Particulars of The Experiments Performed

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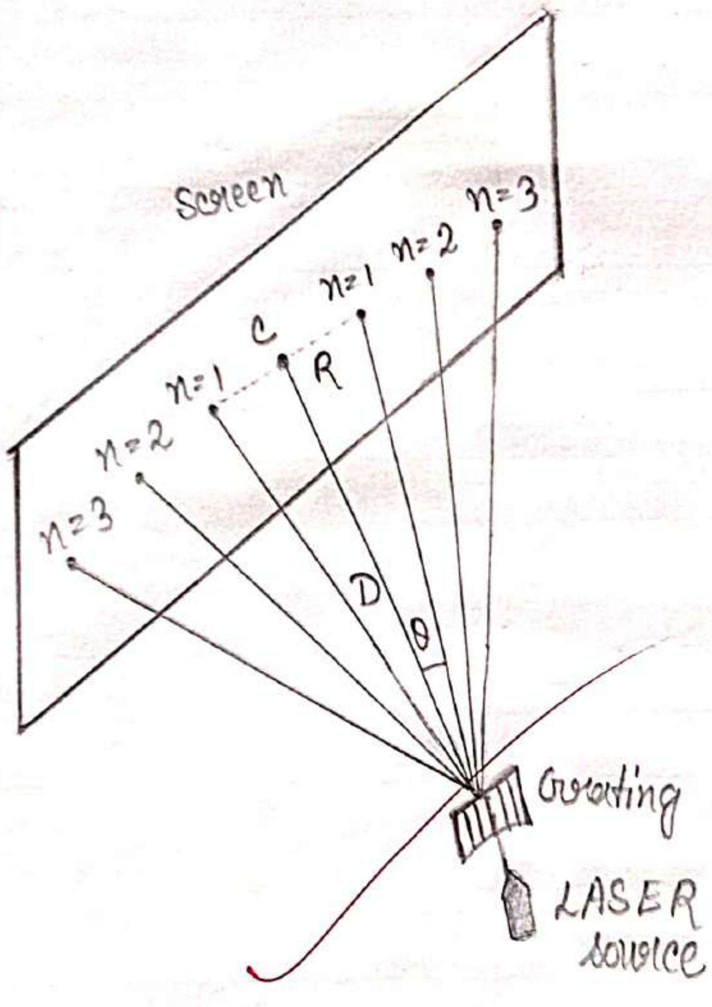

Screen
n=3
n=2
n=1
C
R
n=1
n=2
n=3
D
θ
Grating
LASER
source

Expt.No.

Experiment No : 1

Aim → To determine the wavelength of a LASER by diffraction method.

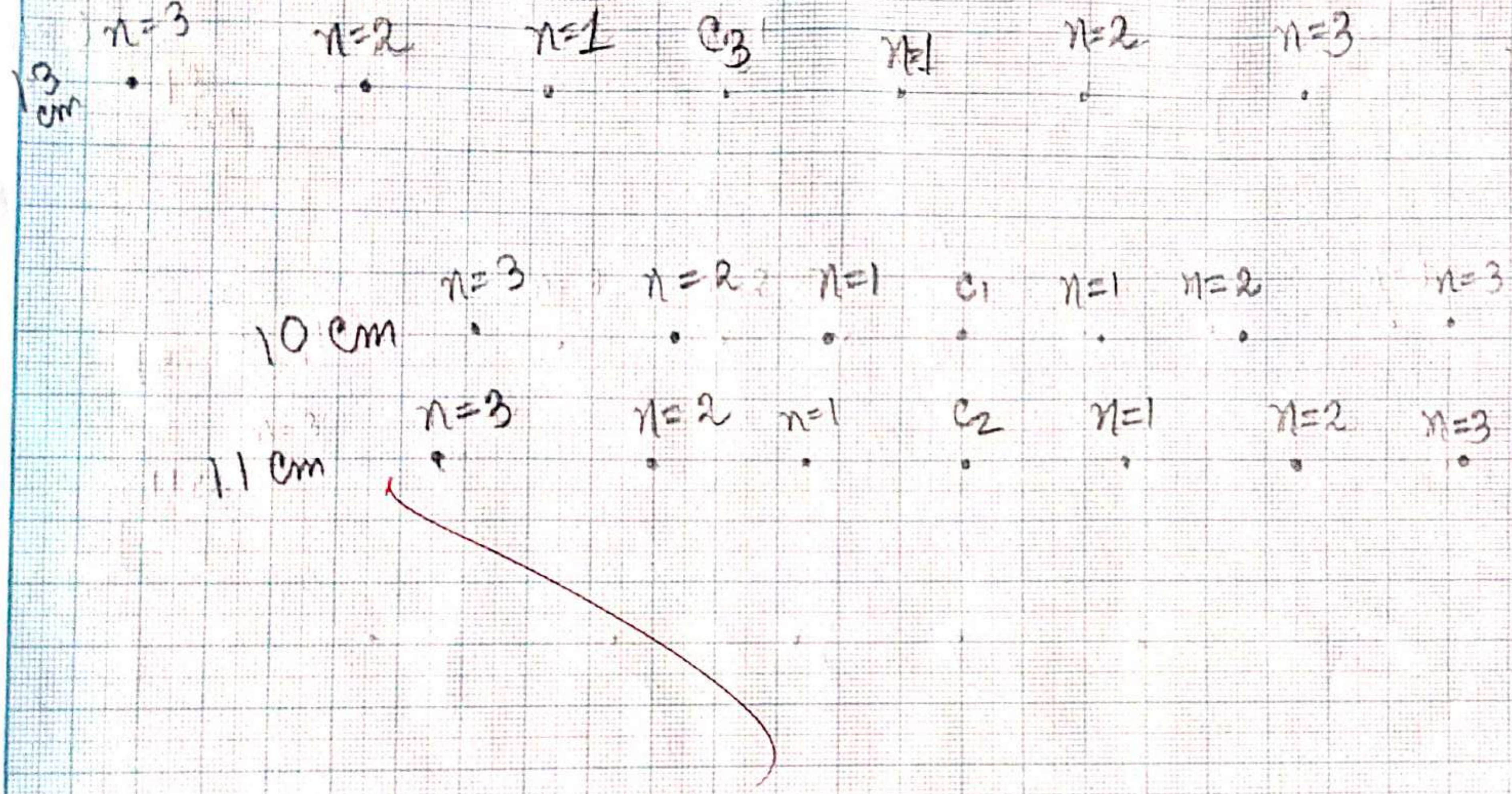
Apparatus → LASER source, Transmission grating, meter scale, screen with mm graph paper.

Theory → The bending of light from the sharp corners of an obstacle or slit (whose size is comparable with the wavelength of light) and spreading into the regions of the geometrical shadow is called diffraction of light.

If a parallel beam of light of wavelength λ is coming out from diffraction grating, placed vertically on the optical bench, then the diffracted rays from the grating, will form on a screen, a number of primary maxima of different order numbers (n) on both sides of the central maximum of zero order. If θ be the angle of diffraction of nth order primary maximum then, $\sin\theta = mn\lambda$, where m is the number of ruling per cm of the grating surface. Hence,

$$\lambda = \frac{\sin\theta}{mn}$$

If the value of m is known, the wavelength λ of unknown rays can be found out.


13 cm
n=3
n=2
n=1
C3
n=1
n=2
n=3
10 cm
n=3
n=2
n=1
C1
n=1
n=2
n=3
11 cm
n=3
n=2
n=1
C2
n=1
n=2
n=3

Expt.No.

Page No. 2
Date. 9.11.22

Observations:-

Table-1:- Measurement of angle of diffraction for different orders

No. of Obs.	distance between screen and the grating D (cm)	Order of the spot n	distance from the central spot Right Side, R (cm)	Left Side, L (cm)	Mean distance W=(R+L)/2 (cm)	$\sin\theta = \frac{W}{\sqrt{W^2+D^2}}$
		1	2.3	2.3	2.3	0.22
1	10	2	4.7	4.7	4.7	0.42
		3	8.2	8.2	8.2	0.63
		1	2.6	2.6	2.6	0.23
2	11	2	5.5	5.3	5.4	0.44
		3	8.5	8.5	8.5	0.64
		1	2.8	2.9	2.9	0.22
3	13	2	5.8	5.8	5.8	0.41
		3	9.1	10	9.8	0.60

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Expt.No

Calculation →

For order No → 1 :

Mean $\sin\theta = (0.22 + 0.23 + 0.22)/3 = 0.22$

$$\lambda = \frac{\sin\theta}{mn} = \frac{0.22}{2952.75 \times 1} = 7.4 \times 10^{-5} \text{ cm}$$

For order No → 2 :

Mean $\sin\theta = (0.42 + 0.44 + 0.41)/3 = 0.42$

$$\lambda = \frac{\sin\theta}{mn} = \frac{0.42}{2952.75 \times 2} = 7.1 \times 10^{-5} \text{ cm}$$

For order No → 3 :

Mean $\sin\theta = (0.63 + 0.64 + 0.60)/3 = 0.62$

$$\lambda = \frac{\sin\theta}{mn} = \frac{0.62}{2952.75 \times 3} = 6.9 \times 10^{-5} \text{ cm}$$

Mean Wavelength →

$$\lambda = \{(7.4 \times 10^{-5} + 7.1 \times 10^{-5} + 6.9 \times 10^{-5})/3\} \text{ cm}$$

$$= 7.13 \times 10^{-5} \text{ cm}$$

$$= 713 \text{ nm}$$

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Table :- 2 :- Calculation of wavelength

$$m = \frac{7500}{2.54} /cm = 2952.75 /cm$$

Order no. n	No of obs. (from Table 1)	Value of Sinθ (from Table 1)	Mean Sinθ	$\lambda = \frac{\sin\theta}{mn}$ (cm)	Mean wavelength (λ) (cm)	Mean wavelength (λ) (nm)
	1	0.22				
1	2	0.23	0.22	7.4×10^{-5}		
	3	0.22				
	1	0.42				
2	2	0.44	0.42	7.1×10^{-5}	7.13×10^{-5}	713
	3	0.41				
	1	0.63				
2	2	0.64	0.62	6.9×10^{-5}		
	3	0.60				

