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Semester	1st	Roll No.	16

INDEX

EXPERIMENT - 1 CALIBRATION OF AMMETER

Object :- To calibrate given ammeter with the help of a potentiometer.

Apparatus :- Potentiometer, two storage batteries, two rheostats ($50\ \Omega$, $150\ \Omega$), a standard cell (cadmium cell), a galvanometer, a standard $1\ \Omega$ resistance, one two-way key, two one-way keys, connections wires, given ammeter.

Formula Used :- The errors in the ammeter readings given by the following expressions respectively:

for ammeter :

$$(I' - I) = \left[\frac{E \times l_2}{l_1} - I \right]$$

where,

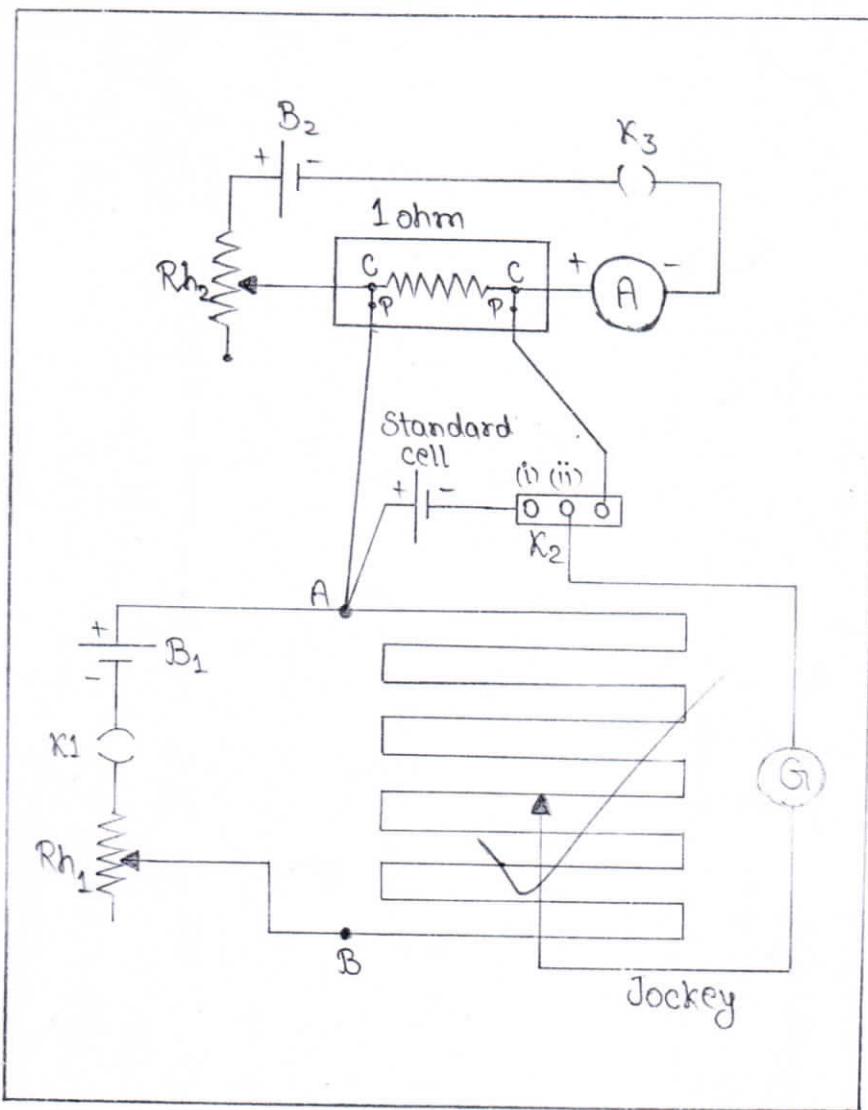
I = Current measured by the given ammeter.

I' = Current measured by the potentiometer.

l_1 = Length of the potentiometer wire corresponding to E.M.F of the standard cell (cadmium).

l_2 = Length of the potentiometer wire corresponding to the current P or potential difference V .

E = E.M.F of the standard cell (for cadmium cell $E = 1.0186$ volt).



Electrical connections for Calibration of Ammeter

Procedure :-

Step I : Standardization of the potentiometer - we make the connections as shown in the fig.1. We close the key K_1 and $K_2(i)$ by keeping the keys K_1 and $K_2(ii)$ open. We put the jockey at the last and B of the 10th wire. At this stage the total length of the wire will be 1000 cm and there will be some deflections in the galvanometer. We adjust the rheostat R_h , till the deflection in the galvanometer is reduced to zero and note down the total balancing length (l_1). In the present case $l_1 = 520$ cm.

Step II : We open the key $K_2(i)$ and close the key $K_2(ii)$ and key K_3 . Adjust the rheostat R_h so that the ammeter and voltmeter read a suitable value (such as $I = 0.1, 0.2, 0.3$ amp). Move the jockey to get the null point, i.e., no deflection position of the galvanometer and note down the balancing length l_2 . Repeat this process for new readings of voltmeter and ammeter. We note down the balancing length l_2 for each reading of voltmeter and ammeter. Now, we calculate the values of I' and I'' using the formula $I' = (E/l_1)l_2$ and $I'' = (E/l_1)l_2$ for each values of lengths l_2 . Since the standard resistance is one ohm. The values of current

Calculations :-

(i) Potential gradient (K) of the potentiometer wire is calculated by

$$K = \frac{E}{l_1} = \frac{1.08}{1000.520} = 2.076 \times 10^{-3} \text{ volt/cm}$$

(ii) The values of current $I' = (E/l_1)l_2$

$$(1) I'_1 = 2.076 \times 10^{-3} \times 53 = 0.1100 \text{ amp}$$

$$I'_1 - I_1 = 0.1100 - 0.1 = 0.0100 \text{ amp}$$

$$(2) I'_2 = 2.076 \times 10^{-3} \times 86 = 0.1785 \text{ amp}$$

$$I'_2 - I_2 = 0.1785 - 0.2 = -0.0215 \text{ amp}$$

$$(3) I'_3 = 2.076 \times 10^{-3} \times 157 = 0.3259 \text{ amp}$$

$$I'_3 - I_3 = 0.3259 - 0.3 = 0.0259 \text{ amp}$$

$$(4) I'_4 = 2.076 \times 10^{-3} \times 227 = 0.4712 \text{ amp}$$

$$I'_4 - I_4 = 0.4712 - 0.4 = 0.0712 \text{ amp}$$

$$(5) I'_5 = 2.076 \times 10^{-3} \times 303 = 0.6290 \text{ amp}$$

$$I'_5 - I_5 = 0.6290 - 0.5 = 0.1290 \text{ amp}$$

$$(6) I'_6 = 2.076 \times 10^{-3} \times 376 = 0.7805 \text{ amp}$$

$$I'_6 - I_6 = 0.7805 - 0.6 = 0.1805 \text{ amp}$$

$$(7) I'_7 = 2.076 \times 10^{-3} \times 378 = 0.7847 \text{ amp}$$

$$I'_7 - I_7 = 0.7847 - 0.7 = 0.0847 \text{ amp}$$

I' and voltage I'' will be equal.

Step III: We have to find out $(I' - I)$ which is equal to errors produced in the ammeter and voltmeter readings respectively. We plot a calibration graph between error $(I' - I)$ and I . Similarly graph can be obtained for ammeter calibration.

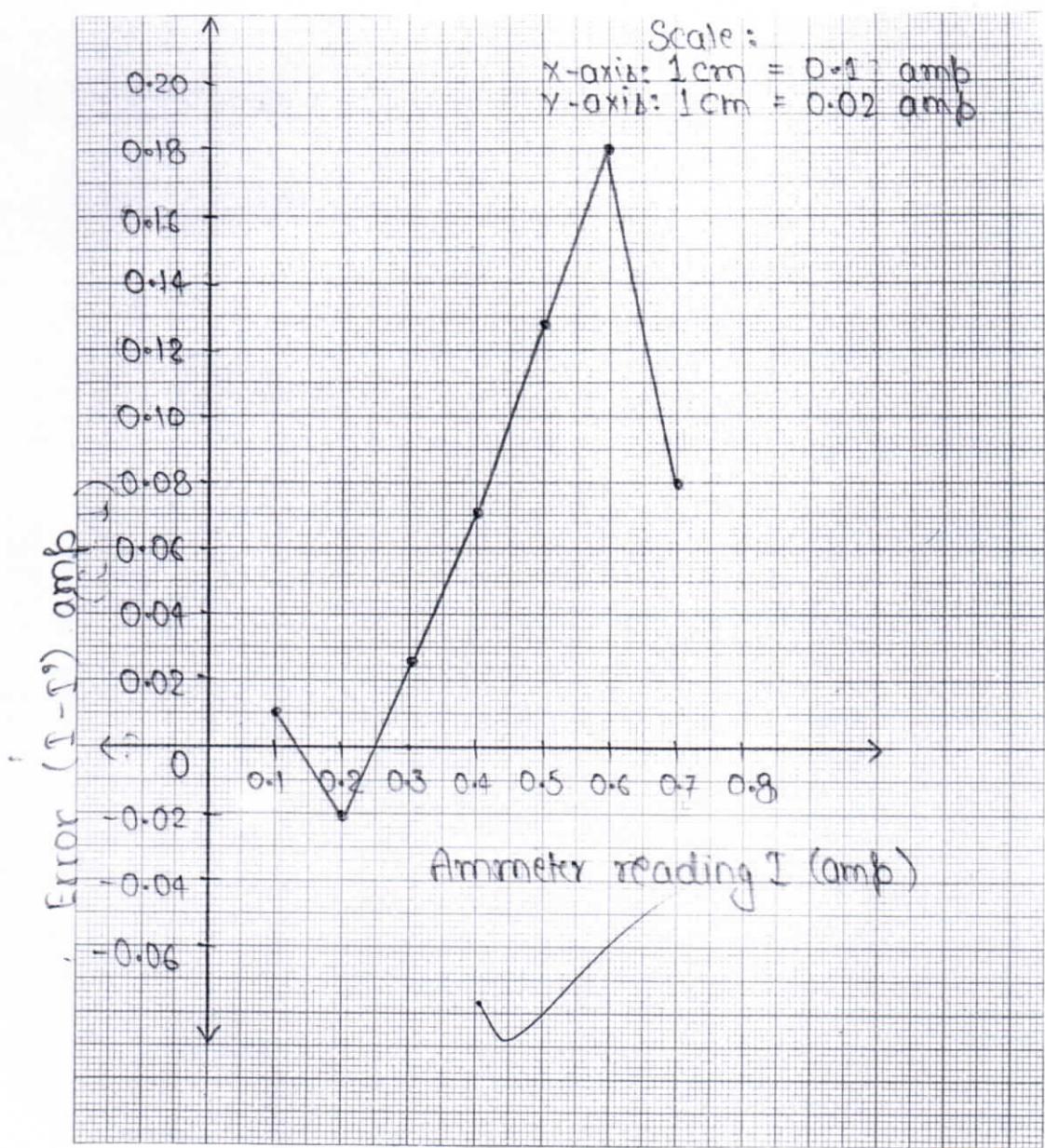
Observations :-

E.M.F of standard cell (E) = 1.08 volt

Balancing length (l_1) of the potentiometer wire corresponding to E.M.F of the standard cell
 $= 520 \text{ cm}$

Table 1: Calibration of Ammeter

S.No.	Ammeter reading I (amp)	Balancing length of the potentiometer wire l_2 (cm)	Potentiometer reading $I' = [E/l_1 \times l_2]$ (amp)	Errors in ammeter $(I' - I)$ (amp)
1.	0.1	53	0.1100	0.0100
2.	0.2	86	0.1785	-0.0215
3.	0.3	157	0.3259	0.0259
4.	0.4	227	0.4712	0.0712
5.	0.5	303	0.6290	0.1290
6.	0.6	376	0.7805	0.1805
7.	0.7	378	0.7847	0.0847



Result :- Calibration curve of ammeter is plotted as shown in graph.

Precautions :-

- (1) Batteries should be fully charged.
- (2) The E.M.F of the battery B_1 , should be greater than the E.M.F of the Standard cell.
- (3) Keys should be closed only when the reading are to be taken.
- (4) The galvanometer used in the experiment should be sensitive.
- (5) The connections should be tightly made.
- (6) The jockey should not be pressed hard on the potentiometer wire.
- (7) The jockey should not be slipped over the wire.

Applications :-

- (1) Digital ammeter are used for the best accuracy they are used in Analog - to - digital converter.
- (2) Digital ammeter are used for the best accuracy they are used in Electronic power supply.
- (3) Digital ammeter is used in Zener diode.
- (4) Sampling ammeter are used scale and pointer meters.
- (5) They can be used in graphic recorders.

10
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EXPERIMENT - 2 TANGENT GALVANOMETER

Object :- To plot a graph showing the variation of magnetic field with distance along the axis of a circular coil carrying current and to estimate from it the radius of the coil.

Apparatus :- Stewart and Gee's apparatus, ammeter, battery, rheostat, commutator, plug key and connection wires.

Formula Used :-

The magnetic field on the axis of circular coil by:

$$B = \frac{2\pi n r^2 i}{10(x^2 + r^2)^{3/2}}$$

where,

B = Magnetic field along the axis of a coil and it is equal to $H \tan \theta$ (horizontal magnetic field).

n = Number of turns in the coil.

