Lab 11 – Reflection and Refraction

Introduction

Light is an ***electromagnetic wave*** that consists of the oscillations of an electric field accompanied by the oscillations of a magnetic field. When light waves arrive at the interface between two media, from medium A to medium B, part of the wave energy is reflected back into A or ***reflects***, and the remainder is transmitted into B. As an electromagnetic wave, light travels at different speeds in different media. Light travels fastest in a vacuum, where it has a speed, $c = 3.00 \times 10^8$ m/s. When electromagnetic wave propagates from a medium A where its speed is v_1 to medium B where its speed is v_2, it will change the direction of motion. This phenomenon is called ***refraction***. Refractive property of a medium is described by a refractive index, $\mathbf{n} = \dfrac{c}{v}$.

This experiment will study the phenomena of reflection and refraction of light. To simplify the study we will overlook the electromagnetic nature of light and use a "light rays" model; such an approach is called "Geometrical Optics". A light ray is a line directed along propagation of electromagnetic energy. Propagating energy forms a front (line of points that just being reached) and ***rays of light are always perpendicular to the frontline.***
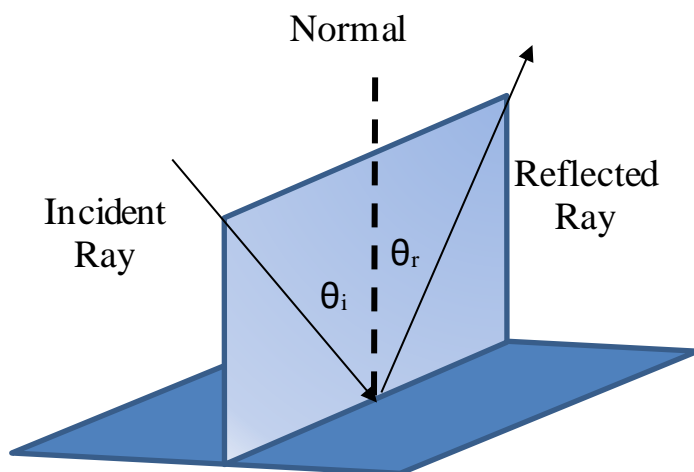

The Law of Reflection of light states that the angle of incidence is equal to the angle of reflection.

The Law of Reflection of light also states that the incident ray, the reflected ray and the normal to the media boundary all lie in the same plane. This is illustrated by Figure 1. Pay attention that both, the angle of incidents and angle of reflection, are measured ***with the normal of the media boundary*** not with the boundary itself.
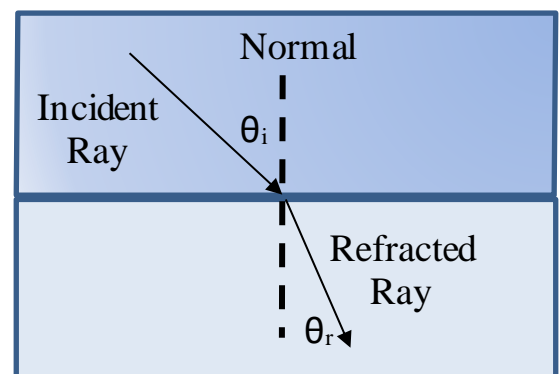
Figure 1. Incident Ray, Reflected Ray, and the normal to the surface are in the same plane.

The Law of Refraction of light also known as Snell's Law gives the relationship between the angles and index of refractions: $n_i \sin\theta_i = n_r \sin\theta_r$

1) When a ray of light enters a medium where its speed is decreased ($n_i < n_r$), it is bent toward the normal.

2) When a ray of light enters a medium where its speed is increased ($n_i > n_r$), it is bent away from the normal.

Figure 2. Trace of the light ray for $n_i < n_r$

In Figure 2, the speed of light in upper medium is greater than in the speed of light in medium below.

