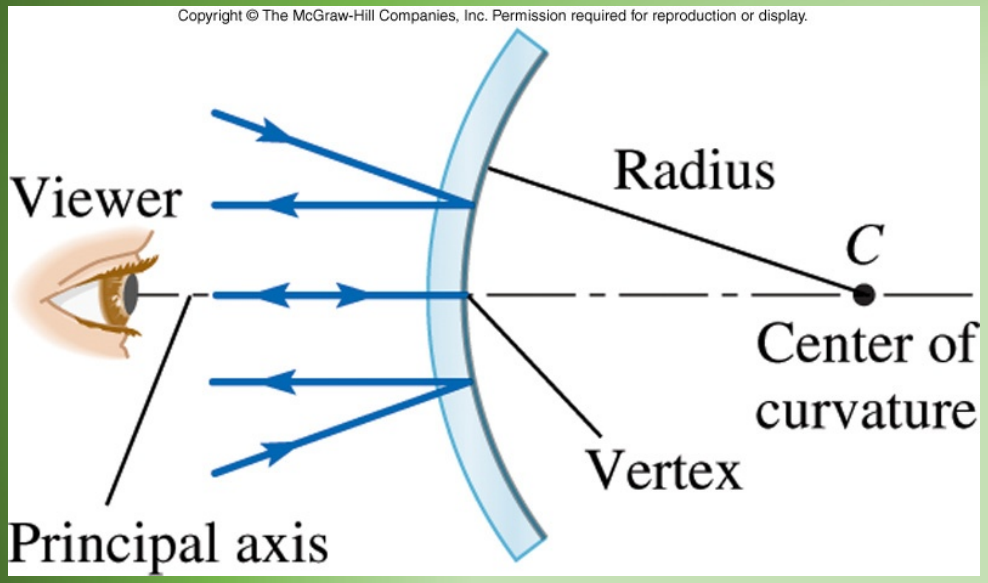
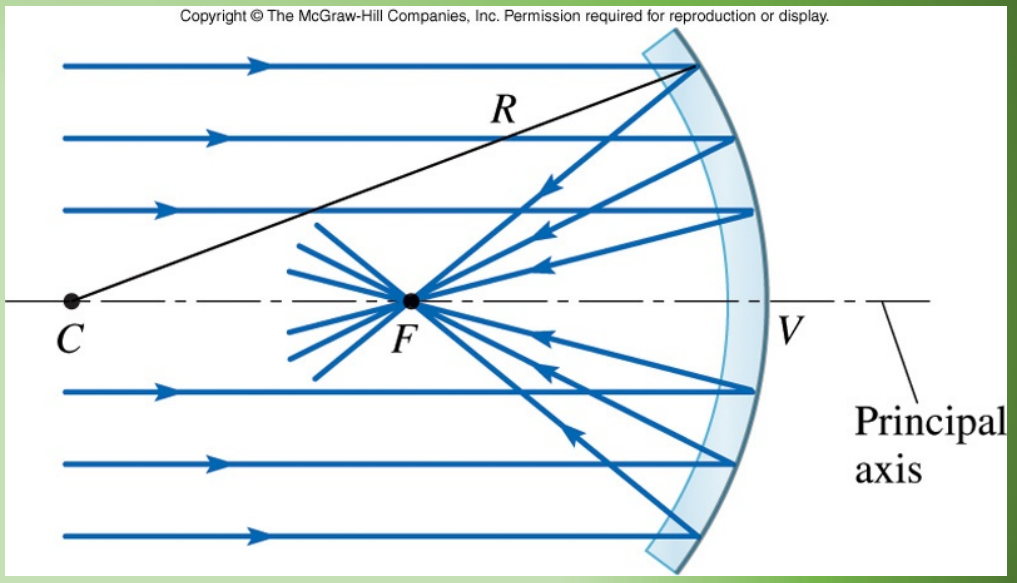
Spherical Mirrors

Convex



Concave



A spherical mirror has the shape of part of a sphere's surface.

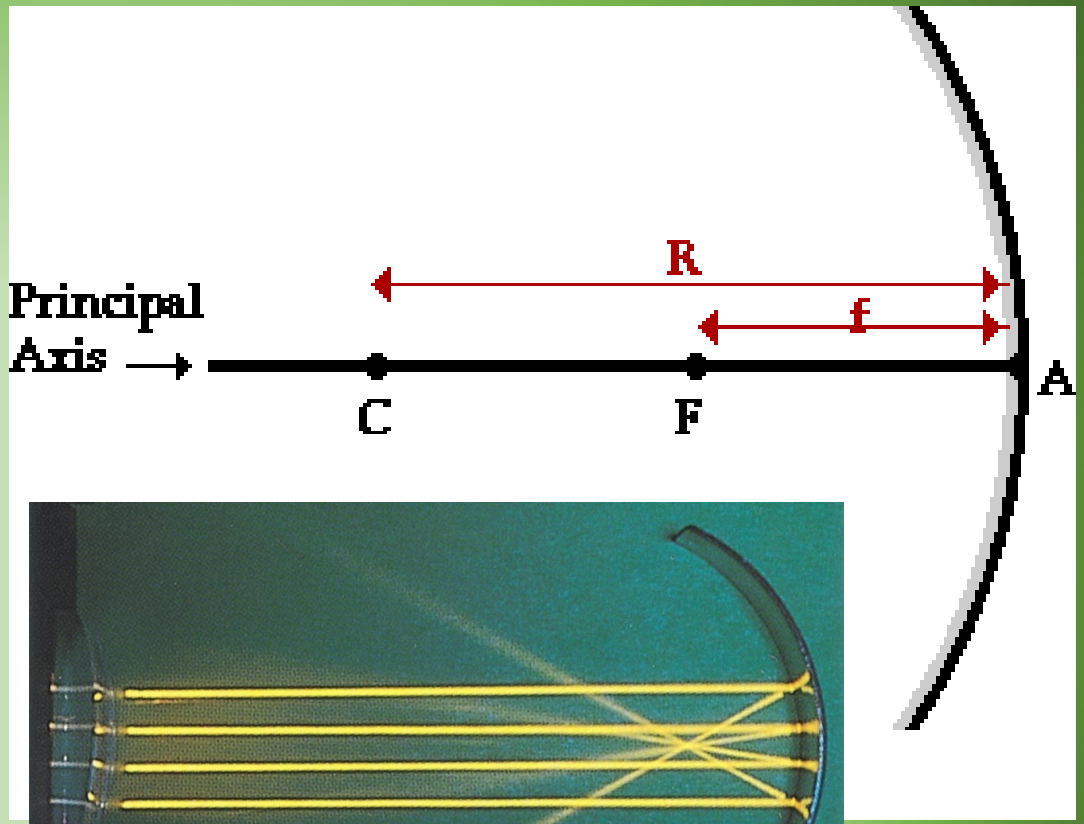
Concave Spherical Mirror (Converging Mirror): A spherical mirror with light reflecting from its silvered, concave surface
Concave mirrors are used whenever a magnified image of an object is needed

Convex mirrors take objects in a large field of view and produce a small image

Side-view mirrors on cars are convex mirrors. That's why they say "objects are closer than they appear"

Concave Mirror

- The **center C** of a concave mirror is outside the mirror.
- **Focal point F** is also outside the mirror, half way between the center and the surface of the mirror.
- The **focal length f** is half of the radius.



Transverse Magnification

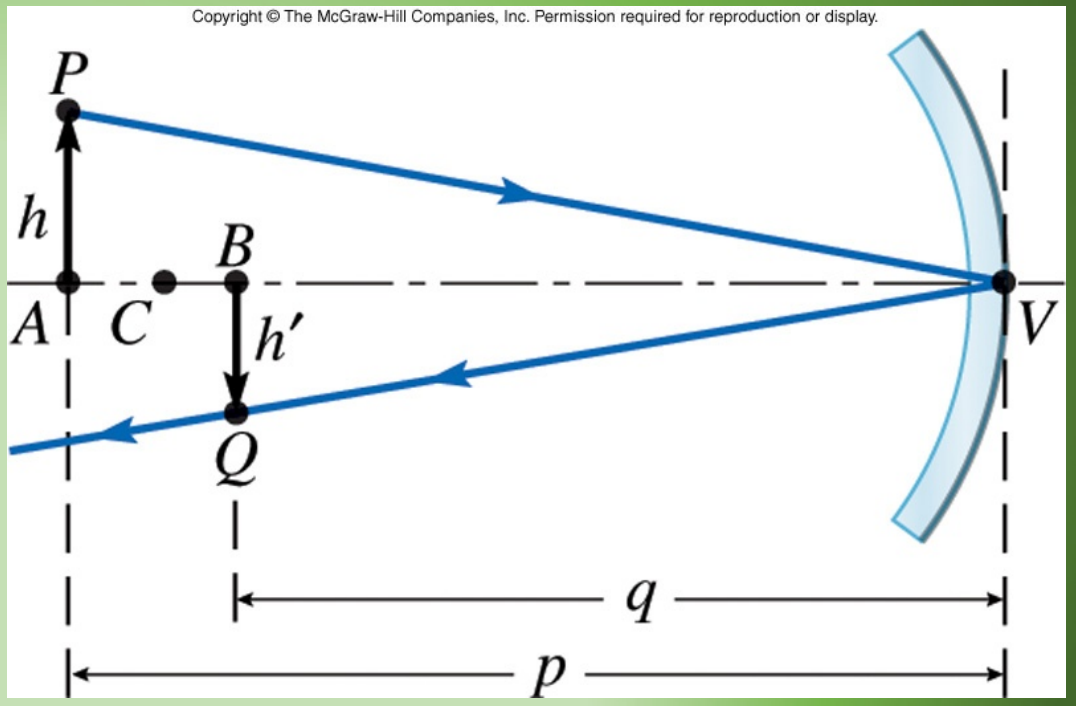
Concave mirrors are used whenever a magnified image of an object is needed

$$|m| = \frac{\text{image size}}{\text{object size}}$$

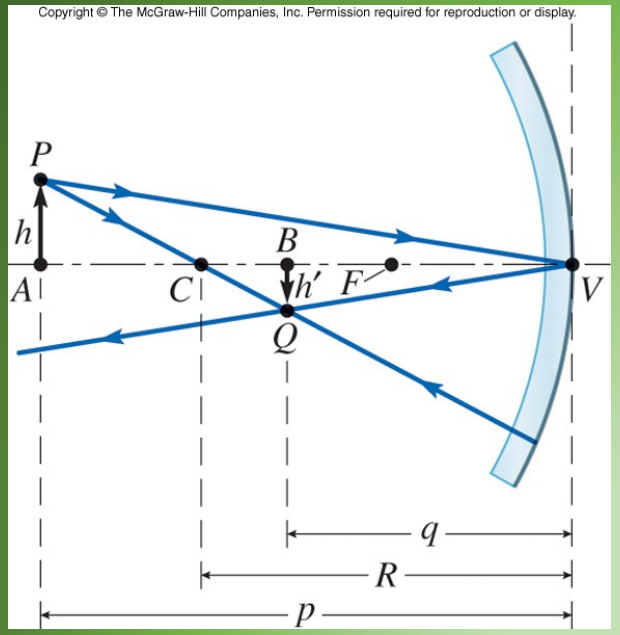
$$m = \frac{h'}{h}$$

Magnification equation:

