PHYSICS 171

UNIVERSITY PHYSICS LAB II

Experiment 10

Geometrical Optics: Reflection of Light

Equipment

Track, Spinning wheel, light source, 3 mirrored triangle piece, concave spherical mirror, half circle viewing screen.

Introduction

The purpose of this activity is to experimentally confirm the Law of Reflection, for flat, concave, and convex mirrors. The Basic Optics Light Source is used to produce a single beam of light. The Ray Optics Kit includes all mirrors that will be used.

Theory

The Law of Reflection

When a ray of light strikes a plane mirror, the light ray reflects off the mirror and changes its direction of travel. By convention, the direction of a light ray is expressed as the angle the light ray makes with a line normal (perpendicular) to the surface, as illustrated.
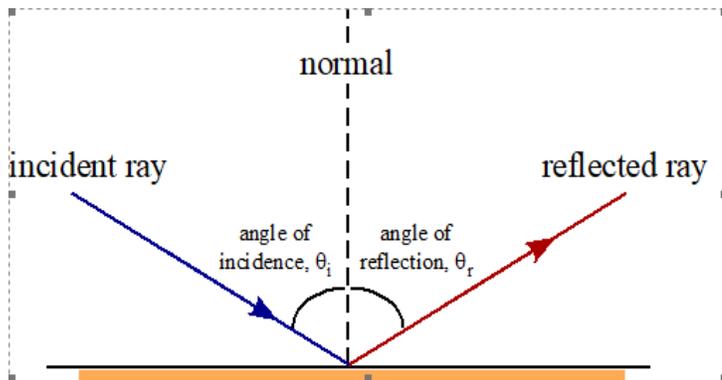
The angle of incidence is the angle between the normal and the incident ray; the angle of reflection is the angle between the normal and the reflected ray. The law of reflection states that the angle of incidence equals the angle of reflection:

$$\theta_i = \theta_r \tag{1}$$

Spherical Mirror Reflection

Light rays reflecting from a mirrored surface obey the Law of Reflection: the incident angle θ_i of a reflected light ray is equal to the reflected angle θ_r, where both angles are measured relative to a line normal to the reflecting surface.

$$\theta_i = \theta_r \tag{2}$$

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In the case of a concave spherical mirror, the surface of the mirror is curved in the shape of a section of a sphere with radius R.
(R is also known as the mirror's *radius of curvature*). Because of this curvature, light rays incident on a concave mirror, parallel to its optical axis, have incident angles that increase as the distance between the optical axis and the light ray increases. These varying incident angles cause the parallel light rays to reflect from the mirror and converge to one point F along the optical axis known as the *focal point*. The distance f from the mirror's surface to the focal point is known as the *focal length* and is equal to half of the mirror's radius of curvature:
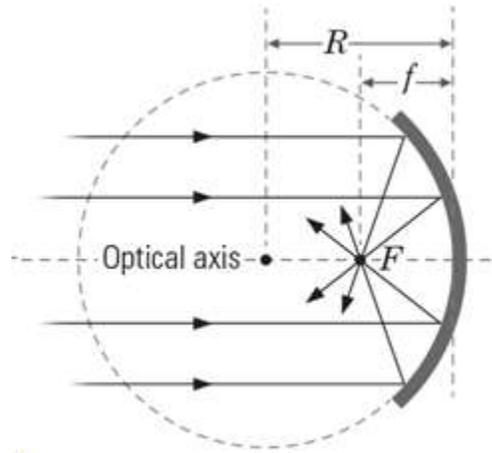
$$f = \frac{R}{2}$$ (3)