Trough Reflection and Refraction, Mirrors and Lenses form an image of an object. The position and nature of the image depends on the focal length of the mirror/lens and the position of the object. Position of the object or image is described by the distance between the object/image and the mirror/lens. Thin-Lens/Mirror Equation states that $f^{-1} = d_o^{-1} + d_i^{-1}$, where f is a focal length of a lens, d_o is the distance to an object or p, and d_i is the distance to an image or q. An object is always considered to be real, therefore d_o is always positive; however, an image could be real (appears on a screen) or virtual (doesn't appear on a screen). Negative sign of d_i indicates virtual nature of an image. A ***real image*** is formed by actual reflected/refracted rays and ***is inverted***; a ***virtual image*** is formed by the extensions of the actual rays and ***is upright***.
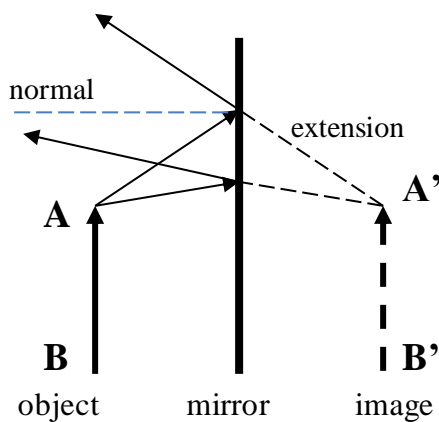

Figure 3. Image formation by a flat mirror

The laws of reflection of light enable us to find the image formed by any mirror, plane or curved.

If the light from an object falls on a **smooth surface**, such as a mirror, the reflection of that light from the mirror appears to rise from the "image" of the object. The effects of such a reflection from a plane mirror are shown in Figure 3 where **AB** is an object, in the shape of an arrow. The figure shows two rays of light from the point A striking the mirror and reflected. Point **A'**, behind the mirror, is where the extensions of reflected rays meet.

So, *any ray from A striking the mirror, after reflection appears to come from A'*. For this reason, **A'** is called the image of **A** in the mirror. To the eye the points **A** and **A'** look similar.

Since the arrow **AB** is a collection of points, the mirror forms an image of every one of the points of the arrow, and the image of the arrow has the shape of an arrow. **A'B'** is referred to as the image of the object **AB** formed by the plane mirror.

Part #1. Image Formed from a Red Reflective Flat Mirror

If you cannot print Sheet A from the end of the instructions, use a blank sheet of paper draw a dot labeled A and a thick line as shown. Trace rays to locate the image of point **A**, which is a source of light, formed by the plane mirror. **ATT:** *Use a ruler for your geometric construction*.

1) Draw two rays towards the mirror starting from **A** where one of rays must strike the mirror head on (perpendicular), with an angle of incidence of 0^0.

2) Draw their reflected rays, each time making sure that you use the laws of reflection of light (if you do not have a protractor, estimate the angles).

3) The point where the reflected rays cross each other is the image of **A** or **A'**.

4) Measure the distance of **A'** from the mirror and the distance of **A** from the mirror. Calculate % Difference between the two measurements.

5) Describe the image in terms of real or virtual; use the location of the image to support the description.

Part #2. Ray Refraction through a Rectangular Acrylic Prism

If you cannot print Sheet B from the end of the instructions, use a blank sheet of paper to draw a rectangle and the lines as shown.
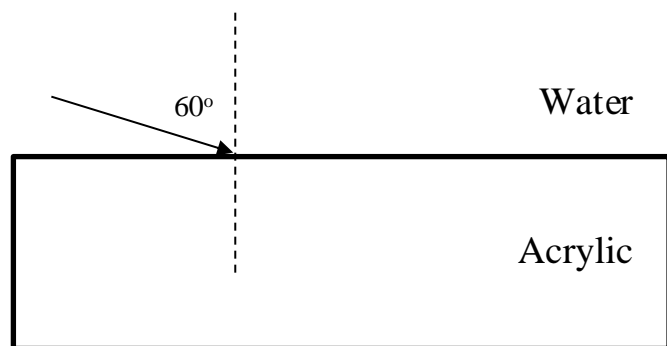
1) Using a ruler, draw the path of a ray that strikes an upper surface of the acrylic slab at an angle of incidence of **60.0⁰** and the normal to the surface at the point of strike (dashed line).

2) Use Snell's Law for the calculations of a refracted angle in acrylic. Look up the refractive index of acrylic and refractive index of water.

Figure 4. Refraction of light in an acrylic prism

3) Repeat the calculations for the ray exiting the acrylic slab (now, the angle between the ray in acrylic and the normal to the lower surface of the slab becomes an incident ray and the angle between the ray in water and the normal becomes a refracted ray).

4) Enter the calculated values into Table 1 which needs to be drawn on the same sheet of paper as the diagram.

Medium	Incident angle, Θ_i (deg)	Refracted angle, Θ_r (deg)
Water to Acrylic		
Acrylic to Water		

Table 1: Angles measured for rays refracting in an acrylic prism.

5) Using a ruler and calculated values of the angles, trace the path after the ray through the glass and as it emerges back into water. If you do not have a protractor, estimate the angles.