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



The Mirror Equation



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

Table 23.2

Sign Conventions for Mirrors

Quantity	When Positive (+)	When Negative (–)
Object distance p	Always*	Never*
Image distance q	Real image	Virtual image
Focal length f	Converging mirror (concave): $f=\frac{1}{2}R$	Diverging mirror (convex): $f=-\frac{1}{2}R$
Magnification m	Upright image	Inverted image

*In Chapter 23, we consider only real objects. Chapter 24 discusses multiple-lens systems, in which *virtual* objects are possible.

Image formation -Ray Diagrams

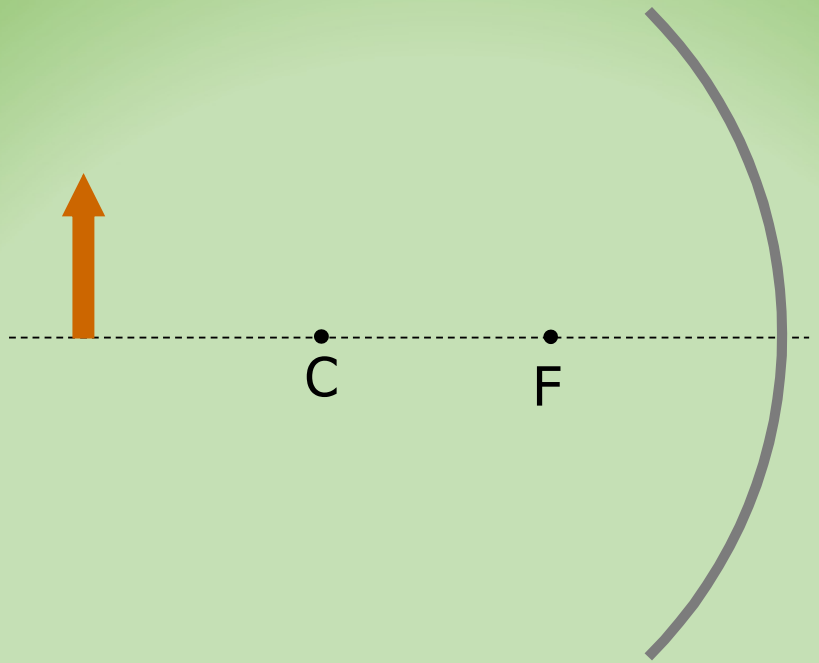
- A ray diagram is a drawing that uses geometry to locate an image formed by a mirror.
- There are different rules for drawing ray diagrams depending on the type of mirror you have.
- For spherical mirrors, there are three different reference rays.
- The intersection of any two rays locates the image

Rules for drawing reference rays

Ray	Line drawn from object to mirror	Line drawn from mirror to image after reflection
1	Parallel to principal axis	Through focal point F
2	Through focal point F	Parallel to principal axis
3	Through center of curvature (C)	Back along itself through C
4	Through vertex	reflect off with an outgoing angle equal to the incoming angle

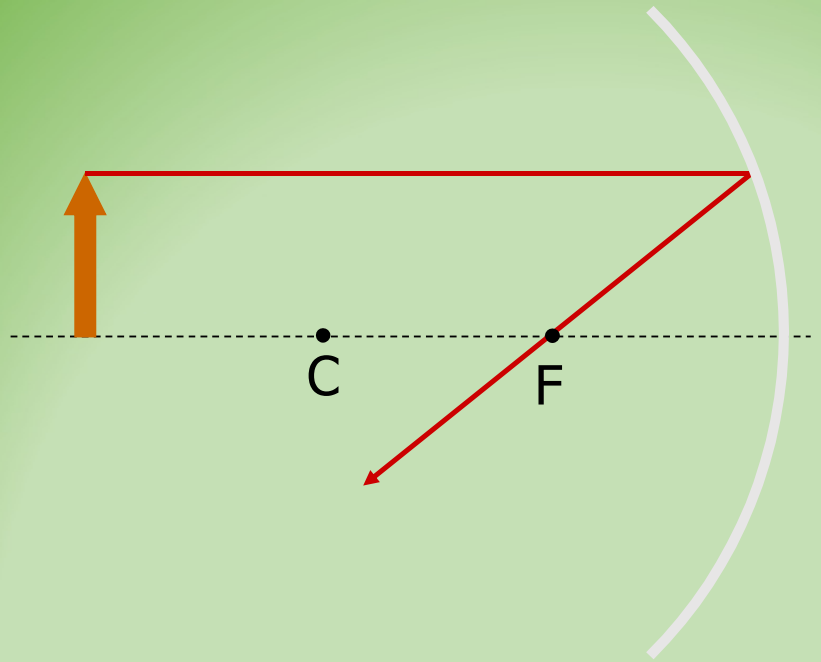
Concave Mirror

For a concave lens, the center of curvature and focal point are on the same side of the lens as the object.



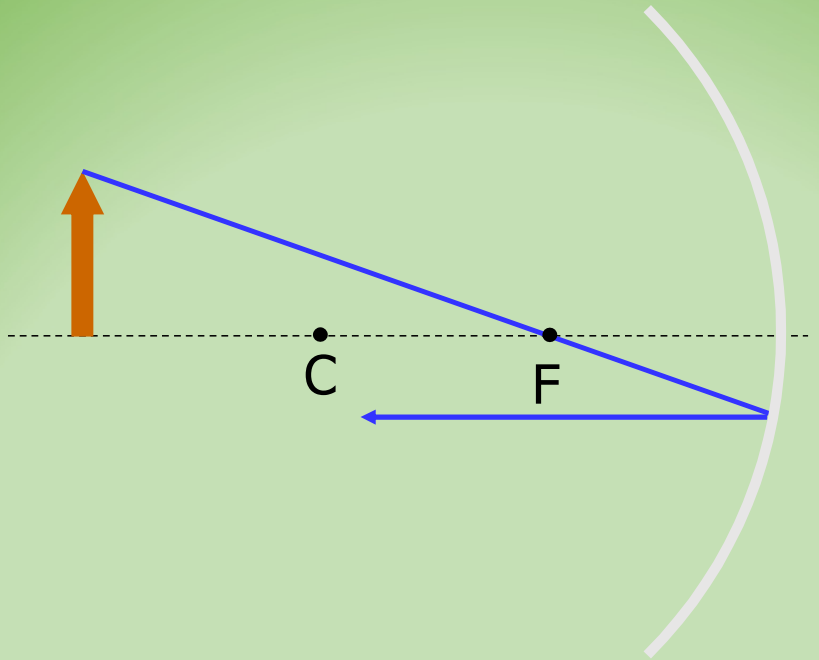
Concave Mirror

Light coming from the object parallel to the axis will always reflect through F.



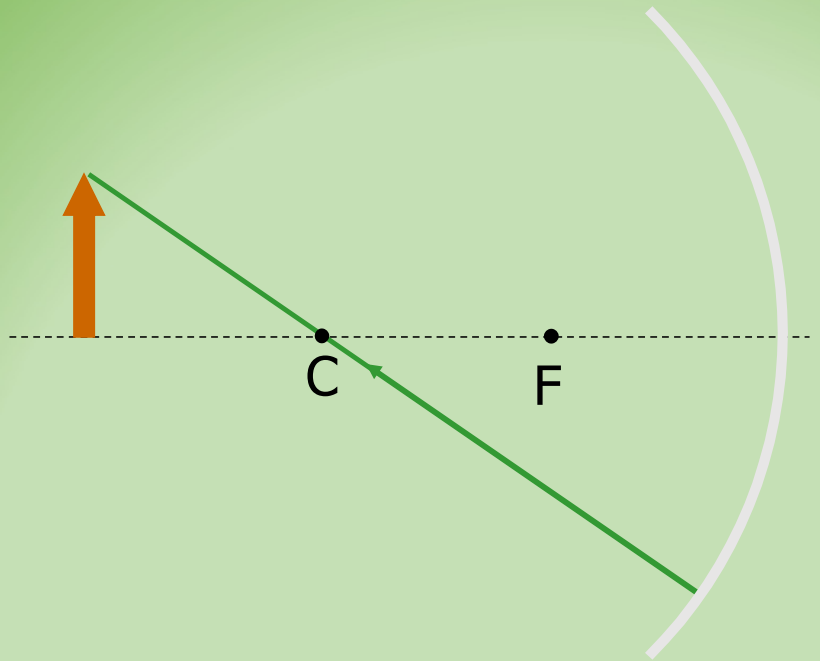
Concave Mirror

Light coming from the object and passing through F before it hits the mirror will always reflect parallel to the axis.



Concave Mirror

Light coming from the object and passing through C before it hits the mirror will always reflect back on itself.



Concave Mirror

Light coming from the object and striking the vertex will reflect off with an outgoing angle equal to the incoming angle. This is often more difficult to draw (unless you measure the angle).

