

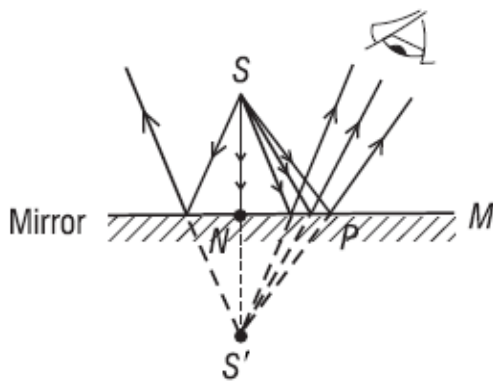
MIRRORS

Plane and spherical mirrors are used to form 3D images of 3D objects. If the size, orientation and location of an object relative to a mirror are known, the law of reflection and ray tracing can be used to locate the image graphically. Appropriate mathematical formulas can also be used to calculate the locations and sizes of the images formed by mirrors. In this chapter we shall use both graphical ray tracing and formulas.

I. IMAGE FORMED WITH PLANE MIRRORS

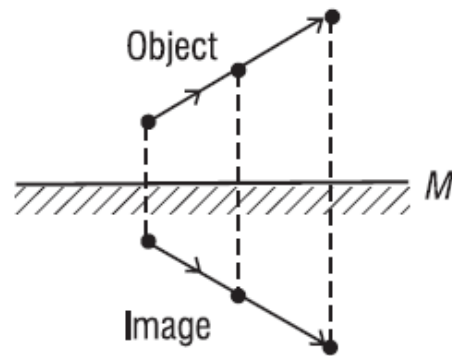
Images with mirrors are formed when many non-parallel rays from a given point on a source are reflected from the mirror surface, converge and form a corresponding image point. When this happens, point by point for an extended object, an image of the object, point by point, is formed.

Image formation in a plane mirror is illustrated as follows,



b) Imaging a point surface

Law of reflection ensures that pair of triangles like SNP and $S'NP$ are equal. The eye sees a point image S' in exactly the same way it would see a real image point object placed there. Since the actual ray do not exist below the mirror surface, the image is said to be a **virtual image**.



a) Imaging an extended object

An extended object is imaged point by point by a plane mirror surface in a similar fashion. Each object point has its image point along its normal to the mirror surface and **as far below the reflecting surface as the object point lies above the surface**. Note that image position does not depend on the position of the eye.

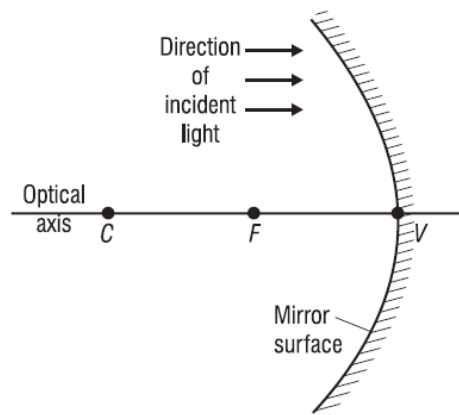
II. IMAGE FORMED WITH SPHERICAL MIRRORS

1. Graphical ray-trace method

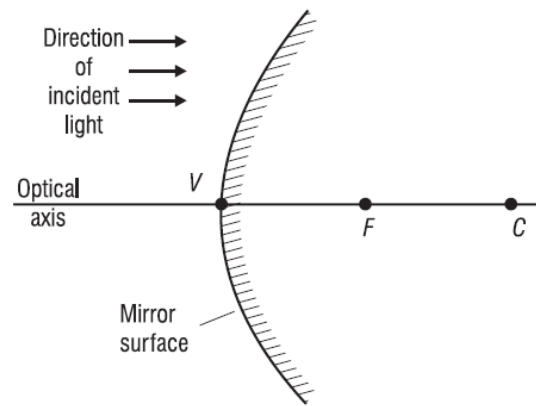
To employ the method of ray tracing, one must agree on the following,

- Light will be incident on a mirror surface initially from the left.
- The axis of symmetry normal to the mirror surface is its optical axis.
- The point where the optical axis meets the mirror surface is the vertex.

To locate an image we use 2 points: centre of curvature C and focal point F .

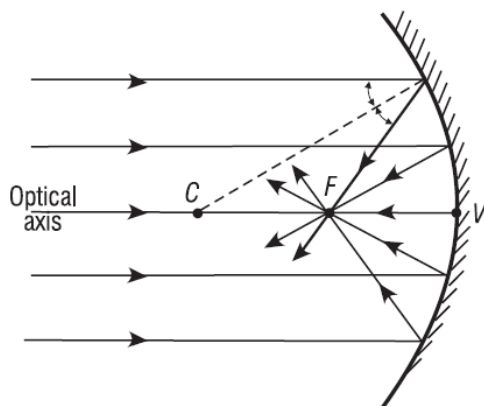


(a) Concave mirror surface

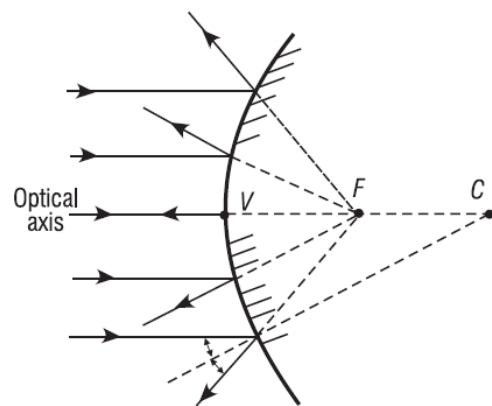


(b) Convex mirror surface

The important connection between parallel rays and the focal points for mirror surfaces is as follows,



