Introduction to Error Analysis and Graph Drawing

1.1 • Name of Experiment → Mass Spring System

• Aim → To determine spring constant of given spring

• Apparatus Used → Spring (of mass 45g), Spring Stand, Stopwatch

• Theory → Formula Used are

$$T = 2\pi \sqrt{\frac{m_0 + (m_s/3)}{k}}$$

m_0 = mass hung
m_s = mass of spring
k = spring constant
T = Time Period

Error in spring constant,

$$\frac{\Delta k}{k} = \frac{\Delta m}{m} + \frac{2\Delta T}{T}$$

• Observation Table:

Sl.	T_{20} (sec)	T (sec)	k (Nm^{-1})
1.	8.570	0.428	9.662
2.	8.667	0.433	9.418
3.	8.218	0.411	~~9.~~ 10.52

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1.1 Calculation:

$$k = \frac{9.662 + 9.418 + 10.52}{3} = 9.86\ Nm^{-1}$$

$$\frac{\Delta k}{k} = \frac{\Delta m}{m} + \frac{2\Delta T}{T} \qquad \left\{ T = \frac{0.428 + 0.433 + 0.411}{3},\ T = 0.424 \right\}$$

$$\Rightarrow \frac{\Delta k}{9.86} = \frac{0.1}{45} + \frac{2 \times 0.01}{0.424} \Rightarrow \Delta k = 0.48\ Nm^{-1}$$

1.2 Calculation:

$$\rho_{avg} = \frac{2(0.00014) + 0.00015}{3} = 0.000143\ \Omega\,cm$$

$$= 1.43 \times 10^{-6}\ \Omega\,m$$

$$\frac{\Delta \rho}{\rho} = \frac{\Delta R}{R} + \frac{2\Delta d}{d} + \frac{\Delta l}{l}$$

$$\frac{\Delta \rho}{1.43 \times 10^{-4}} = \frac{0.1}{11.53} + \frac{2 \times 0.001}{19} + \frac{0.1}{20}$$

$$\Delta \rho = 0.130 \times 10^{-4}\ \Omega\,cm$$

$$\left(\Delta R = \frac{1}{10}\Omega,\ \Delta d = 0.001\,cm,\ \Delta l = 0.1\,cm \right)$$

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- **Result** : Spring constant of spring is 9.86 N/m

1.2 - **Name of Experiment** → Resistivity of nichrome wire

- **Aim** → To measure resistivity of nichrome wire

- **Apparatus Used** → Multimeter, Screw Gauge, Nichrome wire, Scale

- **Theory** → least count of screw gauge = $\frac{\text{One main scale div (1 MSD) cm}}{\text{No. of rotations on CS} \times \text{Total no. of CS divisions}}$

$$\rho = \frac{R\pi d^2/4}{L}$$

R = resistance of nichrome wire
d = diameter of nichrome wire
L = length of nichrome wire

- **Observation**:
Least count of screw gauge = 0.01 mm = .001 cm
Zero error on C.S = 0

* Diameter of wire

S.No	MSR (a)	CSR (b)	Total (a+b×L.C) cm
1.	0	19	.019 cm
2.	0	19	.019 cm
3.	0	19	.019 cm

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S.No.	L (cm)	Resistance(Ω)	Resistivity (Ωcm)
1.	10	5.2	0.00014
2.	30	19	0.00015
3.	20	10.4	0.00014

• Result → Resistance of given nichrome wire is 0.130×10^{-4} Ωcm

1.3. Name of Experiment → Finding τ and initial voltage across capacitor

• Aim → To find τ and initial voltage across capacitor

• Theory → $V = V_0 e^{-t/\tau}$

$$\log V = \log V_0 - \frac{t}{\tau} \log e$$

Time(sec)	Voltage (V)
6.2	5.53
8.7	4.89
10.0	4.58
12.5	4.04
16.3	3.35
18.4	3.05
22.4	2.45

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1.3 Calculation

$$\frac{\log 4.58 - \log 0.33}{10 - 62.5} = -\frac{\log e}{\tau}$$

$$\frac{1.14}{52.5} = \frac{\log e}{\tau}$$

$$\tau = 19.8 \text{ sec}$$

$$\log V = \log V_0 - \frac{t}{\tau} \log e$$

$$\log 4.56 = \log V_0 - \frac{10}{19.8} \log e \Rightarrow V_0 = 7.7V$$

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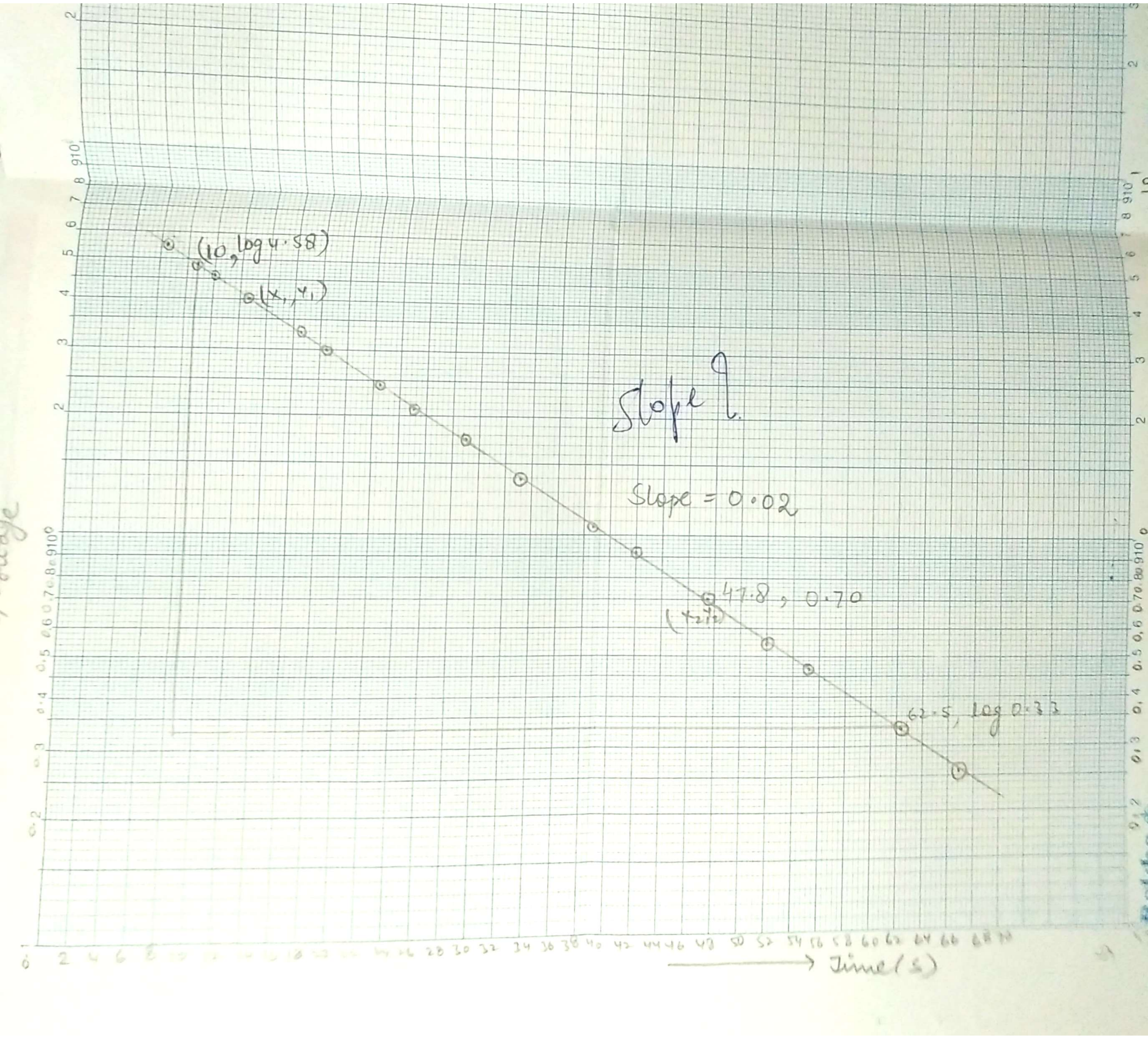

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.4 Calculation :

$$\frac{\log 63.48 - \log 30.77}{\log 3.4 - \log 4.6} = n$$

$$n = \frac{0.314}{-0.13} = -2.4$$

$$\log 63.48 = \log C - 2.4 \log 3.4$$

$$\log C = \log 63.48 + 2.4 \log 3.4$$

$$C = 10^3$$

$$F = CD^n \Rightarrow 10^3 \times (16)^{-2.4}$$

$$\Rightarrow 1.288$$

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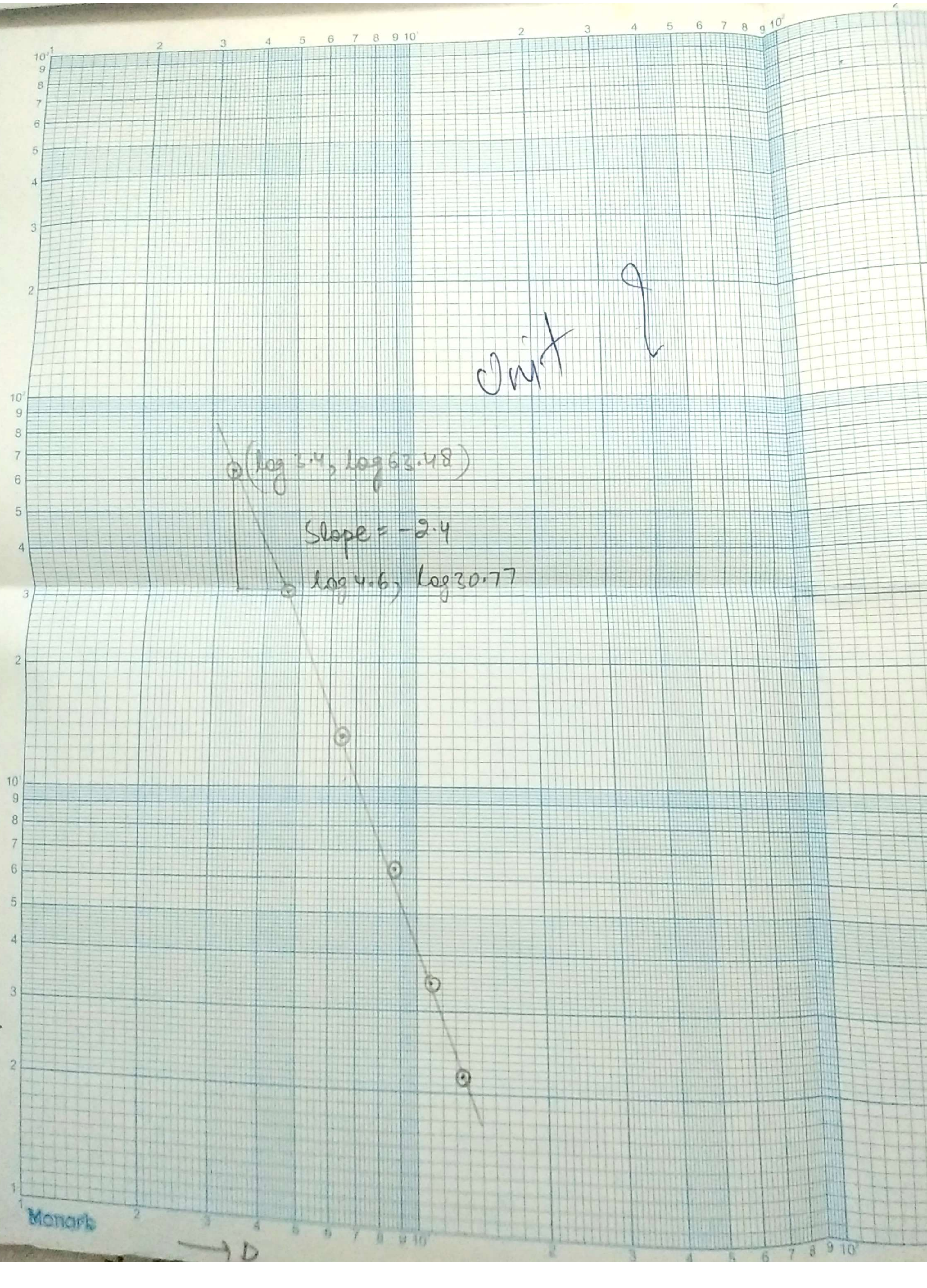

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Time(sec)	Voltage (V)
25.0	2.16
28.5	1.85
32.9	1.44
38.8	1.09
42.0	0.92
47.8	0.70
52.0	0.56
55.4	0.47
62.5	0.33
67.2	0.26

- Result → The τ of capacitor is 19.8 sec and initial votage is 7.7V.

1.4 • Name of Experiment → Resonant Rings

- Aim → To predict resonant frequency for a ring of diameter 16cm

- Theory :

$$F = CD^n$$
$$\log F = \log C + n\log D$$

F = Resonant frequency
D = Diameter

Diameter (cm)	3.4	4.6	6.4	8.7	10.9	13.2
Frequency (hz)	63.48	30.77	13.38	6.24	3.58	2.19

- Result → Resonant frequency for ring of (d=16cm) is

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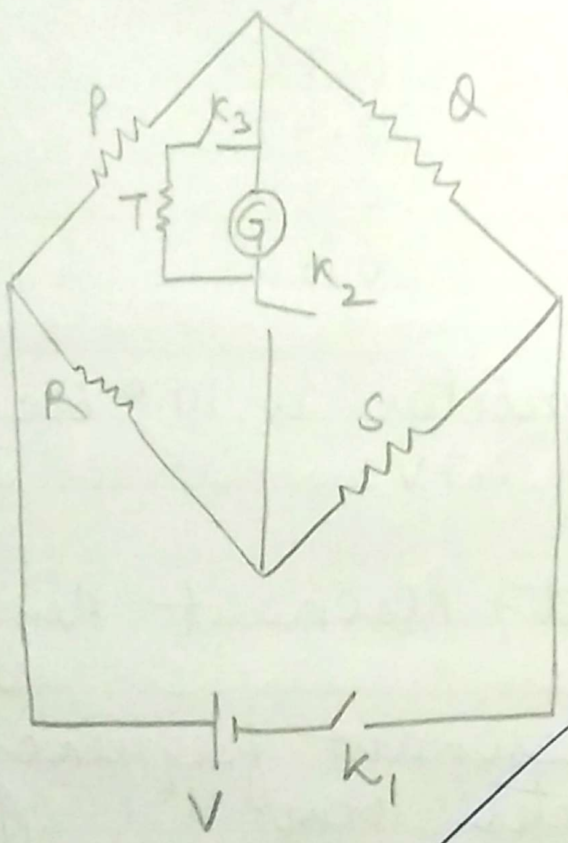

Wheatstone
Bridge

1.5 Name of Experiment → To measure electrical resistance of given material

- Aim → To measure resistance of given material using wheatstone bridge.

- Apparatus Used → Wheatstone bridge setup

- Theory → $P/Q = R/S$ (wheatstone bridge)
$P/Q = 1$ (in multiplier)

- Observation :

1st wire

S.No.	1000(Ω)a	100(Ω)b	10(Ω)c	1(Ω)d	Multiplier	R(Ω)
1.	0	0	0	2	1	2
2.	0	0	2	6	0.1	2.6
3.	0	2	6	6	0.01	2.66
4.	2	6	6	9	0.001	2.669

2nd wire

S.No	1000(Ω)a	100(Ω)b	10(Ω)c	1(Ω)d	Multiplier	R(Ω)
1.	0	0	0	2	1	2
2.	0	0	2	5	0.1	2.5
3.	0	2	5	6	0.01	2.56
4.	2	5	6	8	0.001	2.568

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R with l_2 is $2.568\,\Omega$

- Result → Resistance of wire when length = l_1 is ~~$1.889\,\Omega$~~ $2.669\,\Omega$
  length = l_2 is ~~$1.599\,\Omega$~~ $2.568\,\Omega$ $(l_1 > l_2)$

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e/m of electron by Thomson method

- **Aim** → Determining the value of specific charge e/m of an electron by Thomson Method

- **Apparatus Used** → Deflection magnetometer, two bar magnets, cathode ray oscilloscope, stand arrangement.

- **Theory** → Electric Force, $F_e = Ee$
  Magnetic Force, $F_{mag} = e|\vec{v} \times \vec{B}| = Bev$

$$F_{mag} = Bev = mv^2/r$$

$$\Rightarrow \frac{e}{m} = \frac{v}{Br}$$

$$F_e = F_{mag} \Rightarrow Ee = Bev \Rightarrow v = E/B$$

$$\frac{e}{m} = \frac{E}{B^2 r}$$

$$\frac{e}{m} = \frac{Ey}{B^2 lL}$$

$$\Rightarrow \boxed{\frac{e}{m} = \frac{Vy}{B^2 lLd}}$$

where y is distance b/w spot positions displayed on screen of CRT, l is length of deflection plates, L is dis b/w screen and plates, d is dis. b/w plates & V is applied voltage.

$$B = H \tan\theta$$

$$\therefore \frac{e}{m} = \frac{Vy}{H^2 \tan^2\theta \, lLd}$$

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Calculation:

$$\frac{e}{m} = \frac{V y}{H^2 \tan^2\theta \, l L d}$$

For $y = 1\,cm$

$$V = \frac{8.1 + 8.5}{2} = 8.3$$

$d = 1.4\,cm$

$l = 3.23\,cm$

$L = 14.5\,cm$

$\tan\theta = 2.14$

$$\theta = \frac{55 + 80}{2} = 67.5^\circ$$

$$\frac{e}{m} = \frac{8.3 \times 0.01 \times 10^6}{(0.37 \times 10^{-4})^2 (2.41)^2 \times 14.5 \times 3.23 \times 1.4}$$

$$\Rightarrow \frac{e}{m} = 1.58 \times 10^{11}\ C/kg$$

→ Error

$$\frac{1.75 \times 10^{11} - 1.58 \times 10^{11}}{1.75 \times 10^{11}} \times 100 = 9.7\%$$

For $y = 1.5\,cm$

$$V = \frac{10.5 + 9.1}{2} = 9.8\,V$$

$$\theta = \frac{65 + 60}{2} = 62.5^\circ$$

$\tan\theta = 1.92$

$$\frac{e}{m} = \frac{9.8 \times 0.015 \times 10^6}{(0.37 \times 10^{-4})^2 \times (1.92)^2 \times 14.5 \times 1.4 \times 3.23}$$

$$\frac{e}{m} = 1.95 \times 10^{11}\ C/kg$$

→ Error

$$100 \times \frac{1.95 \times 10^{11} - 1.75 \times 10^{11}}{1.75 \times 10^{11}} = 11\%$$

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Observation Table:

y	V_1	V_2	r_1	r_2	r_3	r_4	$\theta_1 = \theta_2$	$\theta_3 = \theta_4$
1cm	8.1V	−8.5V	13cm	13cm	14cm	14cm	55°	~~85~~ 80°
1.5cm	10.5V	−9.1V	11.5cm	11.5cm	13cm	13cm	65°	60°

Result: Standard value of $\frac{e}{m} = 1.75 \times 10^{11}$ C/kg

Experimental value of $\frac{e}{m} = 1.58 \times 10^{11}$ C/kg

Error = 11%

Your values & error

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Measurement of band gap of semiconductor:

- Aim → • Measurement of resistivity of a semiconductor at room temperature
- Measurement of variation of resistivity with temperature.
- Evaluation of band gap of the given semiconductor from the plotting of acquired data.
- Understanding of the concept of four probe method.

Apparatus Used → Four probe experimental setup

Theory: Conductivity of a semiconductor is given by

$$\sigma = e(\mu_n n + \mu_p p) \qquad (\mu = v_d/E)$$

$$\sigma = \sigma_0 e^{-E_g/2kT}$$

$$\rho = \frac{VA}{lI}$$

Case ① $h \gg a$
$$\rho = 2\pi a \frac{V}{I}$$

Case ② $h \ll a$
$$\rho = \frac{\pi h}{\ln 2}\left(\frac{V}{I}\right)$$

h: thickness of sample , a: dis b/w two probes

$$\sigma = \frac{1}{\rho}$$

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Calculation:

$$\text{Slope} = \frac{y_2 - y_1}{x_2 - x_1} = \frac{-0.412 + 0.18}{3.37 - 2.97} = -0.58$$

$$\sigma = e^{-E_g/2kT}$$

On Graph
$y = \ln\sigma$
$x = 1000/T$
Slope $= y/x$

$$\ln\sigma = \frac{-E_g}{2kT} \times \frac{1000}{1000}$$

$$y = \frac{-E_g \times 1000}{2kT \times 1000}$$

$$\Rightarrow y = \frac{-E_g \times x}{2k \times 1000}$$

$\{ k = 1.38 \times 10^{-23}$ J/

$$\Rightarrow \frac{y}{x} = \frac{-E_g}{2k \times 1000}$$

$$\Rightarrow -E_g = \frac{y}{x} \times 2k \times 1000$$

$$\Rightarrow +E_g = +0.58 \times 2 \times 1.38 \times 10^{-23} \times 1000$$

$$= 0.59 \text{ eV}$$

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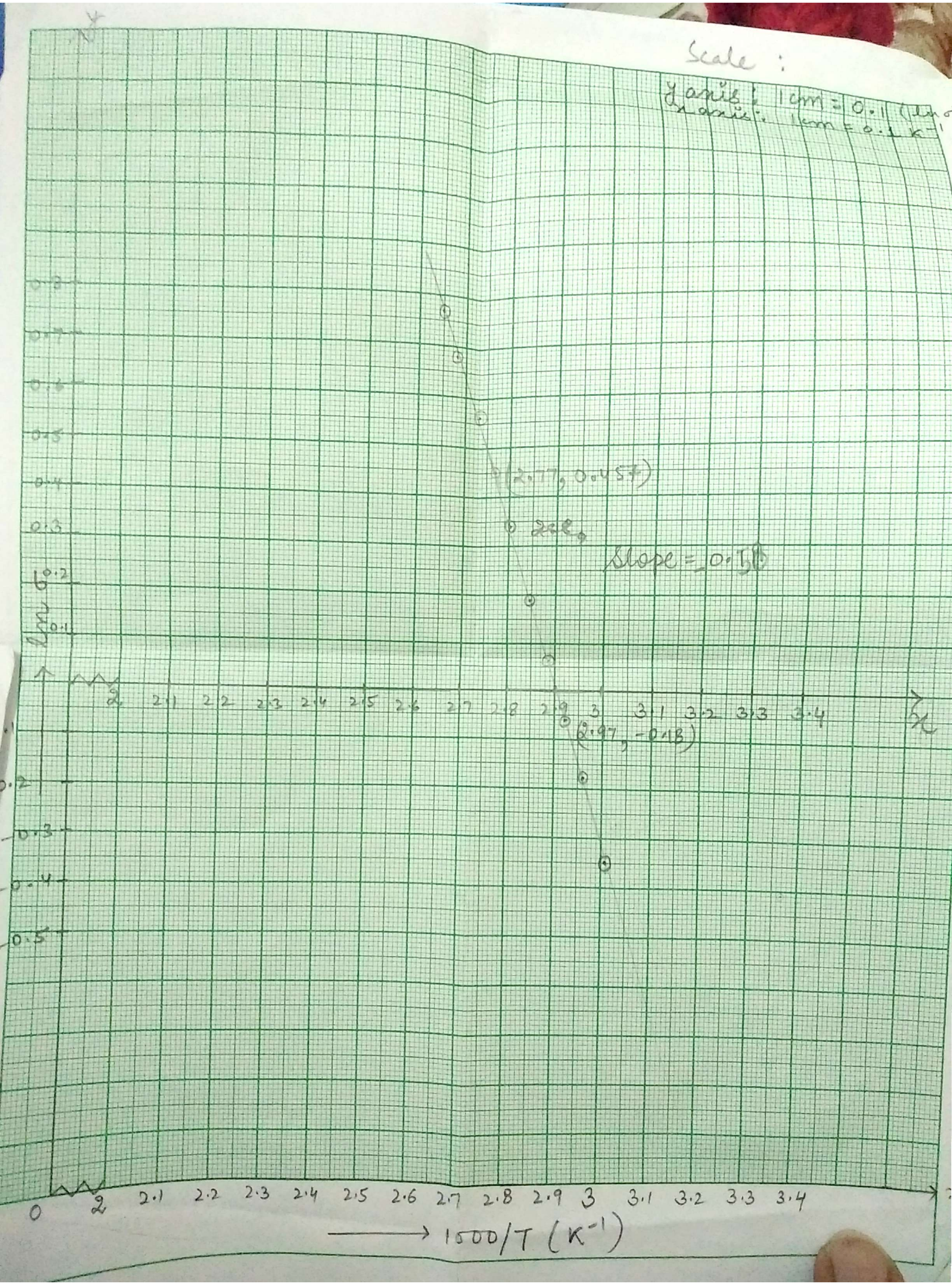

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Observation Table:

S.I.	Temp (T) in (°C)	1000/T (K^{-1})	I during ↑T (in mA)	↑V (mV)	Inc (V/I)	I during ↓T	↓V (mV)	Dec V/I (Ω)	Mean V/I (Ω)	ρ ($2\pi a \frac{V}{I}$) (Ω m)	σ = 1/ρ	ln σ
1.	23°C	3.37	2.99	346.9	116.02	2.96	369.2	124.73	120.37	1.51	0.662	-0.412
2.	28°C	3.32	2.99	354.5	118.56	2.96	368.8	124.59	121.57	1.52	0.657	-0.418
3.	33°C	3.26	2.98	362.0	121.47	2.96	365.4	123.44	122.45	1.53	0.654	-0.425
4.	38°C	3.21	2.98	367.4	123.28	2.96	363.6	122.83	123.05	1.54	0.649	-0.431
5.	43°C	3.16	2.98	368.7	123.72	2.96	355.5	120.10	121.91	1.53	0.654	-0.425
6.	48°C	3.11	2.98	364.6	122.34	2.96	340.3	114.96	118.65	1.49	0.671	-0.39
7.	53°C	3.06	2.97	353.0	118.8	2.96	317.9	107.39	113.09	1.42	0.704	-0.35
8.	58°C	3.02	2.97	333.2	112.18	2.96	289.0	97.63	104.90	1.31	0.763	-0.27
9.	63°C	2.97	2.97	310.6	104.57	2.96	258.1	87.19	95.88	1.20	0.833	-0.18
10.	68°C	2.93	2.96	281.8	95.20	2.96	226.2	76.41	85.80	1.07	0.934	-0.06
11.	73°C	2.89	2.96	250.6	84.66	2.96	195.4	66.01	75.33	0.94	1.064	0.06
12.	78°C	2.84	2.96	220.2	74.39	2.96	167.8	56.68	65.53	0.82	1.219	0.198
13.	83°C	2.80	2.96	192.7	65.10	2.96	143.8	48.58	56.84	0.71	1.408	0.34
14.	88°C	2.77	2.96	167.5	56.58	2.95	130.9	44.37	50.47	0.633	1.579	0.457
15.	93°C	2.73	2.96	145.3	49.08	2.95	123.9	42	45.54	0.571	1.751	0.560
16.	98°C	2.69	2.95	125.7	42.61	2.95	112.1	38	40.30	0.506	1.976	0.681
17.	103°C	2.65	2.95	108.2	36.67	2.95	108.2	36.67	36.67	0.46	2.17	0.776

repeat

Result:

Energy band gap of the given semiconductor is 1.6×10^{-20} J

0.6 – 0.7 eV

convert into eV.

After recalculation E_G = 0.59 eV

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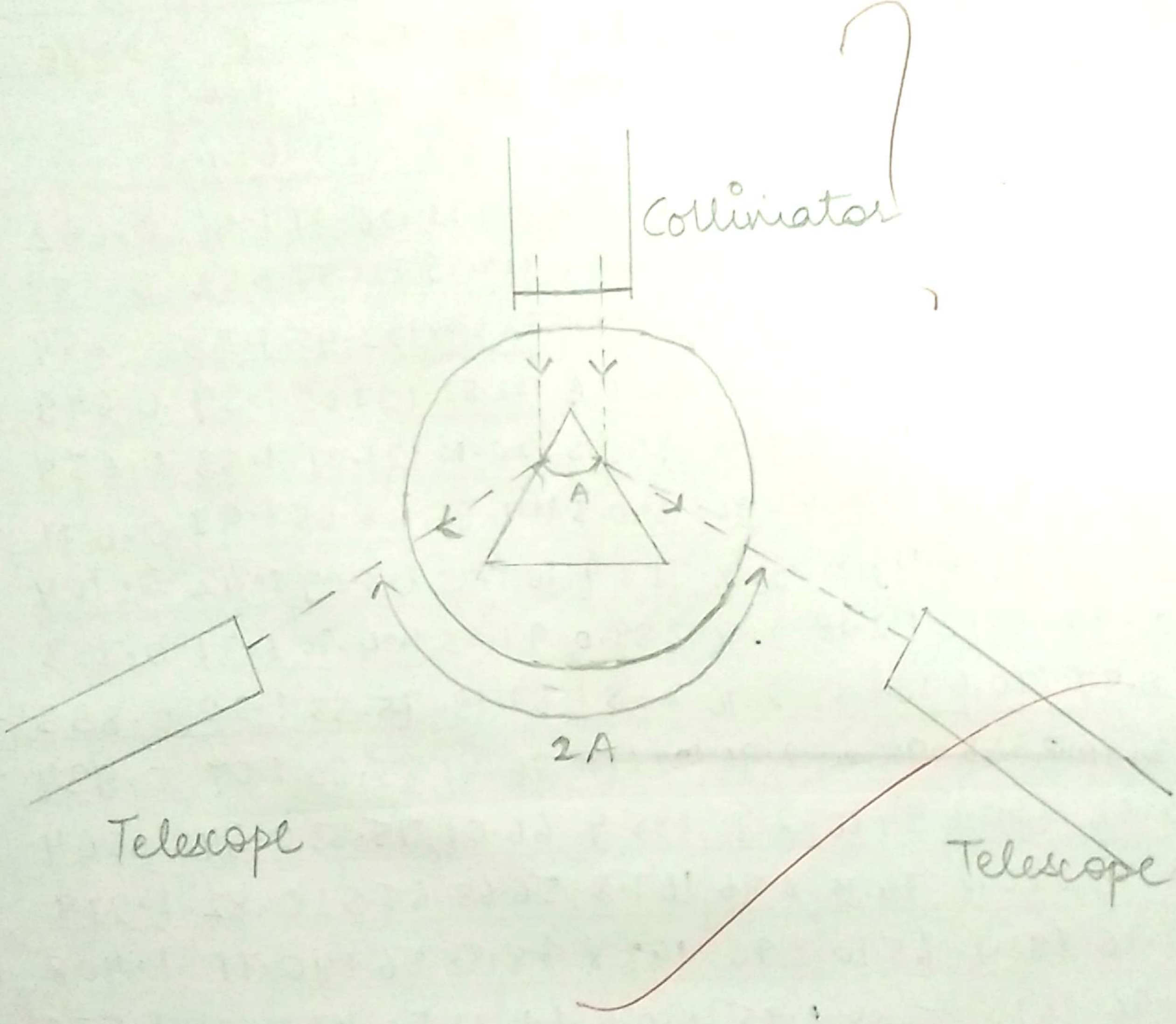

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Refractive index of glass with the help of a prism:

Aim:

- To understand the accurate leveling and focusing of a spectrometer.
- Investigation of the variation in the refractive index, μ of a prism with wavelength λ.
- Determination of the constants a and b of the Cauchy equation which defines the relationship of μ as a function of λ.

Apparatus: Spectrometer, prism, mercury light source, high voltage power supply, magnifying lens, spirit level, torch light etc.

Theory:

$$\delta_{min} = 2(\theta_i - \theta_r)$$

$$\mu = \frac{\sin((A+\delta_{min})/2)}{\sin(A/2)}$$

A = Angle of prism

$$\mu = a + \frac{b}{\lambda^2} + \frac{c}{\lambda^4} + \text{------}$$

{Cauchy equation where a, b, c are constants}

30 Vernier Scale Division (VSD) coincide with 29 CSD

$$L.C = 1CSD - 1VSD$$

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Calculation:

$$\text{Slope} = \frac{AB}{BC} = \frac{1.52 - 1.517}{(5.668 - 4.938)10^{12}} = \frac{3\times10^{-15}}{0.73}$$

$$= 4.10\times10^{-15}$$

Cauchy Equation $\Rightarrow \mu = a + \frac{b}{\lambda^2}$

$b = 4.10\times10^{-15}$ from above

$\cancel{y = mx + c}$ { ~~here~~ $\cancel{c = a}$

$\cancel{m = 4.10\times10^{-15} = b}$

$\cancel{1.517 = 4.10\times10^{-15} \times 4.938\times10^{12} + c}$

$\Rightarrow$ $\cancel{c = 1.517 - 0.002} = 1.515$

$\therefore$ $\boxed{\begin{array}{l} a = 1.505 \\ \cancel{a = 1.5489} \quad \cancel{b = 4.10\times10^{-15}\,m^2} \end{array}}$

$a = 1.499 \quad b = 4.10\times10^{-15}\,m^2$

Calculation of refractive index for $\lambda = 520\,nm$

$$\mu = a + \frac{b}{\lambda^2}$$

$$\mu = \cancel{1.505} + \frac{4.10\times10^{-15}}{(520\times10^{-9})^2} = 1.499 + 0.005$$

1.499

$\cancel{= 1.505 + 0.005}$

$= \cancel{1.59}\ \cancel{1.51}$

$\therefore\ \mu = 1.504$

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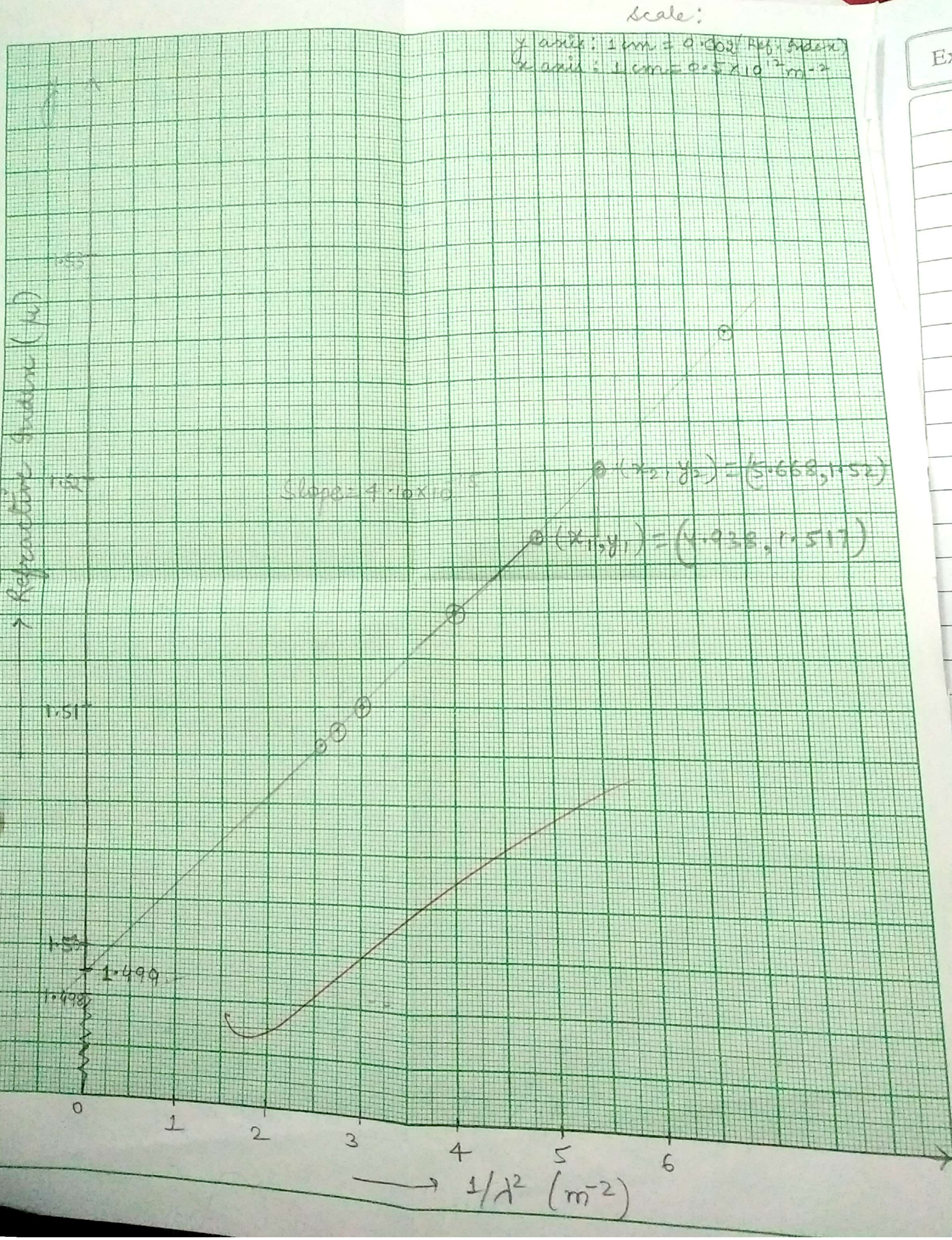

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$$30\,VSD = 29\,CSD$$

$$\Rightarrow 1\,VSD = \frac{29}{30}\,CSD$$

$$LC = \left(1 - \frac{29}{30}\right) CSD = \frac{1}{30}\,CSD$$

Since, $1\,CSD = \frac{1}{2}^{\circ} = 30'$

$$LC = \frac{1}{30} \times 30' = 1'$$

Observation :

MEASUREMENT OF ANGLE OF PRISM

Position I			Position II			$2A = \theta_1 - \theta_2$	A (Prism Angle)
CSR	VSR	Total (θ_1)	CSR	VSR	Total (θ_2)		
297.5°	5'	297°35'	57°30'	8'	57°38'	120°3'	60°1.5'

Angle of Undeviated Ray, $\theta' = 353°53'$

MINIMUM DEVIATION

SI.	Colour	Angle by deviated ray CSR	VSR	θ (deg)	$\delta_{min} = (\theta' - \theta)$	μ	λ (nm)	$1/\lambda^2$ (m^{-2})
1.	Violet	314°30'	6'	314°36'	39°17'	1.525	380	6.925×10^{12}
2.	Indigo	314°30'	15'	314°45'	39°8'	1.52	420	5.668×10^{12}
3.	Blue	314°30'	23'	314°53'	39°	1.519	450	4.938×10^{12}
4.	Green	315°30'	27'	315°57'	38°16'	1.514	495	4.081×10^{12}
5.	Yellow	315°30'	20'	315°50'	38°3'	1.599	570	3.077×10^{12}
6.	Orange	315°30'	23'	315°53'	38°	1.598	590	2.872×10^{12}
7.	Red	315°30'	25'	315°55'	37°58'	1.587	620	2.601×10^{12}

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Precautions:

1. In calculating angle of prism we have two formulas

$$2A = \theta_1 - \theta_2 \rightarrow (1)$$
$$2A = 360 - (\theta_1 - \theta_2) \rightarrow (2)$$

(2) is used when difference is greater than 180°

2. There is too much of calculation of angles so calculation should be done carefully.

Results:

1. Value of Cauchy constants from graph is
$a =$ ~~1.5165~~ 1.499 $b = 4.10 \times 10^{-15}\ m^2$

2. Value of refractive index at wavelength = 520nm is 1.504

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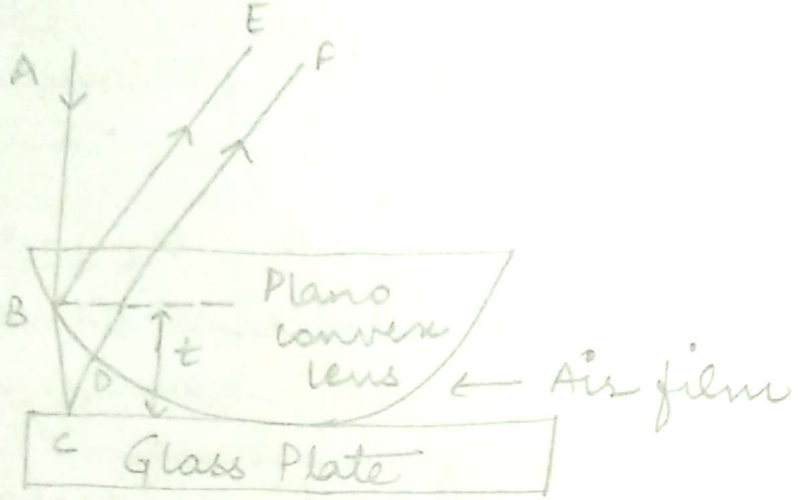
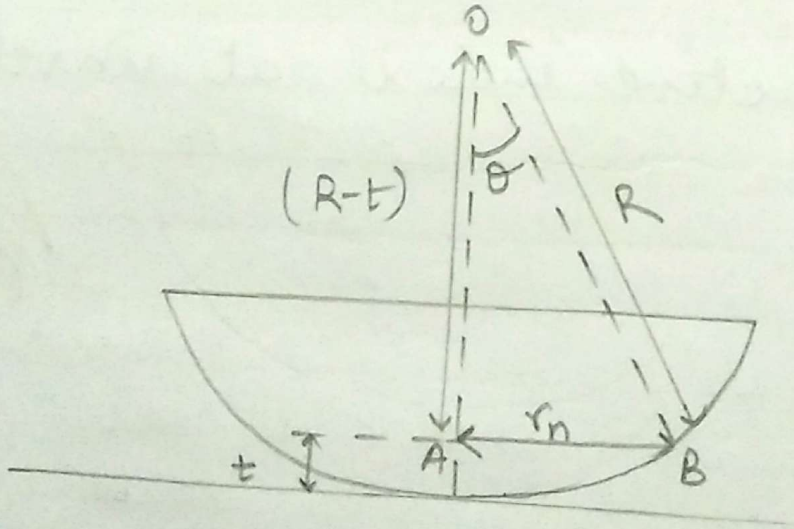


Schematic diagram of the light rays in Newton's ring



Schematic diagram of plano convex lens

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Wavelength of sodium light by Newton's rings:

- **Aim:** To determine the wavelength of sodium light by measuring the diameters of Newton's rings.

- **Apparatus:** Newton's ring microscope, sodium vapour lamp, circular slit plate, light emitting diode source.

- **Theory:** The formation of maximum intensities at some points and minimum intensities at others due to superposition of two coherent light waves is called interference of light. For constructive interference (where intensity of light is maximum)

$$\phi = 2n\pi \qquad (\phi \text{ is Phase difference})$$

For destructive interference (intensity of light is minimum) $\phi = (2n+1)\pi$

Diameter of n^{th} dark fringe is calculated as

$$D_n^2 = \frac{4nR\lambda}{\mu}$$

where D_n = Diameter of n^{th} dark fringe
R = Radius of curvature of plano-convex lens
μ = Refractive Index of medium
λ = wavelength of light

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• Calculation:

$\frac{D_n^2}{n}$ = Slope of line AB = $\frac{39.06 - 19.98}{16-8} = 2.385$

By formula, $D_n^2 = \frac{4nR\lambda}{\mu}$

$\lambda = \frac{D_n^2 \mu}{4nR}$ $(\mu = 1)$

$(R = 100 cm)$

$\lambda = \frac{D_n^2}{4nR} = \frac{2.385}{4 \times 100}$ cm $= 5.962 \times 10^{-7}$ m

$= 596.2$ nm

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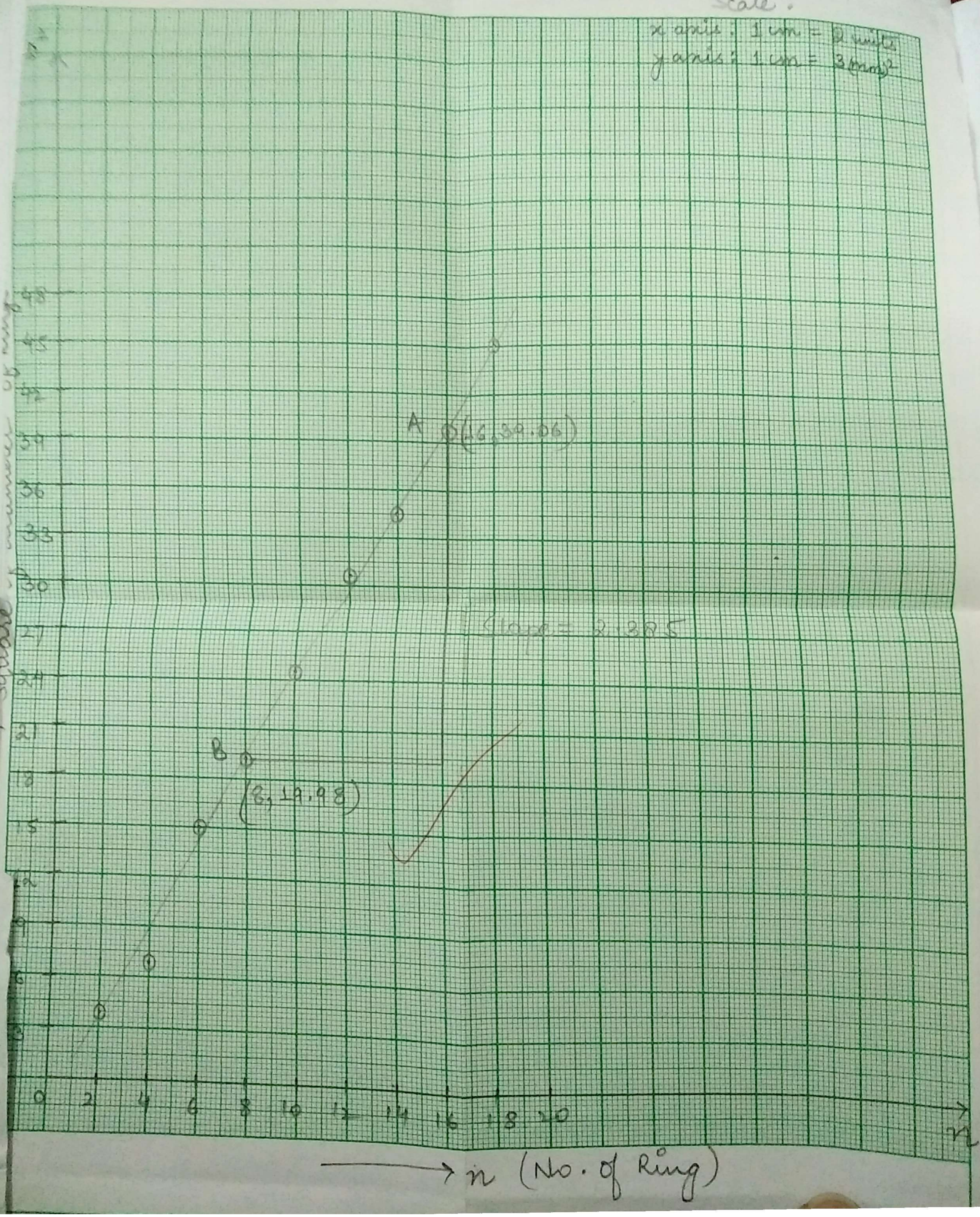
Scale :
x axis : 1 cm = 2 units
y axis : 1 cm = 3 (mm)^2



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- Observation :

Sl.	Ring No.	LHS MSR	LHS CSR	Total (a) (mm)	RHS MSR	RHS CSR	Total (b) (mm)	D = (b−a) (mm)	D^2 (mm^2)	λ (10^{-5} cm)
1.	20	48	11	48.11	41	3	41.3	6.81	46.37	5.79
2.	18	47	95	47.95	41	23	41.23	6.72	45.15	6.27
3.	16	47	75	47.75	41	50	41.50	6.25	39.06	6.10
4.	14	47	54	47.54	41	68	41.68	5.86	34.33	6.13
5.	12	47	45	47.45	41	86	41.86	5.59	31.24	6.50
6.	10	47	23	47.23	42	14	42.14	5.09	25.90	6.47
7.	8	46	88	47.88	42	41	42.41	4.47	19.98	6.24
8.	6	46	58	46.58	42	70	42.70	3.88	15.05	6.27
9.	4	46	23	46.23	43	6	43.6	2.63	6.91	4.31
10.	2	45	56	45.56	43	54	43.54	2.02	4.08	5.1

- Result :

The wavelength of sodium light is 595.2 nm

Teacher's Signature :

Acceleration due to gravity by bar pendulum

- **Aim:** To determine the value of acceleration due to gravity using angular oscillations of a long bar.

- **Apparatus Used:** Stop watch, long bar, meter scale, knife edge.

- **Theory:** Formula used are

$$T = 2\pi\sqrt{\frac{I}{Mgd}} = 2\pi\sqrt{\frac{K^2+d^2}{gd}}$$

$$g = \frac{4\pi^2 (d_1+d_2)}{T^2}$$

$$d_1 + d_2 = L$$

g: acceleration due to gravity
T: Time period of osc.
d: dis of com from pt. of suspension

Error in gravity

$$\frac{\Delta g}{g} = \frac{\Delta d}{d} + \frac{2\Delta T}{T}$$

- **Observation Table:**

S.I.	d(cm)	No. of oscillations Time in 1	Time 2	Time 3	Mean T_{20} (sec)	T (sec)
1.	45	31.29	31.27	31.20	31.25	1.56
2.	40	30.77	30.35	30.86	30.66	1.53
3.	35	29.90	30.25	30.20	30.11	1.50
4.	30	29.76	29.80	29.79	29.78	1.48

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Calculation

$$g = \frac{4\pi^2 d}{T^2}$$

① $d' = d_1 + d_2 = 55\,cm = 0.55\,m$

$T = 1.5\,sec$

$$g_1 = \frac{4 \times (3.14)^2 \times 0.55}{1.5 \times 1.5} = 9.64\,m/s^2$$

$\frac{\Delta T}{T}$

② $d'' = d_1 + d_2 = 60\,cm = 0.6\,m$

$T = 1.48\,sec$

$$g_2 = \frac{4 \times (3.14)^2 \times 0.6}{1.48 \times 1.48} = 10.8\,m/sec^2$$

③ $d''' = d_1 + d_2 = 60\,cm = 0.6\,m$

$T = 1.513\,sec$

$$g_3 = \frac{4 \times (3.14)^2 \times 0.6}{1.513 \times 1.513} = 10.33\,m/sec^2$$

$$g = \frac{g_1 + g_2 + g_3}{3} = \frac{9.64 + 10.8 + 10.33}{3} = 10.2\,m/sec^2$$

$$T = \frac{1.5 + 1.48 + 1.513}{3} = 1.49\,sec$$

$$d = \frac{d_1 + d_2 + d_3}{3} = \frac{0.55 + 0.6 + 0.6}{3} = 0.58\,m$$

$$\frac{\Delta g}{g} = \frac{\Delta d}{d} + \frac{2\Delta T}{T} \Rightarrow \frac{\Delta g}{10.2} = \frac{0.01}{0.58} + \frac{2(0.01)}{1.49}$$

$$\Delta g = 0.310\,m/sec^2$$

$$\%\ Error = \frac{\Delta g}{g} \times 100 = \frac{0.310}{9.8} \times 100 = 3.16\%$$

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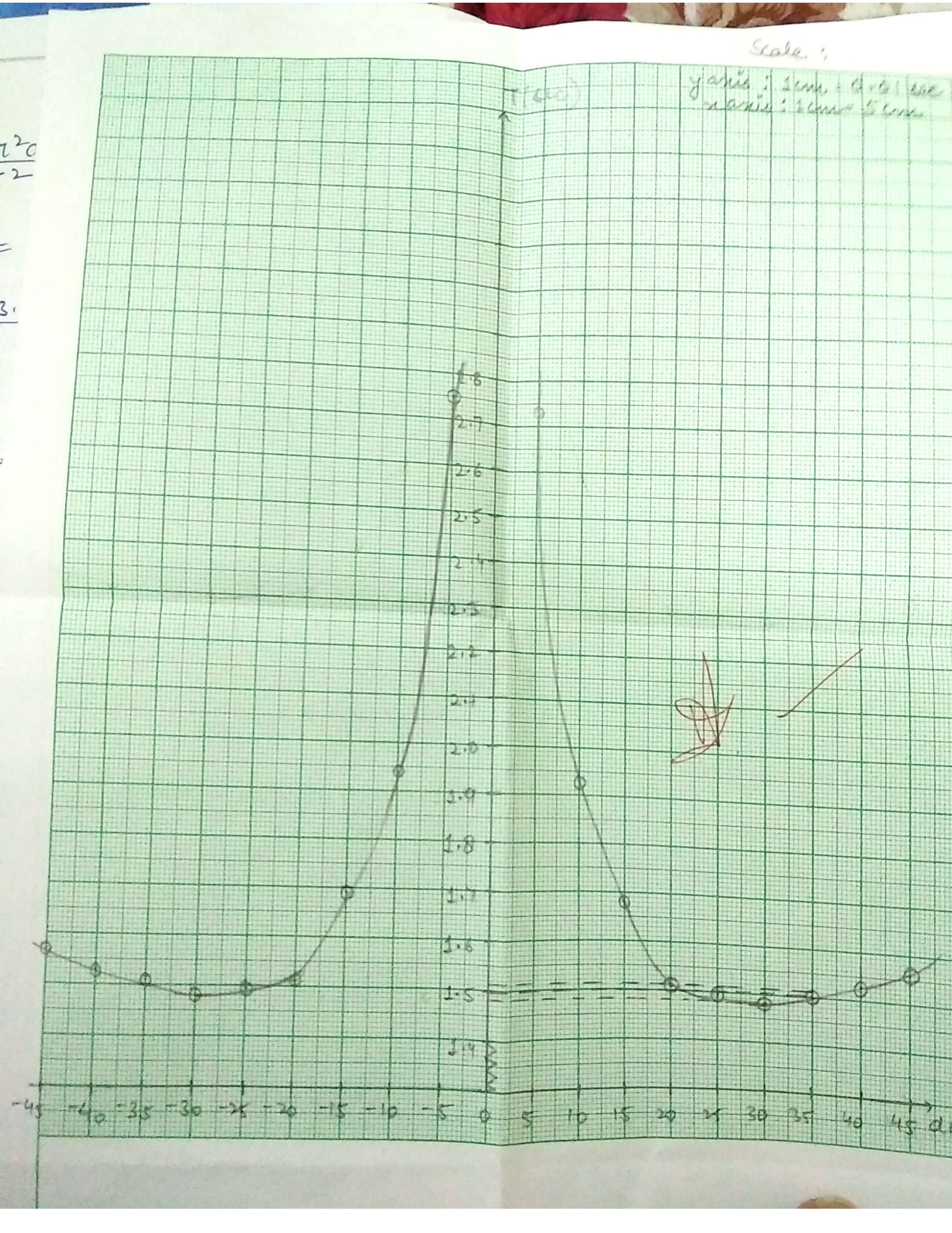

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Sl.	d(cm)	No. of oscillations Time 1	Time 2	Time 3	Mean T_{20} (sec)	T(sec)
5.	25	30.04	30.19	30.08	30.10	1.505
6.	20	30.14	30.39	30.25	30.26	1.513
7.	15	34.14	33.64	33.59	33.79	1.68
8.	10	38.67	38.71	38.90	38.76	1.93
9.	5	54.49	54.88	54.60	54.6	2.73
10.	−45	31.35	31.45	31.4	31.40	1.57
11.	−40	30.80	30.56	30.81	30.72	1.53
12.	−35	30.08	30.256	30.27	30.20	1.51
13.	−30	29.88	29.75	30.04	29.89	1.484
14.	−25	30.15	30.20	30.13	30.16	1.508
15.	−20	30.16	30.42	30.26	30.28	1.514
16.	−15	34.04	33.74	33.69	33.82	1.69
17.	−10	38.75	38.72	39.11	38.86	1.94
18.	−5	54.52	54.98	55.5	55	2.75

Result:

Value of Δg = 0.31 m/sec² and % error is 3.16%.

g

3/3/18

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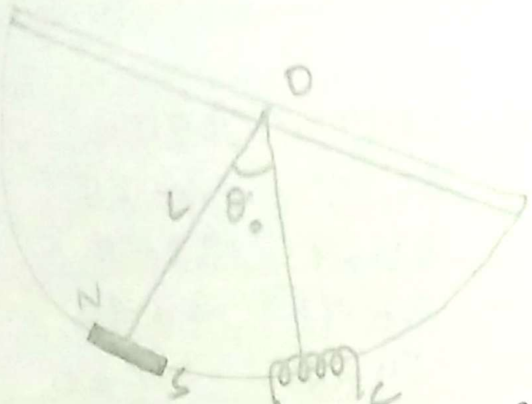
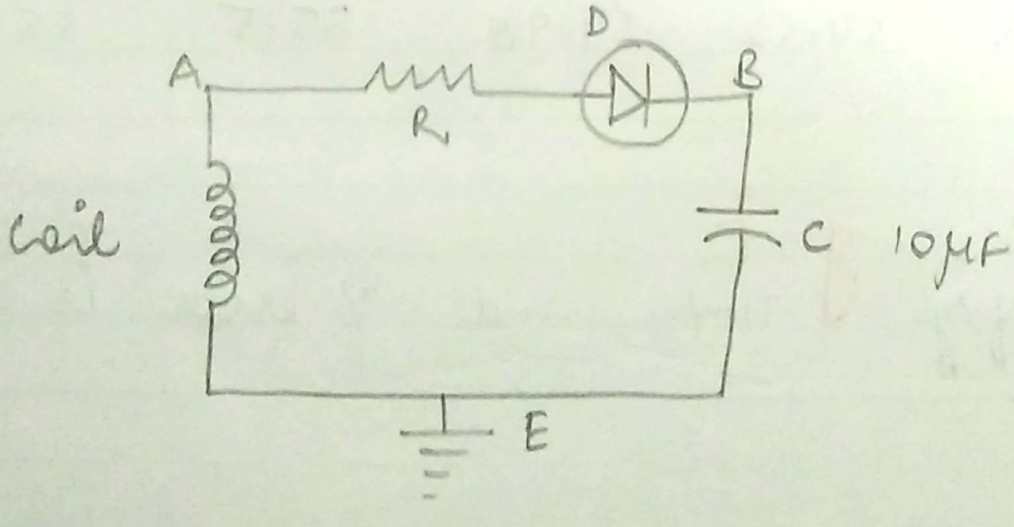


Schematic of the coil moving in and out of the magnetic field



Circuit diagram for charging of capacitor

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Electromagnetic Induction and Van de graff generator

A. Electromagnetic Induction

Purpose: To study the flux and emf in the coil as a function of time

Apparatus: Faraday setup, diode, capacitor, breadboard, connecting wire, CRO etc.

Theory: Faraday's law of electromagnetic induction tells us that a change in magnetic flux gives rise to an induced emf ε given by

$$\varepsilon = -\frac{d\phi}{dt}$$

$$T = 2\pi\sqrt{\frac{I}{MgL}}$$

$$\omega_{max} = \frac{4\pi}{T}\sin(\theta_0/2)$$

$$V_{max} = \frac{4\pi}{T}L\sin(\theta_0/2)$$

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Calculation

$L = 49 cm$

$$V_{max} = \frac{4\pi}{T} \times L \sin(\theta/2)$$

for 40° $\quad V_{max} = \frac{4 \times 3.14 \times 49 \sin 20^\circ}{1.44} = 145.16 cm/s$

for 35° $\quad V_{max} = \frac{4 \times 3.14 \times 49 \sin 35/2}{1.434} = 129.4 cm/s$

for 30° $\quad V_{max} = \frac{4 \times 3.14 \times 49 \sin 15^\circ}{1.42} = 112.17 cm/s$

for 20° $\quad V_{max} = \frac{4 \times 3.14 \times 49 \sin 10^\circ}{1.41} = 55.52 cm/s$

for 10° $\quad V_{max} = \frac{4 \times 3.14 \times 49 \sin 5^\circ}{1.40} = 38.33 cm/s$

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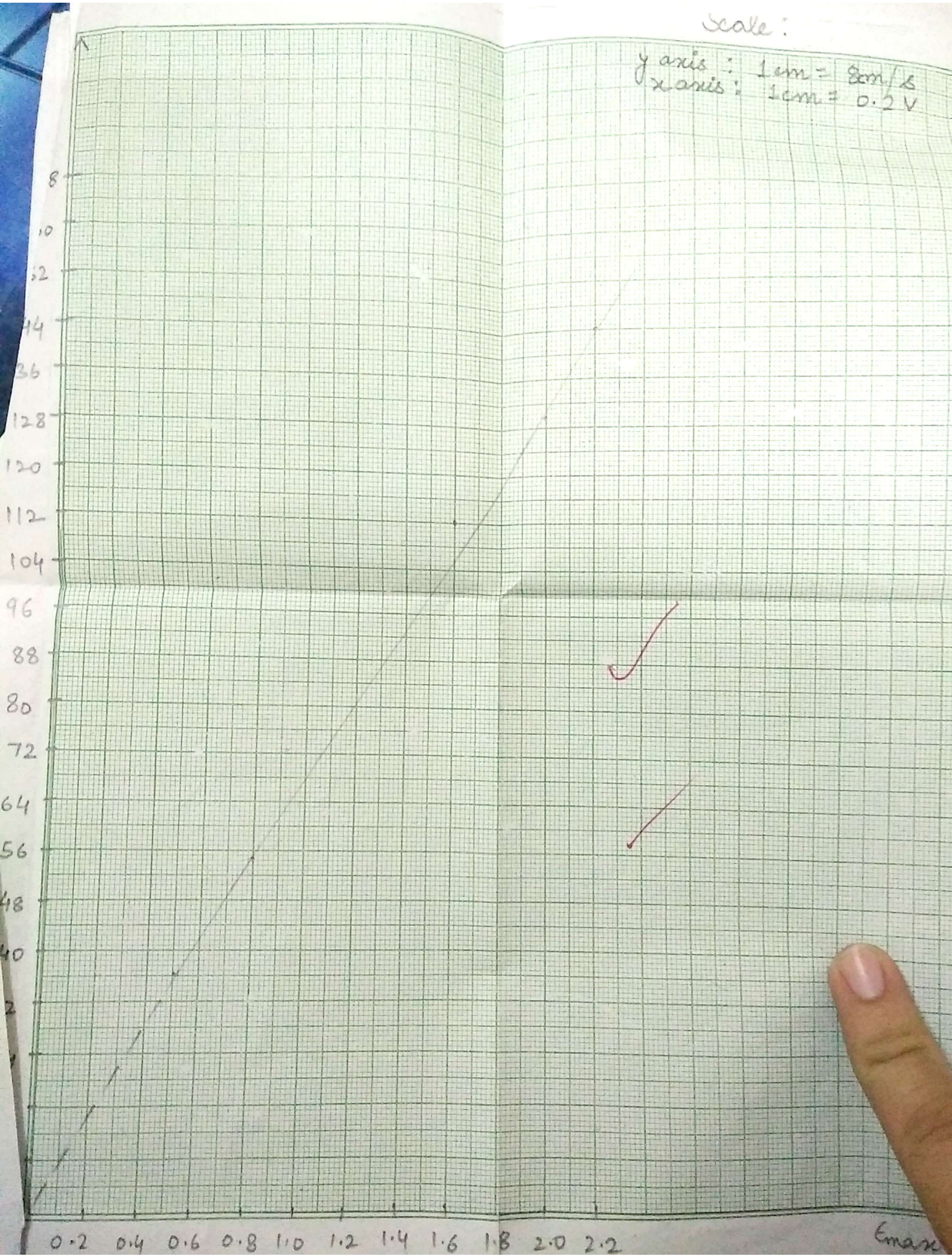

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Observations:

Sl.	θ_0 (deg)	1: T_{20} (sec)	1: $\mathcal{E}_{max}$ (V)	2: T_{20} (sec)	2: $\mathcal{E}_{max}$ (V)	3: T_{20} (sec)	3: $\mathcal{E}_{max}$ (V)	Avg T_{20} (sec)	T (sec)	$\mathcal{E}_{max}$ (V)	v_{max} (cm/s)
1.	40	28.4	2.2	28.8	2.2	29.3	2.2	28.83	1.44	2.2	145.16
2.	35	28.69	2.0	28.7	2.0	28.8	2.0	28.73	1.43	2.0	129.41
3.	30	28.5	1.6	28.6	1.6	28.5	1.6	28.53	1.42	1.6	112.17
4.	20	28.4	0.8	28.2	0.8	28.3	0.8	28.3	1.41	0.8	55.52
5.	10	28.2	0.5	28	0.5	27.9	0.5	28.03	1.40	0.5	38.33

Result: The graph between $\mathcal{E}_{max}$ and v_{max} comes to be a straight line.

7/3/2016

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Mechanical Waves and Eddy currents

A. MECHANICAL WAVES

Aim:

- Creating harmonic standing waves
- Study wavelength (λ) as function of frequency (ν) and to find out the phase velocity v_p.
- To measure linear mass density μ of string

Apparatus: Function generator, amplifier, mechanical oscillator, rubber rope, measuring tape, support rod, support base and weights

Theory:

$$V_p = f\lambda$$

where V_p is phase velocity, f is frequency, λ is wavelength

$$V_p^2 = \frac{T}{\mu} \Rightarrow V_p = \sqrt{\frac{T}{\mu}}$$

T is Tension and μ is mass per unit length

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Calculation

(1) $$V_p = f\lambda = \frac{f}{1/\lambda}$$

$$\text{Slope} = \frac{y_2 - y_1}{x_2 - x_1} = \frac{21-18}{0.019-0.016} = \frac{3}{0.003} = 10\,m/s$$

(2) $$V_p^2 = \frac{T}{\mu} \Rightarrow \mu = \frac{T}{V_p^2}$$

$$\text{Slope} = \frac{V_{p_2}^2 - V_{p_1}^2}{T_2 - T_1} = \frac{146.41\times10^4 - 85.37\times10^4}{0.704 - 0.392}$$