If an object is introduced in front of a concave spherical mirror along its optical axis, beyond the mirror's focal length, an image of that object will form in front of the mirror. This image is said to be a *real image* because it forms where light rays converge onto a viewing screen. Images that are formed by diverging light rays (images that cannot be formed on a viewing screen) are said to be *virtual images*.
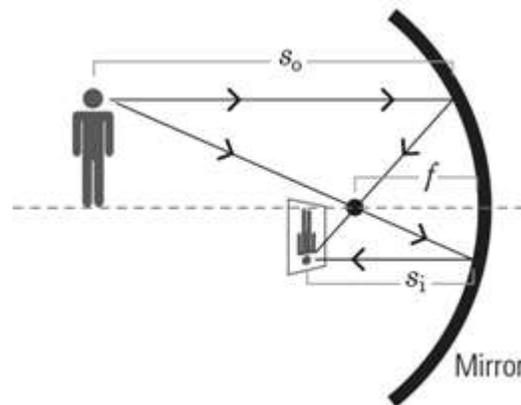
The following spherical mirror equation defines the position of the real image formed by a spherical mirror:

$$\frac{1}{f} = \frac{1}{s_o} + \frac{1}{s_i}$$ (4)

where f is the mirror focal length, s_o is the distance from the mirror to an object (*object distance*), and s_i is the distance from the mirror to the point at which the image of the object is in focus (*image distance*). Using the variables in this equation, you will perform an investigation to experimentally determine the radius of curvature of a concave spherical mirror.

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PROCEDURE A-C: Bouncing Light Off a Flat, Concave and Convex Mirrors

- *Note: **For this and all other activities it may be necessary to darken the room to see the light rays better.***

1. Place the three-way mirror on the spinning wheel. Start with the flat edge and place it flush with the marked line.

2. Place the light source on the table and line up the single light slit with the perpendicular line to the mirror.

3. Turn the wheel 45° and take data of reflected angle.

4. Repeat for an incident ray of incident angle larger than 45°.

- Make sure you always shine the light to the same point on the mirror.

5. Repeat for an incident ray of incident angle less than 45°.

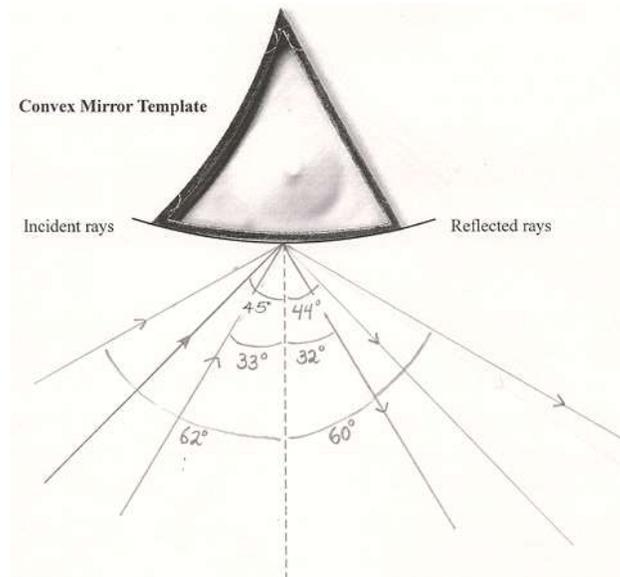**6.** Summarize your measurement in a data table.
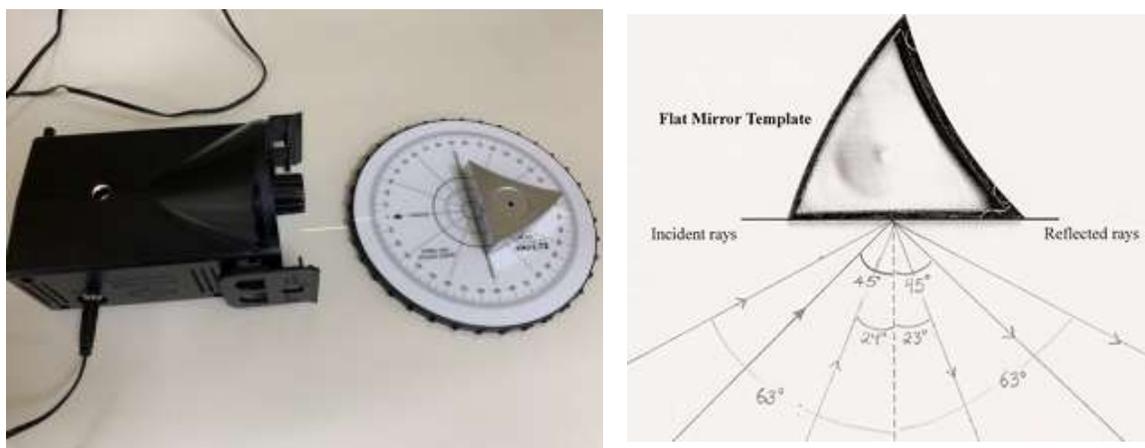
Figure 1. Experiment with a flat mirror

