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 light (wave) travelling in one medium encounters a boundary of another medium, part of the light bounce 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.

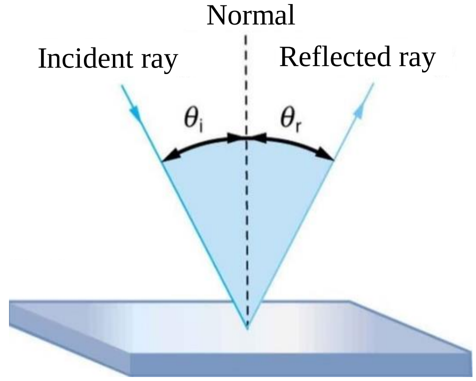
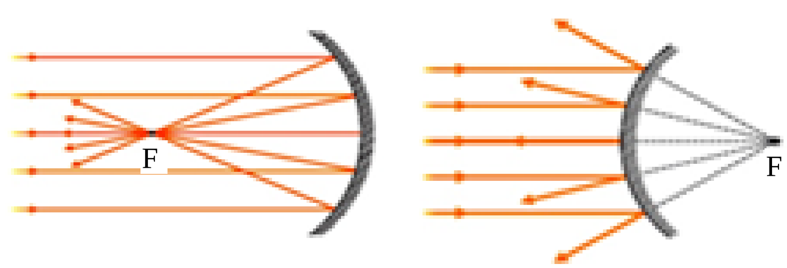


Fig. 1: Reflection of light from a mirror.

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

$$\frac{1}{d_o}+\frac{1}{d_i}=\frac{1}{f} \tag{3}$$

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

$$m=\frac{h_i}{h_o}=-\frac{d_i}{d_o} \tag{4}$$

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

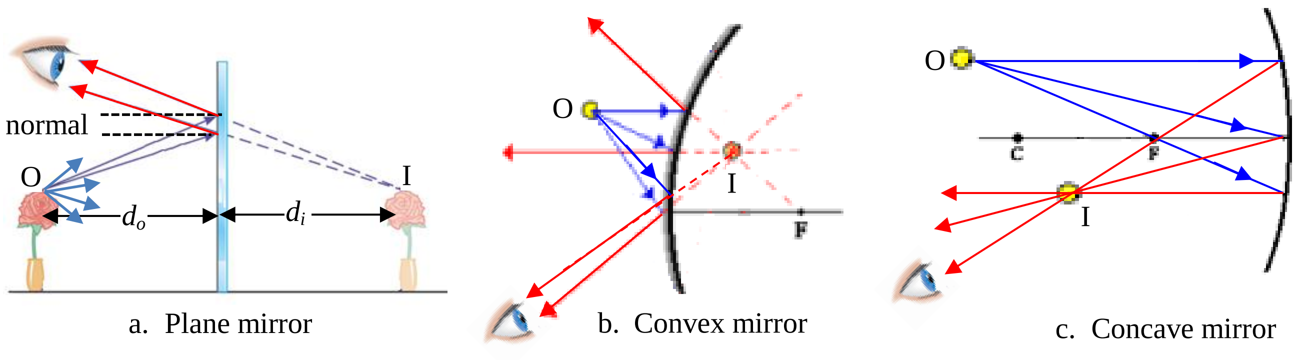


Fig. 3: Image formation by (a) plane (b) convex and (c) concave mirrors.

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.

Apparatus

Plane mirror with holder, pair of compasses, concave-convex cylindrical mirror, scale, protractor, pins, pin board, paper, laser light.

Description of Apparatus

Safety precautions

**** Do not look directly into laser beam ****

*** Do not shine the laser light at your lab partners and take special care to avoid the eyes ***

** Turn off the laser when not in use **

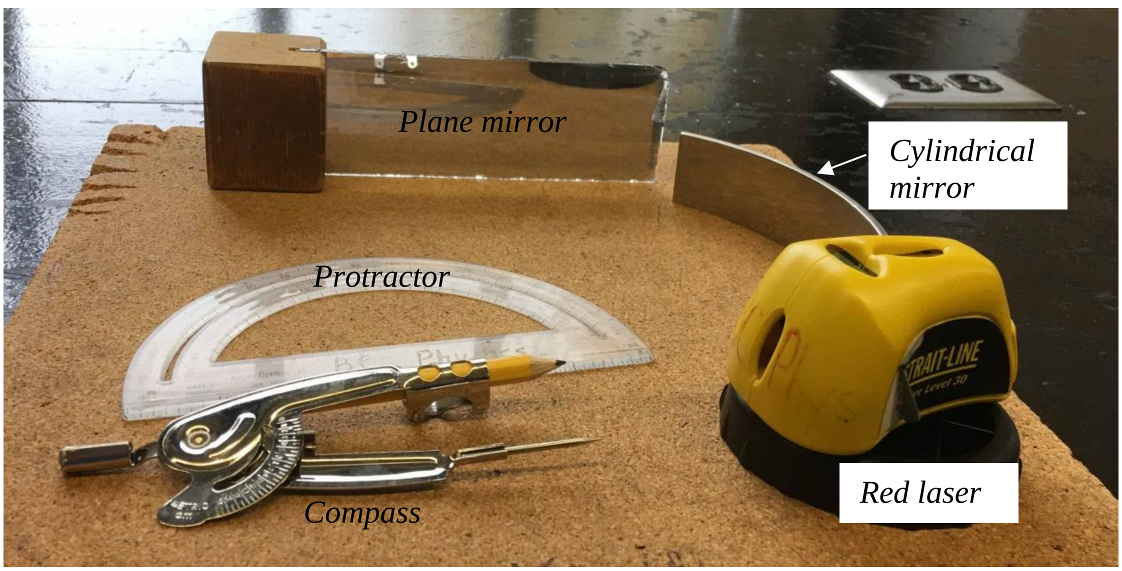


Fig. 4: Apparatus for this lab

Apparatus used in this lab are shown in figure 4. The beam of a laser is used to trace the direction of light. Plane mirror is a simple glass mirror. Concave-convex cylindrical mirror is made by metal and it has reflecting surface on both sides. So we can use it for concave or convex purpose.

Procedure

In this exercise and all through your work in optics, represent the actual path of all rays of light by solid lines and represent virtual rays (prolongations of actual ray paths) by broken lines. Optical surfaces should be represented by heavy solid lines.

Prepare a pencil as sharp as possible. The successfulness of this lab strongly depends on the sharpness of your pencil and your carefulness when you mark dots or draw lines with your pencil.

Part I. Plan mirror

(a) Reflection of light by plane mirror

1. Place a sheet of paper on the cork board, and draw a straight line near the top of the paper. This is the "mirror line". Set up the plane mirror in its holder on the mirror line so that the actual mirror surface is on the line. Adjust the mirror carefully so that the mirror is parallel to line.
2. **Place the laser on the bench table, not on the cork board.** Turn on the laser and shoot the beam to the mirror with an arbitrary angle. You should see the reflected beam. Mark **two dots** about 10 cm apart on the paper along the path of the **incident beam**. You may label both points by 1. Similarly, mark **two dots** on the reflected beam. You may label these points by 1'.
3. Repeat the previous step with the laser beam shooting at another point on the mirror and another arbitrary angle. You may label 2s for this second trial. **TURN OFF the laser.**
4. Now, remove the mirror and draw straight lines joining the dots of the same label up to mirror line and mark arrows to show the incident and the reflected beam for both trials. *Do the two reflected and incident beams converge on the mirror line?*

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

1. Flip the sheet of paper for this part (or use a new sheet) and mark the mirror line across the center of a sheet and place the plane mirror on the line as before. Mark a point 'O' about 10 cm in front of the mirror roughly in the center of space. This point will serve as a point object. *Can you see the image of the point in the mirror?*
2. Now, shoot the laser beam to one half side of the mirror **through the point O** as shown in Fig. 5 and mark two points (one near the mirror and another about 10 cm apart) on the path of the **reflected beam**. You may label them as (1) and (1).
3. Remove the laser beam and shoot the laser beam to anther half side of the mirror **through the point O** again. As before, mark two points on the path of the reflected beam. You may label them as (2) and (2). **Turn off the laser.**
4. Now, remove the mirror. Draw the reflected rays joining these points, i. e., (1) and (1), and (2) and (2) all the way up to the mirror line and mark arrow on each. **Back trace the two paths of the reflected beam with dotted lines** in the area behind the mirror line until they intersect at a point, I. The point I is the image of the point object O formed by the mirror. Draw a dotted line connecting the point O and I. Measure the angle between the mirror line and the line O-I. *What should this angle be?* If your result is more than 10 degrees away from the expected value, repeat the procedure!

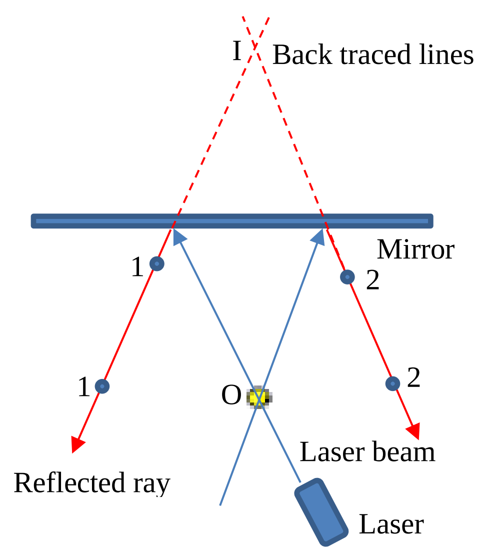


Fig. 5. Laser beam for tracing rays.

(c) Image of a line formed by a plane mirror

1. Use a new sheet of paper. Randomly draw a 5 cm long straight line O-O' (not parallel to the mirror) about 10 cm in front of the mirror. O and O' are extreme points of the line.
2. To find the image of point O, repeat steps b2 – b3 using point O as an object.
3. Now, to find the image of point O', repeat steps b2 – b3 using point O' as an object.
4. Remove the mirror and determine the corresponding image points I and I' for object points O and O' as you did in step b4. Draw a line by connecting the points I and I'. This line is the image of the line O-O' in front of the mirror. *Is this image virtual or real?*

Part II. Image formation by Curved Mirrors

(a) Concave cylindrical mirror

1. On another sheet draw curved mirror line of the ***concave*** cylindrical mirror (not the convex side) near the top of the paper. Mark the center point P on the curved mirror line and determine the center of curvature for this mirror. You may use one of the following methods.