Calculation →

Calculate wavelength λ using the working formula

Proportional error is →

$$\left(\frac{\delta r}{r}\right)_{max} = \frac{\delta w}{w} + \frac{w \cdot \delta w + D \cdot \delta D}{w^2 + D^2}$$

$$= \frac{0.2}{2.3} + \frac{(2.3 \times 0.2) + (10 \times 0.2)}{(2.3)^2 + (10)^2}$$

$$= 0.08 + \frac{0.46 + 2}{5.29 + 100}$$

$$= 0.08 + \frac{2.46}{105.29}$$

$$= 0.08 + 0.023$$

$$= 0.10$$

∴ Maximum percentage error → $= \left(\frac{\delta r}{r}\right) \times 100$

$$= 0.10 \times 100 = 10\%$$

Calculation of Maximum percentage error :→

We know that $\lambda = \frac{\frac{W}{\sqrt{(W^2+D^2)}}}{mn}$

Therefore the proportional error is →

$$\left(\frac{\delta\lambda}{\lambda}\right)_{max} = \frac{\delta W}{W_{min}} + \frac{W\delta W + D.\delta D}{W^2+D^2}$$ [Where, $\delta W = \delta D = 2 \times 0.1$ Cm]

$$= \frac{0.2}{2.3} + \frac{(2.3 \times 0.2) + (10 \times 0.2)}{(2.3)^2 + (10)^2}$$

$$= 0.10$$

Calculate $d\lambda/\lambda$ putting values of W and D and multiply it by 100 to get maximum percentage error.

Conclusion :→

1. Wavelength of the given LASER is λ = 713 nm
2. Percentage error in λ = 10 %.

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Expt.No.

Precautions and discussions :

1. do not stare into the LASER beam.

2. The gratting plane must be parallel to the screen.

3. The LASER source should be steady.

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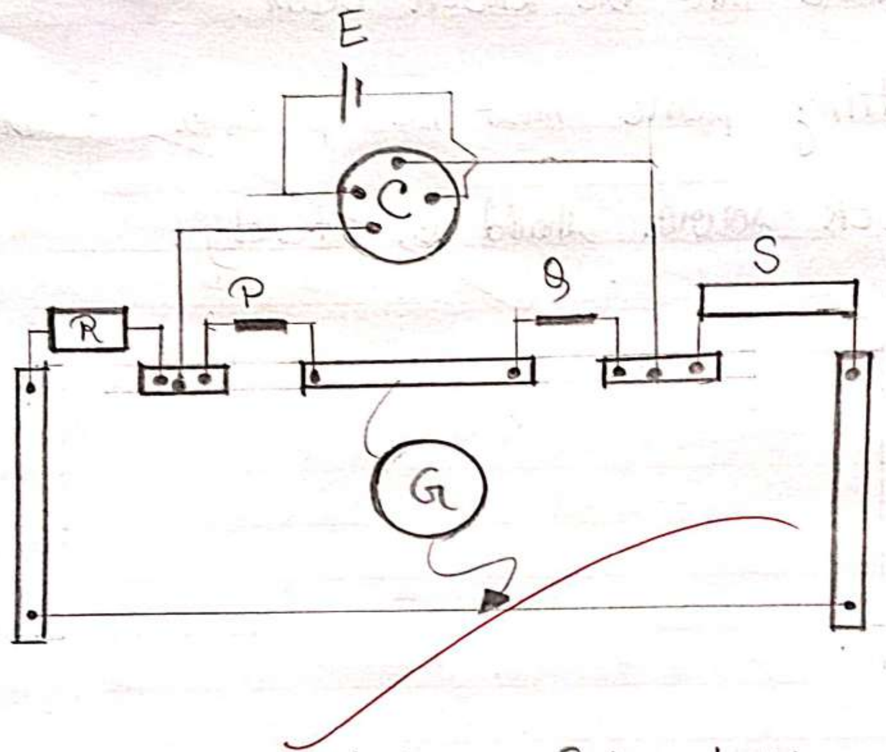

Circuit diagram of Carry Foster bridge

Expt.No.

Experiment No : 2

Aim : To determine the value of unknown resistance by Carey Foster's bridge.

Apparatus : Carey Foster's bridge, Unknown resistance, three resistance boxes of low value, Galvanometer, Plug commutator(C), Connection wires etc.

Theory :

Figure-1 shows a Carey Foster's bridge circuit. Here P and Q are two nearly equal resistances (each of 1Ω) ; S is a thick copper strip having zero resistance ; R is known resistance.

When the bridge is balanced, let the null point be l_1 cm from the left end of the bridge wire. If, by interchanging R and S, the null point is obtained at l_2 cm from the same end, we have $R = \rho(l_2 - l_1)$

$$\text{or } \rho = \frac{R}{(l_2 - l_1)} \quad \text{---} \quad (1)$$

where ρ is the resistance per unit length of the bridge wire.