Part #3. Image Formation by a Curved Mirror

If you cannot print Sheet C from the end of the instructions, use a blank sheet of paper to copy each of the diagrams.

An object in the shape of an arrow **AB** is placed in front of a concave mirror. In the diagrams from Sheet C, trace the rays to *locate the image of the arrow (draw the ray from the head of the arrow)*. Call the image of **A** as **A'**. Remember that it takes tracing at least two rays starting from the arrowhead to locate where the image is. ***In the first diagram three of such incident rays have already been drawn, choose two of them.***
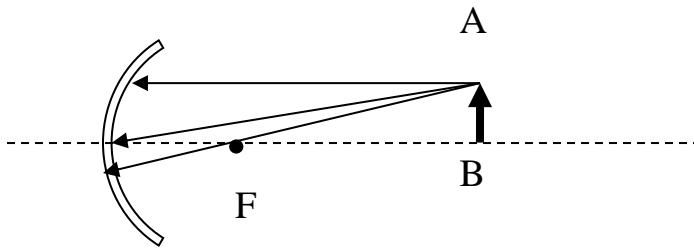
The ray that goes through the focus will reflect …

The ray that goes parallel to optic axis will reflect …

The ray that strikes the mirror in the middle will reflect …

Case 1: The arrow is placed farther than one radius or 2f (beyond C) from the mirror.

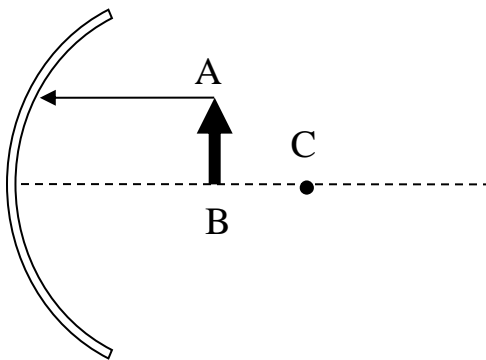*Describe the image following the questions below, include description into Sheet C:*

A

B

F

Is the image **A'B'** upright or inverted with respect to the object **AB**?

Is the size of the image **A'B'** greater or smaller than the size of the object **AB**?

Is the image real or virtual?

Case 2: The arrow is placed between the focal point **F** and the center of curvature **C or 2f**.

Locate the focal point accurately on this diagram using a ruler and add the second ray yourself.

A

C

B

Describe the image following the questions below, include description into Sheet C:

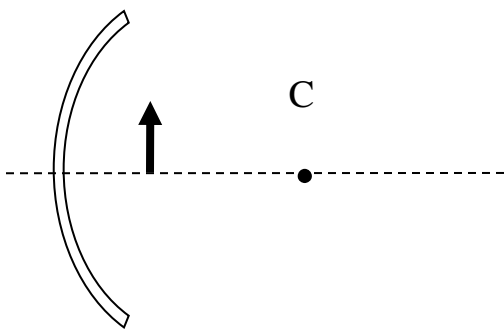Is the image **A'B'** upright or inverted with respect to the object AB?

Is the size of the image **A'B'** greater or smaller than the size of the object **AB**?

Is this image real or virtual?

Case 3: The arrow is placed between the mirror and the focal point **F**.

Locate the focal point accurately on the diagram from Sheet C using a ruler.

Draw both rays coming to the mirror yourself. Choose rays wisely.

C

Describe the image following the questions below, include description into Sheet C:

Is the image **A'B'** upright or inverted with respect to the object AB?

Is the size of the image **A'B'** greater or smaller than the size of the object **AB**?

Is this image real or virtual?

