CHITKARA UNIVERSITY

EXPERIMENT 1

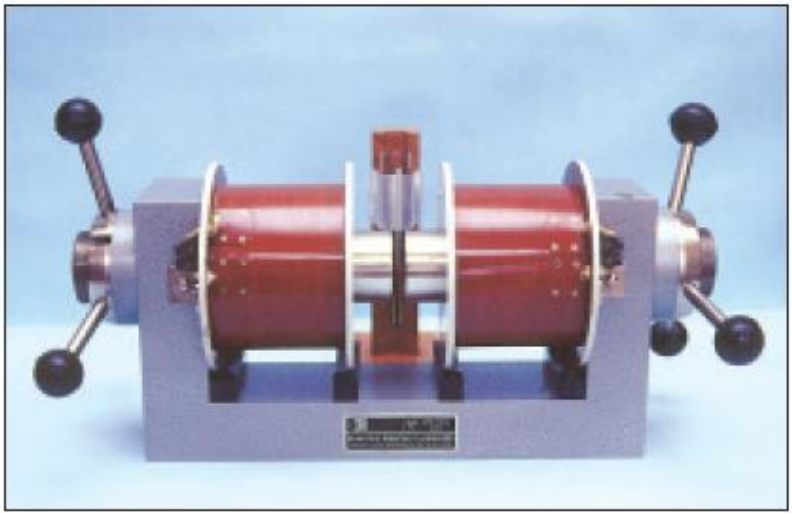
OBJECTIVE:

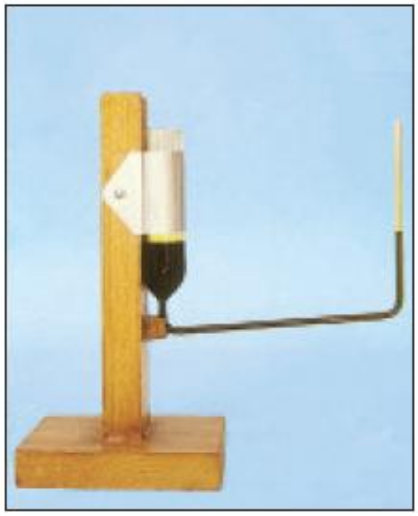
Determine the susceptibility of $FeCl_3$sample by using Quinke's method.

APPARATUSREQUIRED:

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

DIAGRAM:





PRINCIPLE AND THEORY:

If a paramagnetic salt solution (like manganese chloride) or ferromagnetic salt (like ferric chloride) is put in a tube and placed between the poles of a magnet then there is a rise 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 electrons orbital angular motion around the nucleus, and the electrons' intrinsic magnetic moment. The other sources of magnetism are the nuclear magnetic moments of the nuclei in the material which are typically thousands of times smaller than the electrons' 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. The magnetic materials are generally classified into three 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 K, 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:

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

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

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

Then the mass susceptibility of solution is given by

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

PROCEDURE:

1. Note the variation of magnetic field with current by using the Gaussmeter.
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:

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

RESULT:

Mean mass susceptibility of the solution is given by …… $m^2s^{-2}T^{-2}$.

Plot the graph between fall in height (h) versus H^2 and by using its slope value find the mass susceptibility.

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.

SOURCES OF ERROR:

1. Due to evaporation of water the results obtained are slightly less than the actual values.
2. Due to non-uniformity of the narrow limb bore, error due to surface tension may occur.
3. 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.

ORAL QUESTIONS:

1. What do you mean by magnetic materials?
2. What are paramagnetic and ferromagnetic materials?
3. Define magnetic flux density and magnetic field strength.
4. Define permeability and relative permeability.
5. What is the relation between relative permeability and magnetic susceptibility?
6. What do you mean by retentivity and coercivity?
7. Why is ferromagnetism found in solids only and not in fluids?
8. What is magnetic moment?
9. What is magnetic susceptibility?
10. What is Quinke's method?

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EXPERIMENT 2

OBJECTIVE:

Determine the value of specific charge {e/m} of an electron by Thomson Method.

APPARTUS REQUIRED:

Cathode Ray Tube (CRT) is 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;

$$\text{Specific charge } \{e/m\} = \frac{V\lambda}{ILH^2 d} \times 10^7 \text{ e.m.u./gm} \qquad \ldots(1)$$

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.)

The various parameters are:-

I = 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: FF is a filament which when heated emits electron. (control grid) carries a negative charge, so sends out a 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.

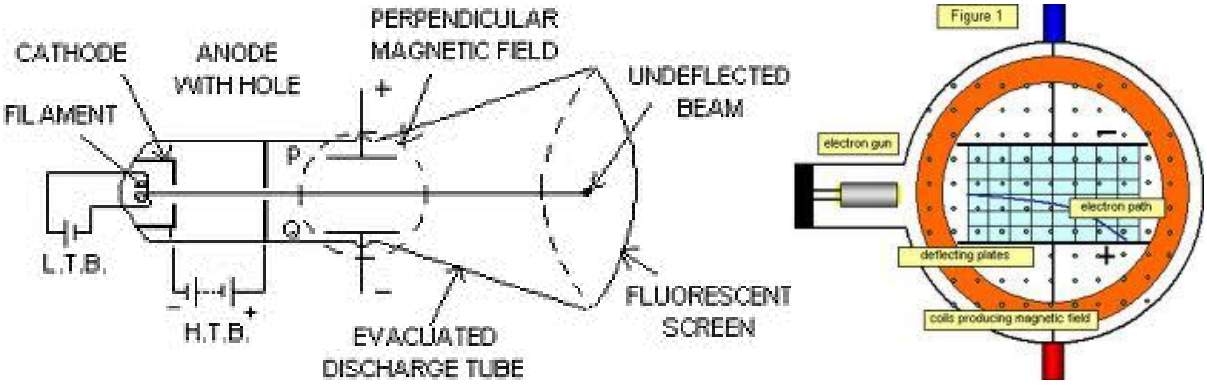

Figure: Layout of a CRT.

The value of e/m is independent 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 $1.7x10^7$ e.m.u./gm.

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 -0.2 cm. 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 0-0 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 equation (1).

11. Repeat steps 5 to 10 for other values of spot deflections.

12. Calculate mean value of e/m for different set of readings.

NOTE: For better accuracy apply deflection voltage only up to 20 volts constant of the cathode ray tubes:-

DESCRIPTION OF CRT 83SJ5:

a) Separation between the plates (d) = 1 cm

b) Length of horizontal pair of plate (I) = 3 cm

c) Distance of the screen from the edges of the plates (L) = 8.5 cm

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

OBSERVATIONS:

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

RESULT:

Mean value of specific charge {e/m} = …….emu/gm.

Standard result : e/m = 1.76×10^7 e.m.u./gm

= 1.76×10^{11} Coulomb/kg

Percentage Error = $\frac{Standard\ resut - calculated\ result}{Standard\ result} \times 100$ = …….. %

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.

