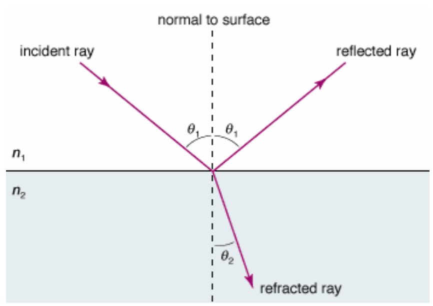
Aim:

To determine the index of refraction of Perspex plastic

Background Information:

When light enters a transparent medium from another, the light appears to bend inside the medium it enters (refer to fig 1 below). This is known as refraction and is caused by the change in speed of light as it enters the medium (Reed, 2009). The angle of refraction depends on the medium's refractive index. The purpose of this experiment is to determine the refractive index of Perspex plastic. All of these variables are related through Snell's Law.

Fig 1. Diagram of light (from Britanica Inc)



Snell's Law states (Weisstein, 2007):

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

Where: n_1 = refractive index of the medium where light is leaving (no units)

n_2 = refractive index of the medium where light is entering (no units)

θ_1 = angle of incident (measured in degrees ^{o})

θ_2 = angle of refraction (measured in degrees ^{o})

For this experiment, light will be travelling from air to the Perspex plastic. The angle of incident is the independent variable and the angle of refraction is the dependent variable. The refractive index of air is 1. Using Snell's Law, the refractive index of Perspex plastic will be determined by rearranging the equation to obtain:

$$n_{Perspex\ plastic} = \frac{n_{air} \sin(\theta_1)}{\sin(\theta_2)}$$

$$= \frac{\sin(\theta_1)}{\sin(\theta_2)}$$

The refractive index for Perspex plastic is known to be 1.49 (A. L. Hyde Company, 2007).

Raw Data:

Below is a raw data table of refraction for a Perspex plastic prism when varying the angle of incident

The uncertainty of the protractor is estimated to be half of the smallest division, which is $\pm 0.5^{o}$. However, there are 2 sides to the protractor. Therefore it is doubled which is $\pm 1.0^{o}$

Table 1. Raw Data of Results of the Angel of Refraction with the Angle of Incident:

	Angle of refraction (Degrees ^{o})($\pm 1.0^{o}$)				
Angle of incident (degrees ^{o}) ($\pm 1.0^{o}$)	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**
10	6	5	6	6	5
20	11	9	11	12	11
30	18	16	17	18	17
40	24	26	24	23	23
50	30	30	29	28	29
60	36	34	33	34	35

Processed Data:

Table 2. Processed Data of Average Angle of Refraction with the Angel of Refraction:

Angle of incident, θ_1		Uncertainty for the angle of incident		Average angle of refraction, θ_2		Uncertainty for average angle of refraction	
Radian value	$sin(\theta_1)$	**Radian value**	**Sin value**	**Radian value**	$sin(\theta_2)$	**Radian value**	**Sin value**
0.1745	0.17	0.02	0.02	0.1047	0.10	0.02	0.02
0.3491	0.34	0.02	0.02	0.1920	0.19	0.03	0.03
0.5236	0.50	0.02	0.02	0.2967	0.30	0.03	0.03
0.6981	0.64	0.02	0.02	0.4189	0.41	0.02	0.02
0.8727	0.76	0.02	0.01	0.5061	0.49	0.02	0.02
1.047	0.87	0.02	0.01	0.5934	0.56	0.02	0.02

Sample Calculations for Processed Data:

Sample Calculations 1. Calculating average for the angle of refraction:

$$Average\ angle\ of\ refraction = \frac{\sum Resistance\ results}{\sum Number\ of\ trials}$$

The average value of the angle of refraction cannot exceed the amount of decimal places of the uncertainty.

<u>Example using results from the angle of incident of 10^{o}</u>

$$Average\ angle\ of\ refraction = \frac{6+5+6+6+5}{5}$$

$$= 5.6^{o}$$

However, the uncertainty for this trial has no decimal places (refer to Sample Calculations 2)

 The average angle of refraction is 6^{o} for the angle of incident of 10^{o}

Sample Calculation 2. Calculating uncertainty for angle of refraction using maximum deviation:

The maximum deviation will be used to calculate the uncertainty for the average angle of refraction. This maximum is determined by subtracting the highest and lowest value from the average angle of refraction and the magnitude of this result will be used as the uncertainty. However, if the instrumental uncertainty is greater than the maximum deviation, then the instrumental uncertainty will be used.

<u>Example using results from the angle of incident of 10^{o}</u>

Uncertainty = Average values – Highest value = 5.2 – 6 = |-0.8| = ±0.8^{o}	Uncertainty = Average value – Lowest value = 5.2 – 5 = |-0.2| = ±0.2^{o}

Since both values of the maximum deviation is less than the instrumental value of 1^{o}

 ±1^{o} will be used as the uncertainty for the average angle of refraction at 10^{o} angle of inflection.

Sample Calculations 3. Converting to radians

To get to radians from degrees, the value in degrees is multiplied by $\frac{\pi}{180}$.

Example using uncertainty of angle of incident and angle of incident of 10°

Converting uncertainty of ±1° to radians:

$1 \times \frac{\pi}{180}$

$= 0.01745$

Converting 10° to radians:

$10 \times \frac{\pi}{180}$

$= 0.1745$

Sample Calculations 4. Calculating $sin(\theta_1)$ and $sin(\theta_2)$:

The sin of the angle of incident and refraction will be needed to be calculated as the refractive index of Perspex plastic is equal to $\frac{\sin(\theta_1)}{\sin(\theta_2)}$, where θ_1 is the angle of incident and θ_2 is the angle of refraction in radians. The answer will be rounded to 2 decimal places as the uncertainty has 2 decimal places.

Example using results from the angle of incident at 0.17^r and angle of reaction at 0.10^r

$sin(\theta_1) = sin(0.17)$

$= 0.1691$

$= 0.17$

$sin\ (\theta_2) = sin\ (0.10)$

$= 0.0998$

$= 0.10$

Sample Calculations 5. Calculating the uncertainty for $sin(\theta_1)$

The uncertainty for y when y = $sin(\theta)$ is $\Delta\theta \times \cos(\theta)$, where θ is in radians, and the uncertainty is rounded to 1 significant figure.

Example for angle of incident at 0.17^r (which has an uncertainty of 0.02^r)

$Uncertainty = \Delta\theta \times \cos(\theta)$

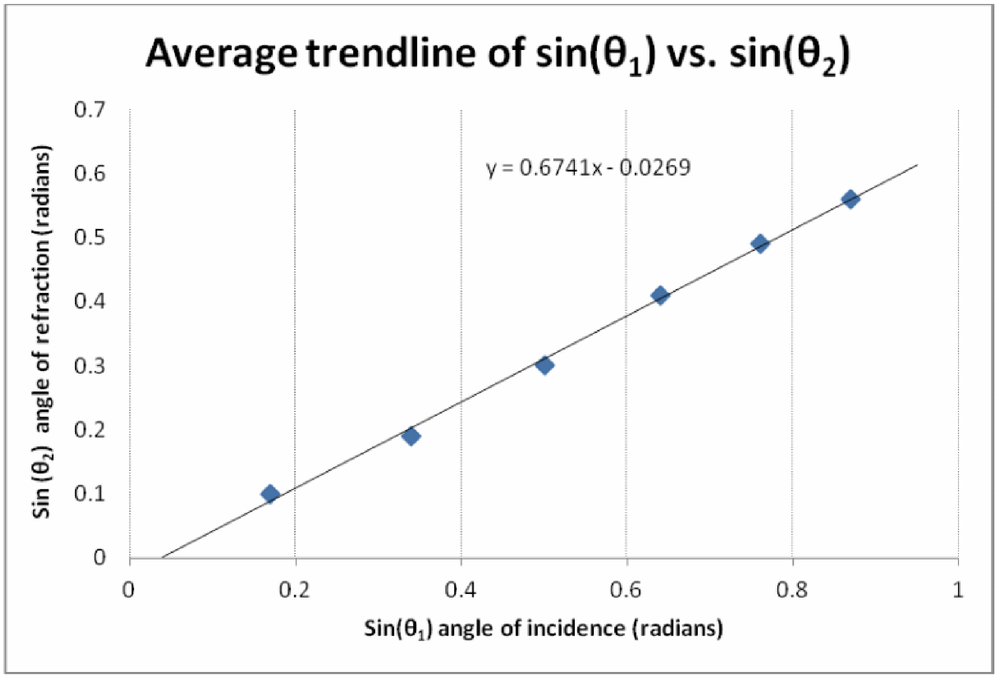
$= 0.02 \times \cos(0.17)$

$= 0.019$

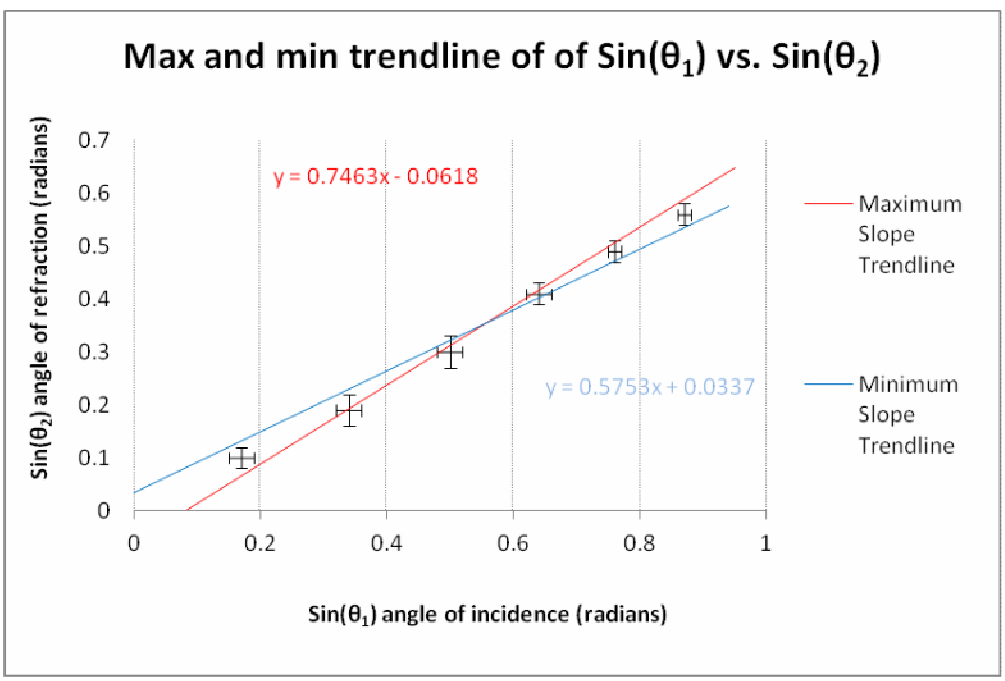
$= 0.02$

Graphing:

Graph 1. Average trendline of sin(θ_1) vs. sin(θ_2):



Graph 2: Maximum and minimum trendline of sin(θ_1) vs. sin(θ_2):



More Sample Calculations:

Sample calculation 4. Calculating the percent uncertainty of the average gradient:

$$Uncertainty\ of\ average\ gradient = \frac{Slope_{max} - Slope_{min}}{2}$$

$$\approx \frac{0.7463 - 0.5753}{2}$$

$$\approx 0.08550$$

$$Percent\ uncertainty\ for\ average\ gradient = \frac{0.08550}{Slope_{average}} \times 100$$

$$\approx \frac{0.08550}{0.6741} \times 100$$

$$\approx 12.68\%$$

$$\therefore \quad \frac{\sin(\theta_2)}{\sin(\theta_1)} = 0.6741 \pm 12.68\%$$

Sample Calculations 6. Calculating the refractive index of Perspex plastic and the uncertainty

Since the angle of incident was the independent variable, and the angle of refraction was the dependant variable, the gradient shows $\frac{rise}{run}$ which is equal to $\frac{\sin(\theta_2)}{\sin(\theta_1)}$. The refractive index of Perspex plastic is $\frac{\sin(\theta_1)}{\sin(\theta_2)}$. Therefore, the inverse of the gradient will determine the refractive index of Perspex plastic.

The uncertainty for the inverse value is the percent uncertainty of the inverse value which will be rounded up to 1 significant figure and the value cannot exceed the amount of decimal places of the uncertainty.

$$n_{Perspex\ plastic} = \frac{1}{gradient}$$

$$= \frac{1}{0.6741} \pm 12.68\%$$

$$= 1.483 \pm 12.68\%$$

$$= 1.483 \pm 0.1880$$

$$= 1.5 \pm 0.2$$

Conclusion:

From graphs 1 and 2, it is evident that the relationship between the angle of incident is directly proportional to the angle of refraction as the graphs show a linear relationship. This can be explained through Snell's Law:

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

Through this equation, it can be seen that $\sin(\theta_1) \propto \sin(\theta_2)$ which explains the linear trendline.

The refractive index for Perspex plastic was found to be 1.5 with an uncertainty of ± 0.2. The actual refractive index of Perspex glass is 1.49 (A. L. Hyde Company, 2007). From these values, the experimental error can be calculated:

$$Experimental\ percentage\ error = \frac{|Experiemental - Theoretical|}{Theoretical} \times 100$$

$$= \frac{|1.5 - 1.49|}{1.49} \times 100$$

$$= 1.49\%$$

The experimental percentage error was found to be 1.49%, which is much less than the percentage uncertainty of 12.68% and shows that the theoretical value lies within the range of the experimental value. Therefore, this experiment supports Snell's Law, which is the relationship between the refractive indexes of the mediums, the angle of incident and the angle of refraction.

Evaluation:

Limitations	**What effect it had on the experiment**	**Improvements**
Thickness of the light and pencil	As both the mark and the light rays were thick. This may have caused random error.	By using a thinner pencil and constantly mark in the middle of the light ray. More trials could be performed in order to
Imperfections of the Perspex plastic	The refractive index may change according to different manufacturers.	Obtaining the refractive index from the manufacturer
Sliding Perspex plastic	The Perspex plastic prism was constantly moved as the angle needed to be measured. The position of the prism creates random error for the angle of incident.	By performing more trials and marking more shape

Bibliography

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Weisstein, E. W. (2007). *Snell's Law*. Retrieved April 23, 2012, from Science World: http://scienceworld.wolfram.com/physics/SnellsLaw.html