End-of-Chapter Exercises

Exercises 1 – 12 are conceptual questions designed to assess whether you understand the main concepts of the chapter.

1. Figure 24.48 shows a beam of light in air (medium 1) incident on an interface along the normal to the interface, with some of the light refracting into medium 2 and some reflecting straight back. What, if anything, is wrong? If nothing is wrong, determine the index of refraction of medium 2. If something is wrong, explain.

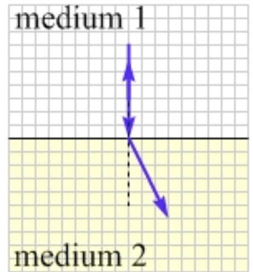


Figure 24.48: A beam of light incident along the normal to an interface, refracting into medium 2. For Exercise 1.

2. As shown in Figure 24.49, a beam of light in medium 1 is incident on an interface separating medium 1 from medium 2. Part of the beam reflects from the interface, and part refracts into medium 2. Describe, qualitatively, how the indices of refraction of the two media compare if the refracted beam follows (a) path a, (b) path b, or (c) path c.

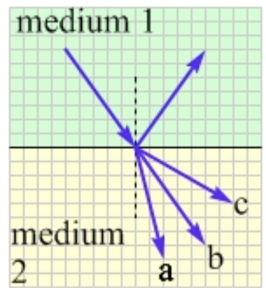


Figure 24.49: Three possible paths for the refracted beam to follow when light in medium 1 encounters the interface between two media, for Exercise 2.

3. Figure 24.50 shows an object near a diverging lens. A single ray is drawn on the ray diagram. Duplicate the diagram, and add a second ray to show the position of the image.

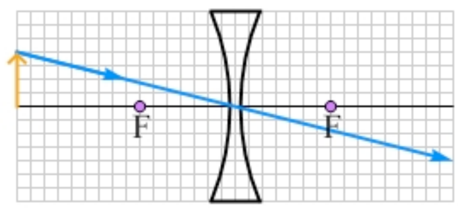


Figure 24.50: A single ray, passing undeflected through the center of a thin lens, is shown on the figure. For Exercise 3.

4. Two rays of light are shown on the ray diagram in Figure 24.51, along with two arrows representing the object and the image. (a) Could this diagram be incorrect? If so, how could it be corrected? (b) Could this diagram be correct? If so, explain how this could be possible.

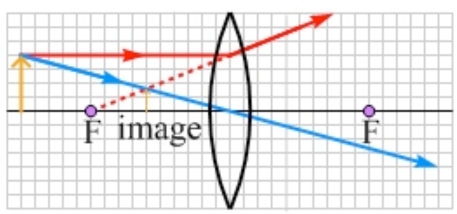


Figure 24.51: A ray diagram, for Exercise 4. Could it be correct, or is it incorrect?

5. Figure 24.52 shows an object in front of a converging lens. First, re-draw the diagram, preferably on a piece of graph paper. For parts (a) – (c), start the ray from the tip of the object and show how the ray is refracted by the lens. (a) On your diagram, draw a ray that travels parallel to the principal axis toward the lens. (b) Draw a ray that travels directly toward the center of the lens. (c) Draw a ray that travels through the focal point between the object and the lens. (d) Use the rays to locate the image on the diagram.

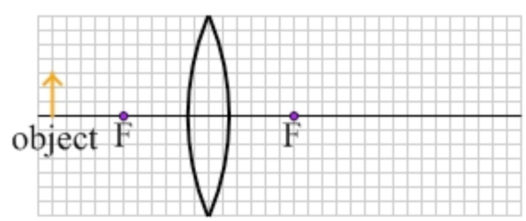


Figure 24.52: An object in front of a converging lens, for Exercise 5.

6. Figure 24.53 shows the virtual image formed by a thin-lens, as well as the locations of the two focal points of the lens. The small squares on the grid measure 1.0 cm × 1.0 cm. The goal of this exercise is to determine the type of lens creating the image, as well as the position and size of the object. (a) How many different solutions are there to this exercise? (b) For each of the solutions, describe the kind of lens that produces the image, the object distance, and the object height. (c) For each solution, sketch a ray diagram.

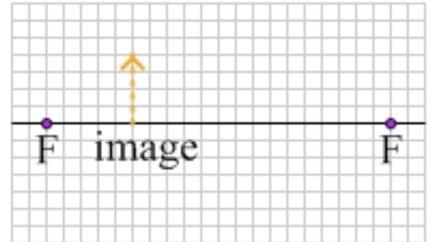


Figure 24.53: The virtual image created by a thin lens, and the locations of the two focal points of the lens. The small squares on the grid measure 1.0 cm × 1.0 cm. For Exercise 6.

7. Assume that the index of refraction of a particular piece of glass varies as shown in the graph in Figure 24.54. If light traveling in this piece of glass encounters a glass-air interface, is the critical angle for total internal reflection larger for violet light, red light, or is it equal for both? Explain.

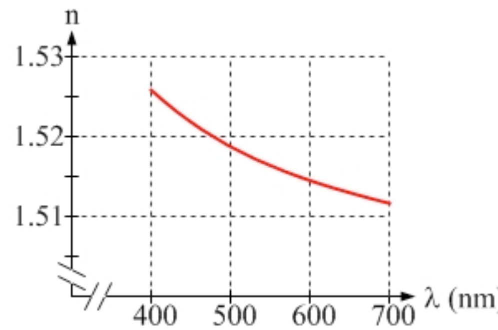


Figure 24.54: A graph of the index of refraction, as a function of wavelength, for a typical sample of glass. The graph is confined to the visible spectrum, from 400 nm (violet) to 700 nm (red). For Exercise 7.

8. In a common demonstration, a small glass beaker virtually disappears when it is placed in a larger beaker full of a particular type of oil. Using the principles of physics addressed in this chapter, explain how this could work.

9. If you wear your eyeglasses under water, can you still see clearly? Explain.

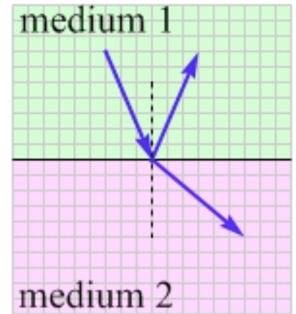
10. Identify whether the lens in this situation is a converging lens or a diverging lens. For each part below, determine which possibility you can rule out, if either. (a) First, when an object is placed 15 cm from a lens, a virtual image is observed. (b) Then, when the object is moved a little closer to the lens, the image is observed to move closer to the lens. (c) As the object is moved closer to the lens, the image is observed to decrease in size.

11. Identify whether the lens in this situation is a converging lens or a diverging lens. For each part below, determine which possibility you can rule out, if either. (a) First, when an object is placed 15 cm from a lens, a virtual image is observed. (b) Then, when the object is moved a little closer to the lens, the image is observed to increase in size. (c) What, if anything, can you conclude about the focal length of the lens?

12. You have an unknown optical device that you are trying to identify. The device could be any one of five things, a plane mirror, convex mirror, concave mirror, converging lens, or diverging lens. To identify the device you make the following observations, in order. For each part, state what, if anything, the observation tells you about what kind of mirror or lens the device is. (a) You observe that when you place an object in front of the device that the device creates an image of the object that is larger than the object. What could the device be? (b) You then observe that the image is inverted compared to the object. Based on this and the previous observation, what could the device be? (c) You then observe that the larger inverted image is on the opposite side of the device as the object. Based on this and the previous observations, what is the device? (d) If the device has a focal length of 10 cm and the object distance is 15 cm, what is the image distance?

Exercises 13 – 15 involve refraction.

13. A beam of light is incident on an interface separating two media. When the angle of incidence, measured from the normal, is 10.0°, the angle of refraction is 18.0°. What is the angle of refraction when the angle of incidence is 30.0°?

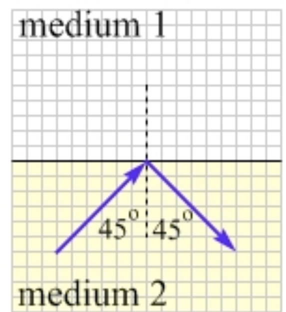


14. Return to the situation described in Exercise 13. If the speed of light in one of the media is 2.80×10^8 m/s, what is the speed of light in the other medium? Is there more than one possible answer? Explain.

15. A beam of light is incident on an interface separating two media, as shown in Figure 24.55. The squares in the grid on the diagram measure 10 cm × 10 cm. (a) Which medium has a larger index of refraction? Explain your answer. (b) If the index of refraction of one of the media is 1.10, what is the index of refraction of the other medium? Is there more than one possible answer? Explain.

Figure 24.55: When a beam of light is incident on the interface separating two media, part of the beam is reflected back into medium 1 and part refracts into medium 2, for Exercise 15.

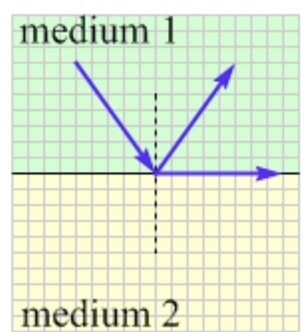
Exercises 16 – 20 involve total internal reflection.



16. As shown in Figure 24.56, a beam of light traveling in medium 2 experiences total internal reflection when it encounters the interface separating medium 2 from medium 1. The angle of incidence is 45°, and medium 1 is air, with an index of refraction of 1.00. What, if anything, can you say about the index of refraction of medium 2?

17. As shown in Figure 24.56, a beam of light traveling in medium 2 experiences total internal reflection when it encounters the interface separating medium 2 from medium 1. The angle of incidence is 45°, and the speed of the light in medium 2 is 1.50×10^8 m/s. What, if anything, can you say about the index of refraction of medium 1?

Figure 24.56: A beam of light in medium 2 experiences total internal reflection when it encounters the interface separating medium 2 from medium 1. For Exercises 16 and 17.



18. As shown in Figure 24.57, a beam of light in medium 1 is incident on an interface separating medium 1 from medium 2. Part of the beam reflects from the interface, and part refracts into medium 2, traveling along the interface between the media. Using the diagram, calculate the critical angle for total internal reflection for this situation.

19. A beam of light is incident on an interface separating two media. When the angle of incidence, measured from the normal, is 18.0°, the angle of refraction is 10.0°. What is the critical angle for this particular interface?

Figure 24.57: When a beam of light in one medium encounters an interface, part of it reflects and part refracts into medium 2, traveling along the interface. For Exercise 18.

20. A small red light-emitting diode (LED) is placed 12.0 cm below the surface of the water in a bathtub. A circle of red light is observed at the water surface. What is the diameter of this circle? Assume that the air above the water has an index of refraction of 1.00, and that the water has an index of refraction of 1.33.

Exercises 21 – 24 are designed to give you practice applying the thin-lens equation.

21. As you are analyzing a thin-lens situation, you write an equation that states: $\frac{1}{f} = \frac{1}{+40\text{ cm}} + \frac{1}{+30\text{ cm}}$. (a) What is the value of $1/f$ in this situation? (b) What is the focal length of the lens? (c) What kind of lens is this?