ORAL QUESTIONS:

1. What is CRO?

2. Why the screen of CRT glow?

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

4. What is specific charge?

EXPERIMENT 3

OBJECTIVE:

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

APPARATUS REQUIRED:

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

THEORY:

The term **ionization energy** (E_I) 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**, and was at one stage measured in volts. 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 types. A hot cathode gas filled diode is known as phantom (or thyratron).A gas filled diode is symbolically represented as shown in fig 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.

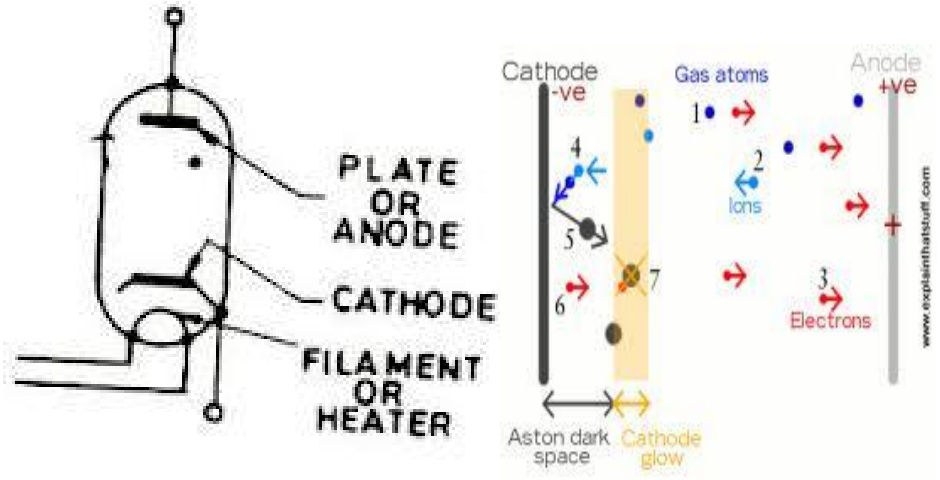

Fig 1 Mercury filled gas diode.

As the plate potential is increased the plate current slowly increases. But when the plate potential is increased beyond a particular value the plate current increases much more rapidly than it does below that critical value. This is because when the plate potential approaches this critical value the electrons arriving at the anode gain enough energy to knock out the electrons from the atom of the gas close to the anode these electrons are also attracted by the anode causing an increase in plate current and the positive ions neutralize some of the space charge, which further helps to increase the kinetic energy of

the thermal electrons. This potential is equal to the ionization potential of the gas and for this value of plate potential there is a marked increase in plate current.

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. 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 fig. 2 and make the connections accordingly.

2. Switch on the power supply and apply a suitable potential to the filament FF 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 15volts.

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 OF gives the value of the ionization potential of mercury.

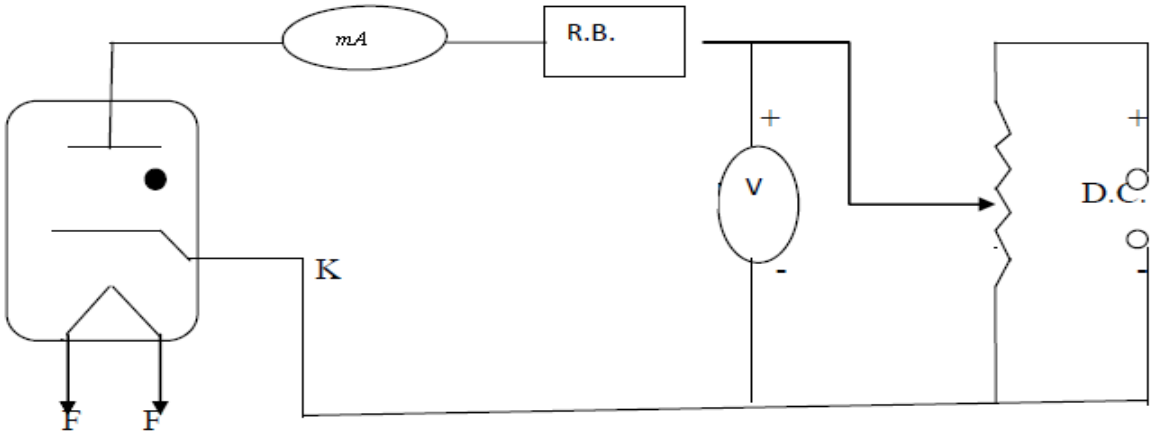

Fig. 2: Circuit diagram showing the scheme of connections.

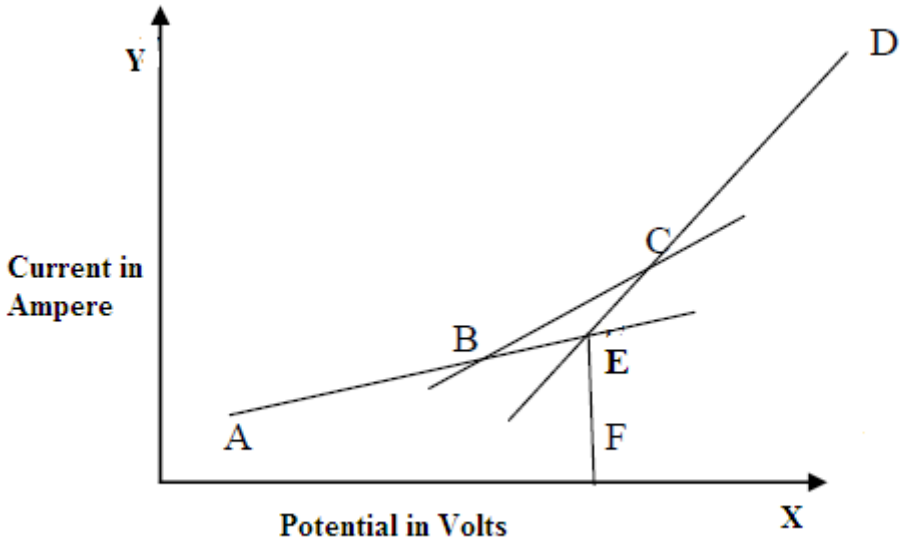

Fig 3: Variation of filament current with applied voltage.

OBSERVATIONS:

Sr.No	**Plate voltage in volts**	**Plate current in A**

1		
2		
3		
4		
5		
6		

RESULT:

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

Standard value of ionization potential = 10.43 V

Percentage error = $\frac{Standard\ resut - calculated\ result}{Standard\ result} \times 100$ = ……%

PRECAUTIONS:

1. A gas filled mercury vapour diode must be used.
2. The positive of the voltmeter as also that of the milliammeter 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 ionosation 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.
5. For accurate measurement of voltage a V.T.V.M. may be used in place of an ordinary voltmeter.

ORAL QUESTIONS:

1. What is the atomic number of mercury?
2. What is ionization potential?
3. How does gas filled diode works?
4. What is the value of ionization potential for mercury?

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EXPERIMENT 4

OBJECTIVE:

Determine the wavelength of laser light with the help of Michelson Interferometer.

APPARATUS REQUIRED:

Michelson Interferometer, Laser source etc.

THEORY:

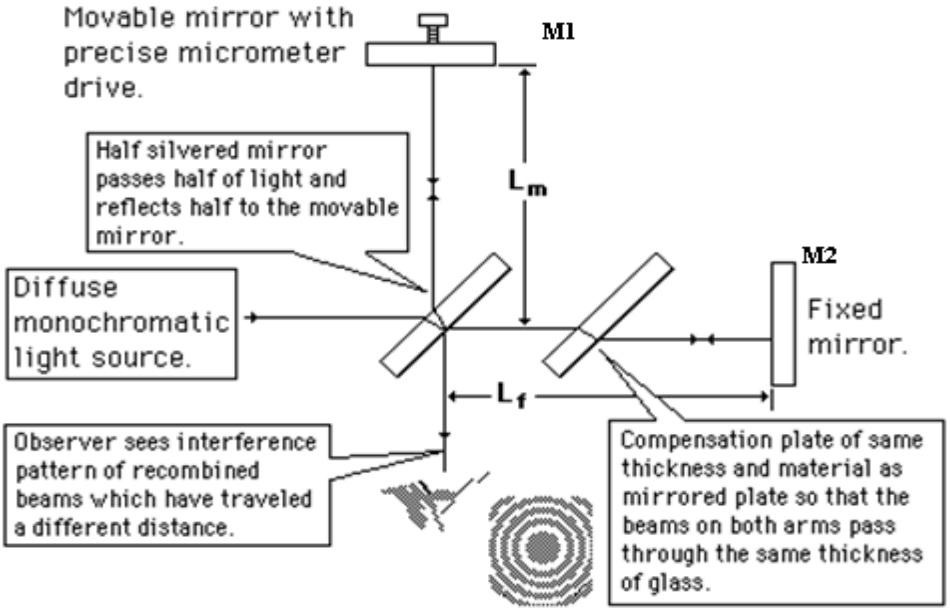
The Michelson interferometer uses light interference to measure distances in units of the wavelength of light from a particular source. It was developed by Albert Michelson in 1893 to measure the standard meter in units of the wavelength of the red line in the cadmium spectrum. It is also known for its 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 (a) measure the wavelength of light from a light source, (b) measure 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. 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 and half the 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

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

Where n = 0 or a positive integer, and λ is the wavelength of the light, and *d* is the distance moved by the mirror.

The resulting image on the observation device will be a series of concentric, circular bright and dark rings. As mirror 1 is moved, the fringes will change from bright to dark etc.



FORMULA USED:

The wavelength of light is given by

$$\lambda = 2(X_2 - X_1) / N$$

Where X1 is the initial position of mirror M1 of Michelson Interferometer, X_2 is the final position of mirror M1 of Michelson interferometer after N number of fringes appeared / disappeared at the centre. N is the number of fringes appeared or disappeared at the centre when the mirror M1 moves by a distance $d = X_2 - X_1$.

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 for about 1 rotation. Then turn it in the same direction enough to see N fringes appear or disappear at the centre. N should be at least 10.

6) Note the initial and the final position.

7) Let the initial reading be X_1.

8) Let the final reading be X_2.

9) 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. $d = X_2 – X_1$.

OBSERVATIOS:

Least count = _____mm

S.No	No. of fringes moved=N	Scale reading (mm)	Distance moved=d (mm)	Wavelength = 2d/N (Å)

CALCULATIONS:

1) Calculate the wavelength using the formula λ=2d/N.

2) Calculate the mean value of wavelengths (λ) obtained from various observations.

3) Standard value of λ for laser user is 6328 Å.

4) Calculate percentage error = (calculated value – standard value / Standard value) ×100 %

RESULT:

The wavelength of light obtained = _____Å

Standard value of wavelength of light = 6328 Å

Percentage error = $\frac{Standard\ resut - calculated\ result}{Standard\ result} \times 100$ = ……%

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.

ORAL QUESTIONS:

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

2. Are two mirrors simply plane mirrors?

3. What type of glass plates are ‘G’ and ‘C’?

4. What is the role of compensatory plate ‘C’?

5. How do you get circular fringes?

6. What will you observe with white light source?

7. What are localized fringes?

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

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EXPERIMENT 5

OBJECTIVE:

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

APPARATUS REQUIRED:

Polarimeter, white light source, sugar, beakers, graduated jar, disc, weight box, balance.

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

$$S = \frac{\theta}{lc} = \frac{\theta v}{lm}$$

where, θ=rotation produced in degrees

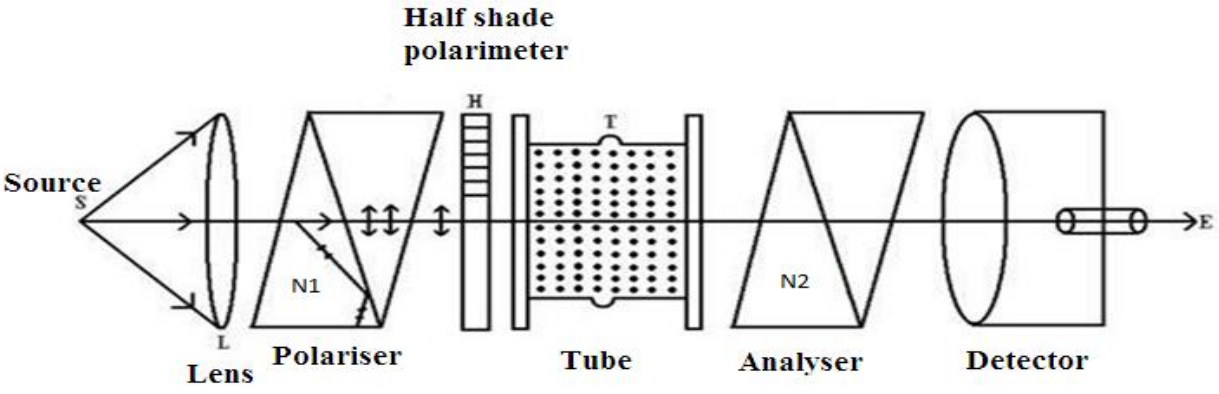
l=length of the tube in decimeter

m=mass of sugar in gms dissolved in water

v=volume of sugar solution

DESCRIPTION OF THE APPARATUS AND THEORY:

Polarimeter in general consists of a source of light a polarimeter and an analyzer provided with a graduated



circular scale. Figure represents the general optical arrangement of most polarimeters. 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. In betweenN_1 and N_2 is placed the tube T containing the liquid under investigation. 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_1canpass 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_2even 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_2has 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:

Room temperature = ….. °C

Weight of the empty watch glass =

Weight of the watch glass + sugar =

Weight 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:

(1) For 1st Solution:

S No	Position of analyzer with distilled water	Position of analyzer with sugar solution	Mean θ in degrees

	Clock wise rotation	Anticlock wise rotation	Clock wise rotation	Anticlock wise rotation	$\frac{1}{4}\left[\left(\theta_1-\theta_1'\right)+\left(\theta_3-\theta_3'\right)\right]$
	One side vernier θ_1	One side vernier θ_3	One side vernier θ_1'	One side vernier θ_3'	
1					
2					
3					

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.

ORAL QUESTIONS:

1. What do you mean by polarization of light?

2. How will you distinguish between unpolarised and plane polarised light?
3. In using a Nicol prism, light is made incident almost parallel to its oblong side. What may happen if incident light is too much convergent or divergent?
4. What is the plane of polarization of plane polarized light obtained from a Nicol?
5. What do you mean by polarised light?
6. How does polarised light differ from ordinary light?
7. What does polarization of light tells about the nature of light?
8. Define plane of vibration and plane of polarization.
9. What is phenomenon of double refraction?
10. Define optic axis and principal section.
11. What are uniaxial and biaxial crystals?
12. What do you mean by optical activity, optical rotation and angle of rotation?

EXPERIMENT 7

OBJECTIVE:

Study the angular divergence of laser beam.

APPARATUS REQUIRED:

A laser source, optical bench, screen.

FORMULA USED:

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

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.

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 directional in nature because of which the intensity of light is very large.

Laser beam is characterized by extremely low divergence. The light emitted by a laser is confined to a rather narrow cone. But, when the beam propagates outward, it slowly diverges or fans out. 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.

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 (1, 2), and the distance (*L*) between these positions are known.

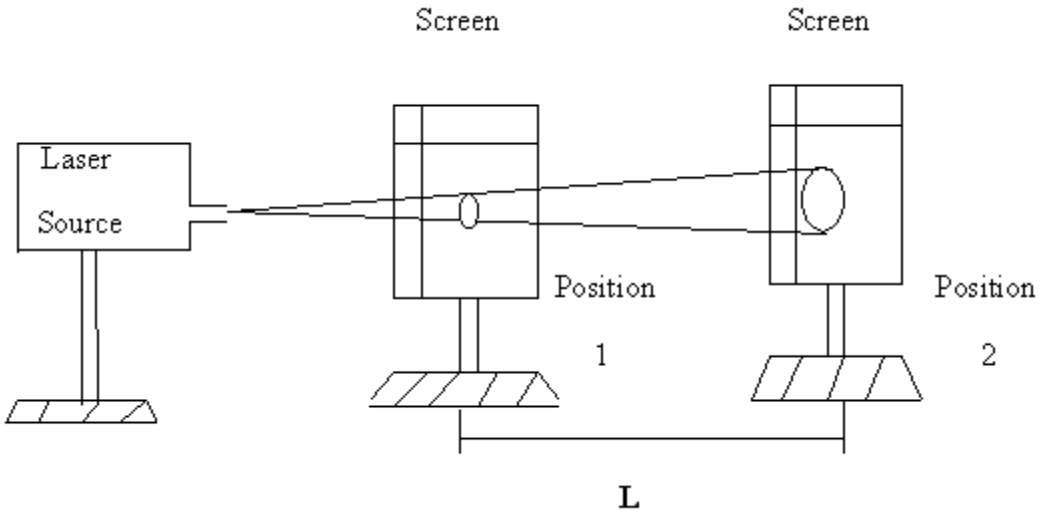


Figure. 1

Fig.1 illustrate the arrangement of the experiment in which D_1 is the diameter of the spot of laser beam at one position and D_2 is the diameter at another position and the distance between these two positions is L.

PROCEDURE:

1. Place the laser source on an upright of an optical bench
2. Place the screen on another upright at some known distance.
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 is D_1.
5. Now move the screen away from the source by some known value. Again measure the size of the spot, this is D_2.
6. Note down the distance between the two positions.
7. Repeat the experiment at least 3 times at different positions of the screen and record the observation table.
8. Using above data calculate the angular divergence θ.

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)	$\theta = \frac{\left[D_2^2 - D_1^2\right]^{1/2}}{L} \times \frac{180}{\pi}$ degrees
1.	….	….	….	….	….	….
2.	….	….	….	….	….	….
3.	….	….	….	….	….	….
						Mean θ = ….

CALCULATIONS:

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

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

θ =……degrees

RESULTS:

The angular divergence of laser beam is ……

The angular divergence of laser beam may vary from 0.2 to 0.5 degrees.

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.

ORAL QUESTIONS:

1. What do you mean by angular divergence of laser light?
2. What are the characteristics of laser light?
3. Name the factors on which by angular divergence of laser light depends.
4. What is difference between ordinary light and laser light?

EXPERIMENT 8

OBJECTIVE:

Determine the wavelength of the laser light by diffraction grating method.

APPARATUSREQUIRED:

A laser source, diffraction grating (15000 lines/inch), screen with paper, power supply, optical bench.

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.

For normal illumination the grating equation is given as

$$n\lambda = (d+b)\sin\theta$$

where

n is the order of the maxima or image formed.

λ is the wavelength of the light used

d+b is the distance between two lines of the grating i.e. grating element

θ is the angular position of the image measured from the normal to the grating or grating element.

PROCEDURE:

1. Switch on the laser.
2. Put the diffraction grating on the stand of the optical bench at some distance from the laser source.
3. A 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 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 Ys.
7. The distance between the diffraction grating is measured as D.

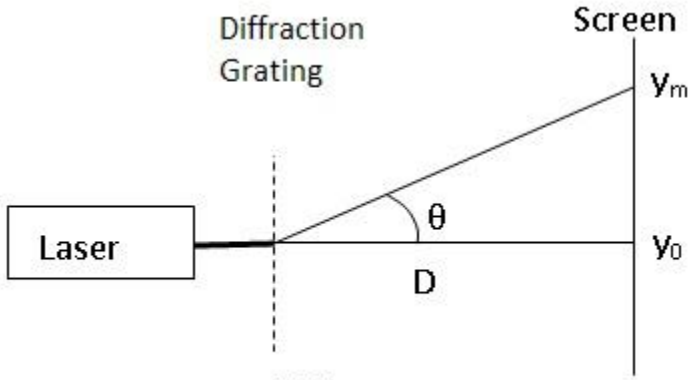


Figure 1 Geometry of diffraction grating experiment

OBSERVATIONS:

As the diffraction grating with 15000 lines /inch is used so that the distance between the two lines of the grating is

$$d+b = 2.54/15000 \text{ cm.}$$

A) For n=1

S.No.	D (cm)	Y_1		Mean Y_1 (cm)	$\tan\theta_1 = Y_1/D$	$\theta_1 = \tan^{-1}Y_1/D$
		L.H.S. (cm)	R.H.S. (cm)			
1.						
2.						
3.						
4.						

B) For n=2

S.No.	D (cm)	Y_2		MeanY_2 (cm)	$\tan\theta_2 = Y_2/D$	$\theta_2 = \tan^{-1}Y_2/D$
		L.H.S. (cm)	R.H.S. (cm)			
1.						
2.						
3.						
4.						

CALCULATIONS:

Distance between diffraction gating and the screen is D=_____ cm.

