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Date(YY/MM/DD) ____/____/____
Section _____ Group # _____

UNIT 29: REFLECTION AND MIRRORS



"There is no light. The Sun sucks dark. In fact it sucks dark so hard that the friction of the dark moving to the Sun causes the Sun to be very hot. The flow of dark towards the Sun interrupted by the Earth causes the side of the Earth away from the Sun to accumulate dark, thus causing Night. As the Earth rotates the dark caught on the night side can then be pulled off, this causing the absence of dark known as Day.

What we call light bulbs are truly dark suckers as well. That is why light bulbs are hot, just like the Sun. When a light bulb is full of dark and won't suck dark any more, it cools off. If you look in old light bulbs you can even see the accumulation of dark. Dark is also heavier than water. This can be seen in the oceans where the deeper you go the darker it gets." — The eric conspiracy.

OBJECTIVES

1. To study the law of reflection.
2. Use ray tracing to locate virtual images formed by mirrors.
3. Measure magnification and focal length of a cylindrical mirror.
4. Form an image using a concave mirror and measure its magnification.

OVERVIEW

Many useful properties of light can be understood with a simple ray theory. In these experiments you will be observing light as it travels through air of uniform density. In this case light propagates in a straight line from its source. One can use a slit plate to select “rays” of light coming from a point source. These rays can be traced back to their origin where they cross at their source.

If light encounters a shiny surface it undergoes specular reflection. Rays reflect from mirrors according to the law of reflection: the angle of incidence equals the angle of reflection where the angle is measured from the normal to the reflecting surface. The rays reflected from a plane or convex mirror will not cross, but if one extends them back in a straight line to the other side of the mirror, these extensions will cross at a point called the virtual image of the source. The virtual image is at the position from where the light appears to come. In these experiments we emphasize point sources because any object can be considered as a collection of point sources. Therefore, the virtual image of any object can be understood as a collection of virtual images of point light sources.

SESSION ONE: RAY TRACING AND REFLECTION

This section allows you to investigate the properties of light by observation. The exercises below require you to stick pins in a board. The pins should always be carefully placed so that they are vertical.

For this activity you will need:

- push pins
- a piece of 8.5" x 11" foamboard
- a small plane mirror with magnet strip on back
- an Optics kit stand
- 2 sheets of plain 8.5" x 11" paper

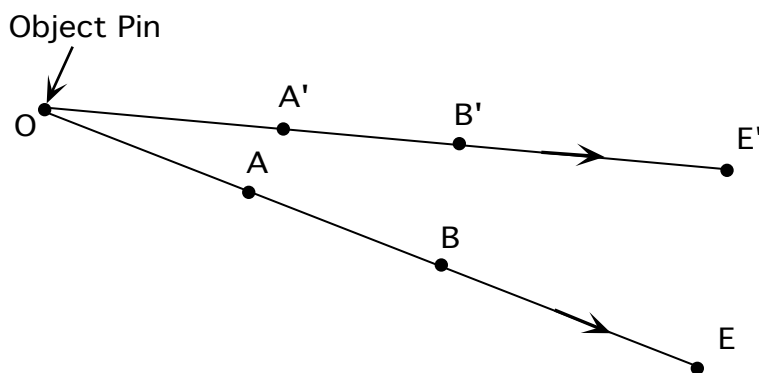


Figure 29.1: Tracing rays.

Activity 29-1: Tracing Light Rays on Paper

(a) Let's first do some ray tracing. Tack a piece of paper on your board and place a pin on the paper. As you look at the pin, light rays are coming from the pin to your eye. If you place something between the pin and your eye, you will block the light from the first pin. You can trace a ray of light by putting pins along its path as shown in Figure 29.1. Call the pin that is the source of the ray the object pin O. If you look at the object pin with your eye at point E (on the surface of the board), then a pin placed at point A will block your view of the object pin. Likewise, a pin placed at point B will block your view of pin A. If you now draw a line through points A and B, you will have the path of the ray from the object pin and your eye. Now move your eye to point E', then locate points A' and B' that define the ray in that direction. By moving your eye all the way around the pin, you could trace a series of rays that come from the object pin. Because you can see the pin from all directions, that is evidence that rays are coming from the pin in all directions.

(b) *Sketch* below the pattern of rays you would get if you moved your eye 360° around the pin in steps of 30°. Put arrows on the rays for the direction of the rays (from the object pin to your eye). This

pattern is very important to understand: an object sends rays out radially.

(b) Now tack a new piece of paper on your board and place a mirror and an object pin O on the paper as shown in Figure 29.2 below. Draw a line on the paper along the front of the mirror. Be sure to keep the mirror located on that line; if it moves during the time you are tracing rays, put it back and check your previous rays.

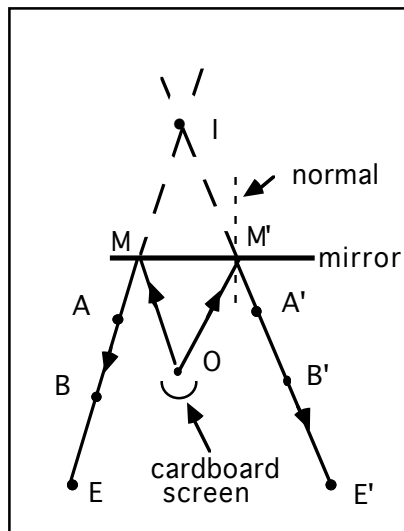


Figure 29.2: Tracing a reflection.

(c) Look at the reflection of the pin in the mirror from point E (E for eye!). Trace the rays that come to your eye by placing pins along the ray as follows: Place one pin (A) near the mirror so that it blocks the *image* of the pin (in the mirror). Then, without moving your eye, place the other pin (B) in front of pin A so that it blocks pin A (and the *image* of pin O). Pin B should be placed some distance from pin A so that you can draw an accurate line.

(d) Repeat for another observation point E'. Be sure to label the rays so you know from which pin they come.

(e) Remove the mirror and the pins and trace the rays to the mirror location and then extend the line behind the mirror location until the extrapolated rays meet. The point behind the mirror where the extrapolated rays meet is called the image point I. If you traced rays from the pin to your eye at many different positions, they would all appear to come from the image point I. Note that the rays that you see do not actually come from this image point, they only appear to come from the image point. Therefore, this is called a **virtual image**.

(f) Draw lines from the object pin (O) to M and M' (labelled in Figure 29.2). These lines represent the rays that actually go from O to M and M', the points where the rays you traced in (e) pass through the mirror line. Draw a line perpendicular to the mirror line at these two points. This line is called a normal line (meaning perpendicular; not that it is not abnormal!).

(g) Measure the angles the incoming rays along OM and OM' make with the normal lines using a protractor. Now measure the angles the outgoing rays along ME and M'E' make. Record the values below. Do you see any relationship between incoming angle and outgoing angle of reflection? If so, explain what it is.

(Note: One lab partner should attach both sheets of paper from this activity to their Activity Guide when it is handed in.)

For the following activities you will need:

- Optics Kit
- 11" x 17" piece of plain paper

The equipment we'll be using for the next few activities is shown in Figure 29.3. You may leave off the viewing screen at first. Plug in the light source and turn it on. The bulb has a linear filament running vertically.

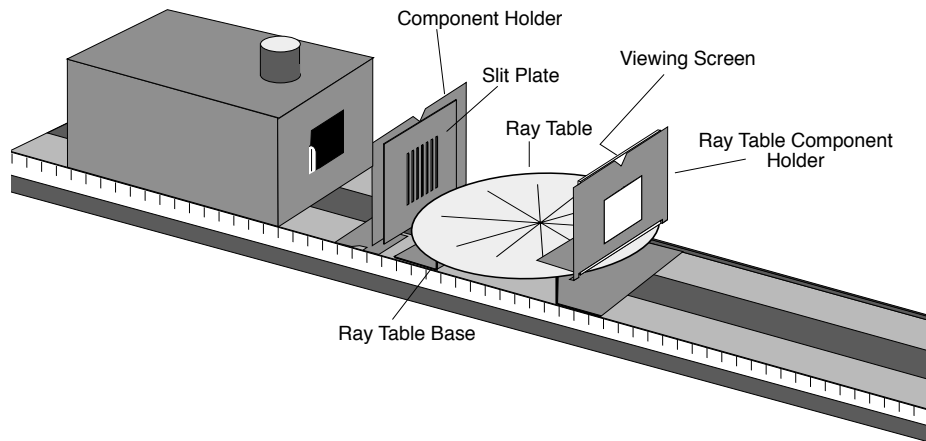


Figure 29.3: Basic Ray Optics Set-up.

🔪 Activity 29-2: Preliminary Observations on Straight-Line Propagation

(a) Observe the rays that emerge from the slit plate. Look at the rays on the ray table then lower your head and peer along a ray. Are you sure that the rays do not bend as they pass through the slits? Sketch the rays you see below.

(b) Vary the distance between the slit plate and the light source and note how the width, brightness and sharpness of the rays change. Observe how the distinctness and the direction of the rays change as you rotate the slit plate so that the slits are not parallel with the light bulb's filament. Summarize your findings below.

Activity 29-3: Locating the Filament

(a) Fold a piece of 11x17 inch paper in half to make an 8.5x11 inch sheet. Tape the paper on the ray table with the fold facing the filament and directly above the ray table base. Turn on the light and trace four rays that cross the paper.

Hint: If the rays are wide, it may be better to trace the edge of the rays. You may mark two points of each ray before removing the paper. Choose points which are widely separated for greater accuracy.

(b) Remove the paper and unfold it. Use a clear plastic ruler to trace the rays back to the source. Mark every point where two rays cross. Find the average distance between the ray table edge to the filament by means of the ray-crossing points you located. Estimate the uncertainty of this average.

Hint: How many crossing points should there be? If two points coincide, include that distance twice in the average. As you measure more and more points, your accuracy increases even though the points may get more scattered.

(c) Measure the distance between the light filament and ray table edge using the optics bench scale. Compare this distance with your ray tracing result. (**Note:** One lab partner should attach the sheet of paper to their Activity Guide when it is handed in.)

The Law of Reflection

The Law of Reflection says that the angle of incidence of a light ray equals the angle of reflection where the angle is measured from the normal to the reflecting surface.

To study this law we will set up the equipment as shown in Figures 29.4 and 29.5. Adjust the components so that a single ray of light is aligned with the bold arrow labelled “Normal” on the ray table degree scale. Carefully align the flat reflecting surface of the ray optics mirror with the bold line labelled “Component”. With the mirror properly aligned the bold arrow on the ray table is normal (at right angles) to the plane of the reflecting surface. Turn on the light and make sure that you can see the incident ray and reflected ray on the ray table as you rotate it.

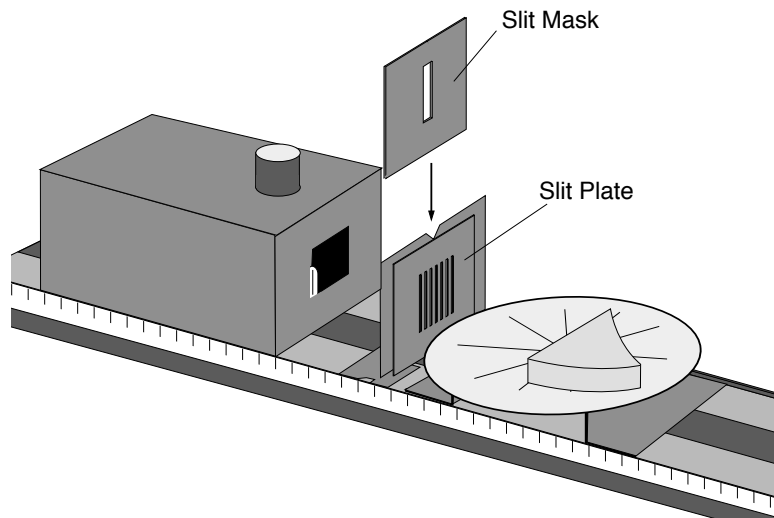


Figure 29.4: Set-up for measuring the law of reflection.

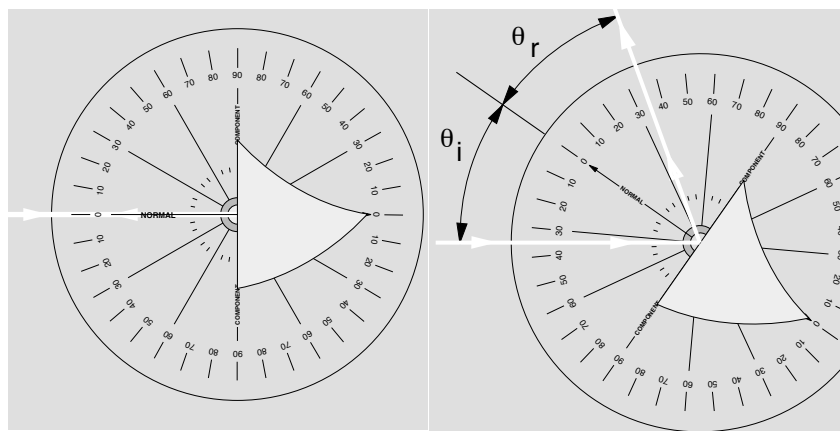


Figure 29.5: Alignment of the Ray Mirror for normal incidence and for incidence at an arbitrary angle

Activity 29-4: Measuring the Law of Reflection

(a) Choose about six different angles ranging from 0° through 90° . Rotate the ray table to each of these incidence angles (θ_i) and measure the corresponding angle of reflection (θ_r1). Repeat your measurements with the incident ray coming from the opposite side of the normal (θ_r2). Record your results in tabular form in the space below.

(b) Are your results consistent with the law of reflection? Are the results from the two trials the same? If not why not?

(c) Part of the law of reflection states that the incident ray, the reflected ray and the normal to the reflecting surface lie in the same plane. Is this adequately tested by this experiment? Explain.

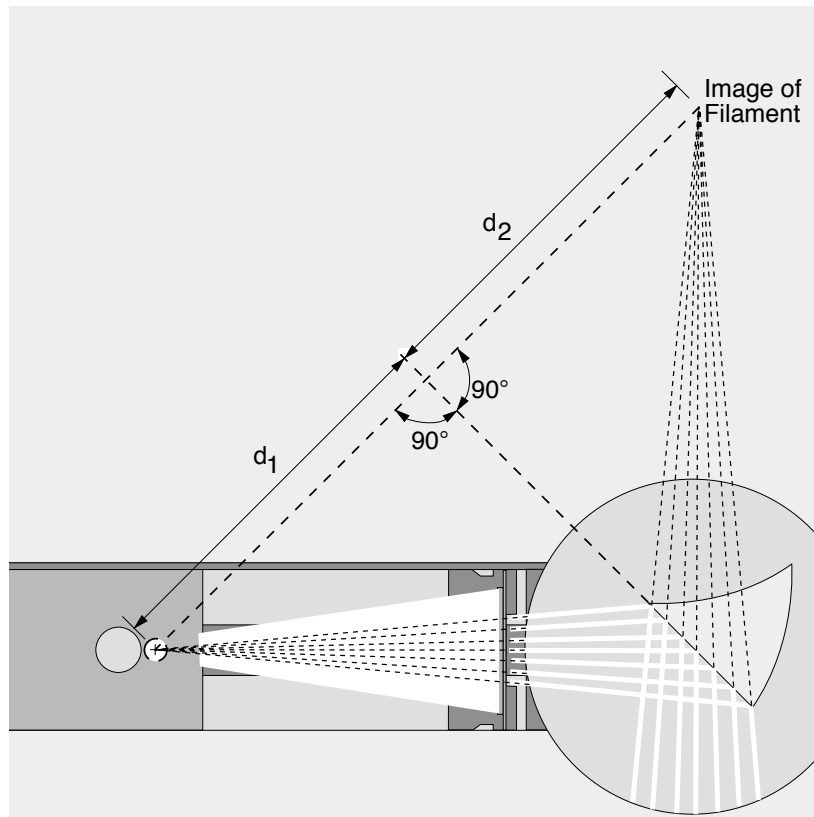


Figure 29.6: Finding a virtual image.

✎ Activity 29-5: Using Ray Tracing to Locate the Virtual Image

(a) Using the diagram in Figure 29.6 as a guide locate the location of the virtual image of the light filament. Record your result below. Also describe what you did and what measurements you made in the space below.

(b) Does the location you determined for the virtual image make sense given what you learned in Activity 29-1? Why or why not?

SESSION TWO: CONCAVE MIRRORS**The Focal Length of a Concave Mirror**

The image formed by a plane mirror is always virtual. A concave mirror can form either a real image or a virtual image. A real image occurs if the rays come from a distant source. If the source is closer than one focal length from the mirror, then a virtual image is formed. If the source is exactly at the mirror's focal point, the rays emerge parallel from the mirror. This is the principle used in flashlights, headlights and spotlights to produce a parallel beam of light.

Ideally, concave mirrors have a paraboloidal shape. Spherical shapes are cheaper to manufacture than paraboloids and most inexpensive concave mirrors are spherical. For most applications the loss in quality is insignificant, particularly where the mirror's f -number (focal length/diameter) is large. In the following exercise you will use the cylindrical ray optics mirror to visualize its image-forming properties and find the mirror's focal length by producing a parallel beam of rays.

For the following activities you will need:

- Optics Kit

***🔗* Activity 29-6: Introduction to Concave Mirrors**

(a) Place the slit plate about 7 cm from the light source and place the parallel ray lens on the other side of the same stand. Use the ray table surface with a centimetre grid and turn it so that the grid is aligned with the optical bench axis. Place the ray optics mirror on the ray table, turn on the light and observe the rays reflected from the concave surface. When the mirror is at the far end of the table you should see the reflected rays converging at the position of the real image. Sketch what you see in the space below.

(b) Turn the mirror so that the image position is off the optical axis of the bench. What happens to the convergence of the rays? Draw a quick sketch below. This effect is known as spherical aberration when it occurs in spherical mirrors.

(c) Now remove the parallel wave lens and put the slit plate on the front of the light source. Also slide up the ray table so its edge touches the source. Slide the mirror closer to the light source until the reflected rays diverge. The rays don't actually cross now, but their projections on the dark side of the mirror will cross at the position of the virtual image. Move the mirror back until the emerging rays are parallel. Measure the distance between the light source and the mirror. Record this value. Remove the mirror from the table and have another group member repeat this measurement to get a second independent value. This distance is known as the focal length (f). How do your two values compare? Do they agree?

Forming an Image with a Concave Mirror

The law of reflection implies that the virtual image formed by a plane mirror will be at the same distance from the mirror as the object, but on the other side. If we form a virtual image using a concave mirror, then the law of reflection tells us that the object-image distance is given by the following formula:

$$\frac{1}{o} + \frac{1}{i} = \frac{1}{f} = \frac{2}{r}$$

where o is the object-mirror distance, i is the image-mirror distance, r is the mirror's radius of curvature and f is its focal length. The magnification of the mirror is given by

$$m = \frac{h'}{h} = -\frac{i}{o}$$

where h' and h are the image and object heights respectively.

Activity 29-7: Forming an Image with a Concave Mirror

(a) Set up the equipment as shown in Figure 29.7 with the concave side of the mirror facing the light source. The viewing screen should cover only half of the hole in the component holder so that light from the filament reaches the mirror. Estimate the focal length of the mirror by positioning the mirror on the optical bench as far from the crossed arrow target as possible. Vary the position of the viewing screen to find where the image of the target is focussed. Record this approximate value of the focal length and have another group member repeat the measurement independently. How do your two values compare?

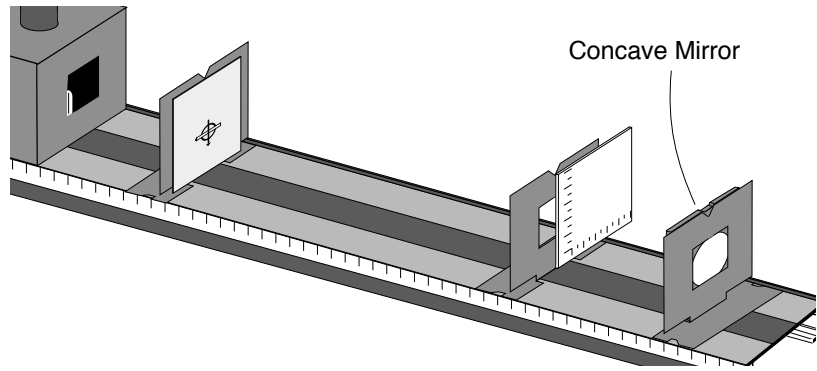


Figure 29.7: Set-up to observe the image from a concave mirror

(b) Choose five distances between 50.0 cm and 5.0 cm. These are object-mirror distances o for which you will measure the image-mirror distances i and the image heights h' . Record o , i , h and h' in the table below. Calculate f from o and i in each instance and record these values in the table below. Show at least one calculation of f in the space below.

o	i	h	h'	$f(\text{calc})$

(c) How do your five values of f agree?

(c) For each of the five distances measured above, calculate the magnification derived from h'/h with that calculated from $-i/o$. Show at least one sample calculation of each in the space below.

$m1 = h'/h$	$m2 = -i/o$

(d) How do your two magnifications agree? Do you see any evidence of a systematic error?