$$= \frac{61.04\times10^4}{0.312}$$

$$\mu = \frac{0.312}{61.04\times10^4} = 0.005\ kg/m$$

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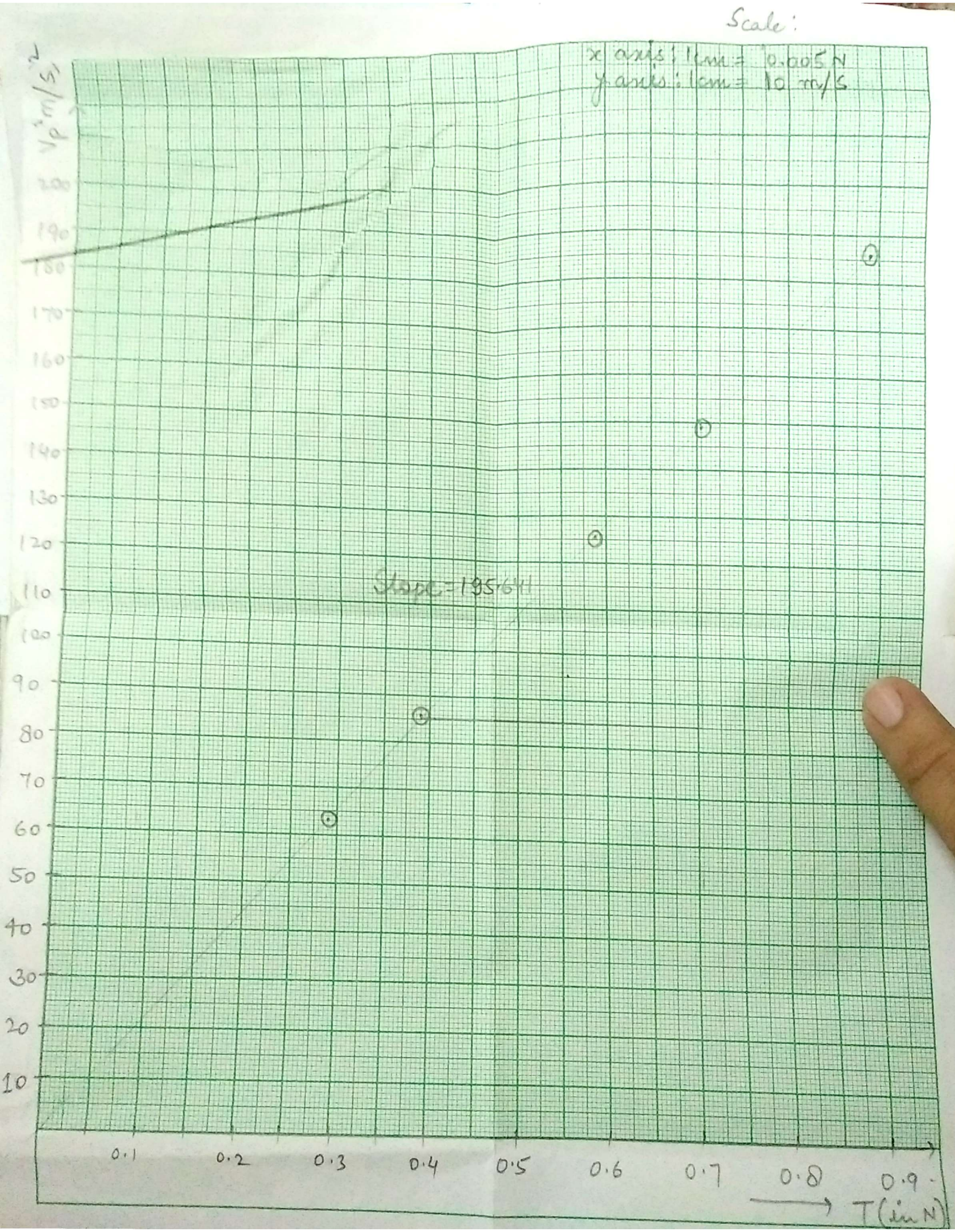

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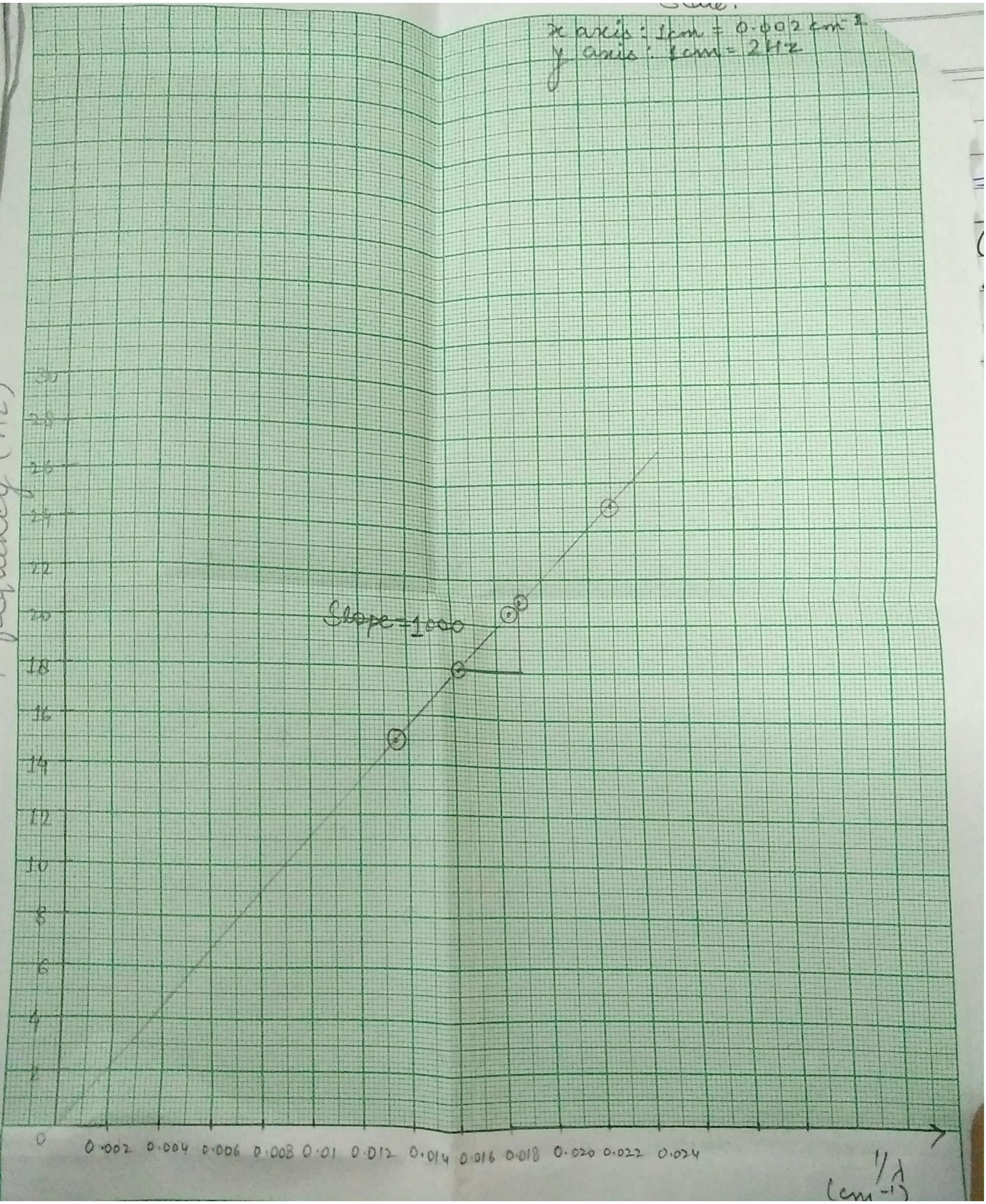

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Observation :

For constant mass $m = 60\,g$

SI.	Frequency (f) (Hz)	No. of loops (n)	length (L) (cm)	$\lambda = 2L/n$ (cm)	$1/\lambda$ (cm^{-1})
1.	15	2	74	74	0.0135
2.	18	3	92	61.33	0.0163
3.	20.7	2	53	53	0.0188
4.	21	2	51.5	51.5	0.0190
5.	25	3	65	43.33	0.023

For constant frequency $f = 22\,Hz$

SI.	Mass (m) (kg)	T=mg (N)	No. of loops (n)	length (L) (cm)	$\lambda=2L/n$ (cm)	$V_p = f\lambda$ (cm/s)	V_p^2 $(cm/s)^2$
1.	30	0.294	2	40	40	880	63.44×10^4
2.	40	0.392	2	42	42	924	85.37×10^4
3.	60	0.588	2	49	49	1078	126.20×10^4
4.	80	0.704	2	55	55	1210	146.41×10^4
5.	90	0.882	2	62	62	1364	186.04×10^4

Results :

1. Phase velocity (for constant mass) $v_p = 10\,m/s$
2. Mass per unit length (for constant frequency) $\mu = 0.005\,kg/m$

Teacher's Signature :

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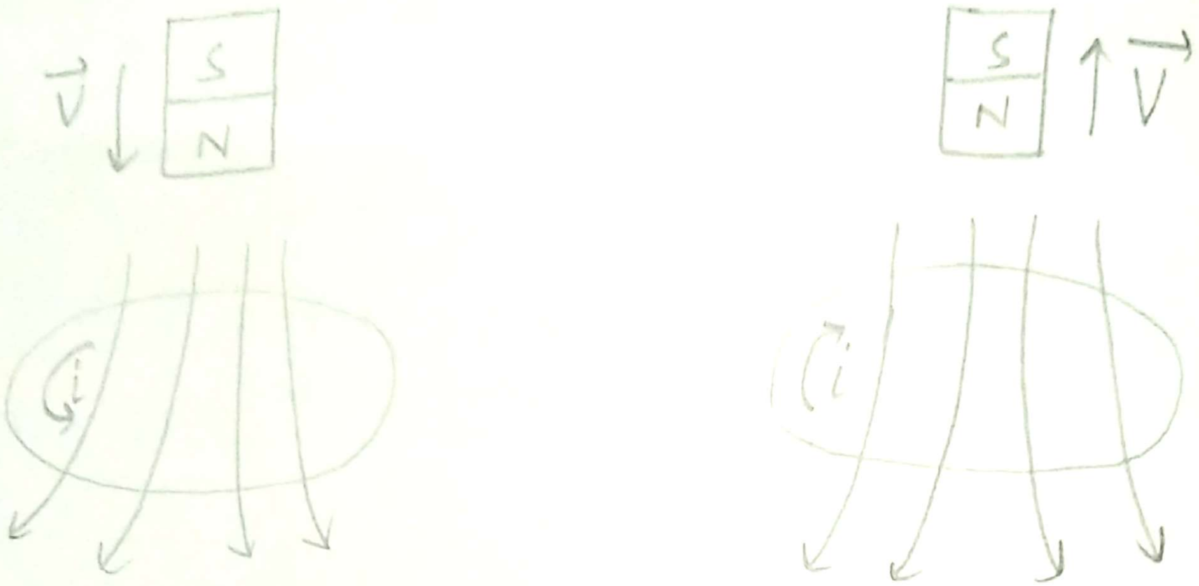
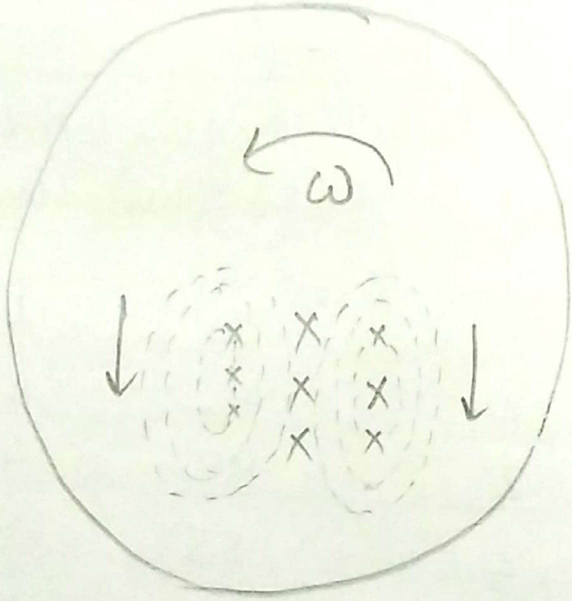


Lenz's Law



Sketch of eddy currents in a rotating disc. Crosses represents a steady magnetic field

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B. EDDY CURRENTS

Purpose: Understand some qualitative and quantitative aspects of eddy currents

Apparatus: Electromagnet (iron core), DC power source of coil, one disc made of copper fitted on a motor, Digital Tachometer, electronic stopwatch, Gauss Digital Meter, metallic plate, magnetic and non-magnetic masses etc.

Theory: According to the law of electromagnetic induction when the flux through coil changes then emf is induced in the coil. This is formulated in Lenz's law which states that

When magnetic flux through a coil changes with time, a current is induced in the coil in such a way so as to oppose the cause of change.

Eddy currents → When magnetic flux in a solid conductor changes, electrons experiencing Lorentz force set a swirling currents in the conductor perpendicular to their motion. These circulating eddies of current create tiny electromagnets with magnetic field that oppose the effect of applied magnetic field.

Teacher's Signature :

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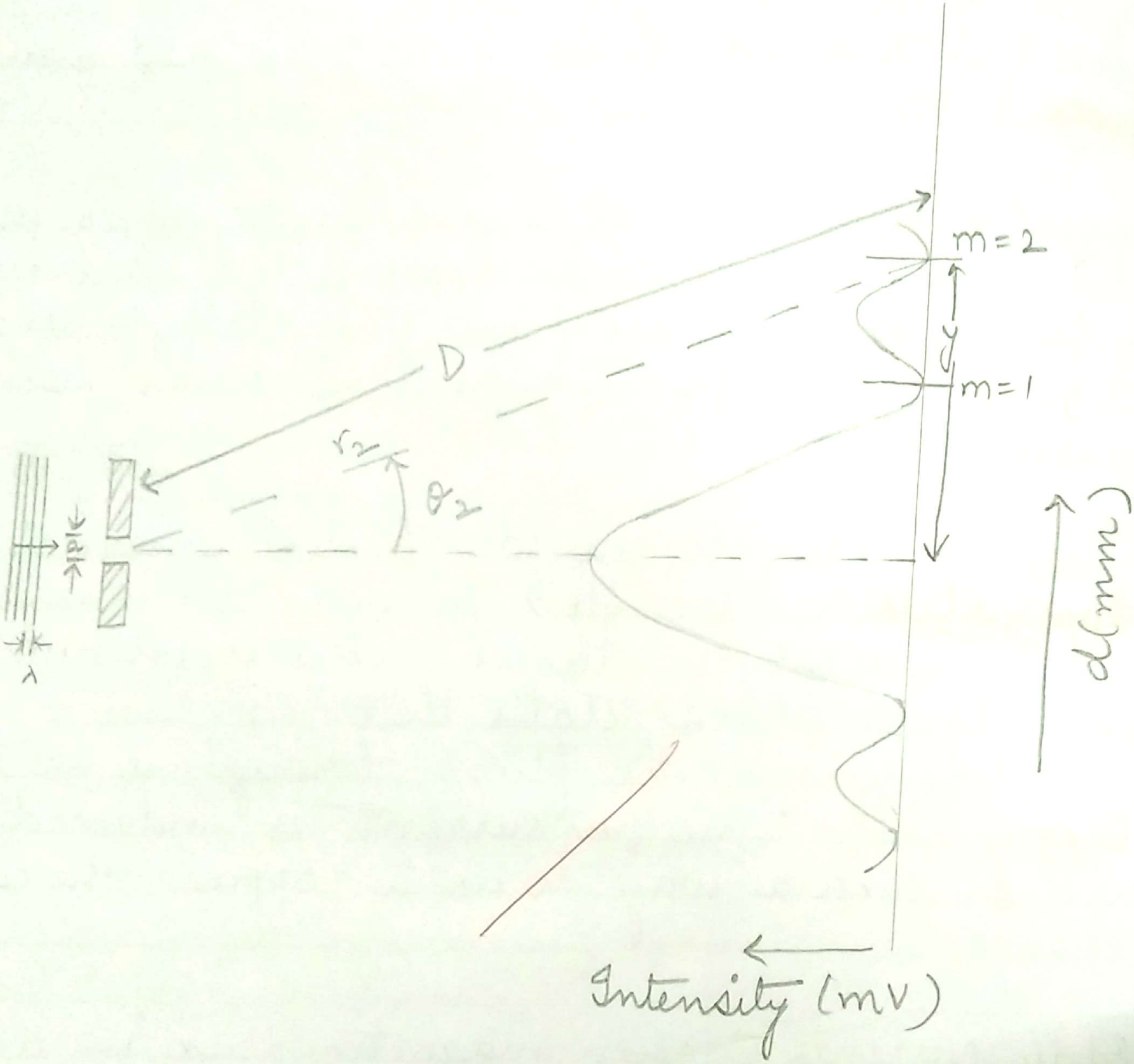

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Fraunhofer Diffraction

Purpose:

- To understand what is meant by Fraunhofer diffraction
- To observe single slit diffraction patterns and plot the intensity profile of the pattern
- Determine slit width from the diffraction formula

Apparatus: Digital Multi-meter, He-Ne laser source, sliding detector, optical rail and mounts.