'θ' the angle of image is calculated as $\theta_1 = \tan^{-1}Y_1/D$ and $\theta_2 = \tan^{-1}Y_2/D$

Further by knowing n, (d+b), θ the wavelength (λ) can be calculated by using the formula

$$n\lambda_1 = (d+b)\sin\theta_1 \quad \text{and}$$

$$n\lambda_2 = (d+b)\sin\theta_2$$

$$\text{Mean } \lambda = (\lambda_1+\lambda_2)/2$$

RESULT:

1. The calculated value of the wavelength of the laser is =……nm
2. The standard value of the wavelength of the laser is = 632.8 nm

$$\% \text{ error} = \frac{Standard\ resut - calculated\ result}{Standard\ result} \times 100$$

= _____ %

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.

ORAL QUESTIONS:

1. Laser stands for

(a) light amplification by spontaneous emission

(b) light amplitude by spontaneous emission

(c) light amplification by stimulated emission of radiation

(d) light oscillation by stimulated emission

2. Laser used during experimental work is

(a) semiconductor laser

(b) ruby laser

(c) He-Ne laser

(d) CO_2 laser

3. Explain the basic condition must for diffraction to take place.

4. Diode laser is a

(a) three level

(b) two level

(c) four level

(d) six level laser

5. What do you mean by atomic excitation?

6. What is the basic difference between ionization and excitation?

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

8. Define wavelength and frequency of electromagnetic wave.

9. What is the realation between wavelength and frequency of electromagnetic wave?

EXPERIMENT 9

OBJECTIVE:

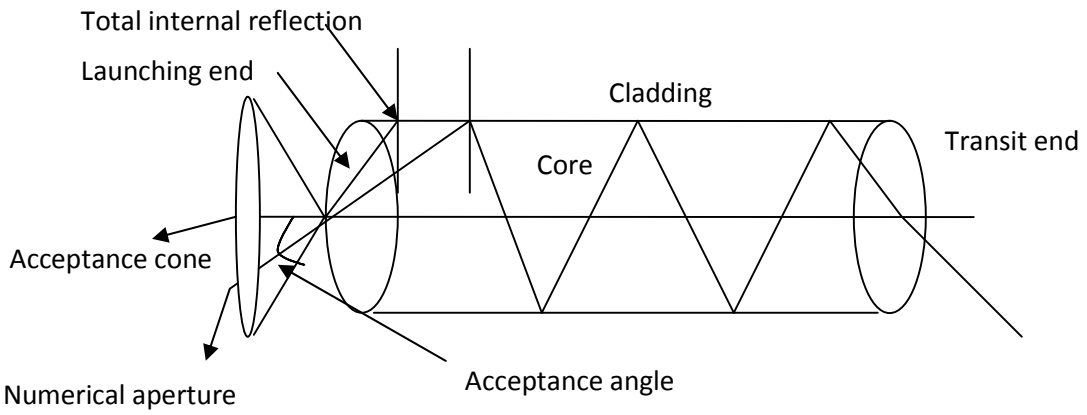
Determine the numerical aperture and acceptance angle of a short-range optical fibre.

APPARATUSREQUIRED:

An optical fibre cable, laser source, numerical aperture jig, white screen and connecting wires.

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 with in this cone of acceptance else it is refracted out of the fibre. Numerically, it is also defined as the sine of the acceptance angle.



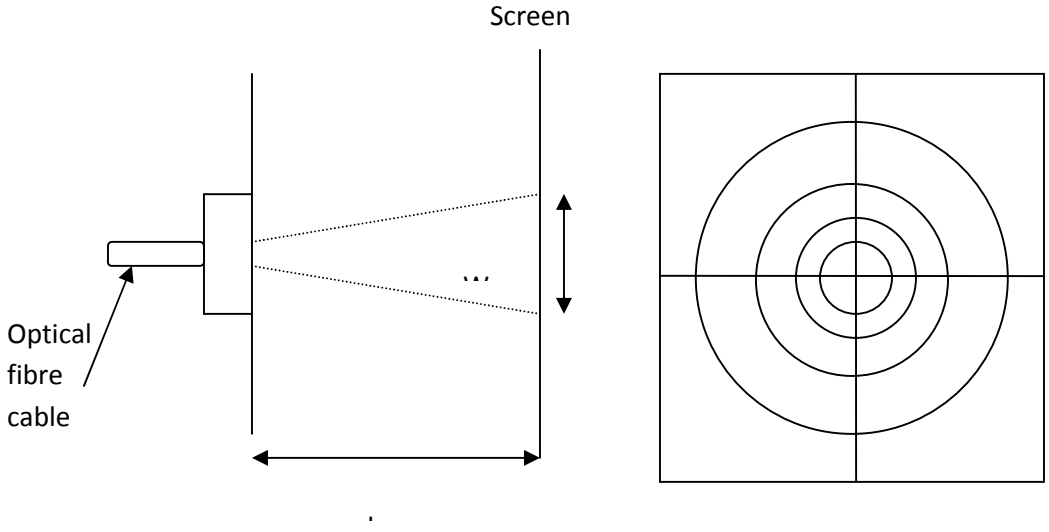
PROCEDURE:

1. Switch on the laser light source.
2. Illuminate the one end of the optical fibre cable with laser light and other end to the numerical aperture jig.

3. Hold the white screen with four circles (10, 15, 20 and 25 mm diameter) vertically at a suitable distance to make the red spot emitted from the optical fibre.
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

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

   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.



Minute view of the screen

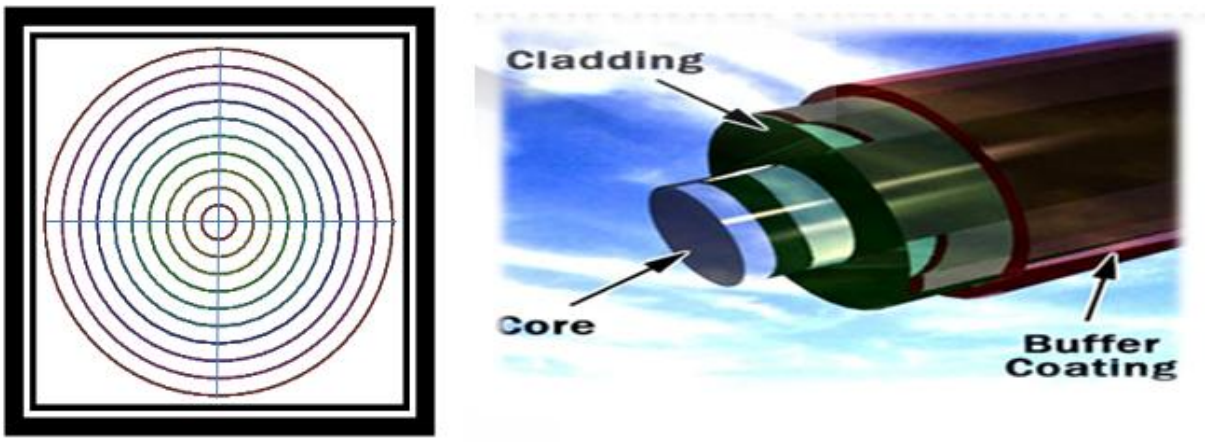


Figure: Nnumerical aperture jig white screen and inner view of optical fibre cable.

OBSERVATIONS:

Sr. No.	L (mm)	W (mm)	NA	θ_0

Compute the numerical aperture from the formula NA = sin θ_0 =W **/** $(4L^2+W^2)^{1/2}$

And this implies that acceptance angle $\theta_0 = \sin^{-1}$ (NA).

RESULT: The average value of the numerical aperture of an optical fibre is = ……

The value of acceptance angle = …… degrees.

Note: The average value of numerical aperture for

(i) Short range optical fibre should lie in the range 0.3 to 0.5.

(ii) Long range optical fibre should lie in the range 0.1 to 0.3.

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.

ORAL QUESTIONS:

1. What do you mean by refractive index?
2. What is difference between reflection and refraction?
3. What is the basic principle of propagation of light in an optical fibre?
4. What are the various conditions for TIR to take place?
5. Define critical angle?
6. The numerical aperture of an optical fibre should lie in the range
   (a) 0.1 to 1.0
   (b) 0.01 to 0.05
   (c) 0.1 to 0.5
   (d) 1 to 100
7. Numerical aperture is
   (a) sine of critical angle
   (b) cos of acceptance angle
   (c) sine of acceptance angle
   (d) acceptance cone
8. Basic principle of propagation of optical signals within the optical fibre is
   (a) Snell's law
   (b) Laws of reflection
   (c) Total internal reflection
   (d) Light propagation principle
9. Name the various optical sources which we prefer for optical fibre communication.
10. Numerical aperture depends upon
    (a) Refractive indices of core and cladding
    (b) Material of core

(c) Light source

(d) Length of optical fibre cable.

11. What are the applications of optical fibres?

12. Name the two types of optical fibres?

13. Which combination is the best one and why;

(a) Step index optical fibre and single mode propagation

(b) Graded index optical fibre and multimode propagation

(c) Step index optical fibre and multimode propagation

(d) Graded index optical fibre and single mode propagation

EXPERIMENT 10

OBJECTIVE:

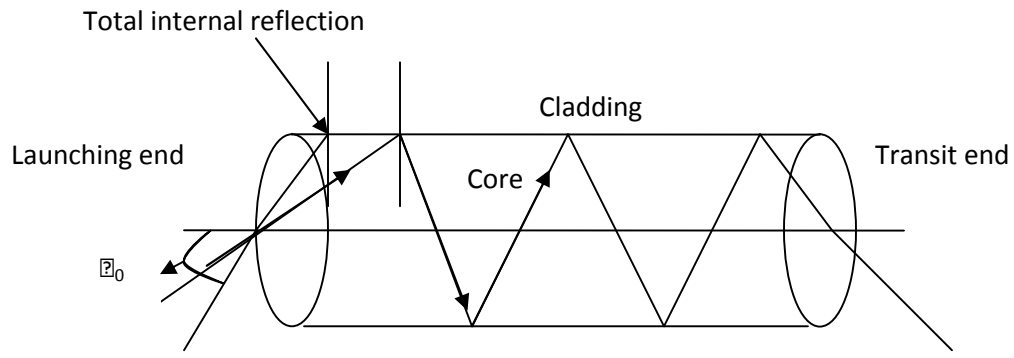
To study the propagation and attenuation loss in an optical fibre.

APPARATUSREQUIRED:

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

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).



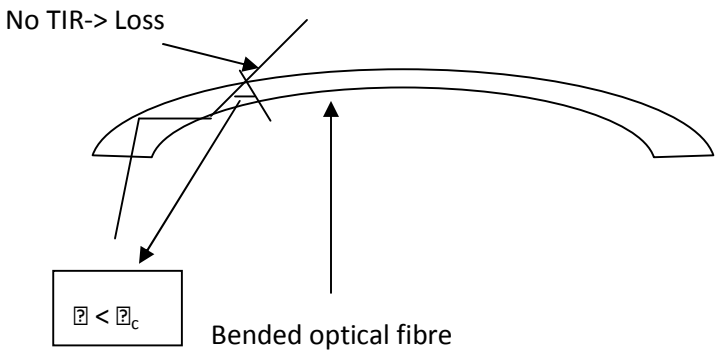
As least losses are there with in the optical fibre due to TIR, but some unavoidable losses are there which always appear in the optical fibres e. g.

(i) propagation loss -------→ depends upon length of the fibre

(ii) attenuation loss--------→ depends upon the geometry of the 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.

FORMULA:

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

where, V_1→ input voltage

V_2 → attenuated voltage

L_1 →length of one (small or large)cable before bending [for attenuation loss]

L_2 →length of one (small or large) cable after bending [for attenuation loss]

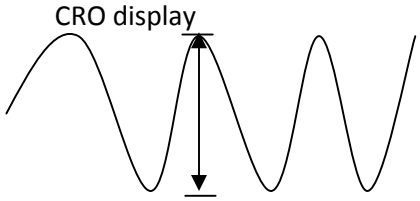
α→loss in nepers/meter.

PROCEDURE:

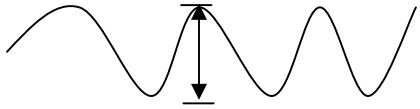
1. Connect power supply to board.
2. Make the neccesary connections
3. Switch on the power supply.
4. Set the oscilloscope channel 1 to 0.5 volt/division and adjust the amplitude to appreciable level.

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:



V_1 = ---------- volts input →



V_2 =---------- Volts output→

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

Note:

1. In case of propagation loss L_1 = 0.5 m and L_2 =1.0 m.
2. In case of attenuation loss L_1 =L_2 = either 0.5 or 1.0 m.

PRECAUTIONS:

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

ORAL QUESTIONS

1. Why we call an optical fiber as optical fiber?
2. How can we control the loss within the optical fiber?
3. CRO stands for……
4. Define micro and macro bending.
5. Can a glass-glass optical fiber be possible?
6. How can we control the loss within the optical fiber?
7. Optical fiber propagates only
   (a) gamma rays
   (b) x-rays
   (c) infrared rays
   (d) optical signals
8. CRO stands for
   (a) carbon radiating operation
   (b) cathode ray oscilloscope
   (c) cathode ray ornament
   (d) none of these
9. "Optical fibres are meaningless without lasers" comment.
10. In an optical fibre the refractive index of the core is
    (a) equal to the cladding
    (b) slightly more than cladding
    (c) less than cladding
    (d) zero
11. What is basic difference between attenuation and dispersion?
12. Give various means of signal loss with in an optical fibre.

EXPERIMENT 11

OBJECTIVE:

To study the variation of dielectric constant with temperature of a substance by using dielectric constant kit.

APPARATUSREQUIRED:

Dielectric constant kit, sample holder, oven, and Barium titanate ($BaTiO_3$) sample.

Figure-1

THEORY

Dielectric or electrical insulating materials are understood as the materials in which electrostatic fields can persist for a long time. These materials offer a very high resistance to the passage of electric current under the action of the applied direct-current voltage and therefore sharply differ in their basic electrical properties from conductive materials. Layers of such substances are commonly inserted into capacitors to improve their performance, and the term dielectric refers specifically to this application. The use of a dielectric in a capacitor presents several advantages. The simplest of these is that the conducting plates can be placed very close to one another without risk of contact. Also, if subjected to a very high electric field, any substance will ionize and become a conductor. Dielectrics are more resistant to ionization than air, so a capacitor containing a dielectric can be subjected to a higher voltage. Also,

dielectrics increase the capacitance of the capacitor. An electric field polarizes the molecules of the dielectric (Figure-2), producing concentrations of charge on its surfaces that create an electric field opposed (antiparallel) to that of the capacitor. Thus, a given amount of charge produces a weaker field between the plates than it would without the dielectric, which reduces the electric potential. Considered in reverse, this argument means that, with a dielectric, a given electric potential causes the capacitor to accumulate a larger charge.

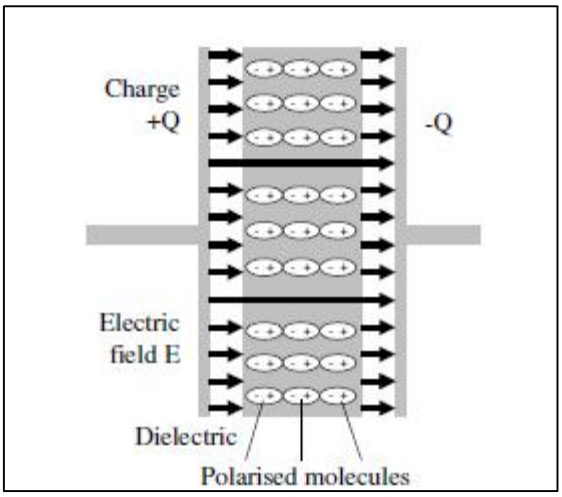


Figure-2

The electrons in the molecules shift toward the positively charged left plate. The molecules then create a leftward electric field that partially annuls the field created by the plates. (The air gap is shown for clarity; in a real capacitor, the dielectric is in direct contact with the plates.)

Dielectric Constant: The dielectric constant (Ɛ) of a dielectric material can be defined as the ratio of the capacitance using that material as the dielectric in a capacitor to the capacitance using a vacuum as the dielectric. Typical values of Ɛ for dielectrics are:

Material	DIELECTRIC CONSTANT (ε)
Vacuum	1.000
Dry Air	1.0059
Barium Titanate	100-1250
Glass	3.8-14.5
Quartz	5
Mica	4-9
Water distilled	34-78
Soil dry	2.4-2.9
Titanium dioxide	100

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BRIEF DESCRIPTION OF THE APPARATUS

1. Probe Arrangement

It has two spring loaded probes. These probe move in pipes and are insulated by teflon bush, which ensure a good electrical insulation. The probe arrangement is mounted in suitable stand, which also hold the sample plate and RTD sensor. The RTD is mounted in the sample plates such that it is just below the sample, separated by a very thin sheet of mica. This ensures the correct measurement of sample temperature. This stand also serves as a lid of the oven. The leads are provided for the connection to RTD and capacitance meter.

Probe Arrangement

2. Sample

Barium Titanate ($BaTiO_3$) plate with top and bottom conducting surface.

3. Oven

This is a high quality temperature controlled oven. The oven has been designed for fast heating and cooling rates, which enhance the effectiveness of the controller.

PROCEDURE

1. Put a small piece of aluminium foil on the base plate. Pull the spring loaded probes upward, insert the aluminium foil and let them rest on it. Put the sample ($BaTiO_3$) on the foil. Again pull the top of one of the probe and insert the sample below it and let it rest on it gently. Now one of the probes would be in contact with the lower surface through aluminium foil.
2. Connect the probe leads to the capacitance meter.
3. Connect the oven to main unit and put the oven on OFF position.
4. Switch on the main unit and note the value of capacitance. It should be a stablereading and is obtained directly in pf.
5. (i) Switch ON the temperature controller and approx adjust the set-temperature. The green LED would light up indicating the oven is ON and temperature would start rising. The temperature of oven in $^{\circ}C$ would be indicated by DPM.

(ii) The controller of oven would switch ON/OFF power corresponding to set temperature. In case it is less than desired, the set temperature may be increased or vice-versa.

(iii) Because of thermal inertia of oven, there would be some over shoot and under shoot before a steady set-temperature is attained and may take 10 minutes for each reading.

(iv) To save time, it is recommended to under adjust the temperature. Example, it is desired to set at 50°C, adjust the temperature set knob so that LED is OFF at 45°C. The temperature would continue to rise. When it reaches 50°C adjust the temperature set knob so that oven is just ON/OFF. It may go up 1 and 2°C, but would settle down to 50°C. Since the change in temperature at this stage is very slow and response of RTD and sample is fast, the reading can also be taken corresponding to any temperature without waiting for a steady state.

OBSERVATIONS AND CALCULATIONS

Sample: Barium titanate ($BaTiO_3$)

Area (A): 8 x 6 mm^2

Thickness (t): 1.42 mm

Permittivity of space (ε_0): 8.85 x 10^{-12} F/m or 8.85 x 10^{-3}pf/mm

Now, $\varepsilon = \frac{C}{C_0}$;

where $C_0 = \frac{A\varepsilon_0}{l}$ = 29.9 x 10^{-3} pf

S.No.	Temperature (°C)	Capacitance, C (pf)	Dielectric constant, ε

RESULT: Write the variation of dielectric constant with temperature.

PRECAUTIONS

1. The spring loaded probe should be allowed to rest on the sample very gently; otherwise it may damage the conducting surface of the sample or even break the sample.
2. The reading of capacitance meter should be taken when the oven is OFF. This would be indicated by the green LED. In ON position there may be some pickups
3. The reading near the Curie temperature should be taken at closer intervals say 1°C.

ORAL QUESTIONS

1. What do you mean by dielectric constant?
2. What do you mean by insulating materials?
3. What is the difference between dielectrics and insulating materials?
4. What is the value of dielectric constant for air?

CHITKARA UNIVERSITY

EXPERIMENT 12

OBJECTIVE:

Study the variation of magnetic field with distance along axis of a circular coil carrying current.

APPARATUS PROCEDURE:

A Stewart and Gee type tangent galvanometer, a strong battery, a rheostat, an ammeter, plug key, a commutator and connecting wires.

THEORY:

The intensity of magnetic field at a point lying on the axis of a circular coil is given by

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

Where, n = number of turns in the coil

r = radius of the coil

i = current in ampere flowing in the coil

= distance of the point from the center of the coil

If the magnetic field B is made perpendicular to the horizontal component of earth's magnetic field (H) then

$B = H \tan\theta$ or $B \propto \tan\theta$

Hence the graph between tanθ and x will be similar to the graph between B and x.

