23-2 Spherical Mirrors

Important Ideas

- For spherical mirrors, the focal point is at half the radius of curvature.
- For a concave mirror, rays parallel to the principal axis reflect and converge through the focal point. The focal length is positive.
- For a convex mirror, rays parallel to the principal axis reflect and diverge away from the focal point. The focal length is negative.
- To locate an image by sketching rays, sketch two *easy* rays from the head of the object (i.e. tip of the arrow representing the object). The rays intersect at the head of the image.
  1. A ray that is parallel to the principal axis reflects through the focal point.
  2. A ray that reflects from the mirror at the principal axis reflects at the same angle relative to the principal axis.
  3. A ray that is in line with the center of the mirror reflects back on itself.
- If an image is formed by converging rays, then the image is a *real* image. (For mirrors, this occurs if the image is in front of the mirrored surface.) The image distance is positive.
- If an image is formed by diverging rays, then the image is a *virtual* image. (For mirrors, this occurs if the image is behind the mirrored surface.) The image distance is negative.
- The mirror equation

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

- The magnification is

$$m = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$

  The image height is negative if the image is inverted. Thus, m is negative if the image is inverted.
- Sign conventions
  - The focal length is positive for a concave mirror, and negative for a convex mirror.
  - The image distance is positive if the image is on the reflective side of the mirror (a real image), and negative if the image is behind the mirror (a virtual image).
  - The image height is positive when the image is upright, and negative when the image is inverted. A similar rule applies to the object height.

Plane and Spherical Mirrors

Type of mirror	Focal length	Image characteristics
Plane	∞	The image is virtual, upright, the same size as the object, and the same distance behind the mirror that the object is in front of the mirror.
Convex (diverging)	$-R/2$, R being the mirror's radius of curvature	The image is virtual, upright, smaller than the object, and located between the mirror and the mirror's focal point.
Concave (converging)	$+R/2$	The image can be real or virtual, and larger than, smaller than, or the same size as the object. See the table below for details.

Table 23.1: A summary of the mirrors we investigated in this chapter.

Images formed by a Concave (Converging) Mirror

Object position	Image position	Image characteristics
∞	At the focal point.	Real image with height of zero.
Moving from ∞ toward the center of curvature.	Moving from the focal point toward the center of curvature.	The image is real, inverted, and smaller than the object. The image moves closer to the center of curvature, and increases in height, as the object is moved closer to the center of curvature.
At the center of curvature.	At the center of curvature.	The image is real, inverted, and the same size as the object.
Moving from the center of curvature toward the focal point.	Moving from the center of curvature toward infinity.	The image is real, inverted, and larger than the object. The image moves farther from the mirror, and increases in height, as the object is moved closer to the focal point.
At the focal point.	At infinity.	The image is at infinity, and is infinitely tall.
Closer to the mirror than the focal point.	Behind the mirror	The image is virtual, upright, and larger than the object. The image moves closer to the mirror, and decreases in height, as the object is moved closer to the mirror.

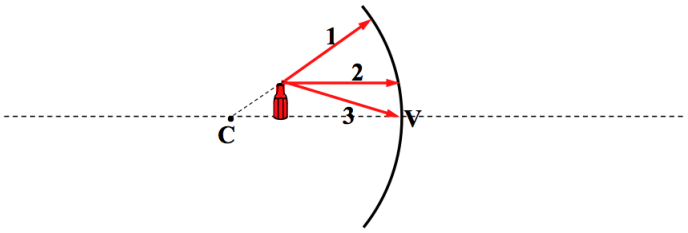
Table 23.2: A summary of the image positions and characteristics for various object positions with a concave mirror.

Examples

1. An object is 10 cm from a concave mirror of focal length 20 cm.
   (a) What is the image distance?
   (b) What is the magnification?
   (c) Is the image real or virtual?
   (d) Is it inverted or upright?

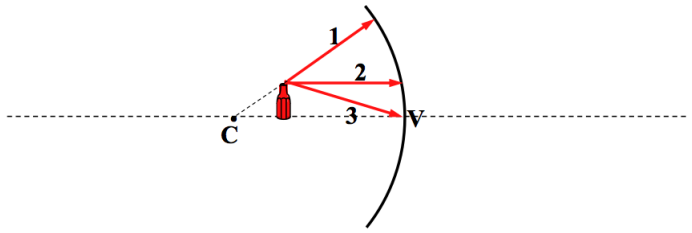
2. A shopper standing 3.00 m from a convex security mirror sees her image in the mirror and notes that the image is about 1/4 of her actual height.
   (a) What is the image distance?
   (b) What is the focal length of the mirror?
   (c) What is its radius of curvature?

3. A ketchup bottle is positioned in front of a concave mirror. Three of the incident rays are shown. _____ get(s) reflected through point C.



   (a) Ray 1
   (b) Ray 2
   (c) Ray 3
   (d) All three rays
   (e) None of the rays

4. A ketchup bottle is positioned in front of a concave mirror. Three of the incident rays are shown. _____ get(s) reflected horizontally to the left.



(a) Ray 1
(b) Ray 2
(c) Ray 3
(d) All three rays
(e) None of the rays

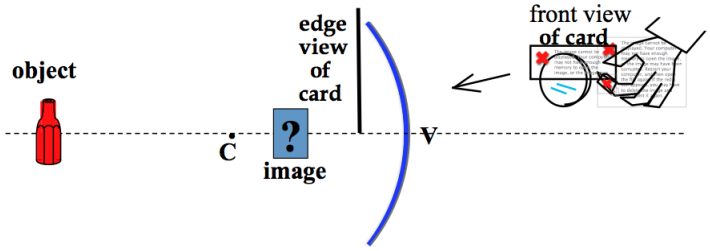
5. A ketchup bottle is positioned in front of a concave mirror. Three of the incident rays are shown. _____ make(s) the same angle with the normal as its reflected ray does.

(a) Ray 1
(b) Ray 2
(c) Ray 3
(d) All three rays
(e) None of the rays

6. A ketchup bottle is positioned in front of a concave mirror. Three of the incident rays are shown. _____ make(s) the same angle with the horizontal as its reflected ray does.

(a) Ray 1
(b) Ray 2
(c) Ray 3
(d) All three rays
(e) None of the rays

7. A concave mirror forms an image of an object as shown.



Suppose the top half of the mirror is blocked by an opaque card. With the card in place, we see

(a) no image.
(b) an image of the entire object.
(c) an image of just the top half of the object.
(d) an image of just the bottom half of the object.