7. Repeat the measurements using a concave mirror (see Figure 2). Summarize the results in a data table.

8. Repeat the measurements using a convex mirror (see Figure 3). Summarize the results in a data table.
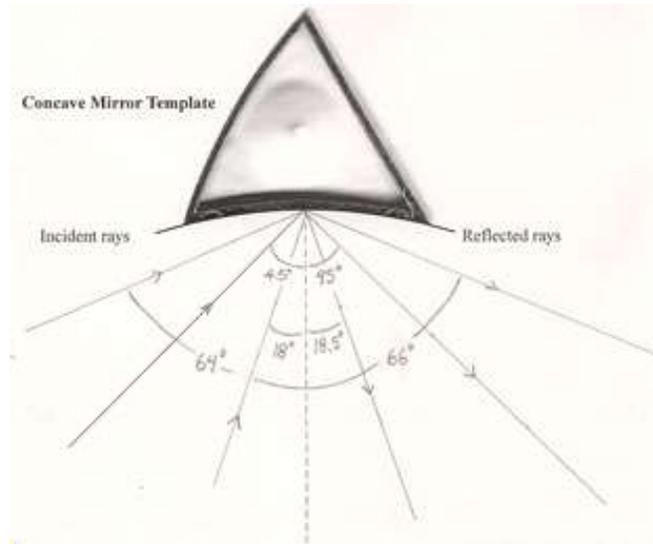
Figure 2. Experiment with a concave mirror

**Figure 3. Experiment with a convex mirror**

PROCEDURE D: Spherical Mirror

9. Lay the optics track flat on your lab table and mount the light source to it so that the "screen zero" (see the bottom of the light source for the screen zero indicator) is aligned

with the 0-cm mark on the track. Make sure the crossed-arrow image on the light source points down the length of the track.

10. Mount the mirror to the track at the 23-cm mark with the concave surface of the mirror facing the light source.

11. Mount the half circle viewing screen to the track at some point between the light source and the mirror.

12. Plug in the light source to turn it on.

13. Slide the viewing screen up and down the optics track between the mirror and the light source until the image of the crossed-arrow target is in focus on the half-screen.

    a. NOTE: Depending on your setup, you may not see the entire image on the viewing screen. Also, the image may not be in perfect focus; however, the *image location* is where the image is most focused. You may need to slide the screen back and forth through the image location until you can determine where the image is the most sharply focused.
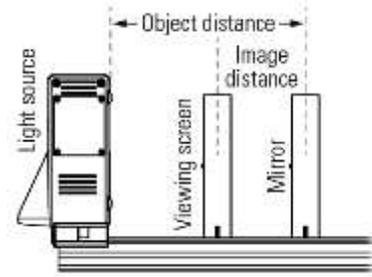
14. Using the graduated scale on the optics track, determine the object distance s_o and the image distance s_i. Record these values in Table 1 in the Data Analysis section below.

15. Slide the mirror 3 cm farther from the light source. (Do not change the light source position.)

16. Slide the viewing screen up and down the optics track between the mirror and the light source until the image of the crossed-arrow target is again in focus on the screen.

17. Record the new object distance and image distance next to Trial 2 in Table 1.

18. Repeat the data collection steps four more times (5 data points in all), increasing the distance between the mirror and the light source by 3 cm in each trial. Record the object distance and corresponding image distance for each trial into Table 1.

