Reflection and Image Formation by Mirrors

Purpose

a. To study the reflection of light

b. To study the formation and characteristics of images formed by different types of mirrors.

Theory

When a light (wave) travelling in one medium encounters a boundary of another medium, part of the light bounces back to the same medium, called the *Reflection* and some part of light may pass into the second medium, called the *Refraction*. In this lab, you will study reflection of light from different mirrors.

Figure 1 shows an example of reflection from a plane surface such as mirror. The incident ray makes an angle with the normal to the surface called the *angle of incidence,* θ_i. The reflected ray makes an angle with the normal to the surface called the *angle of reflection,* θ_r. The law of reflection states that the angle of reflection (θ_r) equals the angle of incidence (θ_i),

$$\theta_r = \theta_i \qquad (1)$$

The normal, incident ray and reflected ray all lie in the same plan.

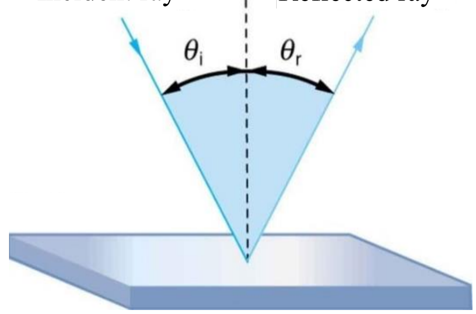
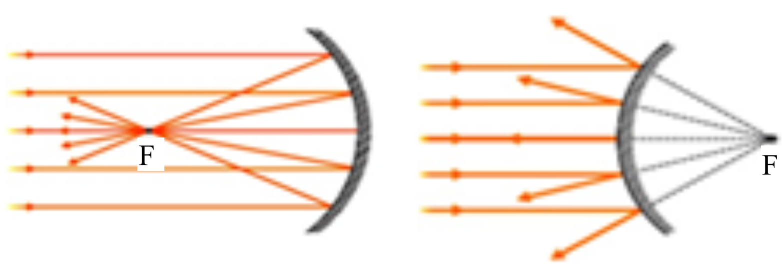


Fig. 1: Reflection of light from a mirror.

You will also study the formation of images by different mirrors. Image formed by mirrors is due to the reflection of light originated from an object. Images may be real or virtual, upright or inverted, and diminished or enlarged. We can locate and characterize the images by tracing the reflected rays. You will exercise and study the image formation by plane mirrors (Fig. 1), and spherical mirrors (concave and convex) as shown in Fig. 2. When parallel rays (could be from a distant object) incident on a concave mirror, the reflected rays converge to a focal point (F), hence also called converging mirror. In case of convex mirror, parallel rays are diverged from the mirror after reflection and appear to come from a virtual focal point (F), hence also called diverging mirror. The distance from the mirror to the focal point is called focal length (f). We can approximate the focal length in a spherical mirror to be equal to half of the radius of curvature.

$$f = \frac{r}{2} \qquad (2)$$



a. Concave (converging) mirror b. Convex (diverging) mirror

Fig. 2: Two different types of spherical mirrors.

For spherical mirrors, relation between object distance (d_o), image distance (d_i) and focal length (f) is given by mirror equation

$$\frac{1}{d_0} + \frac{1}{d_i} = \frac{1}{f} \qquad (3)$$

where d_o, d_i and f are measured from the mirror on the principal axis. The magnification of the image is given by

$$m = \frac{h_i}{h_o} = -\frac{d_i}{d_o} \qquad (4)$$

Both relations given in Eq. (2) and (3) hold for concave as well as convex mirrors. Focal length for concave mirror is taken as position and for convex lens is negative. Follow the sign convention used in your text book.

Figure 3 illustrates how images are formed by a plane mirror and curved mirrors. Consider a point 'O' on an object. The rays of light coming from the point reflect according to the laws of reflection. Out of several possible rays from the point, we need at least two rays to locate the image. For

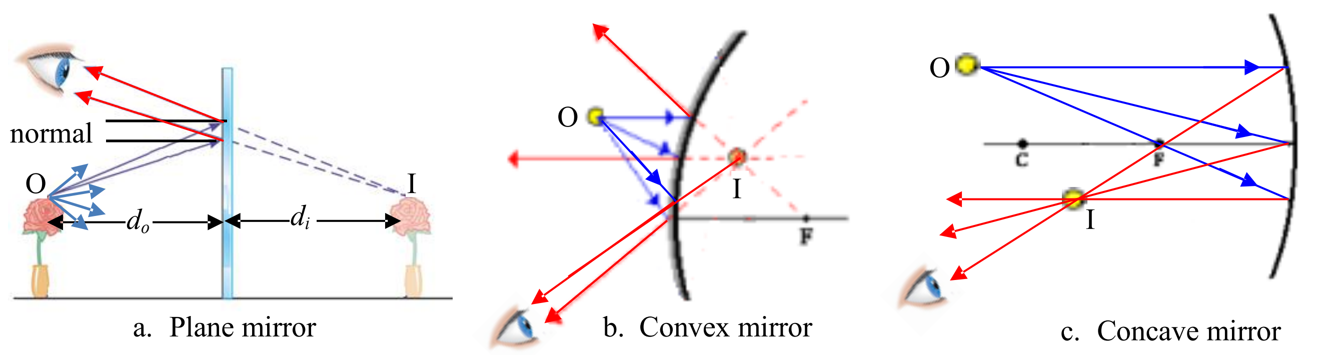


Fig. 3: Image formation by (a) plane (b) convex and (c) concave mirrors.

a plane mirror, as shown in Fig. 3a, the normals are parallel for both incident rays, so they reflect with different angles of reflection. The reflected rays upon incident on our eye see the image. Intersection of the reflected rays is the position of image. However, the reflected rays do not intersect as they are diverged. We have to back trace the reflected rays (by dotted lines) to find the intersection, I. Our eyes see as if the light is coming from the point I behind the mirror. Thus, it is a virtual image. Note the object distance (do) and image distance (di) is same in plane mirrors. For such case the magnification is 1 from Eq. (3). That's why you see your identical image on the mirror. But why does your right hand become left hand and vice versa in mirror?

For convex mirror as shown in Fig. 3b, the reflected rays are again diverged and form a virtual image at I. Note that the image distance is different from the object distance. What do you expect the magnification? For concave mirror shown in Fig. 3c, the reflected rays indeed converge at point I (no back trace needed) which is the image position. Thus, it forms a real image. The rays shown in concave mirrors are special rays – one parallel to principal axis (P ray), one passing through focus (F ray) and one reflected from the center of mirror. Depending upon the position of the object, image formed by a concave mirror could be real or virtual and could also be magnified or diminished.

Simulation tools

This part of the lab uses two online simulators:

Plane mirrors: https://ophysics.com/l9.html

Concave and convex mirrors: https://ophysics.com/l10.html

Procedure

Throughout, you must take screenshots of your work and include them in your final report, to show that you have conducted the simulations.

Part I. Plane mirror

(a) Reflection of light by a plane mirror

1. Open the plane mirror simulation at https://ophysics.com/l9.html.
2. The simulation opens with a default object which is a blue, vertical arrow. However, you can alter the length and angle of the arrow. You can also observe light rays traveling from your choice of so-called "control points".
3. Check the box at the top of the simulation marked "*Control points*". This will enable you to move the top and bottom of the object, and the 4 control points on the plane mirror.
4. Check the box at the bottom of the simulation marked "*Show Grid & Axes*". This will enable you to make measurements.
5. Move the control points for the *object* as follows:
    a. for the top of the object: (-6,2)
    b. for the bottom of the object: (-6,0).

    The object should now appear as a vertical arrow of height 2 units.
6. Move the control points on the *mirror* to the following 4 positions: (0,-3), (0,-1), (0,1) and (0.3).
7. Check the boxes marked "*Show Incident Rays*" and "*Show Reflected Rays*" and "*Show Normals*".
8. Look at the angles made by the incident and reflected rays to the normal through each control point on the mirror. What can you say about the angle of incidence (relative to the normal) and the angle of reflection (relative to the normal)?

(b) Image of a point object formed by plane mirror

1. You are now going to make a point object. Move the lower control point on the current object from the position (-6,0) to (-6,2), in other words so that both of the control points on the object are at (-6,2). All rays should now start from that point.
2. Click the box *"Show Image"* at the top of the screen and the box "*Show Virtual Rays*" at the bottom right of the screen. Where is the image located? Note its (x,y) coordinates. Is the image virtual or real?
3. Move the object so that it is a point object at each of the following locations:
    - (-6,0) ; (-6,-2). [in each case, the top and bottom control points of the object overlap]

In each case, note the (x,y) coordinates where the image is formed

(c) Image of an extended object formed by a plane mirror

1. Set the control points on the object to being different, in order to form an extended object (as in part a). Specifically, set the bottom control point on the object to (-5,0) and the top control point to (-7,2).
2. What is the location of the image? Give the (x,y) coordinates of the top and bottom of the image. Is it real or virtual?
3. The whole object can be dragged by moving it using the mouse. Does the size of the image change if the object is moved towards, or away from, the mirror? What does this tell you about our eyes' perception of images in a flat mirror?

Part II. Image formation by Curved Mirrors

For this part of the lab, you will need to open a different online simulation: https://ophysics.com/l10.html This single simulation can simulate both a concave and a convex mirror. In order to simulate a concave mirror, the object should be to the *left* of the mirror (the default, for part a). In order to a simulate a convex mirror, the object should be dragged to the right of the mirror (part b). The radius of curvature of either type of mirror can be changed by dragging the focus point.

(a) Concave mirror

1. In this simulation, the object is an extended arrow, with the bottom tied to the horizontal axis. You can make the object longer by dragging the top control point on the object, and you can move that control point right and left to move the whole object towards, and away from, the mirror. Drag the focus to (-3,0) and leave it there. This will set the focal length of the mirror to 3 units.
2. Set up an object that is *4 units in vertical height*.
3. Move the object towards, and away from, the mirror, keeping the object 4 units high. Place the object at *three horizontal locations* to the left of the focal point and two horizontal locations to the right of the focal point (but still to the left of the mirror). In each case, note:
   - The location of the image (horizontal position and height)
   - Whether the image is virtual or real *and* whether it is inverted or upright.

(b) Convex mirror

1. Now drag the 4-unit-high object to the *right* of the mirror. From the object's perspective, the mirror is now convex! Make sure that the text at the top right of the simulation says "*Convex Mirror*". Leave the focus of the mirror at the location (-3,0).
2. As in part (a), drag the object towards the mirror (to the left) and away from the mirro (to the right), keeping the object 4 units high. Record values of the following for *4 different horixontal locations of the object, to the right of the mirror:*
   - The location of the image (horizontal position and height)
   - Whether the image is virtual or real *and* whether it is inverted or upright.

Computation

Part I.

In part I, measure the object distance and image distance. Is the image located at the same distance from the mirror as the object? Calculate the ratio d_i / d_o.

Part II.

1. In Table 1, tabulate the value for the ratios d_i / d_o and h_i / h_o.
2. For all images formed by curved mirrors, calculate the focal length f from the values of d_i and d_o, using Eq. 3. Pay attention to the sign convention used for distances in concave and convex mirrors.
3. Designate the type of image formed as: real or virtual; upright or inverted; enlarged or diminished.

Questions

1. What is meant by a virtual image? Under what conditions will a concave mirror give a virtual image?

3. What kind of mirror does a dentist use when he/she wants to observe a magnified image of a tooth, and where does he locate it for this purpose?

4. In a projection lantern at least half the light from the lamp is headed in the wrong direction; where would you put a mirror and what type would you use, to return this light to the vicinity of the filament, this time headed in the right direction?

5. Approximate the focal length of a plane mirror. How do Eqs. 3 and 4 look like under this circumstance?

Data Sheet

Date online experiment performed:

Name(s) of the participant(s):

Note: Screenshots of your work, and this data sheet, must be included in the report.

Table 1. Curved mirrors

Size of object (h_o) =……………….units (boxes in the simulation grid)

Object distance (d_o) =……………….units (boxes in the simulation grid)

Focal length, as set by the user:

Concave =……………units Convex =…………….units

In the table below, all distances are in grid box units.

Mirror type	Object distance (d_o)	Image distance (d_i)	Size of Image (h_i)	$m = \frac{h_i}{h_o}$	$m = -\frac{d_i}{d_o}$	Focal length, from Eq. 3	Nature of image*
Concave (7 trials)							
Convex (4 trials)							

* real or virtual; upright or inverted; enlarged or diminished
e.g. "a real, upright, enlarged image".