22. Return to Exercise 21. What is the object distance in this situation, and what is the image distance?

23. As you are analyzing a thin-lens situation, you write an equation that states: $\frac{1}{f} = \frac{1}{+15\text{ cm}} + \frac{1}{-30\text{ cm}}$. (a) What is the value of $1/f$ in this situation? (b) What is the focal length of the lens? (c) What kind of lens is this?

24. As you are analyzing a thin-lens situation, you write an equation that states: $\frac{1}{+24\text{ cm}} = \frac{1}{+24\text{ cm}} + \frac{1}{d_i}$. (a) What is the value of $1/d_i$ in this situation? (b) What is the image distance?

Exercises 25 – 28 are designed to give you practice applying the general method for analyzing a problem involving lenses.

25. An object is placed 30 cm away from a lens that has a focal length of +10 cm. (a) Sketch a ray diagram, to show the position of the image and the image characteristics. (b) Determine the image distance. (c) Determine the magnification.

26. An object is placed 30 cm away from a lens that has a focal length of –10 cm. (a) Sketch a ray diagram, to show the position of the image and the image characteristics. (b) Determine the image distance. (c) Determine the magnification.

27. You are examining an ant through a magnifying glass, which is simply a converging lens. When the ant is 10 cm from the lens and you look through the lens, you see an upright image of the ant that is 3.0 times larger than the ant itself. (a) Determine the image distance in this situation. (b) Determine the focal length of the magnifying glass. (c) Sketch a ray diagram for this situation.

28. An object is placed 48 cm from a lens. When you look through the lens, you see an image of the object that is 3.0 times larger than the object. (a) What kind of lens is it? (b) Sketch a ray diagram to check your calculations. Make sure you find all possible solutions.

Exercises 29 – 33 involve applications of refraction and lenses.

29. The lens in your digital camera has a focal length of 5.0 cm. You are using the camera to take a close-up picture of a flower that is 12.0 cm from the lens. (a) Determine how far the lens should be from the image-sensing system inside the camera. (b) Determine the magnification in this situation. (c) If you then use your camera to take a photograph of your friend, who is 3.0 m from the lens of the camera, how far should the lens be from the image-sensing system now? (d) Determine the magnification in this new situation.

30. Binoculars generally use pairs of prisms in which the light experiences total internal reflection. Each prism (in blue on the diagram) is right-angled, with the other two angles being 45°. A diagram of the path followed by light as it travels through the prisms to your eyes is shown in Figure 24.58. If the prisms are surrounded by air, determine the minimum index of refraction of the prism material.

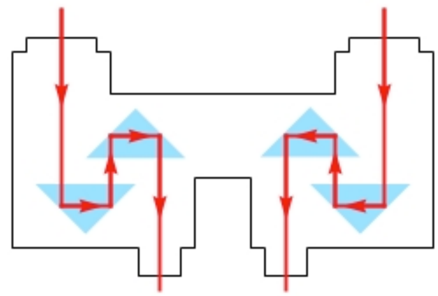


Figure 24.58: A pair of binoculars, with two right-angled prisms on each side to shift the light from the path it is following when it enters the binoculars to a path that takes it right into your eye. For Exercise 30.

31. Diamonds are particularly colorful and sparkly. One reason for this is the relatively large index of refraction of diamond of around 2.4. Another reason is that diamond does exhibit dispersion. Use these facts to explain why light that enters a diamond often experiences a number of reflections within the diamond before emerging, and why this would help spread white light out into its constituent colors.

32. When you are driving along a highway, or walking in the desert, on a hot day, you often see a mirage in the distance, where it looks like there is water on the road, or sand, ahead of you. Do a little research about this phenomenon and write a couple of paragraphs describing it, and the physics relevant to this chapter that are responsible for producing a mirage.

33. As a participant on the reality show *Survivor,* you are stranded on a sunny island with several other individuals. You get the bright idea of trying to start a fire by using your eyeglasses to focus the Sun's rays onto a piece of dry wood. (a) How far from your glasses should the wood be? (b) Do you need to be nearsighted or farsighted for this method to have a chance of working?

General problems and conceptual questions

34. A pulse of light takes 3.00 ns to travel through air from an emitter to a detector. When a piece of transparent material with a length of 40 cm is introduced into the light's path, the pulse takes 3.40 ns. What is the index of refraction of the transparent material?

35. Answer this problem by analogy with optics and refraction. A lifeguard can run at 5.0 m/s along the sandy beach, and can swim at 2.0 m/s through the water. The initial positions of the lifeguard and a swimmer who needs the lifeguard's help are shown in Figure 24.59. Four possible paths for the lifeguard to take are shown on the diagram. Which path should the lifeguard take to minimize the time it takes to reach the swimmer? Explain.

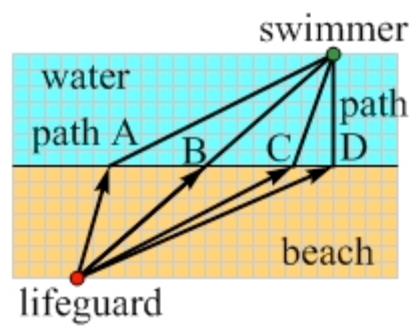


Figure 24.59: A situation involving a lifeguard trying to reach a swimmer in the shortest time, which is analogous to light as it travels from one medium to another. For Exercise 35.

36. A particular converging lens has a focal length of +20 cm. A second lens of exactly the same shape as the first lens has a focal length of +25 cm. Is this possible? Explain.