Figure 4. Experiment with a spherical mirror

DATA PROCEDURE A:
Bouncing Light Off a Flat Mirror

FLAT MIRROR

Angle of Incidence θ_i	Angle of Reflection θ_r
45°	

DATA PROCEDURE B:
Bouncing Light Off a Concave Mirror

CONCAVE MIRROR

Angle of Incidence θ_i	Angle of Reflection θ_r
45°	

DATA PROCEDURE C:
Bouncing Light Off a Convex Mirror

CONVEX MIRROR

Angle of Incidence θ_i	Angle of Reflection θ_r
45°	

DATA PROCEDURE D:

Spherical Mirror Reflection

Table 1: Object distance and corresponding image distance using a concave spherical mirror

Trial	Object Distance s_o (m)	Image Distance s_i (m)	$1/s_o$ (m^{-1})	$1/s_i$ (m^{-1})
1				
2				
3				
4				
5				

1. Calculate the inverse of each object distance and image distance in Table 1. Record your results in the $1/s_o$ and $1/s_i$ columns of Table 1.
2. Plot a graph of $1/s_o$ versus $1/s_i$ in graph 1. You can use a graphing software or by hand using graph below. Be sure to label both axes with the correct scale and units.
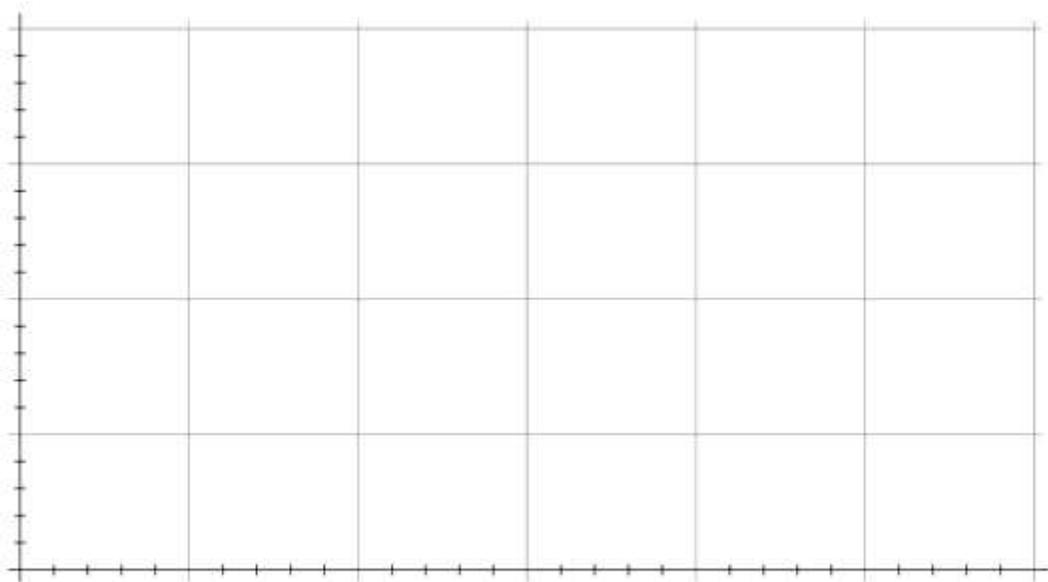
3. Draw a line of best fit through your data in Graph 1 above. You may also use graph paper and attach it to the Lab report. Determine and record the equation of the line here:

   Best fit line
   equation: _____

4. Use the *y*-intercept from the best fit line to determine an experimental value for the radius of curvature *R* of your mirror:

$$y\text{-intercept} = \frac{2}{R}$$

Radius of Curvature *R*
(m): _____

QUESTIONS PROCEDURES A, B, C: Bouncing Light off Mirrors

1. According to the Law of Reflection, the incident angle and the reflection angle must be the same. Discuss: How well does your experiment show this? Does it matter whether the reflective surface is flat or curved? Why?

QUESTIONS PROCEDURES D: Spherical Mirror

2. What is your experimental value for the radius of curvature *R* of your mirror, and how did you determine this value from your data?

3. What are factors that might have caused error in your measured value for radius of curvature? Explain how each factor you list could be avoided or minimized.

4. Ask your instructor for the actual value of the radius of curvature of your mirror, and then calculate the percent error between your experimental value and the actual value.

$$\text{Percent error} = \left| \frac{\text{Actual} - \text{Experimental}}{\text{Actual}} \right| \times 100$$

5. What do you predict happens to the image distance from a concave spherical mirror as the object distance grows very large (much larger than the image distance)? Justify your answer: use mathematical reasoning or data from your experiment, or both, to support your answer.