Measurement of Reflection coefficients and validating Fresnel's Laws of Reflection

MSc Lab Short Experiments

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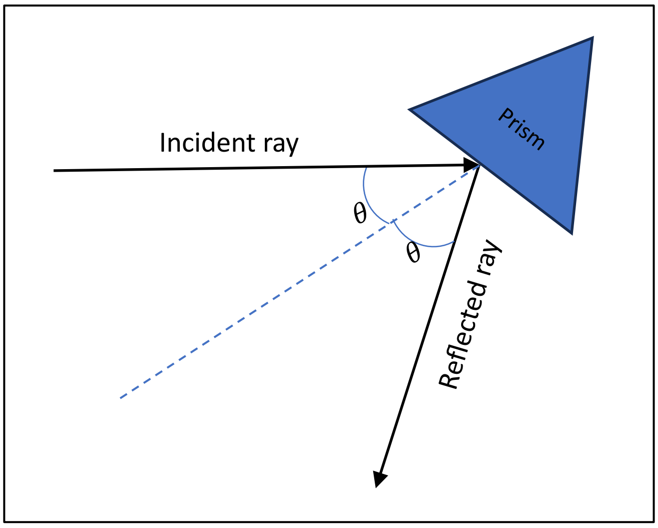
- **Introduction:** Reflection, a fundamental phenomenon of light, occurs when an electromagnetic wave encounters a boundary between two media, causing a portion of the wave to bounce back. In the 19th century, Augustin-Jean Fresnel formulated laws, based on wave theory of light, that describe how the intensity and polarization of reflected and transmitted light depend on the incident angle and refractive indices of the media. Later Maxwell, with his Electromagnetic Theory, gave much deeper explanation about Fresnel's laws. In this experiment we will try to measure the reflection coefficients at various incident angles for the p – polarised and s-polarised lights incident on a glass prism and validate the laws of reflections.

- **Theory and Working Principle:** Light is a transverse electromagnetic wave which is constituent of oscillating electric and magnetic fields in mutually perpendicular directions and perpendicular to direction of propagation. When the light is incident on the interface between 2 mediums, a part of it gets reflected back in the initial medium, other part gets refracted in the second medium. The reflection coefficients for s-polarized (Plane of vibration of electric field is perpendicular to the plane of incidence) and p-polarized (Plane of vibration is parallel to plane of incidence) are different. They are given by the relations below. For s-polarized, i.e. perpendicular polarization, the amplitude reflection coefficient is,



$$\boldsymbol{r}_{\perp}(\theta) = -\frac{\left(\sqrt{\boldsymbol{n}^2-\boldsymbol{sin}^2(\boldsymbol{\theta})}-\boldsymbol{cos}(\boldsymbol{\theta})\right)^2}{(\boldsymbol{n}^2-\mathbf{1})} \quad \text{----------------------------------(1)}$$

For p-polarized, i.e. parallel polarization, the amplitude reflection coefficient is,

$$\boldsymbol{r}_{\parallel}(\theta) = \frac{\boldsymbol{n}^2\boldsymbol{cos}(\boldsymbol{\theta})-\sqrt{\boldsymbol{n}^2-\boldsymbol{sin}^2(\boldsymbol{\theta})}}{\boldsymbol{n}^2\boldsymbol{cos}(\boldsymbol{\theta})+\sqrt{\boldsymbol{n}^2-\boldsymbol{sin}^2(\boldsymbol{\theta})}} \quad \text{----------------------------------(2)}$$

Where $\boldsymbol{\theta}$ is the angle of incidence on the prism surface.

Now in the experiment, we measure current flow through the sensor circuit due to incidence of light on the sensor. So, then the coefficients will be,

$$\boldsymbol{r}_{\perp}(\boldsymbol{\theta}) = \sqrt{\frac{\boldsymbol{i}_{\boldsymbol{\theta}\perp}}{\boldsymbol{i}_{\mathbf{0}\perp}}} \quad \text{-----------------------(3)}$$

$$\boldsymbol{r}_{\parallel}(\theta) = \sqrt{\frac{i_{\theta\parallel}}{i_{0\parallel}}} \quad \text{-----------------------(4)}$$

Where the $\boldsymbol{i}_{\boldsymbol{\theta}\perp}$ is the current flow at angle of incidence $\boldsymbol{\theta}$ for perpendicular polarization, $\boldsymbol{i}_{\mathbf{0}\perp}$ is current value for incident ray in perpendicular polarization and so on.

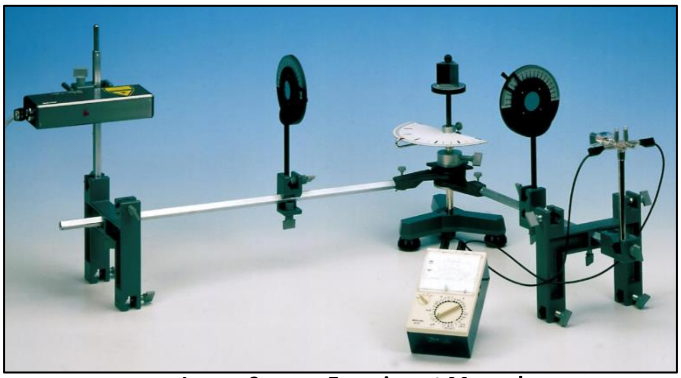


Image Source: Experiment Manual

Now if initially the incident light was linearly polarized with an angle 45^0 w.r.t the plane of incidence, then the change in angle of polarization $\boldsymbol{\alpha}$ (magnitude) with the change in the angle of incidence $\boldsymbol{\theta}$ will be,

$$\boldsymbol{\alpha}(\theta) = \boldsymbol{tan}^{-1}\left(\frac{|\boldsymbol{r}_{\perp}(\boldsymbol{\theta})|}{|\boldsymbol{r}_{\parallel}(\boldsymbol{\theta})|}\right) - \frac{\boldsymbol{\pi}}{\mathbf{4}} \quad \text{---------------------------(5)}$$

❖ **Tasks:** Here in this experiment, we are goanna do,

- Find the reflection coefficients for different incident angles for both parallel and perpendicular polarized light and plot them alongside with theoretical plot.
- Find the rotation of the angle of polarization with change in incident angle for 45^0 polarized incident ray.
- Plot the above alongside with theoretical plot.

❖ **Apparatus**: The apparatus used for this experiment are,

- Laser source.
- Polarizers.
- Prism.
- Experimental frame setup.
- Photosensor.
- Multimeter.
- Power supply.

❖ **Experimental Data and Result:**

Here all the data are processed in python. The data file and code can be accessed by clicking on the link,
https://github.com/Sujoy7471/Expt.Methods/tree/main/Frensel%20Laws%20of%20Reflection

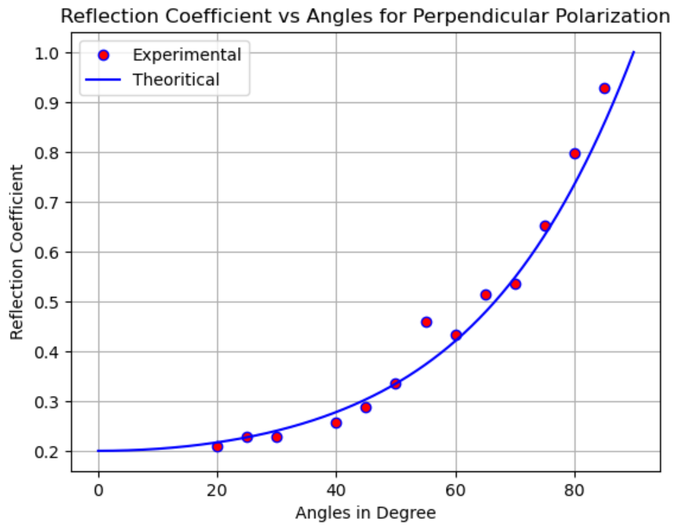
- **Table 1:** Table to obtain $r_{\perp}(\theta)$

Here photocurrent for incident ray is 39.4 mA with background value 3.0 mA.

So, $i_{\theta\perp}$ **= 36.4 mA**

θ (degree)	$ir_{\theta\perp}$ (mA) (Current flow with reflected and background light)	$ib_{\theta\perp}$ (mA) (current flow due to background light)	$i_{\theta\perp} = ir_{\theta\perp} - ir_{\theta\perp}$ (mA)	$r_{\perp}(\theta) = \sqrt{\frac{i_{\theta\perp}}{i_{0\perp}}}$
20	3	1.4	1.6	0.2097
25	3.4	1.5	1.9	0.2285
30	3.6	1.7	1.9	0.2285
40	4.3	1.9	2.4	0.2568
45	4.8	1.8	3	0.2871
50	5.8	1.7	4.1	0.3356
55	9.9	2.2	7.7	0.4599
60	9.1	2.3	6.8	0.4322
65	12.1	2.5	9.6	0.5136
70	13.4	3	10.4	0.5345
75	18.3	2.8	15.5	0.6526
80	25.9	2.7	23.2	0.7983
85	34.4	3	31.4	0.9288

