



Experiment - 2

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Aim of the Experiment :

- 1) Verification of Malus law
- 2) Measurement of reflection coefficient of a glass plate for p- and s- polarizations.
- 3) Determination of Brewster angle.

Apparatus used in the Experiment :

- 1) Diode laser with power supply (3mW 650nm Red)
- 2) Kinematic Laser mount.
- 3) Polarizer.
- 4) Goniometer Based Detector Mount.
- 5) Glass slide Specimen
- 6) Pinhole photodetector with power supply
- 7) Optical rail (500 mm).

Theory :

Malus law : When light passes through a polariser the intensity of the emerging light is directly proportional to the square of $\cos \theta$, where θ is angle between polarizer and plane of polarised light.



Malus law ; $I = I_0 \cos^2 \theta$

Brewster's Angle : The angle of incidence at which a perfectly p-polarised light shows minimum reflection.

$$\tan \theta_B = \frac{n_2}{n_1}$$

Calculations:

Energy Reflection Coefficient = $\frac{\text{Detector Signal}}{\text{Direct Signal}} \times 100$.

As we obtained from graph,

Brewster angle (θ_B) $\approx 56^\circ$

So,

$$n_2 = n_1 \tan (\theta_B)$$

$$n_2 = \tan (56^\circ)$$

$$n_2 \approx 1.8800$$

Error Analysis:

$$\tan \theta_B = \frac{n_2}{n_1}$$

$$\text{So, } n_2 = n_1 \tan \theta_B$$

taking log both sides.

$$\log(n_2) = \log(n_1) + \log(\tan \theta_B).$$

differentiating both sides.

$$\frac{dn_2}{n_2} = \frac{dn_1}{n_1} + \frac{\sec^2 \theta_B}{\tan \theta_B} d\theta_B$$

We know that,

$$\theta_B \approx 57^\circ$$

$$\begin{aligned}\tan \theta_B &\approx 1.5399 \\ &\approx 1.54\end{aligned}$$

$$n_1 = 1.$$

$$n_2 = 1.54$$

$$\Delta \theta_B = 1 \text{ or } \left(\frac{\pi}{180} \right)$$

So,

$$\frac{\Delta n_2}{n_2} = \frac{\Delta n_1}{n_1} + \frac{\sec^2(57^\circ)}{\tan(57^\circ)} \frac{\pi}{180} \quad [\because \Delta n_1 = 0]$$

$$\Rightarrow \Delta n_2 = 0.0551$$

$$\therefore n_2 = 1.48 \pm 0.0551.$$



Sources of Error:

- 1) Zero error of the instrument can not be corrected.
- 2) The axis of diode laser and pinhole photo detector may not be aligned.
- 3) Refractive index of air is not exactly 1.
- 4) Least count error.

Conclusions :

- 1) Brewster angle from Graph $\approx 56^\circ$
- 2) Refractive index of glass (n_2) = 1.48 ± 0.055
- 3) The Graph shifted cannot be completely said to follow 'Malus Law'.
The Graph is shifted towards right along x-axis. This is due to instrumental error in measuring angle. So, the actual curve is of
$$I = I_0 \cos^2(\theta - \phi).$$
- 4) Graph between reflection coefficient and angle of incidence is monotonic for s-polarised light and it decreases to 0% and then increases for p-polarised light.

Precautions :-

- 1) Diode Laser and photo-detector should be aligned at same level and their axis should be same.
- 2) Measure observation in interval of 5° for more precise answer.



Observation for Verification of 'MALUS LAW':

Polarizer

Photodetector

Angle (degrees)

Current

248	2.11×10^{-5}
308	1.35×10^{-4}
318	8.00×10^{-4}
328	1.70×10^{-3}
338	2.80×10^{-3}
348	4.10×10^{-3}
358	5.30×10^{-3}
8	6.40×10^{-3}
18	7.00×10^{-3}
28	7.40×10^{-3}
38	7.00×10^{-3}
48	6.20×10^{-3}
58	5.30×10^{-3}
68	4.30×10^{-3}
78	3.00×10^{-3}
88	2.00×10^{-3}
98	9.00×10^{-4}
108	2.00×10^{-4}
118	2.05×10^{-5}
128	1.15×10^{-4}
138	7.00×10^{-4}
148	1.50×10^{-3}
158	2.80×10^{-3}
168	4.20×10^{-3}
178	5.80×10^{-3}
188	6.50×10^{-3}
198	7.10×10^{-3}

208

7.20×10^{-3}

218

6.70×10^{-3}

228

6.40×10^{-3}

238

5.30×10^{-3}

248

4.10×10^{-3}

258

3.00×10^{-3}

268

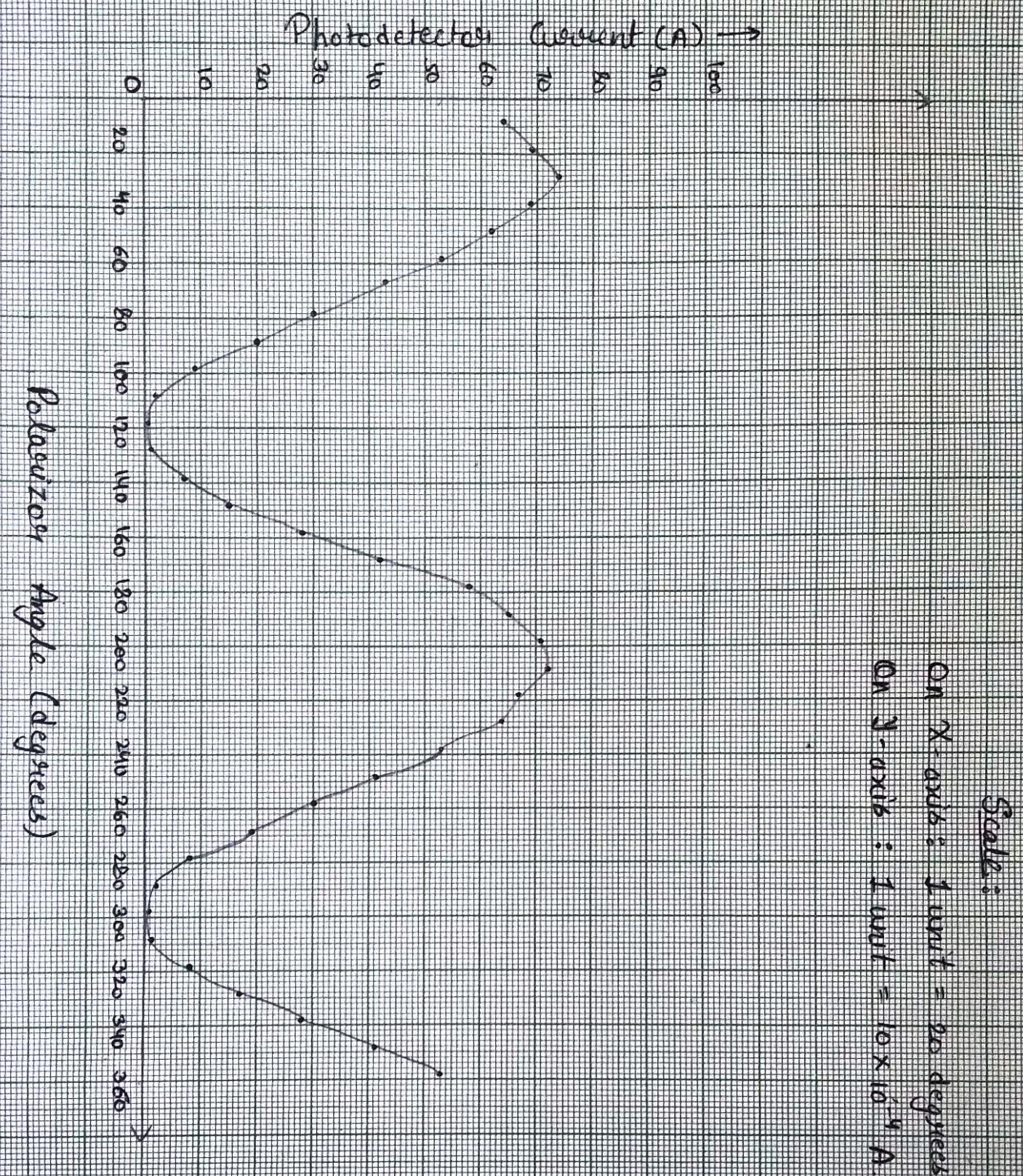
1.90×10^{-3}

278

8.00×10^{-4}

288

2.00×10^{-4}



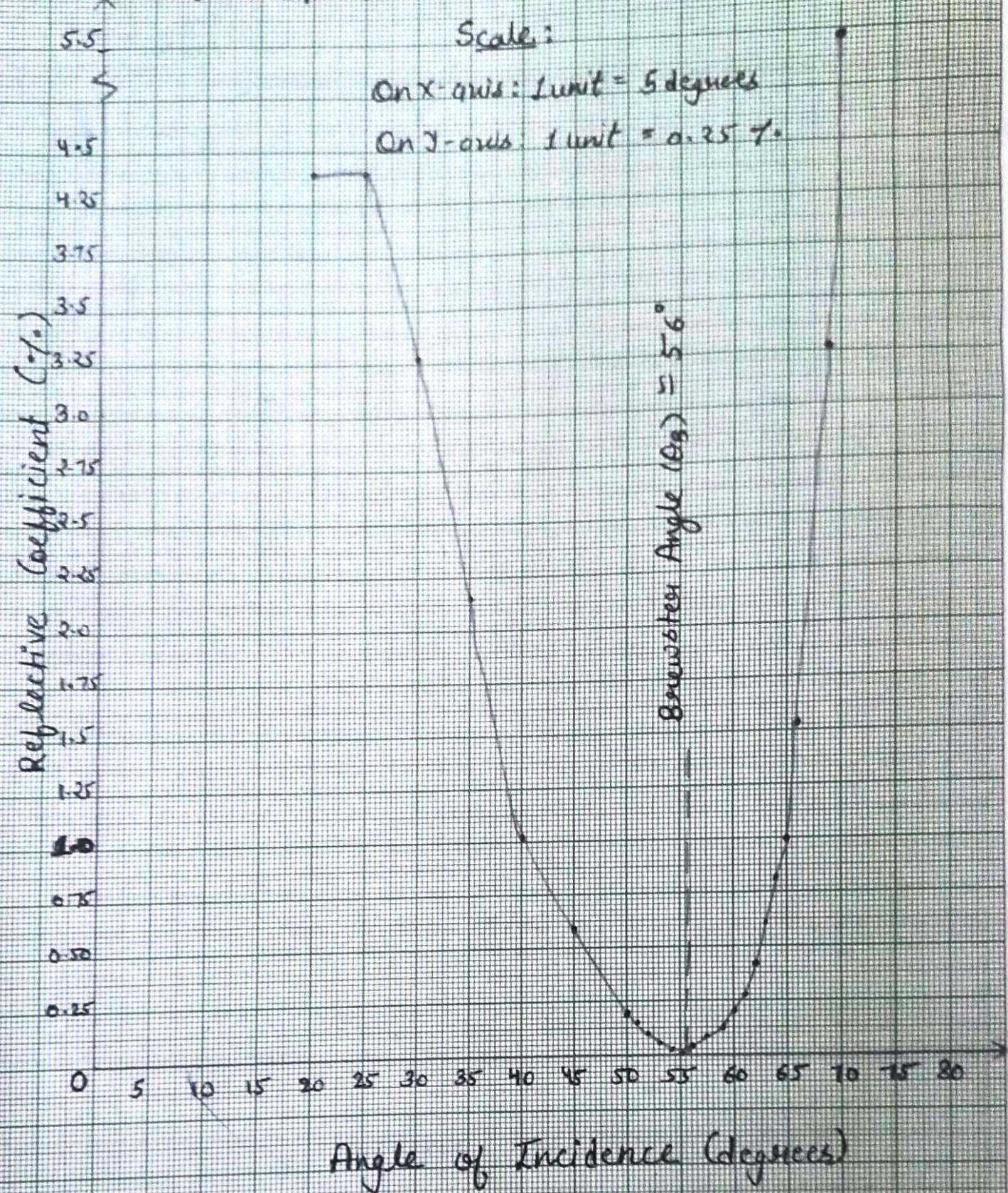


Observations for Brewster's Angle Determination:

Angle of polarizer for P-polarized light = 342°
 Photodetector current corresponding to incident
 intensity of P-polarized part (I_0) = 9.20×10^{-3} A.

Angle of Incidence (degrees)	Photo detector current for P-polarization (A)	Reflection coeff (%)
20	4.00×10^{-4}	4.34
25	4.00×10^{-4}	4.34
30	3.00×10^{-4}	3.26
35	2.00×10^{-4}	2.17
40	1.00×10^{-4}	1.08
45	5.30×10^{-5}	0.57
50	1.92×10^{-5}	0.20
51	1.45×10^{-5}	0.16
52	1.01×10^{-5}	0.10
53	5.70×10^{-6}	0.061
54	3.10×10^{-6}	0.033
55	1.20×10^{-6}	0.013
56	7×10^{-7}	0.007
57	1.90×10^{-6}	0.026
58	5.30×10^{-6}	0.057
59	1.04×10^{-5}	0.11
60	1.81×10^{-5}	0.19
61	2.50×10^{-5}	0.27
62	3.80×10^{-5}	0.41
63	5.40×10^{-5}	0.80
64	7.44×10^{-5}	0.80
65	1.07×10^{-4}	0.99
66	1.41×10^{-4}	1.53
68	3.00×10^{-4}	3.26
70	5.00×10^{-4}	5.43

for P-polarization:



Angle of polarizer for S-polarized light = 252°
 Photodetector current corresponding to incident intensity
 of S-polarized part (I_0) = 5.1×10^{-3} A.

Angle of Incidence (degrees)	Photodetector Current for S-polarization (A)	Reflective coeff (%)
20	3.00×10^{-4}	5.88
25	3.00×10^{-4}	5.88
30	3.00×10^{-4}	5.88
35	4.00×10^{-4}	7.84
40	5.00×10^{-4}	9.80
45	6.00×10^{-4}	11.76
50	7.00×10^{-4}	13.72
51	8.00×10^{-4}	15.68
52	8.00×10^{-4}	15.68
53	9.00×10^{-4}	17.65
54	9.00×10^{-4}	17.65
55	9.00×10^{-4}	17.65
56	1.00×10^{-3}	19.64
57	1.10×10^{-3}	21.56
58	1.10×10^{-3}	21.56
59	1.20×10^{-3}	23.52
60	1.20×10^{-3}	23.52
61	1.30×10^{-3}	26.95
62	1.40×10^{-3}	27.45
63	1.50×10^{-3}	29.41
64	1.6×10^{-3}	31.37
65	1.60×10^{-3}	31.37
66	1.70×10^{-3}	33.33
68	1.80×10^{-3}	35.29
70	1.90×10^{-3}	39.21

For S-polarization:

Scale:

On X-axis: 1 unit = 5 degrees

On Y-axis: 1 unit = 5 %

