Refractive Index of a Material

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I. Introduction

Light travels with a speed of approximately 3.0 x10^8 m/s in a vacuum. In a transparent medium of uniform density, light passes through it in a straight line. On some cases, when light passes through two transparent media of different densities, a part of the light is reflected while the other is being transmitted at the boundary. This transmitted light travels in a different direction, which is called as *refraction*.

Refraction of light is the bending of a light ray when it passes obliquely from one medium to another. In this case, the change in direction of the light is the result of the different speeds at different points on the medium where the light passes. This phenomenon is commonly observed through the naked-eye.

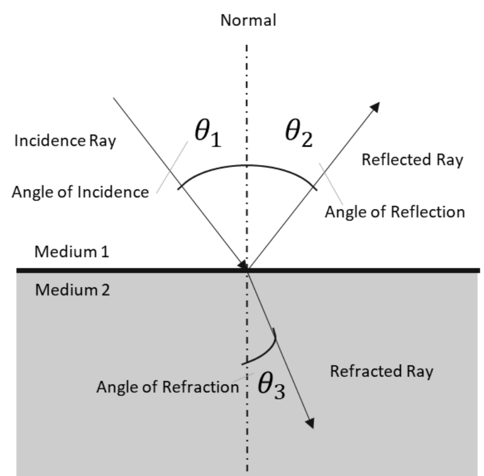


Figure 1: A diagram showing the refraction of light as it passes from one medium 1 to medium 2.

The Snell's Law explains the behavior of light when it passes from one medium to another. Snell's Law describes the relationship between the angles of incidence and refraction. Moreover, the law states that the ratio of the *sines* of angles if incidence and refraction is equivalent to the ratio of the phase velocities of the light in the two media, or simply, it is equivalent to the reciprocal of the ratio of the indices of refraction.

$$\frac{Sin\theta_2}{Sin\theta_1} = \frac{v_1}{v_2} = \frac{n_2}{n_1}$$

$$Equation\ 1: Snell's\ Law\ Equation$$

The index of refraction of a particular medium is also the ratio of the velocity of light in a vacuum to its velocity in the medium. Thus,

$$n_1 = \frac{c}{v_1} \text{ and } n_2 = \frac{c}{v_2}$$

$$Equation\ 2: Relationship\ of\ the\ Index\ of\ Refraction\ and\ the\ Speed\ of\ Light\ in\ the\ Vacuum\ (c).$$

This purpose of this experiment is to describe what happens to a ray of light as it passes from one medium to another medium of different optical properties. Along with that, it aims to determine the index of refraction of two different materials and to measure the critical angle of two different materials.

II. Methodology

In this experiment, cardboard, light source with a single slit, ruler, protractor, graphing papers, masking tape, pins, plastic cuvette, specimens, semicircular lens, and water were used.

All the procedures in the experiment were done twice to minimize errors in measurements. A horizontal line and a vertical line was drawn at the middle of the graphing paper. On one hand, the horizontal line served as the boundary between the two media. On the other hand, the vertical line acted as the normal line. A protractor and a pencil was used to mark 0 ˚, 8 ˚,16 ˚ ,24 ˚, 32 ˚, and 40 ˚ angles from the normal line on both sides of the normal line as shown in the figure below.

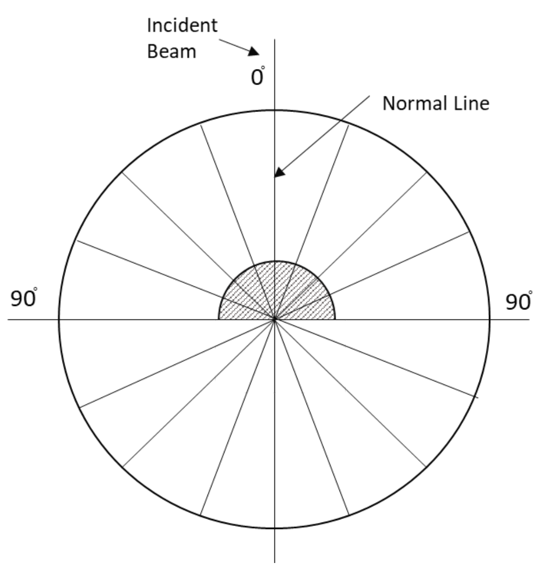


Figure 2: A diagram showing the frame set-up in determining the normal line.

Two media were utilized in the first set-up of the experiment, namely the semi-circular lens and the air. Then a semi-circular lens was placed on the graphing paper such that midpoint of the flat surface of the lens was situated directly above the intersection of the horizontal and vertical lines. A focused light was beamed along the 0 ˚ line of the set-up. Consequently, a pin was placed into to the graphing paper nearest to the midpoint of the semi-circular lens to indicate to which part of the lens the incident light should come out from the first medium. Later, the light was beamed on the 8 ˚,16 ˚ ,24 ˚, 32 ˚, and 40 ˚ lines of the set-up in a consecutive manner. These angles were considered as the angles of incidence and were recorded on a table.

A bent light ray was observed as the light passed from the first medium, the semi-circular lens, to the second medium, which was air. This bent light ray was the refracted ray. With the use of the protractor, the angle towards the refracted ray with respect to the normal line was measured and was recorded on a table. After the light was beamed on the 40 ˚ line of the set-up, the light source was slowly tilted until the refracted ray grazed on the flat surface of the semi-circular lens and was approximately 90 ˚ from the normal line. Consequently, the angle of incidence was then measured with the use of the protractor. This angle was considered as the critical angle.

