Your friend Ritesh says that it's appropriate to call a convex lens a converging lens and a concave lens a diverging lens. How would you convince him that his classification is not always correct? *Hint:* think of the material of the lens and surrounding medium. Check out the experiment in Figure 23.14 on page 726 in the textbook.

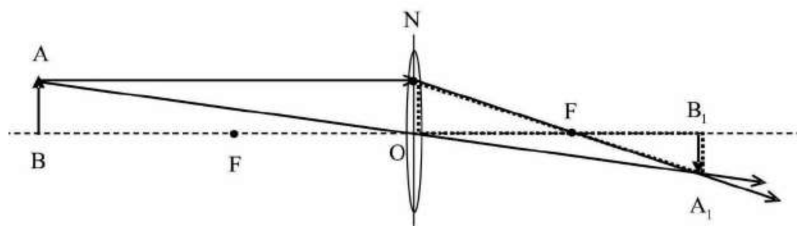
OALG 23.4.5 Practice

Answer Questions 11, 22, and 24 on page 745 and solve Problems 24-28 on pages 746-747.

23.5 Thin lens equation and quantitative analysis of lenses

OALG 23.5.1 Derive

The ray diagram and the reasoning that follows allow us to derive a mathematical relationship between the distance of the object from a convex lens s, the distance of the image s' from the lens, and the focal distance of the lens f. Carefully examine the derivation and evaluate the outcome using limiting case analysis and your knowledge of how lenses form images of objects. AB is a bright object in the figure below; A_1B_1 is the image.



- Triangles BAO and B_1A_1O are similar. Thus $AB/s = A_1B_1/s'$ or $AB/A_1B_1 = s'/s$. Triangles NOF and B_1A_1F are similar. Thus $NO/f = A_1B_1/(s' - f)$. Also, NO = AB.
- Substituting and rearranging, we get $AB/A_1B_1 = (s' - f)/f$
- Combining the above, we get

$$\frac{s'}{s} = \frac{s' - f}{f}$$

After some algebra, we get a relationship that is called the lens equation.

$$\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$$

a. Does the relationship make sense when the object is infinitely far away? Support your answer with a ray diagram.

b. Does the relationship make sense if an object is placed right at the focal point? Support your answer with a ray diagram.

c. Does the relationship make sense when the object is between the lens and the focal point? Support your answer with a ray diagram.

d. Describe carefully all the assumptions that were made deriving the relationship.

e. Read and interrogate a similar derivation on page 730-731 in the textbook. Explain ray diagrams in Figure 23.19. Why are they important?

23.5.2 Apply the lens equation

a. Watch the following video https://youtu.be/8rRLqzG9Ym8 and explain why the sharp image of the candle appears twice during the experiment. Draw ray diagrams to support your explanation.

b. Use the data that you can collect from the video to determine the focal distance of the lens used in the experiment.

OALG 23.5.3 Apply

Your task is to write instructions for 2 lens makers on how to determine the focal distance of a lens. Natalie makes convex lenses and Sheehan makes concave lenses. *Hint*: look at the end-of-chapter Problem 23.40 in the textbook.

a. Instructions to Natalie:
b. Instructions to Sheehan:

OALG 23.5.4 Represent and reason

Equipment: ruler.

Using a ruler, carefully draw ray diagrams to locate the images of the objects listed below. Measure the image locations on your diagrams and indicate if they are real or virtual, upright or inverted. When you are done, check your work using the lens equation. (Choose a scale so that your drawing fills a significant portion of the width of the paper.)

a. An object that is 12 cm from a concave lens with focal length $f = -5\text{ cm}$.

b. An object that is 7 cm from the same lens.

c. An object that is 3 cm from the same lens.

OALG 23.5.5 Represent and reason

Equipment: ruler.

Imagine you have a $+20\text{-cm}$ focal-length convex lens. You place an object 15 cm from the lens on the main axis.

a. Draw a ray diagram to find the image of the object.

b. Use the lens equation to calculate the location of the image.

c. Is the calculation consistent with the ray diagram?

d. What is the meaning of the negative sign in the distance of the image?

23.6 Skills for analyzing processes involving mirrors and lenses

OALG 23.6.1 Regular problem

Solve the problem using the steps in the table below. Then compare your solution to the solution in the textbook Example 23.12.

A simple camera made in the 1880s consisted of a single lens and a light sensitive film placed at the image location. To focus light on the image, the photographer would change the image distance — the distance from the lens to the film. Imagine that the maximum image distance is 20 cm and that the film is a $16\text{ cm} \times 16\text{ cm}$ square. A 1.9-m tall person stands 8.0 m from the camera. What focal-length lens should the camera have? Would you be able to see the entire body of the person on the picture? State the simplifying assumptions you made.