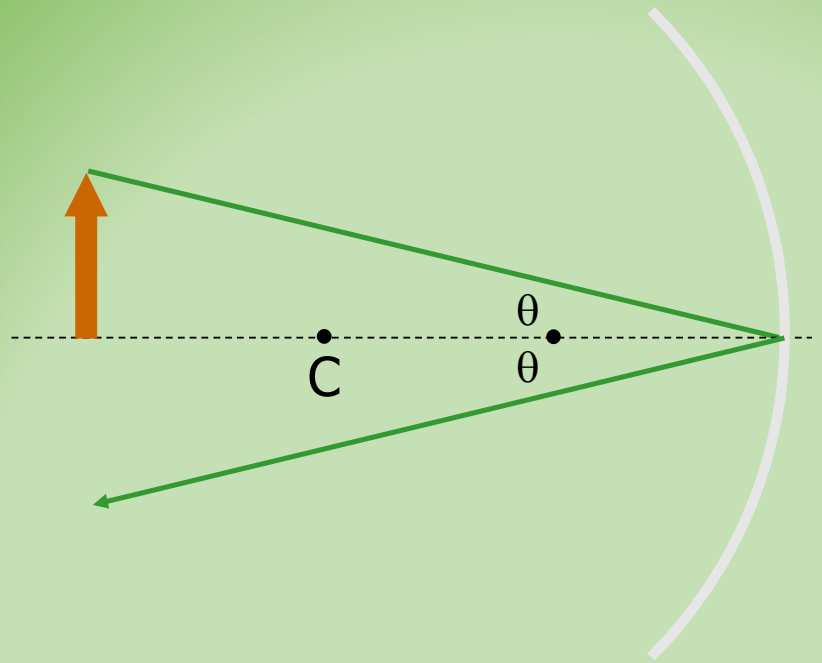
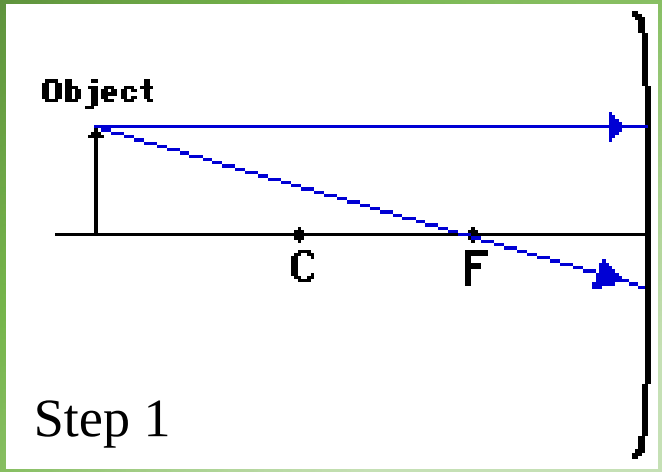
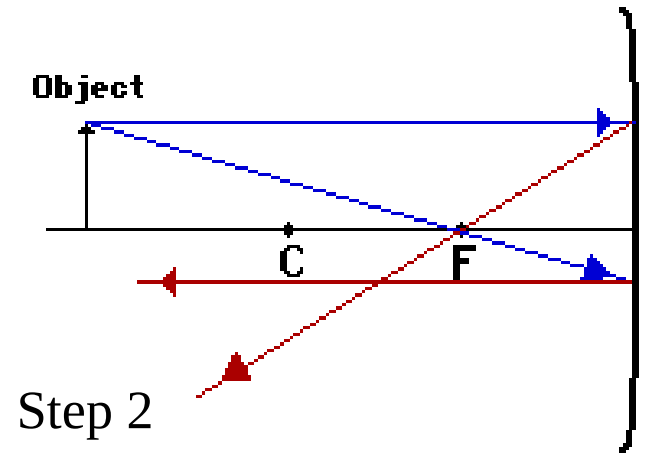
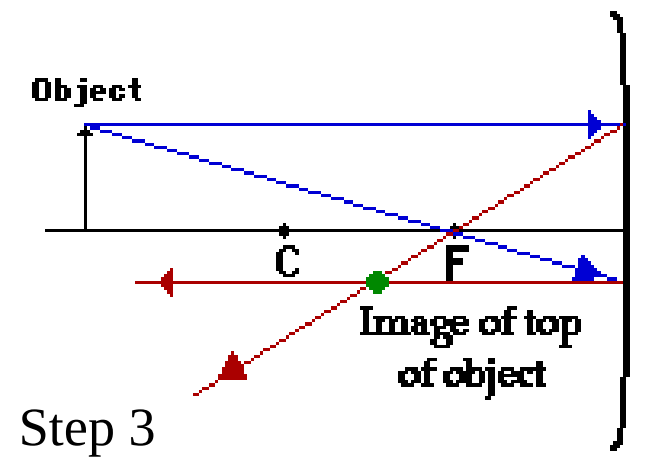
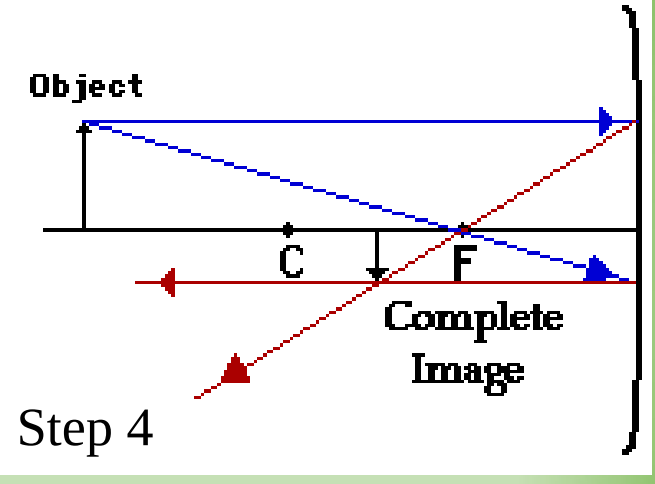


Image from a concave mirror: case 1

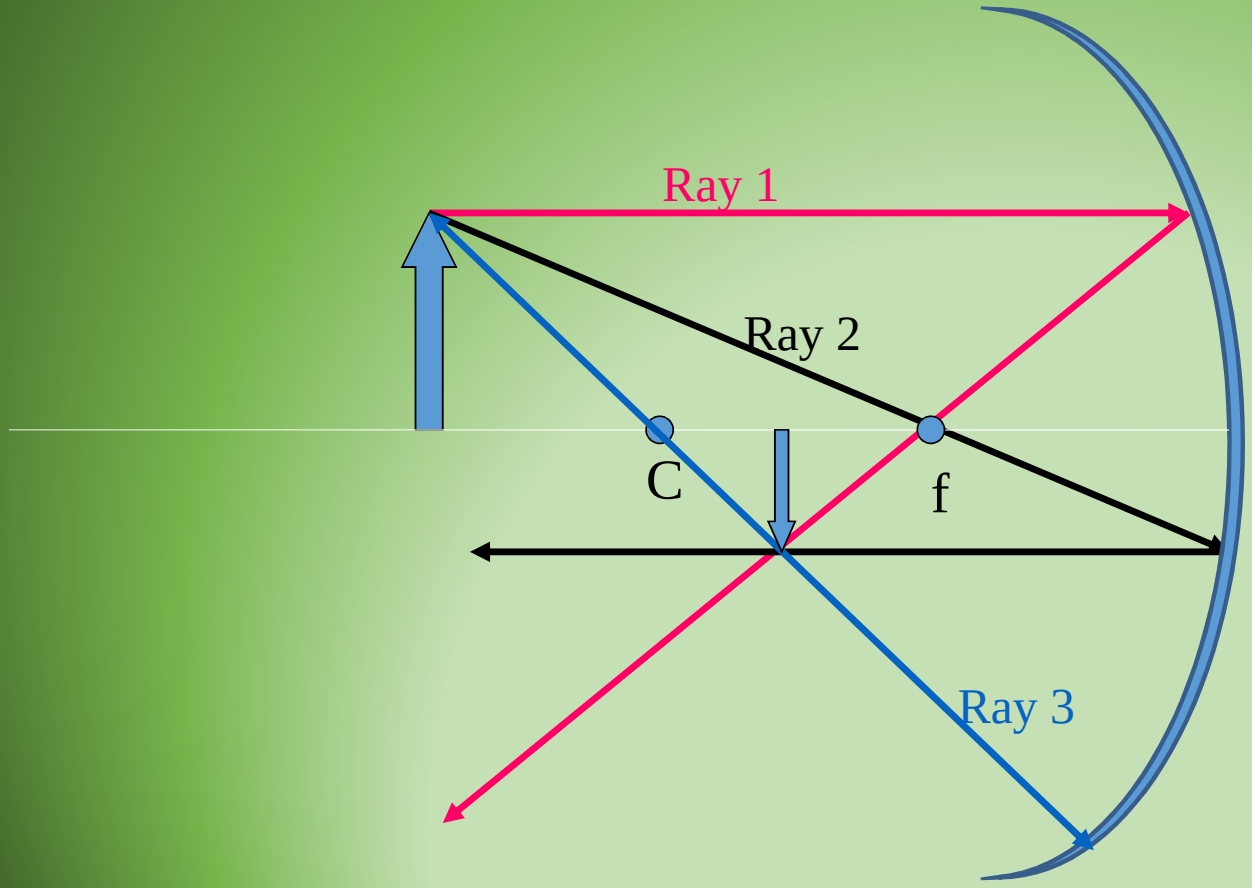








How to draw a ray diagram



The intersection Of any 2 rays gives the image location

Properties of the Image

If we put **an object outside of the center of a concave mirror**, we find the image is

- **Real**, in the sense that all light rays pass through the image.
- **Inverted**, in the sense that the direction of the arrow has been changed.
- The image is **smaller**!

