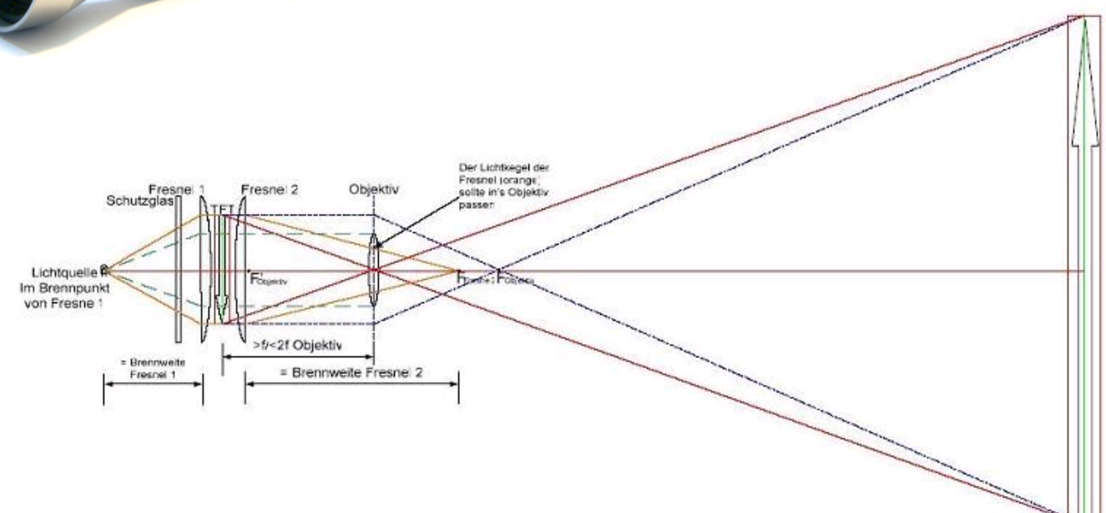
Chapter 34 Images



34.2: One Object and Two Types of Image:

In optics, an **object** shines: sends out light so that it can be seen.

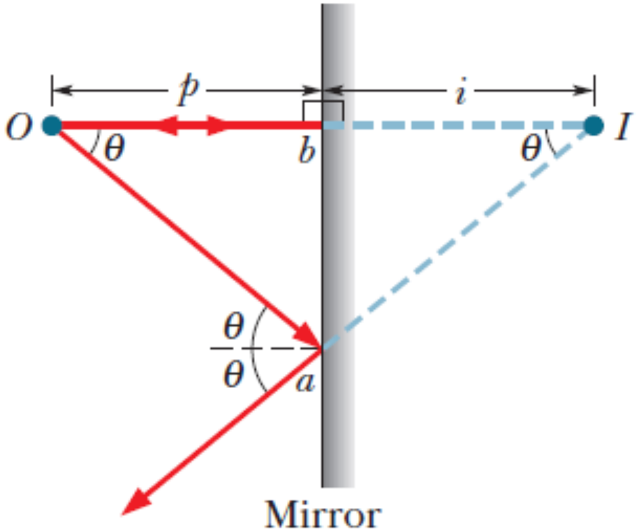
In English, an **image** is what we see, a perception of an object in our brain. In this sense all images are virtual.

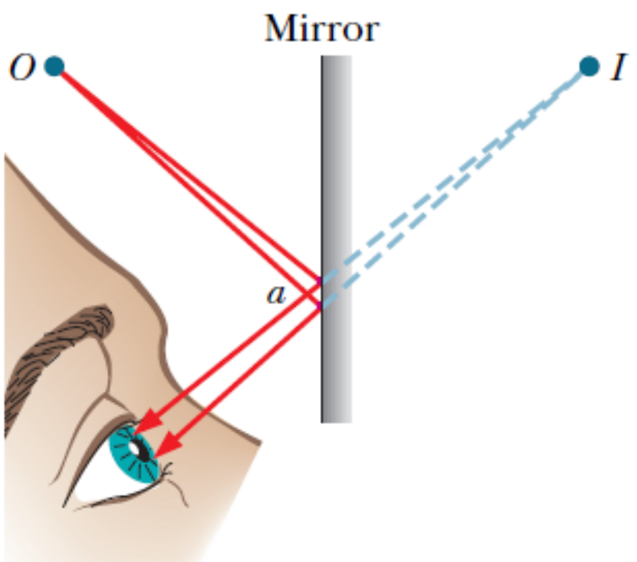
In optics, the word **image** means two things:

1. A **real image** is the representation of an object formed by light rays from an optical system. In this sense, a real image also shines, the same as an object. For example, images on a movie screen, on the CCD senor of your digital camera, are real images.
2. A **virtual image** does not exit in space, it only exists in our brain with the way human forms images (back tracing light rays). But a virtual image is still said to exist at its perceived location in space.

There is another type of virtual image, that's the one "perceived" not by human eyes, but by a set of optical instrument. Sometimes this is called a **virtual object**.

34.3: The simplest optical instrument: the Plane Mirror:



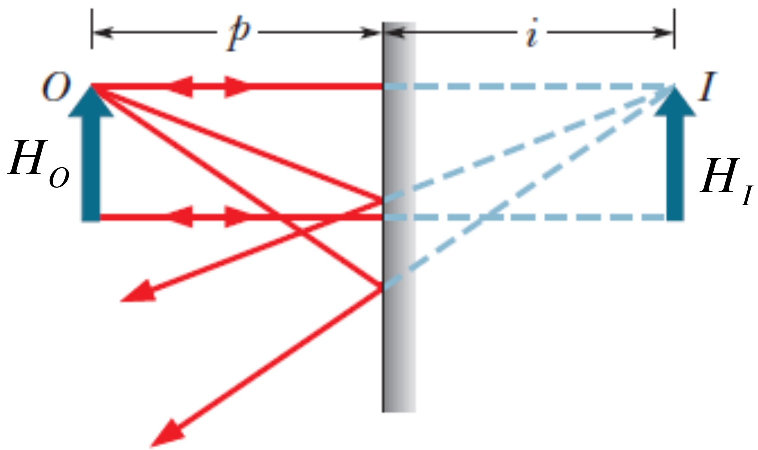


1. Object distance *p*: this is usually a positive value, unless for a virtual object.
2. Image distance *i*: positive for real image, negative for virtual image.
3. Based on the Law of Reflection we have:

$$i = -p$$

This formula applies to all points on an object. But it does not tell the amplification of the image with respect to the object.