37. As shown in Figure 24.60, light traveling in medium 2 experiences total internal reflection at the boundary with medium 1, then experiences reflection and refraction at the boundary with medium 3. Rank the media based on their indices of refraction, from largest to smallest.

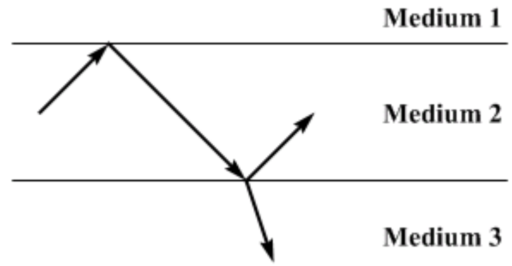


Figure 24.60: The path followed by light that is initially in medium 2. For Exercise 37.

38. A horizontal beam of monochromatic (single wavelength) laser light is incident on a block of glass, as shown in Figure 24.61. The faces of the block of glass are all either horizontal or vertical except for the face at the top right, which is inclined at 45°. The glass has an index of refraction of 1.50, while the air surrounding the glass has an index of refraction of 1.00. Copy the diagram, and sketch the path the light takes through the block, accounting for both refraction and reflection at each air-glass interface the light encounters. Label every point where light emerges from the glass back into the air and, at each of these points, determine the angle at which the light emerges from the glass.

39. Repeat Exercise 38, but now the medium surrounding the glass is water, with an index of refraction of 1.33, instead of air.

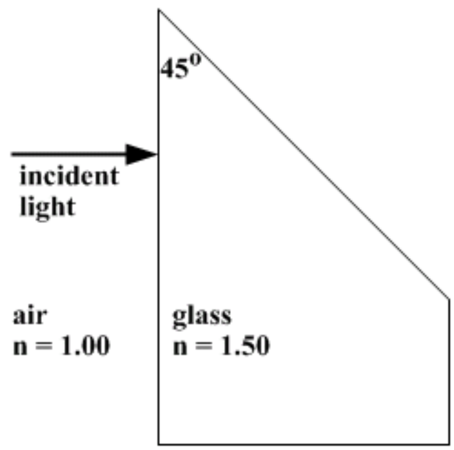


Figure 24.61: Light is incident on a piece of glass that is surrounded by air. For Exercises 38 and 39.

40. As shown in Figure 24.62, a beam of red and violet light is incident along the normal to one surface of a right-angled triangular glass prism. The glass has an index of refraction of 1.52 for red light, and 1.54 for violet light. (a) Draw a sketch showing how the red and violet beams travel from the point at which they enter the prism to the side *ab* of the prism. (b) If the angle at vertex *a* of the prism is $\theta = 30.0°$, determine the angles of refraction for the red and violet beams that emerge from the prism from the side *ab*. Show these refracted beams on your sketch. (c) On your sketch, show how the red and violet beams reflect from side *ab* of the prism.

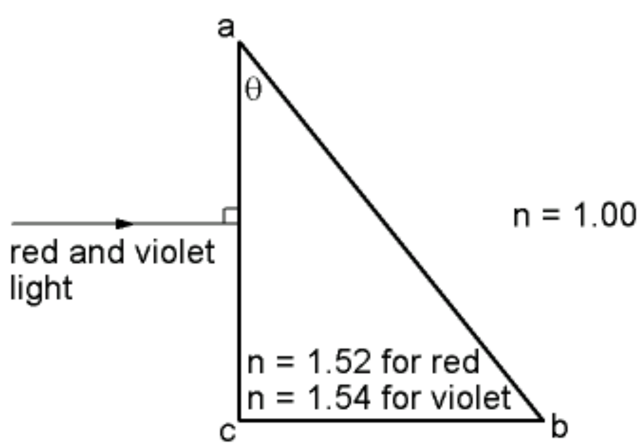


Figure 24.62: A beam of red and violet light entering a right-angled glass prism. For Exercise 40.

41. As shown in Figure 24.63, when an object is placed 12 cm in front of a particular optical device (either a single mirror or a single lens) a **virtual image** is formed 24 cm from the device on the same side of the device as the object. (a) What kind of mirror or lens could this optical device be? (b) Find the focal length of the device.

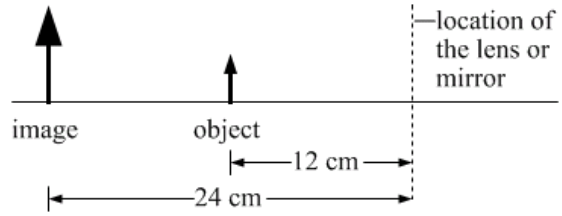


Figure 24.63: When an object is placed 12 cm in front of an optical device, which is either a lens or a mirror, a virtual image is formed 24 cm from the device. For Exercise 41.

42. Galileo Galilei used a telescope to carry out detailed observations of the moons of a particular planet. Do some research about Galileo's telescope, and about the observations he made with it, and write a couple of paragraphs describing the telescope and the observations.

43. In a particular situation, involving an object in front of a lens, the object distance is 20 cm and the magnification is +4.0. Find (a) the image distance, (b) the focal length of the lens.

44. In a particular situation, involving an object in front of a lens with a focal length of +20 cm, the magnification is +4.0. Find (a) the object distance, (b) the image distance.

45. An object is placed a certain distance from a lens. The image created by the lens is exactly half as large as the object. If the two focal points of the lens are 20 cm from the lens, where is the object? Where is the image? (a) Find one solution to this problem. (b) Find a second solution. (c) Sketch ray diagrams for your two solutions.