Image for a concave mirror: case 2

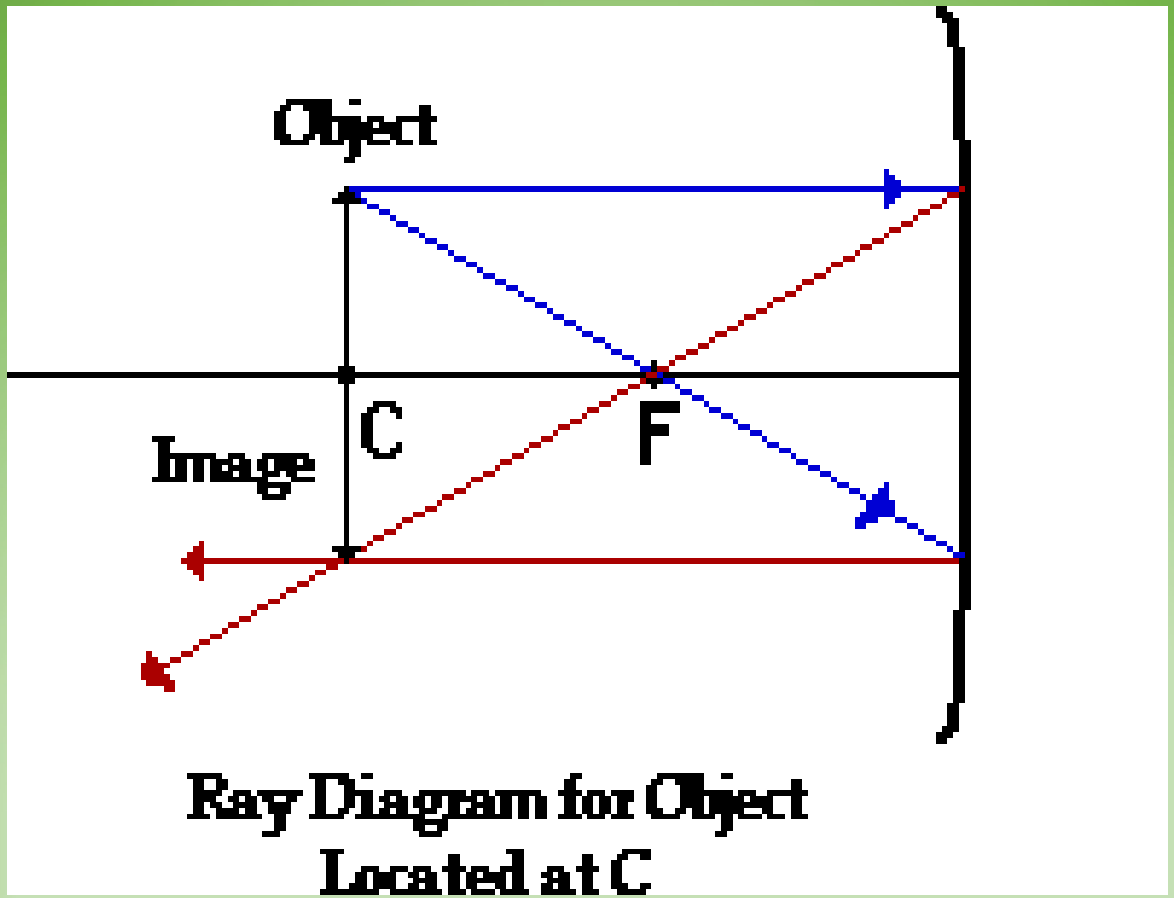
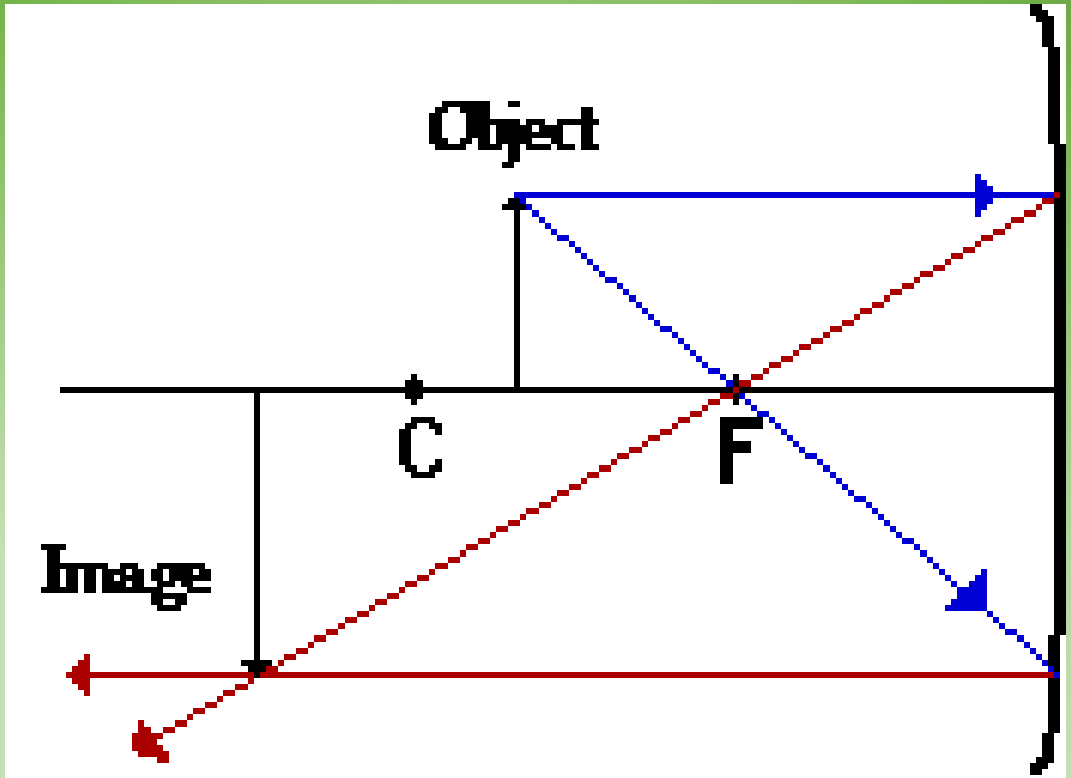


Image for a concave mirror: case 3

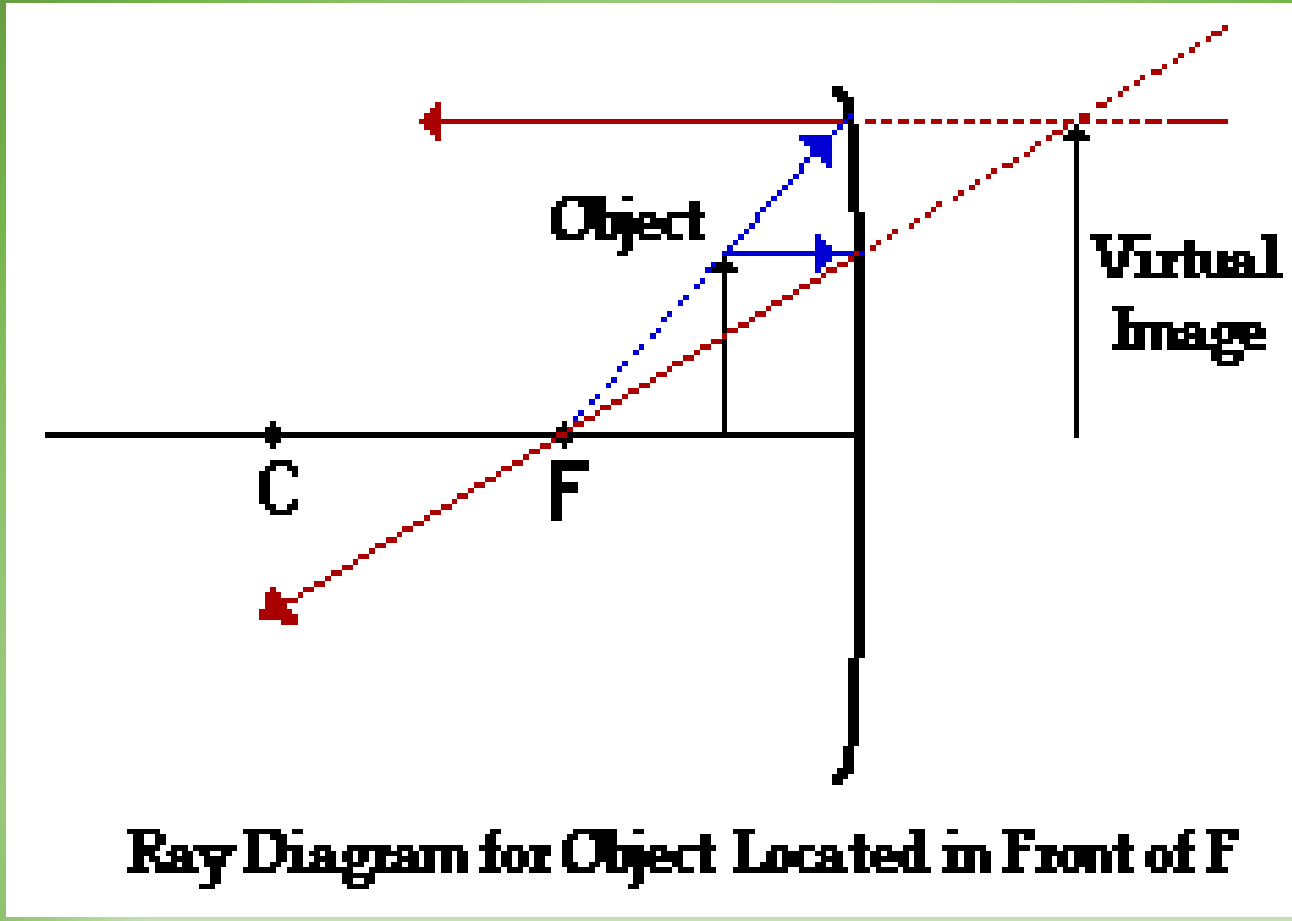


Ray Diagram for Object Located Between C and F

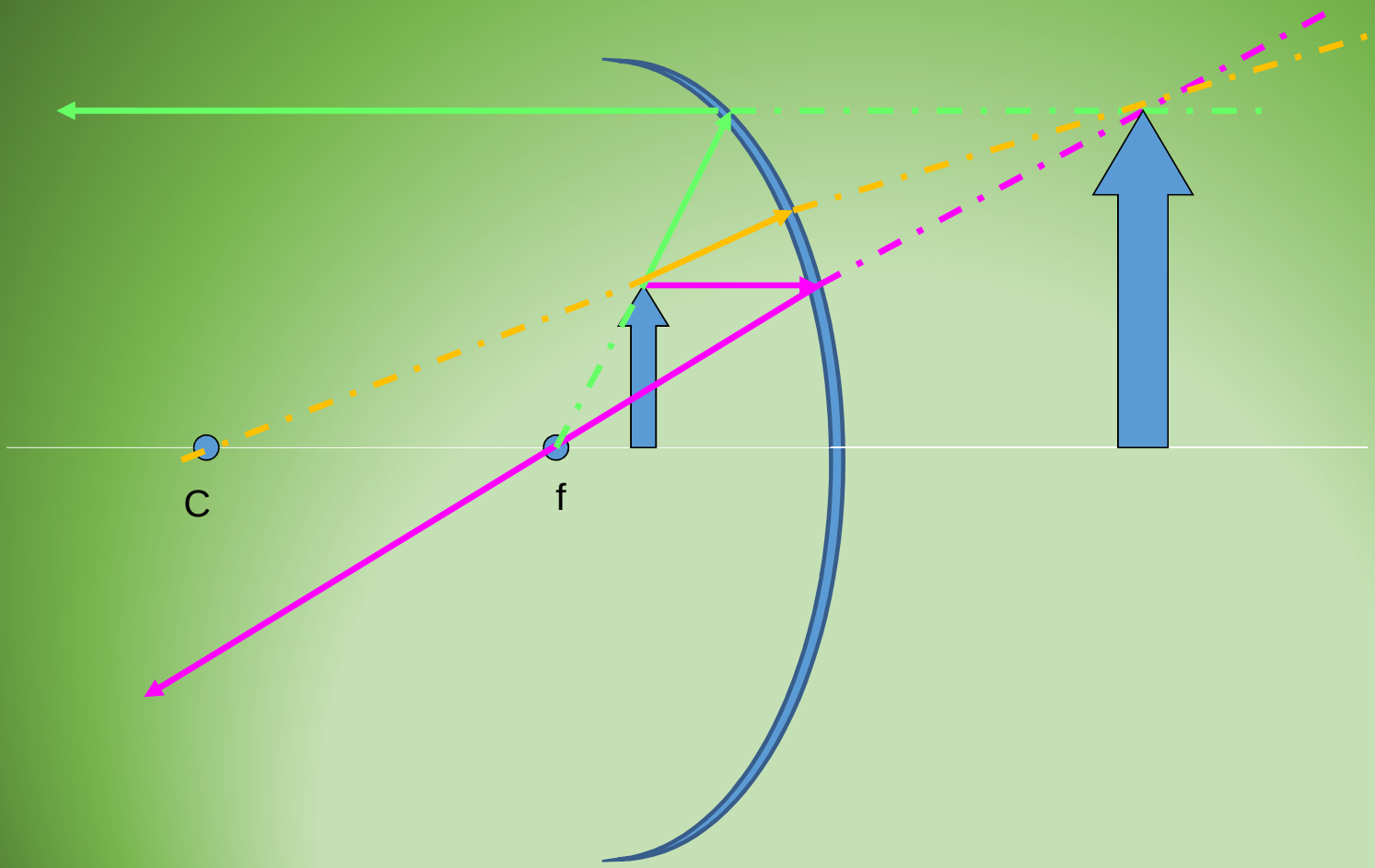
- If the **object is in between the center and the focal point**, the image is
  - **Real**
  - **Inverted**
  - **Magnified** in the sense that the image is bigger than the real object.

- **The direction of the light rays can be reversed and the result is still physically possible! (or the image and object interchanged)**

Image from a concave mirror: case 4



Objects inside the focal point



Properties of the image

- If the object is **closer to the mirror than the focal point F,** the image is:
  - **Virtual**, it is behind the mirror
  - **Upright**, not inverted
  - **Magnified**

  Can be used for shaving!

SUMMARY

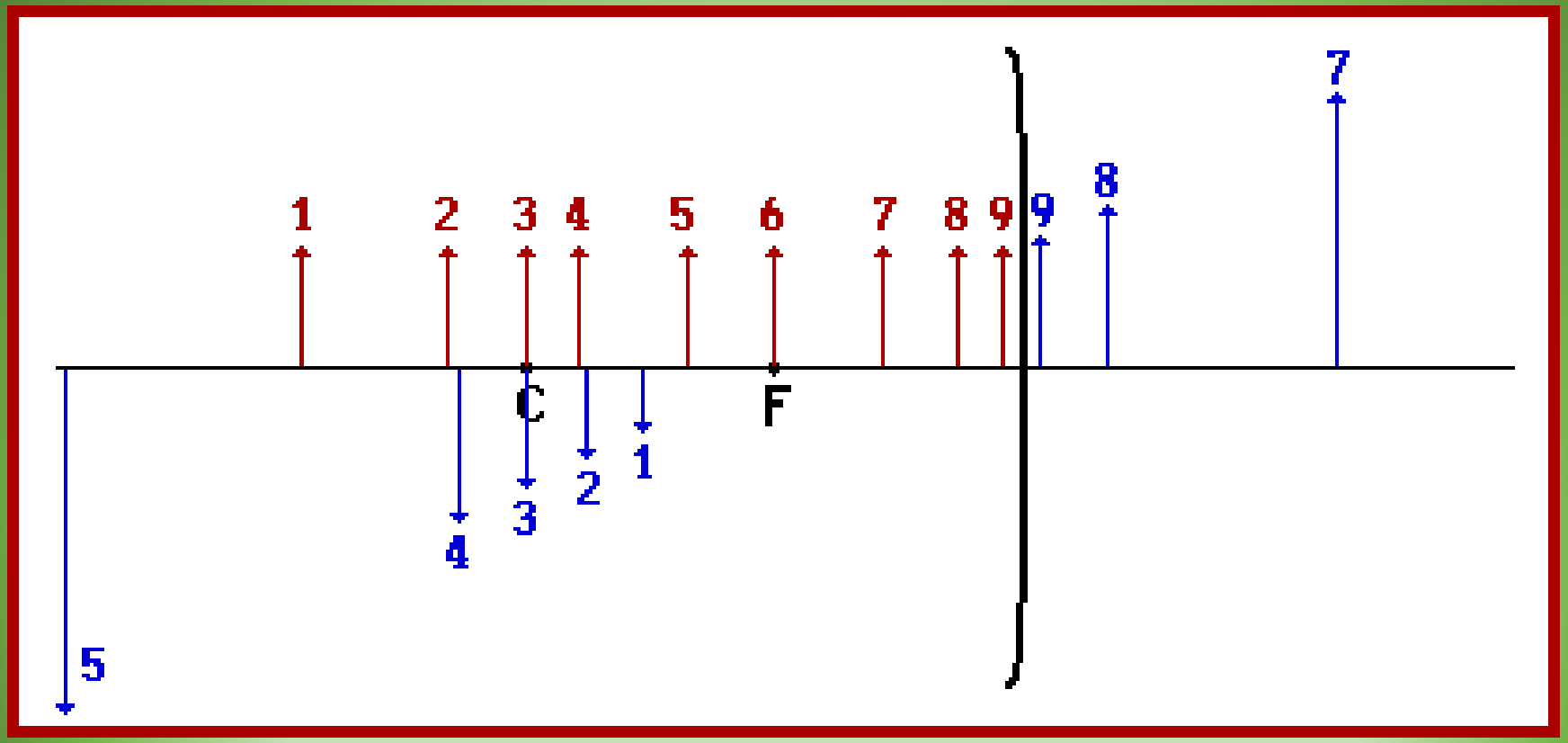
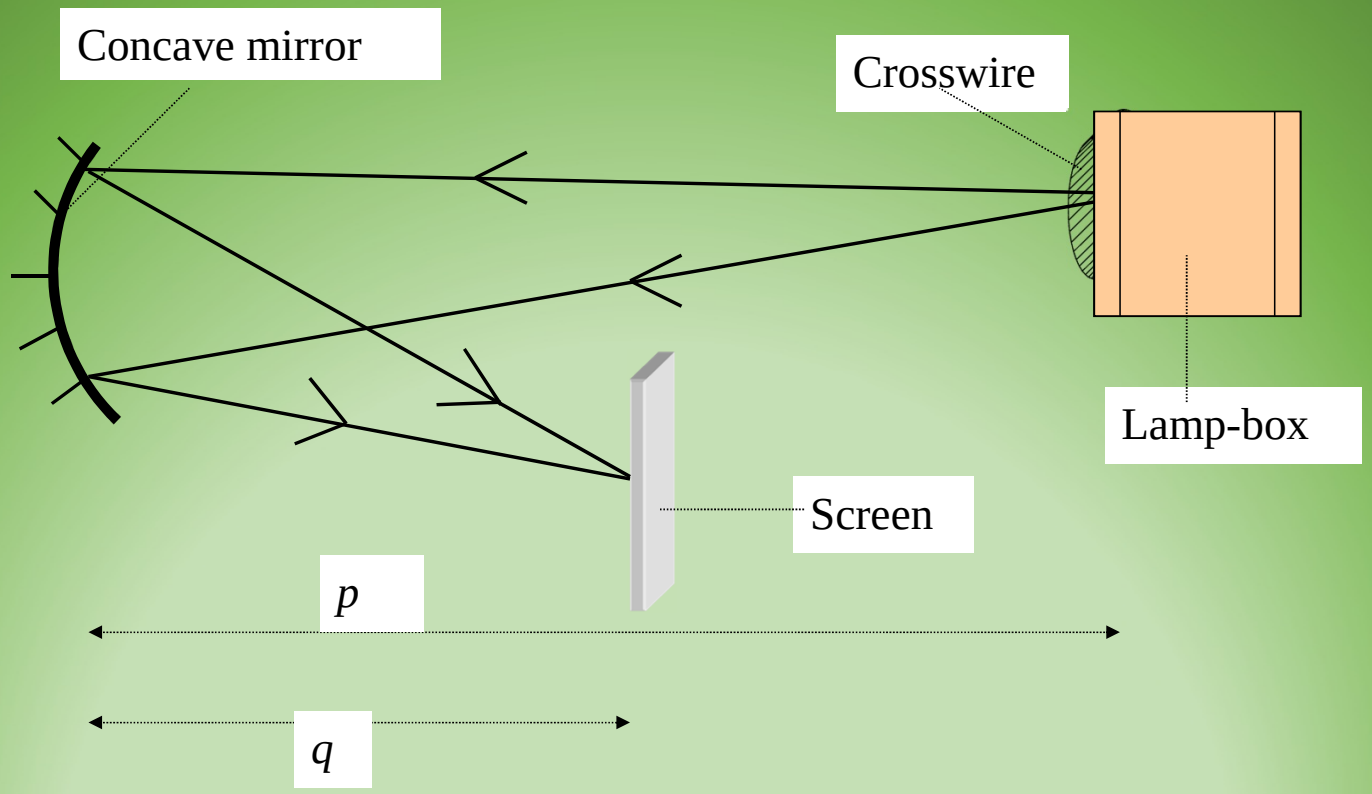


Table 10.1 Image formation by a concave mirror for different positions of the object

Position of the object	Position of the image	Size of the image	Nature of the image
At infinity	At the focus F	Highly diminished, point-sized	Real and inverted
Beyond C	Between F and C	Diminished	Real and inverted
At C	At C	Same size	Real and inverted
Between C and F	Beyond C	Enlarged	Real and inverted
At F	At infinity	Highly enlarged	Real and inverted
Between P and F	Behind the mirror	Enlarged	Virtual and erect

To find the focal length of a concave Mirror



Procedure

•Get the approx. focal length of mirror by focusing distant object on screen – why?

•Place the lamp-box well outside the approximate focal length – why?

•Move the screen until a clear inverted image of the crosswire is obtained.

•Measure the distance *p* from the crosswire (subject) to the mirror, using the metre stick.

•Measure the distance *q* from the screen to the mirror.

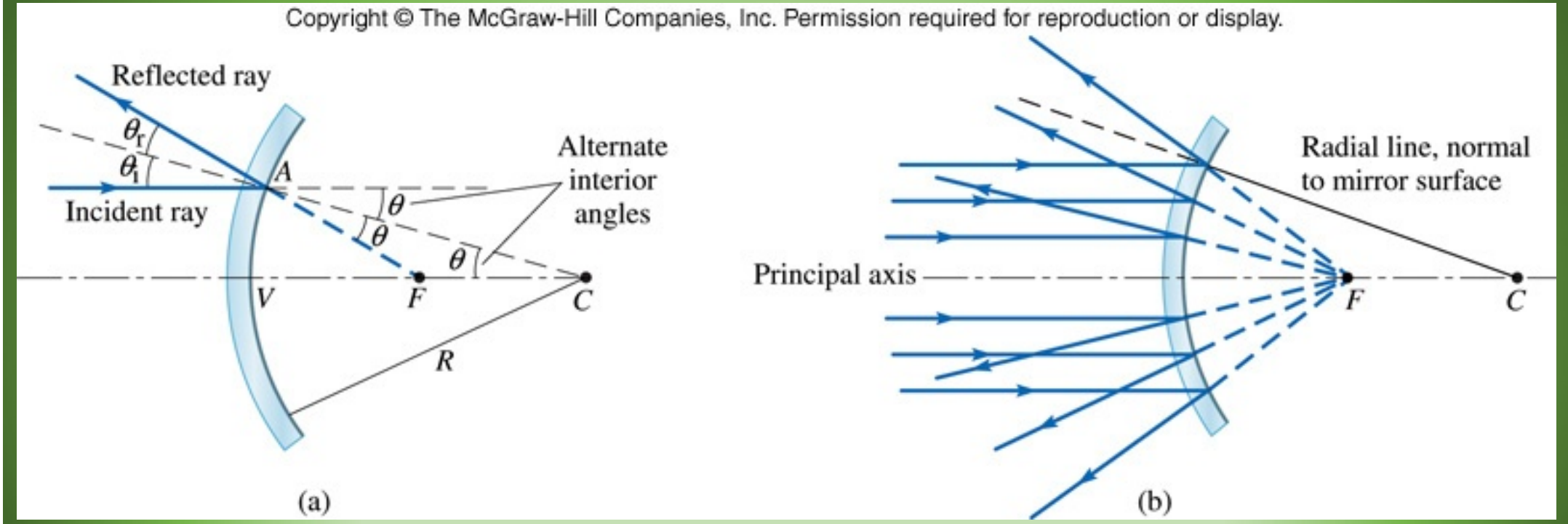
• Calculate the focal length of the mirror using - - - - -

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

•Repeat this procedure for different values of *p*.

•Calculate *f* each time and then find an average value.

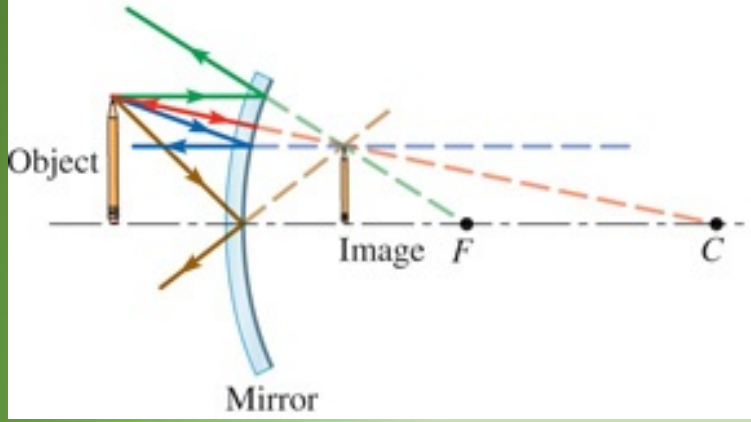
Convex Spherical Mirrors



Convex Spherical Mirrors

- A convex spherical mirror (diverging mirror) is silvered so that light is reflected from the sphere's outer, convex surface
  - The image distance is always negative!
  - The image is always a virtual image!
  - The focal point of a convex mirror is on the principal axis a distance R/2 behind the mirror
  - The focal length is negative !

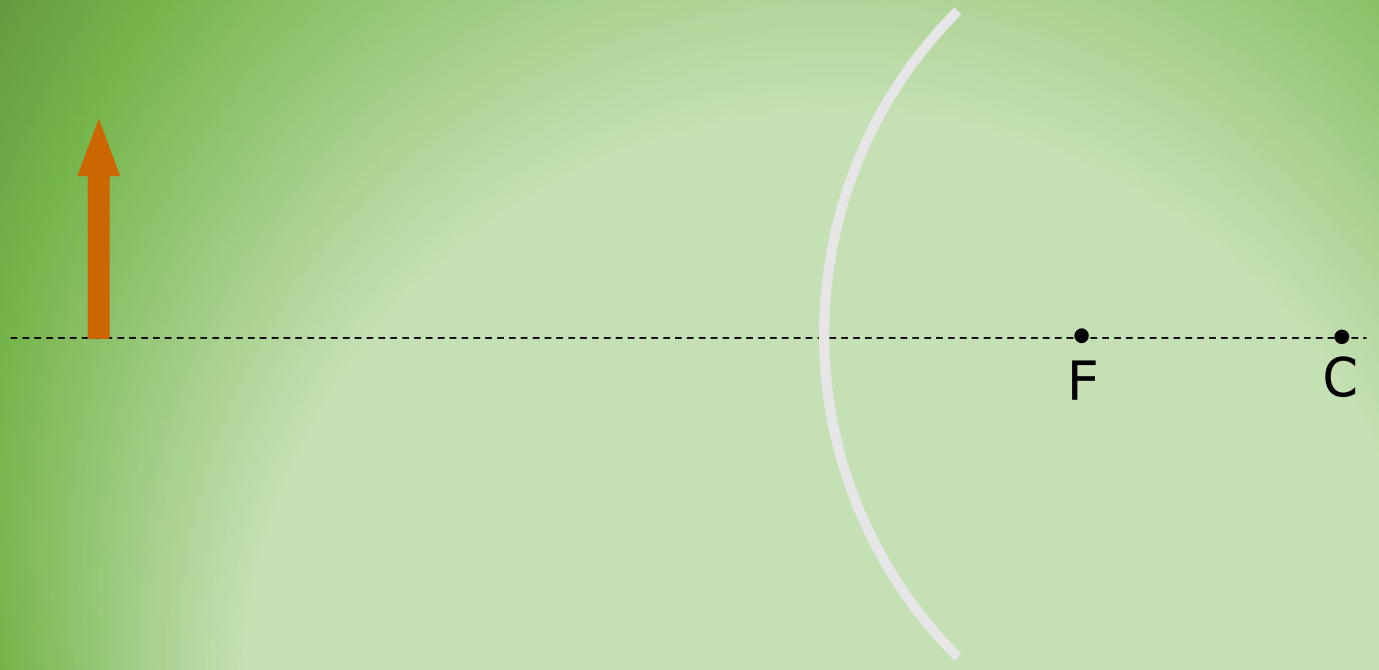
Convex Spherical Mirrors: How do they work?