Bonus (10 points) Case 4: The arrow is placed in front of convex mirror (rear view mirror). There is no work sheet for this case; students must present a picture or scan of self-drawn diagram to claim the bonus.
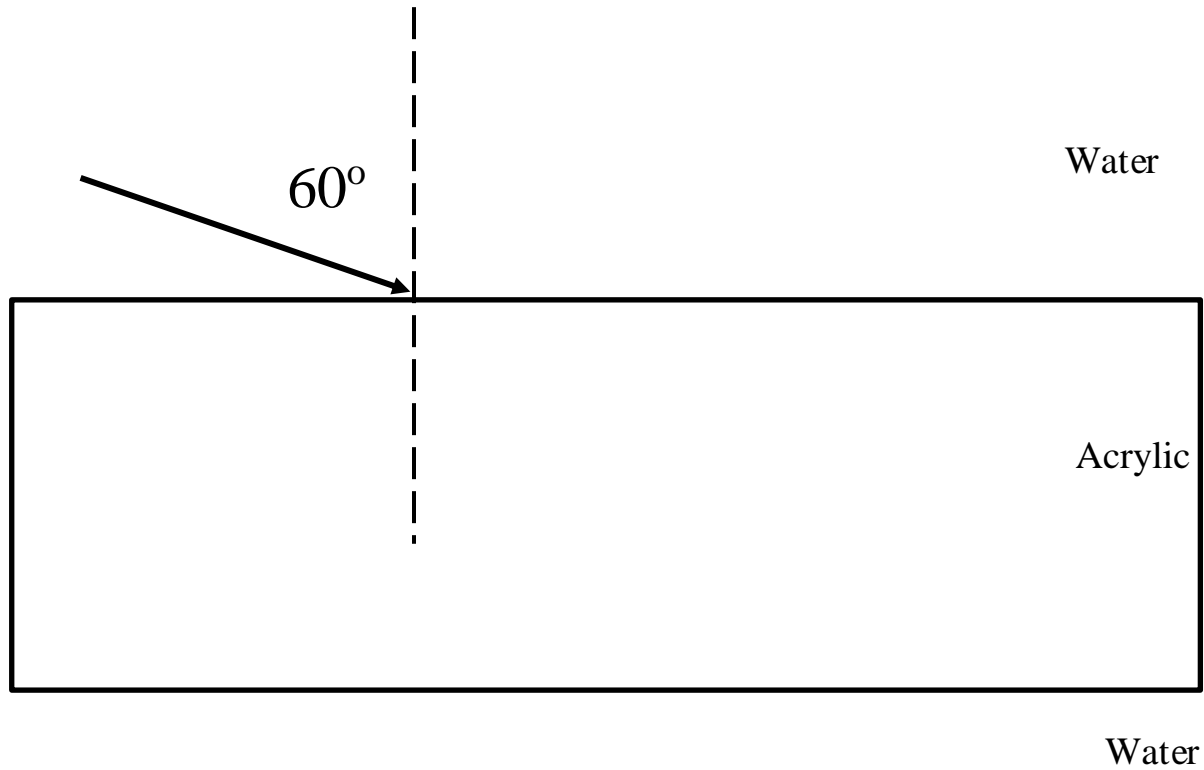
Drawing Sheet A

A •

|

Distance between the mirror and the image:

Distance between the mirror and the object:

% Difference:

Description of the image:

Drawing Sheet B

60°

Water

Acrylic

Water

Refractive Index of Water:

Refractive Index of Acrylic:

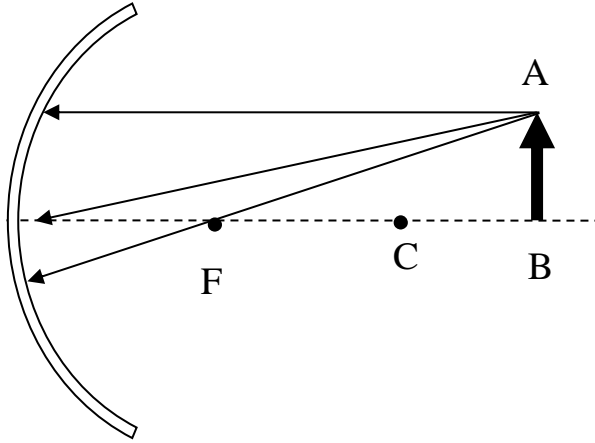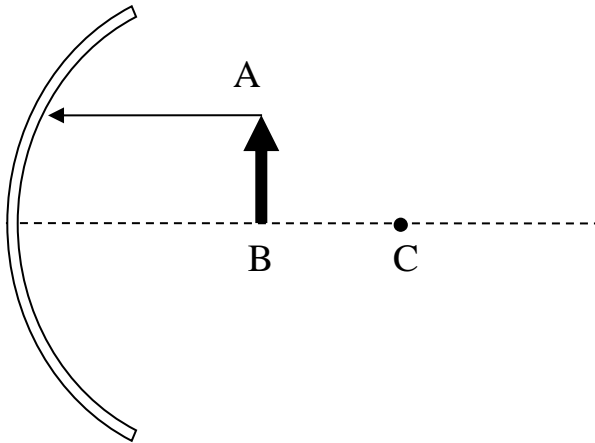| Medium	Incident angle, Θ_i (deg)	Refracted angle, Θ_r (deg)
Water to Acrylic		
Acrylic to Water		

Drawing Sheet C

Image 1 Description:

Image 2 Description:

Image 3 Description: