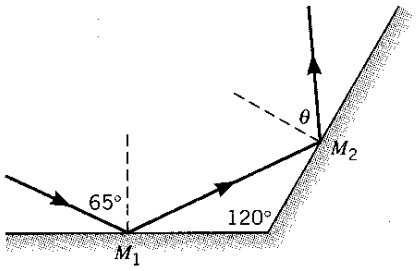
PROBLEMS

ssm Solution is in the Student Solutions Manual. **www** Solution is available on the World Wide Web at http://www.wiley.com/college/cutnell
This icon represents a biomedical application.

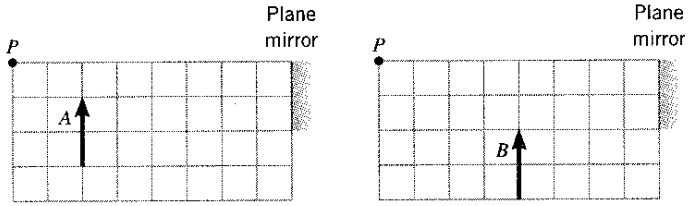
Section 25.2 The Reflection of Light, Section 25.3 The Formation of Images by a Plane Mirror

1. ssm Two plane mirrors are separated by 120°, as the drawing illustrates. If a ray strikes mirror M_1 at a 65° angle of incidence, at what angle θ does it leave mirror M_2?



Problem 1

2. Review Conceptual Example 1 as an aid in understanding this problem. The drawings show two arrows, *A* and *B*, that are located in front of a plane mirror. A person at point *P* is viewing the image of each arrow. Which images can be seen in their entirety? Determine your answers by drawing a ray from the head and foot of each arrow that reflects from the mirror according to the law of reflection and reaches point *P*. Only if *both* rays reach point *P* after reflection can the image of that arrow be seen in its entirety.



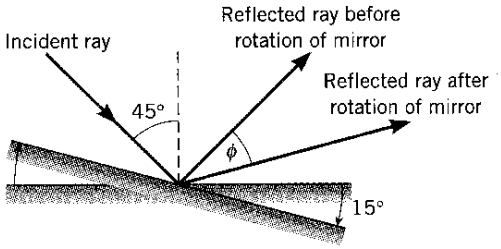
3. A person stands 3.6 m in front of a wall that is covered floor-to-ceiling with a plane mirror. His eyes are 1.8 m above the floor. He holds a flashlight between his feet and manages to point it at the mirror. At what angle of incidence must the light strike the mirror so the light will reach his eyes?

4. Review Conceptual Example 2. Suppose that in Figure 25.9*b* the two perpendicular plane mirrors are represented by the $-x$ and $-y$ axes of an x, y coordinate system. An object is in front of these mirrors at a point whose coordinates are $x = -2.0$ m and $y = -1.0$ m. Find the coordinates that locate each of the three images.

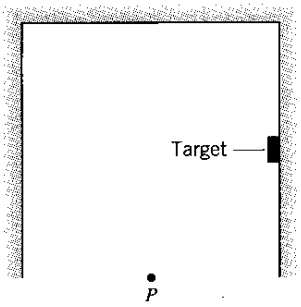
5. ssm www Two diverging light rays, originating from the same point, have an angle of 10° between them. After the rays reflect from a plane mirror, what is the angle between them? Construct one possible ray diagram that supports your answer.

6. On the $+y$ axis a laser is located at $y = +3.0$ cm. The coordinates of a target are $x = +9.0$ cm and $y = +6.0$ cm. The $+x$ axis represents the edge-on view of a mirror. At what point on the $+x$ axis should the laser be aimed in order to hit the target after reflection?

***7.** A ray of light strikes a plane mirror at a 45° angle of incidence. The mirror is then rotated by 15° into the position shown in red in the drawing, while the incident ray is kept fixed. (a) Through what angle ϕ does the reflected ray rotate? (b) What is the answer to part (a) if the angle of incidence is 60° instead of 45°?