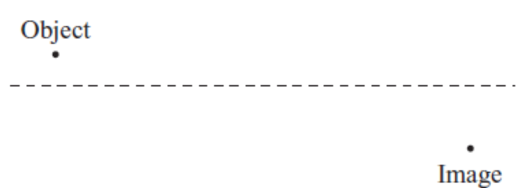
Sketch and Translate • Sketch the situation in the problem statement. • Include the known information and the desired unknown(s) in the sketch.	
Simplify and Diagram • Assume the lens/mirror is only slightly curved and the rays are incident near the principal axis. • Draw a ray diagram representing the situation in	

the problem.	
Represent Mathematically • Use the picture and ray diagram to help construct a mathematical description of the situation.	
Solve and Evaluate • Solve the equations for an unknown quantity. • Evaluate the results to see if they are reasonable (the magnitude of the answer, its units, how the answer changes in limiting cases, and so forth).	.

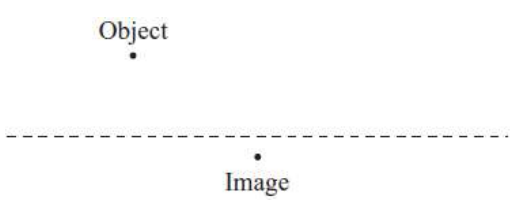
OALG 23.6.2 Diagram Jeopardy

In the figures below, you see the axis of a lens (the lens itself is not shown) and the location of a shining object and its image. Find the location and the type of the lens (convex or concave) that could produce this image, and find the focal points of the lens. When you think you have found an appropriate lens type and lens location, draw a ray diagram to help justify your choice and show the focal length on the diagram.

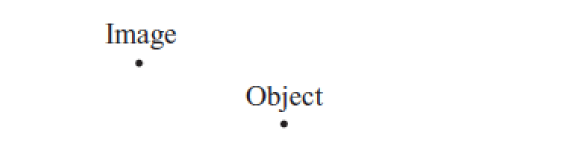
a.



b.

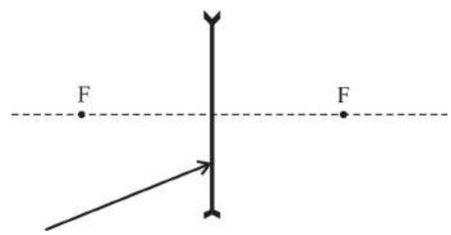


c.



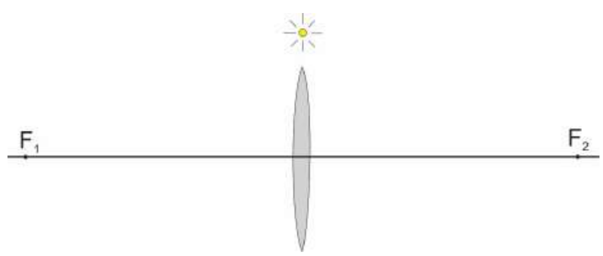
OALG 23.6.3 Represent and reason

In the figure below, you see the location of a thin concave lens and its focal points. You also see a narrow light beam incident on the lens. Draw the light beam after it passes through the lens.



OALG 23.6.4 Represent and reason

You have a thin convex lens of known focal length and a point-like light source. You place the light source right next to the lens as shown in figure below. Use a ray diagram to determine where you should put a plane mirror so that some light from the light source forms a parallel beam after passing through the lens.



OALG 23.6.5 Explain

The photo below shows the "1 FEET DEEP" sign on the side of a children's pool. Examine the letters "FEET DEEP" and answer the following questions.

a. Why do the letters look different even though they are all painted the same size?

b. Why do you see multiple letters?

c. Account for all details. Use ray diagrams.

OALG 23.6.6 Practice

Watch the following video https://youtu.be/7hvrdSEwaaQ and explain:
a. Why do the color circles in the image appear in the inverse vertical order compared to the source (the blue on the bottom and green on top)?

b. Why does the size of the images change as the lens is moved away from the source?

c. Why do sharp images of the lights appear in the same horizontal as the point light sources (red, green, blue)

OALG 23.6.7 Practice

Solve Problems 33-36, and 75-77 on pages 747-749.

23.7 *Single-lens optical systems*

OALG 23.7.1 Read and interrogate

Read and interrogate Section 23.7 in the textbook and answer Review Question 23.7.

OALG 23.7.2 Reason and explain

An unlabeled sketch of the optical system of a simple camera is shown below (real cameras have multiple lenses).

The eye is similar in some ways. Complete the table to identify the analogous elements in the eye and the camera.

Purpose	**Identify the element for the camera.**	**Identify the element for the eye.**
Allows the light from an object to enter the device		
Allows the light to be focused		
A place where the image is captured		
Makes it possible to get sharper images of objects that are at different distances from the place where the image is formed		
Makes it possible to change the amount of light entering the system		

OALG 23.7.3 Represent and reason

The *far point* of the eye is the greatest distance to an object on which an eye can comfortably focus. The *near point* of an eye is the closest distance of an object on which the eye can comfortably focus. A nearsighted person has trouble focusing on distant objects (such as a sign on the highway). A farsighted person has trouble focusing on objects that are near the eye (such as the morning newspaper). Suggest reasons for these defects of vision and possible ways to correct them. Support your answers with ray diagrams.