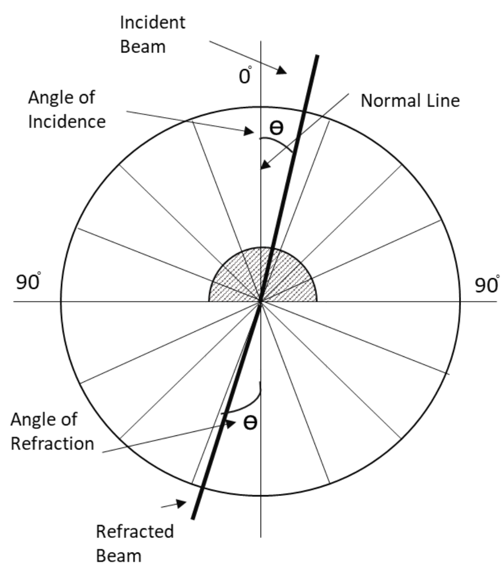
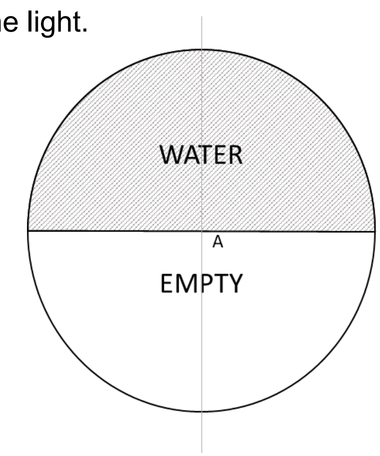


Figure 3: A diagram showing the Incident Beam, Refracted Beam, Angle of Refraction and Angle of Incidence

Same procedures were done on the second set-up that involved a circular cuvette with two semi-circular divisions. On one division, water was placed and the other division was left empty as shown in the figure below. Then, the cuvette was then placed on the graphing paper such that the midpoint of the cuvette was above the intersection of the horizontal and vertical lines. After, same procedures were done to measure the angles of incidence, angles of refraction, and critical angle of the light.



III. Resu

Figure 4: A diagram showing positioning of the cuvette with A as the midpoint of the cuvette. The water is the first medium.

Light bends as it passes from one medium to another medium. The bent rays or refracted rays were due to the mediums' indices of refraction. As shown in Table 1, the semicircular lens has a greater index of refraction than water. On one hand, the semicircular lens was the first and air was the second. On the other hand, water was the first and the empty part of the cuvette was the second.

Table 1. Index of Refraction

Trial	Semicircular Lens (First Setup)			Water (Second Setup)		
	Angle of Incidence	**Angle of Refraction**	**Index of Refraction**	**Angle of Incidence**	**Angle of Refraction**	**Index of Refraction**
1	8.0°	11.25°	1.402	8.0°	11.0°	1.37
2	16.0°	23.25°	1.432	16.0°	23.75°	1.461
3	24.0°	36.0°	1.445	24.0°	32.25°	1.312
4	32.0°	47.0°	1.38	32.0°	44.0°	1.311
5	40.0°	78.75°	1.526	40.0°	55.75°	1.286
	Average Index of Refraction		1.437	**Average Index of Refraction**		1.348
	Critical Angle		42.5°	**Critical Angle**		48.0°

According to Young et al, air has an index of refraction of 1.0 and the semicircular lens and water has indices of refraction of 1.437 and 1.348, respectively, as shown in Table 1. Thus, both the semicircular lens and water has a greater index of refraction compared to that of air. The incident light of both set-ups passed through the first medium and the refracted light comes out from the second. As manifested in Table 1, the angles of refraction were greater than the angles of incidence. This was due to the experimental design wherein the incident light first passed through a medium of high index of refraction compared to the second medium. Moreover, this behavior of refracted lights were to be reversed, thus causing the angle of refraction to be less than the angle of incidence. The values of the indices of refraction in the table were computed with use of Equation 1.

The measured critical angle from the first setup was less than the measured critical angle of the second setup. This behavior was due to the index of refraction of the semicircular lens which is greater than the index of refraction of water. Also, according to Young et al, the critical angle would decrease if the index of refraction were to increase.

IV. Conclusion

The behavior of light when it passes from one medium to another follows the Snell's Law. On one hand, when the incident light first passes through a medium of higher index of refraction is greater than the second medium, the angle of refraction will be greater than the angle of incidence. On the other hand, whenever the incident light first passes through a medium of lower index of refraction than the second, the angle of refraction will be lesser than the angle of incidence. The critical angle and the index of refraction have an indirect relationship.

The two specimens have different index of refraction. The semicircular lens has an index of refraction of 1.437 and the water has an index of refraction of 1.348. This values were calculated using the Snell's Law equation with index of refraction of air which as 1.00.

The experiment is only limited to a minute setup. However, in real case scenarios, same understanding of the behavior of light can explain why does the fork bend if we place it in a glass of water and the like. Moreover, the Snell's Law can also explain the concepts of apparent depth.

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V. References

-Freedman, R.A and Young H. D. (2012). Sears and zemansky's university physics with modern physics. 13 ed.

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