Let the thick copper strip S be replaced by known resistance r and R be replaced by the unknown resistance X. Suppose that l_1' is the distance

Calculation →

For Table 1 →

For order no → 1 →

$$\rho = \frac{R}{(l_2 - l_1)} = \frac{0.2}{19.25} = 0.01\ \Omega/cm$$

of the null point from the left end of the bridge wire obtain with this circuit. Let l_2' be the distance of the null point from the same end obtained with the circuit when r and X are interchanged. Then

$$X = r - \rho(l_2' - l_1') \quad \text{--- (2)}$$

Equations (1) and (2) are the working formulas of the experiment.

Observations:

Instrumental Specifications :→

1. DC voltage source : Battery eliminator
2. Range of the Galvanometer : 250 – 0 – 250 μA

Table - 1: Determination of Resistance per unit length (ρ) of the bridge wire.

No of Obs	Resistance in (Ω)		Position of the null points (cm)			$(l_2 - l_1)$ (cm)	$\rho = \frac{R}{(l_2 - l_1)}$ (Ω/cm)	Mean ρ (Ω/cm)
	Left gap	Right gap	For direct current	For reverse current	Mean			
1	R=0.2	0	42	42.5	l_1=42.25	19.25	0.01	
	0	R=0.2	61.5	61.5	l_2=61.5			

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Calculation:→

- For Table → 1 →

For order no → 2 →

$$P = \frac{R_1}{(l_2 - l_1)} = \frac{0.4}{25.75} = 0.01\ \Omega/cm$$

For order no → 3 →

$$P = \frac{R_2}{(l_2 - l_1)} = \frac{0.6}{33.75} = 0.02\ \Omega/cm$$

$$\text{Mean } P = \{(0.01 + 0.01 + 0.02)/3\}\ \Omega/cm = 0.013\ \Omega/cm$$

- For Table → 2 →

For order no → 1 →

$$X = \{r - P(l_2' - l_1')\} = \{0.2 - 0.013(-9.5)\}\ \Omega$$
$$= \{0.2 + 0.12\}\ \Omega = 0.32\ \Omega$$

For order no → 2 →

$$X = \{r_1 - P(l_2' - l_1')\} = \{0.4 - 0.013(1)\}\ \Omega$$
$$= 0.387\ \Omega$$

For order no → 3 →

$$X = \{r_2 - P(l_2' - l_1')\} = \{0.6 - 0.013(19)\}\ \Omega$$
$$= \{0.6 - 0.247\}\ \Omega$$
$$= 0.353\ \Omega$$

$$\text{Mean } X = (0.32 + 0.387 + 0.353/3)\ \Omega = 0.35\ \Omega$$

Expt.No.

Date. 5.11.22

No of obs.	Resistance in (Ω)		Positions of the null points (cm)			(l_2-l_1) (cm)	$\rho=\frac{R}{(l_2-l_1)}$ (Ω/cm)	Mean ρ (Ω/cm)
	Left gap	Right gap	For direct current	For reverse current	Mean			
2	$R_1=0.4$	0	37.5	37.5	$l_1=37.5$	25.75	0.01	
	0	$R_1=0.4$	63.5	63	$l_2=63.25$			
3	$R_2=0.6$	0	34.5	34.5	34.5	33.75	0.02	0.013
	0	$R_2=0.6$	68.5	69	68.25			

Table - 2 : determination of Unknown Resistance X

No. of obs	Resistance in the (Ω)		Positions of the null points for (cm)			$(l_2'-l_1')$ (cm)	$X = r-\rho(l_2'-l_1')$ (Ω)	Mean X (Ω)
	Left gap	Right gap	Direct Current	Reverse Current	Mean			
1	$r=0.2$	X	56	56	$l_1'=56$	−9.5	0.32	
	X	$r=0.2$	46.5	46.5	$l_2'=46.5$			
2	$r_1=0.4$	X	51	51	51	1	0.387	0.35
	X	$r_1=0.4$	52	52	52			
3	$r_2=0.6$	X	42.5	42.5	42.5	19	0.353	
	X	$r_2=0.6$	61.5	61.5	61.5			

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Expt.No.

Calculations:

Calculate the value of ρ and x using working formulas (1) and (2)

Calculation of Maximum Percentage Error:

We have, $\rho = \frac{R}{(l_2 - l_1)}$

The maximum proportional error,

$$\left(\frac{\delta \rho}{\rho}\right)_{max} = \frac{\delta(l_2 - l_1)}{(l_2 - l_1)}$$ [where, $\delta l = 0.1 cm$ (one division of meter scale)]

$$= \frac{2\,\delta l}{(l_2 - l_1)}$$

$$= \frac{2 \times 0.1}{19.25}$$

$$= 0.013$$

Using a typical observed value of $(l_2 - l_1)$ we can calculate maximum percentage error in ρ as

$$\left(\frac{\delta \rho}{\rho}\right)_{max} \times 100\%$$

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Calculations →

$$\left(\frac{\delta x}{x}\right)_{max} = \left(\frac{\delta P}{P}\right)_{max} + 2\,\frac{\delta l}{|(l_2' - l_1')_{min}|}$$

$$= 0.013 + 2 \times \frac{0.1}{|-9.5|}$$

$$= 0.013 + \frac{0.2}{9.5}$$

$$= 0.013 + 0.02 = 0.03$$

Percentage error in $P = 0.013 \times 100$
$= 1.03\%$.

As $X = r - \rho(l_2' - l_1')$

$$\left(\frac{\delta X}{X}\right)_{max} = \left(\frac{\delta \rho}{\rho}\right)_{max} + 2\frac{\delta l}{|(l_2' - l_1')_{min}|}$$

$$= 0.013 + 2 \times \frac{0.1}{|-9.5|} = 0.03$$

Now using a typical set set of observed data we can calculate $\left(\frac{\delta X}{X}\right)_{max} \times 100\%$ as maximum percentage error.

Maximum percentage error $= \left(\frac{\delta X}{X}\right)_{max} \times 100\%$

$= 0.03 \times 100\% = 3\%$

Conclusion :-

1. The resistance per unit length of the bridge wire $\rho = 0.013$ (Ω/cm)
2. Percentage error in $\rho = 1.03\%$
3. The value of unknown resistance, $X = 0.35$ (Ω)
4. Percentage error in $X = 3\%$

Precautions and discussions :-

1. If the bridge wire is not perfectly uniform, R is to be chosen such that the length between two null points is as large as possible.

2. Also the unknown resistance X should be measured by selecting values of r which give greater lengths between the null points l_1' and l_2'.

3. The error due to the "end correction" does not appear in this method of measurement since the difference of the lengths between the null point is involved.

4. The experiment is to be performed with direct as well as reverse current to eliminate the effect of current due to thermo-emf.

5. The specific resistance of the bridge wire can be obtained by multiplying ρ with the area of cross-section of the wire.

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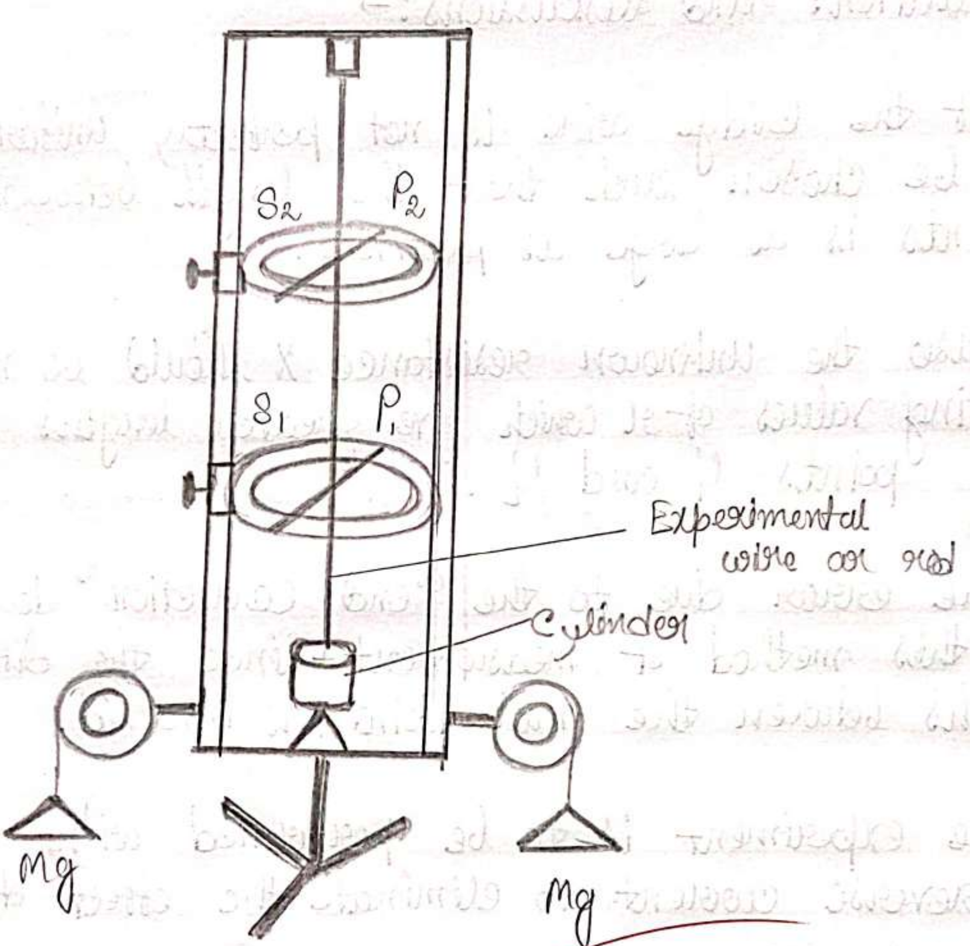

S_2
P_2
S_1
P_1
Experimental
wire or rod
Cylinder
Mg
Mg

Experiment No:-4

Aim: To determine the rigidity modulus of the material of a wire by dynamic method.

Apparatus: Barton's rigidity apparatus, screw gauge, slide calipers, weight box, meter scale.

Theory: The modulus of rigidity of a wire is defined as the ratio of shearing stress and shearing strain within elastic limit.

If a solid cylinder be suspended by a long wire from a torsion head, forming a torsional pendulum. Suppose the length of the wire = l, radius of the wire = r, load placed on each of the pans = m, the diameter of the cylinder = d, twist in the wire = θ radian,

then the moment of torsional couple = $\frac{\pi \eta \theta r^4}{2l}$,
where η = modulus of rigidity of the material of the wire.
The moment of the external couple exerted by the load on the pans = mgd.

For equilibrium

$$\frac{\pi \eta \theta r^4}{2l} = mgd$$

or, $$\eta = \frac{mgd\,2l}{\pi \theta r^4}$$

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If the angle of twist is expressed in degrees and if it be ϕ degree then $\phi^\circ = \frac{\pi\phi}{180}$ radian $= \theta$

So $\eta = \frac{mgd\,2\,l \times 180}{\pi r^4 \pi \phi} = \frac{360\,gld}{\pi^2 r^4}\left(\frac{m}{\phi}\right)$

The modulus of rigidity of a wire is given by,

$$\eta = \frac{360\,ldg}{\pi^2 r^4}\left(\frac{m}{\phi}\right)$$

This is the working formula for determination of modulus of rigidity of the material of the wire, where, l = length of the wire, g = acceleration due to gravity, d = diameter of the cylinder, r = radius of wire, m = mass of the weight, ϕ = angle of twist in degree.

Observations :→

1. Length of the wire (l_1) = 42 cm. (up to upper circular scale)

2. Length of the wire (l_2) = 84 cm. (up to lower circular scale)

Calculation :→

For Table → 1

For order no - 1 - Circular scale reading = (73 - 22) × 0.01
= 0.51

For order no - 2 - circular scale reading = (77 - 22) × 0.01
= 0.55

For order no - 3 - Circular scale reading = (83 - 22) × 0.01
= 0.061

Mean diameter = $\frac{1.51 + 1.55 + 1.61}{3}$

= $\frac{4.67}{3}$ = 1.55

For Table → 2

For order no - 1 - Vernier scale reading → 7 × 0.01 = 0.07

For order no - 2 - Vernier scale reading → 5 × 0.01 = 0.05

For order no - 3 - Vernier scale reading → 6 × 0.01 = 0.06

Mean diameter = $\frac{6.37 + 6.35 + 6.36}{3}$ = $\frac{19.08}{3}$ = 6.36

Table - 1 : Determination of radius of the wire (r)

Least count of the screw gauge = $\frac{1m}{100}$ = 0.01 mm

No. of obs.	Linear scale reading (mm)	Circular scale reading	Total reading D (mm)	Mean diameter D (mm)	Radius r = D/2 (mm)	Radius r (Cm)
1	1mm	0.51	1.51			
2.	1mm	0.55	1.55	1.55	0.77	0.077
3	1mm	0.61	1.61			

Table - 2 : Determination of diameter of the cylinder (d)

Vernier constant of the slide calipers = $\frac{0.1}{10}$ = 0.01 Cm

No. of obs.	Main Scale Reading (cm)	Vernier scale reading	Total reading d (cm)	Mean diameter d (cm)
1	6.3	0.07	6.37	
2	6.3	0.05	6.35	6.36
3	6.3	0.06	6.36	

Calculation →

For Table-3 :→

For order no. 1 → Mean reading → $\frac{1}{2}(5+6) = \frac{11}{2} = 5.5$ → upper scale

" " → $\frac{1}{2}(4+5) = \frac{9}{2} = 4.5$ → Lower scale

For order no. 2 → Mean reading → $\frac{1}{2}(20+21) = 20.5$ → Upper scale

" " → $\frac{1}{2}(35+36) = 35.5$ → Lower scale

For order no. 3 → Mean reading → $\frac{1}{2}(35+36) = 35.5$ → Upper scale

" " → $\frac{1}{2}(68+67) = 67.5$ → Lower scale

For order no. 4 → Mean reading → $\frac{1}{2}(53+52) = 52.5$ → Upper scale

" " → $\frac{1}{2}(97+97) = 97$ → Lower scale

For order no. 5 → Mean reading → $\frac{1}{2}(68+63) = 67.5$ → Upper scale

" " → $\frac{1}{2}(130+131) = 130.5$ → Lower scale

For order no. 6 → Mean reading → $\frac{1}{2}(83+83) = 83$ → upper scale

" " → $\frac{1}{2}(160+160) = 160$ → Lower scale

For order no. 1 → Angle of twist → $(5.5-5.5) = 0$ → upper scale $(4.5-4.5) = 0$ Lower scale

For order no. 2 → " " " → $(20.5-5.5) = 15$ → " $(35.5-4.5) = 31$ → "

For order no. 3 → $(35.5-5.5) = 30$ → " $(67.5-4.5) = 63$ → "

For order no. 4 → $(52.5-5.5) = 47$ → " $(97-4.5) = 92.5$ → "

For order no. 5 → $(67.5-5.5) = 62$ → " $(130.5-4.5) = 126$ → "

For order no. 6 → $(83-5.5) = 77.5$ → " $(160-4.5) = 155.5$ →

Table - 3: determination of angle of twist for various loads

No. of obs.	Load on each pan, m (gm)	Pointer reading in degree: When load increasing (a)		Pointer reading in degree: When load decreasing (b)		Mean reading ½(a+b) (degree)		Angle of twist φ (degree)	
		Upper scale	Lower scale	Upper scale	Lower scale	Upper scale	Lower scale	Upper scale	Lower scale
1	0	5	4	6	5	5.5	4.5	0	0
2	50	20	35	21	36	20.5	35.5	15	31
3	106	35	68	36	67	35.5	67.5	30	63
4	150	53	97	52	97	52.5	97	47	92.5
5	200	68	130	63	131	67.5	130.5	62	126
6	250	83	160	83	160	83	160	77.5	155.5

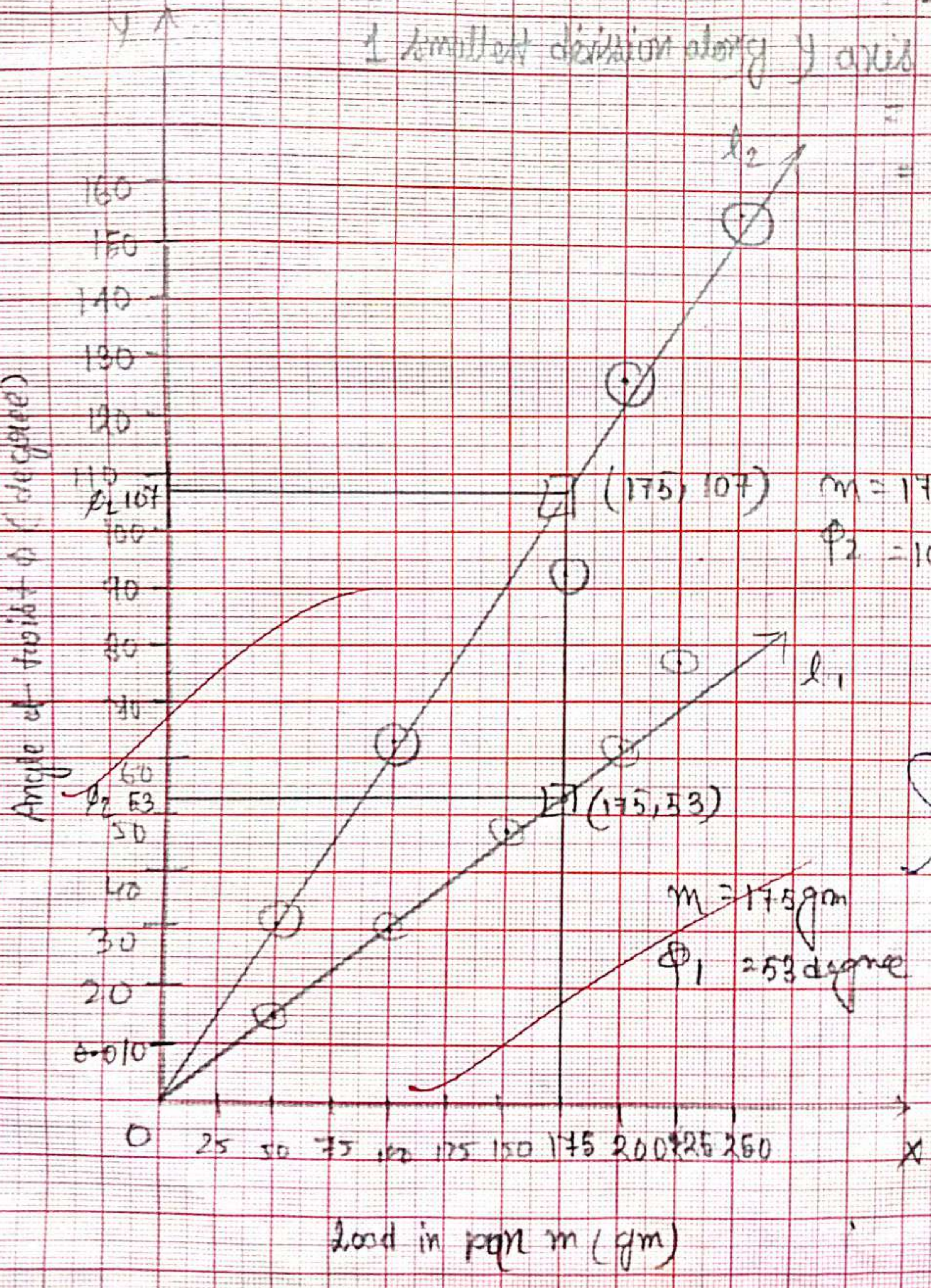
Scale – 1 smallest division along x axis is $= \frac{25}{10}$ gm

$= 2.5$ gm

1 smallest division along y axis is

$= \frac{10}{10}$ degree

$= 1$ degree



Expt.No.

