

Physics 1C

Lecture 26A

*"If Dracula can't see his reflection in the mirror,
how come his hair is always so neatly combed?"*

--Steven Wright

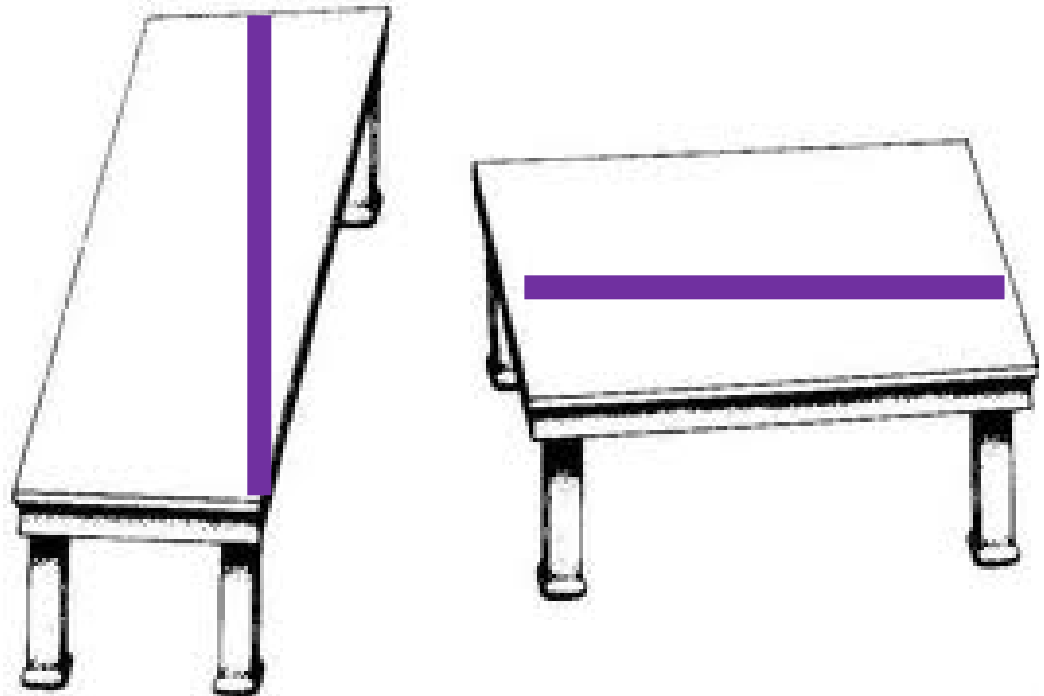
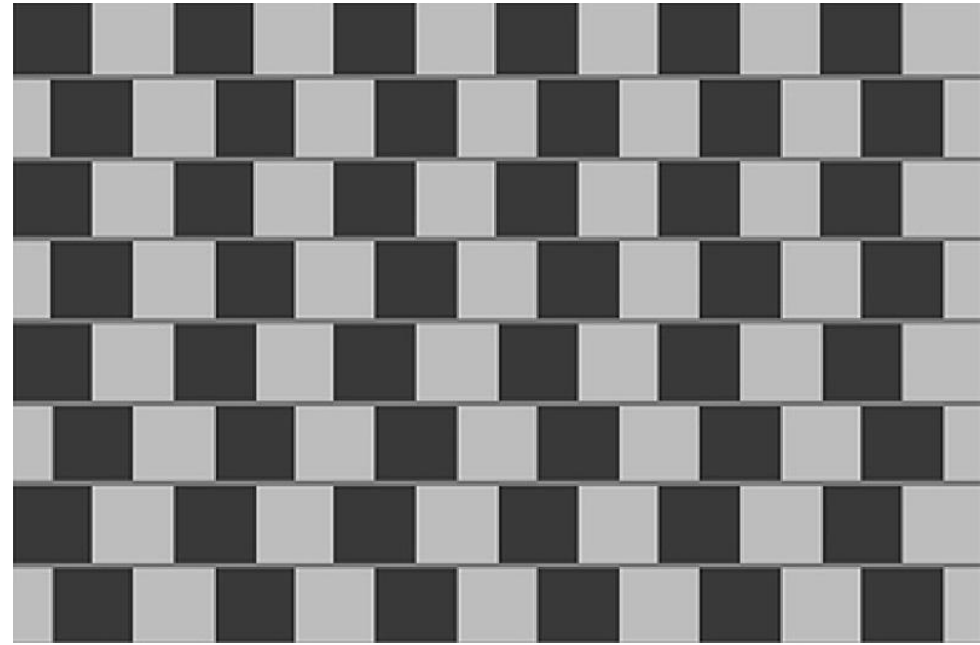
Announcements

Today discuss mirrors and
lenses

Magnification

Focal length

Mirror equation



Mirrors and Lenses

As we have noted before, light rays can be diverted by optical systems to fool your eye into thinking an object is somewhere that it is not.

The simplest optical systems are mirrors and lenses.

Mirrors and lenses will divert light rays from an object source and create an image.

Mirrors use **reflection** of light to divert the light rays.

Lenses use **refraction** of light to divert the light rays.

Mirrors and Lenses

Images are formed at the point where rays actually intersect or appear to originate.

There are two types of images: **real** and **virtual**.

A real image is one in which light actually passes through the image point.

Real images can be displayed on a screen.

A virtual image is one in which the light does not pass through the image point.

The light **appears** to diverge from that point.

Virtual images cannot be displayed on screens.

Mirrors and Lenses

For both mirrors and lenses:

The **object distance**, p , is the distance from the object to the mirror or lens.

The **image distance**, q , is the distance from the image to the mirror or lens.

The **lateral magnification**, M , of the mirror or lens is the ratio of the **image height** to the **object height**.

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 or refract through the lens.

Mirrors

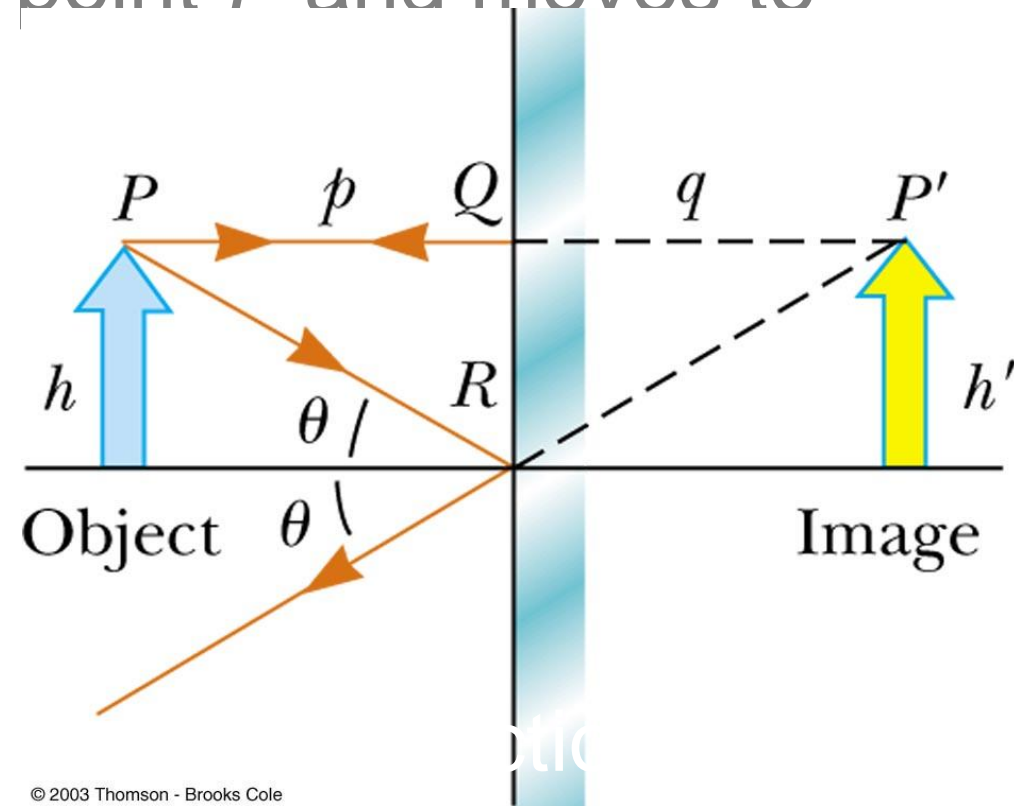
The simplest possible mirror is the **flat mirror**.

We will examine light rays diverging from the top of the object (point P) to geometrically determine the location of the image.

The first light ray starts at point P and moves to point Q .

Since this light ray is at 0° to the normal it will just reflect back on itself.

A second light ray starts at point P and moves to R .



Flat Mirrors

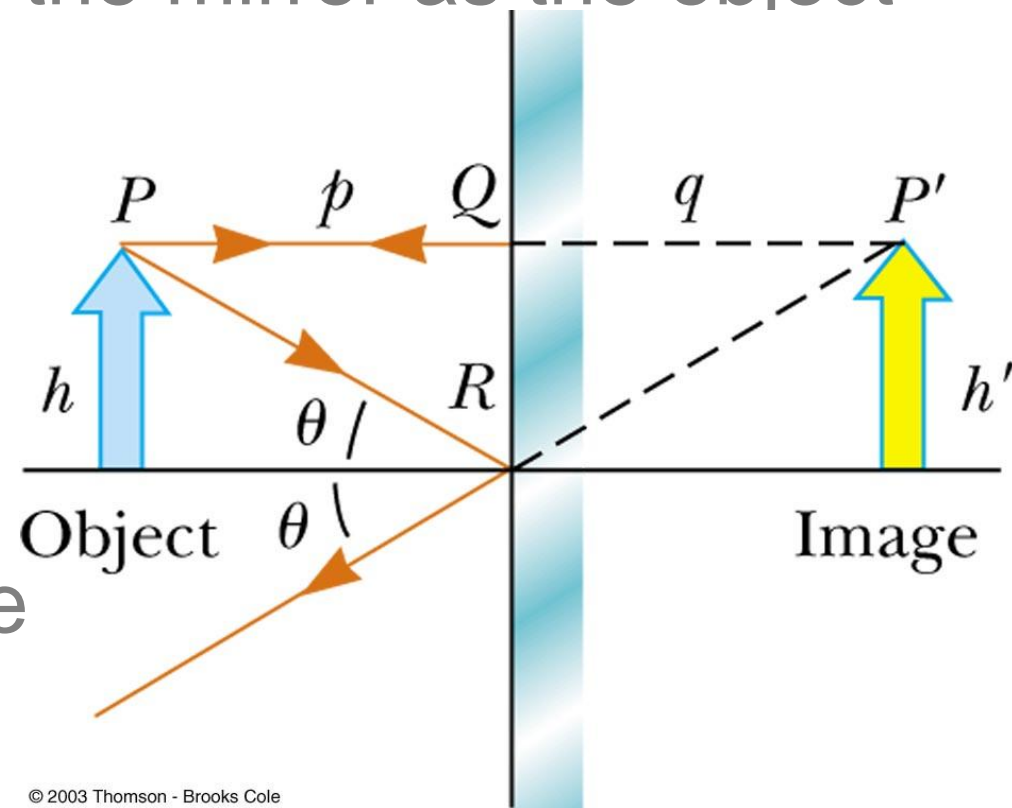
This light ray will reflect off of the mirror according to the Law of Reflection.

Tracking back these light rays shows us where the image is.

The image is as far behind the mirror as the object is in front ($p = q$).

The image is unmagnified as the image height is the same as the object height ($h = h'$ and $M = 1$).

The image is upright (same orientation as object).

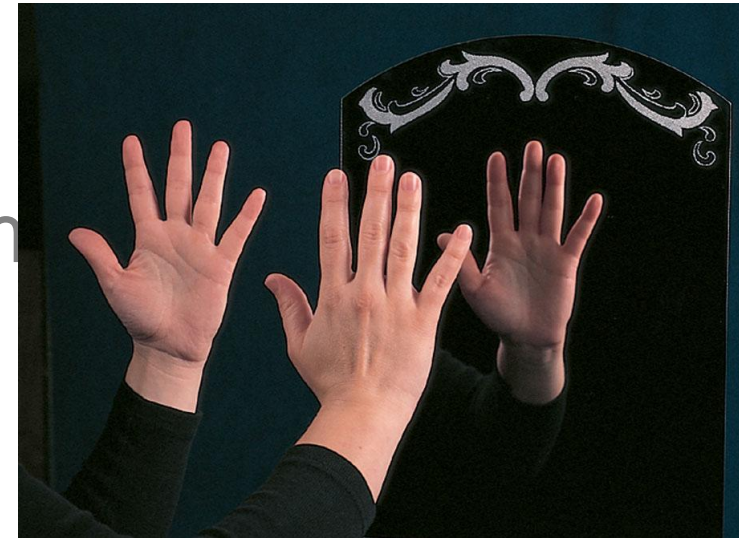


Flat Mirrors

The image is always virtual.

It is not where real light rays converge; only where our eye believes these light rays came from.

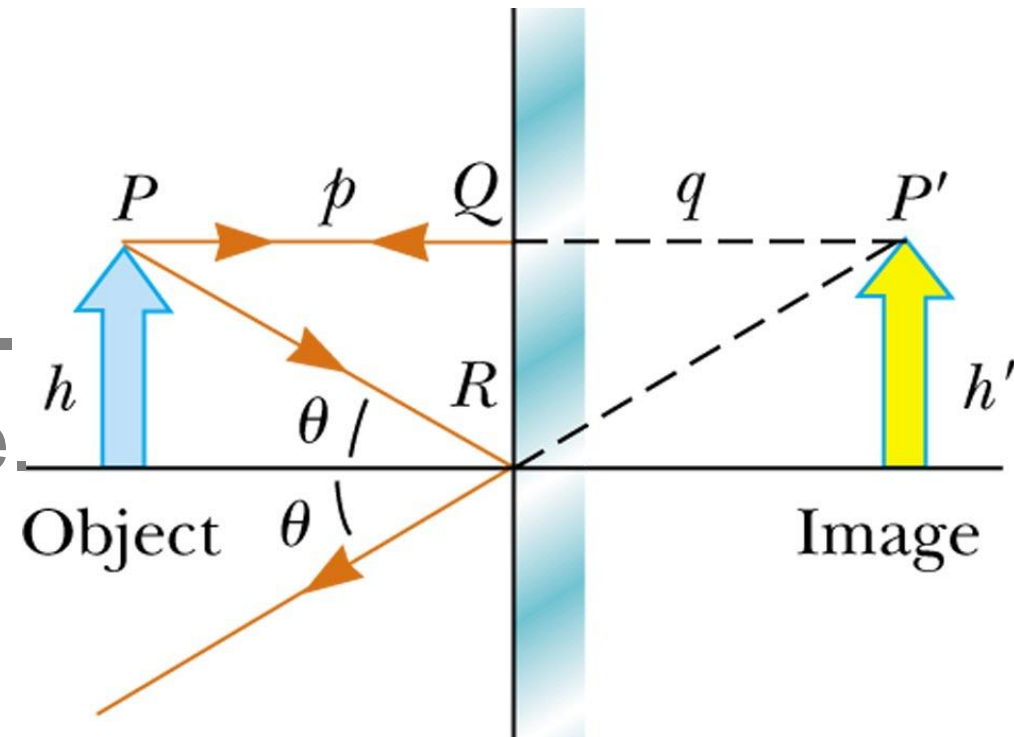
These dashed imaginary rays are known as **virtual light rays**.



Virtual images are composed of virtual light rays.

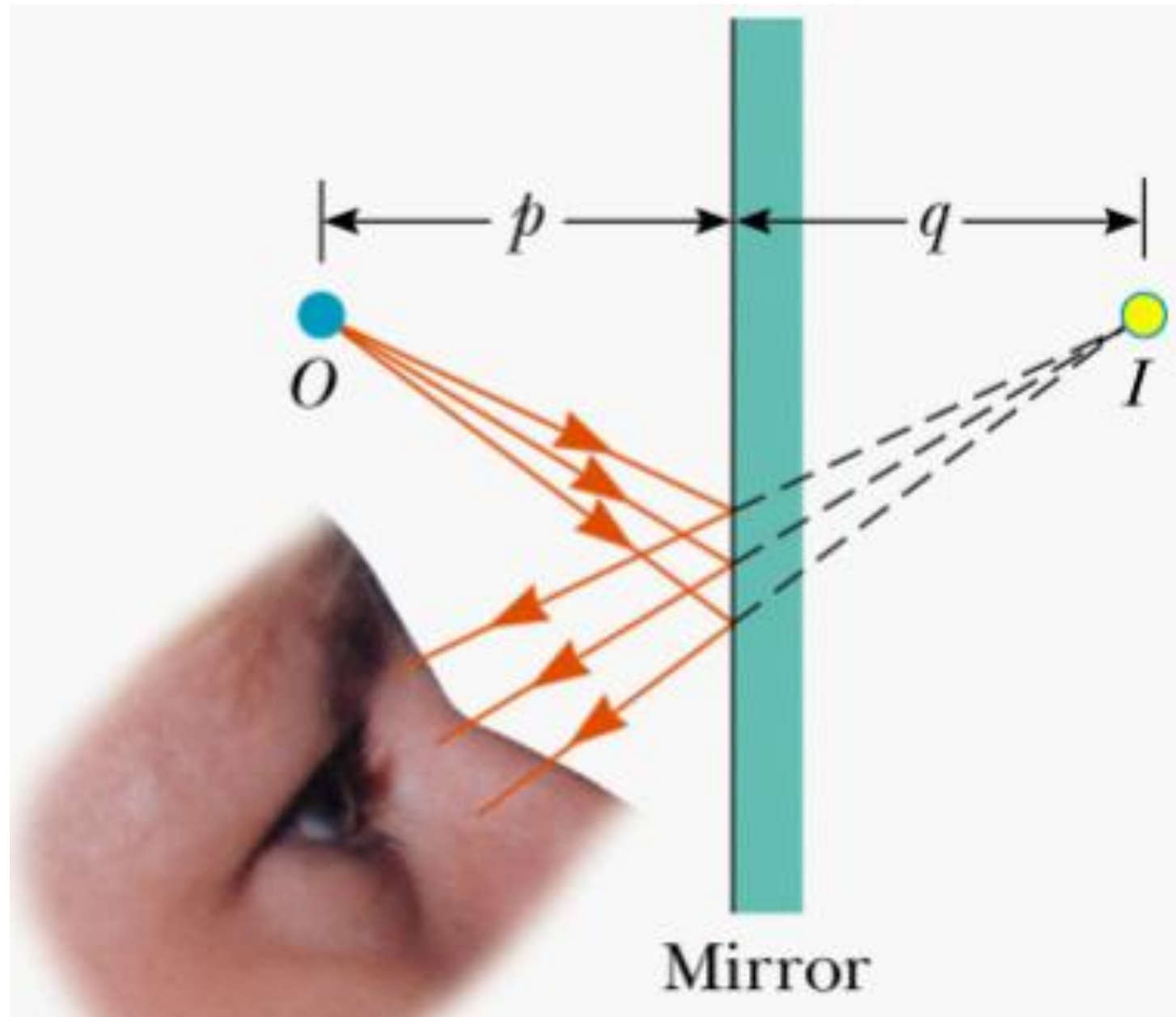
There is an **apparent** **left-right reversal** in the image.

That is actually a **front-back reversal**.



Flat Mirrors

Your eye tracks back these virtual light rays to form the image.



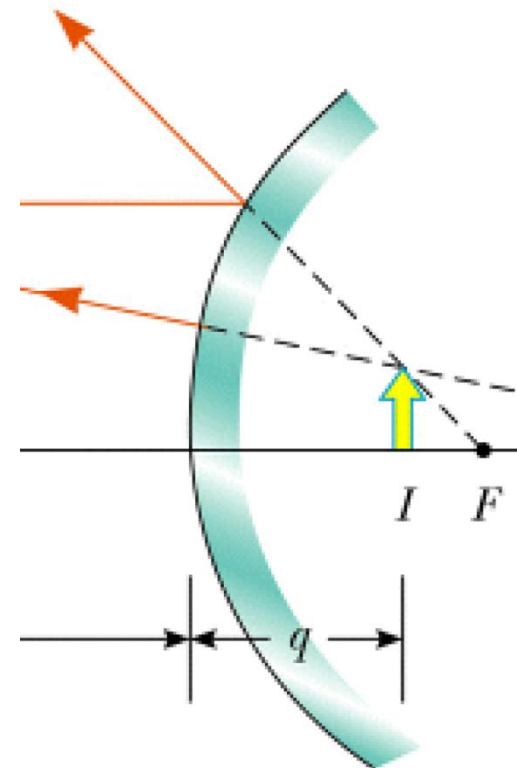
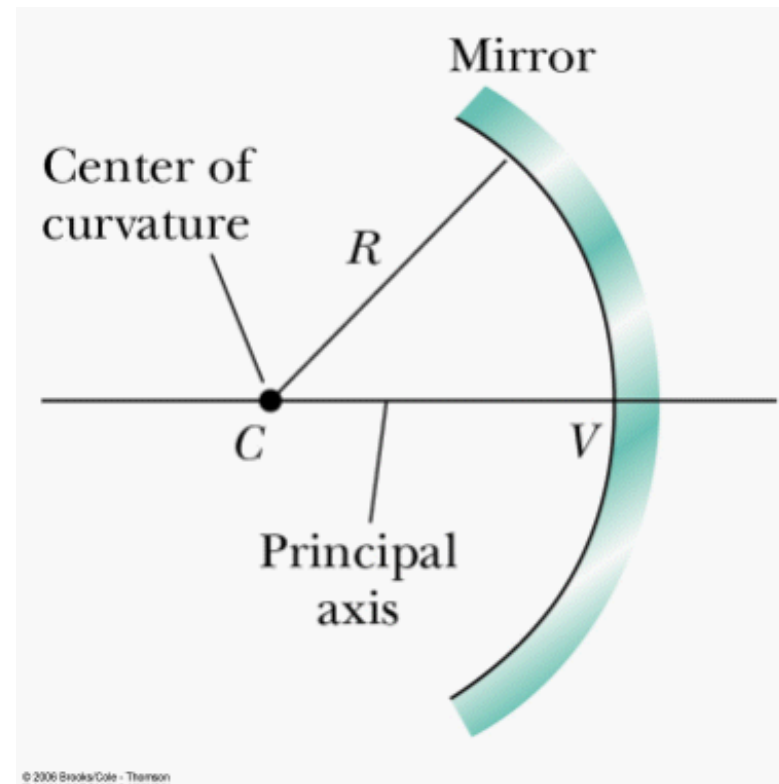
Mirrors

There are different types of mirrors.

Spherical mirrors have the shape of a segment of a sphere.

Concave spherical mirrors have the reflective part on the inner side of the curve.

Convex spherical mirrors have the reflective part on the outer side of the curve.



Concave Mirrors

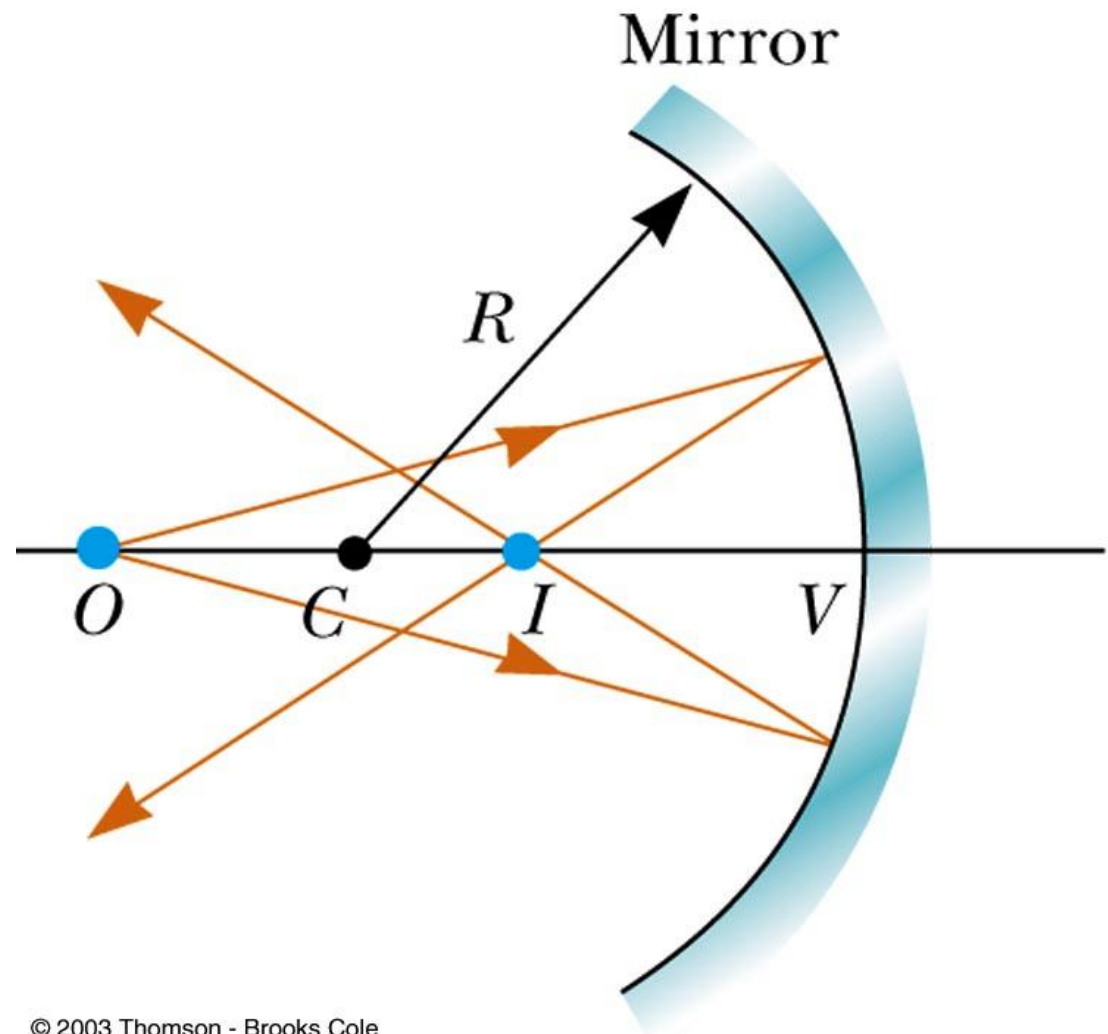
For concave mirrors we define the following points:

The **radius of curvature**, R , is the radius of the spherical mirror.

The center of curvature, C , is the center of the spherical mirror.

Point V is the center of the spherical segment.

A line drawn through C to V is called the **principal axis**.

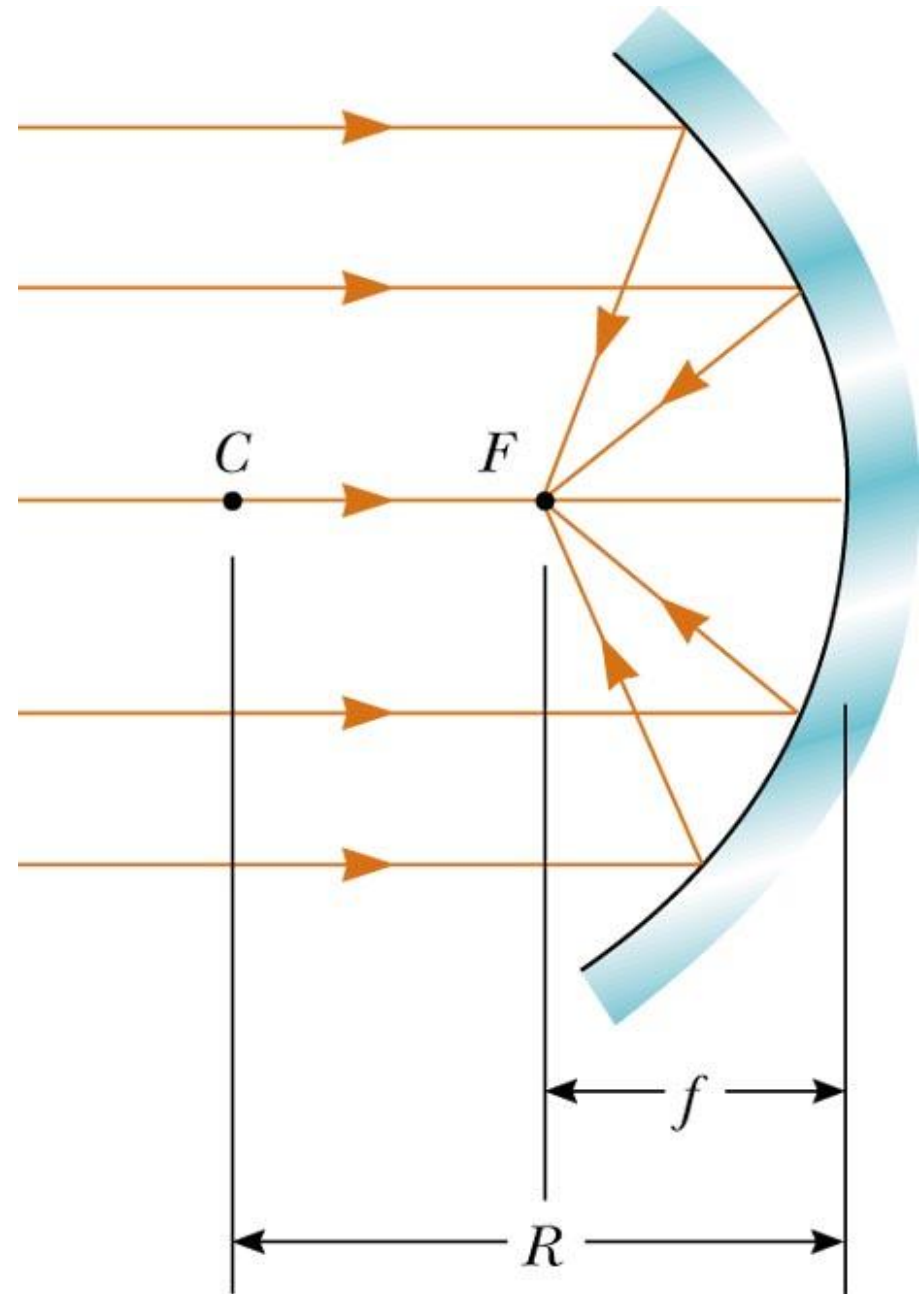


Concave Mirrors

If an object is very far away ($p = \infty$), then the incoming light rays are essentially parallel.

These light rays will become focused at a single point on the principal axis.

In this special case the image will be formed at a point that is $1/2$ the distance from the center of the mirror to point C .



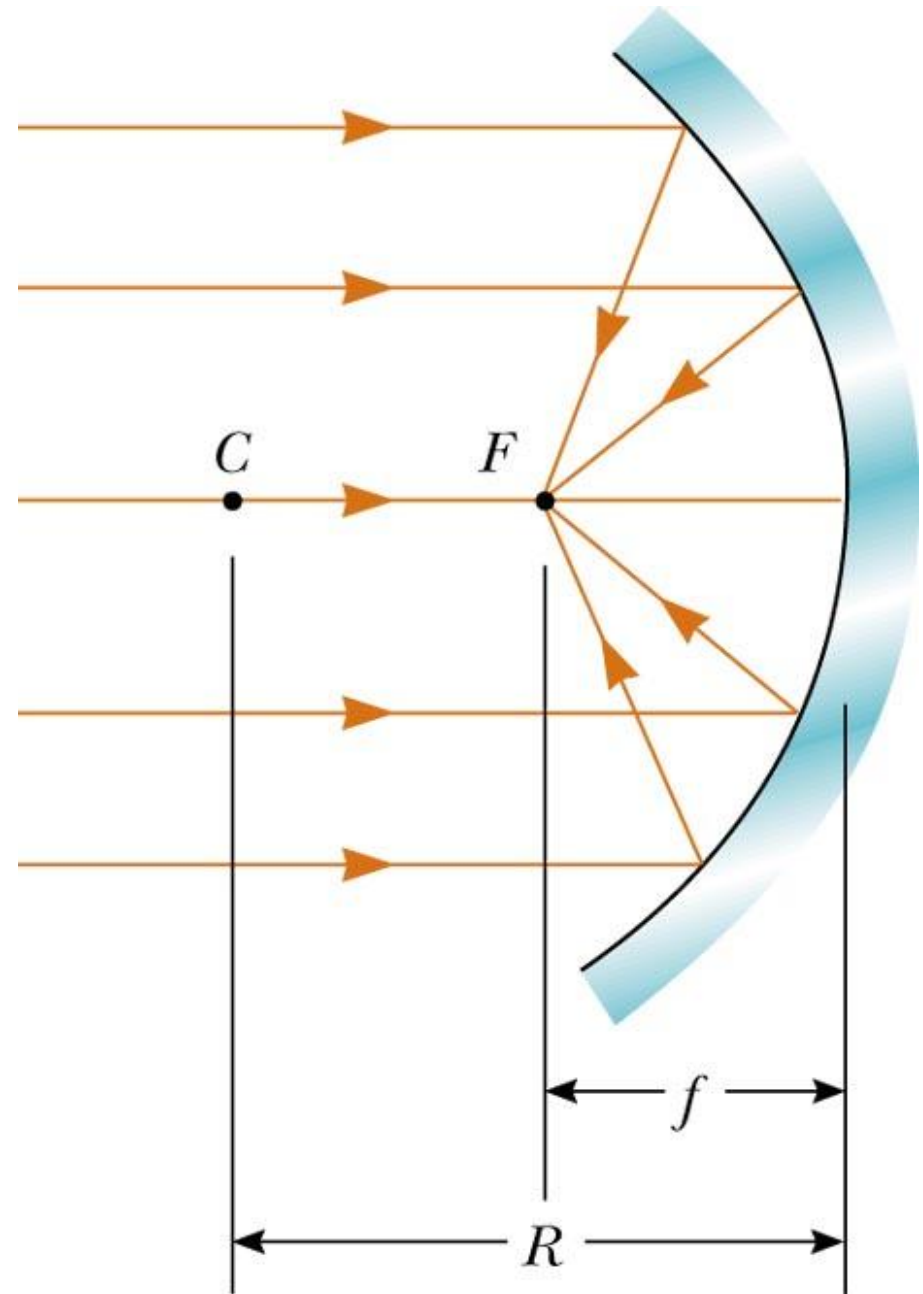
Concave Mirrors

This point is called the **focal point**, F . The length from the mirror to the focal point is called the **focal length**, f .

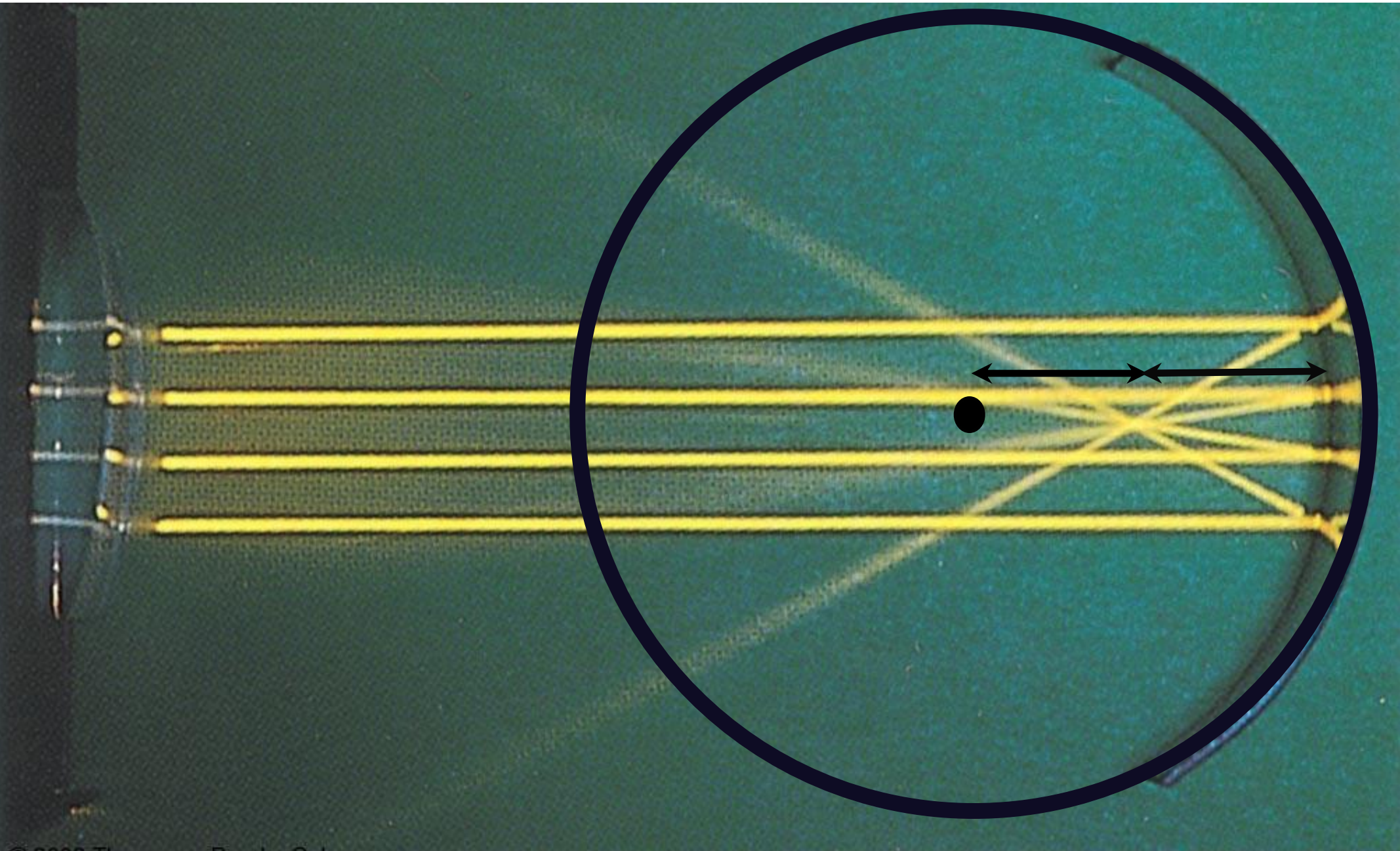
The focal length, f , is $1/2$ the radius of curvature, R .

The focal point is dependent on the curvature of the mirror, not on the location of the object.