34.3: Plane Mirrors, Extended Objects and Lateral Amplification



Based on the Law of Reflection and simple geometry one can prove that:

$$\underbrace{M \equiv \frac{H_I}{H_o} = -\frac{i}{p}}_{\text{True for all mirrors and lenses}} = 1$$

So for plane mirrors, the image is:

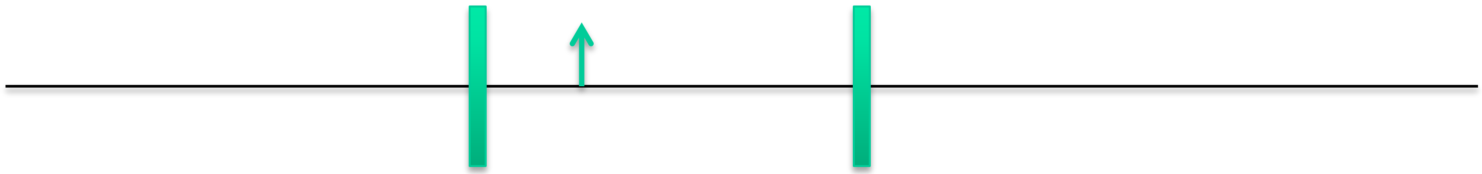
1. virtual;
2. the same distance to the mirror as the object is;
3. the same size and orientation.
4. front-to-back symmetry.

34.3: Plane Mirrors, two examples

1. What is the minimum length of a plane mirror in which you can see your full image?

2. What is the minimum length of a plane mirror in which you can your brother's full image?

34.3: Mirror Maze: images with many mirrors



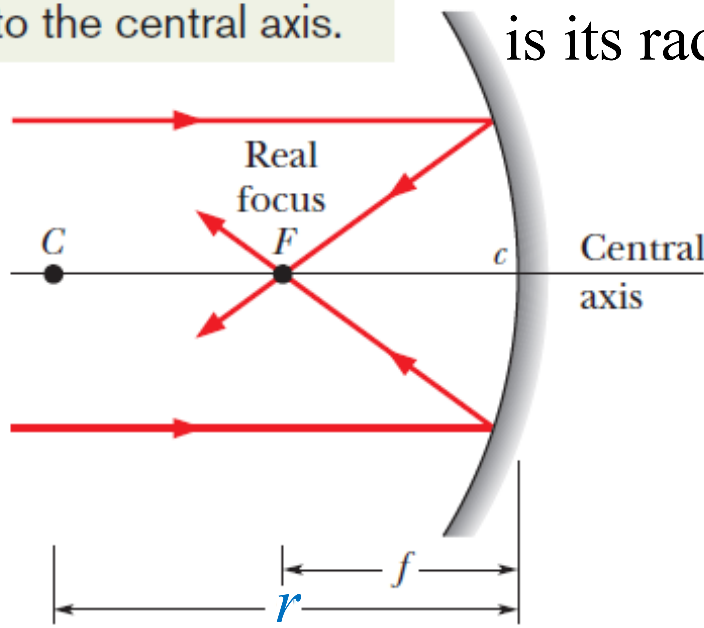
You stand between two parallel plane mirrors. You are 0.5 m to the mirror on your left and face it. The mirror behind you is 1.5 m from you. Find the image distances (with respect to the left mirror) of the first 2 images you see in the left mirror.

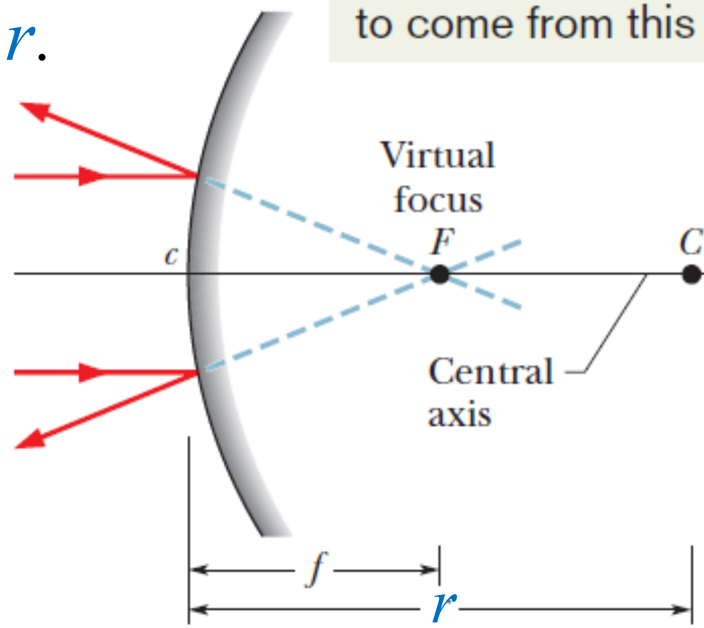
34.4: Spherical Mirrors: light rays converge or diverge.

To find the focus, send in rays parallel to the central axis.

The only parameter that defines a sphere is its radius r.

If you intercept the reflections, they seem to come from this point.





Concave or converging mirror. Light rays parallel to the central axis meet at one point on the central axis ➔ focal point F.

Focal length:

$$f = \frac{|r|}{2}$$

Convex or diverging mirror. The focal point is defined as the virtual image of light rays parallel to the central axis.