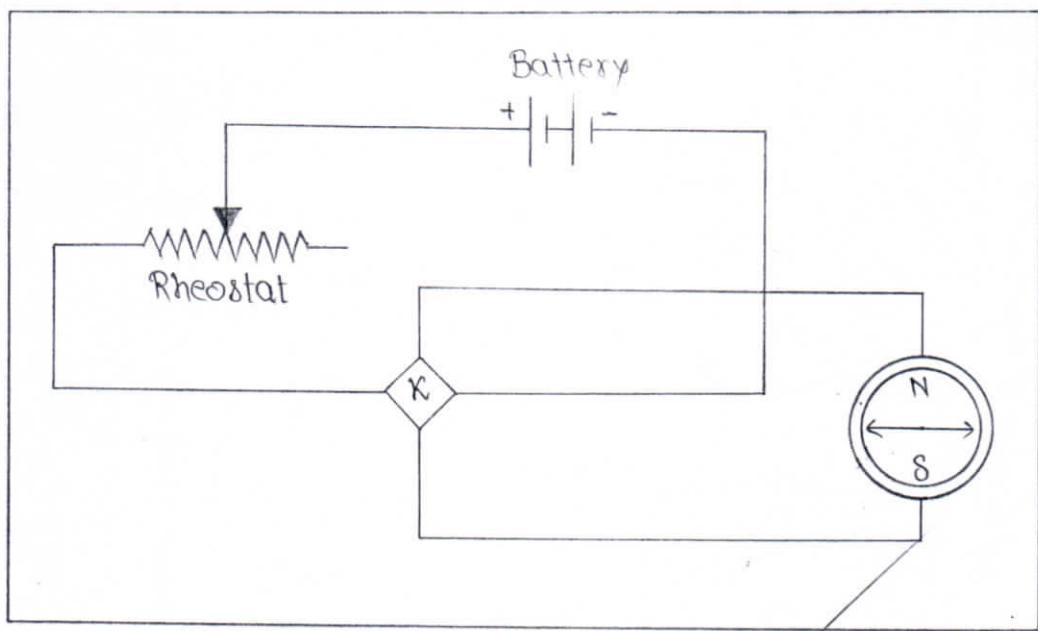
r = Radius of the coil.

i = Current flowing in the coil (in amperes).

x = Distance of the point the centre of the coil.

Procedure :-

Step I : We place the compass box on the sliding bench so that its magnetic needle is at the centre of the coil. We level the base of the coil with the



Circuit Diagram

help of a spirit.

Step II : We rotate the instrument in the horizontal plane in such a way that the coil lies roughly in the magnetic meridian and the compass box is rotated till the pointer ends read 0-0.

Step III : By using commentator, we flow the current in one direction and note down the deflection of the needle. We now reverse the direction of current and again note down the deflection. If both the deflections are equal that means the coil is in magnetic meridian.

Step IV : We adjust the current in the coil such that the deflection in the magnetic needle is of the order $70^\circ - 75^\circ$ and note down the reading of both side of pointer. We reverse the direction of current and again note down reading of both the ends of pointer.

Step V : We move the compass box through 2 or 5 cm and note down the deflection. We again move through 2 or 5 cm and continue to take reading till the compass box reaches the end of the bench.

Step VI: We take the measurements for other side of the bench.

Step VII: We calculate θ according to the observation table and determine $\tan\theta$.

Step VIII: Now we plot a graph taking position (x) along the X-axis and $\tan\theta$ along the Y-axis.

Step IX: The distance between the two points of inflexion on the curve will be the radius of the coil. The radius (r) of the coil also be estimated by taking the mean value of inner and outer radii of the coil.

Observations :-

Table 1: Measurement of Deflection (in one side)

S.No.	Distance of needle from centre(x)	Current one way	Current reversed	$\theta = \theta_1 + \theta_2 + \theta_3 + \theta_4$	$\tan\theta$
		θ_1 (deg.)	θ_2 (deg.)	θ_3 (deg.)	θ_4 (deg.)
1.	0	70	70	84	77
2.	5	65	65	75	70.75
3.	10	50	50	55	53
4.	15	32	32	36	34
5.	20	20	20	20	20
6.	25	12	12	14	13
7.	30	10	10	12	11.25
8.	35	7	7	2	4.5

Table 2 : Measurement of Deflection (in other side)

S.No.	Distance of needle from centre (x)	Current one way		Current reversed		$\theta = \theta_1 + \theta_2 + \theta_3 + \theta_4$	$\tan \theta$
		θ_1 (deg.)	θ_2 (deg.)	θ_3 (deg.)	θ_4 (deg.)		
1.	0	70	70	84	84	77	4.3
2.	5	65	65	70	70	67.5	2.4
3.	10	52	52	55	55	53.5	1.4
4.	15	34	34	32	32	33	0.65
5.	20	21	21	16	16	18.5	0.33
6.	25	13	13	9	8	10.75	0.18
7.	30	9	9	5	5	7	0.12
8.	35	5	4	4	3	4	0.06

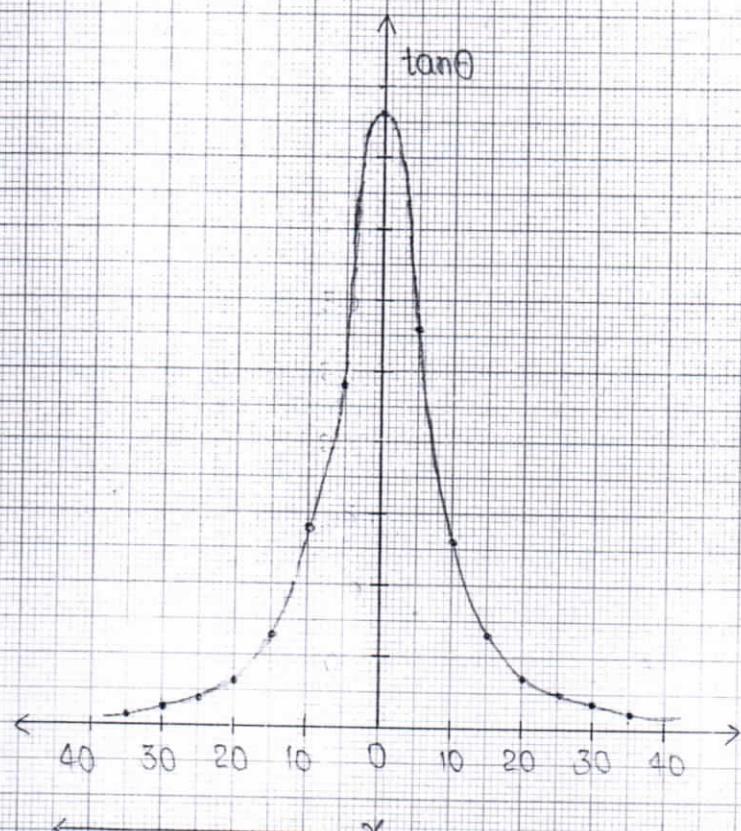
Result :-

Various of magnetic field along the axis of current carrying circular coil is shown in the graph.

Precautions :-

- (1) The current flowing in the coil should remain constant.
- (2) The deflection of the needle should be noted in the range of 30° to 75° .
- (3) There should not be any magnetic material near the apparatus.
- (4) Compass box should be adjusted in horizontal plane by leveling it.
- (5) Coil should be exactly adjusted in the magnetic meridian.

Scale:
On x-axis: 1cm = 10 cm
On y-axis: 1dm = 0.5



Distance from the centre of
the coil in cm

Applications :-

- (1) To know the location of a particular place through magnetic map.
- (2) In designing the shape and weight of a satellite.
- (3) In navigation.
- (4) In designing the motors and generators.
- (5) In the electromagnetic induction devices such as transformers.
- (6) In the construction of ammeter, voltmeter and galvanometer.

10
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EXPERIMENT-3 VISCOSITY

Object :- To determine the coefficient of viscosity of water by Poiseuille's method.

Apparatus :- A capillary tube of uniform bore and a constant level reservoir fitted on a board, a manometer, travelling microscope, stop watch and graduated jar.

Formula Used :-

The coefficient of viscosity η of a liquid is given by the formula

$$\eta = \frac{\pi P r^4}{8Vl} = \frac{\pi (\text{neg}) r^4}{8Vl} \text{ kg/(m-sec) or Poise}$$

where,

r = Radius of the capillary tube.

V = Volume of water collected per second.

l = Length of the capillary tube.

ρ = Density of liquid ($\rho = 1.00 \times 10^3 \text{ kg/m}^3$ for water).

h = Difference of levels in manometer.

Description of Apparatus :-

The apparatus used for the purpose of determination of the coefficient of viscosity of water is shown in fig.(1).

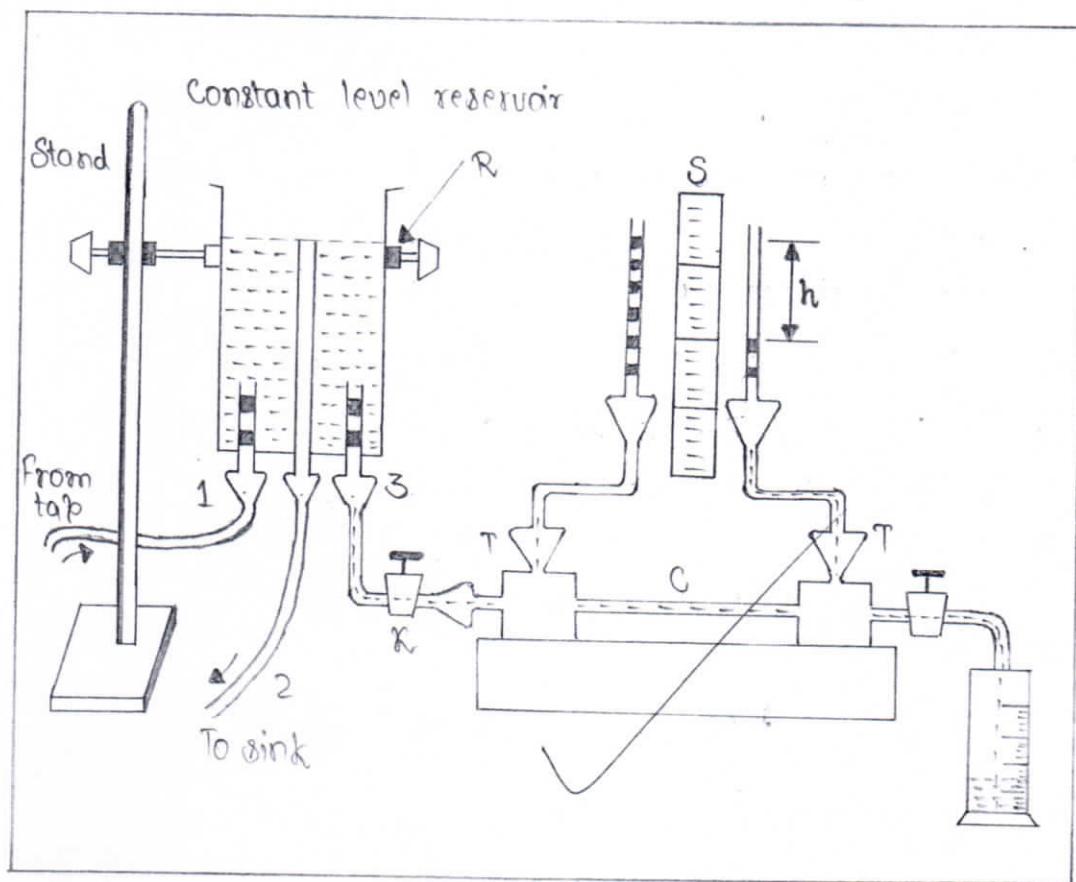


Fig. (1)

The capillary tube C is well fitted in T and T whose upper parts are jointed by rubber tubing to two upright glass tube forming the manometer. With the help of the pinch cock X, a steady flow of water is maintained through the capillary tube. The water is collected in a graduated cylinder on the other side of the capillary tube i.e., the volume of water flowing per second can be determined. The pressure difference is recorded by noting the difference in heights of the liquid in the manometer.

According to the formula, the pressure difference is made constant by a constant pressure device. It consists of a reservoir provided with three tubes. The water enters through tube (1) and flows into the capillary tube through tube (3) while the excess of water comes out through tube (2). The height of water level is maintained constant in the reservoir, hence the pressure difference is constant at the two ends. By raising or lowering the reservoir, the pressure is changed.

Procedure :-

- (1) We allow the water to enter the constant level reservoir through tube (1) and leave through tube(2) in such a way that water comes drop by drop from the capillary tube. This is adjusted with the help of pinch cock K. It should be remembered that all the bubbles should be removed from the capillary.
- (2) When everything is steady, we collect the water in a graduated jar for few minutes and thus calculate the volume V of the water flowing per second.
- (3) We note the difference of the level of water in the manometer. This gives us h .
- (4) We vary h by raising or lowering the reservoir. For each value of h , find the value of V . We must take atleast six readings in this way.
- (5) We measure the length l and diameter of the tube.
- (6) We draw a graph between h and V and hence find the value of $[h/V]$ from the graph.

Calculations :-

The coefficient of viscosity η for water is given by

$$\eta = \frac{\pi \rho g r^4 h t}{8 \ell V}$$

$$\eta = \frac{3.14 \times 10^3 \times 9.8 \times (0.1 \times 10^{-2})^4 \times 0.2 \times 10^{-2} \times 356}{8 \times 35.5 \times 10^{-2} \times 10 \times 10^{-6}}$$

$$\eta = \frac{2190.96 \times 10^{-11}}{284 \times 10^{-8}}$$

$$\eta = 7.71 \times 10^{-3}$$

$$\eta = 0.0077 \text{ Poise}$$

Observations :-

S.No.	Manometer reading		Pressure difference h (meter)	Measurement of V		V meter ³ sec
	One end (meter)	Other end (meter)		Total volume of water collected. (meter) ³	Time t (sec)	
1.	1.8	2.0	0.2	10×10^{-6}	360	10×10^{-6}
2.	1.2	1.4	0.2	10×10^{-6}	356	356
3.	1.2	1.4	0.2	10×10^{-6}	352	

Result :- The coefficient of viscosity of water at 27°C
 $= 0.0077 \text{ Poise}$

Standard Result :- $\eta = 0.008 \text{ Poise}$

Percentage Error :- $\frac{0.008 - 0.0077}{0.008} \times 100 = 3.75\%$.

Precautions and Sources of Error:-

- (1) The tube should be placed horizontally to avoid the effect of gravity.
- (2) The value to h should not be made large and should be so adjusted that the water comes out as a slow trickle.
- (3) The radius should be measured very accurately as it occurs in fourth power in the formula.
- (4) The pressure difference should be kept small to obtain streamline motion.

EXPERIMENT - 4 NEWTON'S RINGS

Object :- To determine the wavelength of the sodium light by Newton's ring.

Apparatus :- Sodium lamp, plano-convex lens, plane glass, optical arrangement for Newton's rings, travelling microscope, etc.

Introduction

In this experiment the physical property of interference of light will be used to determine the wavelength, λ , of a light source. The interference fringe system here is a pattern of concentric circles, the diameter of which we will measure with a travelling microscope (which has a Vernier scale). If a clean convex lens is placed on a clean glass slide (optically flat) and viewed in monochromatic light, a series of rings may be seen around the point of contact between the lens and the slide. These rings are known as Newton's rings and they arise from the interference of light reflected from the glass surfaces at the air film between the lens and the slide. The experimental set-up is shown in figure 1.

Formula Used :-

The wavelength λ of light by :

$$\lambda = \frac{D_{n+p}^2 - D_n^2}{4pR}$$

where,

D_{n+p} = Diameter of $(n+p)^{\text{th}}$ ring.

D_n = Diameter of n^{th} ring.

p = An integer number, and

R = Radius of curvature of the curved face of the
plano-convex lens = 100 cm.

Procedure :-

Step I: We place the plano-convex lens on the surface of plane glass plate in such a manner that its convex surface touches the glass plate and then light is allowed to fall normally on the surface of this combination with the help of glass G at 45° to the vertical as shown in fig. 1.

Step II: Now with the help of microscope we see the concentric circular rings in the field of view of the microscope objective (fig. 2).

Step III: We move the microscope horizontally in one direction with the help of screw. We fixed up the cross-wire tangential to the ring and note this reading.

Step IV : We again move the microscope horizontally in same direction and cross-wire is fixed tangentially to the successive bright fringes noting the vernier reading till other side is reached.

Step V : The value of $(D_{n+1}^2 - D_n^2)$ and λ can also be obtained as follows,

$$\lambda = \frac{D_{n+1}^2 - D_n^2}{4PR}$$

Observations :-

- (A) Measurement of Least Count of Travelling Microscope
least count of the vernier of the travelling microscope = 0.01 mm = 0.001 cm
- (B) Table : Diameter of Newton's ring

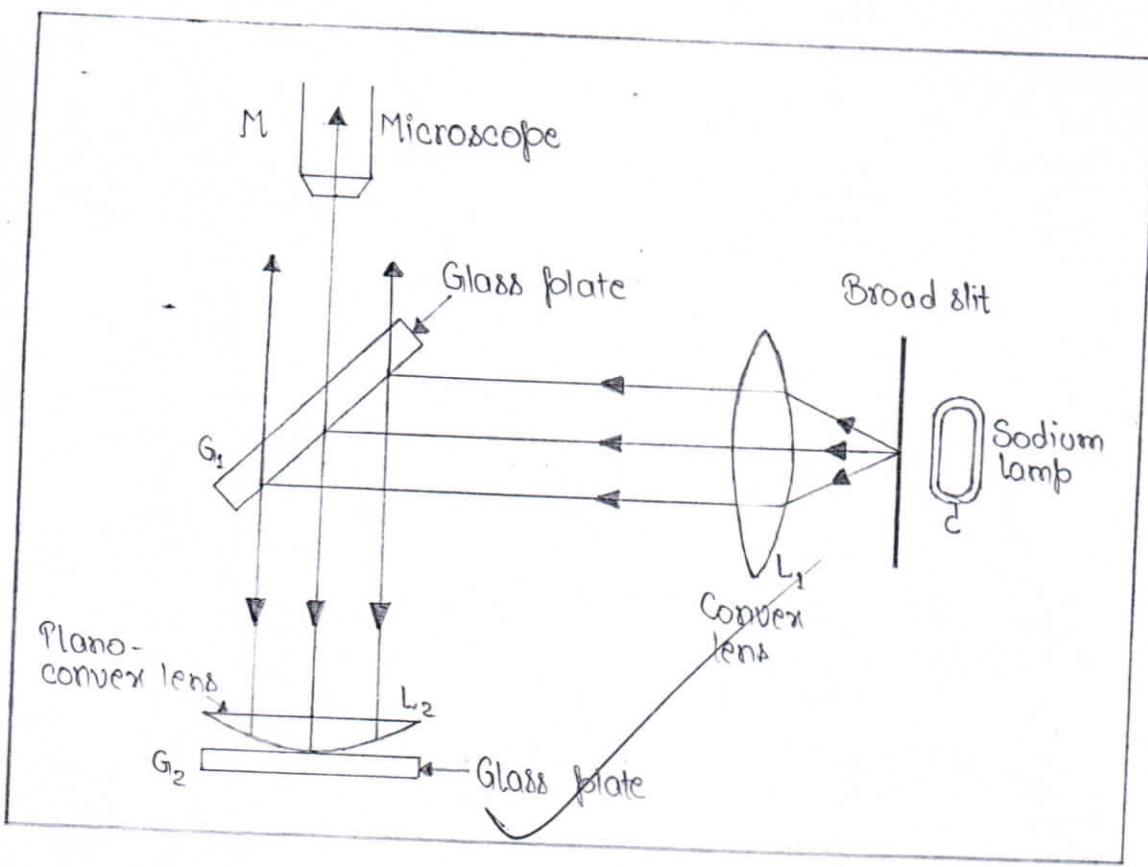


Fig 1: Optical Arrangement of Newton's Rings

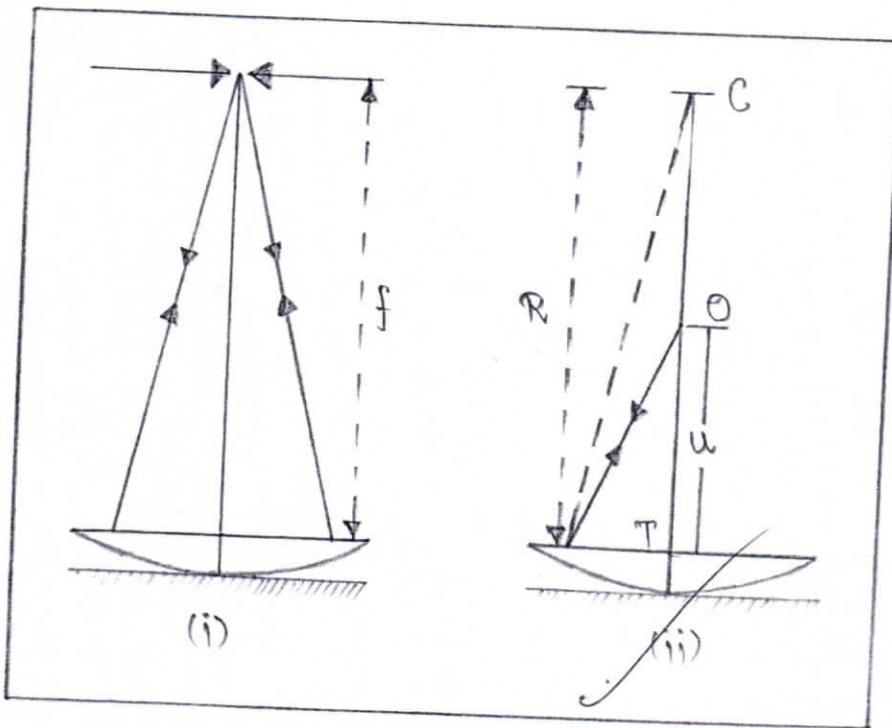


Fig 3: Radius of Curvature of Newton's Ring.

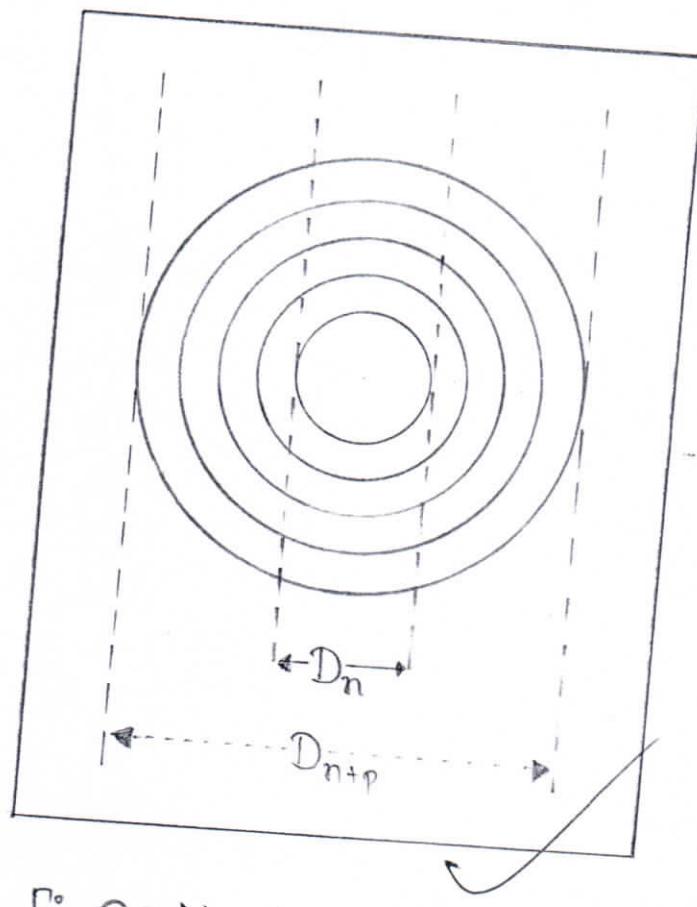


Fig 2: Newton's Rings

S.No.	No. of the ring	Micrometer Reading	Diameter \varnothing	$D^2 = (D_{n+p}^2 - D_n^2)$	Mean cm^2	P
		Left end (a) cm	Right end (b) cm	$(a-b)^2$ cm^2	cm^2	
1.	2	10.133	9.991	0.142	0.020	0.258 0.19475 8
2.	4	10.205	9.951	0.254	0.065	0.210
3.	6	10.250	9.910	0.340	0.116	0.213
4.	8	10.290	9.870	0.420	0.176	0.098
5.	10	10.331	9.804	0.527	0.278	
6.	12	10.333	9.809	0.524	0.275	
7.	14	10.374	9.800	0.574	0.329	
8.	16	10.300	9.777	0.523	0.274	

Result :-

The mean value of wavelength λ of sodium light
 $= 6085 \text{ A}^\circ$ (using formula)

Error Analysis :-

Standard mean value of wavelength λ of Sodium
 light $= 5893 \text{ A}^\circ$

$$\text{Percentage error} = \left[\frac{\text{Standard value of } \lambda - \text{Measured value of } \lambda}{\text{Standard value of } \lambda} \right] \times 100$$

Calculations :-

Using formula,
from Table,

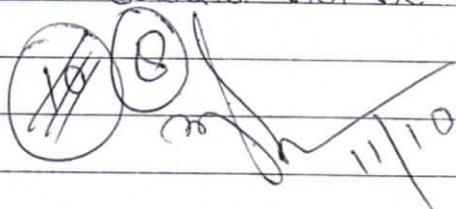
$$\begin{aligned} D_{n+p}^2 - D_n^2 &= \frac{0.258 + 0.210 + 0.213 + 0.098}{4} \\ &= \frac{0.779}{4} \\ &= 0.19475 \text{ cm}^2 \end{aligned}$$

$$\begin{aligned} \lambda &= \frac{D_{n+p}^2 - D_n^2}{4\pi R} \\ &= \frac{0.19475}{4 \times 8 \times 100} \\ &= 6.085 \times 10^{-5} \text{ cm} \\ &= 6085 \text{ A}^\circ \end{aligned}$$

$$\text{Percentage error} = \frac{5893 - 6085}{5893} \times 100 \\ = -3.26\%$$

Precautions :-

- (1) Glass plate and lens should be cleaned thoroughly.
- (2) The plano-convex lens should be of large radius of curvature.
- (3) Cross-wire should be focused on a bright ring tangentially.
- (4) Cross-wire should not be touched.



EXPERIMENT-5 NODAL SLIDE

Object :- To determine the focal length of the combination of two lenses separated by a distance with the help of nodal slide and to verify the formula

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{x}{f_1 f_2}$$

Apparatus :- Nodal slide arrangement (optical bench, plane mirror, cross slit and a lamp) and two convex lenses.

Formula Used :- Focal length (F) of combination of two lenses separated by a distance x is given by:

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{x}{f_1 f_2}$$

where,

f_1, f_2 = focal lengths of the given lenses respectively.

Procedure :-

Step I : We mount the lamp, cross slit, two separated by a known distance and mirror on uprights of the optical bench and adjust in such a way that their axes lie along same horizontal line. Initially we keep lens L_1 towards the plane mirror.

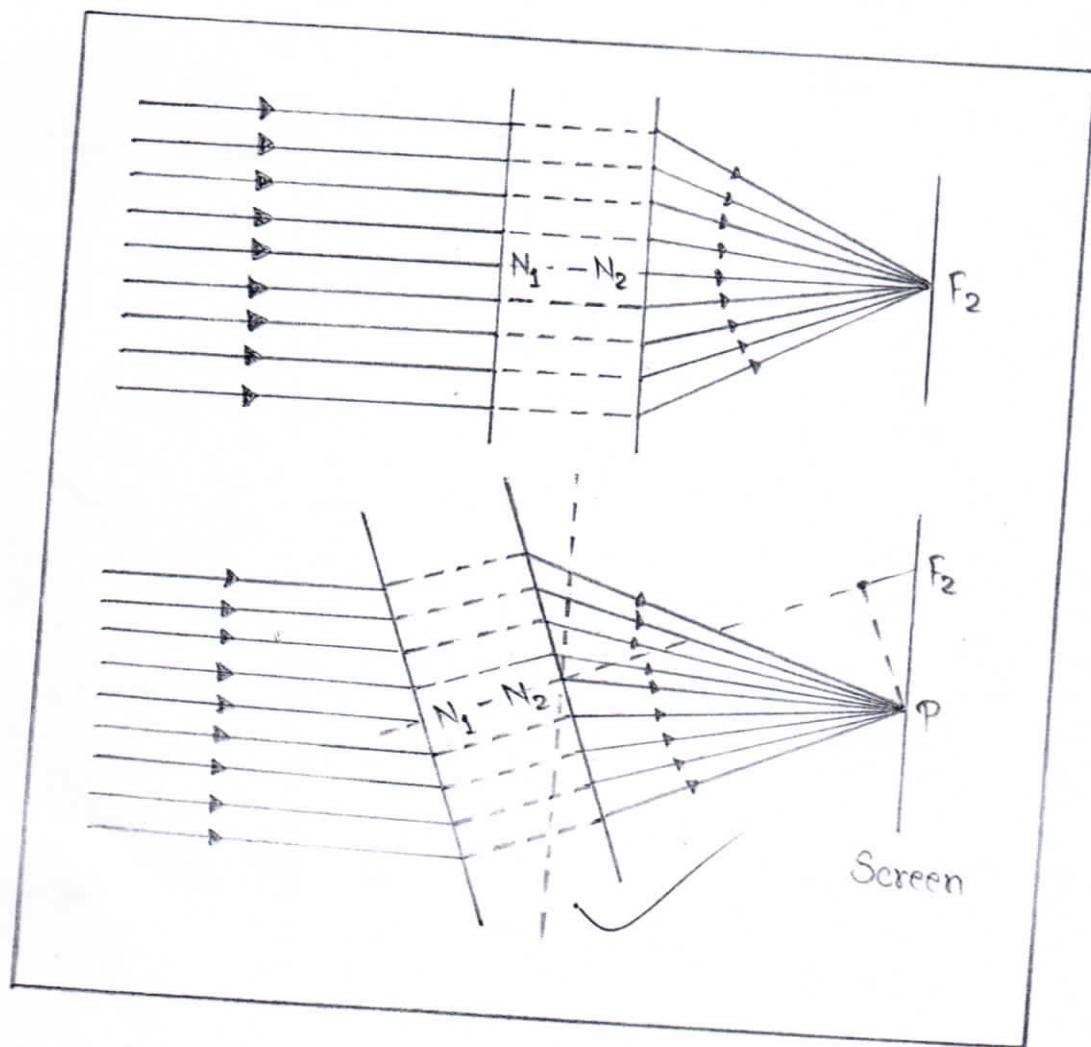
Step II : We move the lens system as a whole (i.e., nodal stand) towards or away from the slit till a clear and well defined image of the cross slit is formed on the same screen (beside the cross slit).

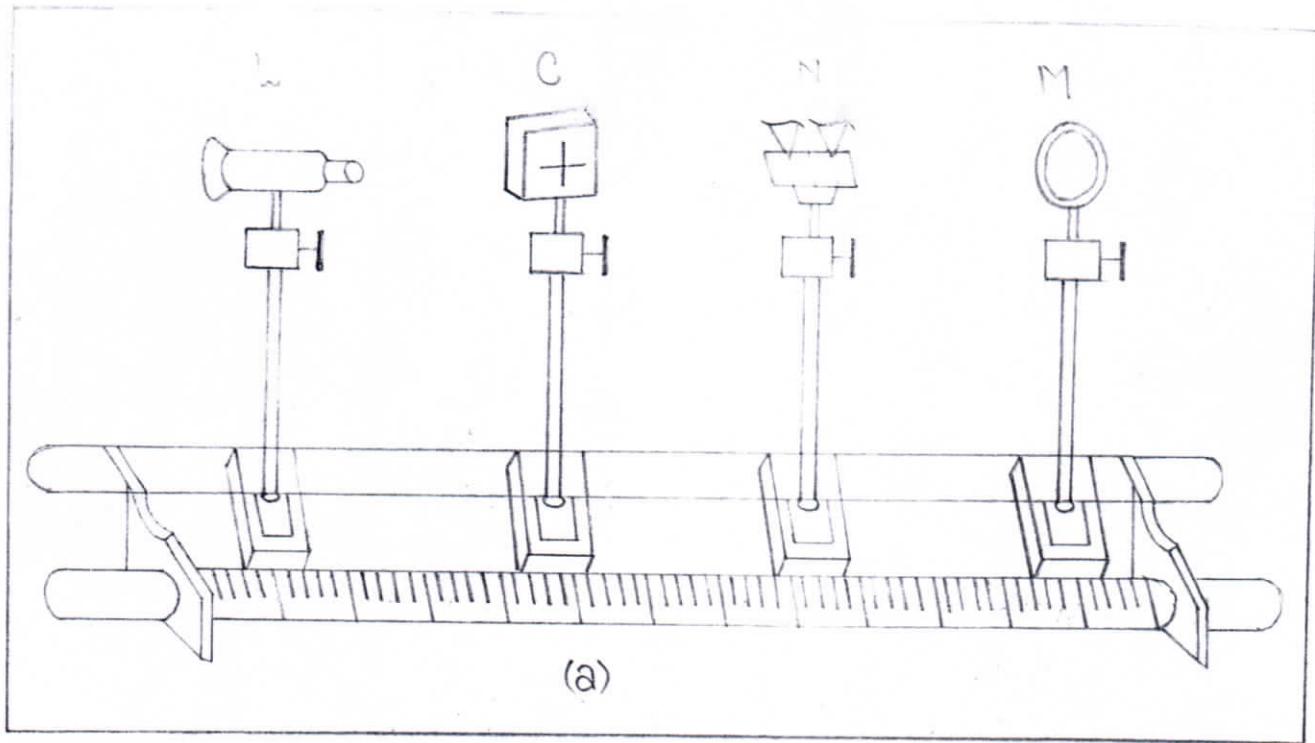
Step III : We noted the reading for the position of the cross slit and the position of the lens. The difference between the two gives the focal length f_1 of the lens L_1 .

Step IV : We remove the first lens and mount the second lens L_2 and repeat the similar procedure to find out the focal length f_2 of the L_2 lens.

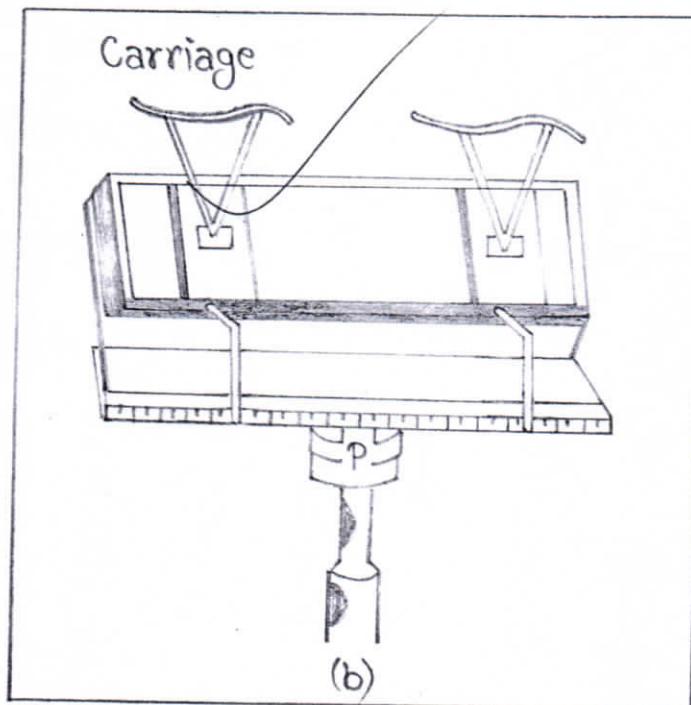
Step V : We mount both the convex lens (L_1 and L_2) on the nodal slide arrangement and note down their positions. Note down the distance between two lenses (in table 2).

Step VI : We noted the reading for the position of the cross slit and the position of the lens. The difference between the two gives the focal length of the two lenses in combination $F(c)$.





(a)



(b)

Fig.1(a,b): Nodal Slide Arrangement

Observations :-

Table 1: Focal Length of a lens

S.No.	Light	Lens L ₁			Mean	Lens L ₂			Mean
	incident on slit	Position of cross slit (a) (cm)	Position of lens (b) (cm)	f ₁ = (a~b) (cm)	f ₁ (cm)	Position of cross slit (a) (cm)	Position of lens (b) (cm)	f ₂ = (a~b) (cm)	f ₂ (cm)
1.	One face Other face	20.7	38.3	17.6	18.2	18	37.1	19.1	19.1
2.	One face Other face	20	39.1	19.1		20	39	19	
3.	One face Other face	15	32	17		16	35	19	
4.	One face Other face	22	41	19		13	32.2	19.2	

Table 2: Focal Length of the Combination

S.No.	Distance between lenses (cm)	Position of cross slit (a) (cm)	Position of the axis of rotation of nodal slide (b) (cm)	Focal length of combination $F = (a-b)$ cm	Calculated value of focal length (cm)	Difference (c-d)
1.	5	23	33	10	10.8	0.8
2.	5	22	32	10		
3.	5	20	30	10		
4.	5	18	28	10		

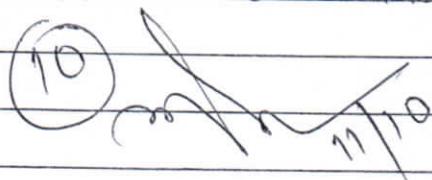
Result :- Since the experimental and theoretical values are nearly same , hence relations

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{x}{f_1 f_2}$$

are verified.

Precautions :-

- (1) The axis of the lenses and the mirror should be adjusted in a straight line passing through the center of the cross slit.
- (2) Slits should be well illuminated.
- (3) Source , slit and nodal slide arrangement and plane mirror must be adjusted to the same height.
- (4) Bench error should be determined.



Calculations :-

Value of the combined focal length is calculated with the help of the following relation:

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{2\kappa}{f_1 f_2}$$

$$\frac{1}{F} = \frac{1}{18.2} + \frac{1}{19.1} - \frac{5}{(18.2 \times 19.1)}$$

$$\frac{1}{F} = 0.055 + 0.052 - 0.014$$

$$\frac{1}{F} = 0.093$$

$$F = 10.8 \text{ cm}$$

Average focal length of combination (c)

$$= \frac{10 + 10 + 10 + 10}{4}$$

$$= 10 \text{ cm}$$

Difference (c-d) = ~~10 - 10.8~~

~~= -0.8 cm~~

EXPERIMENT-6 POLARIMETER

Object :- To determine the specific rotation of cane sugar solution using half shade polarimeter.

Apparatus :- Polarimeter tube, sodium lamp, sugar solution, beaker, physical balance, weight box and half shade polarimeter.

formula Used :- The specific rotation of the plane of polarimeter of cane sugar solution in water is determined by:

$$S = \frac{\theta}{LC}$$

$$S = \frac{10\theta}{LC}$$

where,

θ = Angle of rotation of plane of vibration degrees.

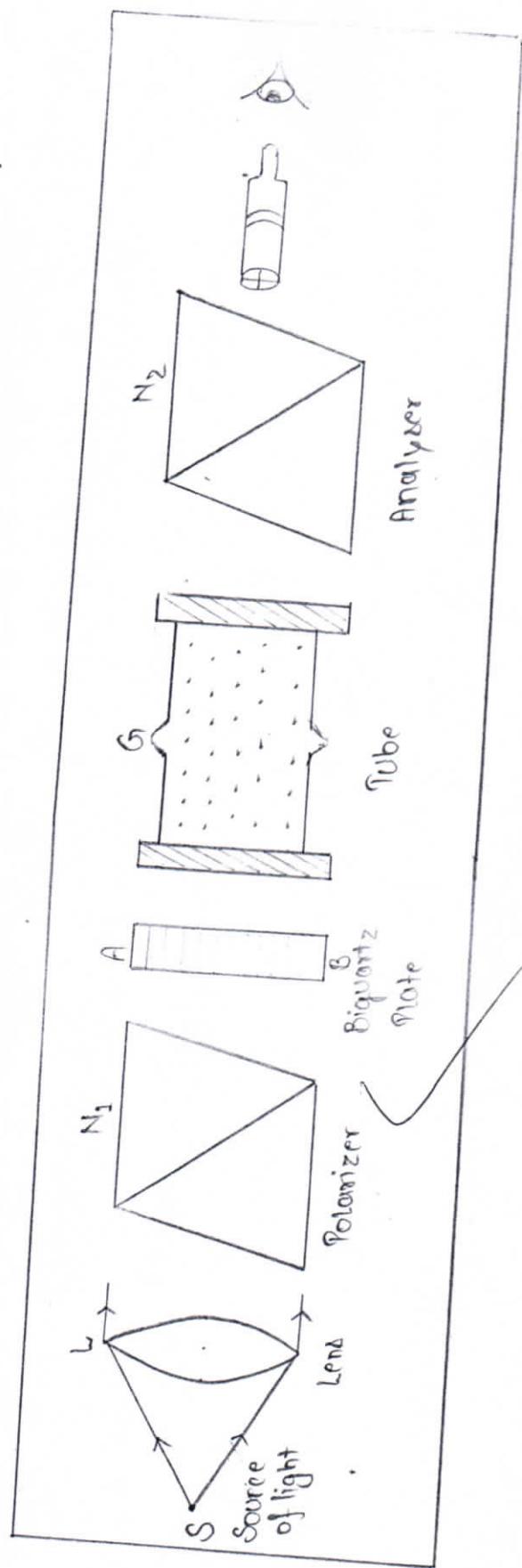
L = Length of polarimeter tube in dm and cm respectively.

C = Concentration of sugar solution in gm/cc.

Procedure :-

Step 1: First of all we clean the polarimeter tube and fill with clean water properly to minimising the air.

Step 2: We place the polarimeter tube in proper place



Fig(1). Setup for Half Shade Polarimeter

as shown in fig(1).

Step 3: We switch on the source of light and see through eye-piece two halves of unequal intensity. We rotate the analyzer in clockwise direction until the intensity of two halves appears the same and we note down analyzer reading.

Step 4: We rotate the analyzer screw in anti-clockwise direction until the intensity of two halves appears the same and note down the reading.

Step 5: We rotate the screw from mean position 180° in any direction and repeat the step 3 and 4.

Step 6: We fill the polarimeter tube with cane sugar solution and repeat the experiment for different concentrations of the sugar solution. We plot the graph between angle of rotation and concentration. The specific rotation can also be determined using this slope of this graph.

Observations :-

- (i) Room temperature = 32°C .
- (ii) Mass of sugar dissolved (m) = 10 gm
Volume of the solution (V) = 100 cc

Initial concentration of cane sugar solution (C)

$$= \frac{m}{V} = 0.1 \text{ gm/cc}$$

(iii) Length of the polarimeter (L) = 20 cm

(iv) Value of the division of main scale = 1 degree

Total number of divisions on the vernier scale (n) = 10

Least count of the vernier = 0.1 degree

S.No.	Analyser reading with pure water						$a = \frac{x+y}{2}$	
	Clockwise			Anticlockwise				
	M.S	V.S	Total (x)	M.S	V.S	Total (y)		
1.	140	7	140.7	183	1	183.1	161.9	
2.	135	3	135.3	182	3	182.3	158.8	
3.	140	0	140.0	180	5	180.5	160.25	
4.	134	6	134.6	180	0	180.0	157.3	

S.No.	Concentration of solution gm/cc	Analyser reading with sugar solution						$b = \frac{x+y}{2}$	$\theta = a - b$ (deg.)		
		Clockwise			Anticlockwise						
		M.S	V.S	Total (x')	M.S	V.S	Total (y')				
1.	10	126	5	126.5	172	7	172.7	149.6	12.3		
2.	10	124	3	124.3	170	0	170.0	147.15	11.6		
3.	10	126	2	126.2	172	1	172.1	149.15	11.1		
4.	10	117	5	117.5	169	5	169.5	143.5	13.8		

Mean = 12.2

Result :- The specific rotation of cane sugar solution = 12.2 degree

Calculation:

$$\text{Mean value of } \theta = \frac{12.3 + 11.65 + 11.1 + 13.8}{4}$$
$$= 12.2 \text{ degree}$$

The specific rotation of given cane sugar solution is calculated by :

$$S = \frac{10\theta}{LC}$$

$$S = \frac{10 \times 12.2}{0.2 \times 10}$$

$$S = 61^\circ \quad \checkmark$$

Error Analysis :-

$$\% \text{ error} = \frac{\left(\frac{\text{Standard value of S.P. rotation}}{\text{Measured value of S.P. rotation}} - 1 \right) \times 100}{\left(\frac{\text{Standard value of S.P. rotation}}{\text{S.P. rotation}} \right)}$$

$$= \frac{66.57 - 61.00}{66.57} \times 100$$

$$= 8.37 \%$$

Precaution :-

- (1) There should be no bubble in the polarimeter tube during whole experiment.
 - (2) Cane sugar solution be freshly prepared for the measurement of specific rotation.
 - (3) Polarimeter should not be touched during the whole experiment.
- ⑨ Oct 10, 2010

EXPERIMENT - 7 ENERGY BAND GAP

Object :- To determine the energy band gap of a semi-conductor using a PN junction diode.

Apparatus :- Energy band gap setup, connecting leads, oven and thermometer.

Formula Used :-

Energy band gap is given by

$$\Delta E = \frac{\text{slope}}{5.036} \text{ eV}$$

where, the slope is of the graph is obtained by plotting $\log I_s$ Vs $10^3/T$.

I_s is reverse saturation current and T is temperature in K.

Procedure :-

Step I : We connect the circuit as shown in the fig. We switch ON the instrument using main switch keeping temperature control knob fully anti-clockwise.

Step II : We adjust the Voltmeter to a fixed value of voltage.

Step III : We keep the temperature control knob on medium position. Temperature starts increasing and

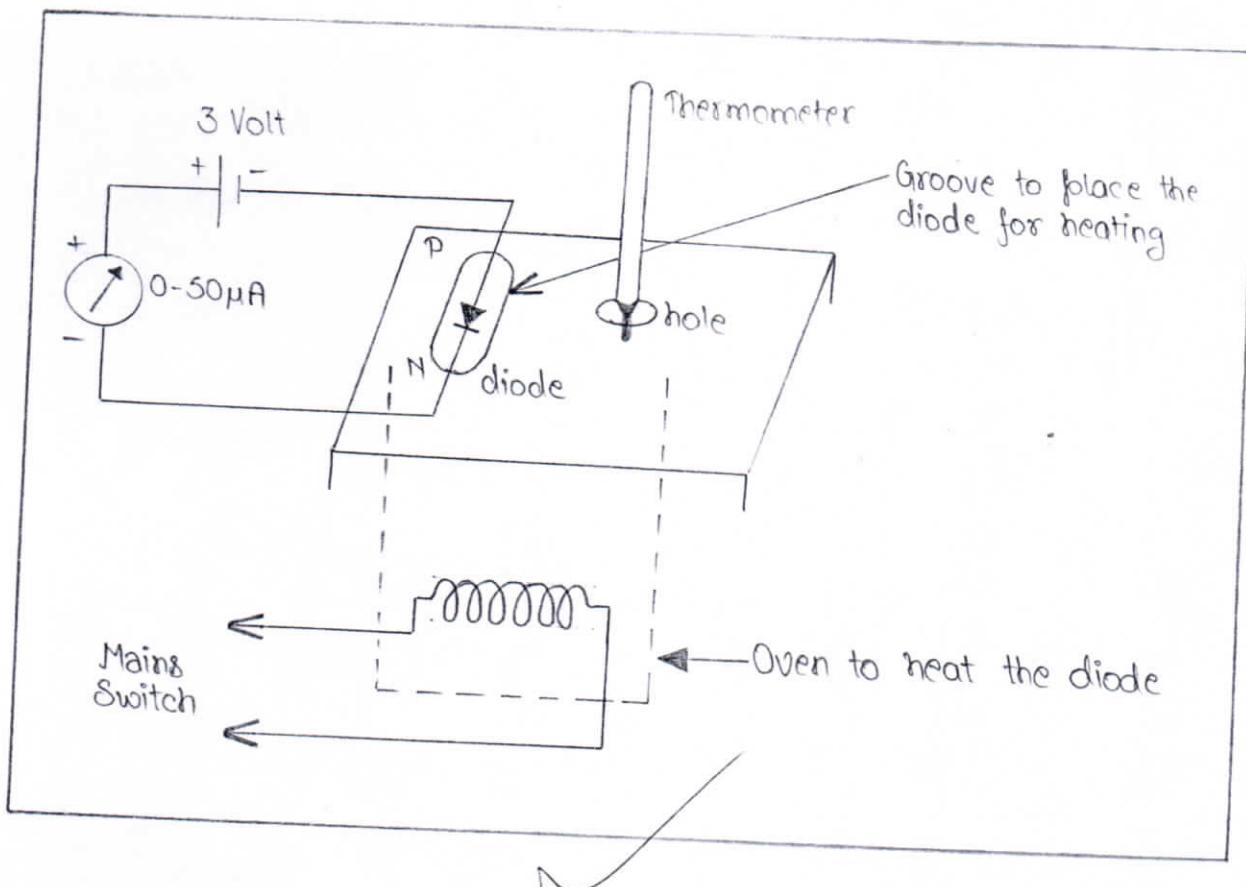


Fig 1: Setup for p-n junction Diode

the reading of micro ammeter also starts increasing.

Step IV: When temperature reaches to $80(^{\circ}\text{C})$ degree, we switch off the oven. The temperature will rise further, say about $85(^{\circ}\text{C})$ and will become stable.

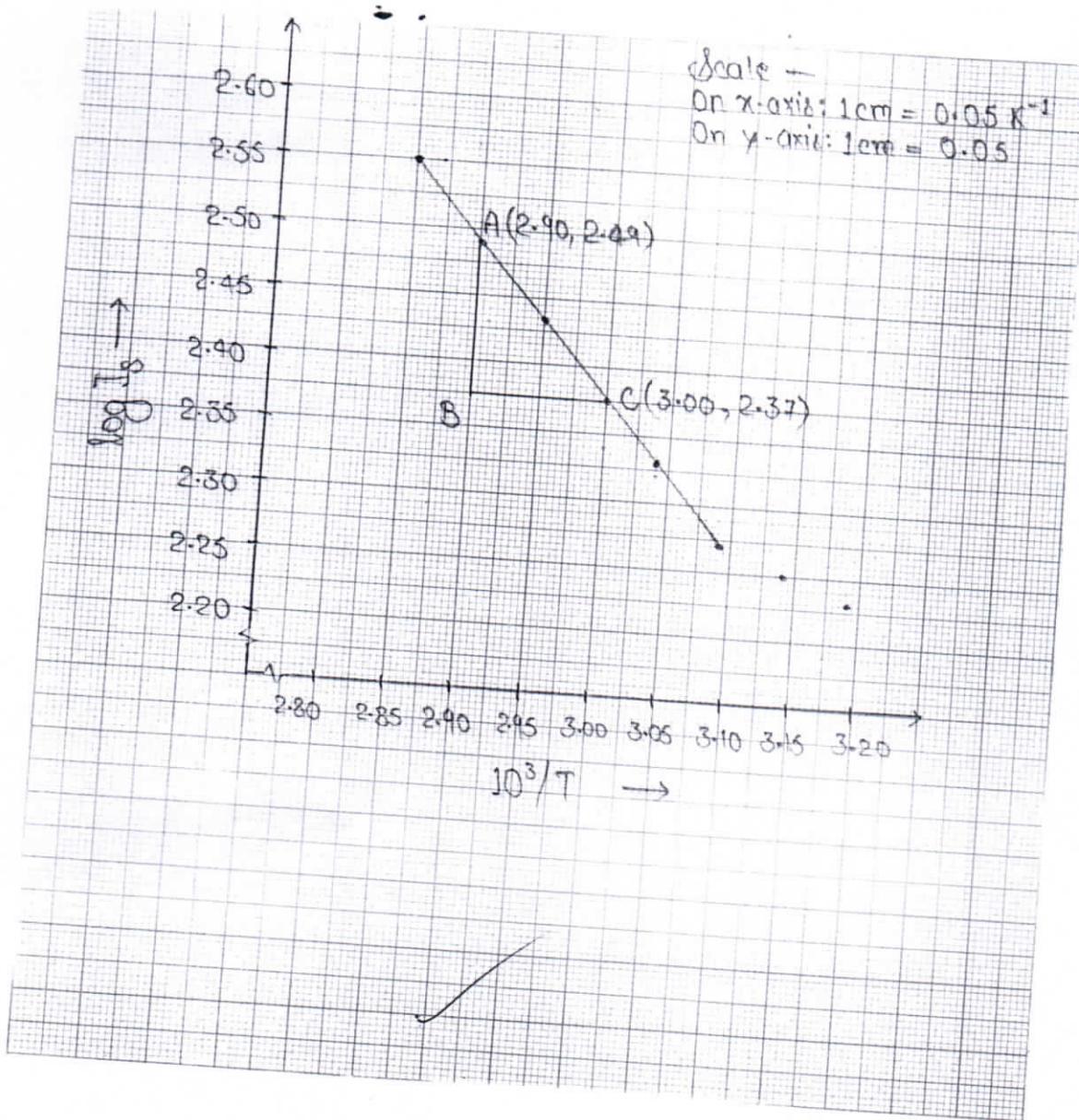
Step V: As the temperature starts falling, we go on recording the values of micro ammeter after every 5°C drop in temperature and the corresponding value of current.

Step VI: We plot the graph between reverse saturation current and temperature for different voltage.

Observations :-

Table 1: Measurement of Current and Temperature

S.No.	Temperature T ($^{\circ}\text{C}$)	Temperature T (K)	Reverse Current I_{RS} (μA)	$\log_e I_s$ (μA)	$10^3/T$ (K^{-1})
1.	75	348	360	2.55	2.85
2.	70	343	305.316	2.49	2.90
3.	65	338	270	2.43	2.95
4.	60	333	235	2.37	3.00
5.	55	328	215	2.33	3.04
6.	50	323	190	2.27	3.09
7.	45	318	180	2.25	3.14
8.	40	313	170	2.23	3.19



Calculations :-

Energy band gap is calculated by

$$\Delta E = \frac{\text{Slope}}{5.036} \text{ eV}$$

$$\text{Slope} = \frac{AB}{BC} = \frac{0.12}{0.1} = 1.2$$

$$\begin{aligned}\Delta E &= \frac{\text{Slope}}{5.036} \\ &= \frac{1.2}{5.036} = 0.238 \text{ eV}\end{aligned}$$

Calculated value of $\Delta E = 0.238 \text{ eV}$

Standard value of $\Delta E = 0.7 \text{ eV}$

Error Analysis :-

$$\text{Percentage error} = \frac{\left(\frac{\text{Standard value}}{\text{of } \Delta E} - \frac{\text{Measured value}}{\text{of } \Delta E} \right)}{\left(\frac{\text{Standard value}}{\text{of } \Delta E} \right)} \times 100$$

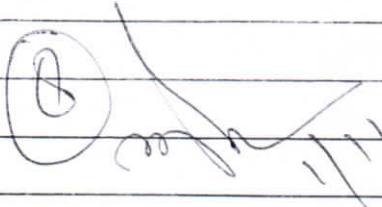
$$= \frac{0.7 - 0.238}{0.7} \times 100$$

$$= \underline{\underline{66\%}}$$

Result :- The graph between $\log_{10} I_s$ and $10^3/T$ is a straight line.

Precautions :-

- (1) Maximum temperature should not exceed 80°C .
- (2) Voltage supplied should not exceed 10V.
- (3) All the connections should be properly connected.



EXPERIMENT - 8 STEFAN'S LAW

Object :- To verify Stefan's law by Electrical Method.

Apparatus :- Experimental set up of Stefan's law (set up consists of D.C. voltmeter (0-10V), D.C. ammeter (0-1 amp), electric bulb (having tungsten filament), variable resistance, battery etc.).

Formula Used :- According to Stefan's law "the rate of emission of radiant energy (E) from the black body per unit area is directly proportional to the fourth power of its absolute temperature (T)"

$$\text{i.e., } E \propto T^4 \quad \text{or} \quad E = \sigma T^4$$

where σ is Stefan constant $\sigma = 5.67 \times 10^{-8}$ Joule sec⁻¹ m⁻² K⁻⁴.
Stefan's law for perfect black bodies is given by :

$$E = \alpha (T^4 - T_0^4)$$

This is called Stefan-Boltzmann law.

For non-perfect black bodies Stefan's law is modified as given below:

$$P = C(T^\alpha - T_0^\alpha)$$

If $T \gg T_0$, then

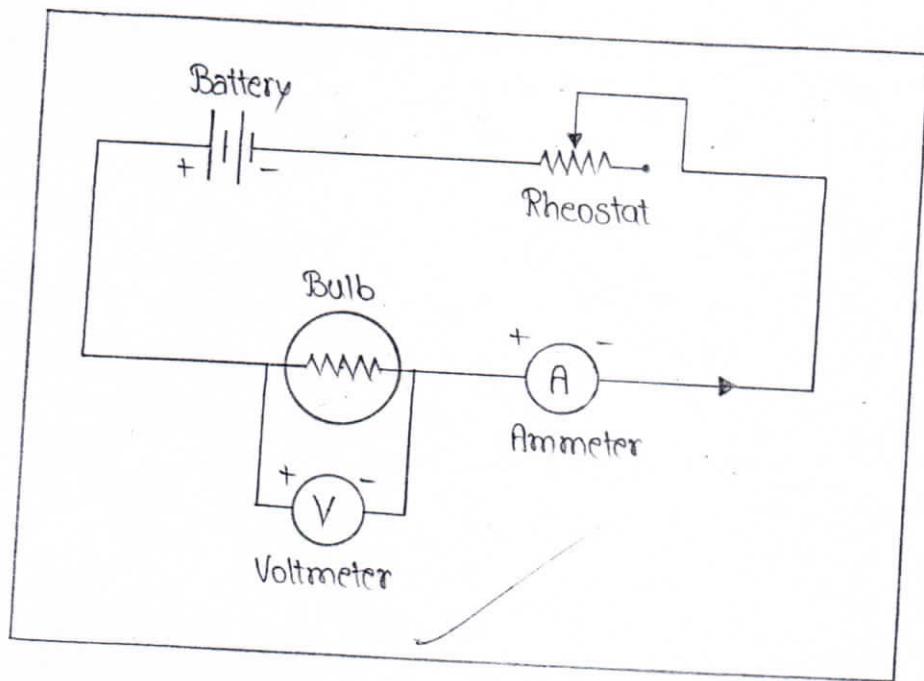
$$P = CT^\alpha$$

or

$$\log P = \alpha \log T + \log C.$$

where, P is total power radiated by the non-perfect black body at temperature T and surrounded by another body at Temp T_0 .

The graph between $\log P$ and $\log T$ should be straight line whose slope gives α .



Circuit Diagram for Stefan's Law

- (1) Power P radiated by the body : In this electrical method tungsten filament of the vacuum diode is used as the radiating body. The electric power (V/I) should be equal to the power radiated by the body.
- (2) Temperature T of the radiating body : With different increasing and decreasing values adjust the current such that bulb should glow each time. Then take the readings of V and I . Ratio V/I is found which gives R_g . This is the filament resistance at 800 K.

From R_f/R_0 vs T graph, one obtain $R_{800}/R_{273} = 3.9$ or $R_{800}/R_0 \text{ } ^\circ\text{C} = 3.9$

Or $R_0 = R_g/3.9$ substitute the average value of R_g to get the value of R_0 .

Procedure :-

Step I : ^{We} Connect the apparatus as shown in figure 1.

Step II : ^{We} Increase the filament current (I) from a value below the glowing stage to value high enough to get dazzling light. We note down the values of V and I every time.

Step III : We find out $R_f(V/I)$ for each reading and calculate (R_f/R_0) .

Step IV : With the help of the graph between R_f/R_0 vs T (we obtained by plotting the standard values of R_f/R_0 vs T (as given in table 3)) we deduce the temperature T for each value of (R_f/R_0) .

Step V: We deduce the power ($P = VI$) radiated by the filament and plot a graph between $\log P$ and $\log T$ which will be a straight line.

Observation Table :-

Table 1: Determination of filament resistance (R_f) at temperature $T = 800\text{ K}$

S.No.	Current increasing			Current decreasing			R_f (Mean)
	Voltage (V)	Current (Ampere)	$R_f = V/I$ (ohms)	Voltage (V)	Current (Ampere)	$R_f = V/I$ (ohms)	
	(Volts)	(amperes)		(Volts)	(amperes)		
1.	0.50	0.08	6.25	0.50	0.08	6.25	8.98
2.	0.75	0.10	7.50	0.75	0.10	7.50	
3.	1.00	0.12	8.33	1.00	0.12	8.33	
4.	1.25	0.14	8.92	1.25	0.14	8.92	
5.	1.50	0.16	9.37	1.50	0.16	9.37	
6.	1.75	0.18	9.72	1.75	0.18	9.72	
7.	2.00	0.19	10.52	2.00	0.19	10.52	
8.	2.25	0.20	11.25	2.25	0.20	11.25	

Table 2: Measurement of Power (P) Radiation by Filament

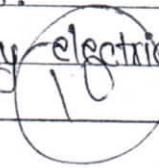
S.No.	Current increasing	$R_f = V/I$	R_f/R_0	Temp (T) from graph	$\log T$	$P=VI$ (watt)	$\log P$
	V (Volts)	I (amp)	(ohms)				
1.	0.50	0.08	6.25	2.71	623	2.79	0.040 -1.39
2.	0.75	0.10	7.50	3.26	683	2.83	0.075 -1.12
3.	1.00	0.12	8.33	3.62	733	2.86	0.120 -0.92
4.	1.25	0.14	8.92	3.87	783	2.89	0.175 -0.75
5.	1.50	0.16	9.37	4.07	813	2.91	0.240 -0.61
6.	1.75	0.18	9.72	4.22	833	2.92	0.315 -0.50
7.	2.00	0.19	10.52	4.57	903	2.95	0.380 -0.42
8.	2.25	0.20	11.25	4.89	953	2.97	0.450 -0.34

Calculation and Graph :-

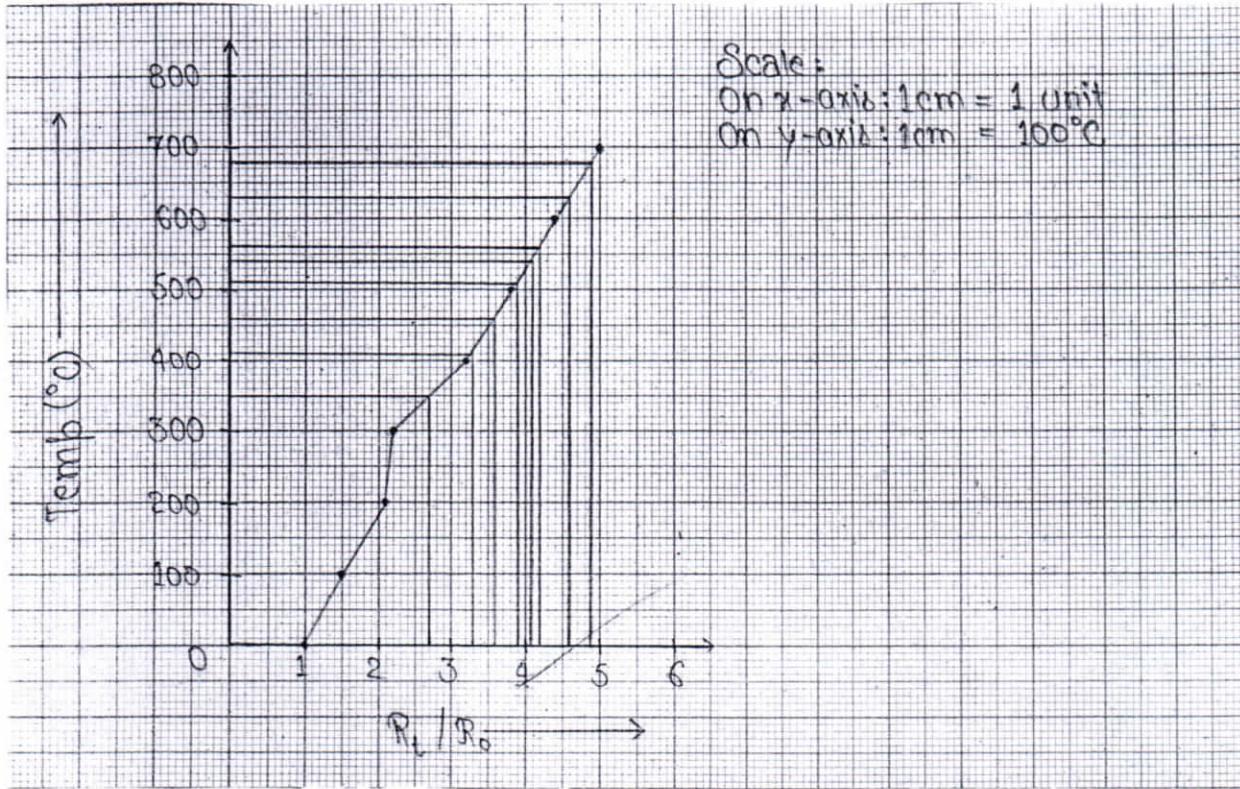
The value of α is calculated from the slope of the graph plotted between $\log P$ vs $\log T$.

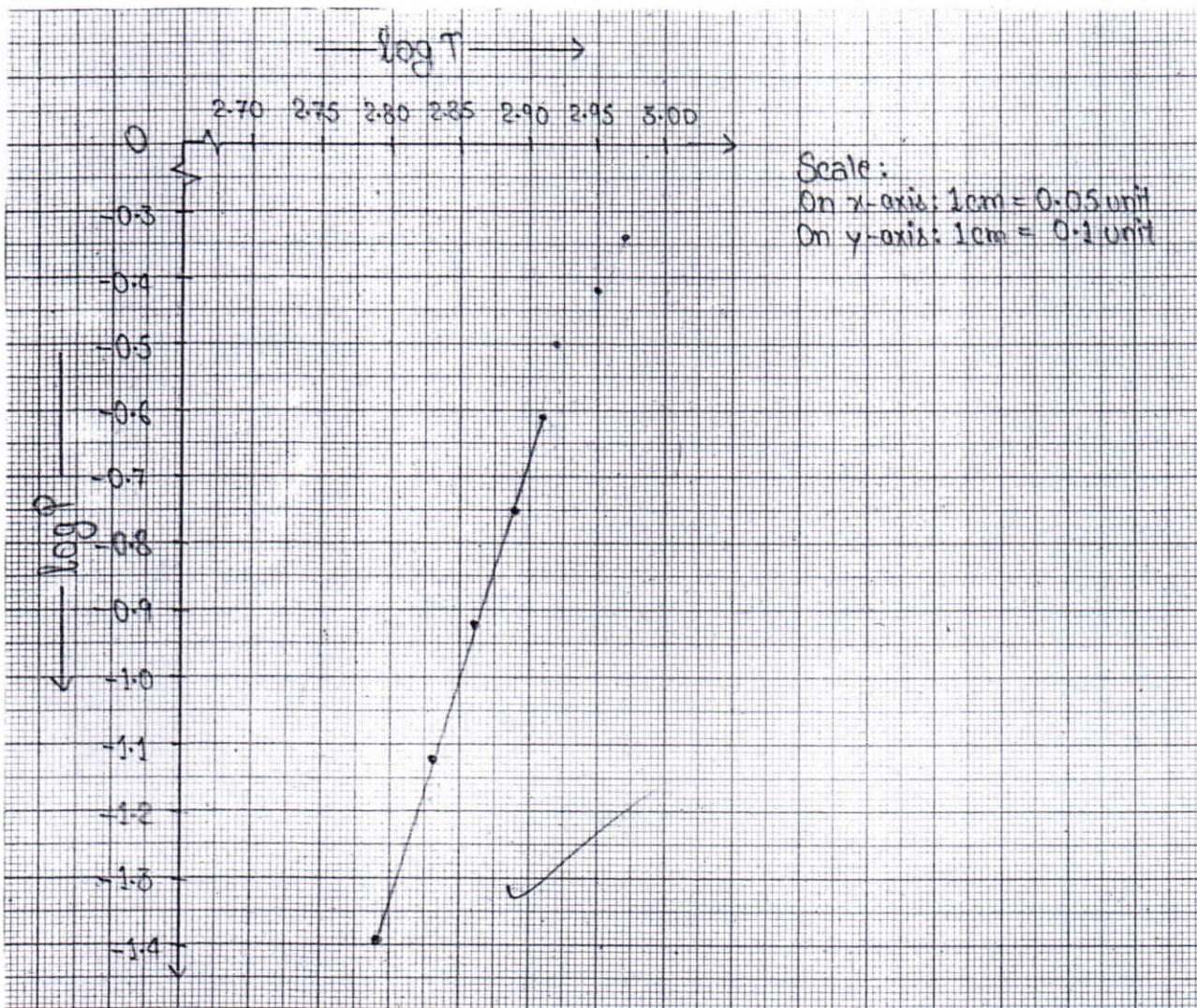
Precautions and Sources of Error:-

- (1) Readings of voltmeter and ammeter should be noted only when the bulb starts glowing.
- (2) Change the current in steps gradually.
- (3) To obtain accurate resistance at a specific temperature, the filament voltage and filament current should be noted every time after achieving a steady state.
- (4) There should not be any electrical fluctuations during the measurements.



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EXPERIMENT - 9 CAREY FOSTER'S BRIDGE

Object :- To determine the resistance per unit length and specific resistance of the material of a given wire using Carey Foster's Bridge.

Apparatus :- Carey - Foster's bridge, resistance box, Leclanche cell, thick copper strip, jockey, plug key, galvanometer, given wire, screw gauge and connection wires.

Formula Used :- The resistance per unit length (ℓ) of bridge wire is given by the formula

$$X - Y = \ell(l_2 - l_1) \quad \dots \dots (1)$$

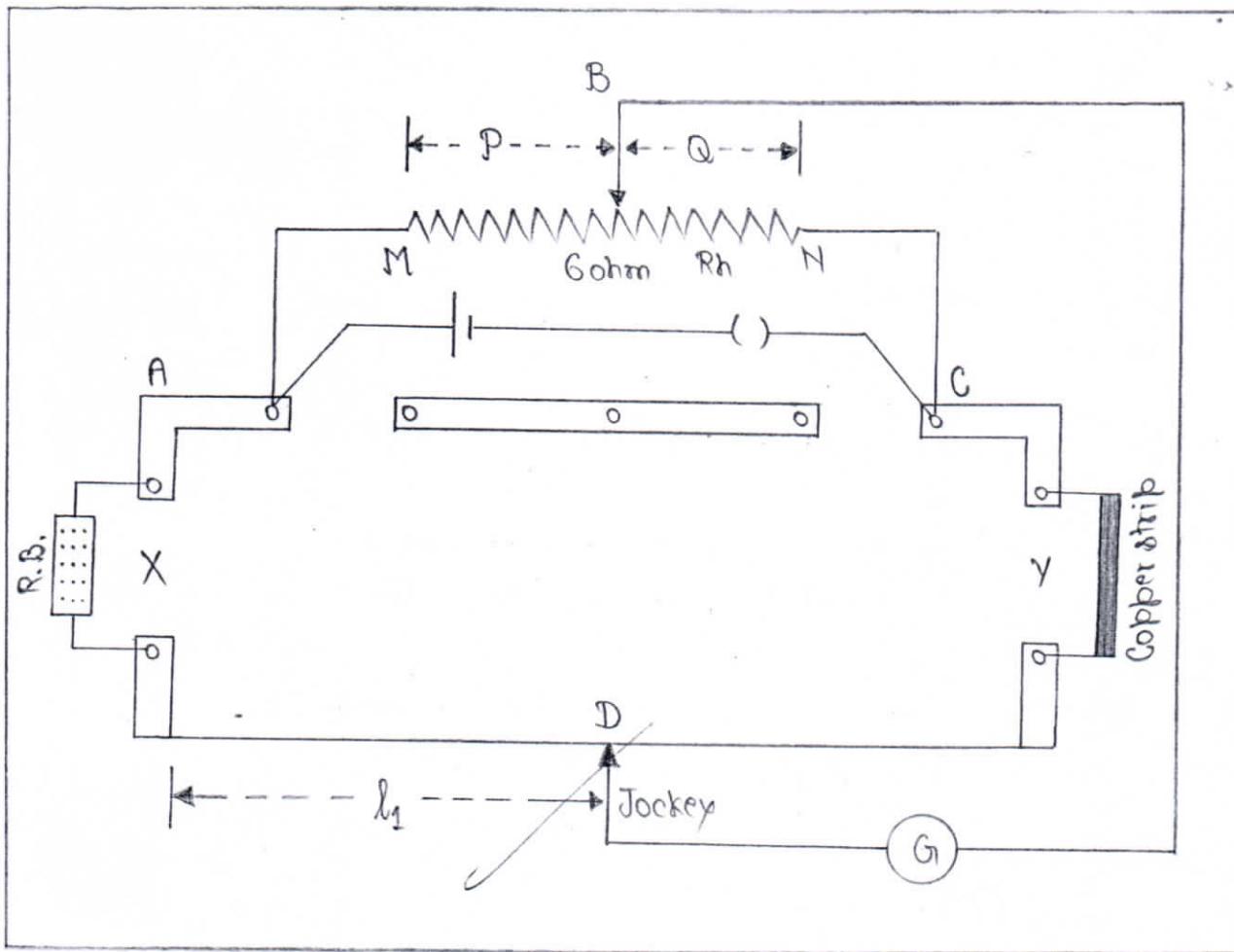
where X and Y are two resistances in the outer gaps of the Carey - Foster's bridge and l_2 and l_1 denote the length of the balance point on the bridge wire before and after interchanging the resistance. If $Y=0$ and $X=R$ (known resistance), then we have

$$R = \ell(l_2 - l_1)$$

or
$$\ell = \frac{R}{l_2 - l_1} \quad \dots \dots (2)$$

Using equation(2) the resistance per unit length (ℓ) can be calculated and knowing the value of ℓ , the unknown resistance Y can be calculated provided X is known.

After measuring the resistance, the length of the wire is measured. Now the length of wire whose resistance is one ohm can be calculated.



Experimental Arrangement of Carey-Foster Bridge

The specific resistance can be calculated by the formula

$$K_s = \gamma \pi r^2 / l$$

where,

r = Radius of the wire.

l = Length of the wire.

γ = Resistance of the given wire.

Procedure :-

Step I : We arrange the apparatus as shown in Fig 1.

Step II : We connect the resistance box in the left gap and a copper strip in the right gap of the Carey - Foster's bridge.

Step III : We set the sliding contact of the rheostat in the middle of it so that the two resistances P and Q are nearly equal.

Step IV : We introduce a resistance r in the resistance box and slide the jockey on the wire of Carey - Foster's bridge until the null point is obtained. We note this reading as l_1 .

Step V : We interchange the position of resistance box and copper strip and obtain null point again by sliding the jockey on the wire. This gives us the readings as l_2 .

Step VI : We change the value of resistance R and obtain different sets of observations.

Step VII: We calculate the value of resistance R and obtain per unit length ρ for each set of observation using the formula $\rho = R / \ell (l_2 \sim l_1)$ and calculate the mean value of ρ .

Step VIII: We connect the resistance box in the left gap and a given wire in the right gap of the Carey-Foster's bridge and find l_1' and l_2' . Only change is that we replaced copper strip by a given wire.

Step IX: We calculate the resistance of the wire using $R = X - \rho(l_2' - l_1')$.

We take different sets by changing the value X in the decimal resistance box.

Step X: We calculate the radius of a given wire using screw gauge and measure the effective length of the wire.

Observations :-

Table 1 : Measurement of ' ρ '

S.No.	Resistance introduced 'R' (ohm)	Position of the Balance Point	$(l_2 - l_1)$ (cm)	$\rho = \frac{R}{l_2 - l_1}$ (ohm/cm)	Mean ρ (ohm/cm)
1.	0.1	48	52	0.025	0.0282
2.	0.2	46.5	53.5	0.028	
3.	0.3	44.5	55.5	0.027	
4.	0.4	43.2	56.8	0.029	
5.	0.5	42.3	57.7	0.032	

Table 2: Measurement of Wire resistance

S.No.	Resistance introduced in decimal ohm box X	Position of null point with decimal ohm box in Ohm box X		$(l_2' - l_1')$	Resistance of the wire	Mean γ (ohm)
		l_1' (cm)	l_2' (cm)	(cm)	$\gamma = X - l(l_2' - l_1')$	
1.	0.1	63	37	-26	0.8332	0.8944
2.	0.2	62	38	-24	0.8768	
3.	0.3	60.5	39.5	-21	0.8922	
4.	0.4	59.2	40.8	-18.4	0.9188	
5.	0.5	58	42	-16	0.9512	

Table 3: Measurement of radius of the given wire.

Length of the wire $l = 16 \text{ cm}$

$$r = 0.017 \text{ cm}$$

Result :-

The specific resistance of a given wire $= 50.72 \times 10^{-6} \text{ ohm-cm}$

Error Analysis :-

$$\text{Percentage error} = \left[\frac{\text{Standard value}}{\text{of sp. res.}} - \frac{\text{Measured value}}{\text{of sp. res.}} \right] \times 100$$

$\left[\frac{\text{Standard value}}{\text{of sp. res.}} \right]$

Here, Standard value is $49.1 \times 10^{-6} \text{ ohm-cm}$.

Calculation :-

The specific resistance (κ_s) of wire is calculated by :

$$\kappa_s = \gamma \pi r^2 / l$$

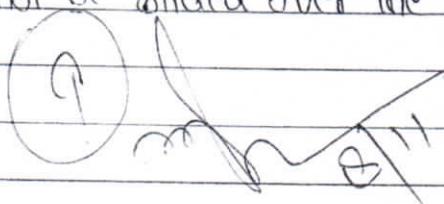
$$\kappa_s = \frac{0.8944 \times 3.14 \times (0.017)^2}{16}$$

$$\kappa_s = 50.72 \times 10^{-6} \text{ ohm-cm}$$

$$\text{Percentage error} = \frac{(49.1 \times 10^{-6}) - (50.72 \times 10^{-6})}{(49.1 \times 10^{-6})} \times 100 \\ = -3.29\%$$

Precautions :-

- (1) All the connection must be tight.
- (2) The battery key should be pressed for that time only when observations are being taken.
- (3) The ends of the connecting wires should be properly cleaned.
- (4) The balance point should be detected as near the middle point of the bridge wire.
- (5) A shunted galvanometer must be used.
- (6) The jockey should not be滑过 the bridge wire.



EXPERIMENT - 10 CALIBRATION OF VOLTMETER

Object :- To calibrate given voltmeter with the help of a potentiometer.

Apparatus :- Potentiometer, two storage batteries, two rheostats ($50\ \Omega$, $110\ \Omega$), a standard cell (cadmium cell), a galvanometer, a standard $1\ \Omega$ resistance, one two-way key, two one-way keys, connection wires, given voltmeter.

Formula Used :- The error in the voltmeter readings is given by the

$$(V' - V) = E(l_2/l_1) - V$$

where,

V = Potential difference measured by the voltmeter.

V' = Potential difference measured by the potentiometer.

l_1 = Length of the potentiometer wire corresponding to E.M.F of the standard cell (cadmium).

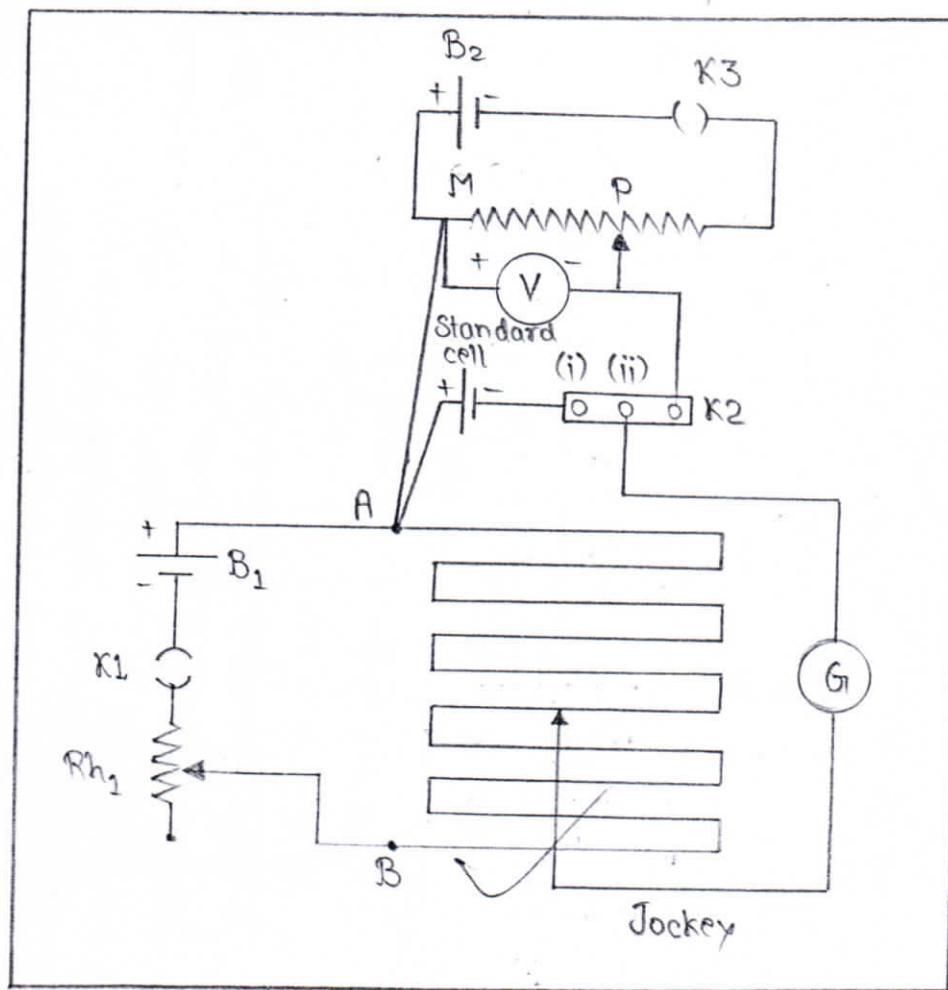
l_2 = Length of the potentiometer wire corresponding to the current I or potential difference V' .

E = E.M.F of the standard cell (for cadmium cell)

$$E = 1.0186 \text{ volt}$$

Procedure:-

Step I : Standardisation of the potentiometer - we make the connections as shown in fig 1 and 2. We close the key K_1 and $K_2(i)$ by keeping the keys K_1 and $K_2(ii)$ open. We put the



Electrical connections for Calibration of Voltmeter

jockey at the last and B of the 10th wire. At this stage the total length of the wire will be 1000 cm and there will be some deflection in the galvanometer. We adjust the rheostat R_h , till the deflection in the galvanometer is reduced to zero. Note down the total balancing length (l_1). In the present case $l_1 =$

Step II: We open the key $K_2(i)$ and close the key $K_2(ii)$ and key K_3 . We adjust the rheostat R_h , so that the ammeter and voltmeter read a suitable value (such as $V = 0.1, 0.2, 0.3$ volt). We move the jockey to get the null point, i.e., no deflection position of the galvanometer and note down the balancing length l_2 . We repeat this process for new readings of voltmeter and ammeter. We note down the balancing length l_2 for each reading of voltmeter and ammeter. Now we calculate the values of I' and I'' using the formula $I' = (E/l_1)l_2$ and $I'' = (E/l_1)l_2$ for each values of lengths l_2 . Since the standard resistance is one ohm. The values of current I' and voltage I'' will be equal.

Step III: We find out $(V' - V)$ which is equal to errors produced in the ammeter and voltmeter readings respectively. We plot a calibration graph between error $(V' - V)$ and V as shown in fig 3.

Observations :-

E.M.F. of standard cell (E) = 1.08 volt

(for cadmium cell $E = 1.018$ volt, for Daniel cell $E = 1.080$ volt).

Balancing length (l_1) of the potentiometer wire corresponding to E.M.F. of the standard cell = 390 cm

Table 1: Calibration of Voltmeter

S.No.	Voltmeter reading V (volt)	Balancing length of the potentiometer wire l_2 (cm)	$V' = El_2/l_1$ (volt)	Errors in voltmeter $(V' - V)$ (volt)
1.	0.1	894	2.4674	2.3674
2.	0.2	798	2.2024	2.0024
3.	0.3	610	1.6836	1.3836
4.	0.4	708	1.9540	1.5540
5.	0.5	506	1.3966	0.8966
6.	0.6	315	0.8694	0.2694
7.	0.7	416	1.1482	0.4482

Result :-

Calibration curve of voltmeter is plotted as shown in graph.

Precautions :-

- (1) Batteries should be fully charged.
- (2) The E.M.F. of the battery B_1 should be greater than the E.M.F. of the standard cell.
- (3) Keys should be closed only when the reading are to be taken.

Calculation :-

(i) Potential gradient (κ) of the potentiometer wire is calculated by:

$$\kappa = \frac{E}{l_1} = \frac{1.08}{390} = 2.76 \times 10^{-3} \text{ volt/cm}$$

(ii) The values of the voltage $V' = (E/l_1)l_2$

$$(1) V'_1 = 2.76 \times 10^{-3} \times 894 = 2.4674 \text{ volt}$$

$$V'_1 - V_1 = 2.4674 - 0.1 = 2.3674 \text{ volt}$$

$$(2) V'_2 = 2.76 \times 10^{-3} \times 798 = 2.2024 \text{ volt}$$

$$V'_2 - V_2 = 2.2024 - 0.2 = 2.0024 \text{ volt}$$

$$(3) V'_3 = 2.76 \times 10^{-3} \times 610 = 1.6836 \text{ volt}$$

$$V'_3 - V_3 = 1.6836 - 0.3 = 1.3836 \text{ volt}$$

$$(4) V'_4 = 2.76 \times 10^{-3} \times 708 = 1.9540 \text{ volt}$$

$$V'_4 - V_4 = 1.9540 - 0.4 = 1.5540 \text{ volt}$$

$$(5) V'_5 = 2.76 \times 10^{-3} \times 506 = 1.3966 \text{ volt}$$

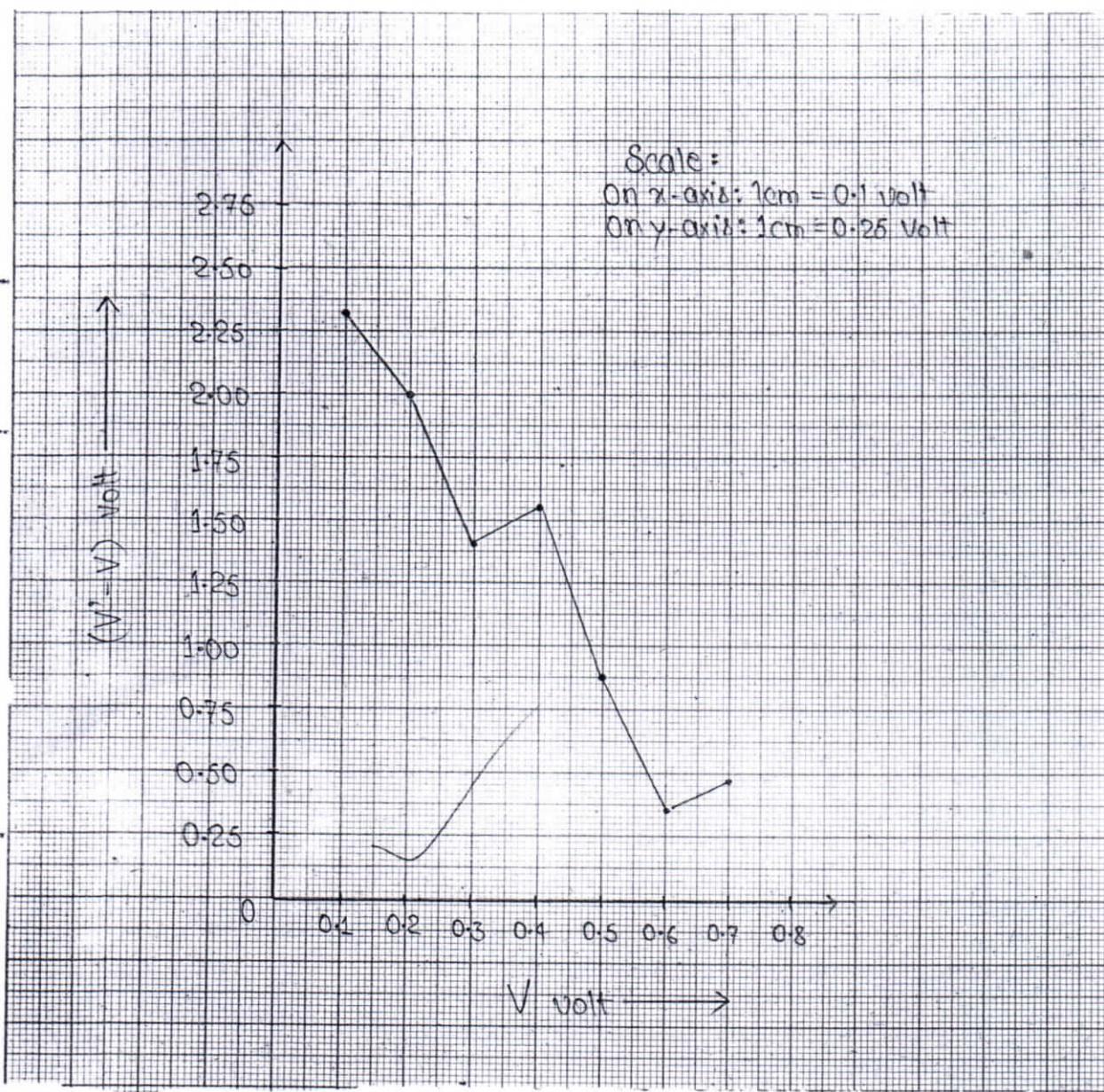
$$V'_5 - V_5 = 1.3966 - 0.5 = 0.8966 \text{ volt}$$

$$(6) V'_6 = 2.76 \times 10^{-3} \times 315 = 0.8694 \text{ volt}$$

$$V'_6 - V_6 = 0.8694 - 0.6 = 0.2694 \text{ volt}$$

$$(7) V'_7 = 2.76 \times 10^{-3} \times 416 = 1.1482 \text{ volt}$$

$$V'_7 - V_7 = 1.1482 - 0.7 = 0.4482 \text{ volt}$$



- (4) The galvanometer used in the experiment should be sensitive.
- (5) The connections should be tightly made.
- (6) The jockey should not be pressed hard on the potentiometer wire. ✓
- (7) The jockey should not be slipped over the wire.

(9) ~~math, 15/11~~