San Diego Mesa College
Physics 197 Laboratory Experiment
Title: Reflection and Refraction of Light

Name:____________________________________
Date: ____________________________________
Group Members: __________________________
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Objective: To observe the behavior of visible light as it encounters reflective and transparent surfaces and to define terms used to describe such systems.

Theory: When energy encounters a boundary, there are three possible events that may occur:

1) The energy passes through the object
2) The energy is absorbed by the object
3) The energy is reflected from the object

When the energy source emits electromagnetic energy in the visible spectrum, we have developed commonly used terms to denote these events. Objects are said to be 'transparent' if the light passes through them, while objects that reflect light are called 'opaque'. Objects that are in an intermediary state and are denoted by the label 'translucent'. If an object absorbs all visible light that falls upon it, such an object would be called 'invisible'.

As the light travels from the source, interacts with the object and makes its way to our eyes we denote the path traveled by the light as a 'ray'. It is also possible that an object emits light, but this will be discussed in another experiment.

When light passes through a boundary, the direction of energy propagation may change based upon the physical properties of the material. This change in direction is called 'refraction'. The relationship between the incoming or 'incident' ray and the transmitted or 'refracted' ray is governed by Snell's Law:

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

where the angles are measured with respect to the normal and the n values are called the indices of refraction.

Equipment:

- Cork Board
- Ruler/Protractor
- Standing Mirror
- Equilateral Plastic Prism
- Straight Pins
- Sheets of White Paper
- Clear Plastic Block

Part I: Ray Tracing
Setup and Procedure:

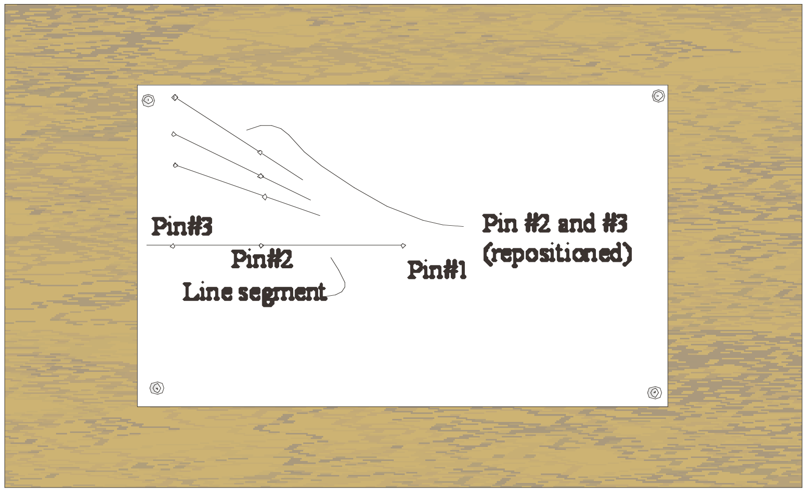
1) Attach a piece of clean white paper to the cork board using push pins at each corner.
2) Insert a straight pin (Pin 1) vertically into the middle of the paper. Insert another straight pin (Pin 2) vertically into the paper about 8cm in front of Pin 1. Write a small number 1 and 2 near the base of the appropriate pin.
3) Lower your head to the level of the table, close one eye and look at Pin 2. Move your head until Pin 2 obscures Pin 1.
4) Remove both pins, and use the ruler/protractor to draw a straight line segment that connects the two pinholes and extends a few cm beyond the hole made by Pin 2.
5) Replace the pins in their respective holes and look down the line segment that you just drew. This line segment is called a 'ray trace'. You will label this 'Ray Trace 1'

Can you now see Pin 1?

Can you conclude that the light reflected from Pin 1 travels in a straight line?

You will now use the technique of making one pin 'disappear' behind the other to establish some more properties of reflected light.

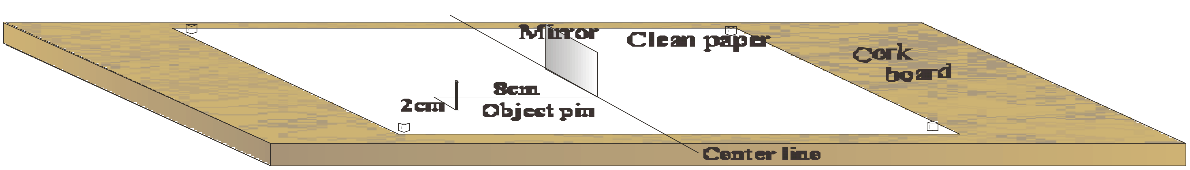
6) Place a third pin (Pin 3) along the ray trace you created in 5) but a few cm closer to you than Pin 2 and look down the ray trace. You should only be able to see Pin 3
7) Move Pin 2 about 1 cm to the right or left of Ray Trace 1 and adjust your viewing position until Pin 2 obscures Pin 1.
8) Remove Pin 3 from the paper and place it in a new position such that it obscures Pins 1 and 2.
9) Remove Pins 2 and 3 and draw a ray trace connecting the pinholes.
10) Repeat steps 7)-9) until you have a total of four ray traces as shown below.



11) Extend Ray Traces 1-4 towards the location of Pin 1.

What, if anything can you conclude about the light that reflects off Pin 1?

Part II: Reflection of Light
Setup and Procedure



1) Secure a new sheet of paper to the cork board and place the mirror near the middle of the paper.
2) Draw a line bisecting the paper that marks the back edge of the mirror.
3) Place a pin 8 cm in front of and 2 cm to the right of the edge of the mirror, as indicated in the diagram. This is Pin 1, also called the Object Pin(**OP1**).
4) Lower your head to table level and adjust your position until you can see the image of the OP in the mirror.

Where does this image appear to be located?

5) Take a second pin (**OP2**) and place it about 4 cm in front of the mirror and toward the opposite side the mirror as the location of **OP1**.
6) Adjust your gaze so that OP2 obscures the image of OP1. Place another pin (**OP3**) so that it blocks both OP2 and the image of OP1.
7) Remove all three pins and the mirror.
8) Draw a ray trace between the positions of OP2 and OP3 and extend it past the line denoting the position of the rear of the mirror to within a few cm of the rear of the paper.
9) Locate the intersection of this ray trace and the line locating the mirror, Extend a line from this point through the location of OP1

You have now just demonstrated that the light ray originating from OP1 traveled in a straight line to the mirror and then from the mirror to your eye in its location near OP3. Why was the rear of the mirror chosen as the intersection point?

10) Now draw a line segment that originates at the intersection of the rays and the line marking the back of the mirror. The line segment should be drawn perpendicular to the mirror line, extending towards the front of the paper.
11) Use the protractor to measure the angle formed by the perpendicular segment and the ray trace from OP1 and record it below:

Angle of Incidence: ______________

12) Now use the protractor to measure the angle formed by the perpendicular segment and the ray trace from OP2 and OP3. Record it below and comment on the relationship.

Angle of Reflection: _____________

13) Replace the mirror and OP1 to their initial positions, Move OP2 to a new location and repeat the procedure of ray tracing four more times, so you have a total of five lines crossing the line of the mirror.

Do the lines seem to have a common point of intersection? Where is this point in relation to the apparent location of the image of OP1 addressed in step 4)?

So, to your eyes, it appears as though all the light rays that describe OP1 originated at a point *behind* the plane of the mirror. This point is called the Image Point (**IP**).

14) Measure the perpendicular distance from the back of the mirror to OP1 and record it below. Repeat the process for IP1, then place a pin to mark IP1.

X_{OP1} = _________________________ X_{IP1} = ____________________________

15) Now position your eye so you can simultaneously see the bottom of the *image* of OP1 and the top of the pin placed at IP1.

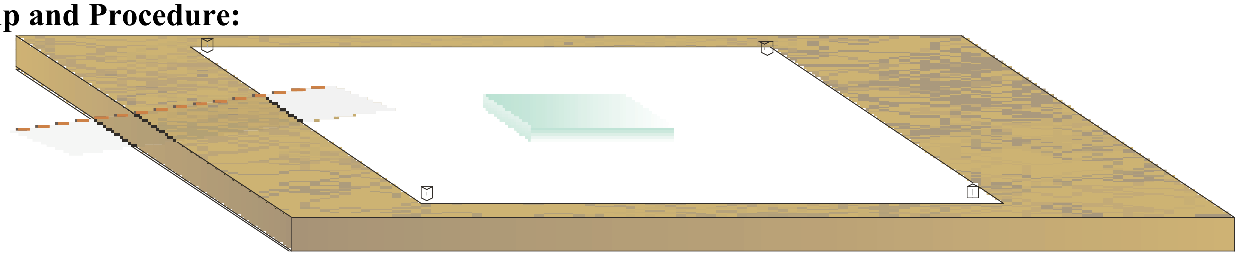
Describe what you see. Can you see a difference in size between the image of the object and the pin at the image position? Slowly lift the mirror and comment on your observation.

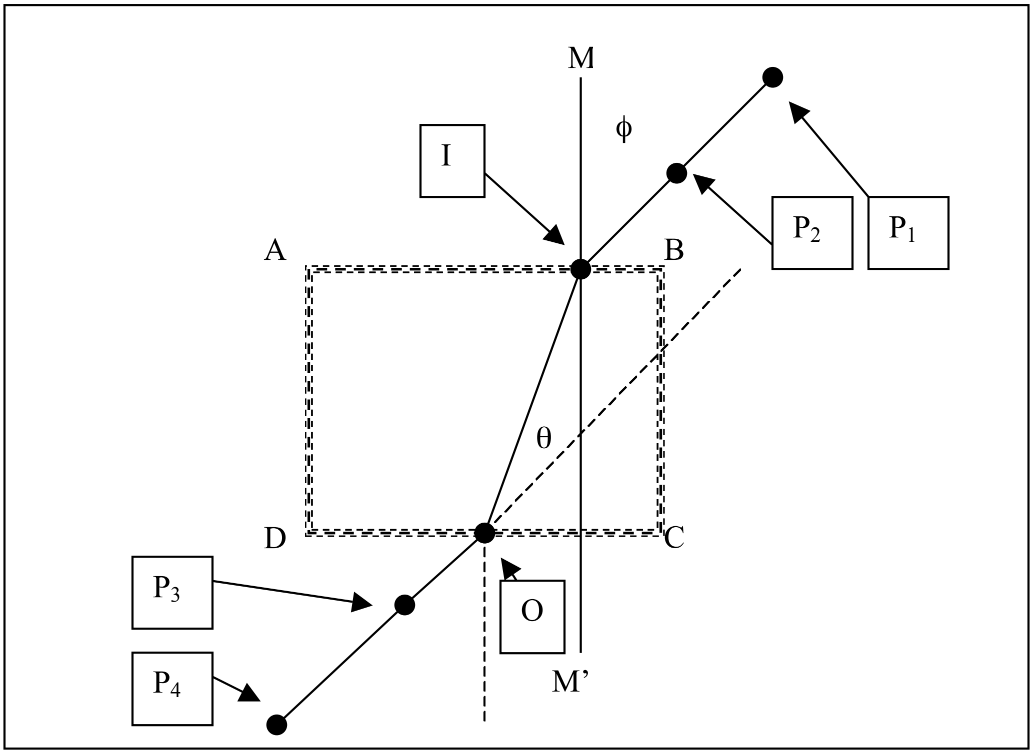
16) Now place a pin directly in front of the mirror and adjacent to the image of OP1 so you can compare the sizes of the image of OP1 and an actual pin.

Comment on the sizes of the image and the comparison pin.

So, a plane mirror 'creates' an image of an object. The rays diverging from the comparison pin and the image of OP1 both carry information about the object with which they interacted. Even though our eyes intercept only a small portion of these rays we are still able to judge many attributes of the object's surface. Since the geometry of the plane mirror does not change the spatial relationships of the rays, the image of the object appears to be identical in size and location to the object itself. To repeat – there is no difference in the information carried by the rays before and after interaction with the surface of the mirror. This is similar in many ways to the elastic collision of an object with a massive surface, where the direction of the momentum is reversed, but the magnitude is unchanged.

Part III: Refraction of Light
Setup and Procedure:





1) Take a clean sheet of paper and fasten it to the cork board. Draw a line (**MM'**) bisecting the paper. Place the plastic block upon the paper with the long edge of the block in the same direction as the long side of the paper with about _ of the length of the block on one side of the line. Trace the outline of the block and label the four corners as A,B,C,D. Remove the block.
2) Where the line **AB** intersects with line **MM'**, label that as point **I**. Draw a line from point **I** towards the near edge of the paper that makes a 45 degree angle (ϕ) with **MM'**.
3) Place a pair of pins at distances of 1" and 2" from point I. Label these points as P_1 and P_2, respectively.
4) Carefully replace the block on the paper, and look through side **CD** until you find a position where P_2 obscures P_1.
5) Maintain this position and insert a pin in location P_3 such that it obscures both P_1 and P_2. Then insert P_4 in such a way that it is closer to the edge of your paper than P_3 and it obscures all the other pins.
6) Remove the block and pins P_3 and P_4. Draw a line segment extending from P_4 through P_3 and towards line **MM'**. Where this segment crosses line **CD**, mark the point as **O**.
7) Draw a line segment from point **O** to point **I**.
8) Starting at point O, draw a line segment perpendicular to line **CD**, which should also be parallel to **MM'**. Now determine the angle θ made by the refracted ray inside the block.
9) Repeat steps 2) through 8) for ϕ = 25 degrees and fill in the data table below using Snell's Law to calculate the index of refraction of the block.

Data:

ϕ	θ	n_{block}
45		
25		

Show all calculations in the space below:

Analysis:

Look up the standard index of refraction of Lucite plastic. Calculate the percent error between the standard accepted value for Lucite and the average index of refraction obtained through your experiment.

$$\%error = \left| \frac{n_{accepted} - n_{experimental}}{n_{accepted}} \right| * 100 =$$

Conclusion: Briefly discuss the physics involved in the experiment, summarize the data, address potential sources of error and methods to reduce or eliminate them, and state whether or not the experimental results validate the theory.