46. Figure 24.64 shows an object and a real image created by a lens. Assume the boxes on the grid measure 10 cm × 10 cm. Find the position of the lens, and its focal length.

Figure 24.64: This figure shows an object and a real image created by a lens. For Exercises 46 and 48.

47. Figure 24.65 shows an object (the larger arrow) and the virtual image of that object, created by a lens. Assume the boxes on the grid measure 10 cm × 10 cm. Find the position of the lens, and its focal length.

Figure 24.65: The larger arrow represents an object, while the smaller arrow represents the virtual image of that object, created by a lens. For Exercise 47.

48. Sketch a ray diagram for the situation shown in (a) Figure 24.64, (b) Figure 24.65.

49. In the situation shown in Figure 24.66, a small red LED (light-emitting diode) is placed on the principal axis at one of the focal points of a particular converging lens. The LED can be considered to be a point source. Draw a ray diagram to show what happens to rays of light that are emitted by the LED and are refracted by the lens.

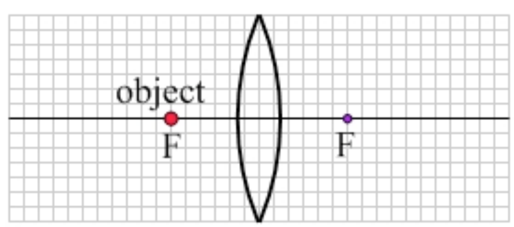


Figure 24.66: A small red LED (light-emitting diode) is placed at one focal point of a converging lens, for Exercise 49.

50. In the situation shown in Figure 24.67, a small red LED (light-emitting diode) is placed on the principal axis, 7.0 cm from a converging lens that has a focal length of 14 cm. The LED can be considered to be a point source. Find the location of the image of the LED.

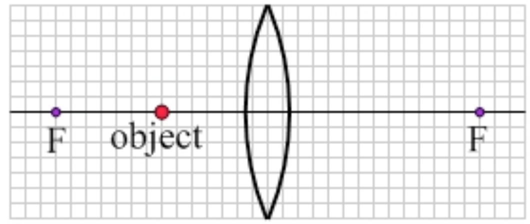


Figure 24.67: A small red LED (light-emitting diode) is placed in front of a converging lens, for Exercises 50 and 52.

51. In the situation shown in Figure 24.68, a small red LED (light-emitting diode) is placed 4.0 cm above the principal axis, and 8.0 cm away from a diverging lens that has a focal length of –12 cm. The LED can be considered to be a point source. Find the location of the image of the LED.

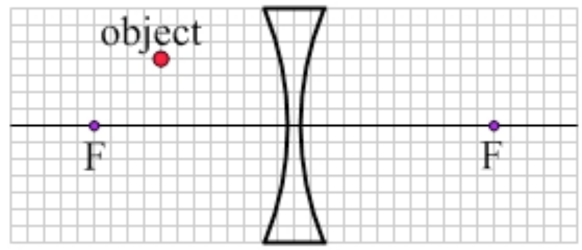


Figure 24.68: A small red LED (light-emitting diode) is placed in front of a diverging lens, for Exercises 51 and 52. The LED is 4.0 cm above the principal axis.

52. Draw several rays showing how the image of the LED is formed in (a) Figure 24.67, and (b) Figure 24.68.

53. A model of a dinosaur is placed 36 cm away from a converging lens that has a focal length of +20 cm. The model is 8.0 cm tall. Determine (a) the location of the image, (b) the height of the image, (c) whether the image is real or virtual, and (d) whether the image is upright or inverted.

54. Repeat Exercise 54, with the model of the dinosaur 15 cm from the lens instead.

55. A model of a horse is placed 36 cm away from a lens that has a focal length of –20 cm. The model is 8.0 cm tall. Determine (a) the image location, (b) the height of the image, (c) whether the image is real or virtual, and (d) whether the image is upright or inverted.

56. Return to the situation described in Exercise 55. Describe what happens to the position and size of the image if the model is moved a little bit farther from the lens.

57. Return to the situation described in Exercise 53. Describe what happens to the position and size of the image if the model is moved a little bit farther from the lens.

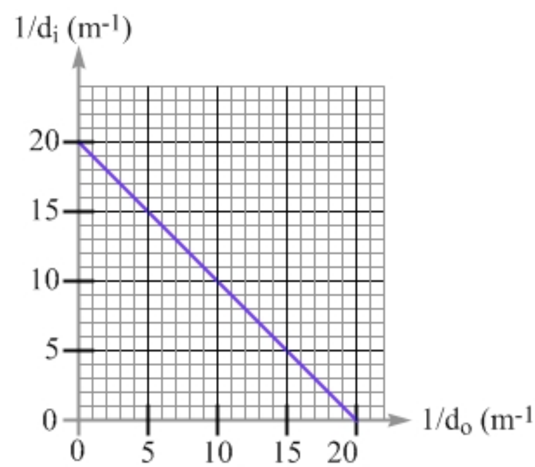


Figure 24.69: A graph of $1/d_i$ as a function of $1/d_o$ for a particular lens. For Exercise 60.

58. A particular lens has a focal length of +40 cm. (a) For this lens, plot a graph of $1/d_i$ as a function of $1/d_o$ for object distances between +20 cm and +80 cm. (b) How can you read the focal length directly from the graph?

59. Repeat Exercise 58, but now plot a graph of d_i as a function of d_o.

60. Figure 24.69 shows a graph of $1/d_i$ as a function of $1/d_o$ for a particular lens. What kind of lens is it, and what is the focal length of the lens?