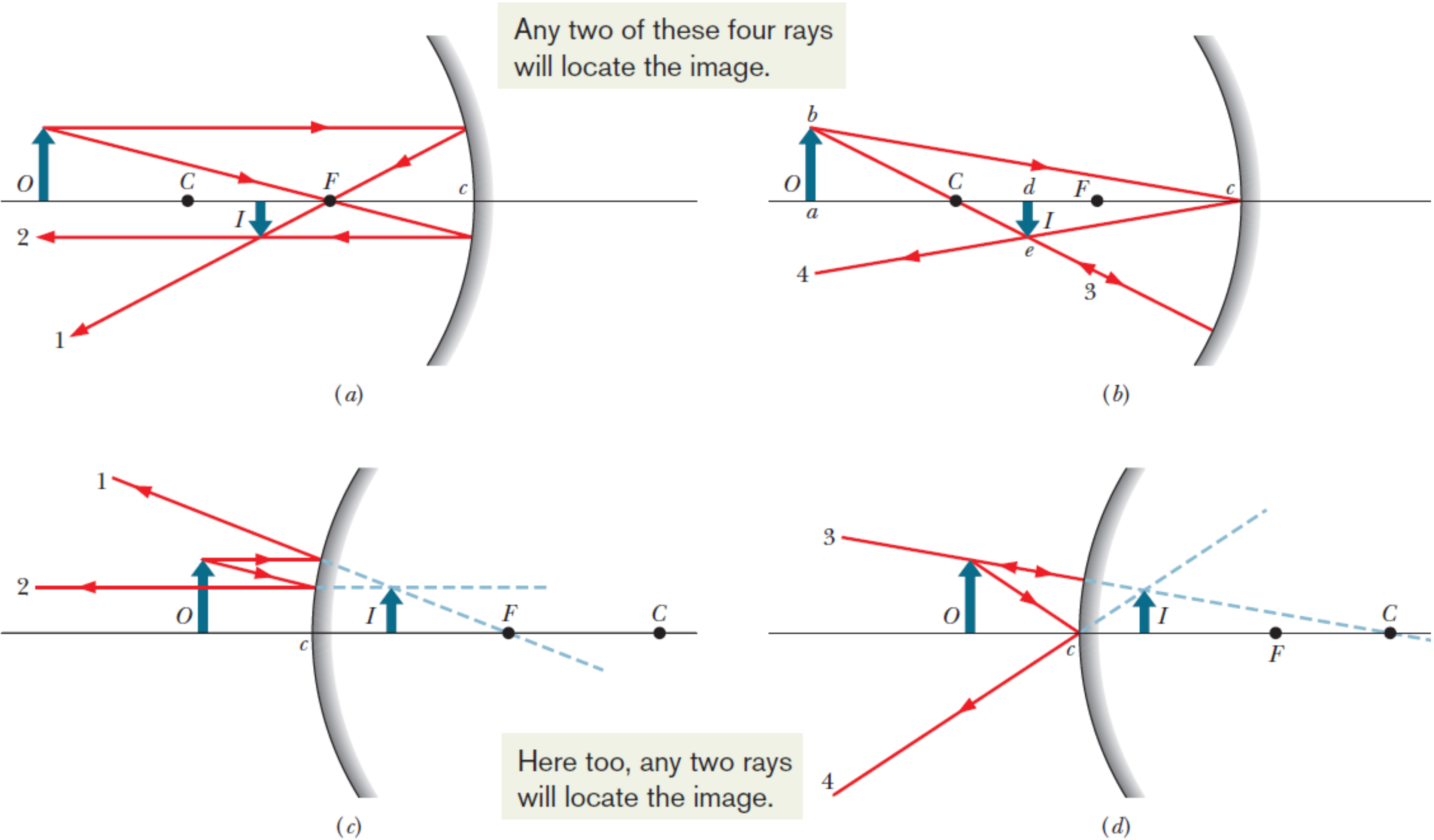
Focal length:

$$f = -\frac{|r|}{2}$$

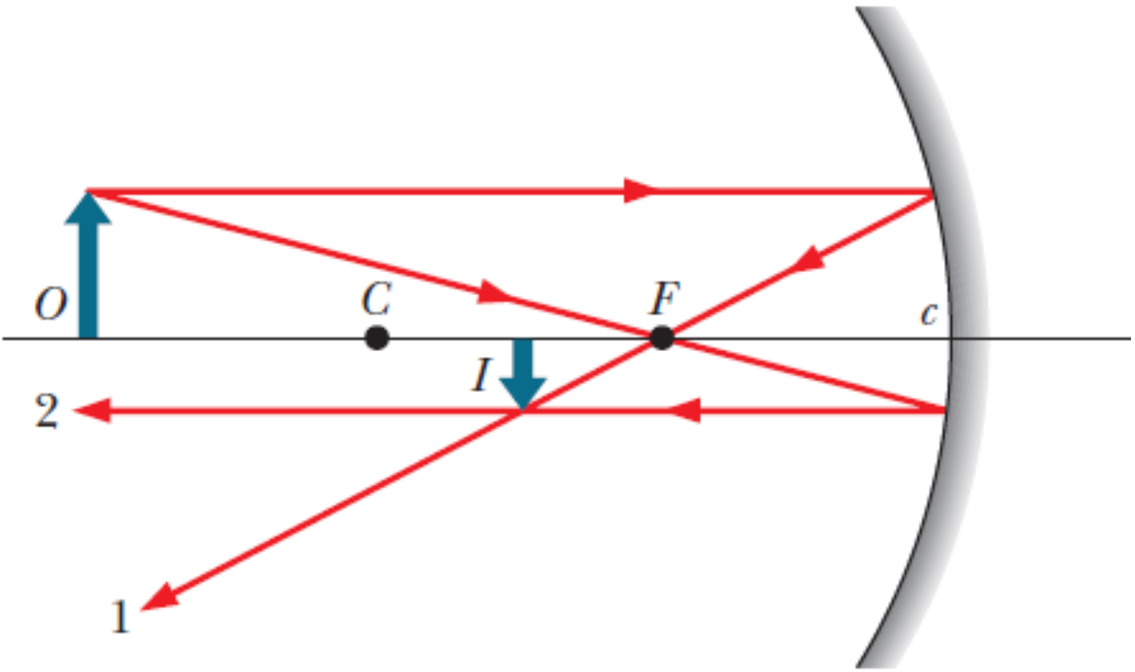
one example

- You use a concave mirror to make a fire with the sun light. The focal length of the mirror is 20 cm. You hold it towards the sun and try to light a small wood stick at its tip. Where you want to place this tip?

34.5: Find Images from Spherical Mirrors: the ray diagram way



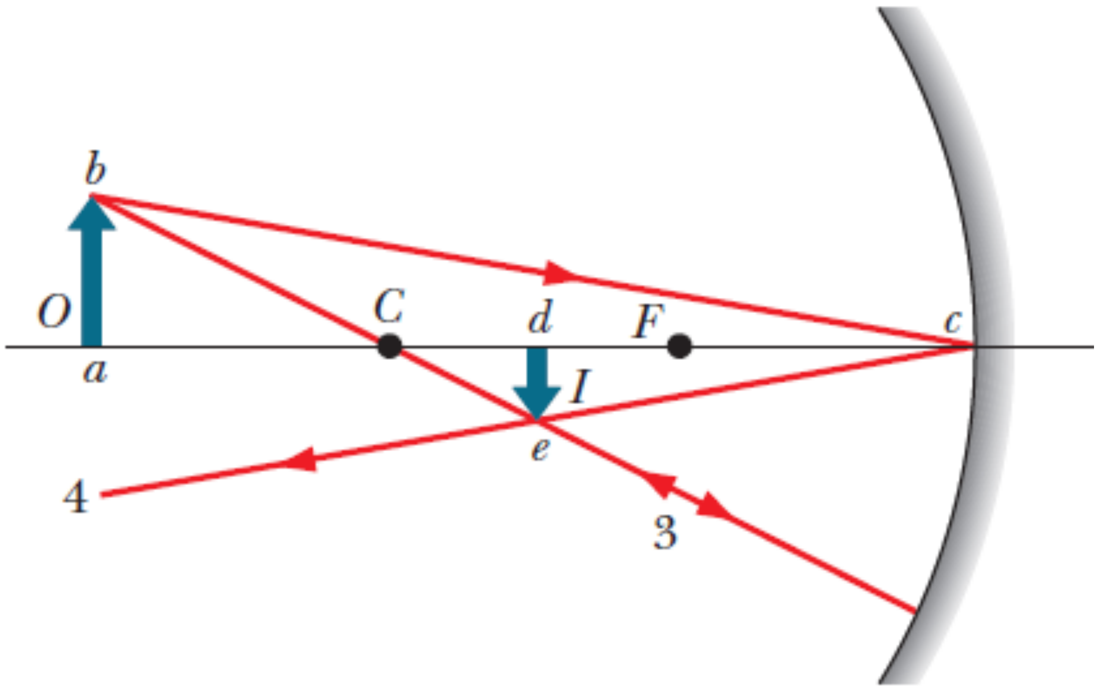
34.5: Find Images from Spherical Mirrors: the ray diagram way



