MIRRORS AND REFLECTION

PART 1 – ANGLE OF INCIDENCE, ANGLE OF REFLECTION
In this exploration we will compare \( \theta_i \) (angle of incidence) and \( \theta_r \) (angle of reflection). We will also investigate if rays are reversed by the plane mirror.

EQUIPMENT: Pasco ray box, protractor, ruler, plane /curved mirror set, white paper

1. Place the ray box, label side up, on a white sheet of paper on the table. Adjust the box so one white ray is showing.
2. Place the mirror on the table and position the plane surface of the mirror at an angle to the ray so that both the incident and reflected rays are clearly seen.
3. Trace the surface of the plane mirror on the paper, the incident ray and reflected ray.
4. Indicate the incoming and the outgoing rays with arrows in the appropriate directions. On the paper, draw a normal to the plane mirror surface between incident and reflected ray.
5. Measure the angle of incidence (\( \theta_i \)) and the angle of reflection (\( \theta_r \)), from the normal to the mirror surface. Record the angles in the data table, below.
6. Change the angle of incidence and measure the incident and reflected angles again. Repeat this procedure for a total of three different incident angles.
7. Move the ray box on the paper and adjust it so it produces the three primary color rays. Shine the colored rays at an angle to the plane mirror. Mark the position of the surface of the plane mirror and trace the incident and reflected rays. Indicate the colors of the incoming and the outgoing rays and mark them with arrows in the appropriate directions.

<table>
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<tr>
<th>Angle of Incidence (( \theta_i ))</th>
<th>Angle of Reflection (( \theta_r ))</th>
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Question 1: Based on this experiment, what is the relationship between the angle of incidence and the angle of reflection?
PART 2 – USING THE RAY MODEL

In this Exploration we will consider how light rays reflected from an object travel and enter our eyes. We will also see how a process called **triangulation** can be used to find the location of an object. Finally, we will find that as an object becomes more distant, the light rays either emitted or reflected from it become more parallel.

**EQUIPMENT:** straight pin or push pin, tape, ruler, corkboard, paper, plane mirror with support (last item for Part 3)

1. On a tabletop, place a piece of paper on top of a flat piece of corkboard, and then place a straight pin vertically in the middle of the paper.

2. As shown in the photo at right, close one eye and look at the pin with your other eye, making sure that your open eye is at the same height as the paper. Place a ruler so that one edge of the ruler is directly between your eye and the pin. Draw a line along that edge of the ruler.

3. Repeat this process by viewing the pin from several different angles around the paper. Each line you draw will represent a light ray that comes from the pin. (Although the pin only reflects light, we will still use the phrase “comes from the pin” to describe the direction from which the light rays are coming before they enter your eye.)

4. Remove the pin and use the lines you have drawn to determine the location of the pin.

The steps above are a procedure for locating an object through triangulation. Triangulation can help scientists identify the location of an object. To determine the location of an object by using triangulation, scientists find the paths of different light rays that are emitted or reflected from the object. Scientists then trace these rays back to their origin. The location of the object will be the point where the light rays cross. Triangulation has many practical applications: geologists often use it to determine the location of earthquakes, and it is the process that enables global positioning satellites (GPS) to determine the latitude and longitude of an object on Earth.

5. When using triangulation, what is the minimum number of lines that will enable you to determine the location of the pin? Explain. ______________

6. Consider your answer from Step 5; is this the optimum number of lines? Would you be able to locate an object more accurately if you used more lines? Remember, it is called **triangulation:**
PART 3 – THE PLANE MIRROR

When you look at an object’s reflection in a mirror, you do not see the object itself, but an image of that object. If you try to touch this image, you will find that you only touch the surface of the mirror. In this section, you will learn about images formed by the reflection of light from a plane mirror. A plane mirror is a mirror that is flat, not curved. We will observe properties of images, such as their size, location, and if they are upright or inverted. We will also investigate the meaning of the physics term image. Later, we will examine images formed by curved mirrors, such as those found in fun houses, telescopes, and rearview mirrors.

1. Use the diagram and directions below to set up the equipment for this Exploration. Use legal paper for this activity oriented in “landscape mode”.