Theory: Diffraction is the wave phenomena which describes the deviation from straight line propagation of a wave when it encounters an obstruction.

Fraunhofer diffraction pattern intensity due to rectangular slit will be

$$I = I_0 \frac{\sin^2\beta}{\beta^2}$$

Minima eq^n : $a \sin\theta_m = m\lambda$

If θ_m is small, $\sin\theta_m \simeq \theta_m = m\lambda/a$

further from geometry $\sin\theta_m = \theta_m = y/D$

$$a = \frac{m\lambda D}{y}$$

Teacher's Signature :

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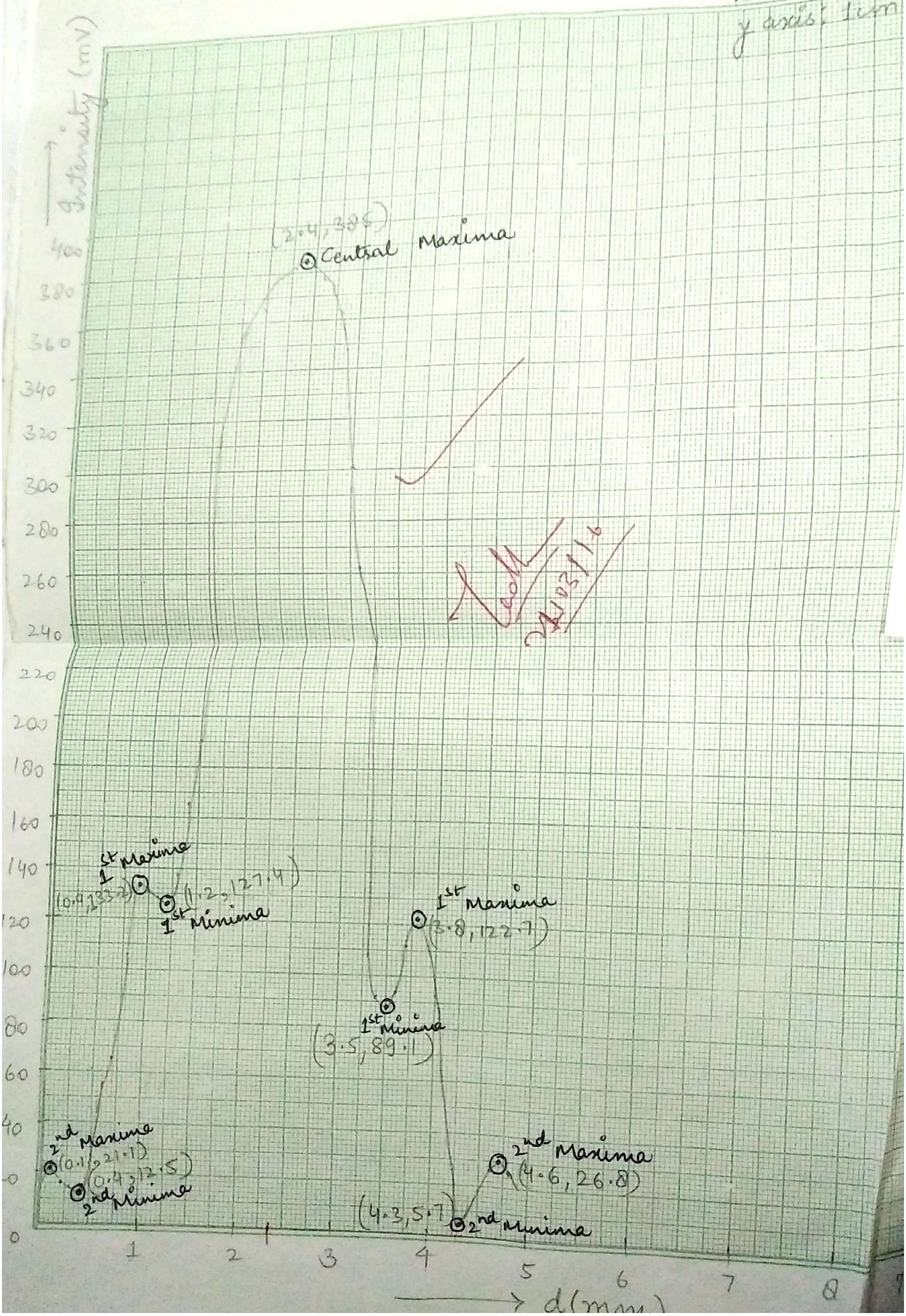
Scale
x axis: 1cm =
y axis: 1cm



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y : distance b/w central maxima to m^{th} order minima pt.
D = dis b/w slit and photo diode

Observation :

Sl.No	Distance MSR (mm)	VSR	Total Reading (mm)	Intensity (mV)
1.	0	10	0.1	21.1 2^{nd} Maxima
2.	0	30	0.2	16.9
3.	0	50	0.3	15.4
4.	0	70	0.4	12.5 2^{nd} Minima
5.	0	90	0.5	30.6
6.	1	10	0.6	56.2
7.	1	30	0.7	66.1
8.	1	50	0.8	106.2
9.	1	70	0.9	133.2 1^{st} Maxima
10.	1	90	~~0.~~ 1.0	131.3
11.	2	10	1.1	129.6
12.	2	30	1.2	127.4 1^{st} Minima
13.	2	50	1.3	138.6
14.	2	70	1.4	165.8
15.	2	90	1.5	190.6
16.	3	10	1.6	310
17.	3	30	1.7	324
18.	3	50	1.8	356
19.	3	70	1.9	361
20.	3	90	2.0	365

Teacher's Signature :

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Calculation:

$$a = \frac{m\lambda D}{dy}$$

$D = 54\,cm = 0.54\,m$

(1) $m = 2$

λ (for He-Ne Laser) $= 632.8\,nm = 632.8 \times 10^{-9}\,m$

$y_1 = 2.4 - 0.4 = 2\,mm$

$$a_1 = \frac{2 \times 632.8 \times 10^{-9} \times 54 \times 10^{-2}}{2 \times 10^{-3}}$$

$= 3.4171 \times 10^{-4}\,m$

(2) $m = 1$ $y_2 = 2.4 - 1.2 = 1.2\,mm$

$$a_2 = \frac{1 \times 632.8 \times 10^{-9} \times 54 \times 10^{-2}}{1.2 \times 10^{-3}}$$

$= 2.847 \times 10^{-4}\,m$

(3) $m = 1$ $y_3 = -2.4 + 3.9 = 1.5\,mm$

$$a_3 = \frac{1 \times 632.8 \times 10^{-9} \times 54 \times 10^{-2}}{1.5 \times 10^{-3}}$$

$= 2.2780 \times 10^{-4}\,m$

(4) $m = 2$ $y_4 = 4.3 - 2.4 = 1.9\,mm$

$$a_4 = \frac{2 \times 632.8 \times 10^{-9} \times 54 \times 10^{-2}}{1.9 \times 10^{-3}}$$

$= 3.5969 \times 10^{-4}$

$$a = \frac{a_1 + a_2 + a_3 + a_4}{4} = 3.03 \times 10^{-4}\,m = 0.303\,mm$$

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Sl. No	Distance MSR (mm)	VSR	Total Reading (mm)	Intensity (mV)
21.	4	10	2.1	378
22.	4	30	2.2	380
23.	4	50	2.3	382
24.	4	70	2.4	385 Central Maxima
25.	4	90	2.5	383
26.	5	10	2.6	377
27.	5	30	2.7	373
28.	5	50	2.8	363
29.	5	70	2.9	335
30.	5	90	3	305
31.	6	10	3.1	262
32.	6	30	3.2	252
33.	6	50	3.3	109
34.	6	70	3.4	92.3 1st [illegible]
35.	6	90	3.5	89.1 1st Minima
36.	7	10	3.6	94.3
37.	7	30	3.7	112.0
38.	7	50	3.8	122.7 1st Maxima
39.	7	70	3.9	98.4
40.	7	90	4.0	93.2
41.	8	10	4.1	45.7
42.	8	30	4.2	36.8
43.	8	50	4.3	5.7 2nd Minima
44.	8	70	4.4	16.4
45.	8	90	4.5	18.5
46.	9	10	4.6	26.8 2nd Maxima
47.	9	30	4.7	25

Teacher's Signature :

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Result :

The calculated slit width from the diffraction pattern $\boxed{a = 0.303 \text{ mm}}$

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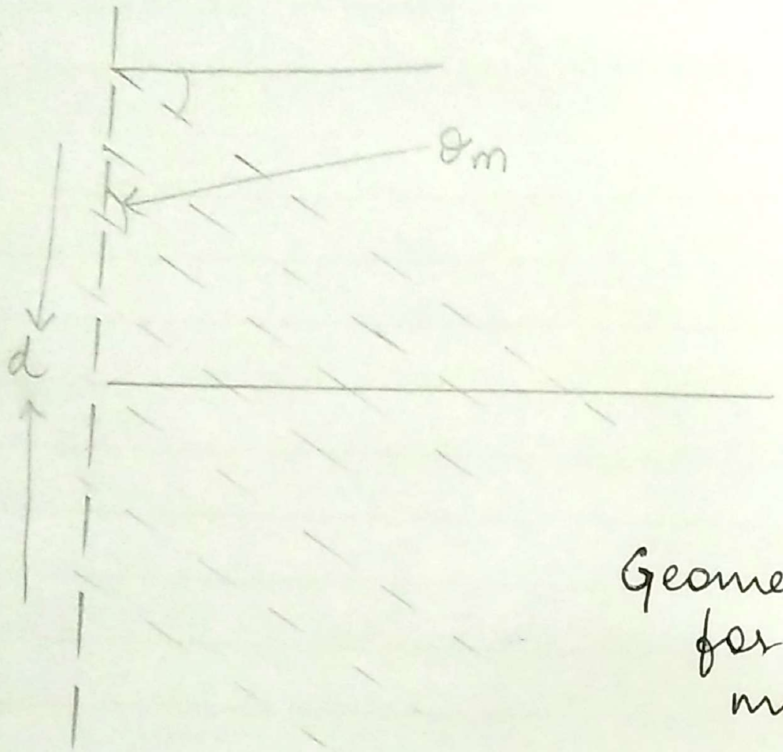
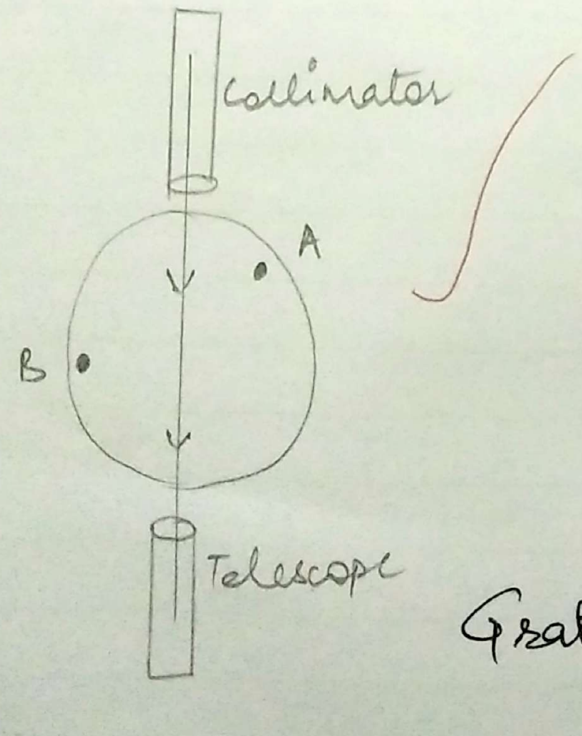
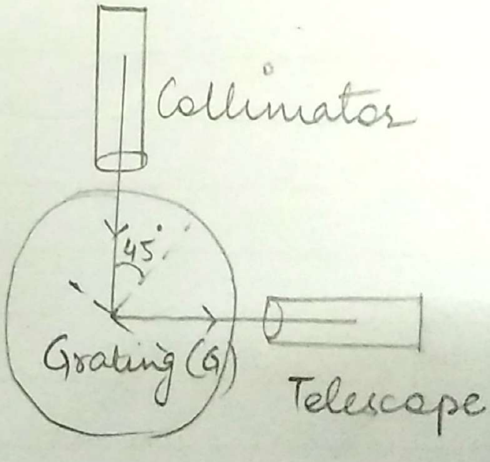


Geometrical conditions for diffraction from multiline grating





Grating settings

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DIFFRACTION GRATING

Aim : • To understand diffraction, diffraction grating and how diffraction grating works with the help of basic diffraction grating equations and experimental studies.