Ray 1: A ray that is initially parallel to the central axis reflects through the focal point *F*;

Ray 2: A ray that reflects from the mirror after passing through the focal point emerges parallel to the central axis.

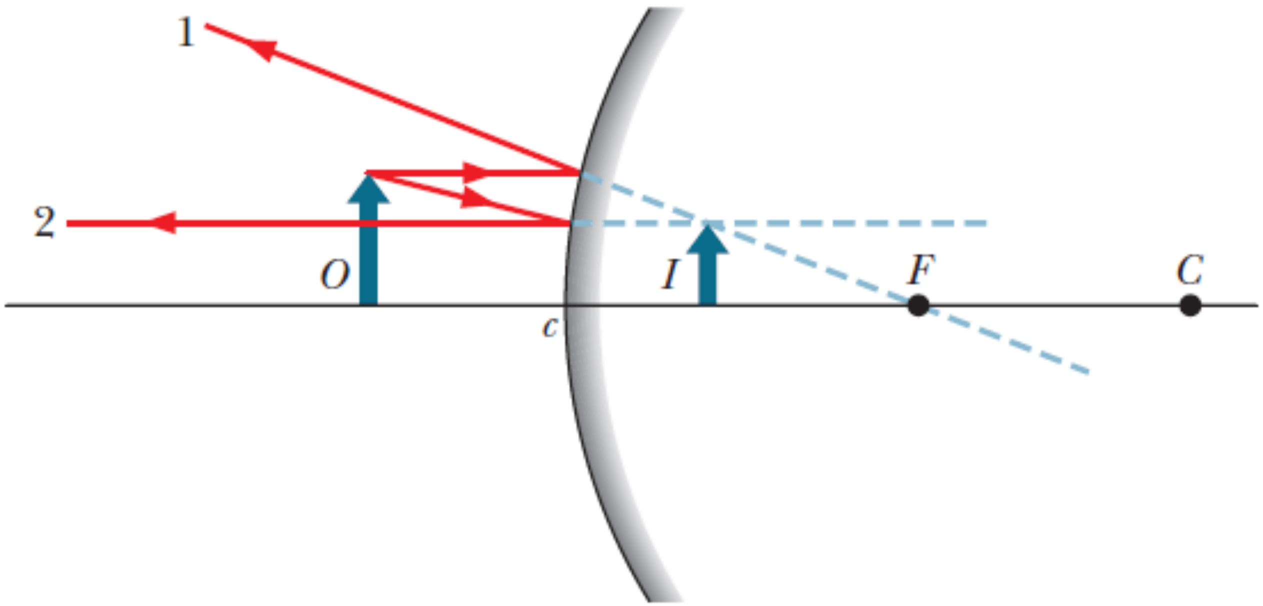
34.5: Find Images from Spherical Mirrors: the ray diagram way

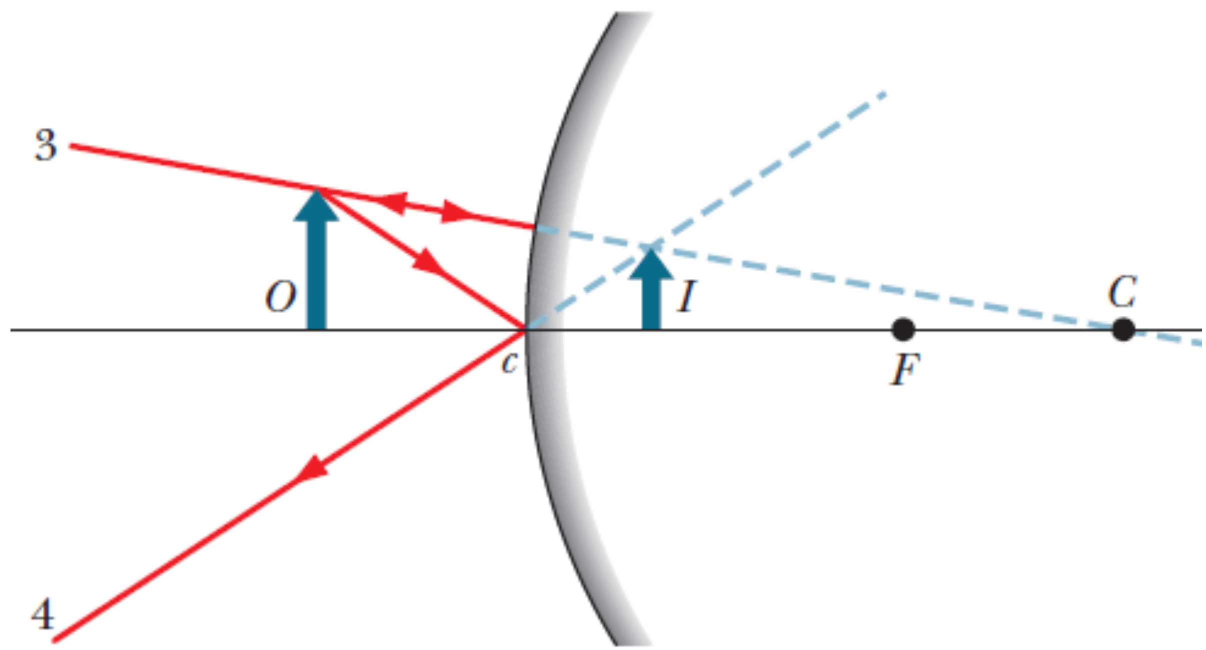


Ray 3: A ray that reflects from the mirror after passing through the center of curvature *C* returns along itself.

Ray 4: A ray that reflects from the mirror at point *c* is reflected symmetrically about that axis.

34.5: Find Images from Spherical Mirrors: the ray diagram way

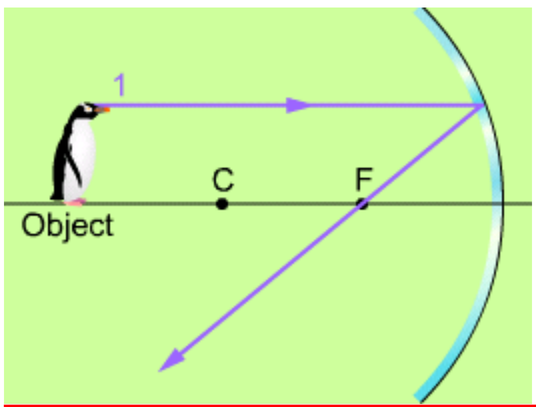




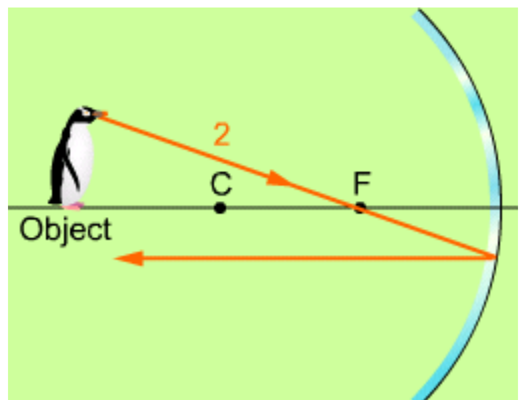
With convex mirror, one always needs to back trace (where is your eye position?) to find the image location.

Find the image

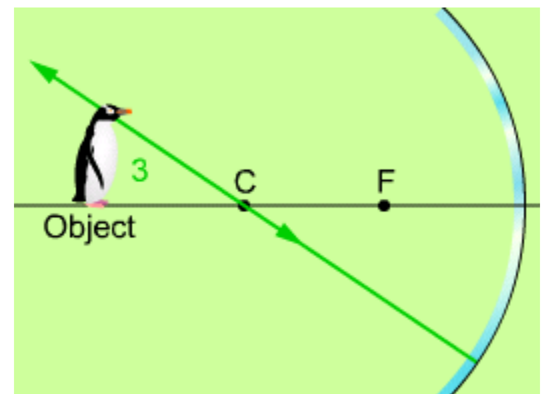
- Method 1: the ray diagram



Ray 1 starts as an incident ray that is parallel to the principal axis. It reflects off the mirror and passes through the focal point after it reflects.



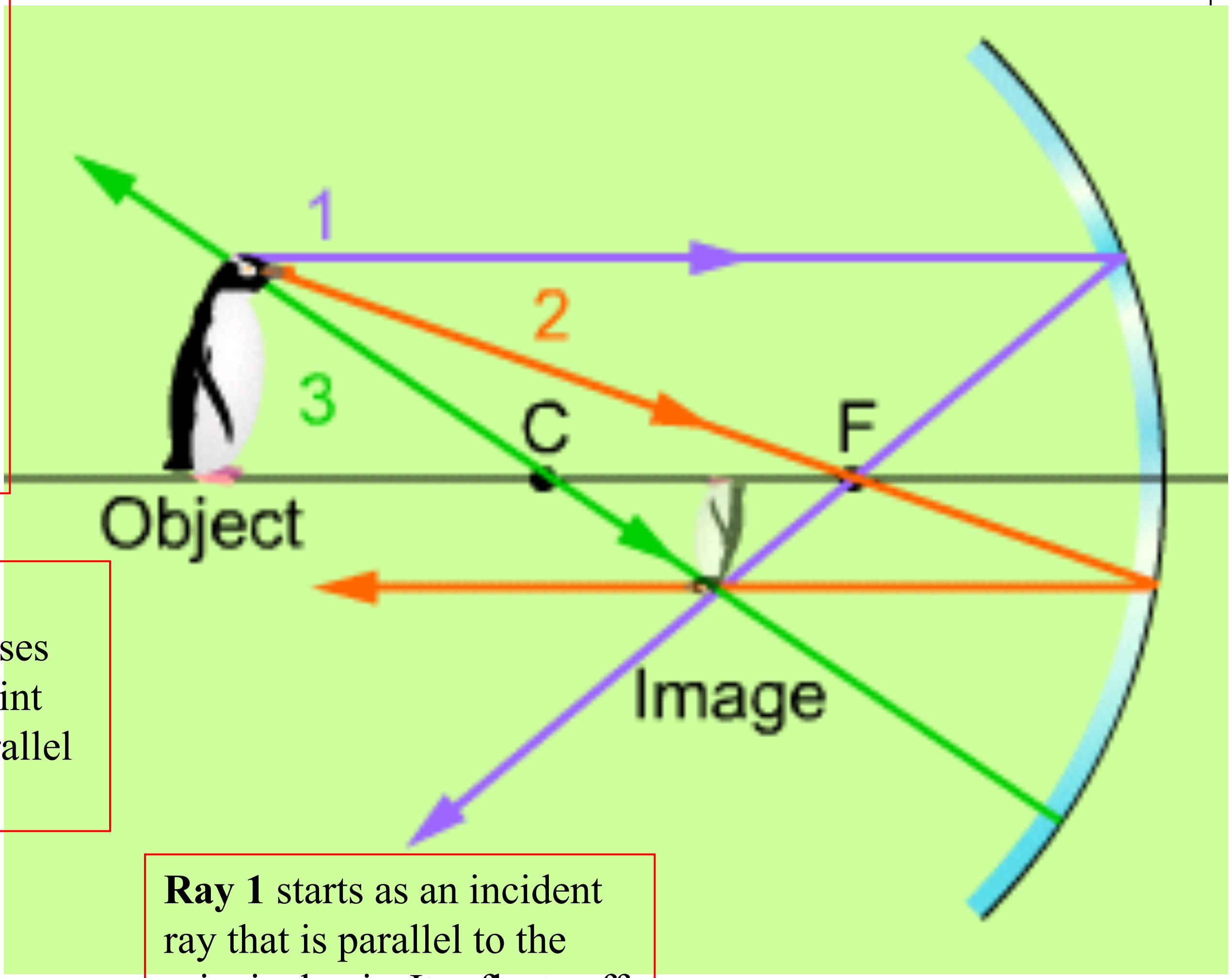
Ray 2 starts as an incident ray that passes through the focal point and then reflects parallel to the principal axis.



Ray 3 begins as an incident ray that passes through the center of curvature, strikes the mirror perpendicularly, and reflects back, moving along the same line as the incident ray.

The ray diagram

Ray 3 begins as an incident ray that passes through the center of curvature, strikes the mirror perpendicularly, and reflects back, moving along the same line as the incident ray.

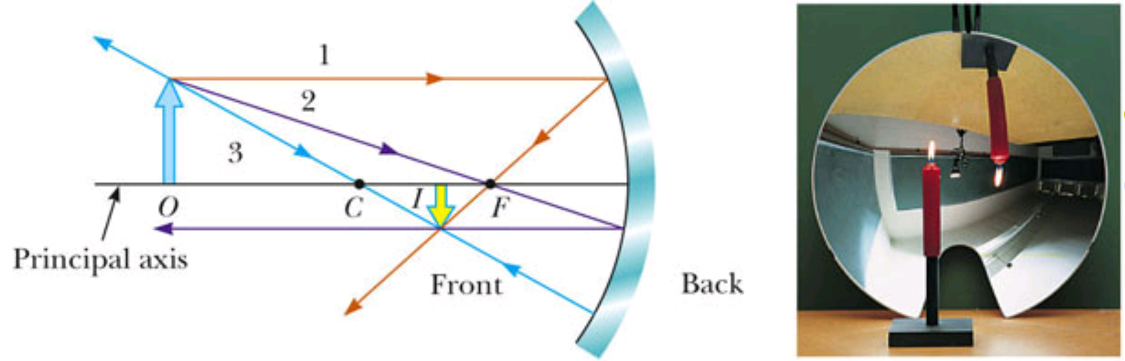


Ray 2 starts as an incident ray that passes through the focal point and then reflects parallel to the principal axis.

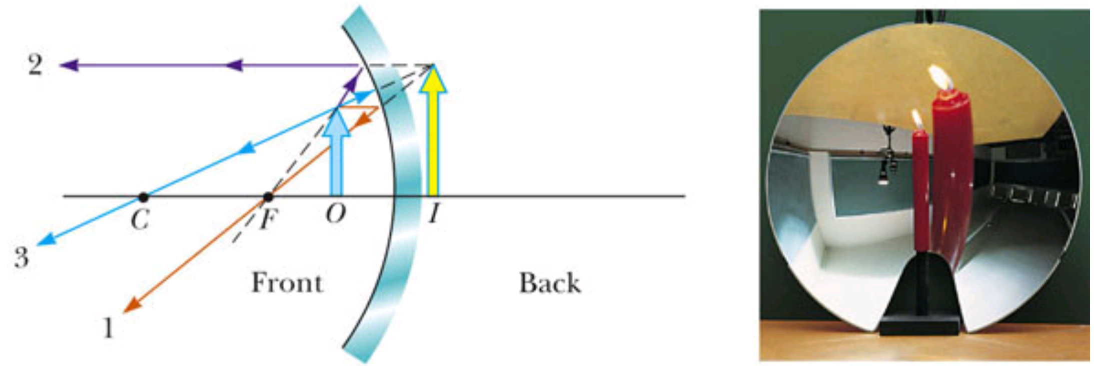
Ray 1 starts as an incident ray that is parallel to the principal axis. It reflects off the mirror and passes through the focal point after it reflects.

Image up-side-down, smaller, real

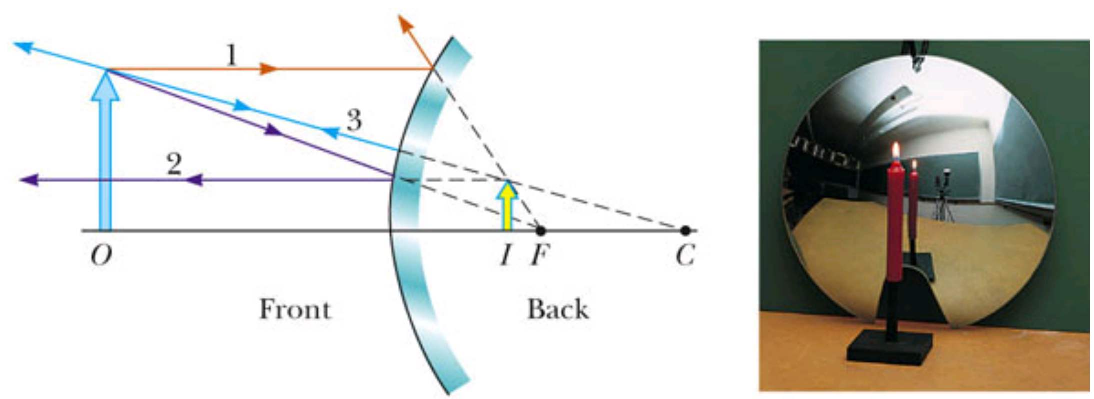
The five object locations and their images



(a)



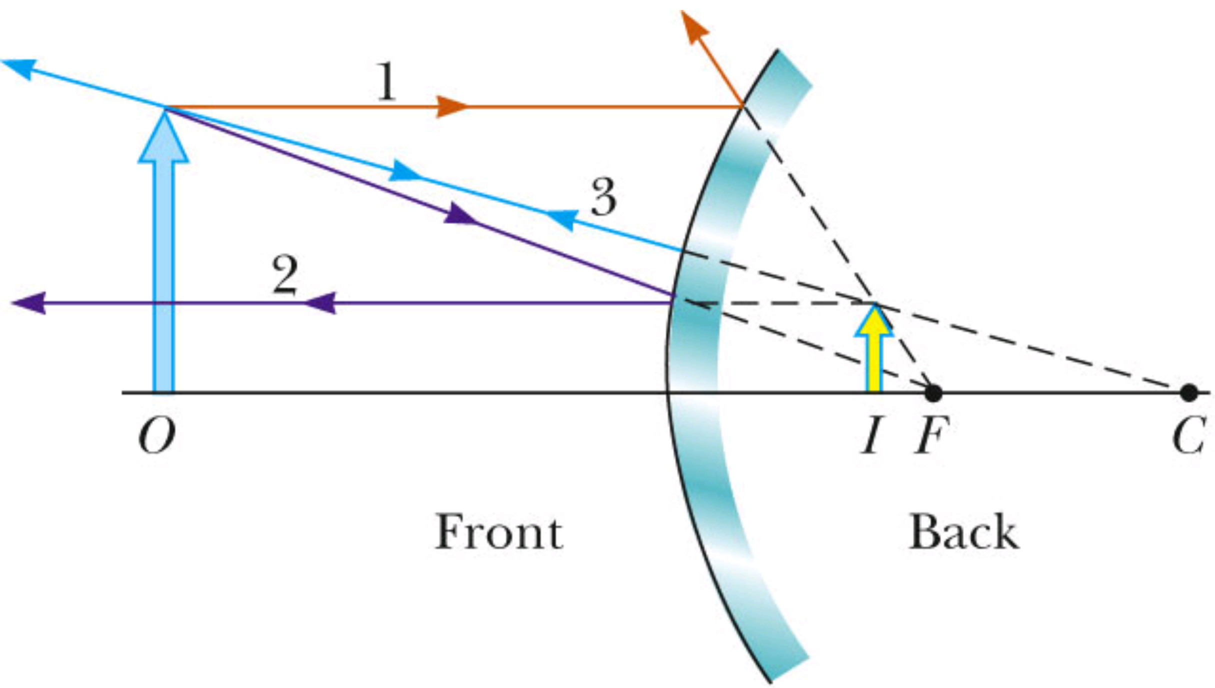
(b)



(c)

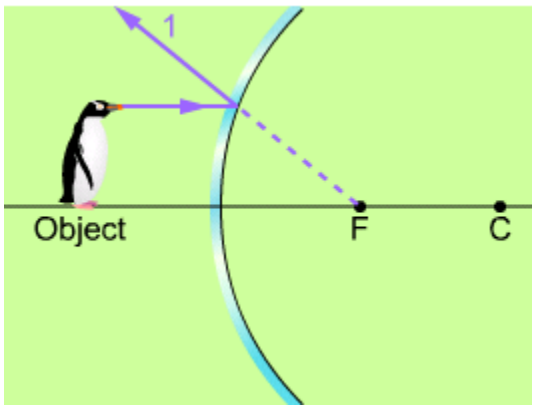
Convex Mirrors

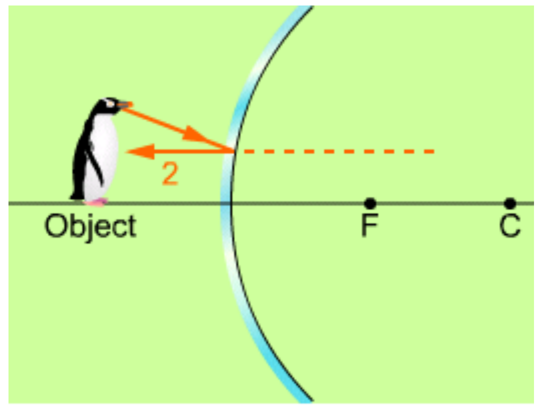
- A **convex mirror** is sometimes called a diverging mirror
  - The light reflects from the outer, convex side
- The rays from any point on the object diverge after reflection as though they were coming from some point behind the mirror
- The image is virtual because the reflected rays only appear to originate at the image point

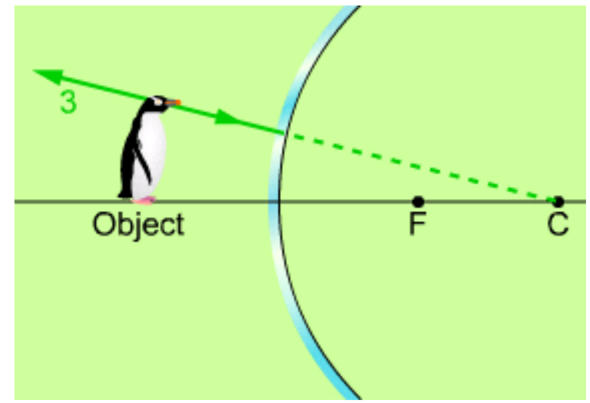


Find the image

- Method 1: the ray diagram







Ray 1. Ray 1 is incident parallel to the principal axis. If we extend the reflected component of this ray backward through the mirror, the virtual ray will pass through the focal point.

Ray 2. Instead of passing through the focal point, the incident part of ray 2 is directed toward it. Before it can reach the focal point behind the mirror, it reflects parallel to the principal axis. Its virtual extension behind the mirror is also parallel to the axis.

Ray 3. The incident component of Ray 3 is directed toward the center of curvature on the far side of the mirror and reflects back along the same line. The virtual extension of the reflected ray passes through the center of curvature.

Only one case for a diverging mirror

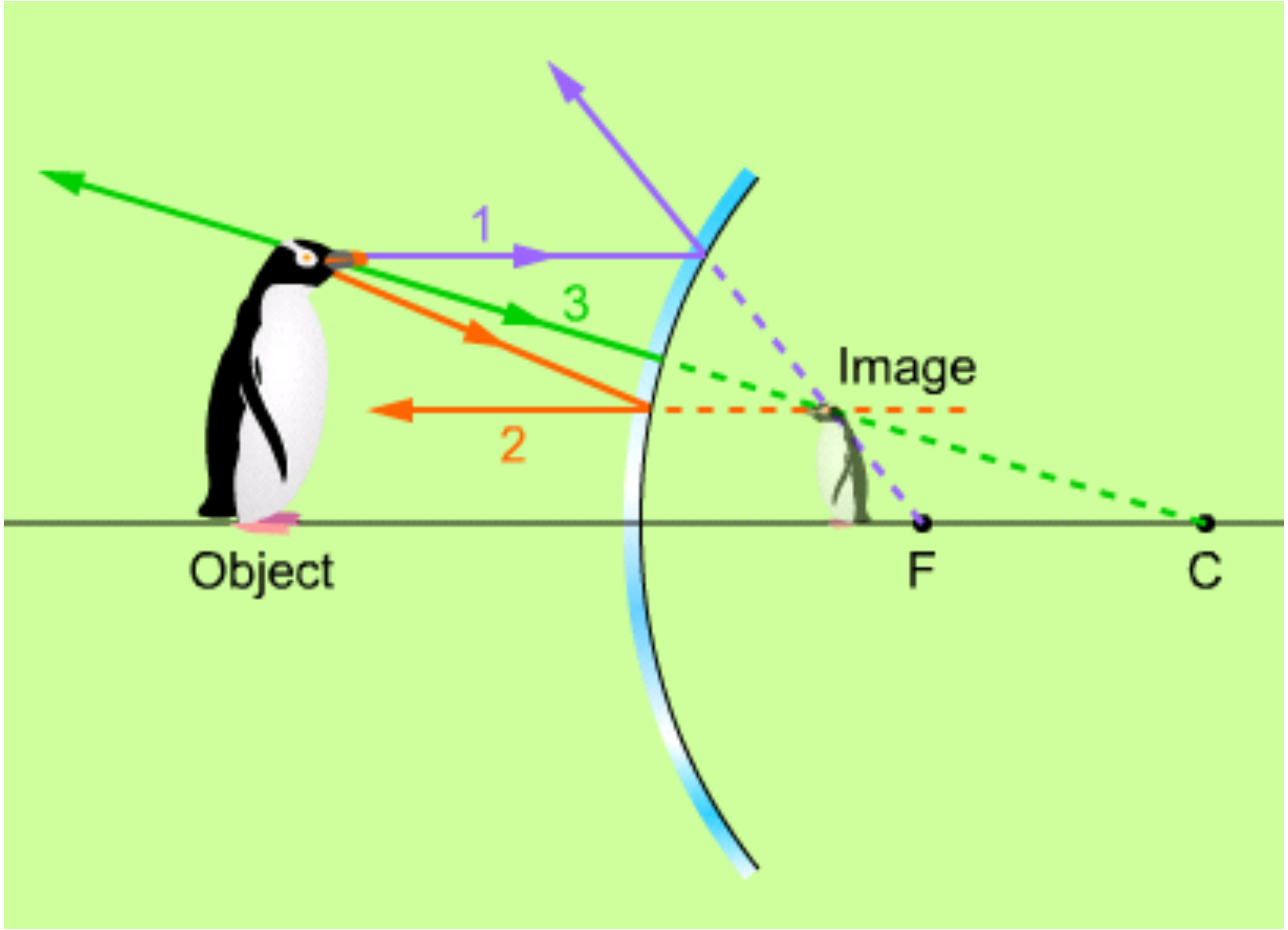


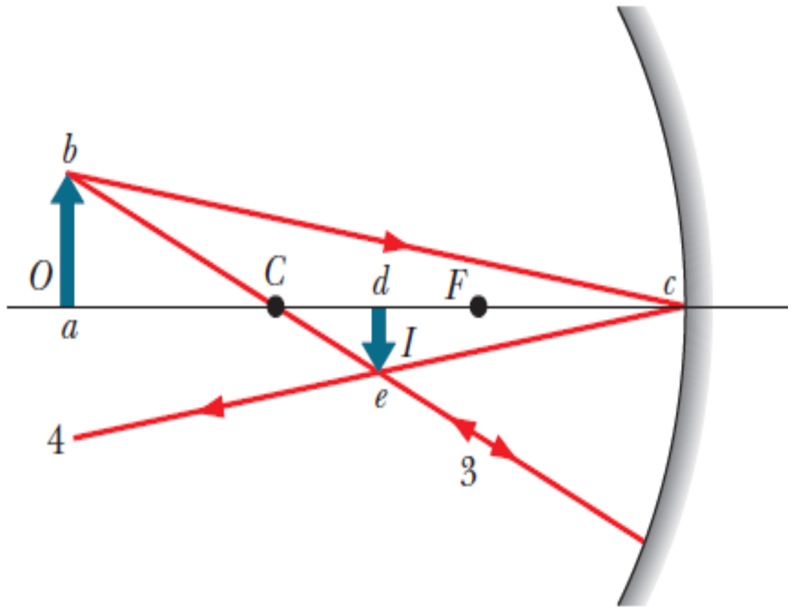
Image always upright, smaller, virtual

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 or no image
  - 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 decreases, the virtual image increases in size

34.5: Image amplification from Spherical Mirrors:

Consider ray 4. It is reflected at point *c* so that the incident and reflected rays make equal angles with the axis of the mirror at that point.



The two right triangles *abc* and *dec* in the figure are similar (have the same set of angles); so we can write

$$\frac{de}{ab} = \frac{cd}{ca}.$$

The quantity on the left (apart from the question of sign) is the lateral magnification *m* produced by the mirror. Because we indicate an inverted image as a negative magnification, we symbolize this as -*m*. However, *cd =i* and *ca =p;* therefore

$$m = -\frac{i}{p} \qquad \text{(magnification)},$$

34.5: Calculation about Images from Spherical Mirrors:

When light rays from an object make only small angles with the central axis of a spherical mirror, a simple equation relates the object distance *p,* the image distance *i,* and the focal length *f* :

$$\frac{1}{p} + \frac{1}{i} = \frac{1}{f} \qquad \text{(spherical mirror).}$$

The size of an object or image, as measured perpendicular to the mirror's central axis, is called the object or image height. Let h_o represent the height of the object, and h_i the height of the image. Then the ratio h'/h is called the lateral magnification m produced by the mirror.

$$m \equiv \frac{h_i}{h_o} = -\frac{i}{p}$$

34.5: a few words on this lateral magnification m:

Compared with the object:

$$m \equiv \frac{h_i}{h_o}$$

$|m| > 1$ Image size magnified

$|m| = 1$ Image the same size

$|m| < 1$ Image size shrined

$m > 0$ Image same orientation

$m < 0$ Image orientation flipped

Example, Image produced by a spherical mirror:

A tarantula of height h sits cautiously before a spherical mirror whose focal length has absolute value $|f| = 40$ cm. The image of the tarantula produced by the mirror has the same orientation as the tarantula and has height $h' = 0.20h$.

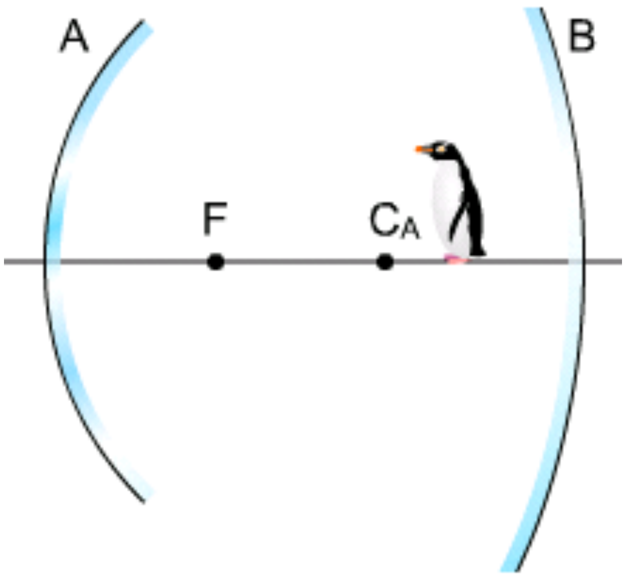
(a) Is the image real or virtual, and is it on the same side of the mirror as the tarantula or the opposite side?

(b) Is the mirror concave or convex, and what is its focal length f, sign included?

More examples

- When you look into a flat mirror, the image distance is the same as the object distance, why?
- The rear review mirror on the side of your car is a convex mirror with a focal length of -0.60 m. If a truck is 10.0 m from this mirror, what is the size of the truck image compare with the actual truck?

How about this problem?



Two concave mirrors' focal points coincide at point F, and the center of curvature of mirror A is indicated. An object is placed between the mirrors as shown. First imagine that mirror A creates an image of the object. The image created by A is then used as the object for mirror B to create the "final" image. Ignore all other images created by the mirrors. (a) Is the final image upright or inverted compared to the object? It may help to draw a ray diagram. (b) Is the final image real or virtual? (c) If the focal length of mirror A is 6.00 cm, the focal length of mirror B is 13.0 cm, and the object is 14.0 cm from mirror A, where is the final image with respect to mirror A?