61. A particular lens has a focal length of +25 cm. (a) For this lens, plot a graph of the magnification as a function of the object distance, for object distances between +10 cm and +40 cm. (b) How can you read the focal length directly from the graph?

62. Refer to Figure 24.23, just above the start of Section 24-5. (a) What, if anything, happens to the image if you cover up the bottom half of the lens, preventing any light from reaching that part of the lens? (b) Does your answer change if you cover up the top half of the lens instead? Explain, and refer to Figure 24.23 in your explanations.

63. Refer to Figure 24.42, in Section 24-9, which shows how light from a distant object is focused on to the retina in your eye. (a) Sketch a ray diagram showing where the image is located when the object is only half the distance from the lens. Assume that neither the focal length of the lens, nor the distance from the lens to the retina, changes. (b) Sketch a second ray diagram showing a corrective lens placed in front of the eye, to correctly focus the image of the object onto the retina.

64. Figure 24.70 shows five parallel rays that are incident on a pair of lenses. The first lens is a converging lens with a focal length of +10 cm, while the second lens is a diverging lens with a focal length of -5 cm. One of the focal points of the converging lens is at the same location as one of the focal points of the diverging lens. (a) Sketch a ray diagram to show what this combination of lenses does to the parallel rays. (b) Describe the function of arranging two lenses in this way.

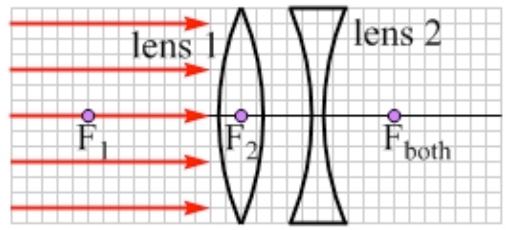


Figure 24.70: A set of parallel rays incident on a pair of lenses, for Exercise 64.

65. As shown in Figure 24.71, an object that is 4.0 cm tall is placed 10 cm to the left of a converging lens that has a focal length of 5.0 cm. A plane mirror is located 9.0 cm to the right of the lens. (a) Find the height and location of the image created by the lens. (b) After passing through the lens, the light encounters the mirror, and a second image is formed. Find the location and height of the image created by the mirror. (c) The mirror sends the light back toward the lens, and the lens creates another image. Find the location and height of this final image. (d) Determine which of these images are real and which are virtual. Justify your answer.

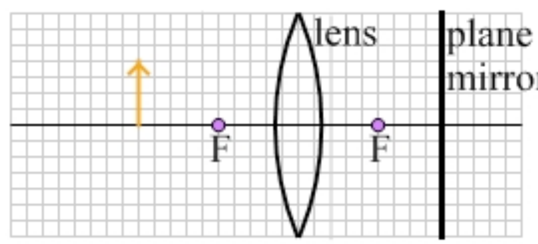


Figure 24.71: An object placed in front of a converging lens, with a plane mirror on the far side of the lens. For Exercise 65. Each square on the grid measures 1.0 cm × 1.0 cm.

66. Comment on following conversation, between two students discussing a situation in which they are trying to determine whether a particular lens is converging or diverging.

Jeremy: The first thing they tell us is that the image produced in the situation is virtual. Doesn't that mean the lens must be a diverging lens? That always gives virtual images.

Bridget: I don't think this tells us much, actually. Converging lenses can also give virtual images, if the object is farther from the lens than the focal point.

Jeremy: OK, so, then they say the image is smaller in size than the object. That doesn't tell us much either, right? Both lenses can produce images smaller than the object.

Student Worksheet: Lenses

One practical application of refraction is in lenses.

There are many parallels between how lenses work and how spherical mirrors work. For one thing, the same equations apply, which is rather surprising.

f is the focal length of the lens, (with an appropriate sign – see below).
The object distance d_o is the distance of the object from the lens.

The object distance d_i is the distance of the image from the lens.

The thin-lens equation: $\frac{1}{f}=\frac{1}{d_o}+\frac{1}{d_i}$ or, equivalently $d_i=\frac{d_o f}{d_o-f}$

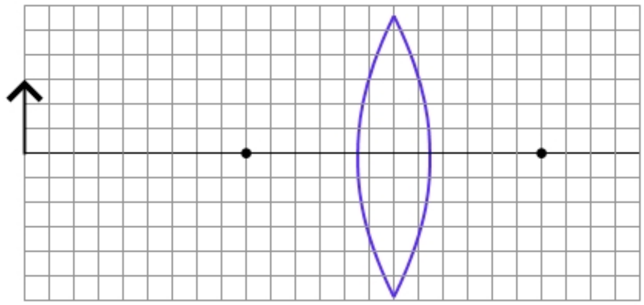
Sign convention: The basic rule on signs for lenses is that the object side of the lens is positive for object distance but negative for image distance, while the far side of the lens is positive for image distance. This is because the light goes through the lens. Lenses have two focal points, one on each side. Converging lenses (like converging mirrors) have positive focal lengths; diverging lenses (and mirrors) have negative focal lengths.

Magnification: The magnification tells us (as should the ray diagram) whether the lens makes an image that is smaller or larger than the object, and whether the image is upright or inverted. $m=\frac{h_i}{h_o}=-\frac{d_i}{d_o}$ where h_i is the image height and h_o is the object height.

Example 1: An object is 15 units away from a convex (converging) lens that has a focal length of +6 units. Where is the image? What are its characteristics? Use the equations to help you.

Ray diagrams for lenses also work much like those for mirrors. The rays now have to obey Snell's Law, rather than the Law of Reflection, which makes it more challenging to figure out where the rays go. Again we have special rays that we draw because we know what they will do.