(a) Concave mirror

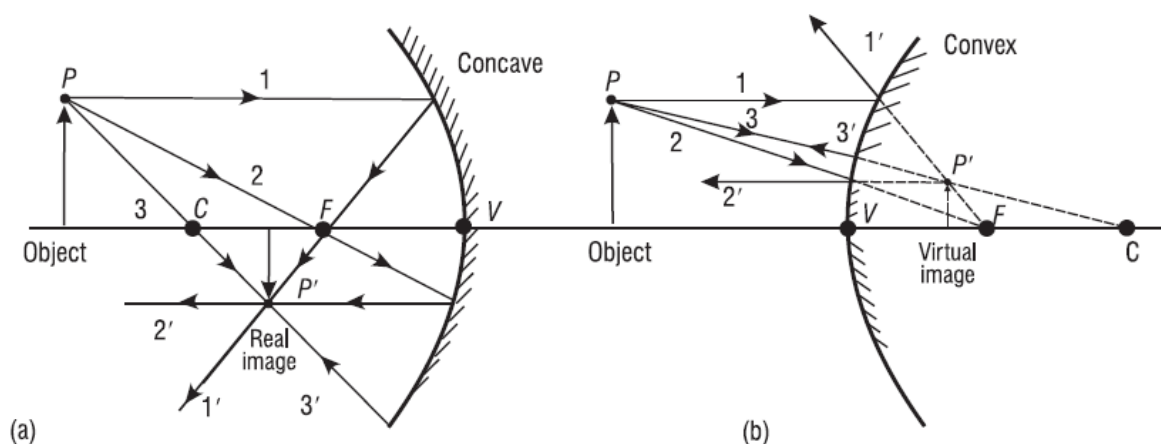


(b) Convex mirror

As long as the transverse dimension of the mirror is not too large, simple geometry shows that the focal point F , for either mirrors, is located at the midpoint between C and V , so that the distance FV is half the radius of curvature. The **distance FV** is called the **focal length**, and is commonly labelled as **f** .

2. Key rays used in ray tracing

The following figure shows **3 key rays** that are used to locate an image point corresponding to a given object point.



Any two, drawn from object tip P, will locate the corresponding image point P'. This is normally sufficient to draw the entire image.

For a concave mirror:

- Ray 1 parallel to optical axis reflects through focal point F.
- Ray 2 passing through centre of curvature C reflects through C.
- Ray 3 passing through focal point F reflects parallel to optical axis.

For a convex mirror:

- Ray 1 parallel to optical axis reflects as if to come from focal point F.
- Ray 2 headed towards centre of curvature C reflects as if to come from C.
- Ray 3 headed towards focal point F reflects parallel to optical axis.

3. Mirrors formulas for image location

In place of the graphical ray-tracing method, one can use formulas to determine image location. The following formulas are derived from algebra, geometry and trigonometry considerations.

See Khan Academy video “Derivation of the Mirror Equation”.

a. Magnification equation:

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

Where,

- m is the magnification
- h_i is the transverse size of the image
- h_o is the transverse size of the object
- d_i is the image distance (from image to mirror vertex V)
- d_o is the object distance (from object to mirror vertex V)

b. Mirror equation:

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} = \frac{2}{r}$$

Where,

- f is the focal length
- r is the radius of curvature of the mirror
- d_i is the image distance (from image to mirror vertex V)
- d_o is the object distance (from object to mirror vertex V)

c. Sign convention:

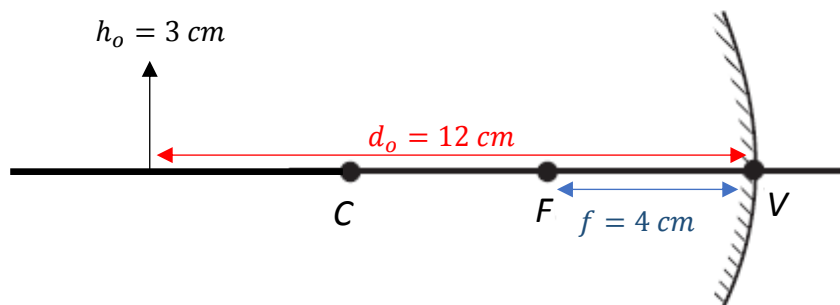
The sign convention to be used in conjunction with the mirror equation is as follows,

- Object and image distances d_o and d_i are both positive when located to the left of the vertex and both negative when located to the right.
- The radius of curvature r and focal length f are positive for concave mirror and negative for convex mirror surfaces.
- Transverse dimensions of object and image h_o and h_i are positive above optical axis and negative below.

4. Examples

In the following cases: locate the image, determine its size, and state whether it is real or virtual, erect or inverted.

i. Concave mirror:



ii. Convex mirror:

