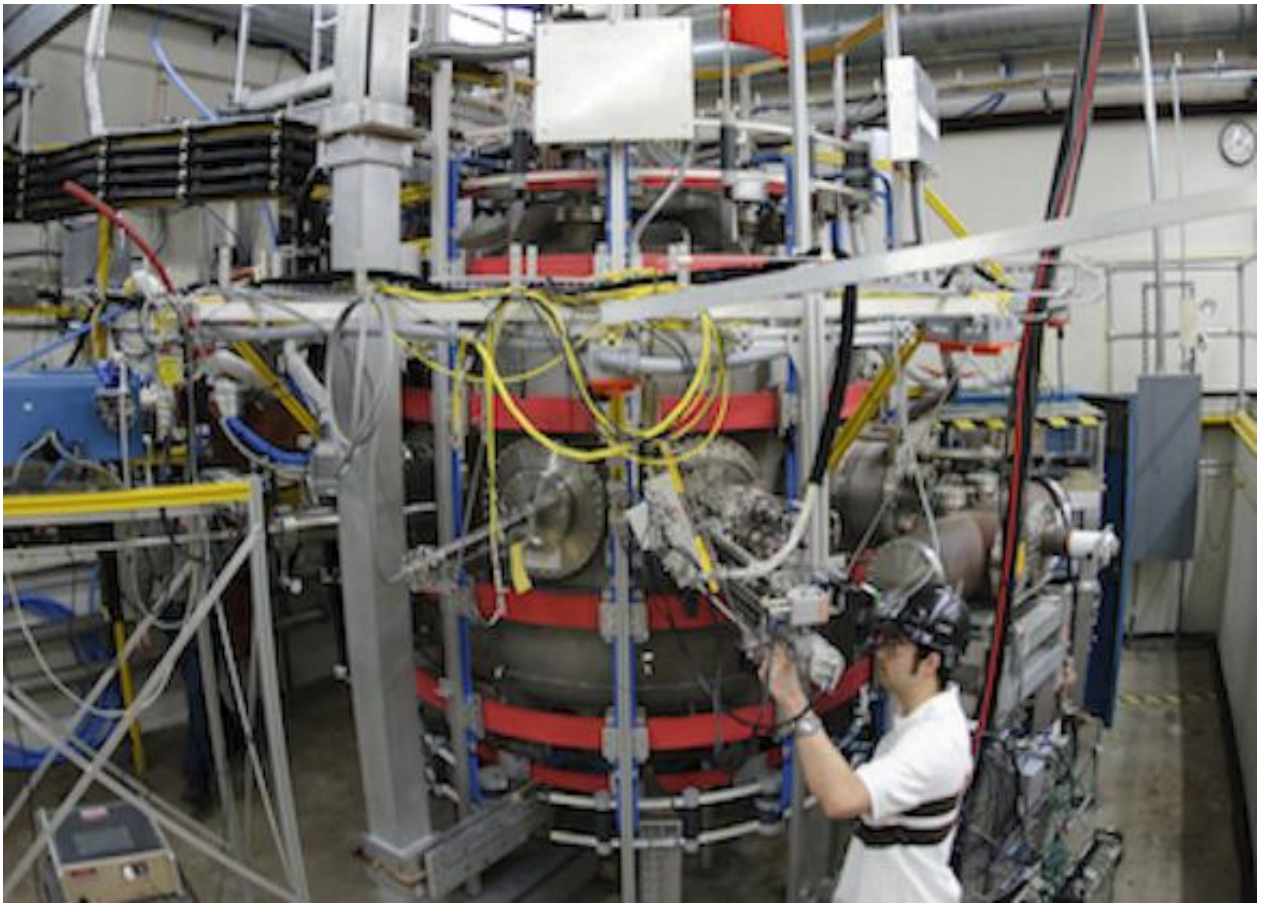
LABORATORY MANUAL

MODERN AND COMPUTATIONAL PHYSICS LAB

COURSE CODE: PH111



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DEPARTMENT OF APPLIED SCIENCES

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OF

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How to write a laboratory report?

The following arrangement of the report is suggested:

Title: This should indicate the nature of the experiment and the specifications used, if any.

Scope of the experiment: A brief statement of the purpose and significance of the experiment should be indicated.

Material: The material used or tested should be described (if any).

Apparatus and method of testing: Special equipment used should be briefly described. The testing procedure should be described.

Data and results of the experiment: All laboratory data shall be submitted in tabular form. Observations relating to the behavior of the materials should be included. All equations or formulae used should be clearly indicated. Calculations should be properly checked. The results of the test should be summarized in tabular or graphical form.

Discussion/Comments on result: The test results should be compared with the standard values and conclusion should be drawn.

Practical aspects of the Experiment: This should be included a brief discussion in which attention should be drawn to the salient facts brought out by the data and graphs. The link of the experiment to the real world situation should be established. The student might refer to literature /websites etc to gain more information about a particular experiment.

Department of Applied Sciences (PHYSICS)
Modern and Computational Physics Lab (PH121)

List of experiments

S. No.	Experiment Details
1	To find out the Magnetic Susceptibility of $FeCl_3$ by Quinke's Method.
2	To determine e/m ratio of electron by using Thomson method**.**
3	To determine the ionization potential of mercury using a gas filled diode**.**
4	To determine the wavelength of light using Michelson's Interferometer.
5	To measure the specific rotation of cane sugar solution using Laurent's half shade polarimeter.
6	To study the laser beam characteristics like wave length, aperture & divergence etc.
7	Study of diffraction using Laser beam and thus to determine the wavelength/grating element.
8	To determine numerical aperture of an optical fibre**.**
9	To determine attenuation & propagation losses in optical fibre**.**
10	To study the Hall effect in a semiconductor**.**
11	To determine Planck's constant by using light emitting diodes.
12	To draw the B-H curve of a given magnetic material.
13	To study the variation of magnetic field with distance along the axis of a circular coil carrying current by Stewart and Gee's method plotting a graph.

Experiment 1

BACKGROUND: The force of magnetization of any magnetic material depends on the susceptibility of material, i.e., on ratio of intensity of magnetization to magnetizing field. Susceptibility refers to that quantity of substance by virtue of which bodies get magnetized. If a salt solution (paramagnetic or ferromagnetic) is put in a U-tube and placed between the poles of a magnet then there is a rise or fall in the liquid level. If the rise in liquid level and amount of applied field is measured accurately, then this will give information about the magnetic susceptibility of the solution. Using this concept find out the mass susceptibility of $FeCl_3$ solution.

AIM: To find out the magnetic susceptibility of $FeCl_3$ by Quinke's method.

APPARATUS: An electromagnet capable of producing field of the order of 10^4 oersted, power supply unit, $FeCl_3$, U-tube, water, funnel 100 cc cylinder, weighting bottle, weight box and gauss meter.

FORMULA USED: The mass susceptibility (χ_s) of solution is given by

$$\chi_s = \frac{2\,gh}{H^2}$$

Where g is acceleration due to gravity, h is rise or fall in height of solution, H is magnetic field strength.

THEORY: If a paramagnetic salt solution (like Ferric Chloride) is put in a U-tube and placed between the poles of a magnet then there is a rise or fall in the liquid level. If the rise in liquid level is measured accurately, then this will give information about the susceptibility of the solution. It was established by Faraday in 1845 that magnetism is universal property of every substance. In magnetic materials, sources of magnetization are the orbital and spin angular motion of electrons around the nucleus. The other sources of magnetism are the nuclear magnetic moments of the nuclei in the material. The nuclear magnetic moments are typically thousands of times smaller than the electron magnetic moments, so they are negligible in the context of the magnetization of materials. The magnetism of materials is mainly an outcome of the interactions of magnetic moments of their constituent atoms or molecule.

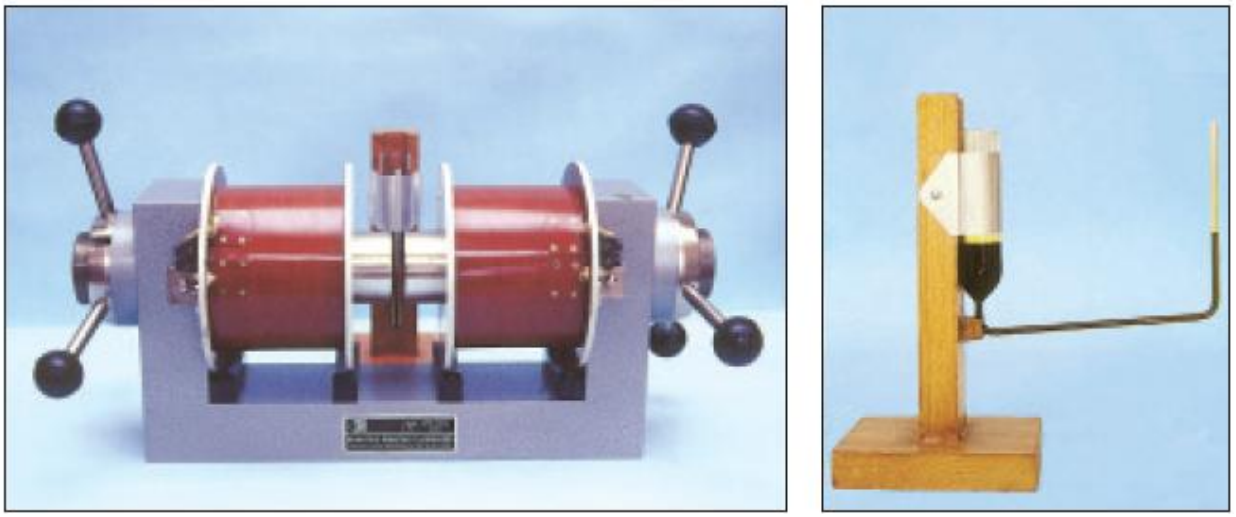


Figure 1: (a) U-tube place in electromagnet (b) U-tube

The magnetic materials are generally classified into three major categories (1) diamagnetic (2) paramagnetic (3) ferromagnetic. The magnetic materials, for which susceptibility is negative, are diamagnetic, whereas, the materials with small positive value are called paramagnetic and the materials with high value of susceptibility are known as ferromagnetic. **Weber**, tried to explain magnetic properties on the basis of molecular currents. The molecular current gives rise to the intrinsic magnetic moment to the molecule, and such substances are attracted in a magnetic field, and called paramagnetic. The repulsion of diamagnetic is assigned to the induced molecular current and its respective reverse magnetic moment. The force acting on a substance, either of repulsion or attraction, can be measured with the help of an accurate balance in case of solids or with the measurement of rise in level in narrow capillary in case of liquids. The force depends on the susceptibility of the material, *i.e., on ratio of intensity of magnetization to magnetizing field (I/H)*. Evidently, it refers to that quantity of substance by virtue of which bodies get magnetized.

Quantitatively: it refers to the extent of induced magnetization in unit field. If the force on the substance and field are measured, the value of susceptibility (K) can be calculated.

The value of the susceptibility (K) of liquid aqueous solution of a paramagnetic substance in air is given by a well known expression:

$$K = \frac{2(\rho - \sigma)\, gh}{H^2} \qquad (1)$$

Where ρ is the density of the solution, σ is the density of air, g is the acceleration due to gravity, h is the height through which column rises on raising the field, H is the magnetic

field at the centre of the pole pieces. But the density of air (1.22 Kg/m^3) is very small as compared to density of water (1000 Kg/m^3), so density of air can be neglected. Hence equation (1) becomes

$$K = \frac{2\rho\, gh}{H^2} \qquad (2)$$

Then the mass susceptibility of solution is given by

$$\chi_s = \frac{K}{\rho} = \frac{2\, gh}{H^2}$$

PROCEDURE:

1. Calibrate the gauss meter to measure deflection in terms of Maxwell turns.
2. Fill a U-tube which is thoroughly cleaned with a solution of $FeCl_3$ in water containing 25 gm of a hydrated salt ($FeCl_3.6H_2O$) per cc for the solution.
3. Now insert the narrow limb of U-tube vertically between the pole pieces of the electromagnet and adjust the funnel limb so that when the magnet is energized the meniscus is in the central region of the uniform magnetic field. Also note the corresponding current in the ammeter.
4. Switch off the current and again note the reading of the meniscus and take a reading. Note the fall in height *h* of the meniscus for a particular current. Repeat the experiment for different values of magnetizing current.

OBSERVATIONS:

Take value of acceleration due to gravity = 980 cms^{-2}

Sr. No.	Current (A)	Magnetic field H, (gauss)	H^2	Initial position of the meniscus (cm)	Final position of the meniscus (cm)	Fall in height (cm)	Mass susceptibility $\chi_s = (2gh)/H^2$
1.							
2.							
3.							
4.							

RESULT: Mean mass susceptibility of the solution is given by …… cm^{2}s^{-2}gauss^{-2}

PRECAUTIONS:

1. Check the joints between rubbers and glass tube so that there is no leakage of solution.

2. Solution should be prepared carefully so that salt is dissolved uniformly.
3. The magnetic field should remain uniform during the experiment.
4. Due to non-uniformity of the narrow limb bore, error due to surface tension may occur.
5. Since the bore is very narrow, so there may be deformation of the liquid in the tube due to application of magnetic field and so the rise or fall of the liquid meniscus may be read wrongly.

VIVA-VOCE:

Q.1What are diamagnetic materials?

Q.2 Distinguish between paramagnetic and ferromagnetic materials?

Q.3 What the units of magnetic field and how they are related to each other?

Q.4 What is magnetic moment?

Q.5 What is magnetic susceptibility?

Q.6 What are domains of ferromagnetic materials?

Q.7 What is intensity of magnetization?

Q.8 Why FeCl3 solution rise or fall in U-tube?

ASSIGNMENT:

1. To determine fall in height of $FeCl_3$ solution of given mass susceptibility.
2. To determine magnetic field of given ferromagnetic material of known susceptibility.

LEARNING OUTCOME:

Student will learn to calculate susceptibility and will be able to distinguish between different types of magnetic materials on the basis of measured susceptibility. Student will be able to measure magnetic field of electromagnet.

Experiment 2

BACKGROUND: An electron is deflected in electric and magnetic fields. However the deflection depends upon charge 'e', mass 'm' and velocity 'v' of the electron. By arranging crossed electric and magnetic fields, the electrostatic deflection is counter balanced by magnetic deflection. This condition enables one to determine the specific charge 'e/m'. You are given with a cathode ray tube mounted on wooden stand, bar magnet, compass box one set, wooden stand having two arms fitted with scales to measure the distance of the poles of the magnets. Using suitable arrangement and above concept determine the value of specific charge ratio of an electron.

AIM: To determine the value of specific charge (e/m) of an electron by Thomson Method.

APPARATUS: Cathode ray tube (CRT) mounted on a wooden stand, power supply fitted with voltmeter to measure the deflecting voltage, bar magnets (permanent) one pair, compass box one set, wooden stand having two arms fitted with scales to measure the distance of the poles of the magnets.

FORMULA USED: The specific charge for an electron can be calculated using following relation;

$$\text{Specific charge } \{e/m\} = \frac{V\lambda}{lLH^2 d} \times 10^7 \text{ e.m.u./gm}$$

Where $H = H_e \tan\theta$ (here H_e is the horizontal components of earth magnetic field of the place where experiment is performed, usually we take its value = 0.345G.)

Where various parameters are:-

l = Length of Horizontal pair of plate.

L = Distance of the screen from the edges of the plates.

V = Voltage applied to the plates.

λ = Total deflection of the spot on the screen.

H = Intensity of the applied field.

d = Separation between the plates.

THEORY: Cathode Ray Tube (CRT) consists of three basic components:

1. **Electron Gun**: Electron gun is a filament which when heated emits electron. Control grid carries a negative charge and emit beam of electrons which are accelerated by the anodes.

2. **Deflecting System**: This system deflects the beam of electrons either electrically or magnetically.
3. **Fluorescent Screen**: When beam impinges on it spot is produced. The value of e/m is independent of the nature of gas and material of the cathode of the discharge tube which indicate that electrons are fundamental of all materials. Present accepted value of e/m is 1.7×10^7 e.m.u./gm.

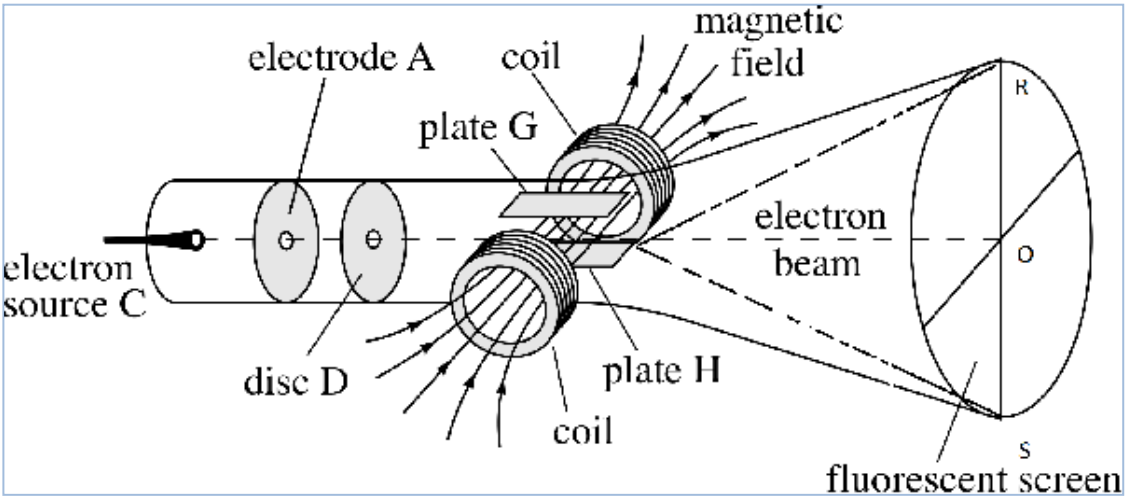


Figure1: Inner layout of a CRT

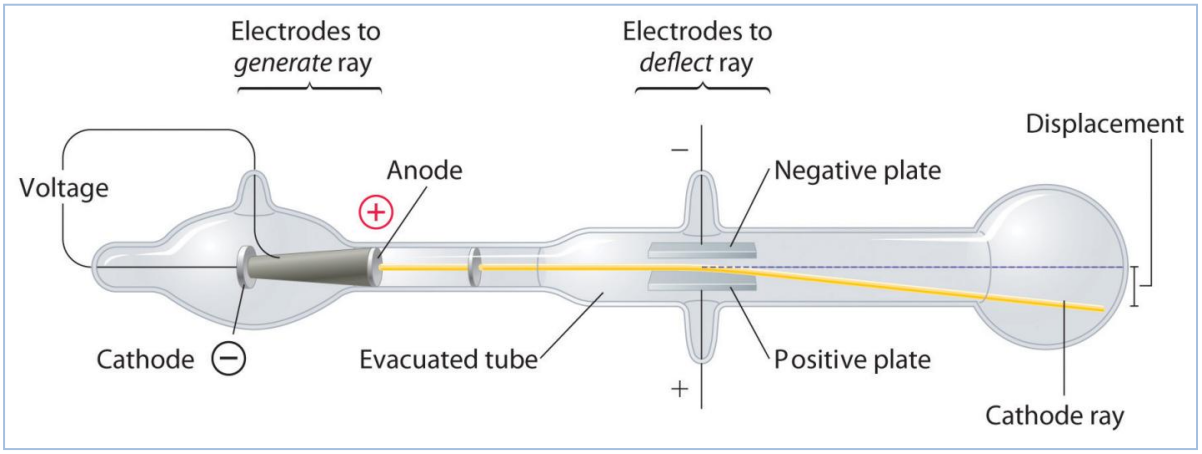


Figure 2: Displacement of electron beam in a CRT

PROCEDURE:

1. Mount Cathode Ray Tube (CRT) in armed wooden stand such that the CRT faces towards north & south direction while arms of this stand towards east & west direction (set the direction with the help of compass box.)
2. Connect the CRT Plug to the power supply socket mounted on the front panel.
3. Switch on the instrument using ON/OFF toggle switch provided on the front panel.
4. Set the deflection voltage to zero volt & x shift control potentiometer to middle position. Adjust the intensity & focus of the spot (clear as small as a point) on screen of CRT through the deflection selector switch towards forward position.
5. Read the initial reading of spot on the scale attached to the screen of the CRT, say it is -0.2cm. Now give a deflection to the spot in the upward direction by applying deflecting voltage such that the final reading is +0.8 cm. So the total deflection on the screen of the spot is (0.2 + 0.8) = 1.0 cm. Note down this applied voltage (V) & deflection of the spot (λ) in observation table.
6. Now place bar magnets on both sides of the wooden stand arms such that their opposite poles face each other and their common axis is perpendicular to the axis of CRT. The magnets should be kept in such a manner that these may be mode to slide along the scales.
7. Adjust distance and polarity of the magnets so that the spot traces back to its initial position (which was -0.2 cm).
8. Remove CRT stand and place a magnet meter compass box mounted in a stand in center of the armed wooden stand. Adjust the pointer of the compass box to read **o-o** without disturbing the direction of armed wooden stand.
9. Note down the deflection angle (θ) through compass box & note down it in the observation table and calculate the value of magnetic field *H*.
10. Calculate the value of e/m using formula mentioned above.
11. Repeat steps 5 to 10 for other values of spot deflections.
12. Calculate mean value of e/m for different set of readings.

Description of CRT 83SJ5

a) Separation between the plates (d) = …… cm

b) Length of horizontal pair of plate (l) = ….. cm

c) Distance of the screen from the edges of the plates (L) = ….. cm

d) Horizontal component of earth's magnetic field (B_H) = 0.345 G

OBSERVATIONS:

S. No.	Voltage Applied (V)	Spot Deflection (λ)	Compass Box Deflection (θ)	Magnetic Field Applied (H)	Specific Charge {e/m} e.m.u./gm
1.					
2.					
3.					
4.					

Mean value of specific charge (e/m) …….. emu/gm

PRECAUTIONS:

1. The movement of bar magnets should be slow to detect the minor deflections.
2. Reading on the CRT should be carefully checked.
3. Handle the CRT with proper care.

VIVA-VOCE

Q 1. What is CRO?

Q 2. Why the screen of CRT glow?

Q 3. Why the electron beam spot is shifted with the movement of magnet?

Q 4. What is specific charge?

Q 5. What is the standard value of specific charge?

Q 6. What are the units of magnetic field?

Q 7. What are cathode rays?

Q 8. How you calculate percentage error?

ASSIGNMENT:

1. To determine intensity of magnetic field produced by magnets.
2. To determine e/m for charged particles.

LEARNING OUTCOMES: Student will be able to calculate specific charge ratio and to evaluate percentage error. He will learn about cathode rays and their deflection using magnets.

Experiment 3

BACKGROUND: The potential needed to remove electrons from an atom is known as ionization potential. The ionization potential is measured using a vapor filled gas diode. When the anode of the gas filled diode is at a positive potential with respect to the cathode, electrons move across the tube from the cathode to the anode. As the plate potential is increased beyond a particular value the plate current increases much more rapidly than it does below that critical value. This potential is equal to the ionization potential of the gas. Using this concept determine the ionization potential of mercury using a gas filled diode**.**

AIM: To find the ionization potential of mercury using a gas filled diode.

APPARATUS: A gas filled (mercury vapour) diode, a D.C. power supply, a voltmeter, a millimeter and connecting wires.

THEORY: The term **ionization energy** of an atom or molecule means the energy needed to remove electrons from an atom. Large atoms require low ionization energy while small atoms require high ionization energy. This quantity was formerly called **ionization potential**, i.e., the potential needed to remove electrons from an atom and was measured in volts (V). The name "ionization energy" is now strongly preferred. In atomic physics the ionization energy is measured using the unit "electron volt" (eV).

Ionization potential of mercury: The ionization potential of mercury can be determined by introducing mercury vapor at a low pressure of 10mm to 50mm of mercury column in an evacuated tube fitted with a cathode and an anode. A mercury vapor filled gas diode is the most suitable for the purpose. The cathode of the gas diode may be directly or indirectly heated. A hot cathode gas filled diode is known as phantom (or thyratron). A gas filled diode is symbolically represented as shown in figure 1. The dot in the tube shows the presence of the gas or vapour.

When the anode or plate of the gas filled diode is at a positive potential with respect to the cathode, electrons move across the tube from the cathode to the anode. This electronic current depends upon two factors:

(1) The number of electrons emitted per unit area from the cathode and its temperature.

(2) The effect of space charge region, *i.e.*, the negatively charged region containing the electron cloud due to the accumulation of electrons emitted by the cathode.

As the plate potential is increased, the plate current slowly increases. When the plate potential is increased beyond a critical value, the plate current also increases more rapidly. This is because when the plate potential approaches critical value, the electrons arriving at the anode gain enough energy to knock out the electrons from the atom of the gas. These electrons are also attracted by the anode causing an increase in plate current. The positive ions neutralize some of the space charge, which further helps to increase the kinetic energy of the thermal electrons. This value of plate potential is called the ionization potential of the gas. Circuit diagram to determine ionization potential of mercury is given in figure 2.

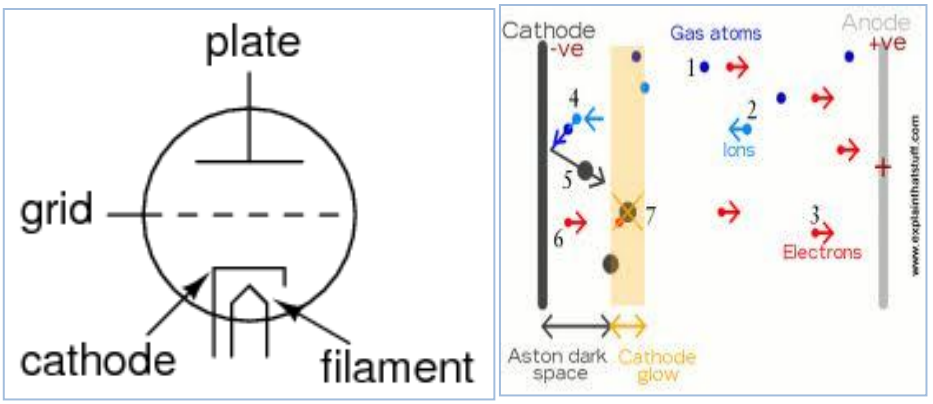


Figure 1 Mercury filled gas diode.

If a graph is plotted between plate potential and plate current; the plate current at first increases slowly for a given increase in plate voltage and when the plate potential is equal to or greater than the ionization potential there is a greater increase in plate current for the small increase in plate potential. The change in slope is, however, not very abrupt but there is a short curved portion within which the change in plate current goes on becoming more and more rapid. To find the value of ionization potential the two straight portions AB and CD of the graph are produced to meet at a point E (Figure 3). If we draw a perpendicular EF on the X-axis, then OF represents the ionization potential as shown in figure 3.

PROCEDURE:

1. Draw the diagram showing the scheme of connections as in figure 2 and make the connections accordingly.
2. Switch on the power supply and apply a suitable potential to the filament of the gas diode. The filament is heated in a short time to become red hot.

3. Adjust the voltmeter reading to 1 volt and note the corresponding value of the current in the millimeter. Increase the plate potential by 1 volt and note the voltmeter reading as well as the millimeter reading. Proceed till the plate potential is about 14 volts.

4. Taking the plate voltage along the x-axis and plate current along the y-axis plot a graph between plate current and plate voltage as shown in Fig 3. Draw the straight line AB between the first few points and the straight line CD between the last few points and produce AB and DC to meet at E. Draw EF perpendicular to the X-axis, then point F on X-axis gives the value of the ionization potential of mercury.

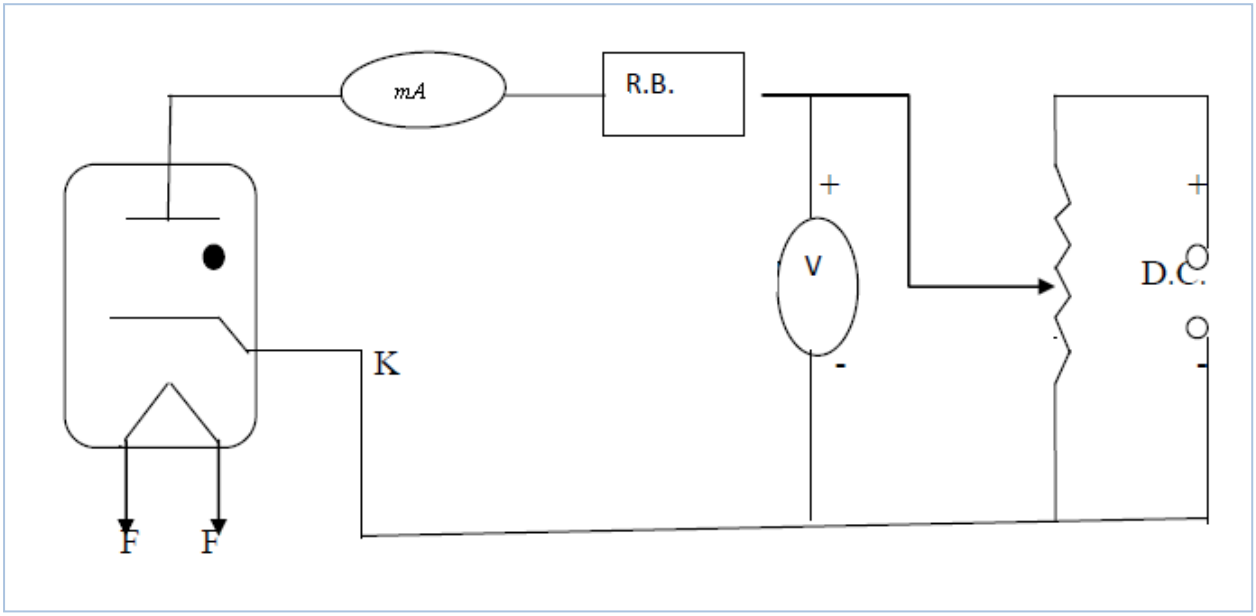


Figure 2: Circuit diagram showing the scheme of connections.

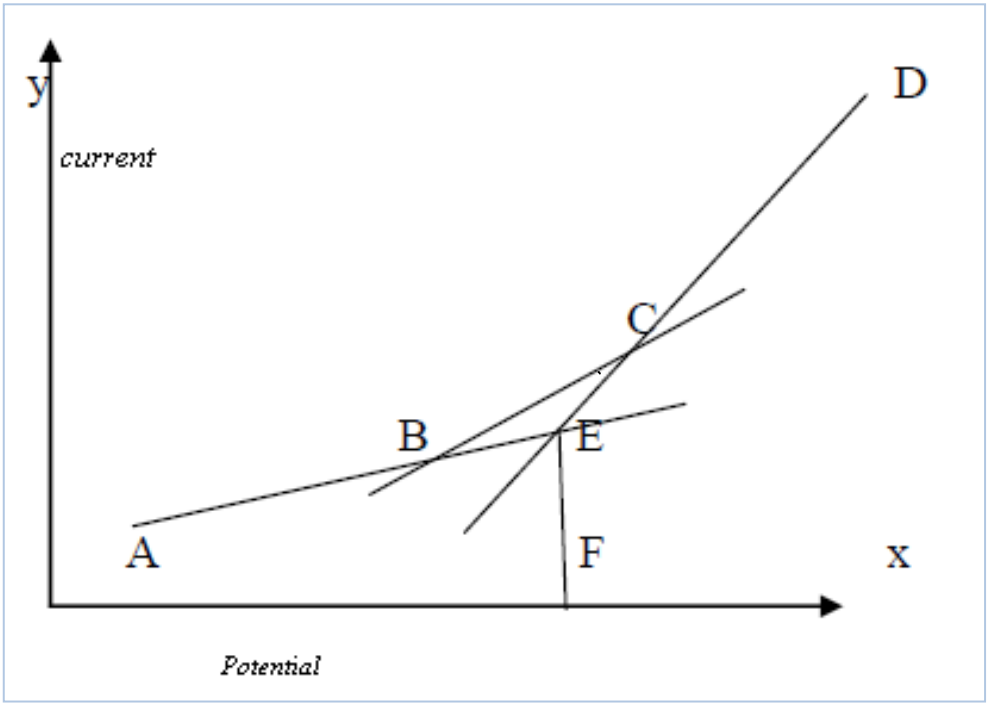


Figure 3: Variation of filament current with applied voltage.

OBSERVATIONS:

Sr. No	Plate voltage in volts	Plate current in mA
1		
2		
3		
4		
5		
6		
7		
8		

Ionization potential of mercury from the graph (observed value) = ……volts

Standard value of ionization potential = 10.41 V

Percentage error = …… %

PRECAUTIONS:

1. A gas filled mercury vapor diode must be used.
2. The positive of the voltmeter as well as millimeter must be connected to the positive of the D.C. supply.
3. The plate potential should not exceed 15 volts.
4. To find the exact position of ionization potential two straight lines joining the first few points and the last few points should be produced to meet. A smooth curve joining all the points should not be drawn.

VIVA-VOCE

Q 1. What is the atomic number of mercury?

Q 2. What is ionization potential?

Q 3. How does a gas filled diode works?

Q 4. How electric potential and potential energy are related to each other?

Q 5. What is the least count of voltmeter?

Q 6. What is the least count of micrometer?

Q 7. What is the standard value of ionization potential of mercury?

Q 8. How gas filled diode is different from pn-junction diode?

ASSIGNMENT:

1. To determine value of voltage of given ionization potential of mercury.
2. To determine value of current of given ionization potential of mercury.
3. To determine the resistance of gas filled diode.

LEARNING OUTCOMES: Student will be able to find ionization potential of gas filled diode, will be able to find voltage or current for the given ionization potential of mercury.

Experiment 4

BACKGROUND: When a beam of light is split into two beams; delay one with respect to the other, and then recombine them to observe their interference pattern. The number of interference patterns gives information about the wavelength of light emitted from unknown source. This concept was given by Michelson. You are given with Michelson interferometer, unknown laser source and screen. Determine the wavelength of unknown laser source.

AIM: To determine the wavelength of laser light with the help of Michelson Interferometer.

APPARATUS: Michelson Interferometer, light source, and screen.

FORMULA USED: The wavelength of light can be calculated using the relation

$$N\lambda = 2d\sin\theta$$

If $\theta = 90^o$, then wavelength is given by

$$\lambda = 2d/N$$

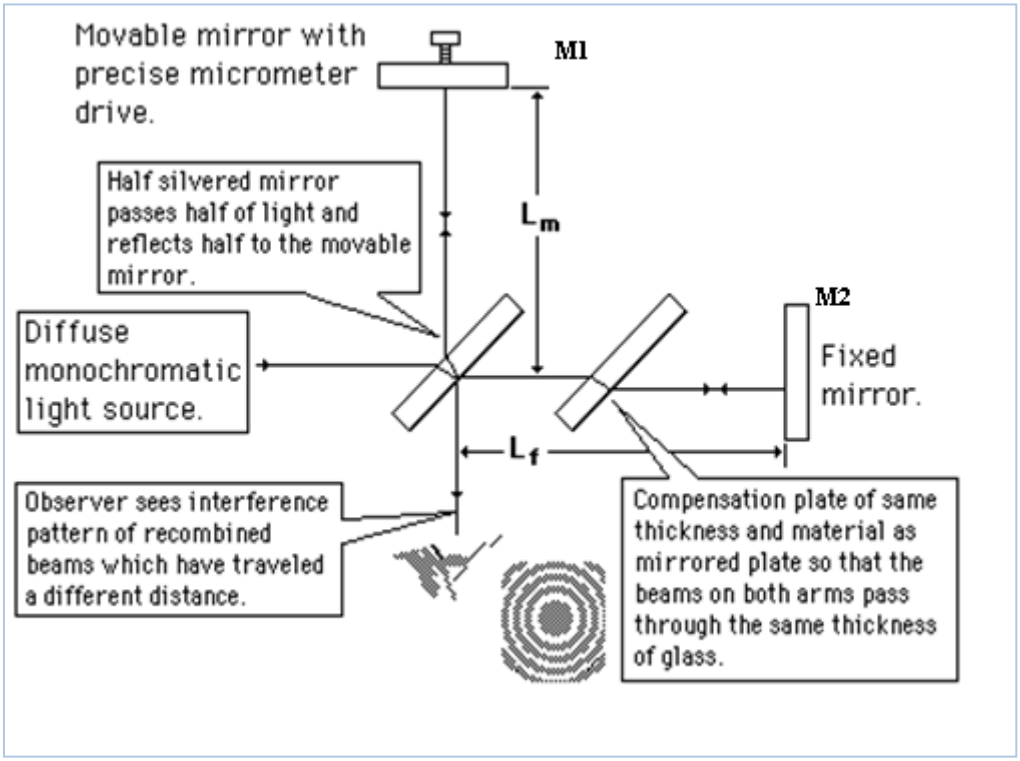
Where N number of fringes appeared at the centre and d is distance moved between two mirrors.

THEORY: The Michelson interferometer uses interference to measure distances in units of the wavelength of light from a particular source. It was developed by Albert Michelson in 1893 to measure the standard meter in units of the wavelength of the red line in the cadmium spectrum. It is also known for its use in demonstrating the non-existence of electromagnetic wave-carrying "ether". Contemporary uses of Michelson interferometer include precision mechanical measurements and Fourier transform spectroscopy. In laboratory, we use a Michelson interferometer to measure the wavelength of light and the index of refraction of air. The basic idea is to split a beam of light into two beams; delay one with respect to the other, and then recombine them to observe their interference pattern. Light from a monochromatic source is directed at a "half-silvered" glass plate, *i.e.* a mirror with a very thin metallic coating. Approximately half the light intensity is reflected to mirror 1 (M1) and half transmitted, so it strikes mirror 2 (M2). The light reflected by these mirrors goes back to the half-silvered plate. Half intensity of each beam then goes to an observation device either telescope or naked eye. The two light sources emit light over an angular range. An observation point at an angle θ with respect to the sources will be at constructive interference if

$$n\lambda = 2d\sin\theta$$

Where n is the number of fringes and λ is the wavelength of the light, and *d* is the distance through which mirror is moved.

The resulting image on the observation device will be a series of concentric, circular bright and dark rings. As M1 is moved, the fringes will change from bright to dark.



PROCEDURE:

1. Calculate the least count of the micrometer screw attached to mirror M1.
2. Turn on the lamp and look through the observation device. If you see the ring pattern (alternate dark and bright) and if it can be changed by turning the micrometer screw then the apparatus is aligned or set.
3. If it is not the case then first of all try to make mirrors M1 and M2 perfectly perpendicular to each other by adjusting the screws behind the mirrors. For this purpose a screen with a pin hole is placed between the half-silvered plate and source. When observed from the observation device four images of the pin hole are seen, two of them are faint and two are intense. Adjust the screws behind M1 and M2 in

such a way that we observe only two intense images of the pin hole. This happens only when the mirrors M1 and M2 are perfectly perpendicular to each other. Remove the pinhole screen.

4. Now move the mirror M1 such that you observe a bright spot at the centre.
5. Turn the micrometer either clockwise or anti-clockwise. Then turn it in the same direction enough to see N fringes appear or disappear at the centre. N should be at least 25.
6. Note the main scale reading (MSR), rough micrometer scale reading (RMSR) and fine micrometer scale reading (FMSR).
7. Let the initial reading be X_1 and final reading as X_2.
8. Measure the distance traveled by mirror M1 when N number of fringes appear / disappear at the centre using initial (X_1) and final (X_2) readings of the micrometer screw. Find the value of distance move by mirror M1 *i.e.* $d = X_2 - X_1$.

OBSERVATIONS:

Least count of main scale reading (MSR) ----------

Least count of rough micrometer scale reading (RMSR) ----------

Least count of fine micrometer scale reading (FMSR) ----------

Sr. No	No. of fringes moved (N)	Main scale reading (mm)	Rough micrometer scale reading (mm)	Fine micrometer scale reading (mm)	Total	Distance moved = *d* (mm)
1						
2						
3						
4						

Mean *d* =

CALCULATIONS:

1) Calculate the wavelength using the formula $\lambda=2d/N$.
2) Standard value of λ for laser user is 6328 Å.
3) The percentage error = {[(standard value)–(calculated value)]/standard value}×100 %

RESULT:

The measured value of wave length of light is----------

The percentage error is----------%

PRECAUTIONS:

1. Mirror M1 and M2 should be perpendicular to each other.
2. The fine adjustment knob should be moved in one direction.
3. Glass plates and mirrors should not be touched or cleaned.
4. The screws behind mirror M1 should be rotated through a very small angle.

VIVA-VOCE:

Q 1. What is interference of light and what do you mean by interferometer?

Q 2. What is the role of compensatory plate 'C'?

Q 3. How do you get circular fringes?

Q 4. What will you observe with white light source?

Q 5. What are localized fringes?

Q 6. When the mirror M1 is moved through a distance 2 λ distances, how many fringes appear or disappear?

Q 7. Name the laser used in present experiment.

Q 8. Explain the working of laser used in present experiment.

ASSIGNMENT:

1. To determine path difference between two mirrors.
2. To determine order of fringes of given LASER wavelength.

LEARNING OUTCOMES:

Student will be able to work with lasers and interferometer. Students will be able to study the interference pattern produced by laser. They will also learn to calculate the wavelength of any unknown laser using Michelson interferometer.

Experiment 5

BACKGROUND: Light emitted from some source vibrates in all directions at right angles to the direction of propagation and is un-polarized. The process of conversion of un-polarized light into polarized light is called polarization. When one decimeter of the solution divided by the weight of the dissolved substance in unit volume is kept in the path of light the amount of rotation produced by solution is called specific rotation of solution. You are given with sugar solution and Laurent's half shade polarimeter to measure the specific rotation of cane sugar solution.

AIM: To find the specific rotation of sugar solution by Laurent's half shade polarimeter.

APPARATUS: Polarimeter, sodium lamp, sugar, beakers, graduated jar, disc, weight box and balance.

FORMULA: The specific rotation (S) of the plane of polarization of sugar dissolved in water can be determined by the following formula.

$$S = \frac{\theta V}{l\, m}$$

Where, θ = rotation produced in degrees

l = length of the tube in centimeter

m = mass of sugar in grams dissolved in water

V = volume of sugar solution

THEORY:

Polarimeter in general consists of a source of light a polarizer and an analyzer provided with a graduated circular scale. Figure 1 given below represents the general optical arrangement of most polar meters.

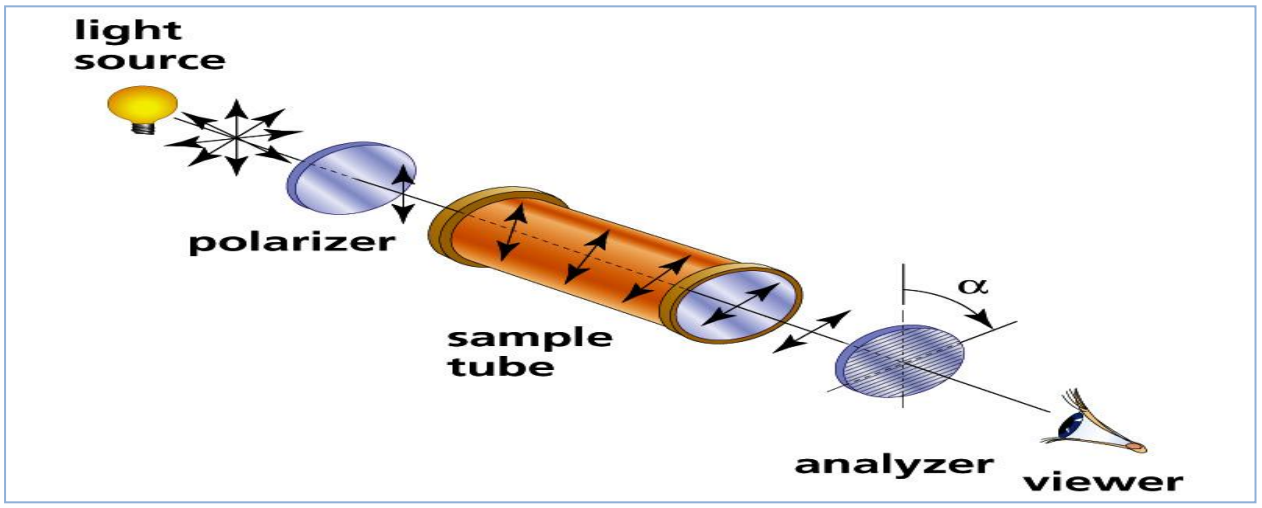


Figure 1 : Pictorial view of experimental set up.

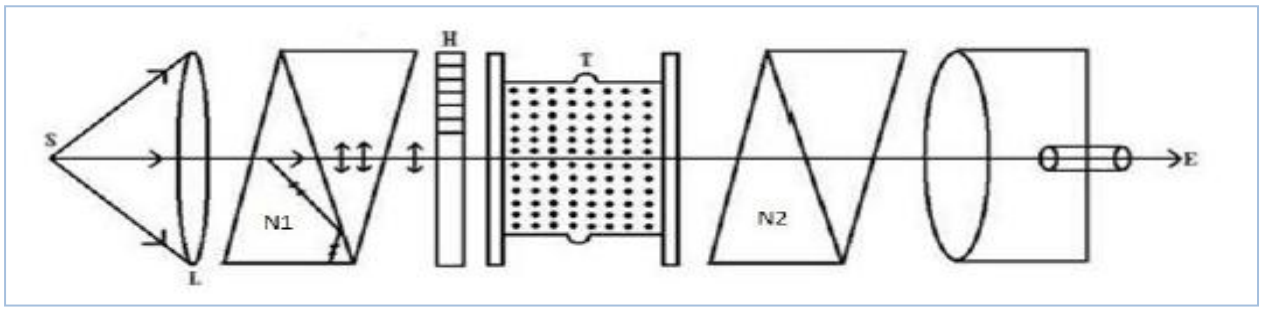


Figure 2 : Geometrical view of experimental set up.

In figure 2, S is a source of light, so placed that it is nearly at a focus of the lens L so that parallel pencil of rays enters the nicol prism N_1 which serves to polarize the beam of light passing through it. The polarizing nicol is immediately followed by a Laurent half shade. The other nicol prismN_2 analyses the transmitted beam and detects its plane of polarization and is placed in front of a low power telescope. The tube T containing the liquid under investigation is placed in between N_1 and N_2. The tube is closed on both sides with metal caps. When this tube is filled with solution containing an optically active substance, the air bubbles (if any) will appear at the upper side of the wide portion of the tube. The light from N_1 can pass through N_2only if $N_2$is placed in exactly the same way as N_1. In this case the nicols are said to be parallel. If however, N_2 is turned from this position by a right angle no light from N_1can pass through N_2. In this position the nicols are said to be crossed. Certain substances like quartz, solution of sugar etc. possess the property of rotating the plane of polarized light, when it passes through them. On inserting the active substance on account of the rotation of plane of polarization, some light will pass through N_2 even when it is set in crossed position.

It is found that rotation of N_2in one direction or the other will again bring N_2 into a plane in which light is once more stopped. Thus we can get the amount of rotation by measuring the angle through which N_2 has turned.

Specific rotation is defined as the amount of rotation produced by one decimeter of the solution divided by the weight of the dissolved substance in unit volume. Let *W* grams be dissolved in100 c.c. and suppose a length l cm of liquid produces a rotation θ.

$$S = \theta \Big/ \left(\frac{l}{10}\right) \div \frac{W}{100} v = 1000 \frac{\theta}{lW}$$

PROCEDURE:

1. Weigh sugar in a watch glass and dissolve the sugar in 100 c.c. distilled water.
2. Clean the polarimeter tube and fill it with distilled water. See that there is no air bubble in the tube when the end caps have been screwed. Place the tube in its position inside the polarimeter.
3. Look through the analyzer when it will be observed that two portions of the field of view of the device are in equally dark/ bright position.
4. Rotate the analyzer till the two portions of the field of view are of same intensity.
5. Take the reading of the analyzer on the circular scale. The settings of the analyzer should be done by rotating the analyzer in the clock-wise as well as by rotating in the anti-clockwise directions.
6. Remove the distilled water from the tube and fill it completely with the sugar solution and again place it in the polarimeter. On looking through the analyzer the previous setting would be disturbed. Adjust the analyzer again till the two portions of the field of views acquire the gray tint shade. Take the reading of the analyzer.
7. Difference between the two settings of the analyzer (6) - (5) gives the value of the angle of rotation.
8. Repeat the experiment with sugar solution of different concentrations.
9. Measure the length of the tube and also note the room temperature.

OBSERVATIONS:

Mass of the sugar employed =

Volume of the water taken =

Least count of the analyzer =

Length of the polarimeter tube =

Table for the Angle of Rotation

Sr. No	Position of analyzer with distilled water		Position of analyzer with sugar solution		Mean θ in degrees
	Clock wise rotation θ_1	Anticlock wise rotation θ_2	Clock wise rotation $\theta_1^{'}$	Anticlock wise rotation $\theta_2^{'}$	$\frac{1}{4}\left[\left(\theta_1-\theta_1^{'}\right)+\left(\theta_2-\theta_2^{'}\right)\right]$
1					
2					
3					

Mean = ……

RESULT:

The specific rotation of sugar solution at room temperature =

PRECAUTIONS:

1. The polarimeter tube should be well cleaned.
2. Care should be taken that there is no air bubble when the tube is filled with liquid.
3. Care should be taken in weighing sugar and measuring the quantity of water.
4. Note the temperature of the room and also the wavelength of the light used.
5. Start with a concentrated solution and then go on diluting by adding water to it.

VIVA-VOCE:

Q. 1.What do you mean by polarisation?

Q. 2.How will you distinguish between unpolarised and plane polarised light?

Q. 3.For what kind of light does this law hold.

Q. 4.What is the plane of polarization of plane polarized light obtained from a Nicol?

Q.5.What does polarization of light tells about the nature of light?

Q. 6.What is phenomenon of double refraction?

Q.7 Name the source of light used in present case.

Q.8 What is polarizer and analyzer?

ASSIGNMENT:

1. To determine polarization in a given specimen.
2. To determine specific rotation a polar molecule using same set up.

LEARNING OUTCOMES:

Student will be able to learn to determine the polarization of given specimen. He will learn about concept of polarization and use of polarizer and analyzer.

Experiment 6

BACKGROUND: For an electromagnetic beam, beam divergence is the angular measure of the increase in the radius or diameter with distance from the optical aperture as the beam emerges. By measuring the distance and diameter at two different positions, we can measure the angular divergence of a laser. You are given with a diode laser, graph paper and a scale. Using above concept, determine angular divergence of diode laser.

AIM: To study the laser beam characteristics like angular divergence and aperture.

APPARATUS: A laser source (0.5m W), optical bench, scale, marker and screen.

FORMULA USED: The angular divergence of laser beam can be calculated using

$$\theta = \frac{\left[D_2^2 - D_1^2\right]^{1/2}}{L} \times \frac{180}{\pi} \text{ degree}$$

where D_1 and D_2 are the diameters of spot at 1st and 2nd position respectively. L is the distance between 1st and 2nd positions.

Aperture of laser beam = $N_1 \text{Sin}\theta$, Where N_1 is the refractive index of medium through which laser light travels.

THEORY: Ordinary light sources emit light in all directions because an ordinary light is non-directional in nature and intensity of this light decreases with increasing distance. Laser beam is unidirectional in nature and slightly diverges through medium. Hence it is characterized by extremely low divergence. For an electromagnetic beam, divergence is the angular measure of the increase in the radius or diameter with distance from the optical aperture as the beam emerges. When a laser beam is allowed to fall on a screen then a circular bright spot is observed on the screen and if screen is moved towards the source then size of the spot decreases and if screen is moved away from the source then size of the spot increases. We can calculate the divergence of a beam if the beam diameters at two separate positions, and the distance (L) between these positions are known.

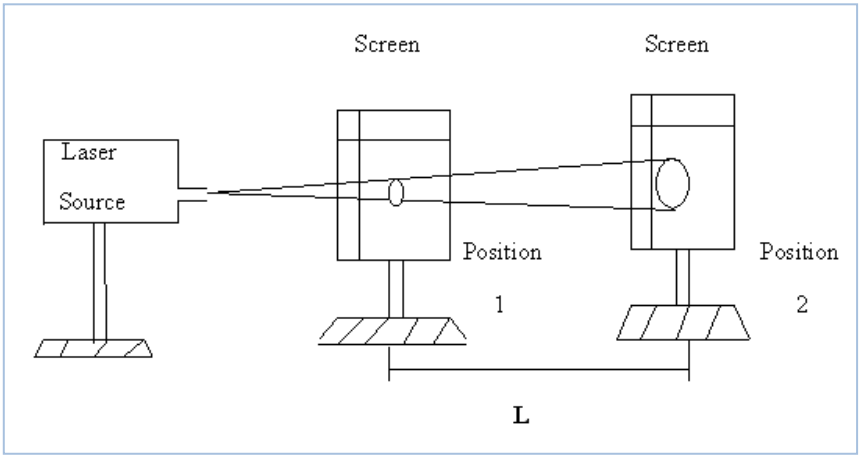


Figure 1: Illustrate the arrangement of the experiment

PROCEDURE:

1. Place the laser source on an upright of an optical bench
2. Place the screen on another upright at a distance of about 40 cm.
3. Switch on the laser source. A laser beam coming from the source forms a circular bright spot (red color) on the screen
4. Measure the size of the spot on the screen. This position is leveled as '*a*' and diameter of spot is leveled as D_1.
5. Now move the screen away from the source to about 100 cm. Again measure the size of the spot. This position is leveled as '*b*' and diameter of spot is leveled as D_2.
6. Note down the distance between the two positions, i.e., $L = b - a$.
7. Repeat the experiment at least 3 times at different positions of '*a*' and '*b*' and record the observation table.
8. Using above data calculate the angular divergence θ.
9. Calculate aperture of laser beam by taking N_1 as refractive index of air.

OBSERVATIONS:

S. No.	Ist position of spot a (cm)	Diameter of 1st spot D_1 (cm)	2nd position of spot b (cm)	Diameter of 2nd spot D_2 (cm)	$L = b - a$ (cm)	$\theta = \frac{\left[D_2^2 - D_1^2\right]^{1/2}}{1} \times \frac{180}{\pi}$ degree
1.						
2.						
3.						

Mean θ = …. degrees

CALCULATIONS: The angular divergence of laser beam can be calculated using formula,

$$\theta = \frac{\left[D_2^2 - D_1^2\right]^{1/2}}{L} \quad \text{radian}$$

$$= \ldots\ldots\ldots\ldots \times \frac{180^0}{\pi} \text{degree} \quad (\pi = 3.14)$$

$$= \ldots\ldots\ldots\ldots\ldots\ldots \text{degrees}$$

Aperture of laser beam = N_1 Sin θ, where N_1 is refractive index of air.

RESULTS: The angular divergence of laser beam is …… degrees

The aperture of beam is …….cm

PRECAUTIONS:

1. Do not look directly at laser beam because it is hazardous to the eyes.
2. The laser source is to be switched off after taking observations.
3. The diameter of laser beam to be accurately measured.
4. The distances are to be measured accurately.

VIVA-VOCE:

Q.1 What do you mean by laser?

Q.2 What is the difference between spontaneous and stimulated emission?

Q.3 What is angular divergence?

Q.4 Define aperture of laser beam?

Q.5 Why four level laser is more preferred than three level laser?

Q.6 What type of pumping is used in gas lasers?

Q.7 What is population inversion in lasers?

Q.8 Why two level laser not possible?

ASSIGNMENTS:

1. To study angular divergence of a laser.
2. To determine aperture of a laser beam.

LEARNING OUTCOMES:

Student will learn about basic concepts about laser. He will be able to calculate the divergence, cause of divergence and aperture of laser beam.

Experiment 7

BACKGROUND: When a beam of light is incident on a plane diffraction grating which constitutes a series of equidistant slits of equal width, the light is diffracted from each slit and these diffracted beams will then interfere with each other on different points on the screen. By knowing the distances of screen-grating and interference patterns, we can determine the separation of two slits in grating. You are given with a grating of configuration 15000 lines per inch, and a diode laser as a source of light. Determine the grating element, i.e., separation of slits of this grating.

AIM: Study of diffraction using laser beam and thus to determine the grating element.

APPARATUS: A laser source (diode laser), diffraction grating (15000 lines /inch), screen with mm graph paper, power supply and optical bench.

FORMULA USED: For normal illumination the grating equation is given as

$$n\lambda = d\sin\theta$$

where n is the order of the maxima or image formed, λ is the wavelength of the light used, d is the distance between two lines of the grating or grating element. And θ is the angular position of the image measured from the normal to the grating or grating element

THEORY: When a beam of light is incident on a plane diffraction grating which constitutes a series of equidistant slits of equal width, the light is diffracted from each slit and these diffracted beams will then interfere with each other on different points on the screen.

PROCEDURE:

1. Switch on the laser.
2. Place the diffraction grating on the stand of the optical bench at some distance from the laser source.
3. A graph paper is fixed on the screen and put the screen at a suitable distance.
4. The position of the grating is moved so that the laser beam gets diffracted to give the bright spots on the graph paper fixed on the screen.
5. The position of the diffraction spots are marked on the mm graph paper with the help of fine pencil.

6. The separations of bright spots of different orders of diffractions from the central maxima are measured and the observations are tabulated as Y.
7. The distance between the diffraction grating and screen is measured as D.
8. Vary D and obtain different values of angle for ist order and 2nd order maxima.

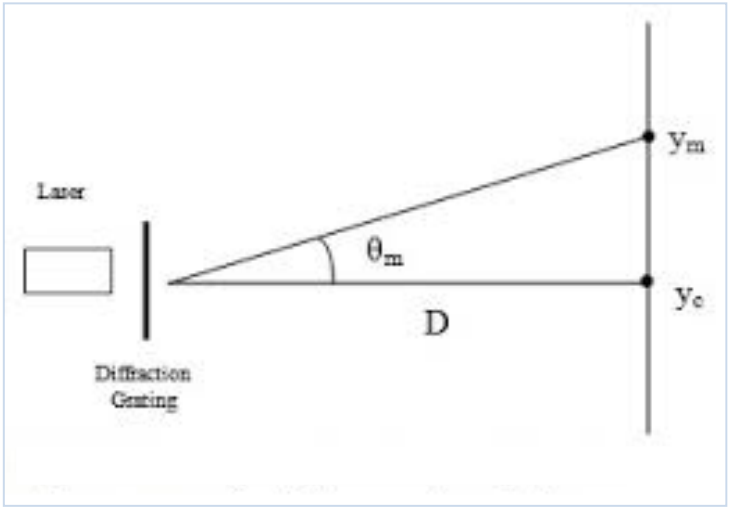


Figure 1 : Layout of the experimental set-up**.**

OBSERVATIONS:

Suppose the diffraction grating with 15000 lines /inch is used so that the distance between the two lines of the grating is d = {25.4/15000} mm = 1693 nm.

Distance between diffraction gating and the screen is D.

A) For n=1

S.N.	D (in cm)	Y_1 (in cm)		Mean Y_1	$\tan\theta_1 = Y_1/D$	$\theta_1 = \tan^{-1}Y_1/D$
		L.H.S.	R.H.S.			
1						
2						
3						
4						

Mean θ_1=

B) For n=2

S.N.	D (in cm)	Y_2 (in cm)		Mean Y_2	$\tan\theta_2 = Y_2/D$	$\theta_2 = \tan^{-1}Y_2/D$
		L.H.S.	R.H.S.			
1						
2						
3						
4						

Mean θ_2=

CALCULATIONS:

Wavelength of laser light = 669 nm (for diode laser)

By knowing *n*, θ, wavelength (λ) grating element (*d*), can be calculated by using the formula

$$n\lambda = d_1\sin\theta_1 \qquad n\lambda = d_2\sin\theta_2$$

Mean $d = (d_1+d_2)/2$ = ……. nm

Percentage error = ……..

RESULT:

1. The calculated value of the grating element = …… nm
2. The standard value of the grating element = …… nm

   Percentage error = ……..%

PRECAUTIONS:

1. Laser should be properly leveled.
2. Direct exposure to laser must be avoided.
3. The tracing of the diffraction patterns should be made accurately and with great care.
4. Distance between the screen and laser source should be measured accurately.

VIVA-VOCE:

Q.1 Explain the basic condition must for diffraction to take place.

Q.2 Why graph paper is used as screen?

Q.3 What is atomic excitation?

Q.4 What is the basic difference between ionization and excitation?

Q.5 How will you define ground state, metastable state and excited state?

Q.6 What is population inversion in lasers?

Q.7 What is the condition of constructive interference?

Q.8 What is the Bragg's diffraction?

ASSIGNMENTS:

1. To determine wavelength of a laser of given grating element.
2. To determine order of maxima in diffraction of given wavelength and grating element.

LEARNING OUTCOMES:

Students will be able to determine the wavelength of unknown laser using a standard grating element and will be able to determine grating element if laser wavelength is given. Student will also be able to determine the angle of diffraction for different gratings.

Experiment 8

BACKGROUND: In order to transmit a signal through optical fibre the light ray should strike with acceptance angle of fibre at core-cladding interface. The sine of the acceptance angle is called numerical aperture of the fibre. We have an optical fibre cable of length 1 meter and a white screen with four concentric circles of 10mm, 15mm, 20mm and 25 mm diameter. Using optical fibre trainer kit, determine the numerical aperture of given optical fibre cable.

AIM: To determine the numerical aperture and acceptance angle of a short-range optical fibre.

APPARATUS: An optical fibre cable, optical fibre trainer board, numerical aperture jig white screen and connecting wires.

FORMULA USED : The numerical aperture (NA) of the optical fibre can be calculated using formula, *i.e.*,

$$\textbf{Numerical Aperture} = \textbf{Sin}\theta_0 = W/(4L^2+W^2)^{1/2},$$

where θ_0 is the acceptance angle of incidence at the input end of the optical fibre, L, is the distance of the screen from the fibre end and W is the diameter of the spot.

THEORY: Numerical aperture of an optical fibre is defined as the light gathering ability of the fibre. Numerical aperture also refers to the maximum angle at which the light incident on the fibre end is totally internally reflected and is properly transmitted along the fibre. The cone formed by the rotation of this angle along the axis of the fibre is the cone of the acceptance of the fibre. The light ray should strike the fibre end within this cone of acceptance otherwise it is refracted out of the fibre. Numerically, it is also defined as the sine of the acceptance angle.