OALG 23.7.4 Regular problem

The image distance for the lens of a person's eye is 2.20 cm. Calculate the focal length of the eye's lens system for an object at the following distances:

a. At infinity.

b. 500 cm from the eye.

c. 25 cm from the eye.

OALG 23.7.5 Regular problem

A farsighted man can see sharp images of objects that are 3.0 m or more from his eyes. He would like to read a book held 30 cm from his eyes. Answer the following questions to determine the focal length of the lenses he needs for his glasses.

He will hold the book 30 cm from his glasses. An eyeglass lens should form an image 3.0 m (300 cm) in front of the lens. The optical system of his eye will look at this image. Draw a sketch of the object (the book), eyeglass lens, and the image of that object. Enter known information in your sketch.	
Draw a ray diagram for the eyeglass lens system described in the first cell of the table. It's similar to that of a magnifying glass.	
Use the lens equation to calculate the focal length of the desired eyeglass lens.	

OALG 23.7.6 Regular problem

A nearsighted woman can see sharp images of objects that are 2.0 m or less from her eyes. She would like to read road signs while driving on a highway. Answer the following questions to determine the focal length of the lenses she needs for her glasses.

She will look at distant signs through her glasses (assume an infinite distance). An eyeglass lens should form an image of this distant object that is 2.0 m (200 cm) in front of the lens. The optical system of her eye will look at this image. Draw a sketch of the distant object, the eyeglass lens, and the image of that object. Enter known information in your sketch.	
Draw a ray diagram for the eyeglass lens system described in the first cell of the table.	

Use the lens equation to calculate the focal length of the desired eyeglass lens.	

OALG 23.7.7 Evaluate the solution

The problem: A man who can focus only on objects in the range of 1.6 m to 4.0 m wants to buy a pair of nonprescription glasses to wear while reading and another pair to wear while driving.

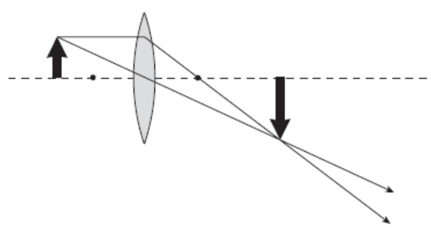
a. Determine the focal length of the glasses he should buy for reading.

b. Determine the focal length of the glasses he should buy for driving.

Proposed solution for part a:

Sketch and translate

A ray diagram of the situation is shown below. The image should be 1.6 m from the lenses when the object (the book) is about 0.4 m from the lenses (a comfortable distance to hold a book from the eye).



Simplify and diagram

We assumed the book was held 0.40 m from the eye — about 16".

Refer to the ray diagram.

Represent mathematically and solve

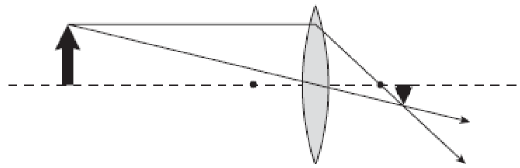
Using the lens equation, we can find the focal length.

$$\frac{1}{f_{\text{reading}}} = \frac{1}{0.4} + \frac{1}{1.6} = +2.0\text{m}$$

Proposed solution for part b:

Sketch and translate

A ray diagram of the situation is shown below. The image should be 4.0 m from the lens when the object (a road sign) is far away—an infinite distance from the lenses.



Simplify and diagram

We assume that the object is at infinity.

Refer to the ray diagram.

Represent mathematically and solve

Using the lens equation, we can find the focal length for the glasses used for distance work.

$$\frac{1}{f_{\text{driving}}} = \frac{1}{\infty} + \frac{1}{4.0} = +0.25\text{ m} = 25\text{ cm}$$

a. Identify any errors in the proposed solutions to this problem.

b. Provide corrected solutions if you find errors.

23.8 Angular magnification and magnifying glasses

OALG 23.8.1 Observe and explain

Equipment: a magnifying glass, a piece of paper with the text printed in tiny letters.

A magnifying glass is a convex lens that when held close to an object (slightly closer than the focal length of the lens) allows you to see its enlarged upright virtual image.

a. Play with the magnifying glass to find the image of the text printed in small letters that you cannot clearly see without the magnifying glass.

b. Draw a ray diagram to explain how a magnifying glass works.

c. If you are using a magnifying glass to read the text in tiny print on a piece of paper that is lying flat on your desk, where is the image of the text that you are reading when you are using the magnifying glass?

OALG 23.8.3 Read and interrogate

Read and interrogate Section 23.8 in the textbook and answer Review Question 23.8.

OALG 23.8.4 Practice

Solve Problems 57-60 on page 748.

23.9 Telescopes and microscopes

23.9.1 Read and interrogate

Read and interrogate Section 23.9 in the textbook and answer Review Question 23.9.

OALG 23.9.2 Practice

Solve Problems 61-65 and 68 on page 748.