Graph :→

Plot of angle of twist for various loads

Calculations :→

From the graph : $m/\phi_1 = \frac{175}{53} = 3.3$ (for l_1)
$m/\phi_2 = \frac{175}{107} = 1.6$ (for l_2)

Modulus of rigidity of the material of the given wire by static method is

$$\eta = \left[\frac{360 \cdot gdl}{\pi^2 r^4}\right]\left(\frac{m}{\phi}\right) \text{ dynes/cm}^2$$

$$\eta_1 = \frac{360 \times 980 \times l_1 \times d \times m}{(\pi)^2 \times (r)^4 \times \phi_1} \text{ dynes/cm}^2 \text{ (From the graph for } l_1)$$

$= 11.07 \times 10^{11}$ dynes/cm^2

$$\eta_2 = \frac{360 \times 980 \times d \times l_2 \times m}{(\pi)^2 \times (r)^4 \times \phi_2} \text{ dynes/cm}^2 \text{ (From the graph for } l_2)$$

$= 10.73 \times 10^{11}$ dynes/cm^2

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Expt.No.

Graph :→

Plot of angle of twist for various loads

Calculations :→

From the graph : $m/\phi_1 = \frac{175}{53} = 3.3$ (for l_1)
$m/\phi_2 = \frac{175}{107} = 1.6$ (for l_2)

Modulus of rigidity of the material of the given wire by static method is

$$\eta = \left[\frac{360 \cdot g d l}{\pi^2 r^4}\right]\left(\frac{m}{\phi}\right) \text{ dynes/cm}^2$$

$$\eta_1 = \frac{360 \times 980 \times l_1 \times d \times m}{(\pi)^2 \times (r)^4 \times \phi_1} \text{ dynes/cm}^2$$ (From the graph for l_1)

$= 11.07 \times 10^{11}$ dynes/cm²

$$\eta_2 = \frac{360 \times 980 \times d \times l_2 \times m}{(\pi)^2 \times (r)^4 \times \phi_2} \text{ dynes/cm}^2$$ (From the graph for l_2)

$= 10.73 \times 10^{11}$ dynes/cm²

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From graph →

For l_1 →

$$\eta_1 = \frac{360 \times 980 \times 6.35 \times 42 \times 3.3}{(3.14)^2 \times (0.077)^4} \text{ dynes/cm}^2$$

$$= 11.07 \times 10^{11} \text{ dyn/cm}^2$$

For l_2 →

$$\eta_2 = \frac{360 \times 980 \times 6.35 \times 84 \times 1.6}{(3.14)^2 \times (0.077)^4} \text{ dynes/cm}^2$$

$$= 10.7 \times 10^{11} \text{ dynes/cm}^2$$

$$\eta = \frac{\eta_1 + \eta_2}{2} = \frac{11.07 \times 10^{11} + 10.7 \times 10^{11}}{2} = 10.9 \times 10^{11} \text{ dyn/cm}^2$$

Average, $\eta = \frac{\eta_1 + \eta_2}{2} = 10.9 \times 10^{11}$ dyn/cm^2

Calculation of Maximum Percentage error :→

For the given relation $\eta = \frac{360 l d g}{\pi^2 r^4} \left(\frac{m}{\phi}\right)$

The maximum proportional error is given by

$$\left(\frac{\delta \eta}{\eta}\right)_{max} = \frac{\delta d}{d} + \frac{\delta l}{l} + 4\frac{\delta r}{r} + \frac{\delta \phi}{\phi}$$

$$= \frac{0.01}{6.35} + \frac{0.2}{42} + 4 \times \frac{0.001}{0.077} + \frac{0.5}{15}$$

$$= 0.0015 + 0.0042 + 0.052 + 0.033$$

$$= 0.09$$

Where $\delta d = 0.01$ cm, $\delta l = 2 \times 0.1$ cm $= 0.2$ cm, $\delta r = 0.001$ cm
$\delta \phi = 0.5^{\circ}$

Substituting a set of measured value of d, l, r and ϕ we can calculate the proportional error. Then multiplying it by 100 we can get maximum percentage error in η

The percentage error is equal to $\left(\frac{\delta \eta}{\eta}\right)_{max} \times 100\%$.

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Conclusion :

1. Modulus of rigidity of the wire $\eta = 10.9 \times 10^{11}$ dyne/cm^2

2. The percentage error in η = 9 %.

Precations and discussions:

1. Care is to be taken to see that the suspension wire may coincide with the axis of the cylinder

2. The radius r of the suspension wire occurs in 4th power and hence it should be measured very carefully otherwise a small error in the measurement of r will increase the error in the determination of n by four time.

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