On the diagram draw the following special rays, all leaving the tip of the object.
1. Draw a straight line from the tip right through the center of the lens.
2. Draw a horizontal line from the tip to the lens, then it goes through the far focal point.
3. Draw a line from the tip through the near focal point to the lens, then horizontal.

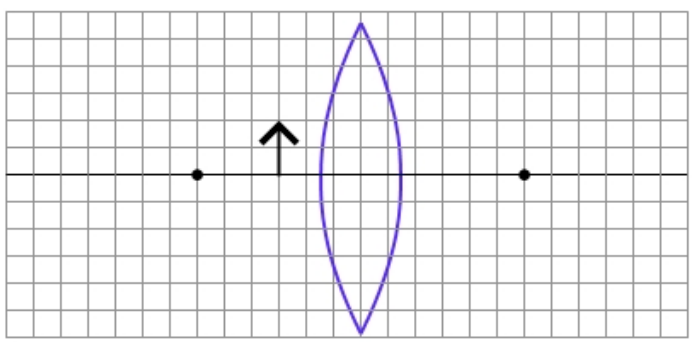


Now draw several more rays from the tip to the lens, and show where they go.

Example 2: An object is 3 units away from a convex (converging) lens that has a focal length of +6 units. Where is the image? What are its characteristics? Use the equations to help you.

On the diagram draw the following special rays, all leaving the tip of the object.

1. Draw a straight line from the tip right through the center of the lens.
2. Draw a horizontal line from the tip to the lens, then it goes through the far focal point.
3. Draw a straight line from the left focal point that goes through the tip of the object to the lens, and changes direction to be horizontal on the far side of the lens.



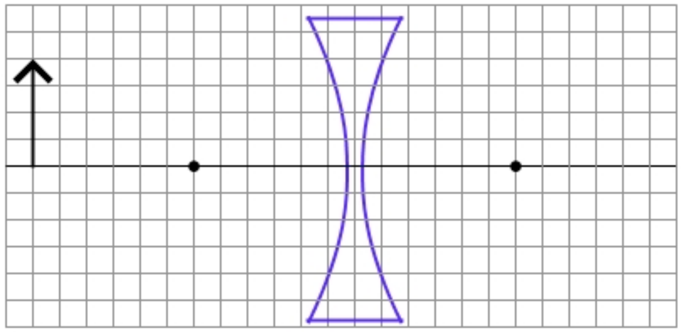
Now draw several more rays from the tip to the lens, and show where they go.

Example 3: An object is 12 units away from a concave (diverging) lens that has a focal length of –6 units. Where is the image? What are its characteristics? Use the equations to help you.

On the diagram draw the following special rays, all leaving the tip of the object.

1. Draw a straight line from the tip right through the center of the lens.
2. Draw a horizontal line from the tip to the lens, then it changes direction to go away from the focal point on the left.

3. Draw a straight line toward the right focal point that changes direction to be horizontal on the far side of the lens.



Now draw several more rays from the tip to the lens, and show where they go.

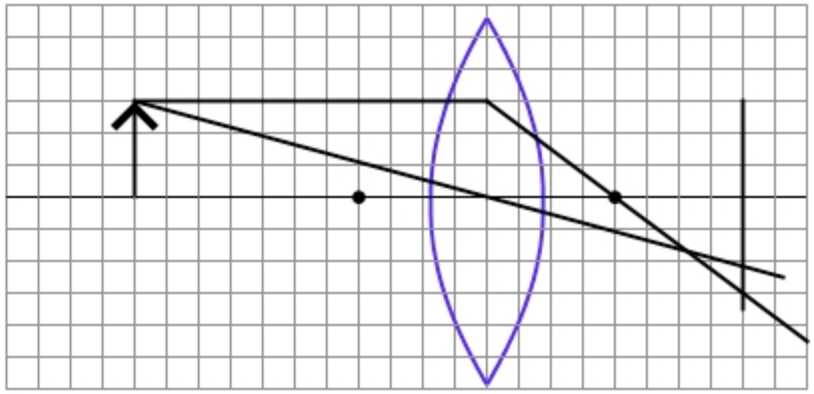
Student Worksheet: The Eye and the Camera

How does an eye work? How does a camera work?

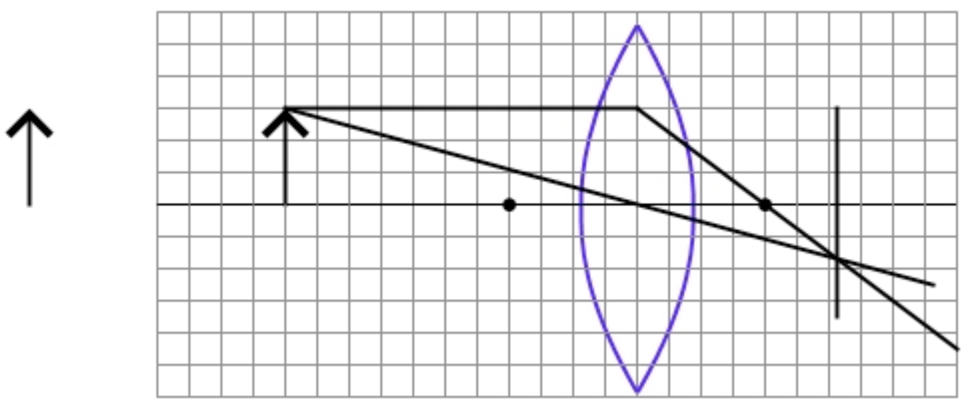
What similarities do you see between an eye and a camera?