- **Output graph for Table 1:**



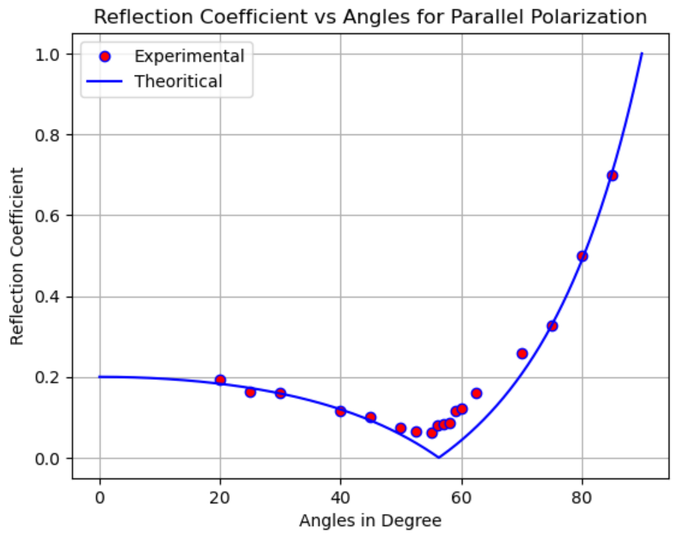
- **Table 2:** Table to obtain $r_{\parallel}(\theta)$

Here photocurrent for incident ray is 43.1 mA with background value 0.0 mA.

So, $i_{\theta\parallel}$ **= 43.1 mA**

θ (degree)	$ir_{\theta\parallel}$ (mA) (Current flow with reflected and background light)	$ib_{\theta\parallel}$ (mA) (current flow due to background light)	$i_{\theta\parallel} = ir_{\theta\parallel} - ir_{\theta\parallel}$ (mA)	$r_{\parallel}(\theta) = \sqrt{\frac{i_{\theta\parallel}}{i_{0\parallel}}}$
20	4.88	3.28	1.60	0.1927
25	3.96	2.81	1.15	0.1633
30	3.88	2.79	1.09	0.1590
40	2.99	2.41	0.58	0.1160
45	3.13	2.69	0.44	0.1010
50	3.24	3.01	0.23	0.0731
52.5	3.36	3.17	0.19	0.0664
55	3.13	2.96	0.17	0.0628
56	3.53	3.26	0.27	0.0791
57	3.45	3.16	0.29	0.0820
58	3.67	3.36	0.31	0.0848
59	4.4	3.83	0.57	0.1150
60	3.8	3.15	0.65	0.1228
62.5	5.6	4.5	1.10	0.1598
70	7	4.1	2.90	0.2594
75	10.2	5.6	4.60	0.3267
80	16.5	5.7	10.80	0.5006
85	28.2	7.2	21.00	0.6980

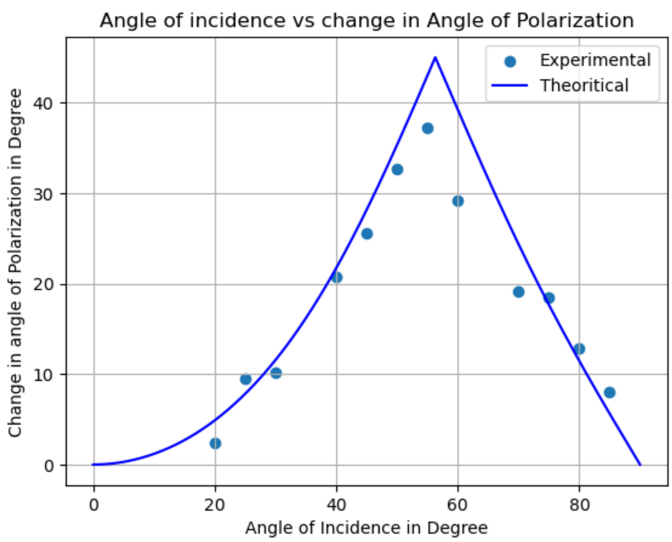
- **<u>Output Graph for Table 2:</u>**



- **<u>Table 3:</u>** Table to find the rotation of the angle of polarization with change in incident angle for 45^0 polarized incident ray.

θ (degree)	$r_\perp(\theta)$	$r_\parallel(\theta)$	$\alpha(\theta)$(degree)
20	0.2097	0.1927	2.4191
25	0.2285	0.1633	9.4481
30	0.2285	0.159	10.1682
40	0.2568	0.116	20.6907
45	0.2871	0.101	25.6185
50	0.3356	0.0731	32.7119
55	0.4599	0.0628	37.2243
60	0.4322	0.1228	29.1387
70	0.5345	0.2594	19.1121
75	0.6526	0.3267	18.4069
80	0.7983	0.5006	12.9089
85	0.9288	0.698	8.0749

- **<u>Output Graph for Table 3:</u>**



- **<u>Comments:</u>** After doing this practical and processing the data obtained, we can clearly see that they are in good agreement with the theoretical predictions. The deviation occurred due to the facts that no value can be measured with infinite precision, there is always errors due to human and apparatus.