Chapter 23

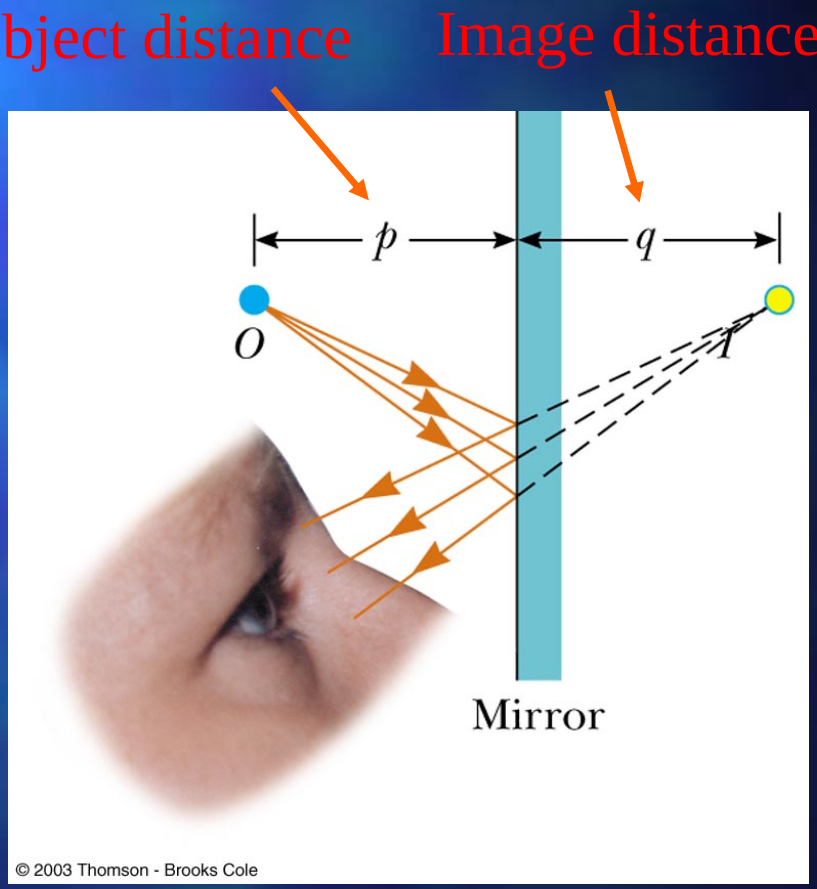
Mirrors and Lenses

Types of Images for Mirrors and Lenses

- A *real image* is one in which light actually passes through the image point
  - Real images can be displayed on screens
- A *virtual image* is one in which the light does not pass through the image point
  - The light appears to come (diverge) from that point
  - Virtual images cannot be displayed on screens

More About Images

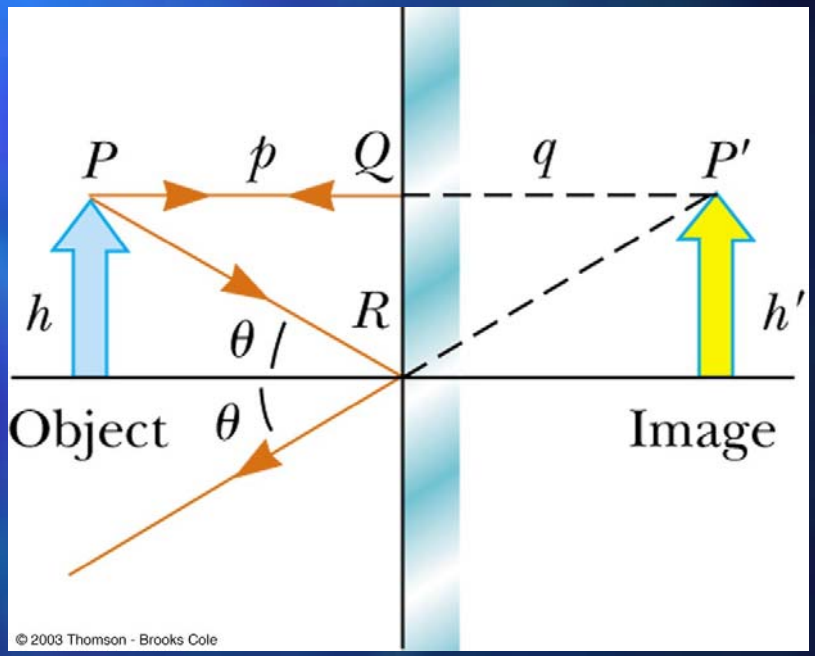
- To find where an image is formed, it is always necessary to follow at least two rays of light as they reflect from the mirror. The image formed by the flat mirror is a virtual image