What differences do you see?

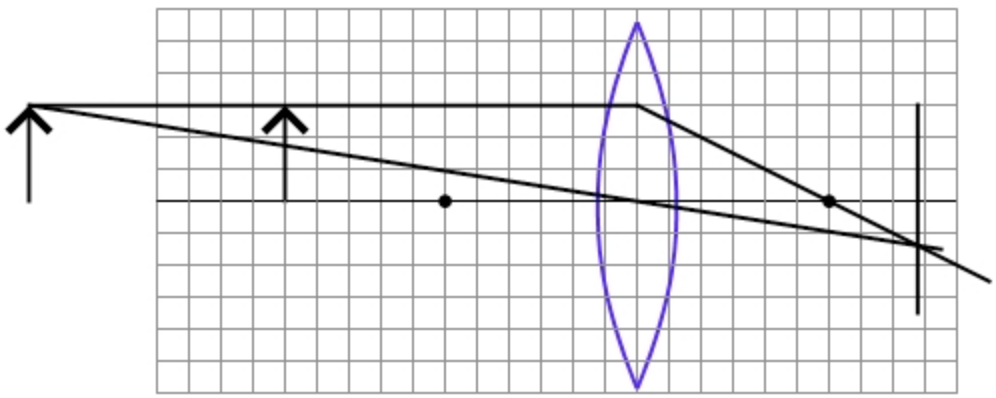
How do you focus? An object is a fixed distance from a screen on which you want to focus an image of the object. The lens you are using is creating an image somewhere other than the screen. What can you do to cause the image to be focused on the screen, without changing the distance from the object to the screen? Come up with as many methods as you can.



Are any of these methods used in the human eye, or in a camera?



The lens in this person's eye is a little too curved, so for an object that is far from the person, the image is created at a place that does not coincide with the retina. Where is the image? The person has no trouble seeing nearby objects, however. What is this problem called? How is it corrected? Sketch a ray diagram on the figure above to show how the rays go when the issue is corrected.



The lens in this person’s eye is not curved enough, so for an object that is close to the person, the image is created at a place that does not coincide with the retina. Where is the image? The person has no trouble seeing distant objects, however. What is this problem called? How is it corrected?
Sketch a ray diagram on the figure above to show how the rays go when the issue is corrected.

Clicker Questions

These questions generally come with diagrams, or animations/simulations, or they accompany in-class demonstrations.

What happens when a parallel beam of light enters a rectangular glass block? Assuming the light exits the block along the side opposite to the side it entered, what path does the light follow when it emerges from the block?

1. The exact path it was following when it entered the block.
2. A path parallel to the original path, but displaced from it.
3. A path perpendicular to the original path.
4. None of the above.

A ray of light traveling in medium 1 encounters an interface between medium 1 and medium 2. Part of the light is refracted into medium 2, and part is reflected back into medium 1, as shown in the diagram.

If the refracted ray follows path D, not bending at all, what can you conclude?

1. $n_1 = n_2$
2. $n_2 > n_1$
3. $n_1 > n_2$
4. $n_1 > n_2$, and the angle of incidence in medium 1 is the critical angle for total internal reflection
5. $n_2 > n_1$, and the angle of incidence in medium 1 is the critical angle for total internal reflection
6. This is not actually possible

If the refracted ray follows path A, what can you conclude?

1. $n_1 = n_2$
2. $n_2 > n_1$
3. $n_1 > n_2$
4. $n_1 > n_2$, and the angle of incidence in medium 1 is the critical angle for total internal reflection
5. $n_2 > n_1$, and the angle of incidence in medium 1 is the critical angle for total internal reflection
6. This is not actually possible

If the refracted ray follows path C, what can you conclude?

1. $n_1 = n_2$

2. $n_2 > n_1$
3. $n_1 > n_2$
4. $n_1 > n_2$, and the angle of incidence in medium 1 is the critical angle for total internal reflection
5. $n_2 > n_1$, and the angle of incidence in medium 1 is the critical angle for total internal reflection
6. This is not actually possible

If the refracted ray follows path F, what can you conclude?

1. $n_1 = n_2$
2. $n_2 > n_1$
3. $n_1 > n_2$
4. $n_1 > n_2$, and the angle of incidence in medium 1 is the critical angle for total internal reflection
5. $n_2 > n_1$, and the angle of incidence in medium 1 is the critical angle for total internal reflection

This is not actually possible

A convex (converging) lens creates an image of a vertical light-bulb filament on a ground glass plate, which acts as a screen. What will happen to the image if the top half of the filament is covered up?

1. The top half of the image will vanish.
2. The bottom half of the image will vanish.
3. The entire image will vanish.
4. The entire image will remain, but will be dimmer.
5. Nothing will change.

What will happen to the image if, instead, the top half of the lens is covered up?

1. The top half of the image will vanish.
2. The bottom half of the image will vanish.
3. The entire image will vanish.
4. The entire image will remain, but will be dimmer.

5. Nothing will change.

An object is placed in front of a lens. The image formed by the lens is two times larger than the object.

What kind of lens is it?

1. convex (converging)
2. concave (diverging)
3. it could be either of the above

The focal length of the lens is 10 cm. We want to know where the object is but first consider this. How many solutions are there to the question "What is the object distance?"

1. 1
2. 2
3. more than 2

A person who is nearsighted can only create sharp images of close objects. Objects that are further away look fuzzy because the eye brings them in to focus at a point in front of the retina. To correct for this, a lens can be placed in front of the eye. What kind of lens is necessary?

1. A converging lens
2. A diverging lens