NAME Henry Madsen LAB PARTNERS ______________

Station Number ______________ ______________

Reflection and Refraction at a Plane Surface

Experiment 1

INTRODUCTION

The laws of reflection and refraction form the basis for the study of optics. The application of these laws to curved surfaces leads to equations relating object distances, image distances, and focal lengths of lenses and mirrors. The purpose of this experiment is to study the laws of reflection and refraction.

THEORY

The index of refraction n of a substance is defined to be

$$n = \frac{c}{v}, \tag{1}$$

where c is the velocity of light in a vacuum (3×10^8 m/sec) and v is the velocity of light in the substance.

When a ray of light is reflected from a surface, the angle of incidence i is equal to the angle of reflection i' (see Figure 1.1). This is the law of reflection. If a ray of light is transmitted from medium 1 into medium 2, the ray is refracted at the boundary between the two different media. The angle of refraction r is related to the angle of incidence i by the expression

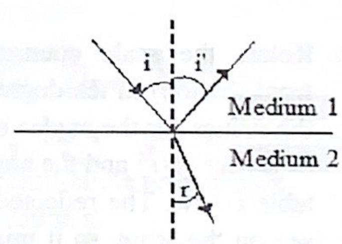


Figure 1.1 Reflection and refraction. If a ray of light is incident on at plane surface, i,i', and r are measured from the normal, shown here as a dashed line.

$$\frac{\sin i}{\sin r} = \frac{n_2}{n_1}, \tag{2}$$

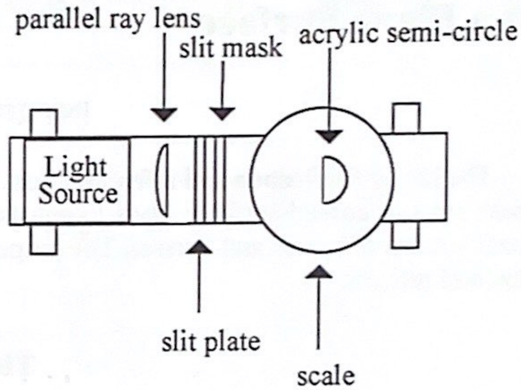
where n_1 and n_2 are the indices of refraction of the media (see Figure 1.1). This is the law of refraction (also called Snell's law). If medium 1 is air, n_1 is approximately equal to 1, and the subscript 2 can be dropped. Snell's law then becomes

$$\sin i \,/\, \sin r = n$$

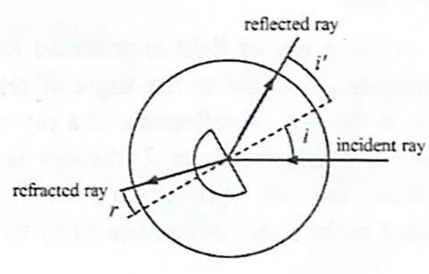
when light travels from air to another medium with index of refraction n.

EXPERIMENT NO. 1

1. Arrange the light source, parallel ray lens, and slit plate on the magnetic optical bench as shown. For the time being, you will not insert the circular scale, the acrylic semi-circle, or the slit mask. Adjust the position of the parallel ray lens until the light rays from the 7 slits are as close to parallel as you can get them. You can tell when they are parallel by allowing the image of the slits to fall on the screen as you slide the screen along the optical bench away from the slit plate. When the rays are parallel, insert the slit mask to block all rays except the central ray. Now insert the circular scale and make sure the ray passes over the zero marks on each side of the scale. You may need to adjust the parallel ray lens from side to side slightly to make this adjustment. Finally, place the acrylic semi-circle on the scale and make sure the center of the flat side is at the center of the scale. This adjustment is critical to obtaining good results, so make sure you have the alignment correct.



2. Rotate the scale counter-clockwise (as viewed from the top) in ten-degree increments and record the values for the angles of incidence i, the angles of reflection i', and the angles of refraction r in the table below. The reflected ray may be difficult to see on the scale, so it might be necessary to hold the white viewing screen next to the circular scale to see the ray better. The figure to the right shows the approximate location of the incident, reflected and refracted rays. The dashed line is the normal to the flat surface.



Angle of incidence (i)	Angle of refraction (r)	Angle of reflection (i')
10.0	7.50	12.00
20.0	14.00	21.00
30.0	21.00	31.00
40.0	27.00	41.00
50.0	31.50	51.00
60.0	37.00	60.00
70.0	34.50	72.00
80.0	42.00	80.00

0	0	0

3. Calculate the sines of the angles of incidence and the angles of refraction and record their values in the table below.

Angle of incidence (i)	sin i	Angle of refraction (r)	sin r
0.0	0	0	0
10.0	.173	7.50	.131
20.0	.342	14.0	.241
30.0	.500	21.0	.358
40.0	.643	27.0	.454
50.0	.766	31.5	.522
60.0	.866	37.0	.602
70.0	.939	39.5	.636
80.0	.985	42.0	.669

4. Plot a graph of sin i versus sin r and calculate the slope of the graph. Show your slope calculations on the graph.

Slope = 1.458

Refer to Eq. (2) and state the physical significance of the slope.

The significance of the slope is the refracted index of the lens

5. Enter the standard value for the index of refraction of the acrylic semi-circle provided by your instructor and calculate the percent error in the index of refraction n.

Standard value for n = 1.4902 Percent error in n = 2.16%

$$\left| \frac{1.458 - 1.4902}{1.4902} \right| \times 100$$

6. Calculate the largest percent difference between the angle of incidence and the angle of reflection.

Largest percent difference = 18.18%

$$\frac{|12-10|}{\frac{10+12}{2}} \times 100$$

7. Continue rotating the scale until the ray strikes the center of the curved surface. Now, as you continue to rotate the scale, the incident ray will make an angle with the normal to the flat surface, and the angle of refraction will be larger than the angle of incidence. If Eq. (2) is written as sin $i = (n_2/n_1)$ sin r, it might seem that sin r could have a value greater than one. You know, of course, that the sine of an angle cannot be larger than one. The value of i for which sin $r = 1$ ($r = 90^\circ$) is called the critical angle for total internal reflection, i_c. Light that strikes the surface at an angle of incidence larger than i_c is totally reflected. Continue rotating the scale until the refracted ray disappears and the ray is totally reflected. Record the angle of incidence for which this occurs.

i_c = 43° Angle at which you first observe colors = 33°

8. Calculate the index of refraction using your results for i_c.

n using i_c = 1.41

$\frac{1}{\sin(43)} = 1.47$

$\frac{\sin(I)}{\sin(r)} = n =$

9. Calculate the percent difference between the value for n in part 8 and the value for n in Part 4.

Percent difference = 1.35%

$\frac{\sin(43)}{\sin(33)}$ $\frac{1.44 - 1.47}{\frac{1.44 + 1.47}{2}}$

10. We will preview the effect of a cylindrical lens in this part. A cylindrical lens focuses light only in one direction, making it possible to see how a lens works. Rotate the scale back to where the single ray is incident on the center of the curved surface. Remove the slit mask so that all 7 rays pass through the acrylic semicircle, which now behaves as a cylindrical lens. Do the rays all seem to come to a point? Now rotate the scale by 180° so that the 7 rays are incident on the flat side of the cylindrical lens. How do the rays for this case appear compared to the case above?

Yes, All rays Come to the Same Spot, Secondly, when All rays Hit the flat side they All Come to the Same Spot as well

QUESTIONS

1. In Part 7, it was clear that the single ray of white light began to separate into colors, and each of the colors disappeared at a slightly different angle. What conclusion concerning the index of refraction and color (wavelength) are you able to draw from this behavior?

1. The refractive index is inversely proportional to the wavelength of light
2. Colors travel with different wavelengths and because of this we only see certain colors
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2. Which configuration of the acrylic semicircle (cylindrical lens) provided the best focusing of the rays as seen in Part 10.

When the light hit the flat side the light was better focused

$(.55, .8)\ (.07, .1)$ $\frac{.8-.1}{.55-.07} = 1.48$

Slope = 1.458