![Diagram of setup](image)

a. Place the corkboard on a table with one edge of the board along the front edge of the table. Place a sheet of paper on top of the corkboard so one edge is also along the front edge of the table.

b. Insert a pin into the paper and corkboard near the table’s edge. The pin will serve as the object.

c. Place a flat mirror parallel to the edge about 10 cm behind the object, and use a pencil to trace the front location of the mirror on the paper.

d. Stand in front of the mirror at position A. With your eyes at the edge of the table and at the same height as the paper, close one eye. Observe the image in the mirror with your open eye. With one eye still closed, observe the image at different locations by moving from position A to the right until you reach position G, at the very end of the paper.

2. In what positions along the table’s edge (if any) are you not able to see the image of the object? ________________________________
______________________________
______________________________
3. From this experiment, determine the positions where you can see the pin with your open eye. Draw light rays on the diagram below to support your hypothesis. Remember, the light rays come from the object and go to the eye.

4. Philosophy alert: If you observe the image of the object, and then close your eyes, does the image still exist? Explain.

5. As you look at the image of the pin, where does it appear to be? Draw it in the figure below.

6. Follow the steps below to locate the object’s image in the mirror.
   a. Position yourself in front of the mirror at position A, and have the ruler within your reach. With your eyes at the table’s edge and at the same height as the paper, close one eye and observe the object’s image with your open eye.
   b. Place the ruler so that one edge of the ruler makes a line from your eye directly to the image. Draw a line along that edge of the ruler from your eye to the mirror—this may be difficult to do, but do the best you can. Repeat this
process with your eye at four positions. (If you have not already done so, draw a line along the front of the mirror to mark the location of the mirror, and draw a dot to mark the location of the pin.)

c. Remove the mirror. Make sure the lines you have drawn intersect with the line marking the mirror’s location. These four intersections mark the location of the image as seen by your eye from four different positions.

d. Begin with one of the intersections and use the ruler to draw a line from the point of intersection to the object. The line you have just drawn and the line you drew from your eye to the mirror, together, define the real path of a light ray. A light ray from the object reflects off the mirror and goes to your eye.

e. Use the ruler to draw lines from each of the other three intersections to the object. These are paths for other light rays the enter your eye at different locations along the table’s edge, a different light ray from the object travels to the mirror, reflects off the mirror, and goes to your eye.

f. For each of the locations where a ray reflects from the mirror, draw a normal line to the mirror.

7. Suppose we let $\theta_i$ represent the angle at which the light goes towards the mirror and $\theta_r$ represent the angle at which the light is reflected from the mirror. Do your observations support the relationship between $\theta_i$ and $\theta_r$ that we saw in Part 1? (For this experiment you may notice that some values are not exact because aligning the ruler with the image is difficult to do without error.)

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________________________________________________________________________________

8. Where do the light rays that enter your eyes appear to originate? ________

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9. Where do the light rays that enter your eyes actually originate? ________

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______________________________________________________________________________
PART 4 – CYLINDRICAL MIRRORS

1. Determine which side of the mirror tool is concave, and which is convex.
2. Using five white rays from the ray box, shine the rays straight into the concave mirror so the light is reflected back toward the ray box.
3. Draw the surface of the mirror and trace the incident and reflected rays. Indicate the incoming and the outgoing rays with arrows in the appropriate directions.
4. The place where the five reflected rays cross each other is the focal point (f) of the mirror. Measure the focal length from the center of the concave mirror to the surface to the focal point.
5. Repeat Steps 1 through 4 for the convex mirror. Note that in Step 2, the reflected rays are diverging for a convex mirror and they will not cross. Use the ruler to extend the reflected rays back behind the mirror’s surface. The focal point is where these extended rays cross.

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<tr>
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<th>Concave Mirror</th>
<th>Convex Mirror</th>
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<tr>
<td>Focal Length (measured)</td>
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<td></td>
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<tr>
<td>Radius of Curvature</td>
<td>12.5 cm</td>
<td>12.5 cm</td>
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Question: How do your experimental results compare with the theoretical relationship between focal length and radius of curvature?

PART 5 – DRAWING RAY DIAGRAMS

Draw a ray diagram for each situation, using the 3 principal rays. Use a ruler to measure all dimensions. For each ray diagram identify the following (list near diagram):

1. \( d_i \) – the image distance (cm ok)
2. is image inverted or upright?
3. is image real or virtual?
4. is image magnified or reduced?
When $d_s = \infty$, the rays converge at $F$.

When $d_s > 2f$, the rays converge at $F$.

When $d_s = 2f$, the rays meet at the focal point $F$.
$f < d_s < 2f$
$d_o = \infty$ (just show where the rays converge)

$d_o > 2f$

$d_o < f$

$f < d_o < 2f$