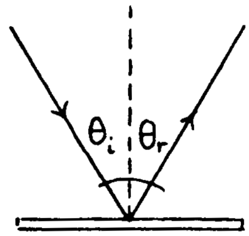
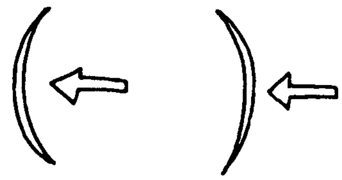
13-2 Reflection

Vocabulary **Reflection:** The bouncing of light.

The angle a beam of light makes when it strikes a surface is described with respect to the **normal,** an imaginary line drawn perpendicular to the surface. When light shines onto a mirror, the angle at which the light enters the mirror (angle of incidence) is exactly equal to the angle at which the light leaves the mirror (angle of reflection). This is called the **law of reflection** and is easily observed in a plane (flat) mirror.



Due to the curvature of a spherical mirror, light reflected from its surface behaves somewhat differently than it does when reflected from a plane mirror. There are two types of spherical mirrors, **converging** (or concave) and **diverging** (or convex).



Converging Diverging

The following terminology is used when describing how light is reflected from converging and diverging mirrors.

Vocabulary **Object distance:** The distance from the mirror to the object. This value is always a positive number.

Vocabulary **Image distance:** The distance from the mirror to the image. An image can be **real** (inverted and able to be projected on a screen), or **virtual** (right-side-up and not able to be projected on a screen).

Vocabulary **Focal point:** The point where parallel rays meet (or appear to meet) after reflecting from a mirror. The distance from this focal point to the mirror is called the **focal length**. The focal length of a converging mirror always has a positive value while the focal length of a diverging mirror always has a negative value.

Vocabulary **Mirror Equation:** $\frac{\mathbf{1}}{\textbf{focal length}} = \frac{\mathbf{1}}{\textbf{object distance}} + \frac{\mathbf{1}}{\textbf{image distance}}$

$$\frac{1}{f} = \frac{1}{d_\mathrm{o}} + \frac{1}{d_\mathrm{i}}$$

Note: Many situations involving mirrors can also be solved using ray diagrams.

Converging (Concave) Mirror

If an object is located more than one focal length from a converging mirror as shown in Figure A, the image it forms is real, inverted, and in front of the mirror. You can actually project this image onto a piece of paper. Both d_o and d_i have positive values.

If the object is at the focal point as in figure B, no image is formed because the reflected rays are parallel.

If an object is located less than one focal length from a converging mirror as in figure C, the image it forms is virtual, upright, enlarged, and behind the mirror. In other words, you must look into the mirror to see the image. Here, d_o has a positive value and d_i has a negative value.

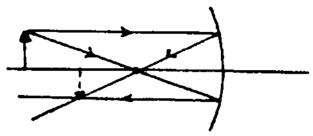


Figure A

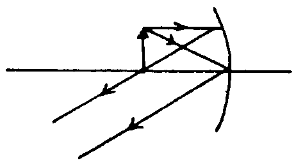


Figure B

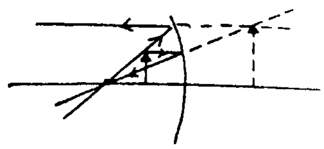
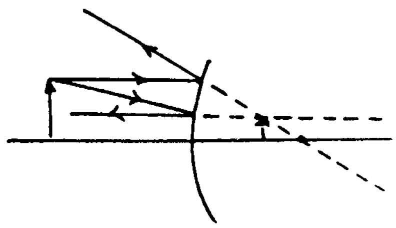


Figure C

Diverging (Convex) Mirror

The image formed by a diverging mirror is always virtual, upright, smaller, and behind the mirror. The image can be seen only by looking into the mirror. Here d_o has a positive value while d_i has a negative value.

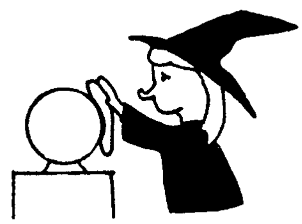


Solved Examples

Example 3: Sitting in her parlor one night, Gerty sees the reflection of her cat, Whiskers, in the living room window. If the image of Whiskers makes an angle of 40° with the normal, at what angle does Gerty see him reflected?

Solution: Because the angle of incidence equals the angle of reflection, Gerty must see her cat reflected at an angle of 40°.

Example 4: Wendy the witch is polishing her crystal ball. It is so shiny that she can see her reflection when she gazes into the ball from a distance of 15 cm. a) What is the focal length of Wendy's crystal ball if she can see her reflection 4.0 cm behind the surface? b) Is this image real or virtual?



a. *Given:* $d_o = 15\text{ cm}$
$d_i = -4.0\text{ cm}$

Unknown: $f = ?$

Original equation: $\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$

Solve: $\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{15\text{ cm}} + \frac{1}{-4.0\text{ cm}}$

Getting a common denominator of 60 cm gives $\frac{1}{f} = \frac{4}{60\text{ cm}} - \frac{15}{60\text{ cm}} = \frac{-11}{60\text{ cm}}$

To find f, take the reciprocal of this sum. $f = \frac{-60\text{ cm}}{11} = \mathbf{-5.5\text{ cm}}$

The minus sign before the answer means that this is the focal length of a diverging mirror.

b. The image seen *behind* a curved surface is always a **virtual image**.

Example 5: With his face 6.0 cm from his empty water bowl, Spot sees his reflection 12 cm behind the bowl and jumps back. a) What is the focal length of the bowl? b) What was surprising about Spot's reflection that may have caused him to jump?

a. *Given:* $d_o = 6.0\text{ cm}$
$d_i = -12\text{ cm}$

Unknown: $f = ?$

Original equation: $\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$

Solve: $\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{6.0\text{ cm}} + \frac{1}{-12\text{ cm}}$

Getting a common denominator of 12 cm gives $\frac{1}{f} = \frac{2}{12\text{ cm}} - \frac{1}{12\text{ cm}} = \frac{1}{12\text{ cm}}$

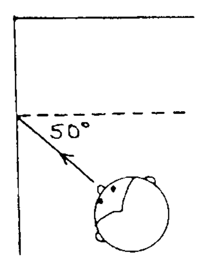
$f = \mathbf{12\text{ cm}}$

The positive answer means that the bowl was acting as a converging mirror.

b. The surprising thing Spot noticed about his reflection was that it appeared larger than life!

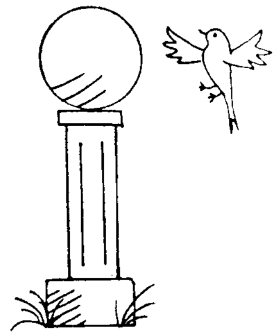
Practice Exercises

Exercise 5: Manish is in a house of mirrors with one of his friends when he comes to two mirrors situated at an angle of 90°. Manish stands so that light shining on his face is incident on one mirror at an angle of 50°, as shown. At what angle will this light reflect from the second mirror?



Answer: ____________________

Exercise 6: A popular lawn ornament in the 1960s was a colored reflecting sphere that sat in the yard as a decoration. a) If a bird is 10.0 cm from a blue reflecting sphere and sees its image reflected 5.0 cm behind the sphere, what is the focal length of the spherical reflector? b) Would the bird's image appear larger or smaller than the bird itself?



Answer: **a.** ______________________

Answer: **b.** ______________________

Exercise 7: Polly applies her mascara while looking in a concave mirror whose focal length is 18 cm. She looks into it from a distance of 12 cm. a) How far is Polly's image from the mirror? b) Does it matter whether or not Polly's face is closer or farther than one focal length? Explain.

Answer: **a.** ______________________

Answer: **b.** ______________________

Exercise 8: A friend is wearing a pair of mirrored sunglasses whose convex surface has a focal length of 20.0 cm. If your face is 40.0 cm from the sunglasses, how far behind the sunglasses is your image?

Answer: ______________________

5. $40°$
7. a) -36 cm