• To measure the wavelength of light source with the help of diffraction grating

Apparatus: Spectrometer, diffraction grating, mercury light source, high voltage power supply, magnifying lens, spirit level, torch light

Theory: The diffraction grating is made by making many parallel scratches on the surface of flat piece of transparent material. The grating used has 6000 lines /cm on it

Grating Eq^n, $m\lambda = d \sin\theta_m$

$$\boxed{\lambda = \frac{d \sin\theta_m}{\lambda}}$$

least count of V.S = 1'

least count of C.S = 30'

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Observation :

$m = 1$

Colour	RHS			LHS			$2\theta_m = \theta_L - \theta_R$	θ_m	$\lambda = d \sin\theta_m$
	CSR	VSR	Total(θ_R)	CSR	VSR	Total(θ_L)			
Violet	71.5°	2′	71.56°	99.5°	7′	99.61°	28.05°	14.025°	403
Blue	70°	12′	70.2°	100.5°	9′	100.65°	30.45°	15.225°	438
Green	66°	8′	66.13°	104.5°	11′	104.68°	38.55°	19.275°	550
Yellow	65°	16′	65.26°	105.5°	6′	105.6°	40.34°	20.17°	574
Orange	64°	13′	64.21°	106°	18′	106.3°	42.09°	21.045°	598
Red	62.5°	15′	62.75°	107°	15′	107.25°	44.5°	22.25°	631

$m = 2$

Colour	RHS			LHS			$2\theta_m = \theta_L - \theta_R$	θ_m	$\lambda = \frac{d \sin\theta_m}{2}$
	CSR	VSR	Total (θ_R)	CSR	VSR	Total (θ_L)			
Violet	55.5°	10′	55.66°	116.5°	20′	116.83°	61.17°	30.585°	424
Blue	53°	6′	53.1°	122.5°	19′	122.81°	69.71°	34.855°	476
Green	43°	3′	43.05°	125.5°	18′	125.8°	82.75°	41.375°	550
Yellow	39.5°	15′	39.75°	128.5°	6′	128.6°	88.85°	44.425°	583
Orange	38°	5′	38.08°	129.25°	6′	129.35°	91.27°	45.63°	596
Red	35°	2′	35.03°	130°	6′	130.1°	95.04	47.52	615

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Result:

Colour	λ theoretical (nm)	m = 1 λ(nm)	error %	m = 2 λ(nm)	error %
Violet	400	403	0.75%	424	6%
Blue	475	438	7.7%	476	0.2%
Green	510	550	7.8%	550	7.8%
Yellow	570	574	0.70%	583	2.2%
Orange	590	598	1.3%	596	1.01%
Red	650	631	2.9%	615	5.3%

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Helmholtz Coil

Aim: To study magnetic field produced by current carrying coils.

Apparatus: Helmholtz coils, connecting wires, gaussmeter, regulated power supply, measuring scale.

Theory: The magnetic induction of a circular coil of radius R, carrying current I, at a distance z from center of loop along the axis is given by:

$$\boxed{\vec{B}(z) = \frac{\mu_0 I}{2} \frac{R^2}{(R^2+z^2)^{3/2}} \hat{k}}$$

At $z=0$

$$\boxed{\vec{B}(0) = \frac{\mu_0 I}{2R}}$$

If there are 2 such parallel coils at a distance s such that the current flows in same dir^n in both coils, then $\vec{B}$ adds in space b/w them. The axial $\vec{B}$ is fairly constant over certain region in the middle of pair of coils.

This $\vec{B}$ is measured using a Hall probe connected to gaussmeter.

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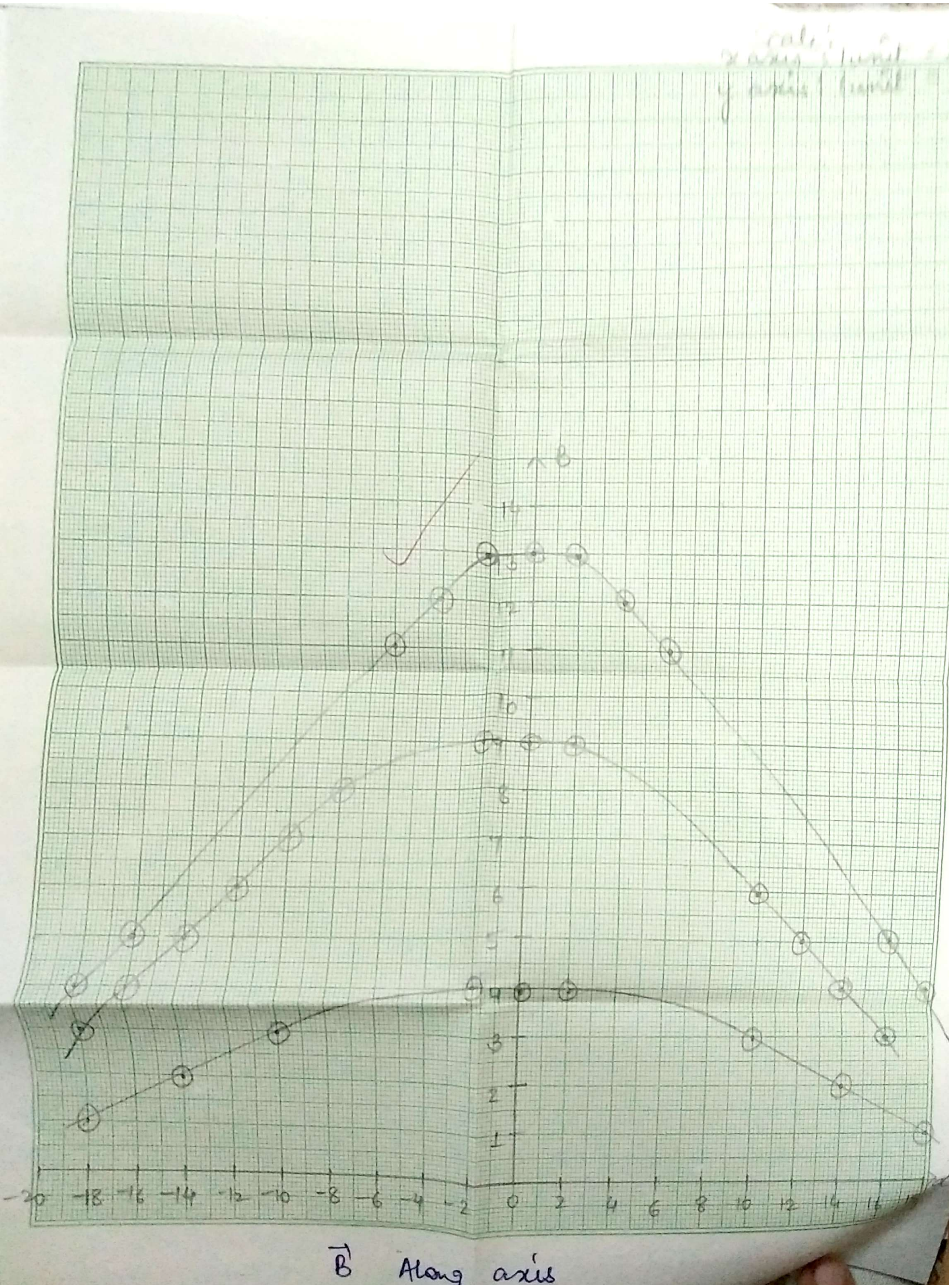

$\vec{B}$ Along axis

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Observation Table:

1) $\vec{B}$ along axis

Dis (cm)	Magnetic field		
	I_1(1A)	I_2=2A	I_3=3A
20	1	2	4
18	1	3	4
16	1	3	5
14	2	4	6
12	2	5	7
10	3	6	8
8	3	6	9
6	4	7	11
4	4	8	12
2	4	9	13
0	4	9	13
-2	4	9	13
-4	4	9	13
-6	4	8	13
-8	4	8	12
-10	3	7	11
-12	3	6	10
-14	2	5	8
-16	2	5	7
-18	1	4	6
-20	1	3	5

2) $\vec{B}$ along diameter

Dis (cm)	Magnetic field		
	I=1A	I=2A	I=3A
16	12	18	27
14	10	15	22
12	8	13	19
10	7	12	17
8	6	10	16
6	5	10	16
4	5	9	15
2	5	9	14
0	4	9	13
-2	5	9	14
-4	5	9	15
-6	5	10	16
-8	6	10	16
-10	7	12	17
-12	8	13	19
-14	10	15	22
-16	12	18	27

Teacher's Signature :

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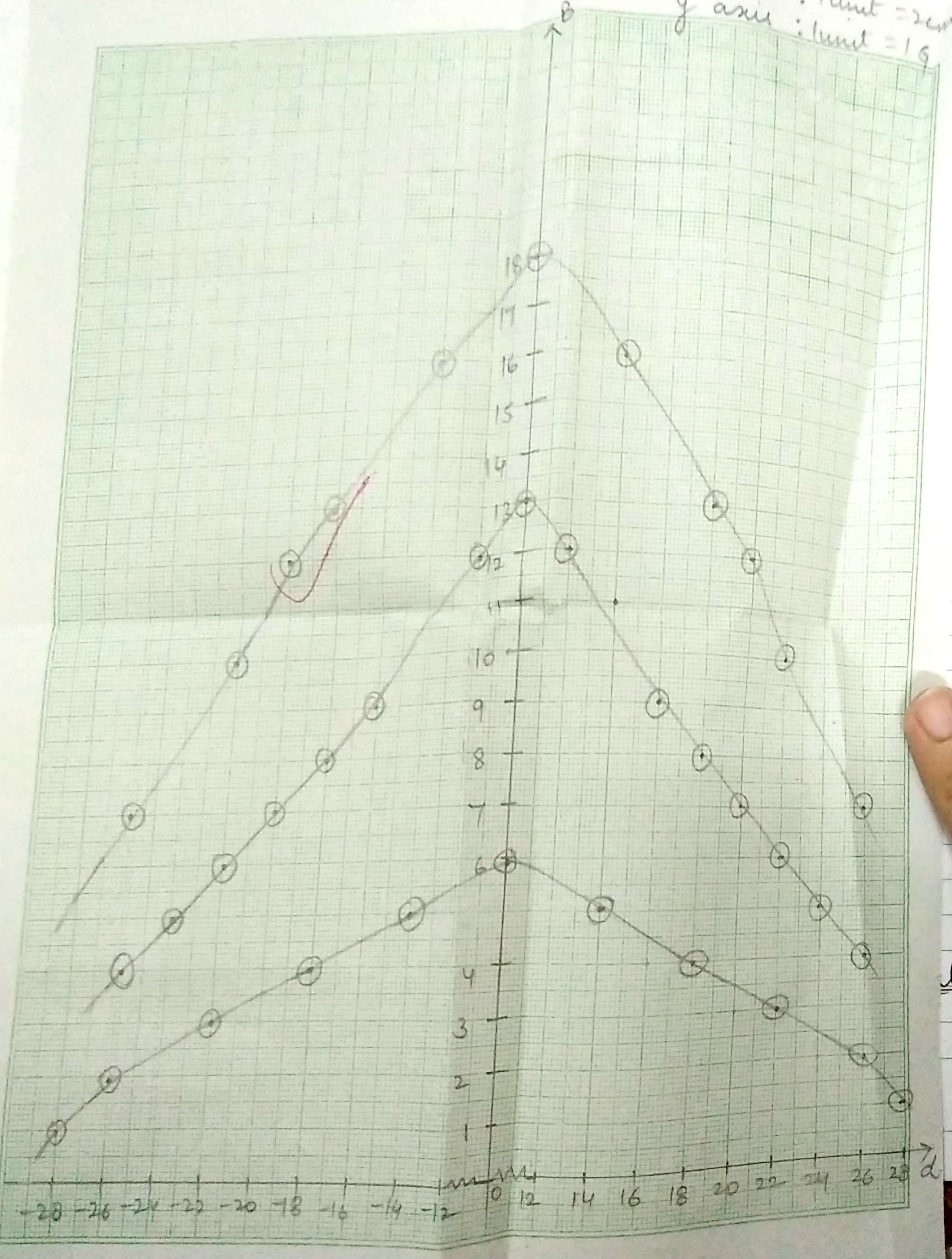
Scale → x axis : 1 unit = 2 cm
y axis : 1 unit = 1 G



Helmholtz Coil

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3) Helmholtz Coil

Distance (cm)	Magnetic field $I_1 = 1A$	$I_2 = 2A$	$I_3 = 3A$
±38	0	2	3
±36	1	2	4
±34	1	2	4
±32	1	3	5
±30	1	3	5
±28	1	4	6
±26	2	4	7
±24	2	5	8
±22	3	6	10
±20	3	7	12
±18	4	8	13
±16	4	9	14
±14	5	11	16
±12	5	12	16
±10	5	13	17
±8	6	13	18
±6	6	13	18
±4	6	13	18
±2	6	13	18
0	6	13	18

Result :

1. we find that values for $\vec{B}$ remains constant

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Expt. No.

in the range of [-10 10] for helmholtz experiment.

2. The graph comes about to be symmetrical about y axis for all 3 cases.

3. The peak limit along axis is small value along diameter.

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