   Method 1: Using a compass draw a chord of radius about 5 cm from the point P to intersect at two points on the curved mirror line. From these two intersection points, draw two perpendicular bisectors by drawing chords on the concave mirror line and locate their point of intersection. The intersection point is the center of curvature. Draw a line joining the point P and the center of curvature. This line is the **principal axis.**

   Method 2: Put back the curved mirror to exactly same location. Shoot the laser beam to point P. Adjust the beam so that it reflects back from the point P along the same line of incident beam. Check again if the beam is reflecting from point P, if not adjust again. Mark a dot on the sheet far away from the mirror and along the laser beam. Now, shoot the laser beam away from point P and adjust the beam so the reflected beam coincides along the same line of incident beam. **Mark two dots** on the sheet (at least 5 cm apart) along the laser beam. Now, remove the mirror and draw a line joining the point P and the first dot point. This line is the **principal axis**. Draw another line connecting last two dot points. Intersection of these two lines is the center of curvature.

2. Measure the radius of curvature (r) of the mirror and record the value in data sheet. On the paper, mark a point halfway between the pole and the center of curvature. The point so marked is the principal focus, F.
3. At a point on the principal axis 16 cm from the pole, draw a line 1.5 cm long perpendicular to the principal axis starting from the axis. Mark the end points of this line O and O', and put an arrowhead at the outer end of the line, O. This line will represent the object. The object distance, d_o, is thus 16 cm. The size of the object, h_o = 1.5 cm.
4. Make sure the mirror is exactly along the curved mirror line. Now shoot the laser beam to determine the image position of the line object O-O' as in the procedure of part I(c). [If it helps to align the laser beam, you may put a pin at the point O (and O') while doing this step.] Mark the image line I-I' and mark an arrowhead on the image. Measure the size of the image, h_i, and the image distance d_i. Record in data sheet.

5. **Ray diagram to construct image:** You are **not to** use laser in this step. In the area of empty region on the sheet, draw again the curved mirror line near the top of another sheet of paper and locate the center of curvature and draw the principal axis. Same as before, construct an object 1.5 cm long at a distance of 16 cm from the mirror. Now, locate the image by *ray diagram*, not by using laser beam. You may draw P ray, F ray and C ray to construct the ray diagram. Measure the image size, h_i, and image distance d_i. Record your measurements in data sheet.

(b) Convex cylindrical mirror

1. On another sheet, near the center, draw the mirror line of the convex cylindrical mirror. Locate its center of curvature by construction and draw the principal axis. Indicate the focus. Again making h_o = 1.5 cm and d_o = 16 cm, determine by both methods, laser beam and ray diagram, the image size and distance in the case of the convex mirror. Two separate diagrams will be needed.

(c) Observation of images by spherical mirrors

There are two spherical mirrors in the lab. In this part, merely notice the changes in the image as an object is moved away from the surface of the spherical concave or convex mirrors. You may observe your image by moving from a far point to closer to the mirrors. These qualitative observations should be recorded in your discussion.

Computation

Part I.

Show all these computed results on the same sheet of paper used in the lab and include them in your report.

(a) For both trials in sheet 1, draw the normals at the points where reflections occur.
Measure the angle of incidence and the angle of reflection using a protractor and compare them.
Are these two angles equal?

(b) 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.

(c) Measure the lengths of the line I-I’ and compare to the length of O-O’. *Is the image length magnified, same or reduced?* Calculate the ratio d_i/d_o and calculate the ratio h_i/h_o compare them.

Measure the angle between O-O' and the mirror line.
Measure the angle between I-I' and the mirror line. Compare the two angles.

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 Eq. 4. Pay attention on the sign convention used for distances in concave and convex mirrors.

   Designate the type of image formed as: real or virtual; erect 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. As one approaches a concave mirror from a large distance, his image may vanish from his sight. For this effect to be most complete, where should the image be (a) at infinity? (b) at the mirror's principal focus? (c) on his eyeball?

   At that moment, where should the observer be?
6. Approximate the focal length of a plane mirror. How do the Eqs. 3 and 4 look like under this circumstance?

Data Sheet

Date experiment performed:

Name of the group members:

Note: Your ray tracing sheets are part of the data sheet and must be included in the report.

Table 1. Curved mirrors

Size of object (h_o) =……………….cm

Object distance (d_o) =……………….cm

Radius of curvature (r):

Concave =……………cm Convex =…………….cm

Mirror type	Method	Image distance (d_i) cm	Size of Image (h_i) cm	$m = \frac{h_i}{h_o}$	$m = -\frac{d_i}{d_o}$	f (cm)	Nature of image
Concave	Laser beam						
	Ray diagram						
Convex	Laser beam						
	Ray diagram						