***8.** The drawing shows a top view of a square room. One wall is missing, and the other three are each mirrors. From point *P* in the center of the open side, a laser is fired, with the intent of hitting a small target located at the center of one wall. Identify five directions in which the laser can be fired and score a hit, assuming that the light does not strike any mirror more than once. Draw the rays to confirm your choices.



****9. ssm** A lamp is twice as far in front of a plane mirror as a person is. Light from the lamp reaches the person via two paths. It strikes the mirror at a 30.0° angle of incidence and reflects from it before reaching the person. It also travels directly to the person without reflecting. Find the ratio of the travel time along the reflected path to the travel time along the direct path.

Section 25.4 Spherical Mirrors, Section 25.5 The Formation of Images by Spherical Mirrors

10. A 2.0-cm-high object is situated 15.0 cm in front of a concave mirror that has a radius of curvature of 10.0 cm. Using a ray diagram drawn to scale, measure (a) the location and (b) the height of the image. The mirror must be drawn to scale.

11. Repeat problem 10 for a concave mirror with a focal length of 20.0 cm, an object distance of 12.0 cm, and a 2.0-cm-high object.

12. A convex mirror has a focal length of -40.0 cm. A 12.0-cm-tall object is located 40.0 cm in front of this mirror. Using a ray diagram drawn to scale, determine the (a) location and (b) size of the image. Note that the mirror must be drawn to scale.

13. ssm Repeat problem 10 for a convex mirror with a radius of curvature of 1.00×10^2 cm, an object distance of 25.0 cm, and a 10.0-cm-high object.

14. Repeat problem 10 for a concave mirror with a focal length of 7.50 cm, an object distance of 11.0 cm, and a 1.0-cm-high object.

*__15.__ A plane mirror and a concave mirror ($f = 8.0$ cm) are facing each other and are separated by a distance of 20.0 cm. An object is placed 10.0 cm in front of the plane mirror. Consider the light from the object that reflects first from the plane mirror and then from the concave mirror. Using a ray diagram drawn to scale, find the location of the image that this light produces in the concave mirror. Specify this distance relative to the concave mirror.

Section 25.6 The Mirror Equation and the Magnification Equation

16. A coin is placed 8.0 cm in front of a concave mirror. The mirror produces a real image that has a diameter 4.0 times larger than that of the coin. What is the image distance?

17. ssm A concave mirror has a focal length of 42 cm. The image formed by this mirror is 97 cm in front of the mirror. What is the object distance?

18. A clown is using a concave makeup mirror to get ready for a show and is 27 cm in front of the mirror. The image is 65 cm *behind* the mirror. Find (a) the focal length of the mirror and (b) the magnification.

19. A concave mirror ($R = 64.0$ cm) is used to project a transparent slide onto a wall. The slide is located at a distance of 38.0 cm from the mirror, and a small flashlight shines light through the slide and onto the mirror. The setup is similar to that in Figure 25.19*a*. (a) How far from the wall should the mirror be located? (b) The height of the object on the slide is 1.20 cm. What is the height of the image? (c) How should the slide be oriented, so that the picture on the wall looks normal?

20. An object that is 25 cm in front of a convex mirror has an image located 17 cm behind the mirror. How far behind the mirror is the image located when the object is 19 cm in front of the mirror?

21. ssm The image behind a convex mirror (radius of curvature = 68 cm) is located 22 cm from the mirror. (a) Where is the object located and (b) what is the magnification of the mirror? Determine whether the image is (c) upright or inverted and (d) larger or smaller than the object.

22. A convex mirror produces an image that is half the size of an object that is placed 13 cm in front of it. What is the focal length of the mirror?

23. ssm www A small postage stamp is placed in front of a concave mirror (radius = R), such that the image distance equals the object distance. (a) In terms of R, what is the object distance? (b) What is the magnification of the mirror? (c) State whether the image is upright or inverted relative to the object. Draw a ray diagram to guide your thinking.

*__24.__ A dentist's mirror is placed 2.0 cm from a tooth. The *enlarged* image is located 5.6 cm behind the mirror. (a) What kind of mirror (plane, concave, or convex) is being used? (b) Determine the focal length of the mirror. (c) What is the magnification? (d) How is the image oriented relative to the object?

*__25.__ An object is placed in front of a convex mirror, and the size of the image is one-third that of the object. What is the ratio d_o/f of the object distance to the focal length of the mirror?

*__26.__ The same object is located at the same distance from two spherical mirrors, A and B. The magnifications produced by the mirrors are $m_A = 4.0$ and $m_B = 2.0$. Find the ratio f_A/f_B of the focal lengths of the mirrors.

*__27. ssm www__ An image formed by a convex mirror ($f = -24.0$ cm) has a magnification of 0.150. Which way and by how much should the object be moved to double the size of the image?

**__28.__ A concave mirror has a focal length of 30.0 cm. The distance between an object and its image is 45.0 cm. Find the object and image distances assuming that (a) the object lies beyond the center of curvature and (b) the object lies within the focal point.

**__29.__ Using the mirror equation and the magnification equation, show that for a convex mirror the image is always (a) virtual (i.e., d_i is always negative) and (b) upright and smaller, relative to the object (i.e., m is positive and less than one).

ADDITIONAL PROBLEMS

30. The image of a very distant car is located 12 cm behind a convex mirror. (a) What is the radius of curvature of the mirror? (b) Draw a ray diagram to scale showing this situation.

31. ssm www When viewed in a spherical mirror, the image of a setting sun is a virtual image. The image lies 12.0 cm behind the mirror. (a) Is the mirror concave or convex? Why? (b) What is the radius of curvature of the mirror?

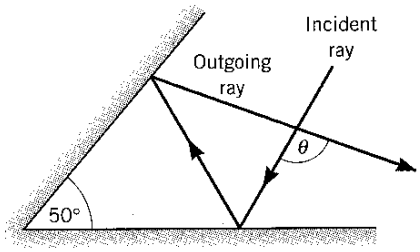
32. Review Conceptual Example 1 before attempting this problem. A person whose eyes are 1.70 m above the floor stands in front of a plane mirror. The top of her head is 0.12 m above her eyes. (a) What is the height of the shortest mirror in which she can see her entire image? (b) How far above the floor should the bottom edge of the mirror be placed?

33. The focal length of a concave mirror is 17 cm. An object is located 38 cm in front of this mirror. Where is the image located?

34. Convex mirrors are being used to monitor the aisles in a store. The mirrors have a radius of curvature of 4.0 m. (a) What is the image distance if a customer is 15 m in front of the mirror? (b) Is the image real or virtual? (c) If a customer is 1.6 m tall, how tall is the image?

35. ssm The image produced by a concave mirror is located 26 cm in front of the mirror. The focal length of the mirror is 12 cm. How far in front of the mirror is the object located?

*__36.__ The drawing shows two plane mirrors that intersect at an angle of 50°. An incident light ray reflects from one mirror and then the other. What is the angle θ between the incident and outgoing rays?



*37. In Figure 25.21*b* the head-up display is designed so that the distance between the digital readout device and virtual image 1 is 2.00 m. The magnification of virtual image 1 is 4.00. Find the focal length of the concave mirror. *(Hint: Remember that the image distance for virtual image 1 is a negative quantity.)*

*38. A candle is placed 15.0 cm in front of a convex mirror. When the convex mirror is replaced with a plane mirror, the image moves 7.0 cm farther away from the mirror. Find the focal length of the convex mirror.

*39. **ssm** An object is located 14.0 cm in front of a convex mirror, the image being 7.00 cm behind the mirror. A second object, twice as tall as the first one, is placed in front of the mirror, but at a different location. The image of this second object has the same height as the other image. How far in front of the mirror is the second object located?