Principal rays for convex mirrors

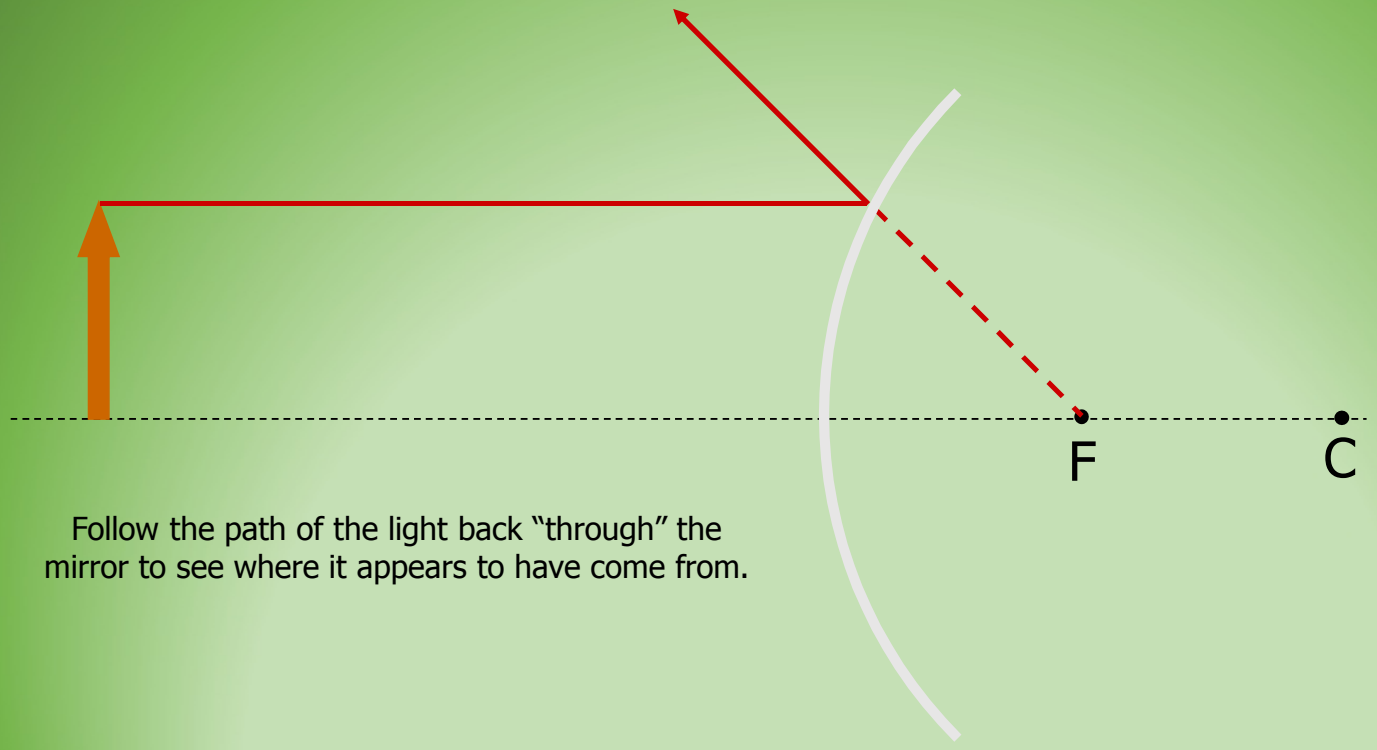
1. A ray parallel to the principal axis is reflected as if it came from a focal point.
2. A ray along a radius is reflected back upon itself.
3. A ray directed toward the focal point is reflected parallel to the principal axis.
4. A ray incident on the vertex of the mirror reflects at an equal angle to the axis.

For a convex lens, the center of curvature and focal point are on the opposite side of the lens as the object. Light from the object will never actually pass through C or F.



Convex Mirror

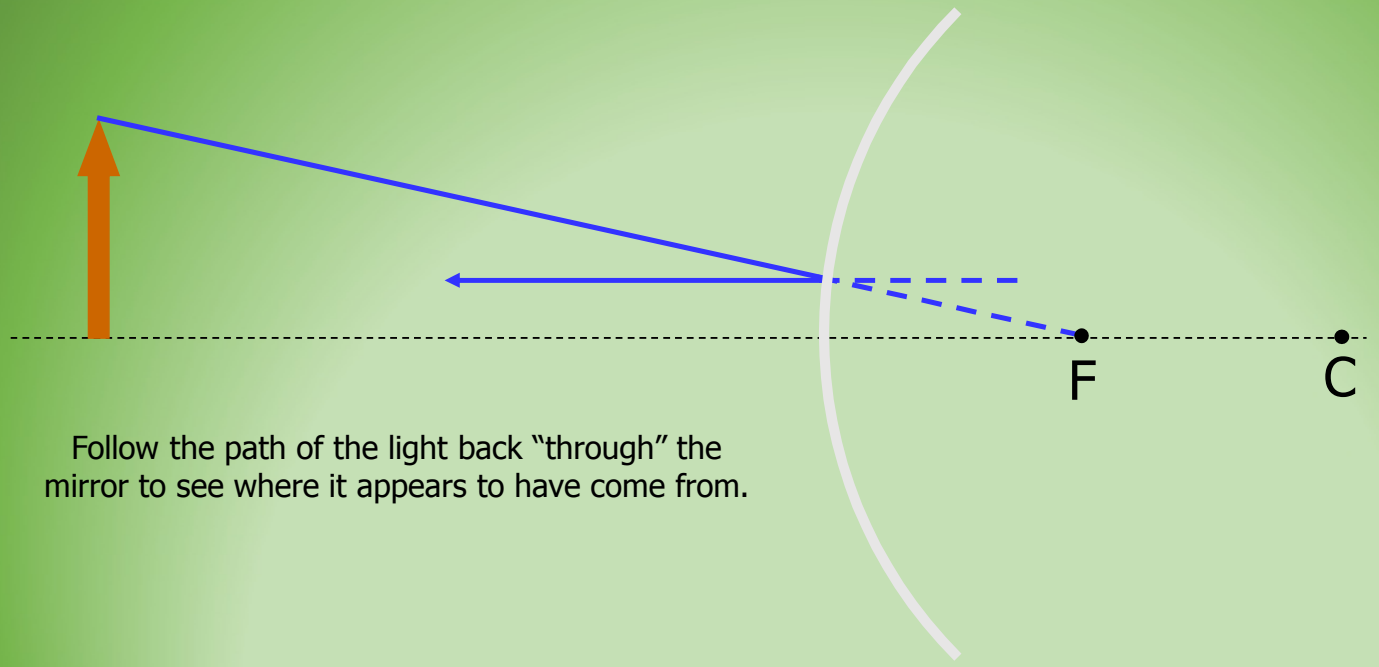
Light coming from the object parallel to the axis will always reflect back as if it had come from F.



Follow the path of the light back "through" the mirror to see where it appears to have come from.

Convex Mirror

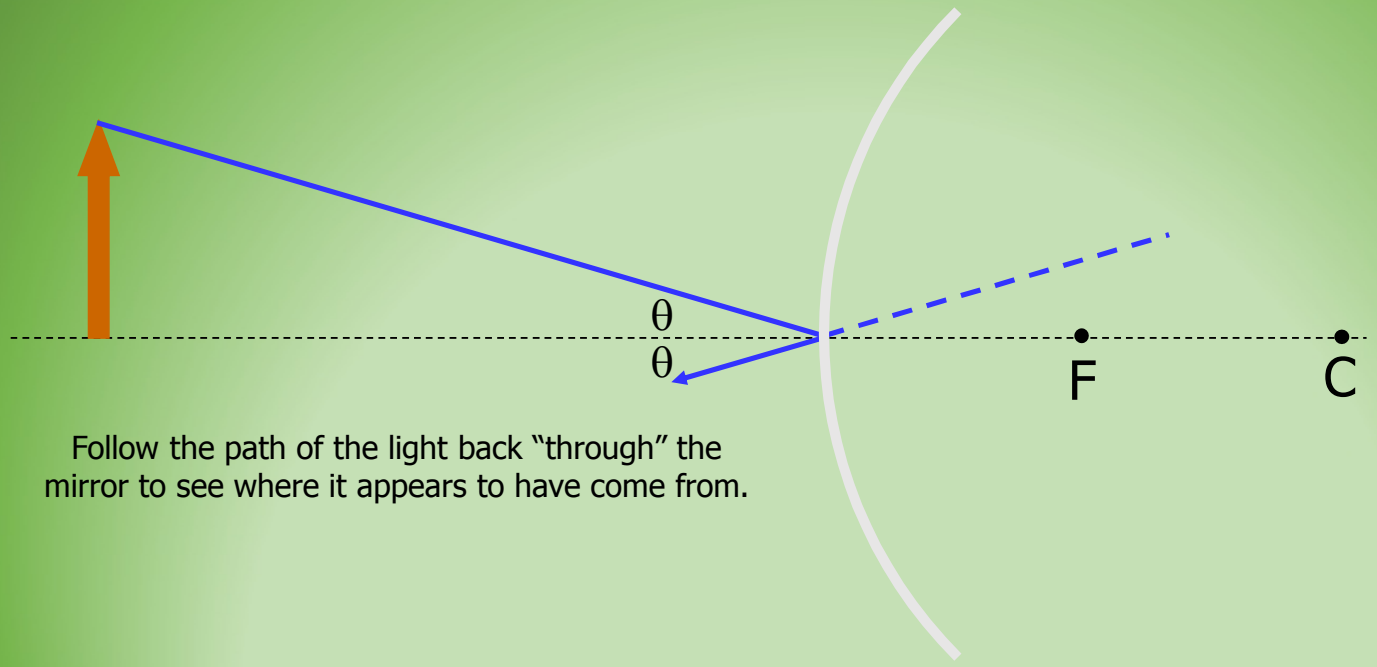
Light coming from the object and directed at F will always reflect back parallel to the axis.



Follow the path of the light back "through" the mirror to see where it appears to have come from.

Convex Mirror

Light coming from the object and striking the vertex will reflect back with an outgoing angle equal to the incoming angle. This is often more difficult to draw (unless you measure the angle).

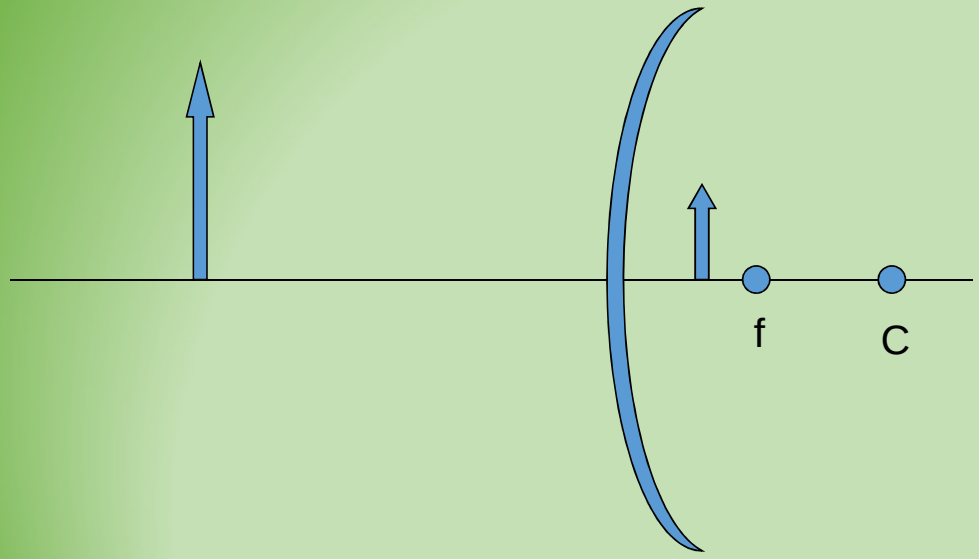


Follow the path of the light back "through" the mirror to see where it appears to have come from.

