EXPERIMENT NO. 1 (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, traveling 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 you 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: $$\lambda = \frac{D^2_{n+p} - D^2_n}{4pR}$$

Where,

D_{n+p}	= Diameter of $(n+p)^{th}$ 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: The plano-convex lens on the surface of plane glass plate is placed 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 concentric circular rings are seen in the field of view of the microscope objective) (Fig. 2.)

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

Step IV: Again the microscope is moved 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 $(D^2_{n+p} - D^2_n)$ and λ can also be obtained as follows:

$$\lambda = \frac{D^2_{n+p} - D^2_n}{4pR}$$

OBSERVATIONS:

(A) Measurement of Least Count of Traveling Microscope

Lest count of the vernier of the traveling microscope = 0.01 mm = 0.001 cm

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(B) Table: Diameter of Newton's ring

S.No.	No. of the ring	Micrometer Reading		Diameter D (a-b) cm	$D^2 = (a - b)^2$ cm^2	$(D^2_{n+p} - D^2_n)$ cm^2	Mean cm^2	p
		Left end (a) cm	Right end (b) cm					
1.	2	4.838	4.456					
2.	4	4.896	4.421					
3.	6	4.946	4.386					8
4.	8	4.985	4.335					
5.	10	5.018	4.291					
6.	12	5.052	4.371					
7.	14	5.074	4.239				------	
8.	16	5.120	4.210					

CALCULATION :

(A) Using Formula:

From Table $D^2_{n+p} - D^2_n$ = ………………..

$$\lambda = \frac{D^2_{n+p} - D^2_n}{4pR}$$

RESULT:

The mean wavelength λ of sodium light = ……………… A° (using formula)

ERROR ANALYSIS: (I) Using formula :

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

Standard mean value of wavelength λ of Sodium light = 5893 A°

PRECAUTIONS:

(i) Glass plate and lens should be cleaned thoroughly.

(ii) The plano-convex lens should be of large radius of curvature.

(iii) Gross-wire should be focused on a bright ring tangentially.

(iv) Cross-wire should not be touched.

APPLICATIONS:

1. In finding the wavelength of monochromatic light.
2. In finding the radius of curvature of the convex lens.
3. To find the thickness of the thin film.
4. In the explanation of formation of rainbow.
5. In the explanation of film formation in soap bubble.

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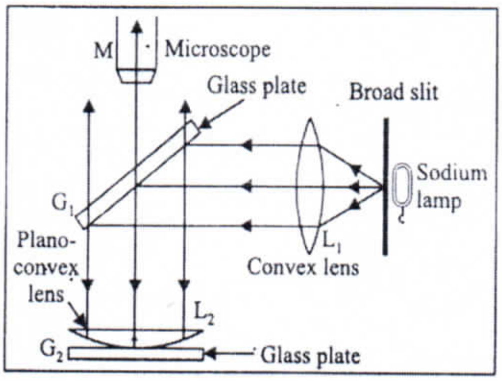

Fig 1: Optical Arrangement of Newton's Rings

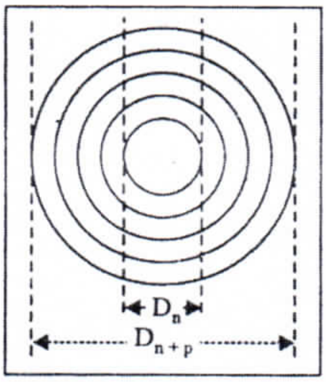

Fig 2: Newton's Rings

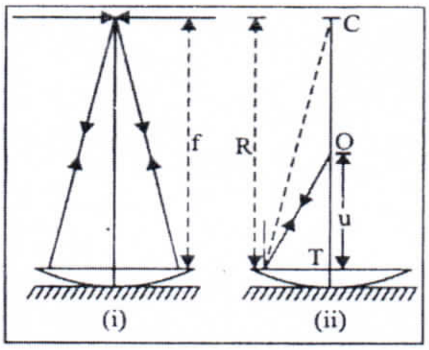

Fig 3: Radius Of Curvature of Newton's Ring

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EXPERIMENT NO. 2 (NODAL SLIDE)

OBJECT:

To determine the focal length of the combination 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: 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 keep lens L_1 towards the plane mirror.

Step II: 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: 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: Remove the first lens and mount the second lens L_2. Repeat the similar procedure to find out the focal length f_2 of the L_2 lens.

Step V: 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: 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).

OBSERVATIONS:

Table 1: Focal Length of a Lens

S. No.	Light incident on	Lens L_1			Mean f_1 (cm)	Lens L_2			Mean f_2 (cm)
		Position of cross slit (a) (cm).	Position of lens (b) (cm).	$f_1 =$ (a ~ b) (cm)		Position of cross slit (a) (cm).	Position of lens (b) (cm).	$F_2 =$ (a ~ b) (cm)	
1)	One face Other face	15	31.8	16.8		18.5	35.1	16.6	
2)	One face Other face	20	36.8	16.8		20	36.6	16.6	
3)	One face Other face	16.1	33	16.9		17	33.8	16.8	

4)	One face Other face	17.5	34	16.5		16	25.6	9.6	

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. (c)	Calculated value of Focal Length cm. (d) (F determine by formula)	Difference (c-d)
1.	4	16	26.1			
2.	4	15	25			
3.	4	14.	24.3			

CALCULATIONS:

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

$$\frac{1}{F} = \frac{1}{f1} + \frac{1}{f2} - \frac{x}{f1\,f2}$$

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.

PRACTICAL USES OF THE KNOWLEDGE:

1. To calculate the power of combination of two or more lenses
2. To calculate the focal length of combination of two or more lenses.
3. Used by the optician to make specs to correct the myopia and hypermetropia.
4. In designing the telescope and compound microscope.

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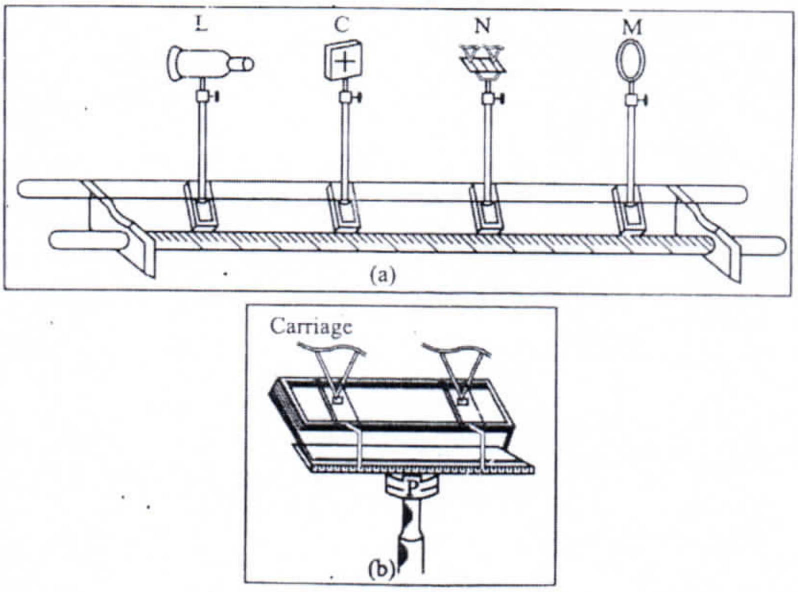

Fig 1(a,b): Nodal Slide Arrangement

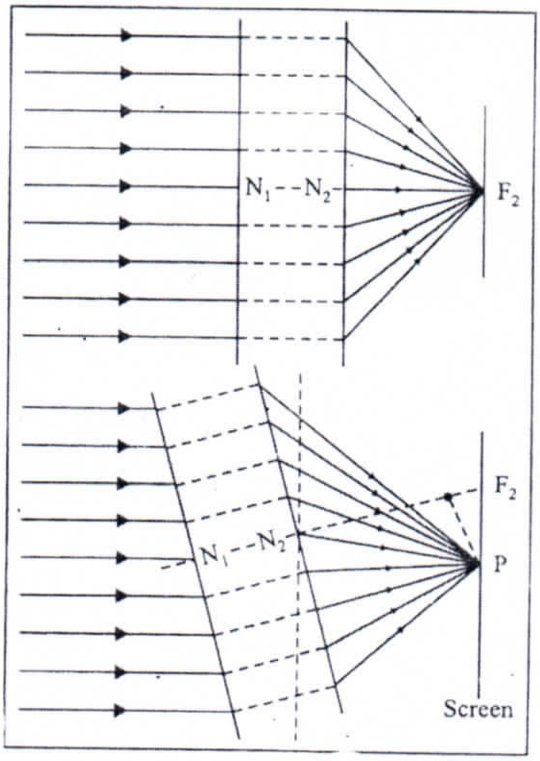

Fig 2:

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EXPERIMENT No. 3 (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 I: First of all clean the polarimeter tube and fill with clean water properly to minimizing the air.

Step II: Place the polarimeter tube in proper place as shown in Fig. 1.

Step III: Switch on the source of light and see through eye-piece two halves of unequal intensity. Rotate the analyzer in clockwise direction until the intensity of two halves appears the same and note down analyzer reading.

Step IV: Rotate the analyzer screw in anti clockwise direction until the intensity of two halves appears the same and note down the reading.

Step V: Rotate the screw from mean position 180^0 in any direction and repeat the steps (III) and (IV).

Step VI: Fill the polarimeter tube with cane sugar solution and repeat the experiment for different concentrations of the sugar solution. Plot graph between angle of rotation and concentration (Fig. 2). Specific rotation can also be determined using this graph the slope of the graph.

OBSERVATIONS:

(i) Room temperature = ... °C

(ii) Mass of sugar dissolved (m) = ... gm

Volume of the solution (F) = ... cc.

Initial concentration of cane sugar solution (C) $= \frac{m}{V} =$....... (gm/cc)

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

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(iv) Value of the division of main scale = ... degree.
Total number of divisions on the vernier scale (n) = ...
Least count of the vernier = ... degree.

$$Mean = \frac{A+B+C+D}{4}$$

Analyser reading with pure water						$a = \frac{X + Y}{2}$
Clockwise			**Anticlockwise**			
M.S.	**V.S.**	**TOTAL X**	**M.S.**	**V.S.**	**TOTAL Y**	
174	6	174.6	186	6	186.6	deg. 180.6
176	0	176	188	0	188	182
178	0	178	190	0	190	184
198	0	198	190	0	190	194

Concetration of solution gm./c.c.	Analyzer reading with sugar solution						$b = \frac{X' + Y'}{2}$	θ = a-b deg.
	Clockwise			**Anticlockwise**				
	M.S.	**V.S.**	**Total X'**	**M.S.**	**V.S**	**Total Y'**		
10/100	160	3	160.3	172	5	172.5	deg. 166.4	14.1
10/100	163	4	163.4	174	0	174.0	168.7	13.8
10/100	165	5	165.5	176	2	176.2	170.85	13.65
10/100	165	5	165.5	176	2	176.2	170.6	11.7

CALCULATION :
The specific rotation(s) of given cane sugar solution is calculation by:
Taken L=20 cm

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

RESULT:
The specific rotation of cane sugar solution = ... (using formula)

ERROR ANALYSIS:

$$\text{Percentage error} = \left(\frac{\text{Stan. value of sp.rotation} - \text{measured value of sp.rotation}}{\text{Standard value of sp. rotation}} \right) \times 100$$

= .... %

PRECAUTIONS:
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.

PRACTICAL USES OF POLARIMETER

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Research Applications
Research applications for polarimetry are found in industry, research institutes and universities as a means of:

- Isolating and identifying unknowns crystallised from various solvents or separated by high performance liquid chromatography (HPLC).
- Evaluating and characterising optically active compounds by measuring their specific rotation and comparing this value with the theoretical values found in literature.
- Investigating kinetic reactions by measuring optical rotation as a function of time.
- Monitoring changes in concentration of an optically active component in a reaction mixture, as in enzymatic cleavage.
- Analysing molecular structure by plotting optical rotatory dispersion curves over a wide range of wavelengths.
- Distinguishing between optical isomers.

In each of these applications, the AUTOPOL offers up to six discrete wavelength selections to observe the effect of wavelength upon an optically active substance.

Quality and Process Control Applications
Quality and process control applications, both in the laboratory or on-line in the factory, are found throughout the pharmaceutical, essential oil, flavour, food and chemical industries. A few examples are listed below.

Pharmaceutical Industry
Determines product purity by measuring specific rotation and optical rotation of:

- Amino Acids
- Amino Sugars
- Analgesics
- Antibiotics
- Cocaine
- Codeine
- Dextrose
- Diuretics
- Serums
- Steroids
- Tranquilizers
- Vitamins

Flavor, Fragrance, and Essential Oil Industry
Utilizes polarimetry for incoming raw materials inspection of:

- Camphors
- Citric acid
- Glyceric acid
- Gums
- Lavender oil
- Lemon oil
- Orange oil
- Spearmint oil

Food Industry
Ensures product quality by measuring the concentration and purity of the following compounds in sugar based foods, cereals and syrups:

- Carbohydrates
- Fructose
- Glucose

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- Lactose
- Levulose
- Maltose
- Raffinose
- Sucrose
- Xylose
- Various starches
- Natural monosaccharides

Chemical Industry
Analyzes optical rotation as a means of identifying and characterizing:

- Biopolymers
- Natural polymers
- Synthetic polymers

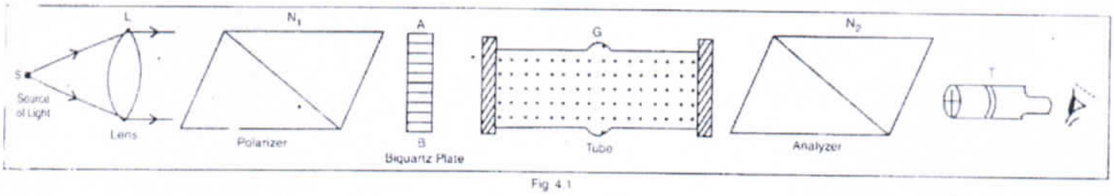
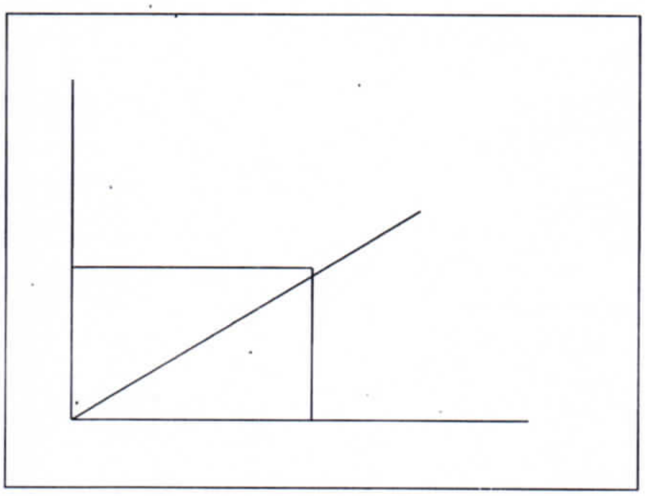


Fig 1: Setup for Half Shade Polarimeter



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EXPERIMENT NO. 4 (ENERGY BAND GAP)

OBJECT:
To determine the energy band gap of a semiconductor using a PN junction diode.

APPARATUS:
Energy band gap set up, connecting leads, oven and thermometer.

FORMULA USED:

Energy band gap is given by

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

where, the slope of the graph is obtained by plotting $\log_e I_S$. Vs $10^3/T$.
I_S is reverse saturation current and T is temperature in K.

PROCEDURE:
Step I: Connect the circuit as shown in the Fig. 1 Switch ON the instrument using main switch keeping temperature control knob fully anti-clockwise.
Step II: Adjust the Voltmeter to a fixed value of voltage.
Step III: Keep the temperature control knob on medium position. Temperature starts increasing and the reading of micro ammeter also starts increasing.
Step IV: When temperature reaches to 80 (^{0}C) degree, switch off the oven. The temperature will rise further, say about 85 (^{0}C) and will become stable.
Step V: As the temperature starts falling, go on recording the values of micro ammeter after every 5°C drop in temperature and the corresponding value of current.
Step VI: Plot graph between reverse saturation current and temperature for different voltage. (Fig 2)

OBSERVATIONS:

Table 1: Measurement of Current and Temperature

S. No.	Temperature T (^{0}C)	Temperature T (K)	Reverse Current I_{RS} (μA)	$log_e I_S$ (μA)	10^3/T (K^{-1})
1.	84	357	220	2.34	2.80
2.	79	352	165	2.21	2.84
3.	74	347	140	2.14	2.88
4.	69	342	125	2.09	2.92
5.	64	337	110	2.04	2.96

Plot graph between log I_s and 10^3/T

CALCULATION:

Energy band gap is calculated by

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

$$Slope = \frac{AB}{BC} = \frac{4.9}{1.4} = 3.5$$

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$$\Delta E = \frac{slope}{5.036} = \frac{3.5}{5.036} = 0.69eV$$

Calculated value of ΔE = 0.69eV

Standard Value of ΔE= 0.7eV

ERROR ANALYSIS:

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

= .... %

RESULT:

The graph between log 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 10 V.
3. All the connections should be properly connected.

APPLICATION:

1. As half wave & full wave reactifier.
2. As voltage regulator in the form of Zener diode.
3. As laser emitting source like LED.
4. As a solar cell which converts solar energy directly in to electric energy.
5. In battery charger & inverter.

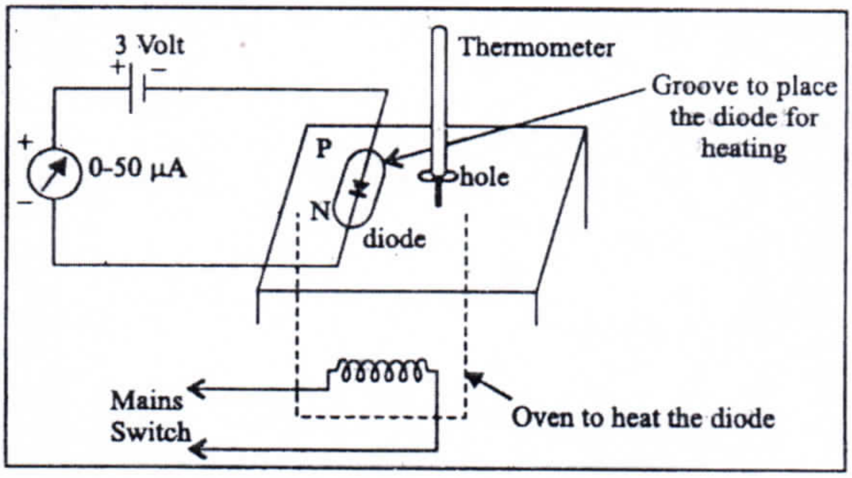

Fig 1: Setup for p-n junction Diode

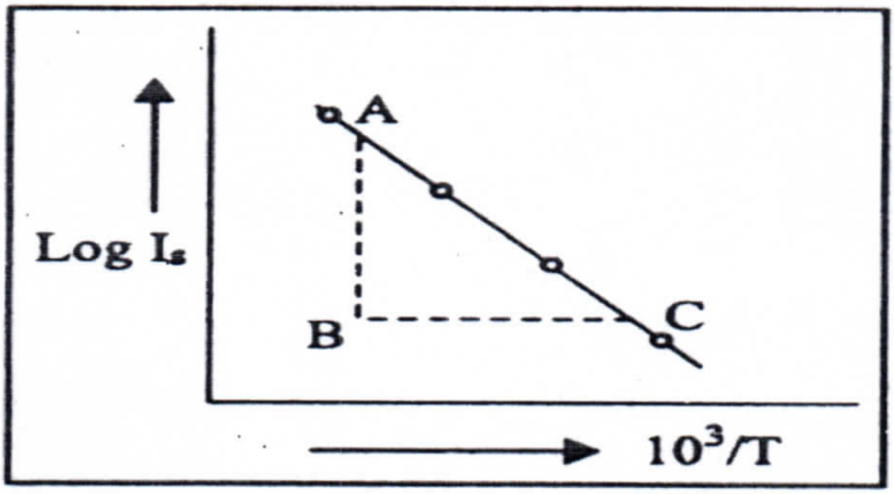

Fig 2: Graph between log I_s and $10^3/T$

EXPERIMENT NO. 5 (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 temp (T)"

i.e. $E \alpha T^4$ or $E = \sigma T^4$

where σ is Stefan constant σ=5.67 X 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 >> To, 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 Temperature T_o.

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

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 Rg. This is the filament resistance at 800K.

From R_t/R_o vs T graph, one obtain R_{800}/R_{273}= 3.9 or R_{800}/R_0 °C= 3.9

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

PROCEDURE:

Step 1: Connect the apparatus as shown in Figures 1.

Step II: Increase the filament current (*I*) from a value below the glowing stage to vale high enough to get dazzling light. Note down the values of *V* and *I every* time.

Step III: Find out R_t(*V/I)* for each reading and calculate (R_t/R_o).

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

Step IV: 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.

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OBSERVATION TABLE:

Table 1: Determination of filament resistance (R_g) at temperature T = 800⁰K

S.No.	Current increasing			Current decreasing			$R_g = \frac{R_{g_1}+R_{g_2}}{2}$ (Mean)
	Voltage (*V*) (*Volts*)	Current (I) (amperes)	R_{g_1} = V/I (ohms)	Voltage (*V*) (*Volts*)	Current (I) (Amp)	R_{g_2} = V/I (ohms)	
1.	1.25	0.20	6.25	2.50	0.30	8.33	
2.	1.50	0.22	6.81	2.25	0.28	8.03	
3.	1.75	0.24	7.29	2.00	0.26	7.69	
4.	2.00	0.26	7.69	1.75	0.24	7.29	7.4
5.	2.25	0.28	8.03	1.50	0.22	6.81	
6.	2.50	0.30	8.33	1.25	0.20	6.25	

Table 2: Measurement of Power (p) Radiation by Filament.

S. No.	Current increasing		$R_t = V/I$ (ohms.)	R_t / R_o	Temp. (T) from graph	Log *T*	P = *VI* (watt)	log *P*
	V (Volts)	I (amps)						
	1.25	0.20	6.25					
1.	1.50	0.22	6.81	3.58	440(K)	2.6	0.33	-0.48
2.	1.75	0.24	7.29	3.84	520	2.71	0.42	-0.37
3.	2.00	0.26	7.69	4.05	530	2.72	0.52	-0.28
4.	2.25	0.28	8.03	4.23	560	2.74	0.63	-0.20
5.	2.50	0.30	8.33	4.39	600	2.77	0.75	-0.12

+273

CALCULATION AND GRAPH:

The value of α is calculated from the slope of the graph plotted between log *P* Vs log T.

ERROR ANALYSIS:

$$\text{Percentage error} = \left(\frac{\text{Standard value of } \alpha - \text{measured value of } \alpha}{\text{Standard value of } \alpha} \times 100 \right)$$

= .... %

RESULT:

The graph of log P vs log T comes out to be a straight line. The slope of line gives α = ... (which is nearly equal to 4).

Hence, $P = CT^{\alpha}$, law is verified.

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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APPLICATIONS :

1. With his law Stefan also determined the temperature of the Sun's surface.
2. We can calculate the effective temperature of the Earth.
3. The temperature of stars other than the Sun can be approximated using a similar means by treating the emitted energy as a black body radiation.
4. It can be used to determine the spectra (absorption, emission) of any material.
5. It can be used to determine the composition of material.

Table 3 : R_t / R_o vs T (°C)

Temperature °C	R_t / R_o	Temperature	R_t / R_o
0	1.00	1100	7.60
100	1.53	1200	8.26
200	2.07	1300	8.90
300	2.13	1400	9.70
400	3.22	1500	10.43
500	3.80	1600	11.17
600	4.40	1700	11.42
700	5.00	1800	12.67
800	5.64	1900	13.50
900	6.37	2000	14.30
1000	6.94		

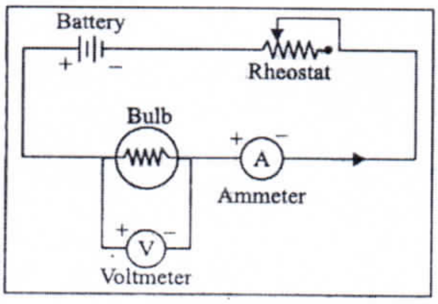
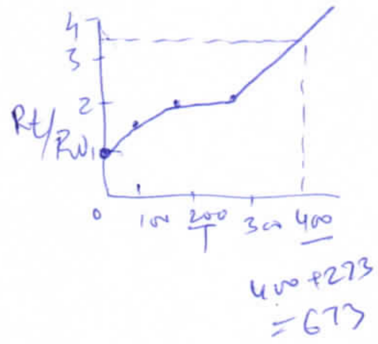


Fig 1: Circuit diagram for Stefan's Law



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EXPERIMENT No. 6 (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 (ρ) of bridge wire is given by the formula:-

$$X\text{-}Y = \rho\,(l_2 - l_1).$$

Where X and Yare two resistances in the outer gaps of the Carey-Foster' 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

or $$\rho = \frac{R}{l_2 - l_1}$$

Using equation (2) the resistance per unit length (ρ) can be calculated and knowing the value of ρ, 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.

The specific resistance can be calculated by the formula-

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

Where,

r	=	Radius of the wire.
l	=	Length of the wire.
Y	=	Resistance of the given wire.

PROCEDURE:

Step 1: Arrange the apparatus as shown in Fig. 1.

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

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

Step IV: 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. Note this reading as l_1.

Step V: Interchange the position of resistance box and copper strip and obtain null point again by sliding the jockey on the wire. This gives the readings as l_1.

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

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

Step VIII: 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 copper strip is replaced by a given wire.

Step IX: Calculate the resistance of the wire using

$Y = X - \rho\,(l_2' - l_1')$.

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

Step X: alculate 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)
		l_1 (cm)	l_2 (cm)			
1.	0.1	77	82	5	.02	0.0276
2.	0.2	75.5	83.5	8	.025	
3.	0.3	75	85	10	.03	
4.	0.4	74.5	87.5	13	.03	
5.	0.5	75	90	15	.033	

Table 2: Measurement of Wire resistance

S. No.	Resistance introduced in decimal ohmbox X	Position of null point with decimal ohm box in		$(l_{2'} - l_{1'})$ (cm.)	Resistance of the wire $Y = X - \rho(l_{2'} - l_{1'})$	*Mean* Y (ohm.)
		$l_{1'}$(cm)	$l_{2'}$ (cm)			
1.	0.1	85.5	78.5	-9	.293	.355
2.	0.2	85	80	-5	.338	
3.	0.3	84.5	82.5	-2	.355	
4.	0.4	84	85	1	.372	
5.	0.5	83.5	86.5	3	.417	

Table 3: Measurement of radius of the given wire

Length of the wire $l = 7$ cm.

r = .017 cm

CALCULATION:

The specific resistance (Ks) of wire is calculated by: $K_s = Y\pi r^2 / l$

$= .355 * 3.14 * (.017)^2 / 7$

$= 46.02 * 10^{-6}$ ohm –cm.

RESULT:

The specific resistance of a given wire $= 46.02 * 10^{-6}$ ohm –cm.

ERROR ANALYSIS:

$$\text{Percentage error} = \frac{\text{Standard value of sp. res.} - \text{measured value of sp. res.}}{\text{Standard value of sp. resistance}} \times 100$$

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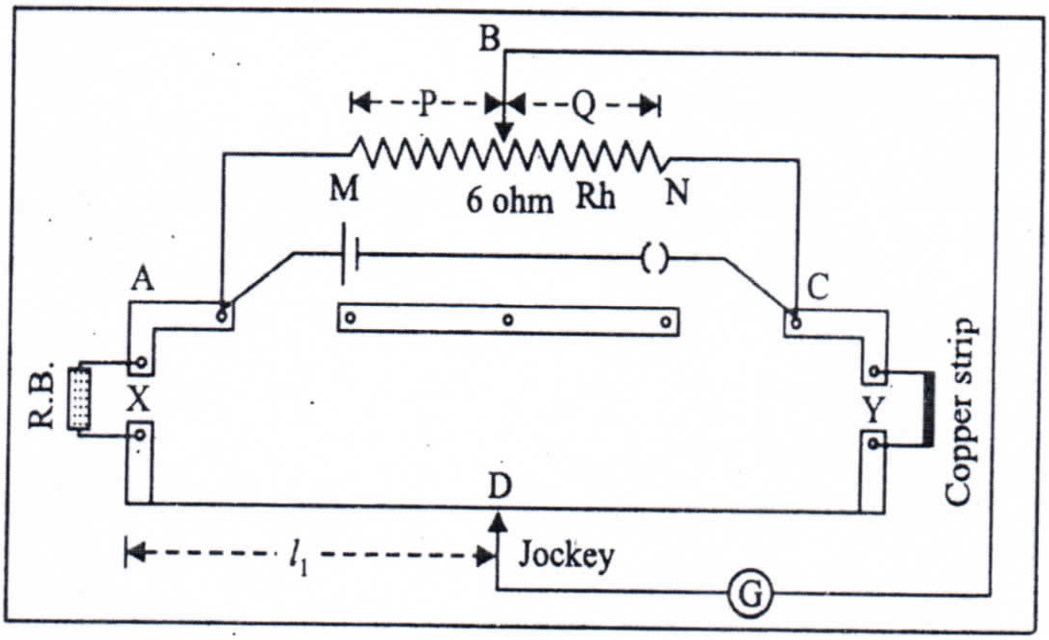
Here Standard value is $49.1*10^{-6}$ ohm –cm.
Percentage error = 6.27%

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 slided over the bridge wire

APPLICATIONS:

1. Variations on the Carey Foster bridge can be used to measure capacitance, inductance, impedance and other quantities, such as the amount of combustible gases in a sample, with an explosimeter.
2. The Kelvin bridge was specially adapted from the Carey Foster bridge for measuring very low resistances.
3. In many cases, the significance of measuring the unknown resistance is related to measuring the impact of some physical phenomenon - such as force, temperature, pressure, etc. - which thereby allows the use of Wheatstone bridge in measuring those elements indirectly.



Experimental Arrangement of Carry Foster Bridge

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EXPERIMENT NO. 7 (CALIBRATION OF VOLTMETER)

OBJECT:

To calibrate given voltmeter with the help of a potentiometer.

APPARATUS:

Potentiometer, two storage batteries, two rheostats (50 Ω, 110 Ω), a standard cell (cadmium cell), a galvanometer, a standard, one two-way key, two one-way keys, connections wires, given voltmeter.

FORMULA USED:

The errors 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 volt).

PROCEDURE:

Step 1: Standardisation of the potentiometer – make the connections as shown in the Fig. 1 & 2. Close the key K1 and K2 (1) by keeping the keys K1 and K2 (2) open. Put the jockey at the last and B of the 10[th] wire. At this stage the total length of the wire will be 1000 cm. and there will be some deflection in the galvanometer. Adjust the rheostat RI_1 till the deflection in the galvanometer is reduced to zero. Note down the total balancing length (l_1). In the present case l_1 = 1000 cm.

Step II: Open the key K_2 (I) and close the key K_2 (2) and key K_3. 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). 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. Note down the balancing length l_2 for each reading of voltmeter and ammeter. Now, 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: Find out and $(V' - V)$ which is equal to errors produced in the ammeter and voltmeter readings respectively. Plot a calibration graph between error $(V' - V)$ *and* V as shown Fig. 3. Similar graph can be obtained for ammeter calibration.

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) = 1000 cm.

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Table 1: Calibration of Voltmeter

S.No	Voltmeter reading V (volt)	Balancing length of the potentiometer wire l_2 (cm.)	$V'=El_2/l1$	Errors in voltmeter $(V' - V)$ (volt)
1.	0.1	131	0.1414	0.0414
2.	0.2	244	0.2635	0.0635
3.	0.3	300	0.3240	0.0240
4.	0.4	410	0.4428	0.0428
5.	0.5	485	0.5238	0.0238
6.	0.6	590	0.6372	0.0372

CALCULATION:

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

$$K = \frac{E}{l_1} = 1.08/1000 = 1.08\text{x}10^{-3} \text{ volt/cm.}$$

(iii) The values of the Voltage $V' = (E/l_1)\, l_2$

RESULT:

Calibration curves 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.
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 Voltmeter are used for the best accuracy they are used in Analog-to-digital converter.
2.Digital Voltmeter are used for the best accuracy they are used in Electronic power supply
3.Digital Voltmeter is used in Zener diode.
4.Sampling voltmeters are used scale and pointer meters,
5.They can be used in graphic recorders.
6.They are used in cathode-ray tubes.
7.They are used in digital indicators for readout of measured quantities.

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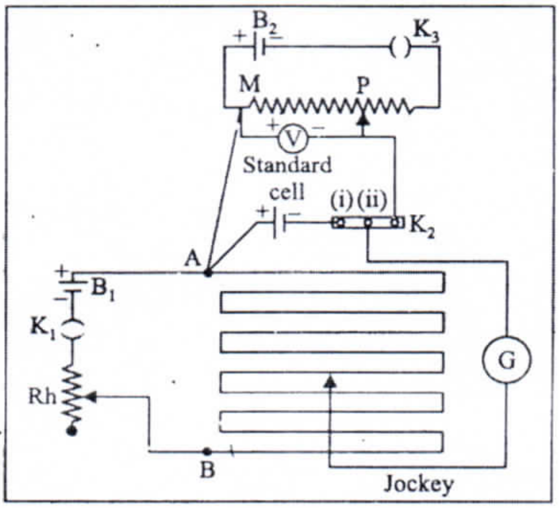

Fig 1: Electrical connections for Calibration of Voltmeter

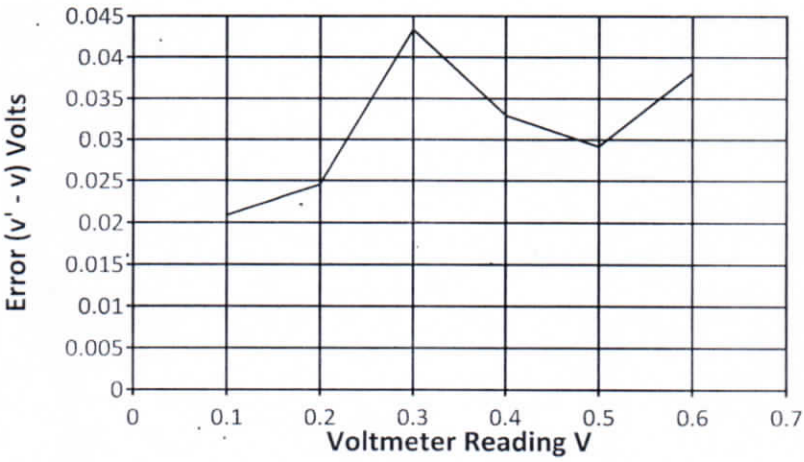

Fig 2: Graph between error and voltmeter readings

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EXPERIMENT NO. 8 (CALIBRATION OF AMMETER)

OBJECT:

To calibrate given ammeter with the help of a potentiometer.

APPARATUS:

Potentiometer, two storage batteries, two rheostats (50 Ω, 110 Ω), a standard cell (cadmium cell), a galvanometer, a standard. 1 Ω 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).

PROCEDURE:

Step 1: Standardization of the potentiometer – make the connections as shown in the Fig. 1 & 2. Close the key K1 and K2 (1) by keeping the keys K1 and K2 (2) open. 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 deflection in the galvanometer. Adjust the rheostat RI_1 till the deflection in the galvanometer is reduced to zero. Note down the total balancing length (l_1). In the present case l_1 = 1000 cm.

Step II: Open the key K_2 (I) and close the key K_2 (2) 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. Note down the balancing length l_2 for each reading of voltmeter and ammeter. Now, 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: Find out (I' – I) which is equal to errors produced in the ammeter and voltmeter readings respectively. Plot.a calibration graph between error (I' – I) *and I* as shown Fig. 3. Similar graph can be obtained for ammeter calibration.

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) = 1000 cm.

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Table 1: Calibration of Ammeter

S.N.	Ammeter reading I (amp)	Balancing length of the potentiometer wire l_2 (cm.)	Potentiometer reading $I' = \left(\frac{E}{l_1} \times l_2\right)$	Errors in ammeter $(I' - I)$ (amp.)
1.	0.1	112	0.1209	0.0209
2.	0.2	208	0.2246	0.0246
3.	0.3	318	0.3434	0.0434
4.	0.4	401	0.4330	0.0330
5.	0.5	490	0.5292	0.0292
6.	0.6	591	0.6382	0.0382

CALCULATION:

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

$$K = \frac{E}{l_1} = 1.08/1000 = 1.08\times10^{-3} \text{ volt/cm.}$$

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

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.

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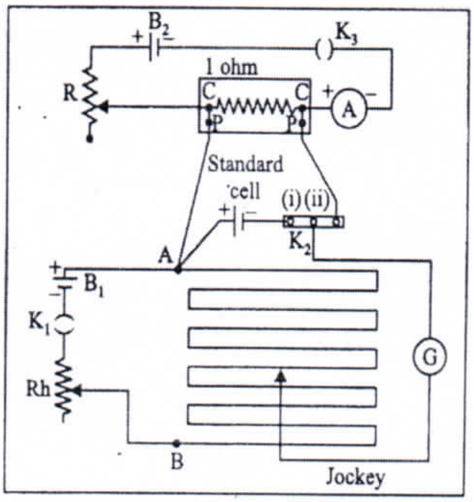
Fig



1: Electrical connections for Calibration of Ammeter

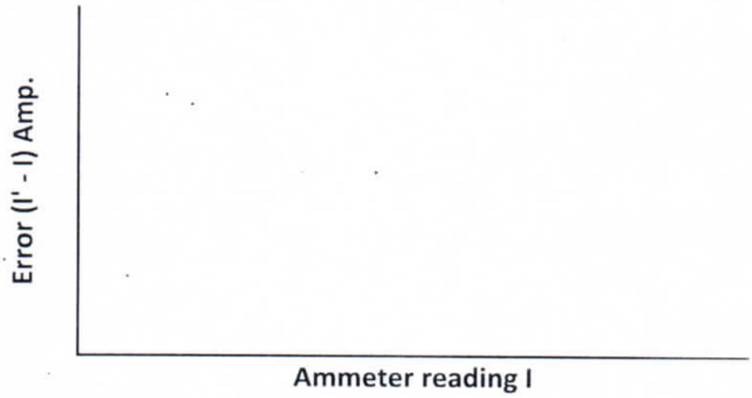


Fig 2: Graph between error and ammeter readings

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EXPERIMENT NO. 9 (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 θ horizontal magneticfield).

- 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 1: Place the compass box on the sliding bench so that its magnetic needle is at the centre of the coil. Level the base of the coil with the help of a spirit (Fig. 1 & 2).

Step II: 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: Using commentator, flow the current in one direction and note sown the deflection of the needle. 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: Adjust the current in the coil such that the deflection in the magnetic needle is of the order $70^0 - 75^0$. Note down the reading of both side of pointer. Reverse the direction of current and again note down reading of both the ends of pointer.

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

Step VI: Take the measurements for other side of the bench.

Step VII: Calculate θ according to the observation table and determine tan θ.

Step VIII: Plot a graph taking position (x) along the X – axis and than θ along Y-axis.

Step IX: The distance between the two points of inflexion on the curve will be the radius of the coil (Fig. 3). 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 the centre (x)	Current One Way		Current Reversed		$\theta = \frac{\theta_1 + \theta_2 + \theta_3 + \theta_4}{4}$ (deg.)	tan θ
		θ_1 (deg.)	θ_2 (deg.)	θ_3 (deg.)	θ_4 (deg.)		
1.		75	75	80	80	77.5	4.5
2.	5	68	68	78	78	73	3.2
3.	10	58	58	68	68	63	1.9
4.	15	40	40	46	46	43	.93
5.	20	25	25	26	26	25.5	.47
6	25	16	17	15	15	15.75	.28

Table 2: Measurement of Deflection (in other side)

S. No.	Distance of needle from the centre (x)	Current One Way		Current Reversed		$\theta = \frac{\theta_1 + \theta_2 + \theta_3 + \theta_4}{4}$ (deg.)	tan θ
		θ_1 (deg.)	θ_2 (deg.)	θ_3 (deg.)	θ_4 (deg.)		
1.		75	75	80	80	77.5	4.5
2.	5	70	70	75	75	72.5	3.1
3.	10	57	58	58	58	57.75	1.5
4.	15	41	41	39	39	40	.83
5.	20	24	24	22	22	23	.42
6	25	15	15	12	12	13.5	.24

RESULT:

Various of magnetic field along the axis of current carrying cicular 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 30^0 to 75^0.
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.

APPLICATIONS:

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

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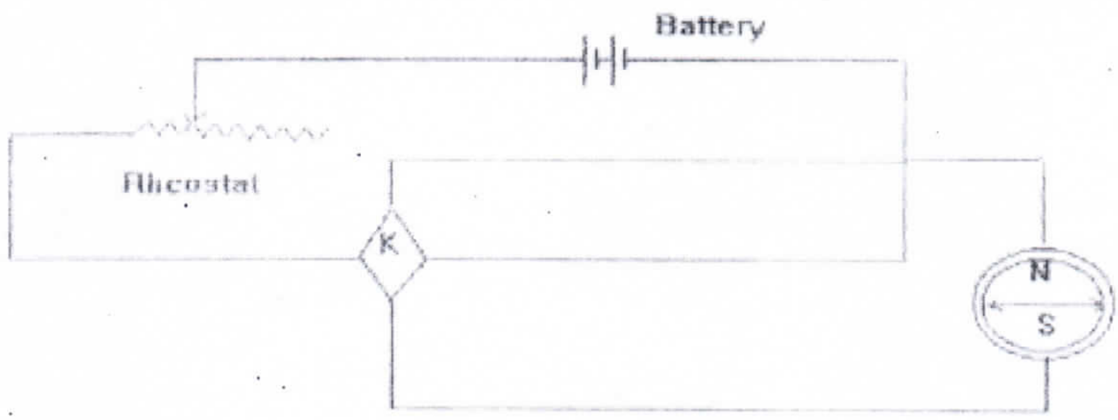

Fig 1: Circuit Diagram

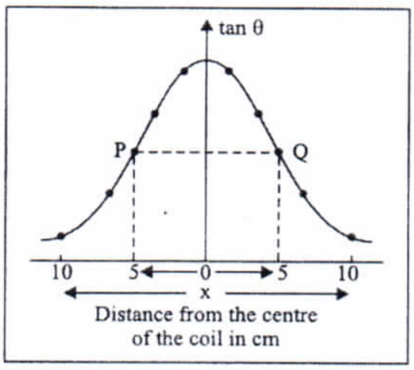

Fig 2: Graph between tanθ and distance from the centre of the coil.

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EXPERIMENT NO. 10

OBJECT:

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

APPARATUS:

Viscosity apparatus, a capillary tube of uniform bore, constant level water tank, a graduated cylinder, stop watch, traveling microscope, meter scale and thermometer.

FORMULA USED:

The coefficient of viscosity of a liquid is given by :

$$\eta = \frac{\pi p r^4}{8 Q 1} = \frac{\pi (h d g) r^4}{8 Q 1}$$

Where,

P = Difference of the pressure across the two ends of the capillary tube = hdg.
h = Difference of levels in the two limbs of the manometer.
d = Density of liquid,
g = Gravitational constant (= 9.8 m/sec),
r = Radius of the capillary tube,
Q = Volume of water collected per see ano.
I = Length of the capillary tube.
For water d = 1.00 x 10^3 kg/m^3, Viscosity of water 20^oC is 1.005 centi poise.

OBSERVATIONS:

Temperature of the water (T_w)= ……..^oC
Density of water (d) = 1.0 gm/cm^3.

Measurement of *h* and .3221UQ

S.No.	Water level in one limb of manometer (a) (cm)	Water level in the other limb of manometer (b) (cm)	*Pressure difference* h (cm) (a) – (b)	Volume of water collected V (cc)	Time taken t (sec.)	Volume of water collected per second Q = V/t (cc/sec)	Mean value of Q (cc/sec)	$\frac{h}{Q}\left(\frac{cm}{cc/sec}\right)$	Mean $\left(\frac{h}{Q}\right)$
1.									
2.									
3.									
4.									
5.									

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Measurement of Diameter of the Capillary Tube

End of the tube	S.No	Position of cross wire						Mean $\left(\frac{d_1 + d_2}{2}\right)$ (cm)	Mean diameter (cm)
		along any diameter (cm)			along perpendicular diameter (cm)				
		One end of section (A)	Other end of section (B)	Diameter $d_1 = (A - B)$	One end of section (C)	Other end of section (D)	Diameter $d_2 = (C - D)$		
I.	1.								d_I= ....
	2.								
II.	1.								d_{II} = ...
	2.								

Radius of the capillary tube $r = \dfrac{d_1 + d_2}{2}$ **= ……………… cm.**

CALCULATION:

The coefficient of viscosity of given liquid is calculated by: :

$$\eta = \frac{\pi\, d\, g\, r^4}{8\, l}\left(\frac{h}{Q}\right)$$

RESULT:

The coefficient of viscosity of water at room temperature (……………..^{o}C) is …………… poise.

ERROR ANALYSIS:

$$\text{Percentage error} = \left(\frac{\text{Standard value of } \eta - \text{measured value of } \eta}{\text{Standard value of } \eta}\right) \times 100$$

= ………………………………… %

PRECAUTIONS:

1. The capillary tube should be of uniform narrow diameter.
2. The capillary tube should be placed horizontally.
3. Too much water should not be collected, otherwise, the manometer reading will change due to which the pressui at the two ends of capillary rube will not remain constant.
4. Temperature of water must be recorded during the experiment.

PROCEDURE:

Step 1: Arrange the apparatus as shown in Fig. 15.1.

Step II: Adjust the height of the constant level tank such that there is some difference (h) in the levels of water in the limps of the manometer . This h gives the pressure difference between the two ends of the capillary tube. Wait for some time to

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attain a steady state flow. In this conditions, the water trickle out in deops from the capillary tube. Flow of water may be controlled with the help of pinch cock K.

Step III: Collect sufficient amount of water in the graduated cylinder and note sown the time (t) during which water is collected . Find out the rate of flow of water (Q) i.e., voltmeter Q of water flowing per second . For same level of water of h, take at least three observations of Q and t.

Step IV: Change the pressure difference (h) between the ends of the capillary tube by raising or lowering the water tank and determine the volume of water flowing per second for each value it has in step (III).

Step V: Note down the temperature of water.

Step VI: Measure the length and diameter of the capillary tube. Traveling microscope is used to measure the diameter.

Step VII: Plot a graph between h and Q as shaecn in fig. 15.2. Find the value of h/Q for the linear portion from the graph.

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