**40. A spherical mirror is polished on both sides. When used as a convex mirror, the magnification is +1/4. What is the magnification when used as a concave mirror, the object remaining the same distance from the mirror?

**41. In the drawing for problem 8, a laser is fired from point *P* in the center of the open side of the square room. The laser is pointed at the mirrored wall on the right. At what angle of incidence must the light strike the right-hand wall, so that after being reflected, the light hits the left corner of the back wall?

CONCEPTS & CALCULATIONS

GROUP LEARNING PROBLEMS

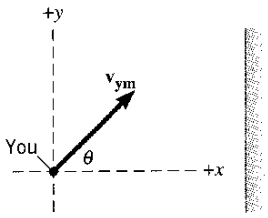
Note: Each of these problems consists of Concept Questions followed by a related quantitative Problem. They are designed for use by students working alone or in small learning groups. The Concept Questions involve little or no mathematics and are intended to stimulate group discussions. They focus on the concepts with which the problems deal. Recognizing the concepts is the essential initial step in any problem-solving technique.

42. Concept Questions (a) Suppose that you are walking toward a stationary plane mirror. Following the method discussed in Section 3.4, express your image's velocity $\mathbf{v}_{IY}$ relative to you in terms of the image's velocity $\mathbf{v}_{IM}$ relative to the mirror and the mirror's velocity $\mathbf{v}_{MY}$ relative to you. (b) How is the mirror's velocity $\mathbf{v}_{MY}$ relative to you related to your velocity $\mathbf{v}_{YM}$ relative to the mirror? Explain. (c) Consider both velocities $\mathbf{v}_{YM}$ and $\mathbf{v}_{IM}$. Do they have the same magnitudes and the same directions? Explain.

Problem When you walk perpendicularly toward a stationary plane mirror with a velocity of +0.90 m/s, what is the velocity of your image relative to you? The direction in which you walk is the positive direction.

43. Concept Questions (a) Suppose that you are walking toward a plane mirror as in the drawing. The view is from above. Following the method discussed in Section 3.4, express your image's velocity $\mathbf{v}_{IY}$ relative to you in terms of the image's velocity $\mathbf{v}_{IM}$ relative to the mirror and the mirror's velocity $\mathbf{v}_{MY}$ relative to you. (b) How is the mirror's velocity $\mathbf{v}_{MY}$ relative to you related to your velocity $\mathbf{v}_{YM}$ relative to the mirror? Explain. (c) Consider both velocities $\mathbf{v}_{YM}$ and $\mathbf{v}_{IM}$. Do they have the same x and y components? Explain.

Problem You walk at an angle of $\theta = 50.0°$ toward a plane mirror, as in the drawing. Your walking velocity has a magnitude of 0.90 m/s. What is the velocity of your image relative to you (magnitude and direction)?



Problem 43

44. Concept Questions (a) For an image that is in front of a mirror, is the image distance positive or negative? (b) Given the image distance, what additional information is needed to determine the focal length? Explain. (c) For an inverted image is the image height positive or negative? (d) Given the object and image heights and a statement as to whether the image is upright or inverted, what additional information is needed to determine the object distance?

Problem A small statue has a height of 3.5 cm and is placed in front of a concave mirror. The image of the statue is inverted, 1.5 cm tall, and is located 13 cm in front of the mirror. Find the focal length of the mirror.

45. Concept Questions These questions refer to Figure 25.22*a*. (a) As the object distance increases, does reflected ray 1 change? (b) As the object distance increases, does reflected ray 3 make a greater or smaller angle with respect to the principal axis? (c) Extending the reflected rays 1 and 3 behind the mirror allows us to locate the top of the image. As the object distance increases, does the image height increase or decrease?

Problem A convex mirror has a focal length of −27.0 cm. Find the magnification produced by the mirror when the object distance is 9.0 cm and 18.0 cm. Verify that your answers are consistent with your answers to the Concept Questions.