Convex Mirror

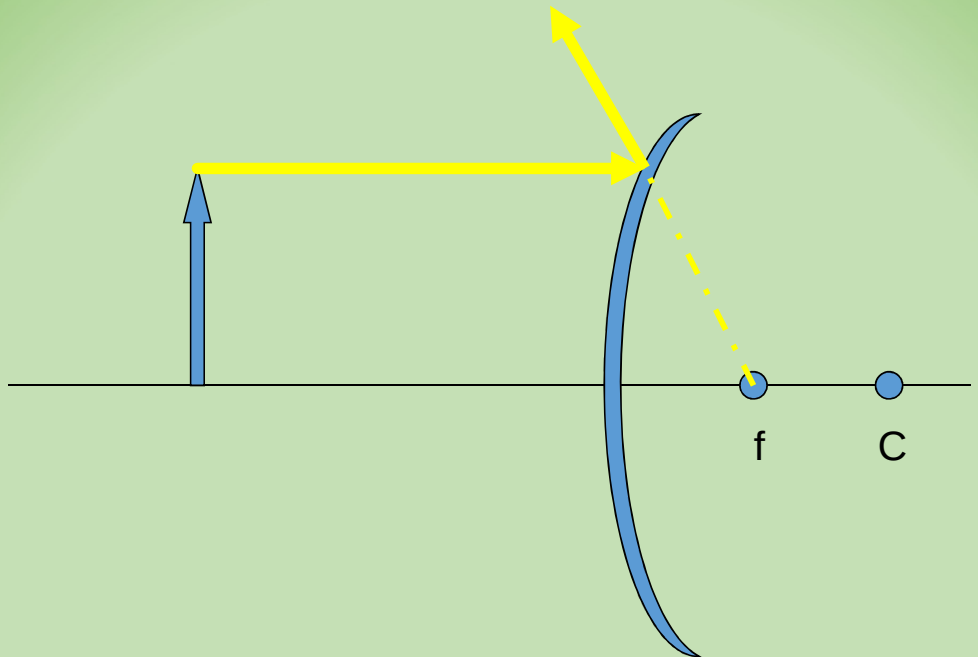
Ray diagrams for convex mirrors

- The focal point and center of curvature are behind the mirror's surface
  - A virtual, upright image is formed behind the mirror
  - The magnification is always less than 1



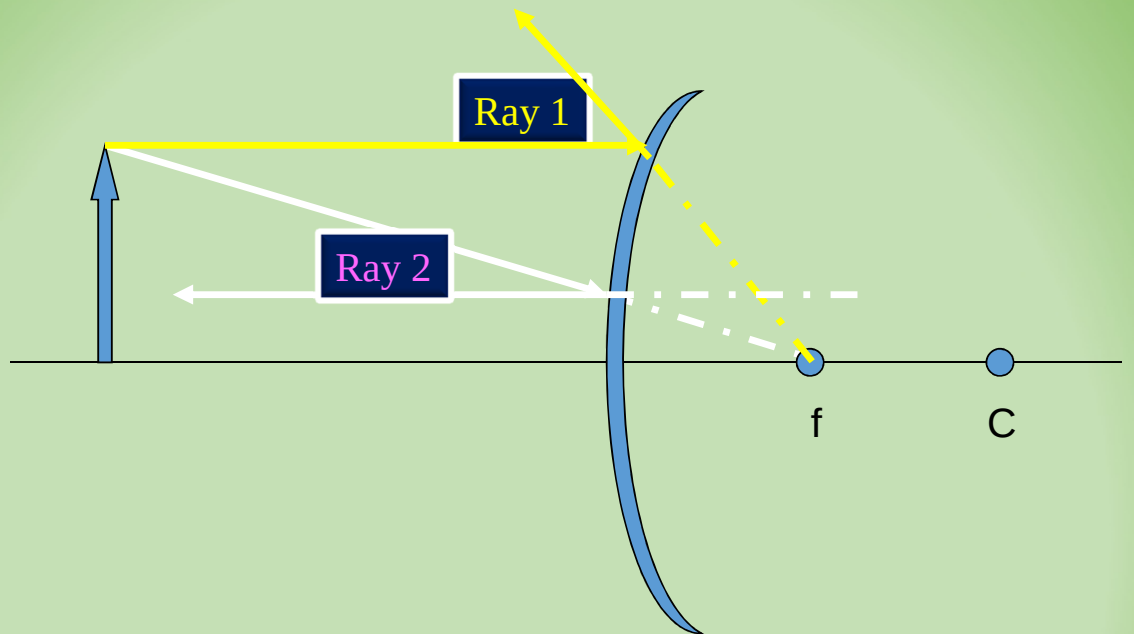
Drawing the reference rays

- Ray 1 is drawn parallel to the principal axis beginning at the top of the object. It reflects from the mirror along a line that intersects the focal point



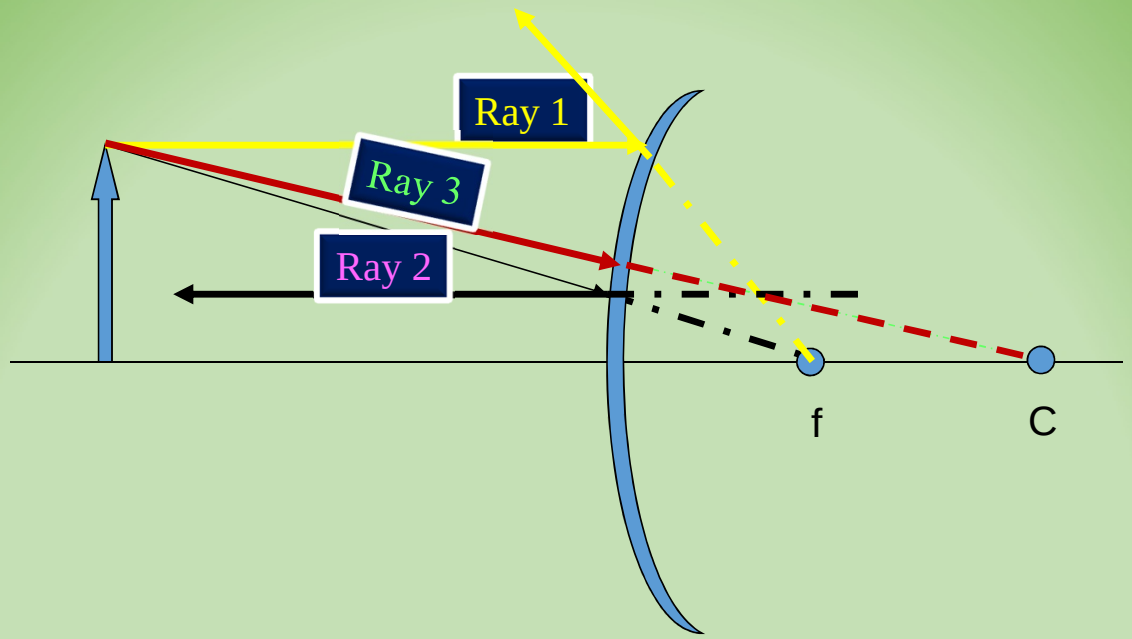
Ray 2

- Ray 2 starts from the top of the object and goes as though its going to intersect the focal point but it reflects parallel to the principal axis



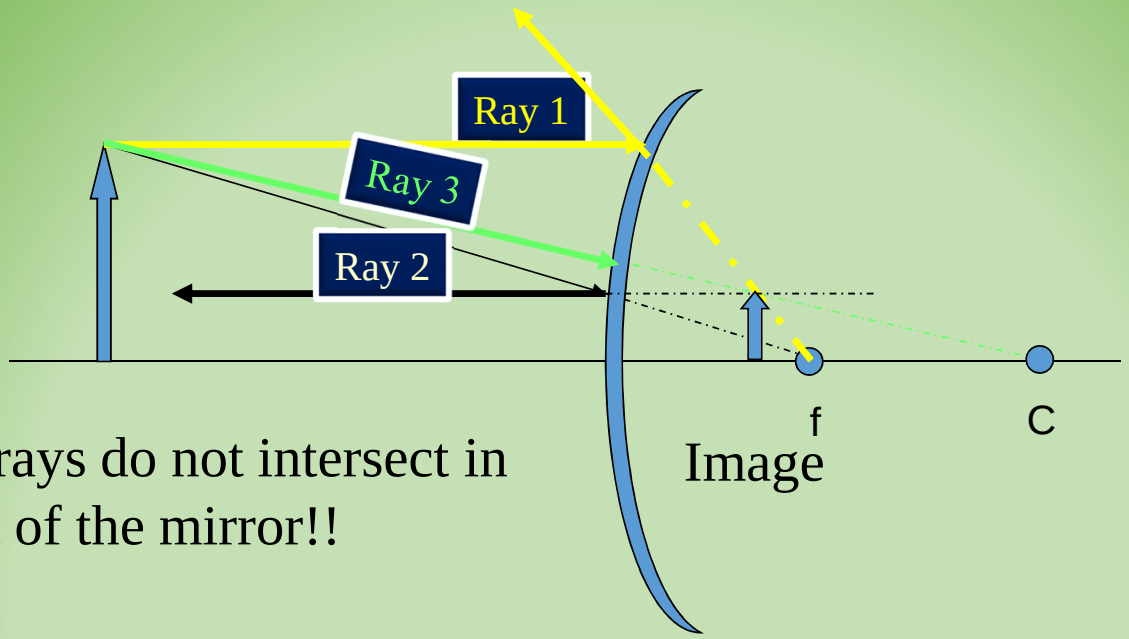
Ray 3

- Ray 3 starts at the top of the object and goes as though its going to intersect the center of curvature



Convex Spherical Image Formation

- The image forms at the intersection of any two of the three rays behind the mirror.



The rays do not intersect in front of the mirror!!

Table 10.2 Nature, position and relative size of the image formed by a convex mirror

Position of the object	Position of the image	Size of the image	Nature of the image
At infinity	At the focus F, behind the mirror	Highly diminished, point-sized	Virtual and erect
Between infinity and the pole P of the mirror	Between P and F, behind the mirror	Diminished	Virtual and erect