Flat Mirror

- Simplest possible mirror
- Properties of the image can be determined by geometry
- One ray starts at *P*, follows path *PQ* and reflects back on itself
- A second ray follows path *PR* and reflects according to the Law of Reflection

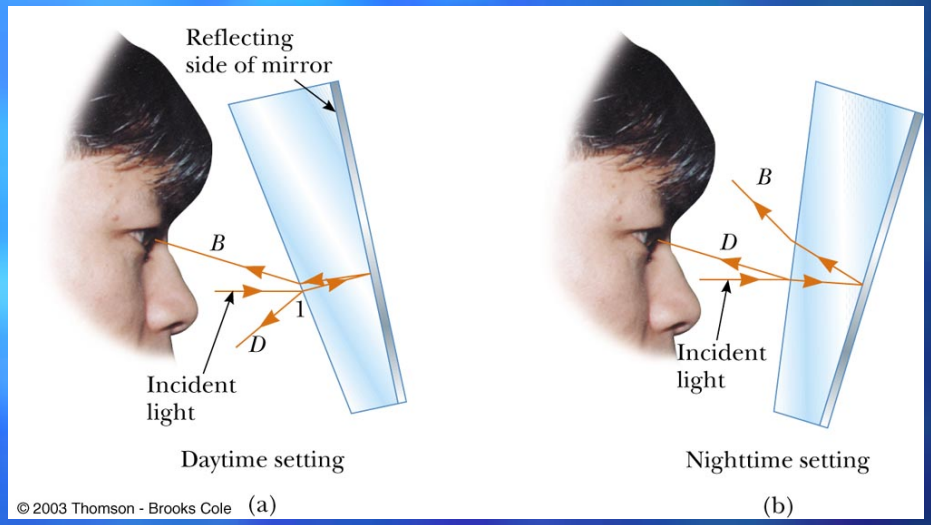
$p=q!$



Properties of the Image Formed by a Flat Mirror

- The image is as far behind the mirror as the object is in front
  - $p = q$
- The image is unmagnified, $M = 1$
- The image is virtual
- The image is upright
  - It has the same orientation as the object
- There is an apparent left-right reversal in the image

Application – Day and Night Settings on Car Mirrors



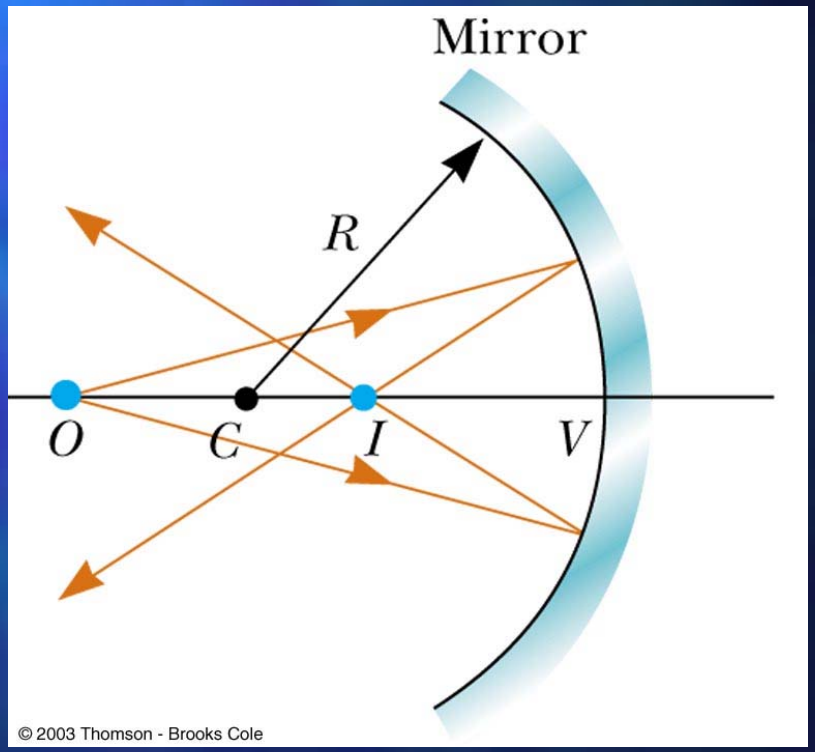
- With the daytime setting, the bright beam of reflected light is directed into the driver's eyes
- With the nighttime setting, the dim beam (*D*) of reflected light is directed into the driver's eyes, while the bright beam goes elsewhere

23.2 Spherical Mirrors

- A *spherical mirror* has the shape of a segment of a sphere
- A ***concave*** *spherical mirror* has the silvered surface of the mirror on the inner, or concave, side of the curve
- A ***convex*** *spherical mirror* has the silvered surface of the mirror on the outer, or convex, side of the curve

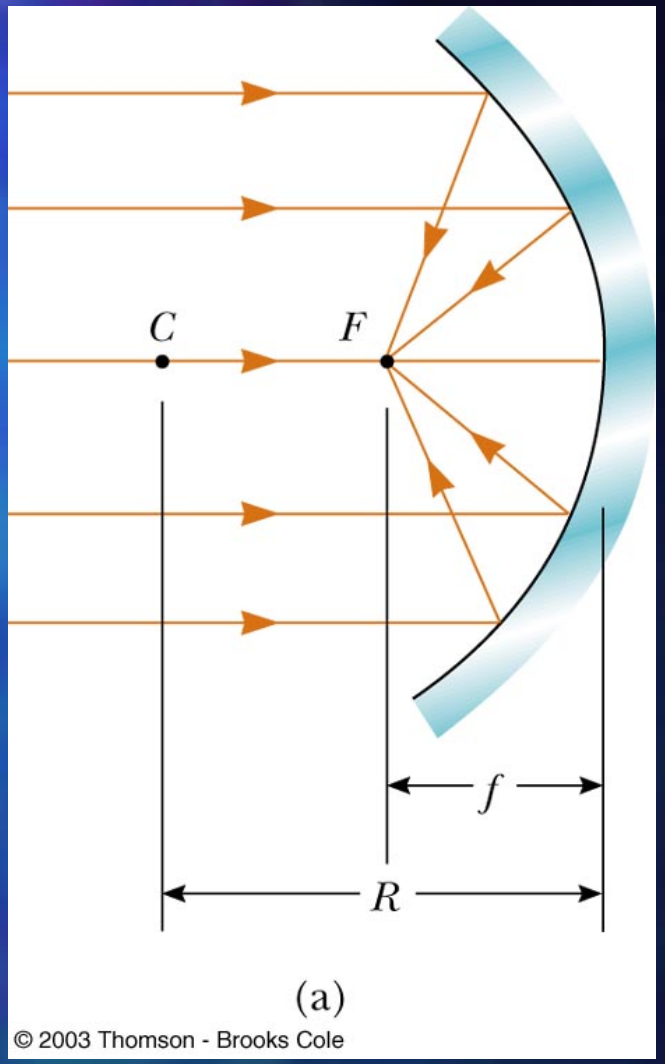
Concave Mirror, Notation

- The mirror has a *radius of curvature* of *R*
- Its *center of curvature* is the point *C*
- Point *V* is the center of the spherical segment
- A line drawn from *C* to *V* is called the *principle axis* of the mirror
- *I* is the image point



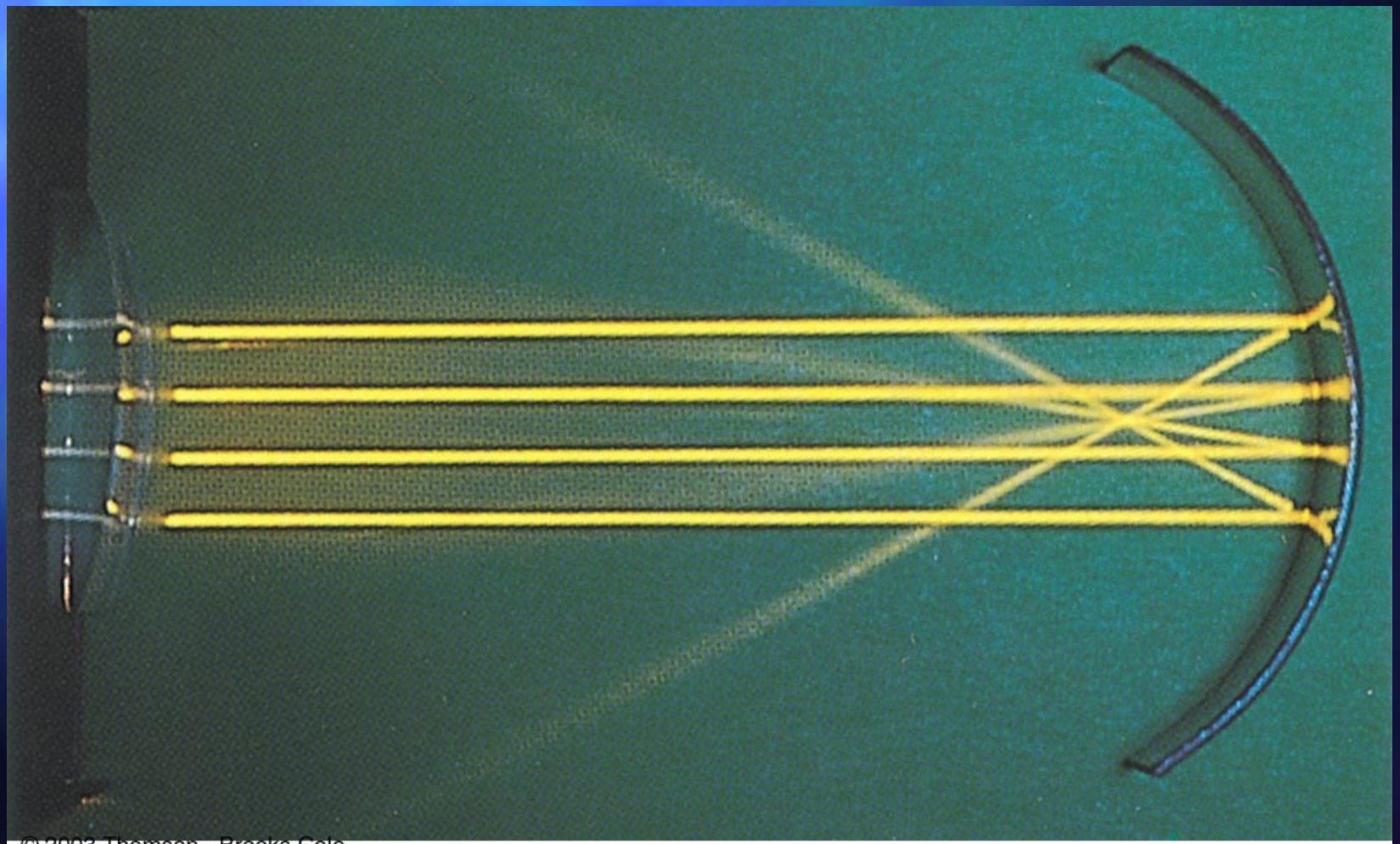
Focal Length

- If an object is very far away, then $p \to \infty$ and $1/p \to 0$;
- $q = R/2$
- Incoming rays are essentially parallel
- In this special case, the image point is called the *focal point*
- The distance from the mirror to the focal point is called the *focal length*
  - The focal length is ½ the radius of curvature



$$f = R/2$$

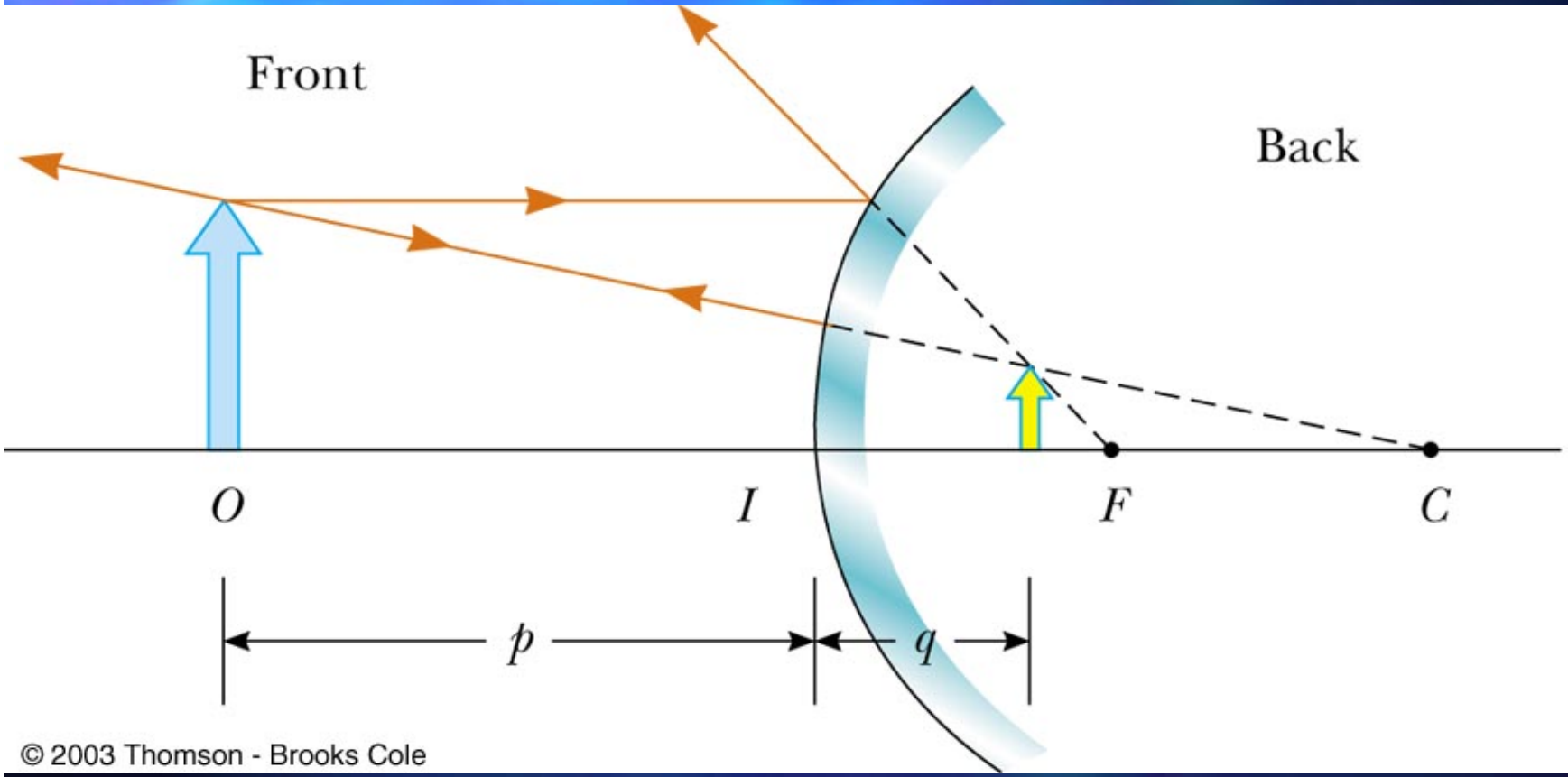
Focal Length Shown by Parallel Rays



23.3 Convex Mirrors

- A **convex** mirror is sometimes called a *diverging* mirror
- The rays from any point on the object diverge after reflection as though they were coming from some point behind the mirror
- The image is virtual because it lies behind the mirror at the point where the reflected rays appear to originate
- In general, the image formed by a convex mirror is upright, virtual, and smaller than the object

Image Formed by a Convex Mirror



Ray Diagrams

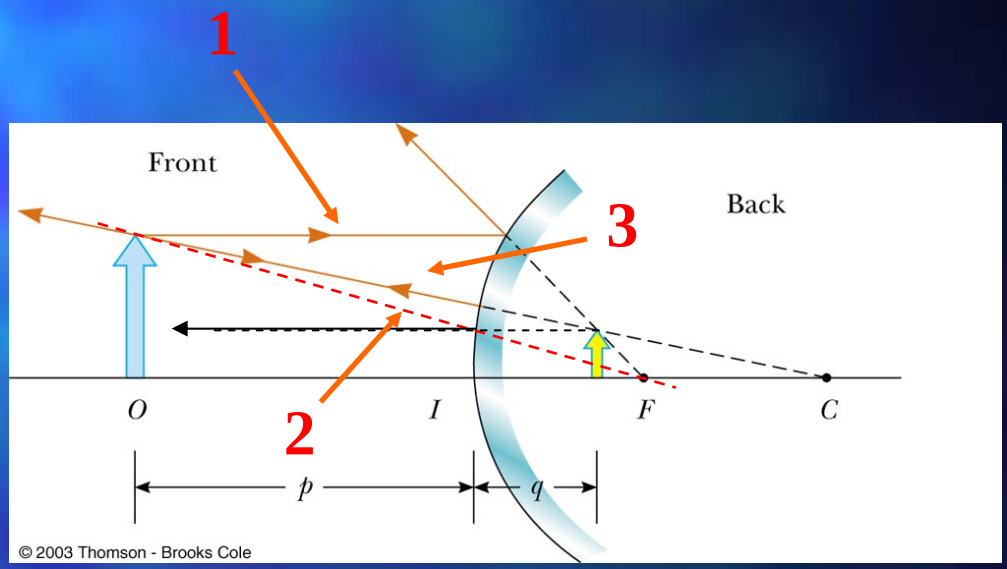
- A *ray diagram* can be used to determine the position and size of an image
- They are graphical constructions which tell the overall nature of the image
- They can also be used to check the parameters calculated from the mirror and magnification equations

Drawing A Ray Diagram

- To make the ray diagram, you need to know
  - The position of the object
  - The position of the center of curvature
- Three rays are drawn
  - They all start from the same position on the object
- The intersection of any two of the rays at a point locates the image
  - The third ray serves as a check of the construction

The Rays in a Ray Diagram

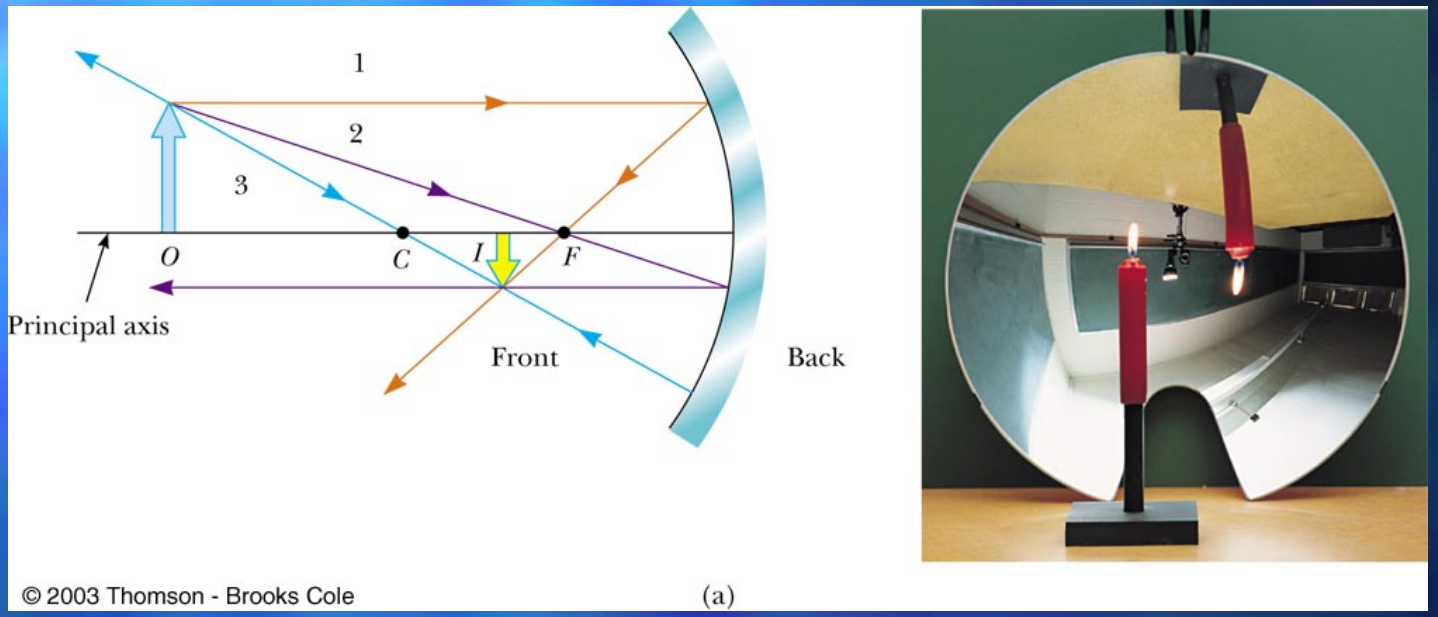
- Ray 1 is drawn parallel to the principle axis and is reflected back through the focal point, *F*
- Ray 2 is drawn through the focal point and is reflected parallel to the principle axis
- Ray 3 is drawn through the center of curvature and is reflected back on itself



Notes About the Rays

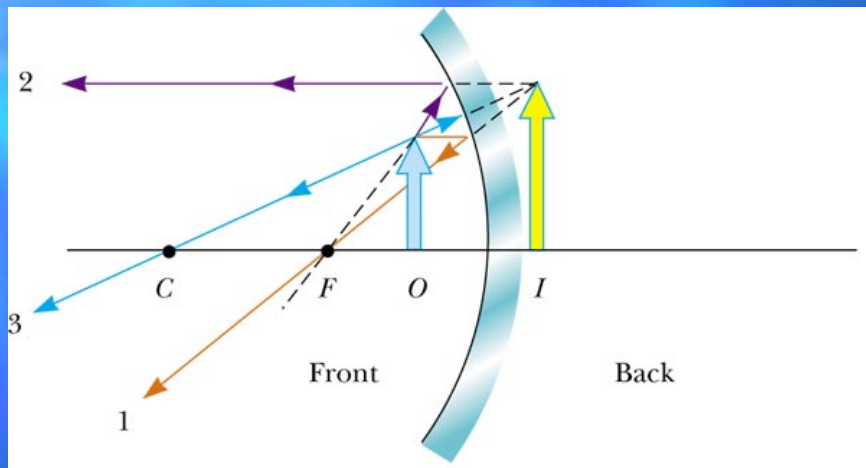
- The rays actually go in all directions from the object
- The three rays were chosen for their ease of construction
- The image point obtained by the ray diagram must agree with the value of q calculated from the mirror equation

Ray Diagram for Concave Mirror, $p > R$



- The image is real
- The image is inverted
- The image is smaller than the object

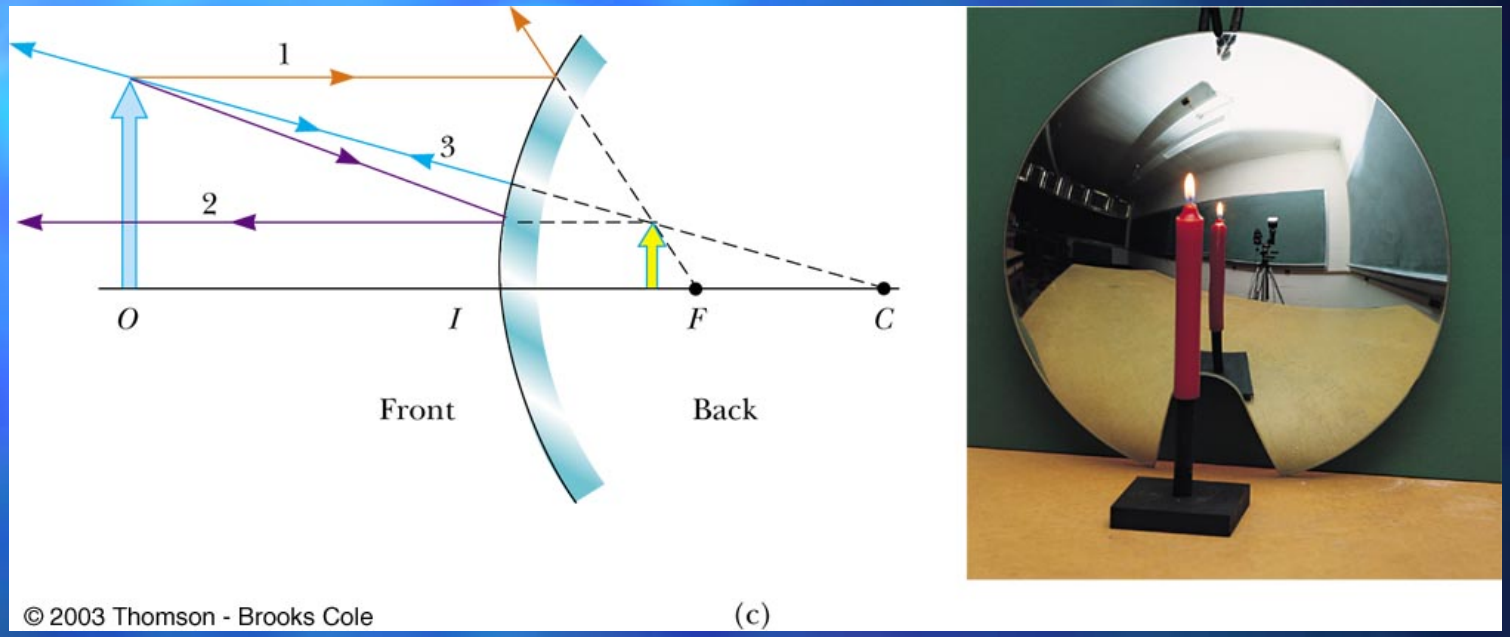
Ray Diagram for a Concave Mirror, $p < f$



(b)

- The image is virtual
- The image is upright
- The image is larger than the object

Ray Diagram for a Convex Mirror



- The image is virtual
- The image is upright
- The image is smaller than the object

Notes on Images

- With a concave mirror, the image may be either real or virtual
  - When the object is outside the focal point, the image is real
  - When the object is at the focal point, the image is infinitely far away (to the left in the previous diagrams)
  - When the object is between the mirror and the focal point, the image is virtual
- With a convex mirror, the image is always virtual and upright
  - As the object distance increases, the virtual image gets smaller