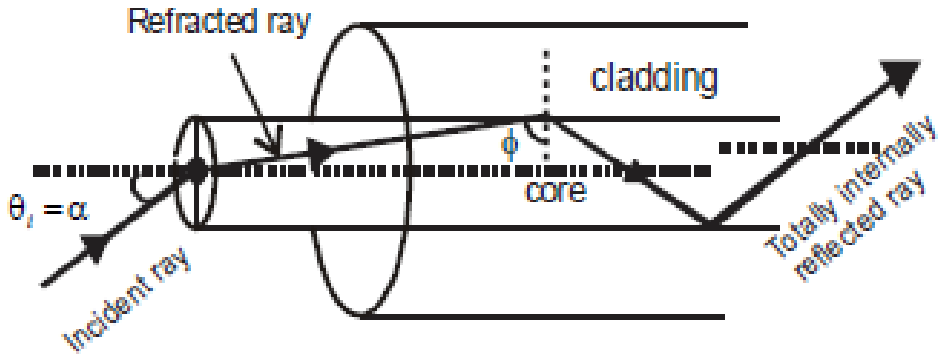


Figure 1 Propagation of signal through optical fibre.

PROCEDURE:

1. Make all the connections as shown in the circuit diagram.
2. Connect one end of the optical fibre cable to the optical fibre trainer and other end to the numerical aperture jig.
3. Hold the white screen with four concentric circles (10, 15, 20 and 25 mm diameter) vertically at a suitable distance to make the red spot emitted from the optical fibre coincide with the 10 cm circle. Note that the circumference of the spot (outermost) must coincide with the circle.
4. Record L, the distance of the screen from the fibre end and note the diameter (W) of the spot.
5. Compute the numerical aperture (NA) of the optical fibre by using the formula

$$\mathbf{NA = Sin\theta_0 = W/(4L^2+W^2)^{1/2},}$$

where θ_0 is called as the acceptance angle is the maximum angle of incidence at the input end of the optical fibre so that he optical ray can just propagate within the optical fibre.

6. Tabulate the reading and repeat the experiment for 15 mm, 20 mm and 25 mm diameter too.
7. In case the fibre is under filled, the intensity within the spot may not be evenly distributed. To ensure even the distribution of light within the optical fibre first remove the twists in the fibre cable.

OBSERVATIONS:

Sr. No.	L (mm)	W (mm)	NA = $W/(4L^2+W^2)^{1/2}$	$\theta_0 = \text{Sin}^{-1}$ (NA).
1				
2				
3				

RESULT:

1. The average value of the numerical aperture of optical fibre is = ……
2. The average value of the acceptance angle of optical fibre is = ……

PRECAUTIONS:

1. The optical fibre cable should be free from twists and folds so as to avoid the power loss.
2. Connections should be proper and tight.
3. The average value of numerical aperture for short range optical fibre should lie in the range. 0.3 to 0.5, whereas for long range optical fibre should lie in the range. 0.1 to 0.3.

VIVA-VOCE:

Q.1 What do you mean by refractive index?

Q.2 What is difference between reflection and refraction?

Q.3 What is the basic principle of propagation of light in an optical fibre?

Q.4 What are the various conditions for TIR to take place?

Q.5 Define critical angle and name the two types of optical fibres?

Q.6 What are the applications of optical fibres?

Q.7 What is the importance of V-number in optical fibre?

Q.8 How you can distinguish between single mode and multimode fibre on the basis of core diameter?

ASSIGNMENT:

1. To determine distance between transit end and screen of given numerical aperture.
2. To determine diameter of given numerical aperture.

LEARNING OUTCOMES:

Student will learn about basics of optical fibre, *i.e.*, how to calculate numerical aperture (light gathering ability) of an optical fibre.

Experiment 9

BACKGROUND: The basic principle responsible for propagation of optical signals within the optical fibre is total internal reflection (TIR). As when bending is done, the angle of incidence at the core-cladding interface is less than critical angle and signal will be lost in the cladding due to refraction. This in turn leads to the loss of the optical power, which is defined as the attenuation of the optical signals. Suppose we have to send a signal between two places in a building. Firstly send the signal through fibre, when it is straight and secondly send the signal when the fibre cable is helical in structure. Determine how much signal is lost in this process.

AIM: To study the signal loss due to attenuation in an optical fibre.

APPARATUS: Optical fibre trainer board, optical fibre cable, connecting wires, CRO and a cylindrical solid.

FORMULA USED: The attenuation loss in an opitcal fibre

$$V_1/V_2 = e^{-\alpha (L_1 + L_2)}$$

where, V_1 is input voltage, V_2 is attenuated voltage, α is the loss in dB/Km.

L_1 = length of one (small or large) cable before bending

L_2 = length of one (small or large) cable after bending

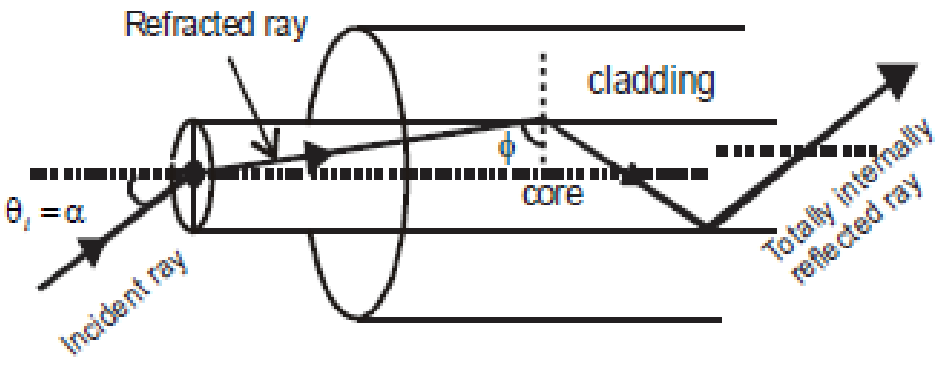


Figure 1: Total internal reflection taking place at core-cladding interface**.**

THEORY: Attenuation is the loss of power. The basic principle responsible for propagation of optical signals within the optical fibre is total internal reflection (TIR). As least losses are there with in the optical fibre due to TIR, but some unavoidable losses are there which always appear in the optical fibres, e. g., Attenuation loss depends upon the geometry of the fibre propagation loss depends on the length of fibre. There are number of ways of observing attenuation loss within the optical fibre, presently used method is the bending of the optical fibre cable. As when bending is done, the angle of incidence at the core-cladding interface is less than critical angle and signal will be lost in the cladding due to refraction. This in turn leads to the loss of the optical power, which is defined as the attenuation of the optical signals. Optical fibre loss is usually specified in 1dB/km for small core optical fibre to 2000 dB/km for large core optical fibre. Loss is by definition is negative decibles.

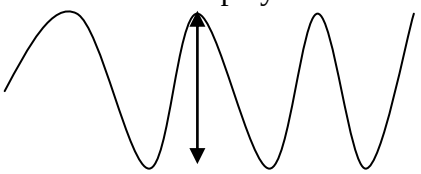
PROCEDURE:

1. Connect power supply to board.
2. Make the following connections
3. Switch on the power supply.
4. set the oscilloscope channel 1 to 0.5 volt/division and adjust the amplitude to appreciable level.
5. Observe the output signal from detector on CRO and name it V_1.
6. Now bend the optical fibre on a cylindrical block and again record the output voltage on CRO and note it as V_2.
7. For bending loss (attenuation loss) L_1=L_2 = 0.5 or 1.0 m.
8. Where as in case of propagation loss no bending is done only we vary the optical fibre cables of two lengths.

OBSERVATIONS:

CRO display

input signal →



Input signal voltage (V_1) = ----- volts

Output signal voltage (V_2) = ----- volts output signal →

L_1 = -------- meters

L_2 = -------meters

CALCULATIONS:

For the calculation of attenuation and propagation loss use the formula

$$V_1/V_2 = e^{-\alpha (L_1 + L_2).}$$

RESULT:

The calculated value of attenuation co-efficient is = -……dB/km

PRECAUTIONS:

1. The bending should not be done randomly. It should be on the cylindrical mandrel to avoid damage of the core of the optical fibre.
2. The observations on the CRO should be taken accurately.

VIVA-VOCE:

Q.1 Why we call an optical fiber as optical fiber?

Q.2 How can we control the loss within the optical fiber?

Q.3 What is basic difference between attenuation and dispersion?

Q.4 Give various means of signal loss with in an optical fibre.

Q.5 List three applications of optical fibre.

Q.6 What is intramodal and intermodal distortion?

Q.7 Can we use optical fibre as sensor for temperature or pressure? How?

Q.8 How to convert signal loss from neper per meter to dB/km?

ASSIGNMENT:

1. To determine attenuation & propagation loss in an optical fibre.
2. To determine length of an optical fibre of known attenuation.

LEARNING OUTCOMES:

Students will learn to calculate the attenuation loss in optical fibre and will also study about the possible causes of attenuation in optical fibre.

Experiment 10

BACKGROUND: Hall Effect is an important tool to characterize the materials especially semiconductors. It directly determines both the sign and density of charge carriers in a given sample. If value of Hall coefficient is negative, the charge carriers are electrons and it represents a n-type semiconductor. If value of Hall coefficient is positive, the charge carriers are holes and it represents a p-type semiconductor. You are given with a semiconductor material, using above concept determine Hall coefficient and number density of charge carriers.

AIM: To determine the Hall coefficient and the carrier concentration in a given semiconductor sample.

APPARATUS: Hall Probe (Ge Crystal), Hall effect set-up, electromagnet, constant current power supply, gauss probe and digital gauss meter,

FORMULA USED: Hall coefficient (R_H) can be calculated using relation

$$R_H = \frac{V_H\, t}{I\, B}$$

Where V_H is Hall voltage, B is applied magnetic field, I is amount of electric current flowing through material, t is the thickness of sample. Hall coefficient is related to carrier concentration (n) by the relation,

$$R_H = 1/ne$$

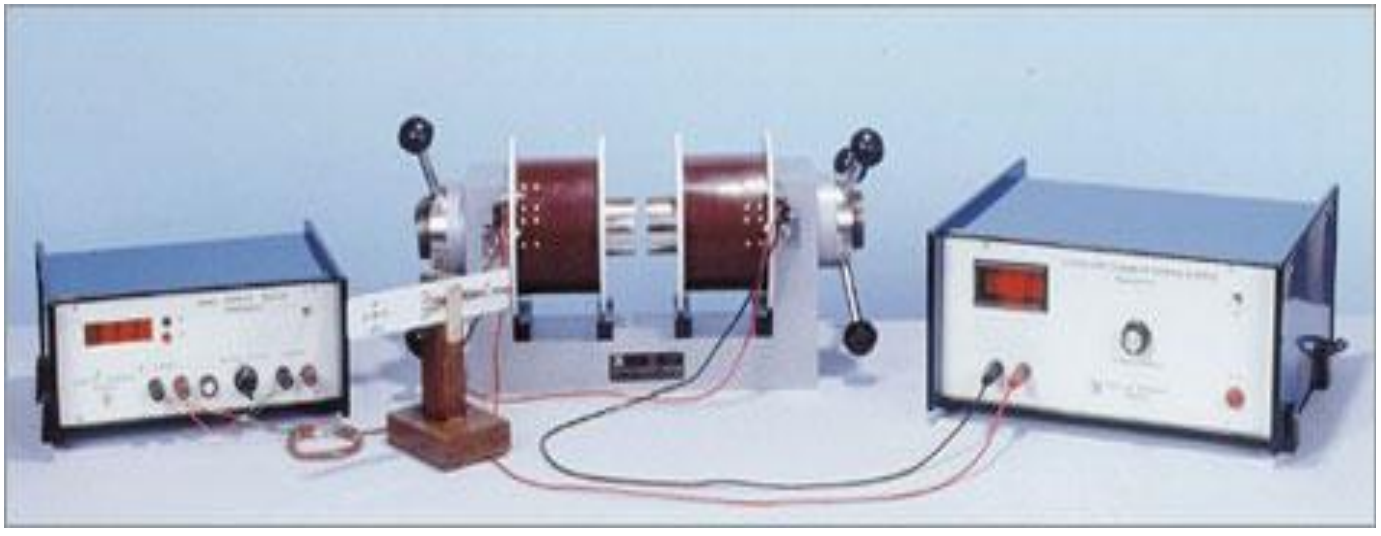


Figure 1 Experimental set up

THEORY: If a current carrying conductor placed in a perpendicular magnetic field, a potential difference will generate in the conductor which is perpendicular to both magnetic field and current. This phenomenon is called Hall Effect. In solid state physics, Hall effect is an important tool to characterize the materials especially semiconductors. It directly determines both the sign and density of charge carriers in a given sample.

Consider a rectangular conductor of thickness ***t*** kept in XY plane. An electric field is applied in X-direction using Constant Current Generator (CCG), so that current ***I*** flow through the sample. If ***w*** is the width of the sample and ***t*** is the thickness. There for current density is given by

$$J_x = I/wt \qquad (1)$$

If the magnetic field is applied along negative z-axis, the Lorentz force moves the charge carriers (say electrons) toward the y-direction. This results in accumulation of charge carriers at the top edge of the sample. This set up a transverse electric field $\mathbf{E_y}$ in the sample. This develop a potential difference along y-axis is known as Hall voltage $\boldsymbol{V_H}$ and this effect is called Hall Effect.

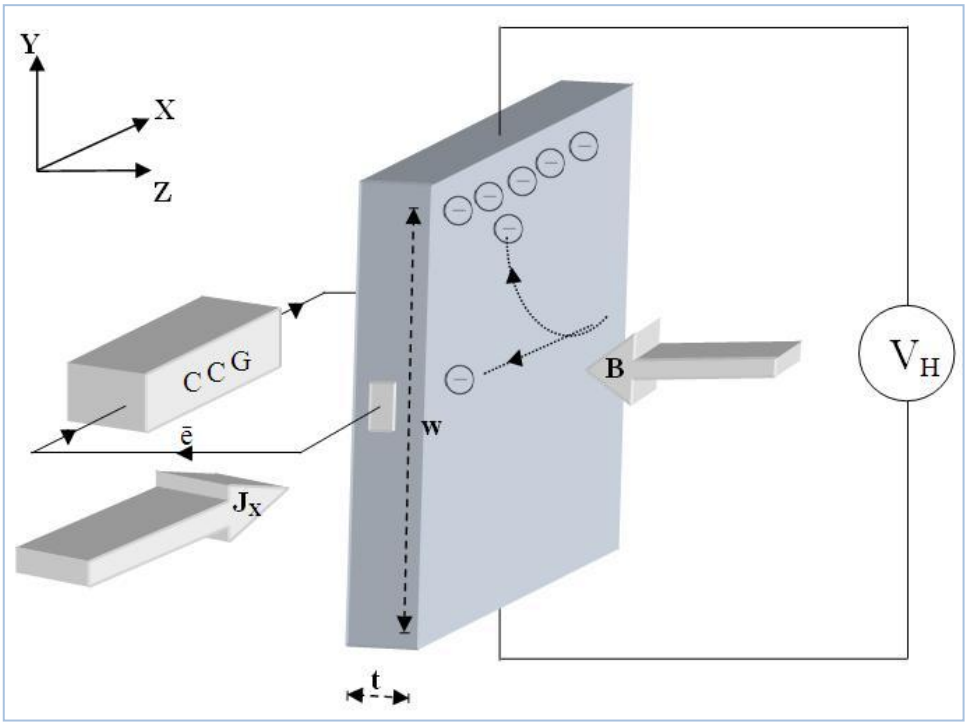


Figure 2 Schematic representation of Hall Effect in a conductor.

CCG – Constant Current Generator, $\boldsymbol{J_X}$ – current density, $\bar{\boldsymbol{e}}$ – electron, ***B*** – applied magnetic field, ***t*** – thickness, ***w*** – width, $\boldsymbol{V_H}$ – Hall voltage

A current is made to flow through the sample material and the voltage difference between its top and bottom is measured using a volt-meter. When the applied magnetic field B=0,the voltage difference will be zero. We know that a current flows in response to an applied electric field with its direction as conventional and it is either due to the flow of holes in the direction of current or the movement of electrons backward. In both cases, under the application of magnetic field the magnetic Lorentz force, $F_m = q(v \times B)$ causes the carriers to curve upwards. Since the charges cannot escape from the material, a vertical charge imbalance builds up. This charge imbalance produces an electric field which counteracts with the magnetic force and a steady state is established. The vertical electric field can be measured as a transverse voltage difference using a voltmeter.

In steady state condition, the magnetic force is balanced by the electric force. Mathematically we can express it as

$$eE = evB \qquad (2)$$

Where '*e*' the electric charge, '*E*' the Hall electric field developed, '*B*' the applied magnetic field and '*v*' is the drift velocity of charge carriers.

And the current '*I*' can be expressed as,

$$I = neAv \qquad (3)$$

Where '*n*' is the number density of electrons in the conductor of length *l*, breadth '*w*' and thickness '*t*'. Using Equations (1) and (2) the Hall voltage V_H can be written as,

$$V_H = Ew = vBw = \frac{IB}{net}$$

$$V_H = R_H \frac{IB}{t} \qquad (4)$$

by rearranging Equation (4) we get $R_H = \frac{V_H\, t}{I\, B}$

where, R_H is called the Hall coefficient.

$$R_H = 1/ne$$

PROCEDURE:

1. Connect the electromagnet to power supply
2. Switch on the electromagnet power supply and increase the current up to some value
3. Ensure the zero setting of digital gauss meter.

4. Measure the corresponding value of the magnetic field by placing the detector probe between the pole pieces of electromagnet using digital gauss meter
5. Record the value of the magnetic field and switch of the gauss meter.
6. Now place the specimen in between the pole pieces and vary the Hall current and note down the corresponding value of Hall voltage.
7. Plot the graph between Hall voltage and Hall current.
8. Measure the slope fro graph and calculate the Hall coefficient and carrier concentration.

OBSERVATIONS:

Sr. No:	Hall current (mA)	Hall Voltage (mV)
1.		
2.		
3.		
4.		
5.		
6.		

Hall coefficient (R_H) can be calculated using relation

$$R_H = \frac{V_H\, t}{I\, B}$$

Where V_H is Hall voltage, B is applied magnetic field, I is amount of electric current flowing through material, t is the thickness of sample. V_H/I will be calculated from the slop of plot between V and I. Putting all the values, we can calculate the Hall coefficient.

Hall coefficient is related to carrier concentration (n) by the relation,

$$R_H = 1/ne$$

RESULT:

1. Hall coefficient of the material = ...Vm/AT
2. Carrier concentration of the material =..... m^{-3}

PRECAUTIONS*:*

1. The magnet power supply can furnish large currents at dangerous voltage levels; do not touch exposed magnet coil contacts.
2. The readings in voltmeter and ammeter should be properly noted.
3. The slop of graph should be properly measured.

VIVA-VOCE*:*

Q.1 What is Hall effect?

Q.2What is the importance of Hall coefficient?

Q.3 Distinguish between intrinsic and extrinsic semiconductors

Q.4 Distinguish between n-type and p-types semiconductor?

Q.5 What is the magnitude of force generated by electromagnet?

Q.6 How percentage error is calculated?

Q.7 What is Hall voltage?

Q.8 What is Lorentz force?

ASSIGNMENT:

1. To determine Hall coefficient of a given specimen.
2. To determine carrier concentration of a given specimen.
3. To determine the given specimen thickness.

LEARNING OUTCOMES:

Student will learn about Hall Effect, Hall voltage and charge carriers. He will be able to distinguish between different types of semiconductors on the basis of Hall coefficient.

Experiment 11

BACKGROUND: In the case of light emitting diodes (LEDs) if an electron of sufficient voltage is passed across a material then a photon is emitted whose energy is equivalent to the work function of that material. The energy of the photons emitted should then be the same as the energy of a given electron. By knowing the applied voltage and frequency of emitted photons, we can determine Planck's constant. You are given with four LEDs, *i.e.*, blue, green, yellow and red. Determine the value of applied voltage and then Planck's constant.

AIM: To determine Planck's constant by using light emitting diodes (LEDs).

APPARATUS: Planck's constant kit, connecting wires, graph paper and LED's.

FORMULA USED: Planck's constant is $h = eV/\nu$, where e is electronic charge, V is voltage reading in voltmeter, ν is the frequency of LED color.

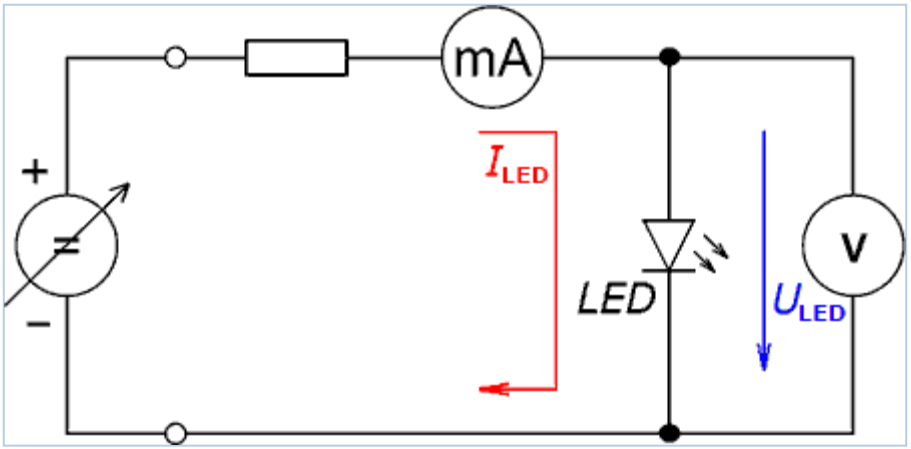


Figure 1: Circuit diagram of Planck's constant set up

THEORY: The energy of a photon is given by the equation:

$$E = h\nu \qquad (1)$$

Where E is the energy of photon, ν is its frequency, and h is a constant. In the case of the photoelectric effect, an electron is emitted from a metal if the energy of the photon is greater than the work function of the metal. If the energy of said photon is greater than the work function of a given material, the electron emitted possesses a voltage, which equals the difference in these energies. In the case of an LED's the opposite is true. If an electron of sufficient voltage is passed across a material then a photon is emitted whose energy is equivalent to the work function of that material. The voltage at which this effect observed is

the 'turn on voltage'. This effect is not normally observed in metals and other typical substances because the photons emitted are usually outside the range of visible light, usually somewhere in the infrared. The energy of the photons emitted should then be the same as the energy of a given electron. The energy of one electron is the charge of an electron (*i.e.* the current flow of one electron per second in amps) times the voltage. Using this knowledge we can define energy as:

$$E = eV \qquad (2)$$

Where, $e = 1.6 \times 10^{-19}$ C (electron charge). From Equations (1) and (2) we have,

$$eV = h\nu$$

$$h = eV / \nu \qquad (3)$$

This equation we will use to determine Planck's constant.

PROCEDURE:

1. Make the connection in the kit as shown in the figure 1.
2. Take the current measurement of each LED by varying the voltage as given in the table.
3. Plot the curve on the graph paper between frequency on X axis and energy on Y axis.
4. The linear portion of the curve is extra plotted back to the X axis. The slope of curve will give measured value of Planck's constant.
5. Compare the measured value with standard value and determine percentage error.

OBSERVATIONS:

Sr. No.	LED Color	Voltage V [volts]	Wavelength λ [nm]	Frequency (ν) [Hz]	Energy [J] = eV	Planck's constant $h = eV/\nu$
1	Blue		475			
2	Green		510			
3	Yellow		570			
4	Red		650			

CALCULATION: Planck's constant is $h = eV / \nu$, where $e = 1.6 \times 10^{-19}$ C (electron charge)

RESULT: Observed value of Planck's constant (h) from graph is =……Js.

Percentage error = ……%

PRECAUTIONS:

1. Some noise may be created in the system during experiment which can be minimized by immersing the diode in the ice during experiment [if available].
2. Connect the LED properly to jack provided on front panel.
3. The reading of voltmeter should be measured accurately. The plot should be properly plotted and interpreted.

VIVA-VOCE:

Q.1. Define Photoelectric effect?

Q.2 What is Reverse Photoelectric effect?

Q.3 Can we observe reverse photoelectric with Metal surface?

Q.4 What is the full form of LED?

Q.5 What is the standard value of h?

Q.6 What is the wavelength of red and blue color?

Q.7 How percentage error is calculated?

Q.8 Who discovered photon?

ASSIGNMENTS:

1. To determine stopping voltage of given LEDs.
2. To determine wavelength of given LEDs.

LEARNING OUTCOMES:

Student will be able to determine the Planck's constant value from different types of LEDs. He will have understanding of photoelectric effect.

Experiment 12

BACKGROUND: A ferromagnetic material is magnetized by placing it in the solenoid. The domains in ferromagnetic material get aligned in the direction of solenoid field. When the field value is reduced to zero, certain induced magnetic field remains within the ferromagnetic material called retentivity. The amount of external filed required to destroy retentive field is called coercivity of material. You are given with a ferromagnetic specimen, determine the retentivity and coercivity and draw B-H curve to find the energy loss in magnetization of material per cycle.

AIM: To draw the B-H curve of a given magnetic material and to find the retentivity and coercivity of the material.

APPARATUS: Two solenoid coils, ferromagnetic specimen rod, reversible key. Ammeter, magnetometer, solenoid. Rheostat and transformer for demagnetizing set-up.

FORMULA USED: Maximum value of magnetic field in solenoid can be calculated as

$$H_{max} = \{4\sqrt{2}\pi \, n \, I_{rms}\}/10$$

Hysteresis loss per unit volume per cycle = $1/4\pi \times$ (area of B-H loop)

THEORY: A ferromagnetic rod is magnetized by placing it in the magnetic field of a solenoid. The magnetized rod causes a deflection (θ) in the magnetometer. The deflection θ is recorded as the current in the solenoid (I) is varied over a range of positive and negative values.

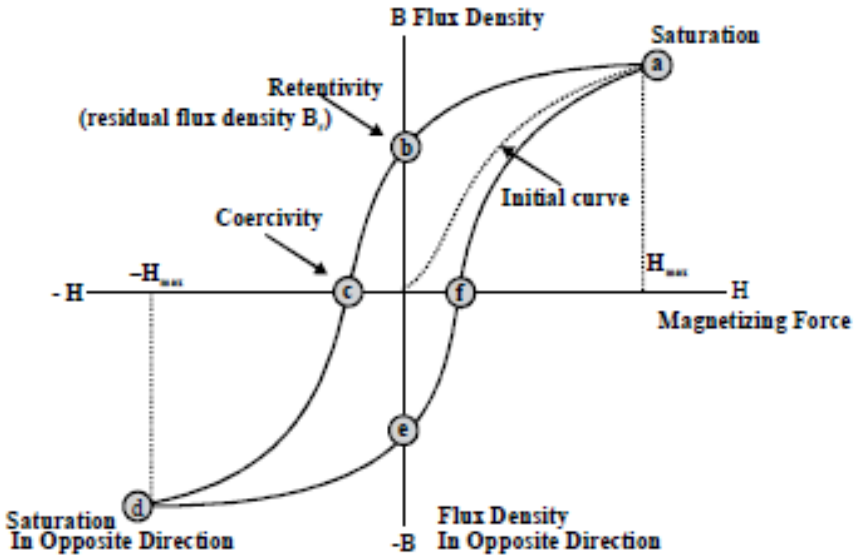


Figure 1 BH curve for a ferromagnetic material.

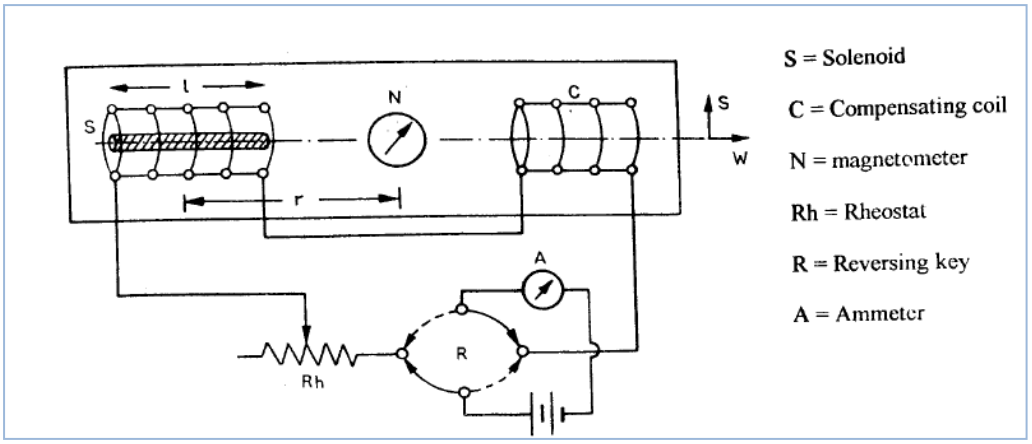


Figure 2 Circuit diagram of experimental set up.

PROCEDURE:

1. Complete the wiring of the apparatus according to the circuit diagram.
2. Alignment of apparatus, i.e. rotate the dial of the magnetometer until 0^o-0^o position is aligned with the axis of the solenoid. In this position the wooden arm is along the E – W position. The horizontal component of earth's magnetic field B_E (along S-N direction) is then perpendicular to the wooden arm.
3. Take the measurement of specimen with the help of screw gauge.
4. Find the value of H_{max} using the above mentioned relation.
5. Draw B-H curve on CRO and trace it using tracing paper.

6. Measure the value of L_X and L_Y.
7. Measure the value of ob and oc as is mentioned in figure.
8. Calculate hysteresis loss per unit volume per cycle.

OBSERVATIONS:

Diameter of the primary of the solenoid=

Radius of the primary of solenoid=

Radius of specimen=

Total no. of wires=

Total area of cross-section=

No. of turns per cm of solenoid=

Y- Amplification factor=

Length of vertical line *h* =

Current in the primary, I_{rms}=

CALCULATIONS:

$$H_{max} = \{4\sqrt{2}\pi \text{ n } I_{rms}\}/10$$

From B-H loop, breadth of B-H loop, L_x =

Calibration constant for H axis, $K_x = 2\ H_{max}/L_x$

Height of B-H loop, L_Y=

Calibration constant for B axis, $K_y = \{2H_{max}\pi R^2 \mu\}/\ hA$

Saturation value of magnetic induction=$1/2K_yL_y$

Retentively = OB × K_y

Coercivity = OC × K_x

Hysteresis loss per unit volume per cycle= $1/4\pi$ × (area of B-H loop)

RESULT:

Hysteresis loss per unit volume per cycle =

PRECAUTIONS*:*

1. The magnet power supply can furnish large currents at dangerous voltage levels; do not touch exposed magnet coil contacts.
2. The BH-curve should be drawn correctly.
3. Measurement of coercivity and retentivity should be measured using graph paper.

VIVA-VOCE:

Q.1 What do you mean by non-linear relationship between B and H?

Q.2 What is the importance of B-H curve?

Q.3 What is coercivity and retentivity?

Q.4 What are hard and soft ferromagnetic materials?

Q.5 Why hysteresis curve is formed?

Q.6 What are magnetic domains?

Q.7 What is the importance of BH curve?

Q.8 Which type of material is used for memory storage?

ASSIGNMENT:

1. To determine B-H curve for different materials.
2. To determine the loss due o magnetization in different materials.
3. To determine the B-H curve for paramagnetic materials.

LEARNING OUTCOMES:

Student will learn about characteristic of magnetic materials.He will be able to determine coercivity and retentivity of material and select a material for particular application.

Experiment 13

BACKGROUND: To study the variation of magnetic field with distance along the axis of a circular coil carrying current by Stewart and Gee's method plotting a graph.

APPARATUS: Stewart and Gee's type tangent galvanometer, a battery, rheostat, ammeter, one-way key, reversing key, connecting wires.

DIAGRAM:

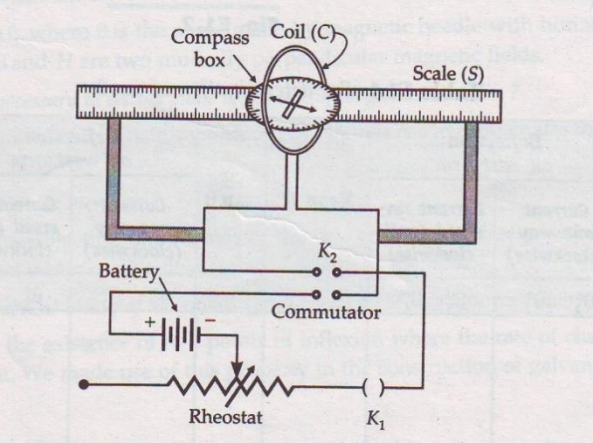


Figure 1: Circuit Diagram

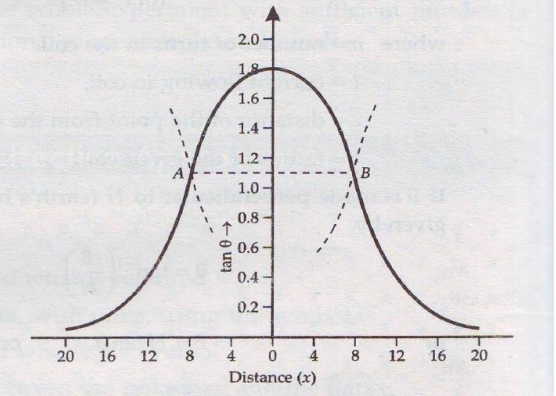


Figure 2: Variation of tan θ vs x

THEORY: The intensity of magnetic field at a point on the axis of a circular coil of radius a having n turns at a distance x from the centre of the coil, in S.I. units is given by

$$B = \frac{\mu_o}{4\pi} \frac{2\pi NIa^2}{\left(x^2+a^2\right)^{3/2}}$$

where I is the current in amperes flowing through the coil. If the field B is perpendicular to horizontal component of earth's field B_H and is the deflection produced in a deflection magnetometer, then

$$B = B_H \tan\theta$$

or

$$B \propto \tan\theta$$

Hence a graph between tan θ and x will be similar to the graph between B and x.

To study the magnetic field of a circular coil , Stewart Gee's type tangent galvanometer can be used. It has a magnetic compass needle pivoted at the centre of a circular compass box. The needle itself is non-magnetic but it has a small permanent bar magnet attached to it at right angles, as shown in **fig1.** There is a coil mounted in a plane, perpendicular to that of the compass box.

One can first align the instrument according to horizontal component B_H of the Earth's magnetic field and then pass current through the coil. Now the magnetic field of the coil (B) and horizontal component of the Earth's field (B_H) get related through the condition $B = B_H \tan \theta$. By sliding the compass box on the horizontal scale, the distance x can be varied and its effect for a constant value of current (I) through the coil can be studied.

PROCEDURE:

1. Place the instrument on a lab table in such a way that the arms of the magnetometer lie roughly in east west direction and the compass box is at the centre of the vertical coil. Rotate the instrument in the horizontal plane till the needle and its image in the mirror provided at the base of the compass box all lie in the same vertical plane. The coil is then set roughly in the magnetic meridian. Now rotate the compass box so that the aluminum pointer lies at the 0-0 line.
2. Now connect the galvanometer to a battery through a rheostat, a one way key K_1 an ammeter and a reversing key K_2 as shown in **fig1.** Use a 3-6 V low current DC source otherwise.
3. Adjust the current so that the deflection in the magnetometer is 60^o-70^o. Reverse the current and again note the deflection. If the in the two cases is nearly the same, the coil lies exactly in the magnetic meridian. Otherwise slightly turn the instrument till the deflection with the direct and reversed currents is almost the same.
4. Slide the compass box along the axis i.e. on the horizontal scale so that the maximum deflection is obtained. In this position the centre of the needle coincides with the centre of the vertical coil. Note the position of the arm against the reference mark P and the corresponding value of the current. Read both ends of the pointer in the magnetometer. Reverse the current using reversing key and again read both ends.
5. Shift the compass box magnetometer by 2cm and again note the reading of the magnetometer keeping the current constant at the same value both for direct and reversed current, in this position the centre of the magnetic needle lies at a distance of 2cm from the centre of the vertical coil.

6. Take a number of observations by shifting the compass box magnetometer in steps of 2 cm.
7. Repeat the observations by shifting the magnetometer in the opposite direction and keeping the current constant value.

OBSERVATIONS: Current = …….A

No.	Distance from the centre x	Left Side (P)				Mean θ	Tan θ	Right Side(Q)				Mean θ	Tan θ
		Direct		Reverse				Direct		Reverse			
		1	2	3	4			1	2	3	4		
1.													
2.													
3.													
4.													
5.													
6.													
7.													
8.													

RESULT:

(i) Intensity of the field is maximum at 0. If we move away from 0 towards the right or left, the intensity of the magnetic field decreases. The curve is first concave towards 0 but the curvature becomes less and less, quickly changes sign at P and Q and afterwards becomes convex towards 0. The points of inflection P or Q where the curvature changes its sign lie at distance r/2 from the centre. Hence the distance between P and Q is radius of the coil.

(ii) The distance where the field due to the coil becomes equal to horizontal component due to earth's magnetic fields can be determined from the graph between θ and x for tan θ = 1 Therefore

$$B = B_H = \_\_\_\_\_$$

(iii) The radius of the coil is given by PQ = _____

PRECAUTIONS:

1. No magnetic substances or current carrying conductors should be there near the apparatus.
2. The plane of the coil should be set vertical and in the magnetic meridian.
3. The current should be kept constant and should be reversed for each observation.

4. While setting the eye should be placed in such a way that the pointer covers its image in the mirror below to avoid any error due to parallax.

VIVA-VOCE:

1. What are the various components of a battery eliminator? Mention their working.
2. What is the role of rheostat in this experiment?
3. Why do we require zero alignment and zero adjustment in this apparatus?
4. Define point of inflection both mathematically as well as graphically.
5. Is the magnetic field uniform at the center? How will you obtain a wider region of uniform magnetic field?
6. Why do we not use the vertical component of earth's magnetic field in this experiment?
7. On which law of physics is this experiment based?
8. Why do we keep the current such that the deflection at the center of the coil is between $60^{\circ} - 70^{\circ}$?

ASSIGNMENT:

Study the variation of magnetic field using coils of different materials and different number of turns.

LEARNING OUTCOME:

Student will learn about the concept of variation of magnetic field generated by current carrying coils.