Physics Laboratory Manual

First year BE Students (2017)

Department of Physics

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Experiment No. 1

1.1 Objective

Measurement of the magnetic field along the axis of a current carrying circular coil to verify Biot Savart Law and to estimate the radius of the coil.

1.2 Apparatus required

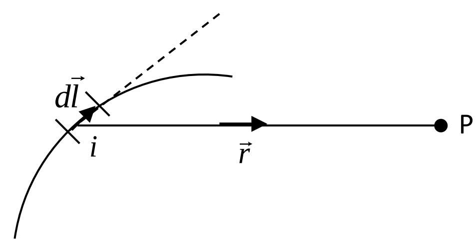
Deflection Magnetometer, Circular coil, DC power supply, Measuring scale.

1.3 Description of the apparatus

A deflection magnetometer consists of a small compass needle pivoted at the centre of a graduated circular scale. The graduations are marked from 0^0 to 90^0 in each quadrant. An aluminium pointer is rigidly fixed perpendicular to the compass needle. The ends of the pointer move on the circular scale. These are enclosed in a cylindrical box known as the magnetometer box. The upper cover of the box is made of glass so that the things inside are visible. The magnetometer box is kept on an aluminium frame having two arms. Meter scales are fitted on the two arms. The magnetometer box can be moved on the two arms as per requirement.

1.4 Theory

According to Biot - Savart Law, the magnetic field at a point P due to a current element $i\,d\vec{l}$ is given by



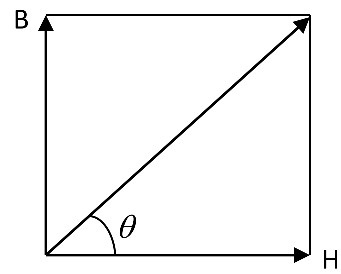
$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{i d\vec{l} \times \vec{r}}{r^3} \tag{1.1}$$

where i is the current, $d\vec{l}$ is the length vector of the current element and $\vec{r}$ is the vector joining the current element to the point P. μ_0 is called the permeability of vacuum. Its value is $4\pi \times 10^{-7}$ T-m/A. The direction of magnetic field is perpendicular to the plane containing the current element and the position vector according to the rule of cross-product.

Applying the above equation, the magnetic field due to a current carrying circular coil at a point on the axis of the coil at a distance x from its centre will be

$$B = \frac{\mu_0}{4\pi}\frac{2\pi n i r^2}{\left(x^2 + r^2\right)^{3/2}} \tag{1.2}$$

where r and n are the radius and the number of turns of the coil respectively. The direction of B at any point on the axis is along the axis of the coil. Therefore, if the coil is placed in the magnetic meridian, then the magnetic field produced by that coil along the axis will be perpendicular to the horizontal component (H) of the earth's magnetic field. If a compass needle is placed at the centre of the coil, then the needle will be deflected along the resultant of B and H .



If the needle is deflected by an angle θ from the magnetic meridian, then

$$B = H \tan\theta \tag{1.3}$$

which is known as the 'Tangent Law'.

1.5 Procedure

a) The magnetometer box is placed at the centre of the coil on the sliding arms. The magnetic needle slowly orients itself along the magnetic meridian.
b) The magnetometer box is rotated slowly in its plane such that the pointer, attached perpendicular to the needle, coincides with the 0-0 marking on the circular scale of the magnetometer.
c) The entire experimental set-up consisting of the deflection magnetometer and the coil is rotated slowly in such a way so as to align the coil along the magnetic meridian. In such a position, the

magnetic field produced by the current carrying coil along its axis will be perpendicular to the horizontal component of earth's magnetic field.

d) The coil is connected to the DC power supply and the current is adjusted such that the deflection of the compass needle is around 75^0. The value of the corresponding current is noted and then using Eq. (1.2), evaluate the magnetic field at the centre of the coil $(x=0)$. This value of magnetic field is used to calculate the value of H using Eq. (1.3). The value of H thus obtained at the centre of the coil, can be assumed to be constant near the vicinity of the experimental area.

e) The magnetometer box is moved slowly on the arms and the deflection of the pointer is noted down at every interval of a distance of 2.5 cm on both sides of the centre of the coil till the deflection becomes less than, say, 10^0. For each position of the magnetic needle, the value of magnetic field is calculated using Eq. (1.3).

f) Plot a graph between the distance of the compass needle (x) from the centre of the coil and the corresponding magnetic field (B). Find the two points of inflexion on the graph. The distance of the point of inflexion from the centre of the coil $(x=0)$ is $r/2$ and hence the radius of the coil will be equal to the distance between the two points of inflexion on the graph.

g) Measure the inner and outer radii of the coil with a measuring scale and take the average of the two radii. This will be the theoretical value of the radius of the coil. Compare this theoretical value of r to that found experimentally in step (f). Find the percentage error in the measurement of r.

1.6 Observation Table

Table 1: Measurement of magnetic field

Sl No.	Distance of the compass needle from the centre (x)	Deflection of the compass needle		Mean $\theta = \frac{\theta_1 + \theta_2}{2}$	$\tan\theta$	$B = H \tan\theta$
		Left end (θ_1)	Right end (θ_2)			

1.7 Results

(a) Horizontal Component of earth's magnetic field :…………….
(b) Theoretical value of r :…………………….
(c) Experimentally measured value of r :…………………….
(d) Percentage error:………………….

1.8 Sources of errors and Precautions

(a) The movement of magnetometer box on the arms should be slow so that the pointer should not deflect abruptly.
(b) In order to avoid any backlash error, the magnetometer box should be moved on the arms in one direction (from one extreme end to the other) while taking observations.
(c) Before switching the DC power supply, ensure that the knob is set for the zero current value.

1.9 Sample Questions

(a) What is the theory of earth's magnetic field?
(b) How the earth's magnetic field is characterized?
(c) The electric field and the magnetic field are not independent; rather they are two aspects of the same entity which we call electromagnetic field. Try to understand this concept.
(d) Apart from magnetic effects, a current has thermal and chemical effects also. Try to explore these three effects of current.
(e) The direction of magnetic field due to a current carrying circular coil around its vicinity is very complex one. Try to find this direction at all possible locations around the vicinity of the circular coil.

Experiment No. 02

2.1 Objective

To determine the resistance per unit length of a Carey Foster's bridge wire and resistivity of a given wire.

2.2 Apparatus required

A Carey Foster's bridge, a Leclanche cell, Weston galvanometer, a 1 -

Ohm coil, a dial pattern decimal - Ohm box, sliding rheostat of small resistance, a single way plug key, thick copper strips, a shunt wire and connecting wires.

2.3 Theory

Carey Foster's bridge is specially suited for the comparison of two nearly equal resistances whose difference is less than the resistance of the bridge wire. As shown in fig.1, two resistances X and Y to be compared are connected in the outer gaps of the bridge in series of the bridge wire. These two resistances together with the bridge wire from the two arms of the Wheatstone bridge. One composed of X plus a length of the bridge wire up to the balance point and the second composed of Y plus the rest of the bridge wire. The remaining two arms are formed by two nearly equal resistances P and Q, which are connected in the inner gaps of the bridge. If $l_1$be the reading on the scale of the position of the null point, we have, from usual Wheatstone bridge principle

$$\frac{P}{Q}=\frac{X+\sigma(l_1+\alpha)}{Y+\sigma(100-l_1+\beta)} \qquad (2.1)$$

$$\frac{P}{Q}+1=\frac{X+Y+\sigma(100+\alpha+\beta)}{Y+\sigma(100-l_1+\beta)}$$

(2.2)

where α and β in units of length of the bridge wire are the end corrections at the left and right ends of the bridge wire respectively and σ is the resistance per unit length of the bridge wire. If now X and Y are interchanged and

2.6 Observations

Table 2.1: Determination of σ

Sl. No	R (Ohm)	P = Q (Ohm)	Position of balance point with copper strip in the		$\sigma = (l_2 - l_1)$ (Ohm/cm)	Mean σ in (Ohm/cm)
			Right gap l_1(cm)	Left gap l_2(cm)		

Table 2.2: Determination of resistance and resistivity of the unknown wire

Sl. No	R (Ohm)	P=Q (Ohm)	Position of balance point with copper strip in the		$(l_2 - l_1)$ (Ohm/cm)	$X = R + \sigma\,(l_2 - l_1)$ (Ohm/cm)	Mean X (Ohm/cm)
			Right gap l_1(cm)	Left gap l_2(cm)			

2.6 Calculation

a) Determine an average value for $(l_2 - l_1)$ for each value of X from each row of data in your version of Table 1.

b) Then calculate values of ρ for the bridge wire from these values of $(l_2 - l_1)$.Using the formula $\rho = X / (l_2 - l_1)$.

c) Use these results to calculate a mean value of ρ in SI units.

d) Use Equation (2.8) to calculate a value of the unknown resistance Y from each row of data in your version of Table 2.

e) Then use these results to calculate a mean value of Y.

2.7 Result

a) The resistance per unit length of the bridge wire . ρ= …… Ω m-1

b) The value of the unknown low resistance Y = ……….. Ω

c) Actual value (if known) = ………. Ω

d) % error =………

2.8 Source of error and Precautions

a) The ends of the connecting wires should be clean and all connections should be firmly made. The decimal - ohm box and thick copper strips should connect the given one-ohm resistance.

b) A rheostat should be used to introduce the resistances P and Q in the inner gaps of the bridges and the sliding contact should be adjusted to be approximately in the middle.

c) It is not absolutely necessary that P and Q should be exactly equal except for high sensitiveness of the bridge, nor should their values be known.

d) If P = Q, the positions of null point before and after interchanging the resistances in the outer gaps will be at equal distances from the middle ‘point of the bridge wire, provided, of course, the wire is uniform. If P and Q differ very much it will not be possible to obtain the two positions of the null point on the bridge wire. The use of rheostat to introduce P and Q in the inner gaps possesses several advantages. Besides being cheap, it is flexible, for it can be used to obtain the null point in any part of the bridge wire and also enables us to take several sets of readings for $(l_2 - l_1)$ for the same values of X and Y. With fixed values for P and Q this could not have been possible.

e) In order that the bridge may have high sensitiveness, the resistances of the four arms should be of the same order. In order to reduce the inaccuracy in the result due to a small error in reading the position of the null point to minimum, the null points while comparing X and Y should lie as near the middle of the bridge wire as possible.

f) While determining the value of ρ the value of R should be comparable with the resistance of the bridge wire so that the two positions of the null.

g) Point before and after interchanging the resistances in the outer gaps lie near the ends of the bridge wire. The value of $(l_2 - l_1)$ will then be almost equal to the entire length of the bridge wire and the error in the value of σ due to non uniformity of the bridge wire will be reduced to minimum.

h) A plug key should be included in the cell circuit and should only be closed when observations are being made.

i) The galvanometer should be shunted by a low resistance wire to avoid excessive deflection in it when the bridge is out of balance. The exact position of the null point should be determined with full galvanometer sensitivity by removing the shunt wire from it.

j) The cell circuit should be closed before depressing the jockey over the bridge wire, but when breaking, reverse order should be followed.

k) The jockey should always be pressed gently and the contact between the jockey and the bridge wire should not be made while the jockey is being moved along.

2.9 Sample Questions

a) What is resistance?
b) What is specific resistance?
c) What is the effect of temperature on resistance?
d) In what materials the resistance decreases with increase in temperature?
e) If the radius of wire is doubled will the specific resistance change?
f) Why is the resistance wire doubled before winding over the bobbin?
g) What is the principle of Carey Foster Bridge?
h) What is the principle of Wheatstone Bridge?
i) When is Carey Foster Bridge most sensitive?
j) Why the resistance for inner ratio arms be equal?
k) What is the minimum difference in resistances that can be measured by Carey Foster Bridge?

Experiment No.- 3

3.1 Objective

Measurement of voltage and frequency of a given signal using cathode ray oscilloscope (CRO)

3.2 Apparatus required

Cathod ray Ossciloscope- 01 numbe & Function Generator-01 number.

3.3 Theory

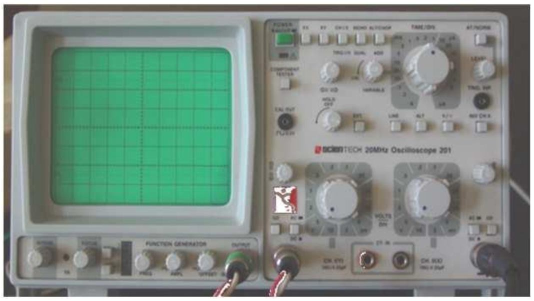
A cathode ray oscilloscope can be used to measure the voltage and frequency of given unknown signal. A RC oscillator can be used to generate an electrical signal of desired frequency and amplitude. In the given experiment the RC oscillator has to be used to generate the signal and the CRO will be used to measure its voltage and frequency.

3.4 Procedure

1) Switch on the CRO. Place the time base knob in horizontal input position and wait for a couple of minutes. Notice a bright spot of light on the screen of the CRO. You can move the spot in vertical or horizontal direction by using the horizontal position knob and vertical position knob respectively. Place the time base in appropriate position (i.e. 1ms/cm or 0.1 ms/cm or any other value). You will notice a bright line on the CRO screen. Your CRO is now ready to measure voltage and frequency of the unknown signal.
2) The RC oscillator is having several knobs, which can be used to select frequency of the signal to be generated. In the top left hand corner you would see three knobs. These knobs can be used to select frequency value, which can be represented by three digits. For example, suppose you are setting the left knob to 6, the middle knob to 5 and the extreme right knob to 4. Then the selected frequency will be 654Hz. below these three knobs you will get a mul-tiplier. The multiplier will multiply the above selected frequency. Thus if you select 654Hz and multiplier position is 10 then the overall frequency will be 6540Hz.
3) Frequency Measurement - The RC oscillator provides you option to vary the voltage of the signal to be generated. This can be done using two voltage selecting knobs (Fine and Coarse). Therefore, using different knobs a signal of given amplitude and given frequency can be generated by the RC oscillator. This signal can now be used as an input to the CRO and its frequency and voltage can be measured.
4) Voltage Measurement - Use the signal generated by RC oscillator as an input to CRO. Place the Y am-plifier in proper value. From vertical scale measure the peak to peak value. This will give the value of peak

to peak voltage of the signal.

Fig. 3.1- The Cathode ray oscilloscope & frequency generator used in Physics Laboratory



3.5 Observation

No. of observation	Frequecy from function generator (f Hz)	Horzontal scale no. of div. in CRO	f_0 volts	Ratio f/f_0	% Error

Table 3.1-Observation table for frequency measurement

No. of observation	Voltage from source (V_{rms} volts)	Vertical scale no. of div. in CRO	V_{p-p} volts	Ratio V_{p-p}/V_{rms}	% Error

Table 3.2- Observation table for voltage measurement

3.6 Calculations

3.7 Results

Students are advised to mention the result based on above obtained values.

3.8 Source of errors & precautions

1) Cautious handling of equipment is necessary as it functions at 220 AC voltage.
2) Selection of frequency in function generator should be done properly.
3) Multiplier knobs in CRO should be checked properly.

3.9 Sample questions

1) What is Lissajous figures ?

2) What are the different engineering applications of Lissajous figures ?

3) What are the different types of waves ?

Experiment No.- 4

4.1 Objective

To determine the unknown frequency by help of Lissajous Figures.

4.2 Apparatus required

Cathod ray Ossciloscope- 01 numbe & Function Generator-02 numbers.

4.3 Theory

When two simple harmonic motions are plotted against each other at right angles, the resulting configuration is called a Lissajous figure. Simple harmonic motions plotted against time gives sinusoidal configurations. Two sinusoidal electrical inputs given to an oscilloscope will give a Lissajous pattern on the screen. The particular pattern depends upon the frequency, amplitude and phase of the applied inputs.

The frequency ratio of the inputs may be determined from an analysis of the Lissajous figure produced. If a Lissajous figure is enclosed in a rectangle whose sizes are parallel to the formation axes of the figure, the frequency ratio of the two inputs may be determined by counting the points of tangency to the sides of the rectangle enclosing the pattern. Once the frequency ratio is known, the input frequency can also be determined from the same.

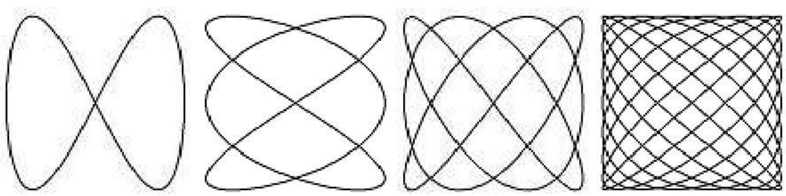
4.4 Procedure

(i) Connect one signal generator to the vertical input and the other to the horizontal input of the oscilloscope. Switch controls so that the oscillo-scope accepts the output of the signal generator instead of the horizontal sweep. Set both the generators for 1000 cycles(say) and make gain adjustments until an ellipse of satisfactory size is observed on the screen. Adjust controls as necessary to stop the ellipse. By switching one of the generators off and on, cause the ellipse to change phase-, noting the var-ious shapes it assumes. By phase changes and amplitude adjustments, one may try to get a circular configuration.

(ii) Leaving the vertical input at 1000 cycles and assuming it to be the standard, adjust the horizontal input generator (the variable) approximately 500 c.p.s. to obtain the 1-2 Lissajous figure shown below.

(iii) Next obtain the 2:1 pattern by varying the horizontal input frequency.

(iv) In like manner, obtain Lissajous figures down to 1:5 and upto 5:1. Sketch all the figures obtained and compare the frequency. Obtained from the Lissajous ratios with the applied horizontal input signal generator.



Sample Lissajous Figures

(v) Changing the frequency of the signal generator, various Lissajous figures may be obtained (e.g. circle, different shape, etc.). Hence, from the known ratio of the respective Lissajous figures, the frequency of the AC source can be measured.

4.5 Observations

No. of observation	Input frequency	Shape of figure	No. of tangency points on X-	No. of tangency points on Y-	Ratio of tangency points	Unknown frequency

			axis	axis		

4.5 Calculations

4.6 Results

Students are advised to mention the result based on above obtained values.

4.7 Sources of errors and Precautions

1) Cautious handling of equipment is necessary as it functions at 220 AC voltage.

2) Selection of frequency in function generator should be done properly.

4.8 Sample questions

1) Describe the functioning of CRO.

2) What is the relation between Vpp and Vrms ?

3) What is CRT ?

4) What are pair of grids in CRO ?

Experiment No. 05

5.1 Objective

To determine the frequency of AC Mains with the help of Sonometer.

5.2 Apparatus

Sonometer with non-magnetic wire (Nichrome), Ammeter, step down trans-former (2-10 Volts), Key, Horse shoe magnet, Wooden stand for mounting the magnet , Set of 50 gm masses, Screw gauge and meter scale (fitted with the sonometer)

5.3 Description of the apparatus

As shown in the given figure below, an uniform Nichrome (non-magnetic) wire is stretched on a hollow wooden box (sonometer), one side of which is tied to the hook H, while the other passes over a frictionless pulley P, A hanger carrying masses is also attached to this end of the non-magnetic wire, A permanent strong horse shoe magnet NS is kept at the middle of the Nichrome wire in such a way that it produces a magnetic field perpendicular to the direction of current, to be flown in the Nichrome wire. Two moveable sharp edged bridges A and B are provided on the wooden box for stretching wire. A step down transformer (2-10V) is connected across the wire.

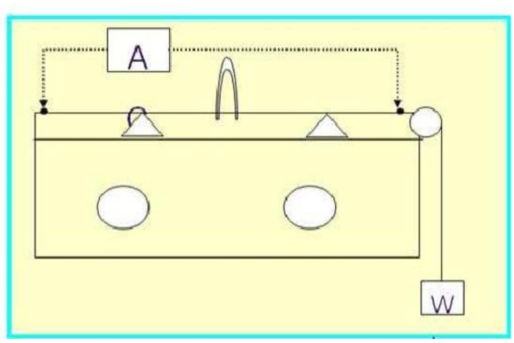


Figure 5.1: Circuit diagram for the experiment on determination of ac frequency using sonometer.

5.4 Theory

Let a sonometer wire stretched under a constant load be placed in an uniform magnetic field applied at the right angles to the sonometer wire in the horizontal plane and let an alternating current of low voltage (by means of the step down transformer) be passed through the wire. On account of interaction, between the magnetic field and the current in the wire (**F = il x B**), the wire will be deflected. The direction of deflection is being given by the Fleming's left hand rule. As the current is alternating, for half the cycle the wire will move upwards and for the next half the wire will move downwards. Therefore the sonometer wire will receive impulses alternately in opposite directions at the frequency of the alternating current passing through the wire. As a con-sequence the wire will execute forced vibrations with a frequency of the AC mains (under the conditions of resonance) in the sonometer wire.

The frequency of AC Mains, which is equal to the frequency of vibration of the sonometer wire in its fundamental mode (only one loop between the two bridges A and B, i.e., having two nodes and one antinode between the two bridges) is given by (under resonance conditions):

$$n = \frac{1}{2l}\sqrt{\frac{T}{m}} \qquad (5.1)$$

where T is the tension applied on the wire and given by T = M g, M being the total mass loaded on the wire (i.e., total mass kept on the hanger and the mass of the hanger) and g the acceleration due to gravity. Symbol l presents the length of the sonometer wire between the two bridges. The mass per unit length of the sonometer wire is represented by symbol m and can be calculated in terms of the radius r of the sonometer wire, and the density d of the material wire (Nichrome) as

$$m = \pi r^2 d \qquad (5.2)$$

Substitution of value of m, evaluated from the equation 5.2, in equation 5.1, gives the value of frequency of AC mains.

5.5 Procedure

a. Measure the diameter of the wire with screw gauze at several points along its length. At each point two mutually perpendicular diameters should be measured. Evaluate the radius of the sonometer wire.[See observation table (a)]

b. Connect the step down transformer to AC mains and connect the trans-former output (6 Volts connection) to the two ends of the sonometer wire through a rheostat, ammeter and a key, as shown in the figure.

c. Place the two movable sharp-edged bridges A and B at the two extremities of the wooden box.

d. Mount the horse shoe magnet vertically at the middle of the sonometer wire such that the wire passes freely in between the poles of the magnet and the face of the magnet is normal to the length of the wire. The direction of current flowing through the wire will now be normal to the magnetic field.

e. Apply a suitable tension to the wire, say by putting 100 gm masses on the hanger [tension in the wire = (mass of the hanger + mass kept on the hanger) xg]. Switch on the mains supply and close the key K and then adjust the two bridges A and B till the wire vibrates with the maximum amplitude (in the fundamental mode of resonance) between the two bridges. Measure the distance between the two bridges (l).[See observation table (b)]

f. Increasing the load M by steps of 250 gm, note down the corresponding values of l for maximum amplitude (in the fundamental mode of resonance). Take three or four such observations.

g. Knowing all the parameters, using the relations given in equations 1 and 2 calculate the frequency of AC mains for each set of observation separately and then take mean

h. Also plot a graph between the mass loaded, M along the X-axis and the square of the length l along Y-axis. This graph should be a straight line. Find the slope of this line and then using the equations 1 and 2,

5.6 Observation Table

Least count of screw gauge = ... cm

Zero error of the screw gauze = ... cm

Table 5.1: Measurement of radius of sonometer wire (r)

Sl. No.	Diameter of wire along one direction. cm	Diameter of wire along one direction. Cm	Mean observed diameter cm.	Mean corrected diameter cm.	mean radius r cm

Sl. No.	Total Mass Loaded = Mass of hanger + Mass on it (M gm.)	Tension in wire T = Mx g (gm-cm/s^2)	Position of first bridge a (cm)	Position of second bridge b (cm)	Length of wire between two bridges l=a-b (cm)	Frequency in (Hz)

Table 5.2: Measurement of T.l and frequency of AC mains

5.7 Calculation

Mass of the hanger M = 320 gm

Acceleration due to gravity(g) = 980 cm/sec^2.

Density of sonometer wire (nichrome) = 8.18848 gm/cc

Calculate the frequency of AC mains from this graph also.

$$Frequency = \sqrt{\frac{g}{(4 \times slope \times m)}}$$

5.8 Source of error and Precautions

a) The wire should be of a uniform area of cross-section, free from kinks and should be taut.

b) The observation should start with minimum distance between the two wedges.

c) The resonance position should obtained by first lowly increasing the distance between wedges and then slowly decreasing it.

d) The weight of hanger should always be included in the load.

e) The pulley should be free from friction.

5.9 Sample Questions

a) What is the principle involved in Sonometer experiment?

b) Which types of waves are produced in Sonometer experiment?

c) What are transverse waves?

d) Which type of transformer is used in sonometer experiment and what is it?

e) What is resonance?

f) Why horseshoe magnet is used in sonometer experiment?

g) Why the current in ammeter sets as low?

h) What is the use of rheostat?

i) What is the frequency of a.c mains in INDIA?

j) What is the frequency of DC?

Experiment No. 06

6.1 Objective

Determine the Planck's constant using Planck's constant setup.

6.2 Apparatus required

Planck's constant set up,LED

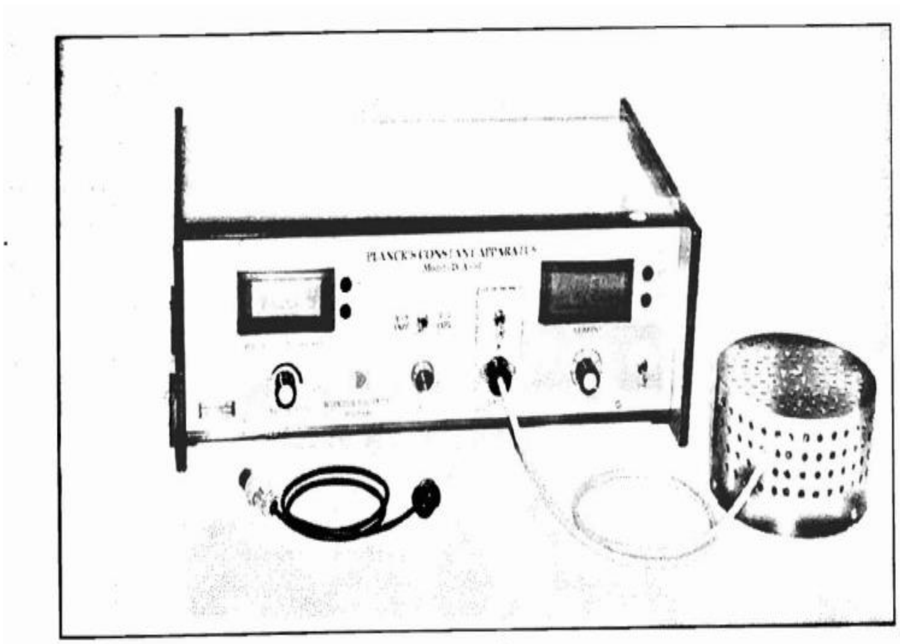


Figure 6.1: Planck's Constant setup

6.3 Description of the apparatus

a. MAINS ON/OFFF SWITCH: To switch On/Off the instrument
b. VOLTAGE ADJ KNOB: To adjust voltage
c. VOLTAGE/TEMPERATURE DPM: Read voltage in V-I mode and temperature of oven T-I mode.

d. LED SOCKET: To connect LED samples.
e. CURRENT DPM: Display current in μA in V-I mode and in mA in T-I mode.
f. V-I/T-1 SWITCH: A two way switch to switch the system between V-I mode and T-I mode.
g. TEMPERATURE CONTROLLER
h. ON/OFF: Switch for oven
i. OVEN: Socket on the panel is to connect the external oven
j. SET-TEMP; Knob to set the temperature
k. OVEN: It is a small oven with built –in RTD sensor.

6.4 Theory

Let us consider the LED diode I-V equation

$$\mathrm{I} \propto \exp\left(\frac{-\mathrm{V_0}}{\mathrm{V_t}}\right)\left[\exp\left(\frac{\mathrm{V}}{\mathrm{V_t}}\right) - 1\right] \text{ ,} \mathrm{V} = \mathrm{V_m} - \mathrm{RI} \qquad (1)$$

Where $V_t = \frac{\eta kT}{e}$, k,T and e are Boltzmann constant, absolute temperature and electronic charge respectively.Vm is the voltameter reading in the external diode circuit and R is the contact resistance. The constant is the material conatnt which depends on the type of diode, location of the recombination region etc. The energy barrier eVo is equal to the gap energy E_g where no external voltage v is applied as pointed out earlier. The quantities which are constant in an LED are the atom impurity density, the charge diffusion properties and the effective diode area. The 'one' in the rectifier equation is negligible if I ≥ 2nA, and the equation becomes

$$I \propto \exp\left[\frac{V - V_O}{V_t}\right]$$

$$\propto \exp\left[e\left(\frac{V-V_O}{\eta kT}\right)\right]$$

(2)

In our experimental set-up the variation of the current I with temperature is measured over about a range of about 30^{O}c at a fixed applied voltage (V ~ 1.8 Volts) kept slightly below Vo .The slope of ln I vs. 1/T curve given e $\frac{(V_o-V)}{\eta k}$ .The constant η may be determined separately from I-V characteristics of the diode at room temperature from the relation

$$\eta = \left(\frac{e}{kT}\right)\left(\frac{\Delta V}{\Delta \ln I}\right) \qquad (3)$$

The Planck's constant is then obtained by the relation

$$h = \frac{eV_O\lambda}{c} \qquad (4)$$

The value of Planck's constant obtained from this method is within 5% of accepted value (6.2x10-34Jolues.Sec)

6.5 Procedure

a. Connect the LED in the socket and switch ON the power.
b. Switch the 2-way switch to V-I position .In this position the 1st DPM would read voltage across LED and 2nd DPM would read current passing through the LED.
c. Increase the voltage gradually and tabulate the V-I reading. Please note there would be no current till about 1.5. Draw the graph: ln I(I in μA) Vs.V.
d. Keep the mode switch to V-I side and adjust the voltage across LED slightly below the band-gap of LED say 1.8V for Yellow/Red LED and 1.95 for Green LED.

e. Switch the “MODE” switch to T-I side
f. Insert the LED in the oven and connect the oven to the socket. Please make sure before connecting the oven switch is in OFF position and SET TEMP knob is at minimum position .Now The DPM would read ambient temperature.
g. Set the different temperature with the help of SET-TEP .
h. Allow about 5 minutes time on each setting for the temperature to stabilize and take the readings of temperature and current.
i. Draw the graph between ln I vs. (1/T).

6.6 Observation Table

Table6.1 Determination of Material Constant η

Sl.No	Junction Voltage V (Volt)	Forward Current I (μA)	lnI

Table 6.2 Determination of Temperature Co-efficient of Current

V = Constant for whole set of reading

Sl.No	Temperature (^oC)	Temperature (^oK)	Current (mA)	1/TX10^{-3} (K^{-1})	lnI(I in mA)

6.7 Calculation

a) Plot a graph between junction voltage and current lnI

b) Calculate the slope of the voltage = $\frac{\Delta V}{\Delta \ln I}$

c) $$\eta = \frac{e}{kT}\frac{\Delta V}{\Delta \ln I}$$

d) Plot a graph between Temperature and current lnI

e) $$\text{Slope} = \frac{\Delta \ln I}{\Delta T^{-1} X 10^{-3}}$$

$$V_0 = V - [\left(\frac{\Delta \ln I}{\Delta T^{-1} X 10^{-3}}\right) X \left(\frac{k}{e}\right) X(\eta)]$$

$$h = \frac{e \times V_0 \times \lambda}{c}$$

6.8 Source of error and Precautions

a. V-I characteristics of LED should be drawn at very low current, so that the disturbance to V_o is minimum

b. ln T-I mode, make sure that the oven switch is OFF and SET TEMP knob is at minimum position before connecting the oven.

c. On each setting of temperature, please allow sufficient time for the temperature to stabilize.

d. In case the LED is replaced please note that height of the portion inside the oven should not be more than 26mm, otherwise it may strike the RTD**.**

6.9 Sample Questions

a) What is Light Emitting Diode (LED)?

b) How it is different from Si/Ge diode?

c) How LED works?

d) Why do you put equal two different energies like eV and hv, what is the condition for that.

e) Which material we use in LED?

f) How photons emit from the LED and from which section of the LED?

g) How do you explain the working of LED by using the energy band diagram in forward biasing?

h) What happens when you provide the forward bias to the LED in terms of conduction band & valence band in the depletion region?

i) Why do not LED starts to glow immediately when you provide the forwarding bias to that?

j) Explain the concept of stopping potential in semiconductor diode V-I Characteristics?

k) Why does Blue color LED stopping potential is greater than the Red color LED?

l) Can we achieve the population inversion process in LED's too? if yes what is the condition for that? if no then why?

m)What symbol we use for the Light Emitting Diode?

n) What information we get from the Planck 's constant, and how one can say that radiation is in discrete form of energy?

Experiment No 7

7.1 Objective

To determine the wavelength of prominent spectral lines of mercury light by a plane transmission grating using normal incidence.

7.2 Apparatus required

A spectrometer, mercury lamp, transmission grating. reading lamp and reading lens.

7.3 Description of Apparatus

1. **Spectrometer**: This is an arrangement for producing pure spectrum. The essential parts of a spectrometer include collimator, prism table, and a telescope (See Figure 7.1).

2. **Collimator**: The collimator provides a narrow parallel beam of light. It consists of a horizontal, cylindrical, metallic tube fitted with an achromatic convergent lens at one end and a short coaxial tube at the other end. The short coaxial tube, which is provided with a vertical slit of adjustable width at the outer end, can be moved inside the main tube with the help of a rack and pinion arrangement. The slit is illuminated by the source of light, whose spectrum is to be examined and the distance between the slit and the convergent lens is so adjusted that the slit lies in the first focal plane of the lens. Under this condition, the rays of

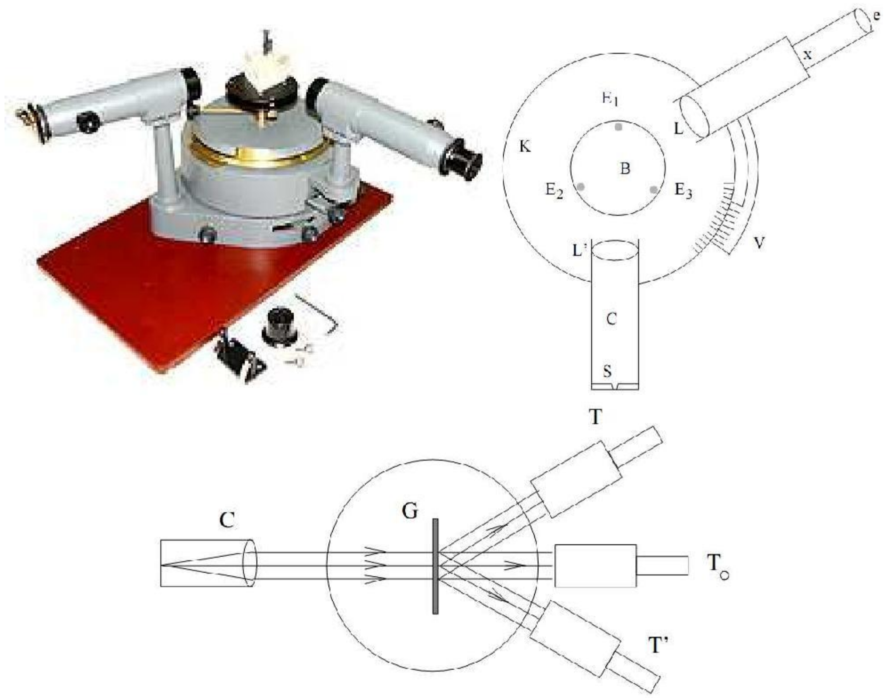


Figure 7.1: Photo of optical spectrometer mounted with a prism and ray diagram of the same.

light emerging from the collimator are parallel. Usually in a spectrom-eter, the collimator is rigidly fixed with its axis horizontal, but in same instruments, it can be rotated about the vertical axis passing through the center of instrument.

3. **Prism Table**: It is a circular table supported horizontally on a vertical rod at the center of the spectrometer. It can be rotated independently of the collimator and telescope about the vertical axis passing through instrument’s center. The rotation of the prism table can be read with the help of two diametrically opposite verniers attached to it and sliding over the circular scale. The prism table can be clamped to the main body of the instrument in any desired position with the help of a clamping screw and then a fine rotation can be given to it with the help of a tangent screw provided at the base. The prism table can be raised or lowered and may be clamped at any desired height with the help of a clamping screw provided for it. It is also provided with the three leveling screws so that the refracting faces of the prism can be adjusted parallel to the axis of the instrument. Concentric circles and straight lines parallel to the line joining any two of the leveling screws are drawn on the surface of the prism table, which help in placing the prism in proper position during the experiment.

4. **Telescope**: It is simple astronomical telescope and consists of a horizontal, cylindrical metallic tube fitted with an achromatic convergent lens (called the objective) at one end and a short coaxial tube called eyepiece tube at the end. The eyepiece tube (provided with the cross-wires and Ramsden eyepiece) can be moved inside the main tube with the help of rack and pinion arrangement. Pulling or pushing the eyepiece in eye-piece tube by hand can also change the distance between the cross-wires and the eyepiece. Thus the telescope can be adjusted to receive parallel rays and to form a clear image upon the cross-wires, which is distinctly visible through the eyepiece. The telescope can be rotated about the central axis of the instrument. It is also provided with a clamping and a tangent screw at the base by which a slow rotation can be given to it. The main circular scale is attached with the telescope so that when the telescope is rotated, the main circular scale also rotates with it. The angle, through which the telescope is rotated, can be measured by reading the position of the Verniers attached to the prism table and sliding over the main scale.

5. **Plane Transmission Grating:** An arrangement, which is equivalent in its action to a large number of parallel slits of same width separated by equal opaque spaces is called diffraction grating. It is constructed by ruling fine equidistant parallel lines on an optically plane glass plate with the help of a sharp diamond point. If the rulings are made on a metallic surface, the grating is called reflection grating.

   The number of ruled lines in a grating varies from 15000 to 30000 per inch and the ruled surface varies from 2" to 6". The gratings available in our BIT Physics laboratory are having 15000 ruled lines per inch and the ruled surface is of around 2".

The construction of a grating requires a great amount of labor and skilful operation. Further, the ruling process takes some time and during this period the temperature must be maintained constant within a fraction of a degree to avoid uneven spacing of lines. An original grating (called the master grating) is therefore very expensive and hence for useful laboratory work, replicas of the master grating are prepared. The commercial process to prepare a replica is to pour a solution of celluloid in amylacetate on the master grating and allow it to dry to a thin strong film. The film, which possess the impression of the grating is then detached from it and mounted in between two optically glass plates. Thus a replica, which we use in laboratories, is prepared.

Grating Element: **The distance** between the centers of any two consecutive ruled lines acting as a slit is called grating element. Let e be the width of the transparent space and d be the width of ruled space, then the grating element = (e + d)

7.4 Measurement of angles with the help of spectrometer

The spectrometer scales are angle measuring utilities for the positions of the telescope which can be rotated about the central axis of the instrument. The main circular scale is attached with the telescope so that when the telescope is rotated, the main circular scale also rotates with it. The angle, through which the telescope is rotated, can be measured by reading the positions of the verniers attached to the prism table and sliding over the main scale. In a spectrometer there are two sets of main circular scales (fitted with the telescope) and vernier scale (attached with the prism table). Both sets are diagonally (left hand and right hand sides) fixed in the instrument and measures angle for a particular telescope position with a difference of 180 degrees. These scales can be used in a similar manner as a simple Vernier Caliper or traveling microscope is used. The Vernier Caliper or traveling microscope is used to measure small distances (in centimeters and fractions whereas spectrometer scales are used to measure small angular displacements (in degrees, minutes, and seconds) {1 degree is equal to 60 minutes, and 1 minute is equal to 60 seconds; (1^{o} = 60' and 1' = 60")

7.4.1 Least Count of the Spectrometer Scale:

BIT Physics Laboratory has two types of spectrometers in which

1. 60 divisions of vernier Scale are equal to 59 divisions of the Main Scale, and
2. 30 divisions of vernier Scale are equal to 29 divisions of the Main scale.

Now, we will find out the least count in first case which 60 divisions of Vernier scale are equal to 59 divisions of the main scale. The method is as follows:

1. Value of one division of circular main scale = 0.5^{o} = 30' (as 1^{o}= 60')
2. Value of one division of sliding vernier scale = (59/60) x 0.5^{o}
3. Least count of spectrometer scale = Value of 1 div. of main scale - value of 1 div. of vernier

   = 0.5^{o}- $[(59/60) \times 0.5]^{o}$

   = $[0.5 \times 1/60]^{o}$ = 0.5' = 30" (THIRTY SECONDS)
4. Similarly the least count of the spectrometer scale in second case in which 30 divisions of Vernier scale are equal to 29 divisions of the circular main scale can also be calculated. In this case the value of least count will be

   1' or 60" .

7.4.2 Taking Readings on the two Spectrometer scales:

Following is an illustration for taking observation reading using the left hand side set of the circular main scale (attached with the telescope) and the corresponding vernier scale (sliding over the circular main scale and attached with the prism table). Assuming that we are using the spectrometer in which 60 divisions of vernier scale are equal to 59 divisions of the main scale.
The 0^{th} division of the vernier scale precedes the circular main scale division whose value is $234^{o}$and 30'. Therefore the main scale division reading is 234^{o}30'

Let 13^{th} division of vernier scale coincides completely with a main scale division. Therefore the vernier scale reading would be =13x Least count of vernier scale ,

=13x30" =390" =6' 30"

Total Spectrometer Scale Reading= Circular Main scale Reading + Vernier Read-ing = 234^{o}36' 30"

Reading of the right hand side scale can be similarly observed. The readings taken from left hand side and right hand side should ideally differ by 180^{o}

Formula Used: The wavelength λ of any spectral line using plane transmission grating can be calculated from the formula $(e+d)\sin\vartheta = n\lambda$, Where (e+d) is the grating element, ϑ is the angle of diffraction, and n is the order of the spectrum. If there are N lines per inch ruled on the grating surface then the grating element is given by (e+d) = 2.54/N cm. Hence $(2.54/N)\sin\vartheta = n\lambda$

Or $\lambda = 2.54\sin\vartheta / nN$ cm.

7.5 Procedure

The whole experiment is divided into two parts (a) Adjustments , and (b) Measurement of the diffraction angle ϑ:

7.5.1 Adjustment of the Spectrometer:

Before doing any measurement with the spectrometer, the following adjustments exactly in the sequence given below must be made:

- The axis of the collimator and the telescope must intersect at the perpendicular to the common axis of the prism table and the telescope (usually being made by the manufacturer).

- The eyepiece should be focused on the cross-wires. For doing it, turn the telescope towards a white wall and adjust the distance between the objective and eyepiece of the telescope with the help of rack and pinion arrangement such that the field of view appears bright. Now alter the distance between eyepiece and the cross-wires by pulling or pushing the eyepiece in the eyepiece tube, till the cross-wires are distinctly visible. This focuses the eyepiece on the cross-wires.

The best method to focus eyepiece without any strain is to see the cross-wires through the eyepiece with one eye and wall directly by the other eye so that there is no parallax between the two. This focusing of the eyepiece may be different for persons of different eyesight. If a second observer cannot see the cross-wires distinctly, he or she may have to move the eyepiece in or out in the eyepiece tube to suit his or her eyesight.

- The collimator and the telescope must be adjusted respectively for emitting and receiving parallel rays of light. This can be done in the following manner.

(a) Illuminate the slit of the collimator with the source of light, whose spectrum is to be analyzed (mercury vapor lamp in this experiment). Bring the telescope in line with the collimator with the help of rack and pinion arrangements such that the image of the collimator slit as seen through the telescope appears to be sharp and well focused. Make the collimator slit as narrow as possible (of course with a clear appearance through the telescope.

(b) Mount the prism on the prism table such that its center coincides with the center of the prism table and adjust the height of the prism table such that the prism is in level with the collimator and the telescope.

(c) Rotate the prism table in such a way that one of the polished surfaces of the prism faces towards the collimator. Turn the telescope towards the second polished surface and observe the spectrum.

(d) Now rotate the prism table in such a direction that the spectrum begins to move towards the collimator axis. Rotate the telescope also so as to keep the spectrum always in the field of view. Continue the rotation of the prism table in the same direction till spectrum becomes stationary for a moment. This corresponds to the position of minimum deviation of the prism. Any further rotation of the prism table in the same direction will cause the spectrum to move in the opposite direction.

(e) Keeping the prism table in minimum deviation position, adjust the collimator and telescope with the help of rack and pinion arrangements to get the spectrum well focused and sharp.

(f) Rotate the prism table slightly through 4^0 or 5^0 from the position of the minimum deviation such that the refracting edge of the prism moves towards the collimator. The spectrum will shift away from the collimator axis and in general becomes blurred. Now focus the collimator on the spectrum with the help of its rack and pinion arrangement to make the spectrum as sharp as possible.

If necessary, the telescope may be slightly turned to keep the spectrum in the field of view but its (telescope) focusing arrangement is not to be disturbed while focusing collimator. Now rotate the prism table slightly through 4^0 or 5^0 from the position of the minimum deviation such that the refracting edge of the prism moves towards the telescope. Focus the telescope on the spectrum with the help of its rack and pinion arrangement to make the spectrum as sharp as possible. This time do not disturb the precious arrangement of the collimator. Repeat this process of alternate focusing the collimator and telescope, till the rotation of the prism table in either direction from the position of minimum deviation, does not cause the spectrum to go out of focus. When this is the case, the collimator and the telescope both will be focused for parallel rays. This process of focusing the collimator and the telescope can be very easily remembered by the following **rule:**

(a) Rotate the prism table such that the refracting edge of the prism is brought

(b) Towards the collimator – Adjust the collimator.

(c) Towards the telescope – Adjust the telescope.

2. The prism table must be optically leveled. For it, proceed as follows:

   3) Mount the prism on the prism table with its refracting edge A at the center of prism table and of its polished surface *AB* perpendicular to the line joining the two leveling screws P and Q.

3. Rotate the prism table such that the refracting edge A faces towards the collimator and the light from the collimator falls simultaneously on both the polished prism surfaces *AB* and *AC*. **Clamp the prism table.**

4. Turn the telescope towards the faces *AB* of the prism till the image of the slit formed due to reflection from this face is received in the field of view of the telescope. Adjust the two leveling screws P and Q to bring the image in the center of the field of view, i.e., the image should be *bisected* at the point of intersection of cross-wires.

5. Next, turn the telescope towards the face *AC* of the prism till the reflected image of slit from this face is received in the field of view of telescope. Adjust the screw R alone to bring the image in the center of field of view.

6. Repeat the procedure of alternate adjustments till the two images formed by the reflections from the faces *AB* and *AC* of the prism are seen exactly in the center of field of view of the telescope. The prism table is then said to be optically leveled.

7.5.2 Adjustment of the grating for normal incidence:

For this proceed as follows:

- Bring the telescope in line with the collimator such that the direct image of the slit falls on the vertical cross wire of the telescope. Note the readings on both spectrometer scales.

- Rotate the telescope through 90^0 from this position and then clamp it. The axis of the telescope will now be perpendicular to the axis of collimator.

- Mount the grating on the prism table such that its ruled surface passes through the center of the prism table and is also perpendicular to the line joining the two leveling screws P and Q. The prism table is now rotated till the reflected image of the slit from the grating surface falls on the vertical cross wire. Adjust the screws P and Q if necessary to get the image in the center of the field of view. The grating surface is now inclined at an angle of 45^0 with the incident rays. Note the readings of both the spectrometer scales.

- Rotate the prism table through 45^0 or 135^0 as the case may be so that the ruled surface of the grating becomes normal to the incident rays and faces the telescope. *Now clamp the prism table*.

- The ruling of the grating should be parallel to the main axis of the instrument:

  For this unclamp the telescope and rotate. The diffracted images of the slit or the spectral lines will be observed in the field of view of the telescope. Adjust the leveling screw R, if necessary, to get these images at the center of the cross wires. When this is done the rulings of the grating will be parallel to the main axis of the instrument.

- The slit should be adjusted parallel to the rulings of the gratings.

  For this rotate the slit in its own plane till the diffracted images of the spectral lines become as bright as possible. The observations may now be taken.

7.5.3 Measurement of the Angle of Diffraction:

To measure the angle of diffraction, proceed as follows:

- Rotate the telescope to one side (say left) of the direct image of the slit till the spectrum of the first order (n=1) is visible in the field of view of telescope. Clamp the telescope and then move it slowly by tangent screw till the vertical cross wire coincides with the red line of the spectrum. Note the readings of both the verniers. Thus go on moving the telescope so that the vertical cross wire coincides in turn with the different spectral lines namely, yellow, green, violet, etc. Each time note the readings of both the spectrometer scales (left and right verniers).

- Unclamp the telescope and rotate it to the other side (say right) of the direct image till the first order spectrum is again visible in the field of view. Clamp the telescope and use the tangent screw to coincide the vertical cross wire on various spectral lines in turn and each time note the readings of the verniers.

- Find the difference in the readings for the same spectral line in two settings. This gives an angle equal to twice the angle of diffraction for that spectral line in the first order (n=1). Half of it is will give the angle of diffraction. Similarly calculate the angle of diffraction for other spectral lines.

- Repeat the above observations for second order spectrum also.

- The number of lines per inch on the grating surface is usually written on the grating. *Note it*.

7.6 Observations

7.6.1 For the adjustment of grating for normal incidence:

1. Least count of the Spectrometer scale:

Value of 1 division of main scale = ...

Division of main scale are equal to . . . . . . divisions of vernier scale.

Value of 1 division of vernier scale=………………

Least count of Spectrometer scale:

= value of 1 division of main scale – 1 division of vernier scale.

2. Reading of the telescope for direct image of the slit:
   V_1 = ... V_2 = ...

3. Reading of the telescope after rotating it through 90^0:
   V_1 = ... V_2 = ...

4. Reading of prism table when reflected image of the slit coincides with the vertical cross wire:
   V_1 =. . . . . V_2 = ...

5. Reading of prism table when rotated through 45^0 or 135^0:
   V_1 =. . . . . V_2 = ...

1. Number of lines N ruled per inch on the grating
2. Grating element (e+d) = 2.54/N

7.6.2 Calculations:

For first order, n=1, $\lambda = (e+d)\sin\theta/2$ cm.

Calculate the value of λ for visible spectral lines also.

7.7 Results

7.7.1 Source of Error and Precautions

- The axes of the telescope and the collimator must intersect at and be perpendicular to the main axis of the spectrometer.
- The collimator must be adjusted so as to give out parallel rays.
- The telescope must be adjusted so as to receive parallel rays and form a well defined image of the slit on the crosswire.
- The prism table must be optically leveled.
- The grating should be so mounted on the prism table that its ruled lines are parallel to the main axis of the spectrometer.

Order	Color of the Spectral line	Spectrum to the left of the direct images			Spectrum to the right of the direct images			2Θ=x-y	Angle (Θ)
		MSR	VSR	Total (X)	MSR	VSR	Total (Y)		
1 st Order	Violet Window 1 Window 2								
	Blue Window 1 Window 2								
	Green Window 1 Window 2								
	Yellow Window 1 Window 2								
	Red Window 1 Window 2								
2 nd Order	Violet Window 1 Window 2								
	Blue Window 1 Window 2								
	Green Window 1 Window 2								
	Yellow Window 1 Window 2								
	Red Window 1 Window 2								

Table 7.1: Table for the measurement of the angle of diffraction

Table 7.2: Observations for grating element (e+d)

Colour of the Spectral Line Spec-	Wavelength as obtained by experiment	Standard value of wavelength	Percentage error %
Violet		4047 Angstrom	
Blue		4358 Angstrom	
Green		5461 Angstrom	
Yellow		5770 Angstrom	
Red		6234 Angstrom	

- The plane of the grating should be normal to the incident light and its ruled surface must face the telescope so that the error due to nonparallelism of the incident rays is minimum.
- The slit should be as narrow as possible and parallel to the ruled surface of the grating.
- While handling the grating one should not touch its faces but hold it between the thumb and the fingers by edges only.
- While taking observations of the spectral lines, the prism table must remain clamped.
- The reading of both the verniers should be recorded. This eliminates the error due to non-coincidence of the center of the graduated scale with the main axis of the spectrometer.

3.8 Sample Questions

- What do you understand by diffraction of light?
- How does it differ from interference of light?
- What is a diffraction grating?
- How is it constructed?
- How do you measure the wavelength of light using grating?
- What is grating element?
- What are the necessary adjustments?
- How do you adjust telescope and collimator for parallel rays?
- How do you set the grating for normal incidence?
-

- Why should the ruled surface of grating face forwards the telescope?

- How many orders of spectra are you getting with the grating?
- Why do you not get more orders?
- What is the difference between a prism spectrum and a grating spectrum?
- What are the various series of lines observed in hydrogen spectrum?
- What is Rydberg constant?
- A transmission grating with 2000 lines/cm is illuminated by a beam of 694.3-nm light from a laser. Spots of light, on both sides of the undeflected beam, appear on a screen 2.0 m away.
    1. How far from the central axis is either of the two nearest spots?
    2. Find how much difference it makes whether you use the approximation $\sin \vartheta \approx \vartheta$.
- When white light passes through a diffraction grating, what is the smallest value of m for which the visible spectrum of order m overlaps the next one, of order m+1? (The visible spectrum runs from about 400 nm to about 700 nm.)

EXPERIMENT No. 8

8.1 Objective

To determine the wavelength of sodium light by Newton's rings method.

8.2 Apparatus required

An optical arrangement for Newton's rings with a plano-convex lens of large radius of curvature (nearly 100 cm) and an optically plane glass plate, A short focus convex lens, sodium light source. Traveling microscope, magnifying lens, reading lamp and a spherometer.

8.3 Description of apparatus

The experimental apparatus for obtaining the Newton's rings is shown in the Figure 1. A plano- convex lens L of large radius of curvature is placed with its convex surface in contact with a plane glass plate P. At a suitable height over this combination, is mounted a plane glass plate G inclined at an angle of 45 degrees with the vertical. This arrangement is contained in a wooden box.

Light from a broad monochromatic sodium source rendered parallel with the help of convex lens L_1 is allowed to fall over the plate G, which partially reflects the light in the downward direction. The reflected light falls normally on the air film enclosed between the plano-convex lens L, and the glass plate P. The light reflected from the upper and the lower surfaces of the air film produce interference fringes. At the center the lens is in contact with the glass plate and the thickness of the air film is zero. The center will be dark as a phase change of π radians is introduced due to reflection at the lower surface of the air film. (as the refractive index of glass plate P (μ=1.5) is higher than that of the air film (μ = 1). So this is a case of reflection by the denser medium. As we proceed outwards from the center the thickness of the air film gradually increases being the same all along the circle with center at the point of contact. Hence the fringes produced are concentric, and are localized in the air film (Figure 2) The fringes may be viewed by means of a low power microscope (traveling microscope) M as shown in the figure.1.

8.4 Working Principle

When a plano-convex lens of large radius of curvature is placed with its con-vex surface in contact with a plane glass plate P a thin wedge shaped film of air is enclosed between the two. The thickness of the film at the point of contact is zero and gradually increases as we proceed away from the point of contact towards the periphery of the lens. The air film thus possesses a radial symmetry about the point of contact. The curves of equal thickness of the film will, therefore, be concentric circles with point of contact as the center.

As Newton's rings are observed in reflected light, the effective path difference x between the two interfering rays is given by

$$x = 2\mu t \cos(t+\theta) + \lambda/2 \tag{8.1}$$

Where t is the thickness of the air film at B and ϑ is the angle of film at that point. Since the radius of curvature of the plano-convex lens is very large, the angle ϑ is extremely small and can be neglected. The term $\lambda/2$ corresponds to a phase change of π radians introduced due to reflection at the denser medium (glass). For air the refractive index (μ) is unity and for normal incidence, angle of refraction is zero. So the path difference x becomes:

$$x = 2t + \lambda/2 \quad (8.2)$$

At the point of contact the thickness of the film is zero, i.e., t = 0, So x = λ/2. And this is the condition for the minimum intensity. Hence the center of the Newton's rings is dark. Further, the two interfering rays interfere constructively when the path difference between the two is given by

$$x = 2t + \lambda/2 = 2n\lambda/2 \quad (8.3)$$

Or

$$2t = (2n - 1)\lambda/2 \text{[Maxima]} \quad (8.4)$$

and they interfere destructively when the path difference is

$$x = 2t + \lambda/2 = (2n + 1)\lambda/2 \quad \text{or} \quad 2t = 2n\lambda/2 \text{ [Minima]} \quad (8.5)$$

From these equations it is clear that a maxima or minima of particular order n will occur for a given value of t. Since the thickness of the air film is constant for all points lying on a circle concentric with the point of contact, the interference fringes are concentric circles. These are also known as fringes of equal thickness.

8.5 Experimental Methods

8.5.1 Calculation of the diameters rings:

Let r_n be the radius of Newton's ring corresponding to a point, where the thickness of the film is t, Let R be the radius of curvature of the surface of the lens in contact with the glass plate p, then we have:

$$R^2 = r_n^2 + (R - t)^2$$

or

$$r_n^2 = 2Rt - t^2 \quad (8.6)$$

Since t is small as compared to R, we can neglect t^2 .and therefore

$$r_n^2 = 2Rt$$

or

$$2t = r_n^2/R \quad (8.7)$$

If the point lies over the n^{th} dark ring then substituting the value of 2t from equation (8.5) we have,

$$r_n^2/_R = n\,\lambda,$$

$$r_n^2 = n\lambda R$$

(8.8)

If Dn is the diameter of the nth ring then,

$$D_n^2 = 4n\lambda R$$

(8.9)

Similarly, if the point lies over a nth order bright ring we have

$$D_n^2 = 2(2n-1)\lambda R$$

(8.10)

8.5.2 Calculation of λ:

From equation (8.10), if D_{n+p} is the diameter of $(n+p)^{th}$ bright ring, we have

$$D_{n+p}^2 = 2[2(n+p)-1]\lambda R$$

(8.11)

Subtracting equation (8.10) from equation (8.11), we get:

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

(8.12)

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

By measuring the diameters of the various bright rings and the radius of curvature of the plano convex lens, we can calculate λ from the equation 8.12.

8.5.3 Formula used

The wavelength λ of the sodium light employed for Newton's rings experi-ment is given by Eq (8.12) where D_{n+p} and D_n are the diameter of $(n+p)^{th}$ and n^{th} bright rings respectively, p being an integer number. R is the radius of curvature of the convex surface of the plano-convex lens.

8.6 Methodology

3.4 Level the traveling microscope table and set the microscope tube in a vertical position. Find the vernier constant (least count) of the horizontal scale of the traveling microscope.

3.5 Clean the surface of the glass plate p, the lens L and the glass plate G. Place them in position and as discussed in the description of apparatus. Place the arrangement in

front of a sodium lamp so that the height of the center of the glass plate G is the same as that of the center of the sodium lamp. Place the sodium lamp in a wooden box having a hole such that the light coming out from the hole in the wooden box may fall on the Newton's rings apparatus and adjust the lens in between of the hole in wooden box and Newton's rings apparatus and adjust the lens position such that a parallel beam of monochromatic sodium lamp light is made to fall on the glass plate G at an angle of 45 degrees.

3.6 Adjust the position of the traveling microscope so that it lies vertically above the center of lens. Focus the microscope, so that alternate dark and bright rings are clearly visible.

3.7 Adjust the position of the traveling microscope till the point of inter-section of the cross wires (attached in the microscope eyepiece) coincides with the center of the ring system and one of the cross-wires is perpendicular to the horizontal scale of microscope.

3.8 Slide the microscope to the left till the cross-wire lies tangentially at the center of the 20^{th} dark ring. Note the reading on the vernier scale of the microscope. Slide the microscope backward with the help of the slow motion screw and note the readings when the cross-wire lies tangentially at the center of the 18^{th} , 16^{th}, 14^{th}, 12^{th}, 10^{th}, 8^{th}, 6^{th}, and 4^{th} dark rings respectively [Observations of first few rings from the center are generally not taken because it is difficult to adjust the cross-wire in the middle of these rings owing to their large width.]

3.9 Keep on sliding the microscope to the right and note the reading when the cross-wire again lies tangentially at the center of the 4^{th}, 6^{th}, 8^{th}, 10^{th}, 12^{th}, 14^{th}, 16^{th}, 18^{th} , and 20^{th} dark rings respectively.

3.10 Remove the plano-convex lens L and find the radius of curvature of the surface of the lens in contact with the glass plate P accurately using a spherometer. The formula to be used is:

$$R = \frac{l^2}{6h} + \frac{h}{2} \qquad (8.14)$$

Where l is the mean distance between the two legs of the spherometer h is the maximum height of the convex surface of the lens from the plane surface.

3.11 Find the diameter of the each ring from the difference of the observations taken on the left and right side of its center. Plot a graph between the number of the ring on X-axis and the square of the corresponding ring diameter on Y-axis. It should be a straight line. Take any two points on this line and find the corresponding values of (D^2_{n+p}- D^2_n) and p for them.

3.12 Finally calculate the value of wavelength of the sodium light source using the formula (8.12).

8.7 Observations

8.7.1 Determination of the Least Count:

Determination of the Least Count of the Horizontal Scale of traveling Microscope

1. Value of one division of the horizontal main scale of traveling microscope = ... cm.
2. Total number of divisions on the Vernier scale = ...which are equal to . . . .
   divisions of main scale of the horizontal scale of the traveling microscope.
3. Value of one division of the Vernier scale = ... cm.
4. Least count of the horizontal scale of the microscope (given by the value of one division of main scale – the value of one division of Vernier scale)=. . . . . . cm.

4. Pitch of the screw = ... cm
5. Number of divisions on circular head = =. . . . .
6. Least count of the spherometer = =. . . . . .cm
7. Mean distance between the two legs of the spherometer, l=. . . . . cm
8. The radius of curvature R of the plano convex lens is (as given by equation 8.14):
   $R = [l^2/6h+h/2]$= . . . . cm
9. The wavelength λ of sodium light is (as given by equation 8.12):
   $\lambda = (D^2_{n+p} - D^2_n)/4pR$. = ... cm. = ... Angstrom units.

8.7.1.1 Calculations from the graph:

1. Plot a graph taking squares of the diameters, D^2_n along the Y-axis and the number of rings along the X-axis.
2. The curve should be a straight line.
3. Take two points P_1 and P_2 on this line and find the corresponding values of $D^2_{n+p} - D^2_n$ and p from it, calculate the value of wavelength of the sodium light from these values.

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Table 8.1: Determination of $D_{n+p}^2 - D_n^2$ and p

Order Of The Rings	Reading of the microscope left hand side (a) cm	Right hand side (b) cm	Diameter of the ring (a- b) cm.	Diameter^2 $(a \sim b)^2$ cm^2	$D_{n+p}^2 - D_n^2$ for p=4 cm^2	Mean value of $D_{n+p}^2 - D_n^2$ for p=4 cm^2
20					$D_{20}^2 - D_{16}^2$=..	
18					$D_{18}^2 - D_{14}^2$=..	
16					$D_{16}^2 - D_{12}^2$=..	
14					$D_{14}^2 - D_{10}^2$=..	
12					$D_{12}^2 - D_8^2$=..	
10					$D_{10}^2 - D_6^2$=..	
8					$D_8^2 - D_4^2$=..	

Table 8.2: Determination of R (radius of curvature of the lens L) using a spherometer

Sl No	Spherometer reading on		H (a~ b) cm	Mean h Cm
	Plane glass plate a cm	Convex surface of lens b cm		

8.8 Results

The value of the wavelength of the sodium light source as calculated

- Using the observations directly = ... Å
- Using the graphical calculations = ... Å
- Mean value of the wavelength of Sodium light = ... Å
- Standard average value of the wavelength of the sodium light = 5893 Å
- Percentage error = ... %

8.9 Sources of errors and precautions:

6. The optical arrangement as shown in Figure 1 should be very clean (use spirit for cleaning these optical elements) and so made that the beam of light falls normally on the plano-convex lens L and glass plate P combi-nation.
7. The plano-convex lens used for the production of Newton's rings should have large value of radius of curvature. This will keep the angle of wedge shape air film very small and therefore the rings will have a larger diam-eter and consequently the accuracy in the measurement of the diameter of the rings will be increased.
8. To avoid any backlash error, the micrometer screw of the traveling micro-scope should be moved very slowly and be moved in one direction while taking observations.
9. While measuring diameters, the microscope cross-wire should be ad-justed in the middle of the ring.
10. The amount of light from the sodium light source should be adjusted for maximum visibility. Too much light increases the general illumination and decreases the contrast between bright and dark rings.

8.10 Sample oral questions:

- What do you understand by the interference of light?
- What are essential conditions for obtaining interference of light?
- What do you understand by coherent sources?
- Is it possible to observe interference pattern by having two independent sources such as two candles?
- Why should be two sources be monochromatic?
- Why are the Newton's rings circular?
- Why is central ring dark?
- Where are these rings formed?
- Sometimes these rings are elliptical or distorted, why?
- What is the difference between the rings observed by reflected light and those observed by transmitted light?
- What will happen if the glass plate is silvered on the front surface?
- What will happen when a little water is introduced in between the plano-convex lens and the plate?
- How does the diameter of rings change on the introduction of liquid?
- Can you find out the refractive index of a liquid by this experiment?
- Is it possible to have interference with a lens of small focal length?
- What will happen if the lens is cylindrical?
- Why do the rings gets closer and finer as we move away from the center.

Experiment no. 9

9.1 Objective

To Study the Hall Effect and to determine the Hall coefficient, charge carrier concentration and mobility of charge carriers in the given sample.

9.2 Apparatus Required

Electromagnet (EMU – 75) and its Constant Current Power Supply (DPS – 175), Digital Gauss meter (DGM – 102), hall Effect Set-up (DGH – 21) having a milli Voltmeter and a constant current Power Supply (mA) and an n-(or p-) type lightly doped Hall probe Germanium crystal.

9.3 Formula used to Basic Theory

We all are aware of the fact that a static magnetic field directly perpendicular to the direction of flow produce a mutually perpendicular to the direction of flow, produce a mutually perpendicular force on the charges. When this happens, electrons and holes will be separated by opposite force (see Figure1). They will bn turn produce an electric field (E_H) which depends on the cross product of the applied magnetic field H_Z and the current density J as :

$$E_H = R_H (J \times H_Z) \tag{9.1}$$

Here R_H is known as hall coefficient. Now, let us consider a bar of semiconductor (say Germanium) having dimension l, b, and d is placed in a uniform magnetic field (Figures 2a, 2b and 3). Let the current density J is directed along X axis and H_Z along the Z axis, then the electric field E_H (= V_H/b; V_H being the hall voltage appearing between the two surfaces perpendicular to side be of the side conductor bar, known as Hall probe) will be along Y axis. This is the Hall Effect. And the Hall Coefficient R_H can be written as:

$$R_H = E_H / JH_Z \qquad (9.2)$$

$$= \{(V_H/b)/(I_X H_Z/bd)\} \text{ [As the current } I_X\text{=Jbd,see figure3]}$$

$$= V_H d/I_X H_Z$$

where V_H in Volt, I_X in Amperes, H_z in Gausses, and the dimension b in cm, the hall coefficient of the semiconductor material can be written as:

$$R_H = [V_H d/I_X H_z].10^7 \qquad (9.3)$$

Volt-cm per Ampere per Gauss.

Knowing the value of Hall coefficient of the material the number of carriers per unit volume N can also be calculated as:

$$N = 1/R_H e \text{ per milli liter.} \qquad (9.4)$$

Here is the electronic charge (=1.6x 10^{-19} Coulomb). Further the mobility of the charge carries.

$$5. = R_{H.}\sigma \qquad (9.5)$$

where σ is the conductivity of the sample in mho per cm (= 0.1 mho per cm in the case of Ge crystal).

9.4 Procedure

The hall experiment procedure can be divided in two parts, viz.,

9.4.1 Measurement of Magnetic field and

9.4.2 Measurement of Hall Voltage with the Hall Probe.

9.4.1 Measurement of Magnetic field:

1. Connect the electromagnet leads to the constant current power supply DPS – 175.

2. Before setting up the electromagnet ready to use, one should first calibrate the digital Gauss meter (DGM – 102) the method is as follows.

Take out the probe along with the cable through the cutting provided on the rear side of the digital Gaussmeter. [The probe (red in colour) is encapsulated in a non – magnetic white colour sheath. It is connected to the instrument digital Gaussmeter by means of four – core cables of suitable length and normally kept inside the instrument. A transport cap is provided for the protection of probe. It is adviced that the probe should not be used at temperature higher than 50ºC. The probe is very delicate and hence the probe should be inserted in its protection cap whenever the probe is not in use and kept inside the instrument]

Zero adjustment: Switch on the digital Gaussmeter. Its reading is adjusted to zero using the ‘ZERO’ control key keeping the probe away from any magnetic field. This adjustment should be checked while keeping the digital panel meter on X 1 range.

Switch on the electromagnet power supply DPS – 175. Give some current value to the electromagnet coil using the current knob.

NOTE: The current knob should be kept at the minimum value before Switching on the power supply DPS – 175.

Select the appropriate range of Gaussmeter. Retract the probe cap and insert the probe in the magnetic field generated between the two poles of the electromagnet. The flat face of the probe is kept perpendicular to the direction of magnetic field. The reading of the digital panel meter multiplied by the range value given the flux density of the magnetic field in Gauss.

NOTE: If the field strength is not known, start with the X10 range.

The direction of magnetic field can also be seen. If the magnetic field indicated by the digital Gaussmeter panel meter is positive (without any sign), the pole facing the side of the probe marked ‘N’ is North pole.

- Now the electromagnet and digital Gaussmeter are ready to use. Allow a fixed current to pass through the electromagnet coil.

- Put the digital Gaussmeter probe in between of the electromagnet poles and read the magnetic field Hz Gauss using the digital Gaussmeter.

- After taking the reading of magnetic field, Switch OFF the digital Gaussmeter and insert the probe in its cap.

9.4.2 Measurement of Hall Voltage with the Hall Probe:

1. Check the Hall Probe, i.e. the lightly doped germanium crystal (See Figure 2b). The germanium crystal is mounted on a sinmica-decorated Bakelite strip. The crystal is connected with four leads. The two green leads are attached lengthwise and are meant for supplying current. Whereas the remaining two red leads are attached widthwise and are for measuring the voltage developed as explained earlier in the basic theory of the experiment, Hall Effect.

2. Connect the widthwise ***red*** contacts of the Ge crystal in Hall Probe to the terminals marked 'Voltage' and the lengthwise ***green*** contacts to the terminals marked 'Current' on the Hall Effect Setup (DHE-21).

3. Switch 'ON' the Hall Setup and adjust current (say a few mA) while keeping the display switch on current side.

4. Switch over the display to Voltage side. There may be some voltage reading even outside the magnetic field. This is due to imperfect alignment of the four contacts of the Hall probe and is generally known as 'Zero Field Potential'. [In case its value is comparable to the Hall Voltage the semiconductor crystal should be adjusted to a minimum possible. ***Please don't perform such operations on your own. Ask your instructor or lab staff to do it.***] In all

cases, this error should be subtracted from the Hall Voltage readings. This ‘Zero Field Potential’ value may be different at different currents supplied to the Ge crystal.

5. Now place the probe in the magnetic field as shown in Fig 2a, and switch on the electromagnet power supply and adjust the current to any desired value. Rotate the Hall probe till the semiconductor crystal become perpendicular to magnetic field. Hall voltage will have a maximum value in this adjustment. Never exceed the current value more than 8 mA.

6. Measure Hall voltage (V_H) for thus set direction and value of current I_X, by switching over the range to ‘Voltage’ side in the Hall Effect Setup. While measuring the Hall Voltage don’t forget to deduct the ‘Zero Field Potential’ value at the particular current value (as described above under point no. 4). Also take the reading of Hall Voltage for this particular value of current but having the opposite direction. (i.e. **two observations for a particular value of current and magnetic field**).

7. Measure the Hall Voltage (V_H) as a function of current I_X (in both the directions), keeping the magnetic field H_Z constant. Plot the I_X versus V_H graph for this particular value of magnetic field H_Z.

8. Repeat the experiment at least for three different values of magnetic fields. The magnetic field value between the two electromagnet poles can be changed by changing the electromagnet current value through the constant current power supply DPS-175.

9. Plot the three graphs separately and find the slope (V_H/I_X) values for the three different values of the magnetic field.

9.5 Observations

a. The thickness of the given Germanium crystal (n-type or p-type), **d=0.5mm**

b. The conductivity of the given crystal, σ **= 0.1mho per cm**

c. Observation of I_X and V_H for different values of H_Z.

(All voltage reading should take care of 'Zero Field Potential' values at corresponding current values).

In our set up, magnetic field is 2000 G, 4000G and 6000 G for 0.5 A, 1.0 A and 1.5 A current.

9.6 Observation Table

Table 1

S. No.	Current I_X mA	**Hall Voltage V_H mV**								
		H_Z = Gauss			H_Z = Gauss			H_Z = Gauss		
		For +ve current	For -ve current	Mean V_H	For +ve current	For -ve current	Mean V_H	For +ve current	For -ve current	Mean V_H
1.										
2.										
3.										
4.										
5.										

9.7 Calculations

1. For $\mathbf{H_Z}$ **=** **Gauss**

   From the V_H versus I_X graph slope V_H/I_X =

   Find Hall Coefficient R_H = $(V_H/I_X).(d/H_Z)\ 10^7$

No. of charge carriers per unit volume, n = $1/R_He$

= -------- per milli liter

The mobility of charge carriers, μ = $R_H.\sigma$

= ------------ units.

Repeat the calculations for other two values of magnetic field and tabulate them in Result table.

9.8 Results

Table 2

	For H_Z = Gauss	**For H_Z = Gauss**	**For H_Z = Gauss**
R_H =			
N =			
μ =			

Correct value of Hall Coefficient for the given sample:

For p-type crystal =

For n-type crystal =

The correct values of charge carrier concentration and mobility should also be evaluated and shown.

9.9 Precautions and Sources of Errors

1. Electromagnet power supply should be connected to a 3-pin AC main's socket having good earth connection.
2. Always increase of decrease the electromagnet current gradually through the power supply DPS-175.
3. Switch 'ON' or 'OFF' the power supply at zero current position.

4. The gauss meter probe is very delicate and should be used at temperatures well below 50^0C.
5. Try to minimize the 'Zero Field Potential'. It should be remembered that 'Zero Field Potential' is function of current flowing through the crystal. Therefore it should be checked before any measurement of Hall voltage.
6. The crystal contacts in Hall probe should neither the loose of nor be too tight. The crystal is thin (0.50 mm) and very brittle.
7. Hall voltage should be measured with a high impedance device (~1MΩ). why?
8. The current through the crystal should not be large enough to cause heating. The current value should not be increased more than 10mA.
9. Although the dimensions of the crystal do not appear in the formula except the thickness, but the theory assumes that all charge carriers moving only lengthwise. Practically it has been found that a closer to ideal situation may be obtained if the length is taken three times the width of the sample crystal.

9.10 Sample Questions

- What is Hall effect?
- What are n-type and p-type semiconductors?
- What is the effect of temperature on Hall Coefficient of a lightly doped semiconductor?
- Do the holes actually move?
- Why the resistance of the sample increases with the increase of magnetic field?
- Why a high input impedance device is needed to measure the Hall Voltage?
- Why the Hall voltage should be measured for both the directions of the current in the sample crystal?
- Is it recommended to measure the Hall voltage for both the directions of the magnetic fields too?

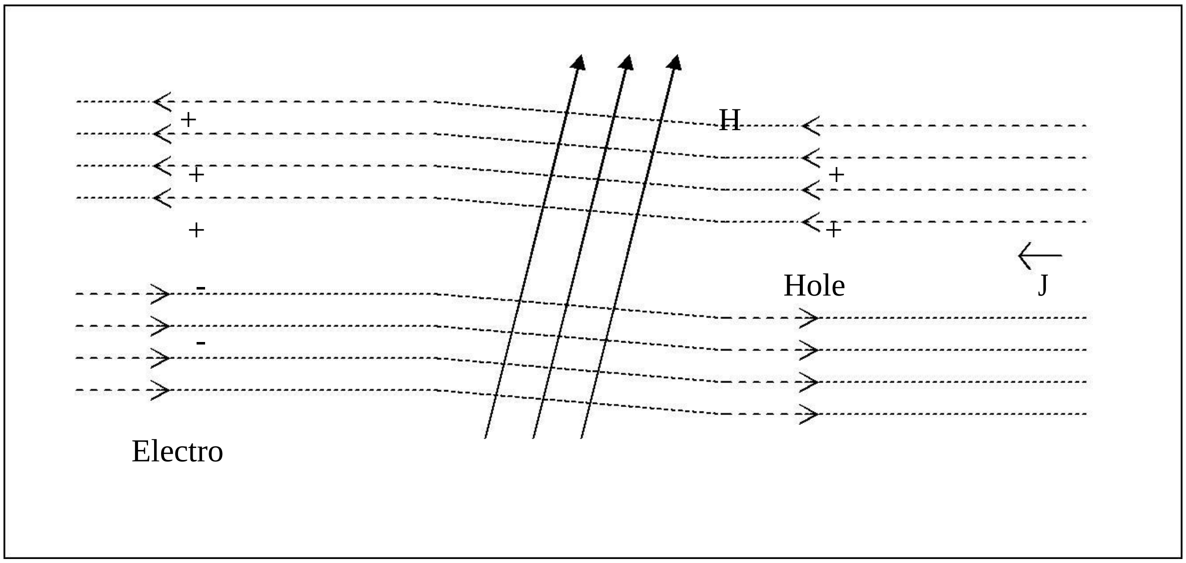
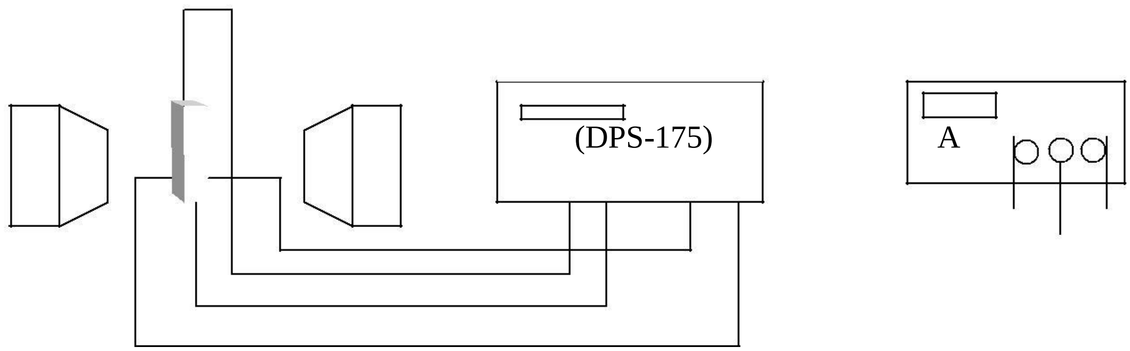


Figure 1: Carrier Separation due to

Constant Current power supply for electromagnet

Hall Effect Set Up (DHE-21)



A

N

S

Green wires for current measurement

Red wires for Voltage measurement

Figure 2a: Experimental set-up

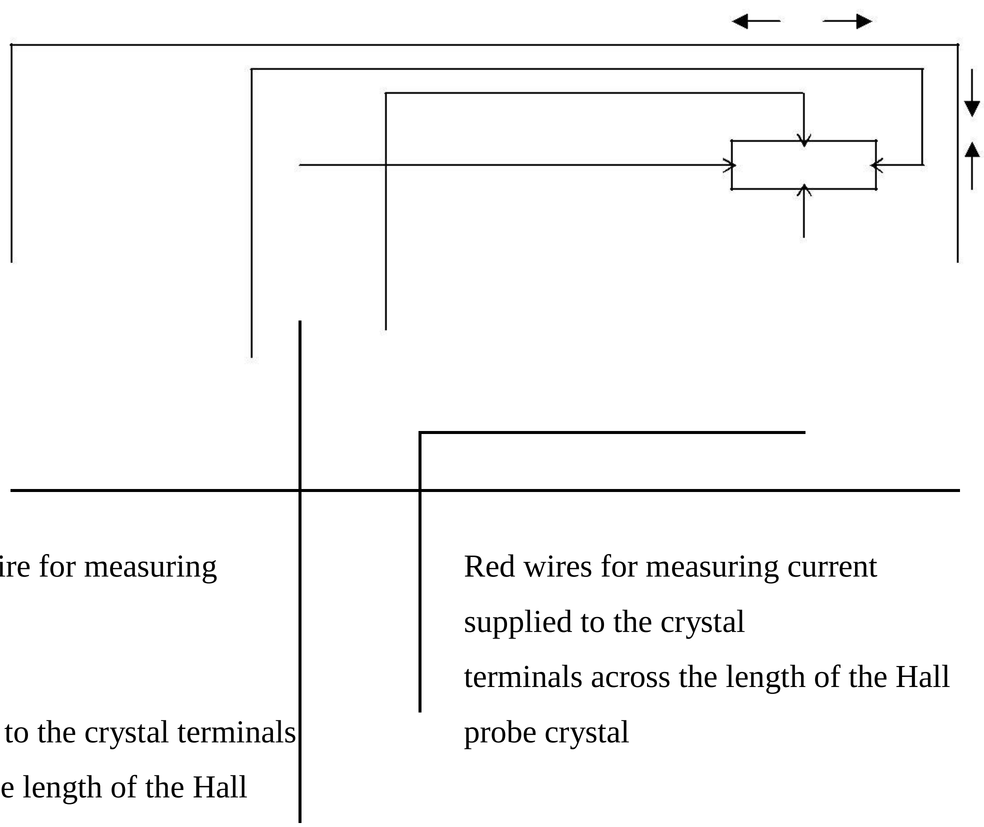


Figure 2b: Semiconductor Bar (Hall

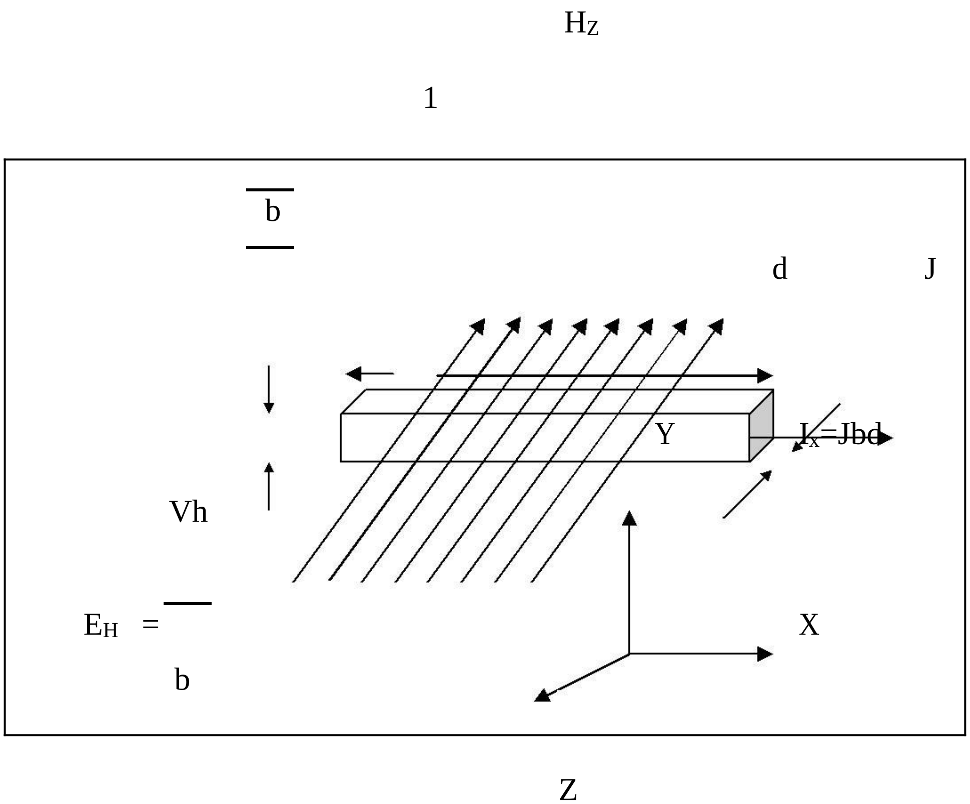


Figure 3: Sample for studying Hall effect

Experiment no. 10

10.1 Objective

To find the coefficient of thermal conductivity of a bad conductor by Lee's disc method.

10.2 Apparatus Required

Lee's disc apparatus, two 110^0C thermometer, circular disc of the specimen of a bad conductor (ebonite or card board), a stop watch, screw gauze, a Vernier calipers, heater, steam generator

10.3 Description of apparatus

The Lee's apparatus is shown in the figure. In Lee's arrangement, a hollow metallic box A known as steam chamber is suspended from a stand in such a way that the upper surface is horizontal. Steam is passed from one end which comes out from the other end. The experimental disc C is placed on the steam chamber. Another disc B of brass well polished is also placed over C such that it is pressed between the steam chamber and brass disc B. The steam chamber A and disc B are provided with two thermometer T_1 and T_2 to note the temperature θ_1 and θ_2 of steam and slab B respectively.

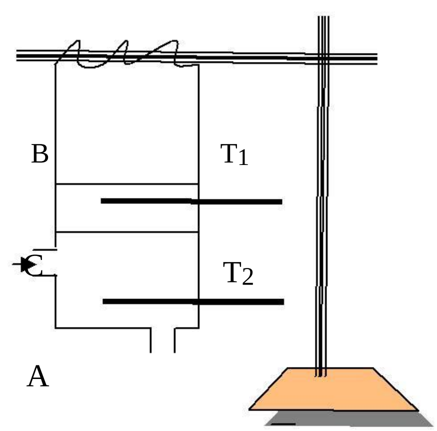


Figure 1

10.4 Theory

On passing steam through the cylindrical vessel a steady state is reached soon. In this condition the rate at which heat is conducted across the specimen disc is equal to rate at which the heat is emitted through the exposed surface of the lower disc. If K is the coefficient of thermal conductivity of the material of bad conductor, d its thickness, r its radius, the temperature θ_1 and θ_2 are the constant readings of the thermometer T_1 and T_2 in the steady state, then rate at which heat is conducted across the disc of the material

$$Q = k\,\pi r^2\,(\theta_1 - \theta_2) / d. \qquad (11.1)$$

If M is the mass of the metal disc, s the specific heat of its material, then rate of cooling at θ_2 is equal to Ms ($d\theta/dt$), where $d\theta/dt$ is the rate of fall of temperature at θ_2.

Therefore $$Q = [k\,\pi\,r^2\,(\theta_1 - \theta_2) / d.] = Ms\,(d\theta/dt) \qquad (11.2)$$

Or $$K = Msd\,(d\theta/dt) / \pi r^2\,(\theta_1 - \theta_2) \qquad (11.3)$$

The rate of cooling is found by heating the metal disc to a temperature about 10 $^\circ$C above the steady temperature θ_2, it is then allowed to cool and temperature is noted after every after 30 seconds till the temperature falls about 10 $^\circ$C below θ_2. A graph is then plotted (see figure 2) between temperature and time. A tangent is drawn at a point P corresponding to temperature θ_2.

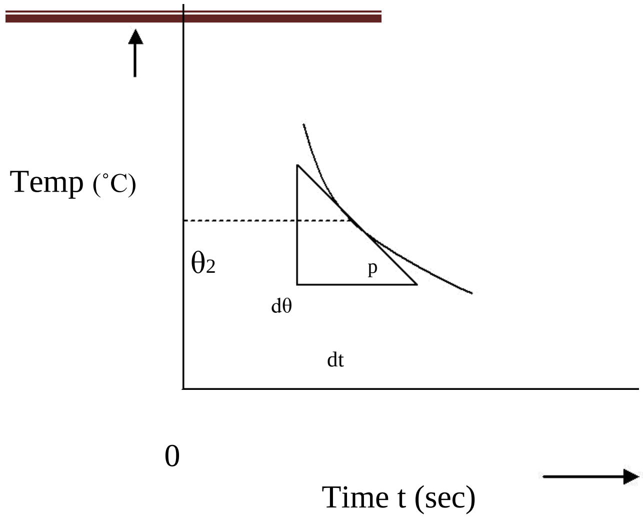


Figure 2

10.5 Procedure

3.13 Note down the mass of the brass disc B as quoted over it.

3.14 Note the radius r and thickness d of the experimental disc C as quoted over it. If r and d are not quoted over the disc C then measure these quantities.

3.15 Insert the two thermometers $T_1$and T_2 in the steam chamber A and brass disc B respectively and set the arrangement as shown in fig 1.

3.16 Allow the steam to pass in the steam chamber.

3.17 Obtain a steady state and note down the readings of the two thermometers.

To measure $d\theta/dt$, the experimental disc C is removed and the disc B is directly placed on the steam chamber to increase its temperature by 10°C above θ_2. The disc B is then suspended separately and allowed to cool.

6. Measure the diameter of the disc with Vernier calipers along two diameters mutually Perpendicular to each other. Also measure the thickness of the disc with a screw gauge at different points. Also find the mass of the disc when cooled.

10.6 Observations

i. Least count of the Vernier calipers =

ii. Least count of the Screw Gauge =

iii. Mass of the Metallic disc B, M = gm

iv. Specific heat of the metal(brass) s = 0.092 kilo-cal/kg-^{0}K

v. Diameter of the disc, D = Main scale reading + (Circular Scale Reading x Least count of screw Gauge)

Take two reading in mutually perpendicular direction and then take the mean.

Mean value of diameter of the disc = ……cm.

Radius of the disc, r = ……cm.

vi. Thickness of the disc, d = Main scale reading + (Circular scale reading x Least count of screw Gauge)

Take four reading at different places directions and then take the mean.

Mean thickness, d = …..cm.

Table 1

Table for ascertaining the steady state

No. of observations	1	2	3	4	5	6	7	8	9	10
Time in minutes	0	1	2	3	4	5	6	7	8	9
Thermo. T_1 reading θ_1 °C										
Thermo. T_2 reading θ_2 °C										

Note: The readings should be started when the steady state is nearly attained**.** Steady state temperature from the above observation:

6. θ_1=…………°C
7. θ_2=……….... °C

Table 2

Table for measurement of (dθ/dt) at θ_2

S. No.	**Time Taken**			**Temperature**
1.	**Minute**	**Second**	**Total Seconds**	
2.	**----**	**10**	**10**	
3.	**----**	**20**	**20**	
4.	**----**	**30**	**30**	
5.	**----**	**40**	**40**	
6.	**----**	**50**	**50**	
7.	**1**	**00**	**60**	
8.	**1**	**10**	**70**	
9.	**1**	**20**	**80**	

10.	**1**	**30**	**90**	

10.7 Calculations

The thermal conductivity of the of the bad conductor

$$K = Msd\ (d\theta/dt) / \pi r^2 (\theta_1 - \theta_2)$$

10.8 Result

The observed value of thermal conductivity of the bad conductor = ……………….

Standard value: for Ebonite: 0.0038 Cal / cm.sec.^{0}C

Percentage error:

10.9 Source of errors and precautions

- Thickness of the disc of the material should be measured at a number of place on its surface.
- The diameter of the disc should be equal to that of the cylindrical vessel and the metallic disc and should be measured in two perpendicular directions.
- The thermometer should be placed close to face of the disc of the specimen.
- There should be a good thermal contact between the disc of the material and the lower surface of the cylindrical vessel and the upper surface of the circular metallic disc. If necessary glycerin may be applied between the surfaces.
- The steady state temperature should be recorded only when the reading of T_1 and T_2 remain constant after an interval of about five minutes.

- The experimental disc should be very thin since in theory we assume that no heat lost from the curved surface of the experimental disc.
- While recording the readings for the cooling rate for the slab A, the experimental disc should be

placed over the slab.

10.10 Oral questions

1. Define coefficient of thermal conductivity.
2. What are the units of the thermal conductivity?
3. Distinguish between steady and variable states.
4. Why steady state readings?
5. What material is best conductor of heat?
6. Why the experimental disc is thin?
7. What way glycerin may help in making proper thermal contact?
8. Why few drops of mercury are interested in the slots meant for thermometers?
9. Why the two thermometers are placed close to the experimental disc?
10. Can this method be used for finding out the thermal conductivity of a good conductor like copper, or silver?
11. Why the cylindrical vessel and metallic discs are nickel - plated?

Experiment No.- 11

11.1 Objective: To determine the mass susceptibility of a paramagnetic substance by Quincke's method.

11.2 Apparatus: Electromagnet and its power supply, A glass tube of uniform fine bore connected to a wide funnel by means of rubber tube, Digital Gaussmeter attached with probe, Traveling microscope, Chemical balance, measuring cylinder, experimental salt(anhydrous $FeCl_3$, Ferric chloride) and water.

11.3 Theory:

A glass U - tube , whose one limb wide and the other one narrow, is filled with the solution of the substance whose susceptibility is to be determined. The narrow limb is then placed between the pole pieces of an electromagnet while the wider limb is slightly away from it. The wider limb can thus be very safely assumed in a magnetic field of negligible intensity. When the current through the coils of the electromagnet is switched on, the meniscus of the liquid in the narrow limb rises(in the case of paramagnetic substances like $FeCl_3$ or $CuSO_4$ or $NiSO_4$ solutions) or falls (in the case of diamagnetic substances like water) through a distance h, which can be measured by means of a traveling microscope. Due to this rise or fall of the liquid meniscus in the narrow limb of the U- tube, the level of the liquid in the wider tube also changes, but the change is very small as compared to the change of the level in the narrow limb. The level of the liquid in the wide limb can therefore be taken as constant during the experiment. (Fig.1)

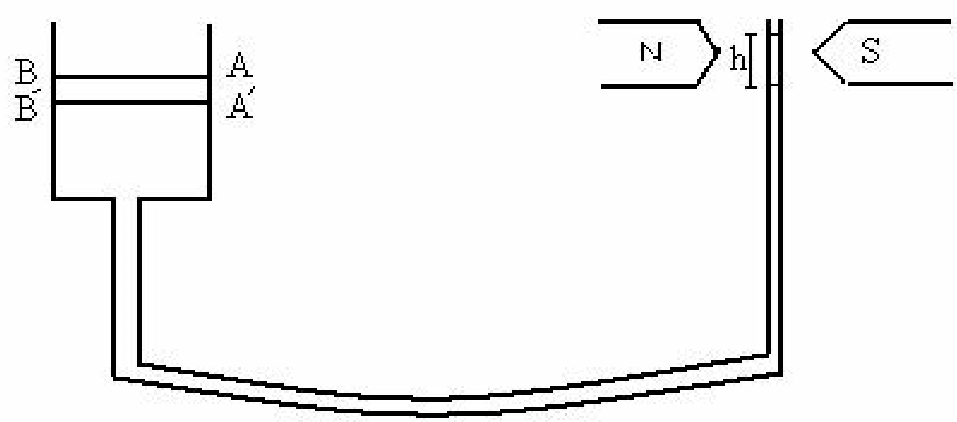


Fig. 1

The upward force experienced by the liquid in the narrow limb of the U-tube due to the action of magnetic field is given by

$$F = 0.5\,(K-K_0)\,A\,H^2$$

Where K and K_0 are the volume susceptibility of the liquid and the surrounding medium(air), A is the area of cross section of the narrow limb and H is the strength of the magnetic field at the liquid meniscus.

If h is the height through which the liquid meniscus in the narrow limb of the U –tube rises or falls and ρ is the density of liquid then the difference of pressure on two sides of the tube is $h \rho g$, where g is the

acceleration due to gravity and the force F is balanced is $h \rho gA$, so that

$$0.5 (K-K_0) A H^2 = h \rho gA$$

$$(K-K_0) = 2h \rho g / H^2 \qquad (1)$$

Neglecting K_0 the volume susceptibility of air, the volume susceptibility of the experimental liquid can be found out as

$$K = 2h \rho g / H^2 \qquad (2)$$

Thus the mass susceptibility of the experimental liquid ($FeCl_3$ say) is given by

$$\chi_{sol} = \frac{2gh}{H^2} \qquad (3)$$

And therefore the h vs H^2 graph will be a straight line and the slope of this straight line will be equal to $\frac{\chi_{sol}}{2g}$.

Now if the χ_w and χ_{sol} are the mass susceptibilities of water and the salt solution then the mass susceptibility of the Ferric Chloride ($FeCl_3$) salt can be determined by

$$\chi_s = [\chi_{sol} - (1 - C_s)\chi_w] / C_s \qquad (4)$$

where C_s is the concentration of the Ferric Chloride solution.

χ_w **= -1.56 x 10^{-6} CGS units**

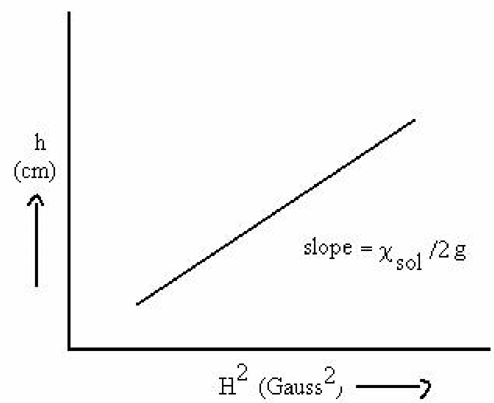


Fig. 2

11.4 Procedure:

The whole experimental procedure can be divided into two parts viz.,

3.18 Measurement of Magnetic Field and
3.19 Measurement of change in height of the liquid in the narrow limb of the U-tube

A. Measurement of Magnetic Field:

8. Connect the two coils of electromagnet in series i.e., the direction of current in both the coils should be same. Otherwise little or no magnetic field would result even at full current (which is supplied through the constant current power supply to the electromagnet)

9. Connect the electromagnet leads to the constant current power supply.

10. Before setting up the electromagnet ready to use, one should first calibrate the digital Gaussmeter. The method is as follows:

(a) Take out the probe along with the cable through the cutting provided on the rear side of the digital Gaussmeter. [The probe is encapsulated in a nonmagnetic white color sheath. It is connected to the instrument digital Gaussmeter, by means of a four core cable of suitable length and is normally kept inside the instrument. A transport cap is provided for protection of probe. It is advised that the probe should not be used at temperature higher than 50^0. The probe is very delicate and hence it is advised that the probe should be inserted in its protection cap whenever the probe is not in use and kept inside the instrument.]

(b) Zero adjustment: Switch on the digital Gaussmeter. Its reading is adjusted to zero value using the ‘Zero’ control key keeping the probe away from any magnetic field. This adjustment should be checked while keeping the digital panel meter on X1 range.

(c) Switch ON the electromagnet power supply. Give some current value to the electromagnet coils using the current knob.

Note: The Current should be kept at the minimum value before switching On the power supply.

(d) The range switch is now set to the appropriate range. Remove the probe cap and insert the probe in the magnetic field generated between the two poles of the electromagnet. The flat face of the probe is kept perpendicular to the direction of magnetic field. The reading of the digital panel meter multiplied by the range value gives the flux density of the magnetic field in Gauss.

Note: If the field strength is not known, start with the X10 range.

(e) The direction of the magnetic field can also be seen. If the magnetic field indicated by the digital Gaussmeter panel meter is positive (without any sign), the pole facing the side of the probe marked ‘N’ is north pole.

11. Now the electromagnet is and digital Gaussmeter are ready to use. Allow a fixed current to flow through the electromagnet coils.

12. Put the digital Gaussmeter probe in between the electromagnet poles and read the magnetic field in gauss using the digital Gaussmeter panel using the appropriate range(Step 3d).

13. After taking the reading of the magnetic field, switch off the digital Gaussmeter and insert the probe in its white cap and keep the encapsulated probe into the cutting provided on the rear side of the Gaussmeter.

14. Switch OFF the supply of current to the electromagnet pole pieces.

B. Measurement of change in height of the liquid in the narrow limb of the U-tube

1. Prepare a solution of Ferric chloride of known concentration (C_S). For this dissolve a weighted amount (say 10gm) of anhydrous FeCl3 salt in 5ml distilled water completely. Increase the volume of the solution to 50ml by adding more water.

- Pour solution in the wide limb of the U tube and adjust it in such a way that the solution meniscus in the narrow limb is at the center of the pole pieces of the electromagnet.
- Focus the traveling microscope for the solution level in the narrow limb of the U tube and adjust the cross wire such that it is tangential to the meniscus. Note down the reading of the traveling microscope.
- Now, switch ON the current through the pole pieces of the electromagnet. The level of the FeCl3 solution in the narrow limb increases. Move the microscope and again set the cross wire tangentially to the meniscus. Note down the reading of this position and switch OFF the current. The difference between the two readings will give the rise in the level of solution due to the action of the magnetic field.
- Repeat the experiment at least for seven or eight values of the magnetic field H and observe the corresponding rise in the FeCl3 solution level in the narrow limb of the U tube, placed in between of the electromagnet pole pieces.

6. Calculate the solution's mass susceptibility χ_{sol} separately foe each set (Equation 3).

7. Plot the h vs. H^2 graph and find the slope thus calculating the value of χ_{sol} .

8. Calculate the mass susceptibility of the $FeCl_3$ salt using relation given in Equation 4.

11.5 Observations:

Least count of the traveling Microscope:
The value of one division of Main scale on the scale in use = ……….cm
…………divisions of Vernier scale = …………divisions of Main scale
The value of one division of Vernier scale = …………cm
Least count of the Microscope scale in use =

Value of one division on main Scale – Value of one division on Vernier Scale

= 0.01mm

Table: Determination of rise in height of the solution level in the narrow limb

S. No.	Magnetic field strength H (in Gauss)	H^2 (in $Gauss^2$)	Rise of solution level (mm)						
			Initial level			Final level			Rise (h) cm
			Main	Vernier	Total	Main	Vernier	Total	
1.									
2.									
3.									
4.									
5.									

11.6 Calculations:

12. Concentration of the solution, C_S = mass of the salt/ total mass of the solution ………gm/ml

13. Mass susceptibility of water $\chi_w = -15.6 \times 10^{-6}$ CGS units

14. Mass susceptibility of the solution, $\chi_{sol} = K/\rho = 2gh/H^2$

Calculate separately for each set and find the mean of them.

$$\frac{\chi_{sol}}{2g} = \ldots\ldots\ldots\ldots$$

$$_{sol} = 2g \text{ x slope of the graph} = \ldots\ldots$$

3. Mass susceptibility of the salt ($FeCl_3$) using equation (4):

$$_s = [\chi_{sol} - (1 - C_s)\chi_w] / C_s$$

Calculate this for both (from step 3 and step 4) values of χ_{sol} .

11.7 Results:

Mass susceptibility of the given salt ($FeCl_3$) : from calculations =………..
Mass susceptibility of the given salt ($FeCl_3$) : from graph = ……………..
Standard result: (for anhydrous $FeCl_3$) = 9600 x 10^{-6}CGS units
Percentage errors : In Calculated result:…………..
In Graphical result:…………..

11.8 Sources of Errors and Precautions:

1. The U-tube should be thoroughly cleaned before the experiment to avoid sticking of liquid on the glass surface.
2. The narrow limb of the U tube should be held vertically and be placed in such a way that the liquid meniscus lies at the center of the pole pieces of the magnet.
3. The solution should be prepared fresh as it changes chemically with time.
4. Electromagnet power supply should be connected to a 3-pin AC mains socket having good earth connections.
5. Always increase or decrease the electromagnet current gradually through the power supply.
6. Switch 'ON' or 'OFF' the power supply at zero current/ voltage position.
7. The Gaussmeter probe is very delicate and should be used at temperatures well below 50^0.