$$f = R/2 \quad (\text{Action Figure})$$



Concave Mirrors

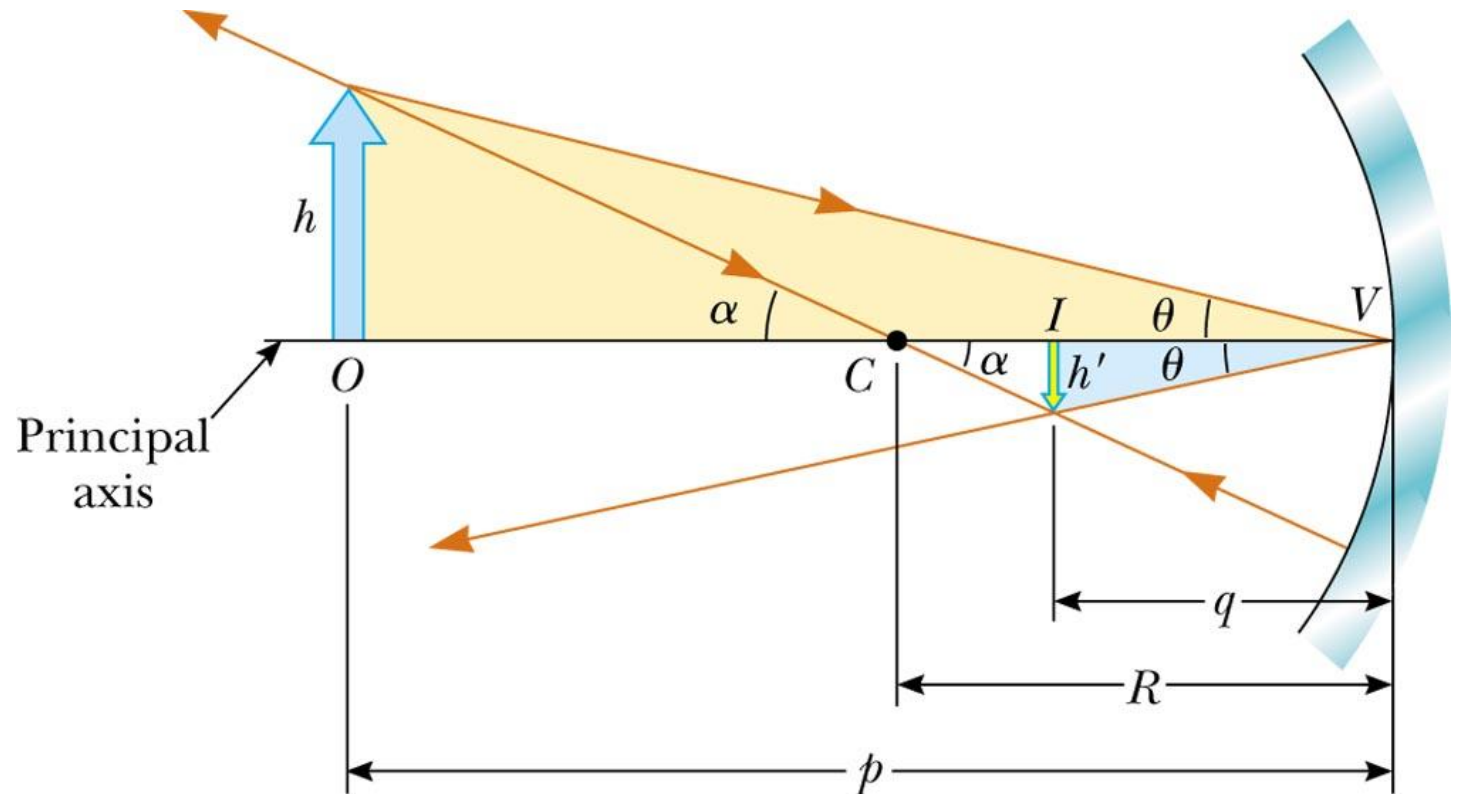


Mirror Equation

You can mathematically relate the object distance, p , and the image distance, q , by using similar triangles.

This gives us the following relationship:

$$\frac{1}{p} + \frac{1}{q} = \frac{2}{R}$$



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But since $f=R/2$,
we get:

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

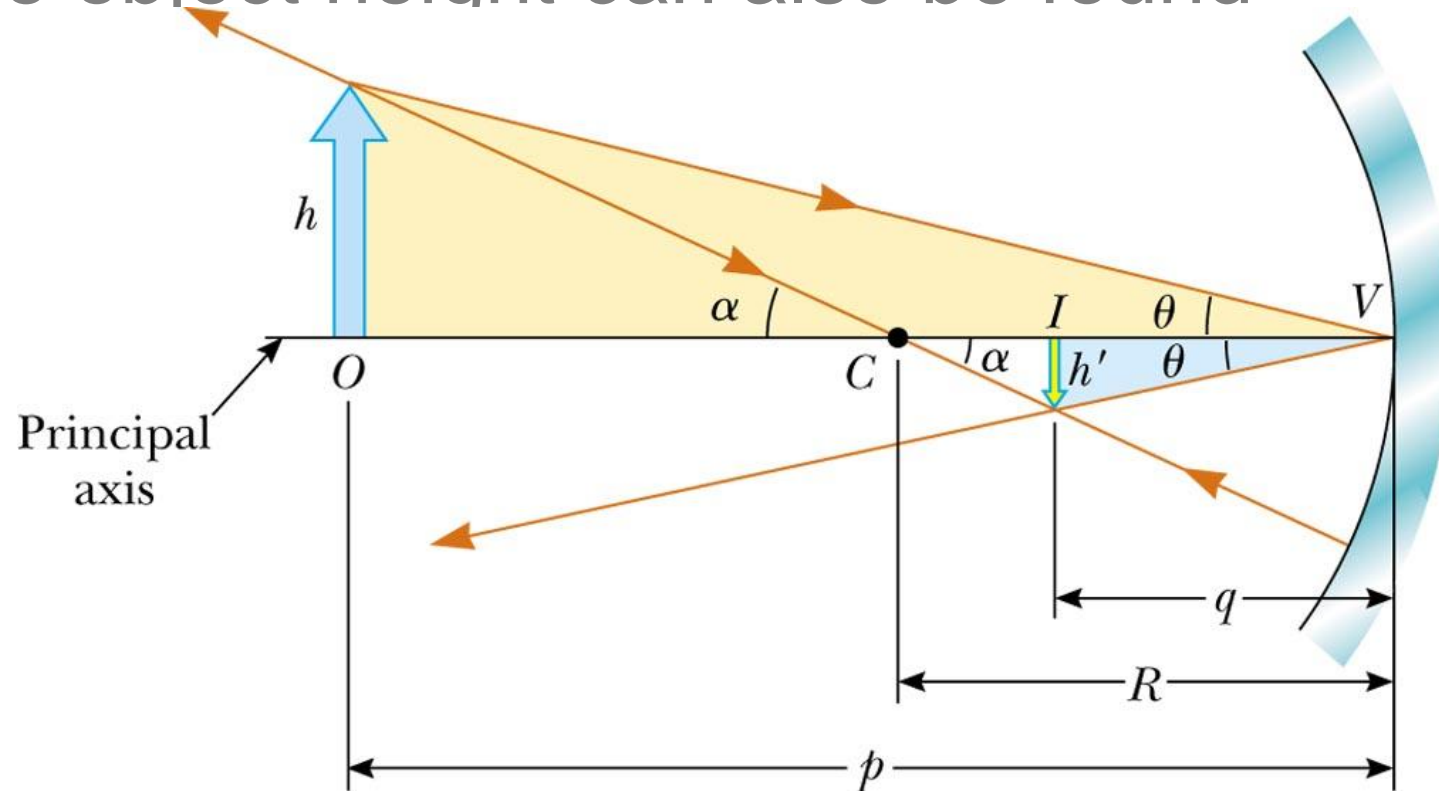
where f is the focal length of the mirror.

Mirror Equation

The lateral magnification, M , of the image height compared to the object height can also be found geometrically.

This gives us the following relationship:

$$M = \frac{h'}{h} = -\frac{q}{p}$$



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where the negative sign comes from the fact that h' is inverted with respect to h .



Clicker Question 26A-1

The focal length, f , of a spherical mirror is:

- A) the distance at which the image is formed.
- B) the distance at which an object must be placed to form an image.
- C) the distance at which parallel light rays are focused.
- D) the distance from the top of the mirror to the bottom of the mirror.
- E) the distance from the object to the center of the mirror.

Ray Diagrams

The most important thing to remember when dealing with the mirror equations is to remember the sign conventions.

TABLE 26.1

Sign Conventions for Mirrors

Quantity	Positive when . . .	Negative when . . .
Object location (p)	object is in front of mirror (real object).	object is in back of mirror (virtual object).
Image location (q)	image is in front of mirror (real image).	image is in back of mirror (virtual image).
Image height (h')	image is upright.	image is inverted.
Focal length (f) and radius (R)	mirror is concave.	mirror is convex.
Magnification (M)	image is upright.	image is inverted.

For a concave mirror f is +, for a convex mirror f is –.

Spherical Mirrors

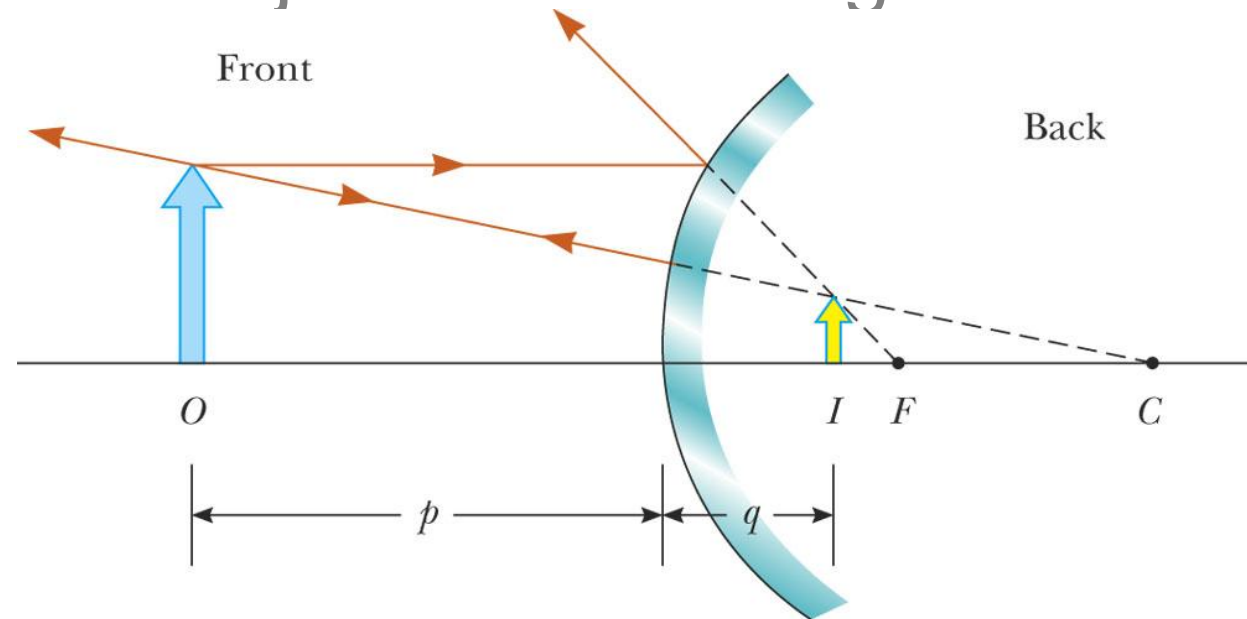
Example

A **convex** spherical mirror of radius of curvature R that is 20.0cm produces an upright image precisely one-quarter the size of an object, a candle. What is the separation distance between the object and its image?

Answer

The coordinate system is already defined by the sign convention.

The center of the mirror is the origin.

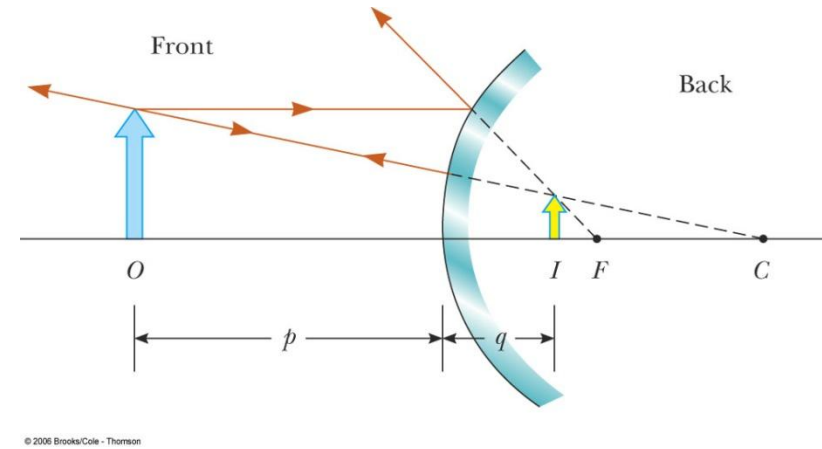


Spherical Mirrors

Answer

First, let's find the focal length of the mirror:

$$f = \frac{R}{2} = -10.0\text{cm}$$



where the negative sign comes from the fact that it is a convex mirror.

The magnification of the object will be:

$$M = -\frac{q}{p} = \frac{1}{4}$$

$$q = -\frac{p}{4}$$

Next, we can turn to the mirror equation:

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f}$$

$$\frac{1}{p} - \frac{4}{p} = \frac{1}{f}$$

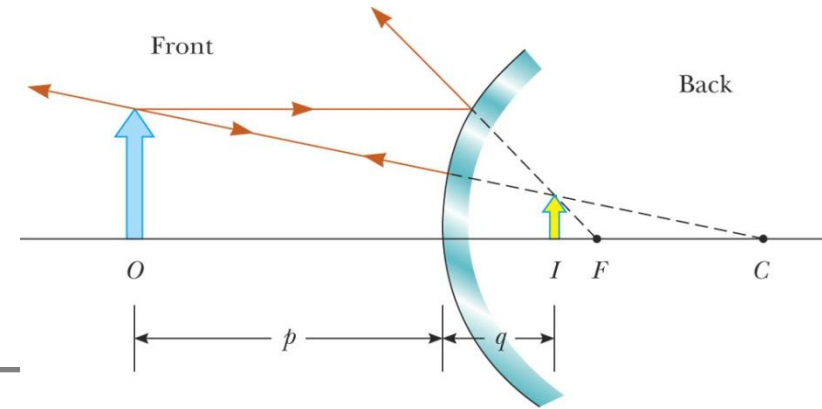
Spherical Mirrors

Answer

This becomes:

$$\frac{3}{p} = \frac{1}{f}$$

$$p = -3f = -3(-10\text{cm}) = 30\text{cm}$$



Then, to find the image distance go back to:

$$q = -\frac{p}{4} = -\frac{30\text{cm}}{4} = -7.5\text{cm}$$

Turning to the sign conventions, this means that the object is to the left of the mirror and the image is to the right of the mirror.

So, for the separation distance, just add the two absolute values.

$$s = |p| + |q| = |30\text{cm}| + |-7.5\text{cm}| = 37.5\text{cm}$$

Intersecting Rainbows



Courtesy David Vier

Extra credit point for 1 paragraph explanation

For Next Time (FNT)

Continue reading Chapter 26

Finish working on the homework for
Chapter 25