DESCRIPTION OF APPARATUS:

The apparatus used to study the variation of magnetic field with distance along the axis of a circular coil is called and Gee type tangent galvanometer as shown in figure (1). It consists of a circular coil of many thin insulated copper wires would wound on a wooden or brass frame. It is fixed on a wooden bench AB with its plane vertical to the bench. The free ends of the wire are connected to two terminals T_1 and T_2 fitted on the base. A deflection magnetometer compass

box is placed inside the coil such that it can slide on the pillars of the bench in such a way that the center of the needle always lies on the axis of tube coil. The distance of the needle from the center of the coil can be read on the graduated scale on the arms of the magnetometer.

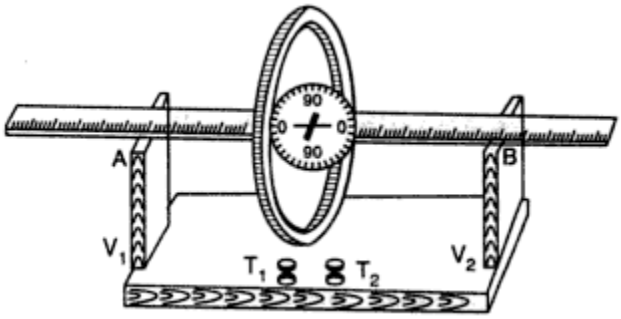


Figure: (1)

PROCEDURE:

1) Place the magnetometer compass box on the sliding bench so that its magnetic needle is at the center of the coil. By rotating the whole apparatus in the horizontal plane, set the coil in the magnetic meridian and the arms of the magnetometer lie east and west roughly. In this case the coil, needle and its image all lies in the same vertical plane. Rotate the compass box till the pointer ends read 0-0 on the circular scale.
2) In order to set the coil exactly in the magnetic meridian set up the electrical connections such that the galvanometer is connected to battery through rheostat, an ammeter, a plug key and a commutator as in the figure (2).
3) Send the current in one direction with the help of commutator and adjust the current such that the deflection of nearly 70^0 to 75^0 is produced in the compass needle. Now Reverse the direction of the current and note down the deflection of the needle. If the deflections are equal then the coil is in magnetic meridian otherwise turn the apparatus a little, adjust pointer ends to read 0-0 till these deflections become equal.

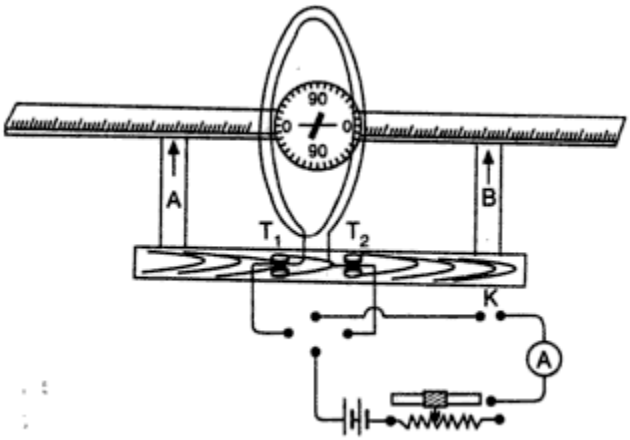


Figure: (2)

4) Now pass the current in the coil and slide the magnetometer along the axis of coil. Find out the position where the deflection becomes maximum. Note the readings of both the ends of the pointer. Reverse the direction of the current and again read both the ends of the pointer. The mean of four readings will give the mean deflection at x = 0.
5) Now shift the compass needle in the steps of 2cm along the axis of the coil and for each position note down the mean deflection. Continue this process till the compass box reaches the end of the bench.
6) Repeat the measurements exactly in the same manner on the either side of the coil.
7) Plot a graph between distance from center of coil x taking along the X-axis and tanθ (mean deflection) along the Y-axis.

OBSERVATIONS:

S. No.	Distance from centre x	Deflection on east arm				Mean θ = $\frac{\theta_1+\theta_2+\theta_3+\theta_4}{4}$ (in deg.)	tanθ	Deflection on west arm				Mean θ = $\frac{\theta_1+\theta_2+\theta_3+\theta_4}{4}$ (in deg.)	tan θ
		Current in one direction		Current in reversed direction				Current in one direction		Current in reversed direction			
		θ_1	θ_2	θ_3	θ_4			θ_1	θ_2	θ_3	θ_4		

1. 2. 3. 4. 5. 6. 7. 8.													

Graph: The variation of the intensity of magnetic field along the axis of a circular coil is shown in figure (3).

RESULT

The graph shows the variation of the magnetic field along the axis of a circular coil carrying current.

P**RECAUTIONS AND SOURCES OF ERROR**

1) The coil should be carefully adjusted in the magnetic meridian.
2) All the magnetic materials and current carrying conductors should be at a considerable distances from the apparatus.
3) The current passed in the coil should be of such a value as to produce a deflection of nearly 70^0-75^0.
4) Current should be checked from time to time and for this purpose am ammeter should be connected in series with the battery.
5) The eye should be kept vertically above the pointer to avoid any error due to parallax.
6) The curve should be drawn smoothly.

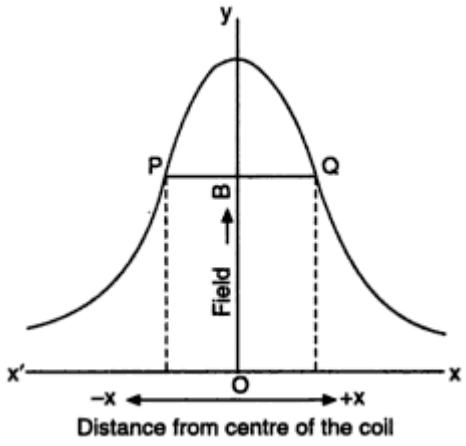


Figure: (3)

ORAL QUESTIONS

1. What is the use of compass box?
2. What do you mean by magnetic field?
3. Explain the variation of the magnetic field along the axis of a circular coil carrying current.

Aim: Determination of Planck's constant.

Apparatus: 0-10 V power supply, a one way key, a rheostat, a digital milliammeter, a digital voltmeter, a 1 K resistor and different known wavelength LED's (Light-Emitting Diodes).

Theory:Planck's constant (h), a physical constant was introduced by German physicist named Max Planck in 1900. The significance of Planck's constant is that 'quanta' (small packets of energy) can be determined by frequency of radiation and Planck's constant. It describes the behavior of particle and waves at atomic level as well as the particle nature of light.

An LED is a two terminal semiconductor light source. In the unbiased condition a potential barrier is developed across the p-n junction of the LED. When we connect the LED to an external voltage in the forward biased direction, the height of potential barrier across the p-n junction is reduced. At a particular voltage the height of potential barrier becomes very low and the LED starts glowing, i.e., in the forward biased condition electrons crossing the junction are excited, and when they return to their normal state, energy is emitted. This particular voltage is called the knee voltage or the threshold voltage. Once the knee voltage is reached, the current may increase but the voltage does not change.

The light energy emitted during forward biasing is given as ,

$$E = \frac{hc}{\lambda} \qquad (1)$$

Where

c -velocity of light.
h -Planck's constant.
λ -wavelength of light.

If V is the forward voltage applied across the LED when it begins to emit light (the knee voltage), the energy given to electrons crossing the junction is,

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

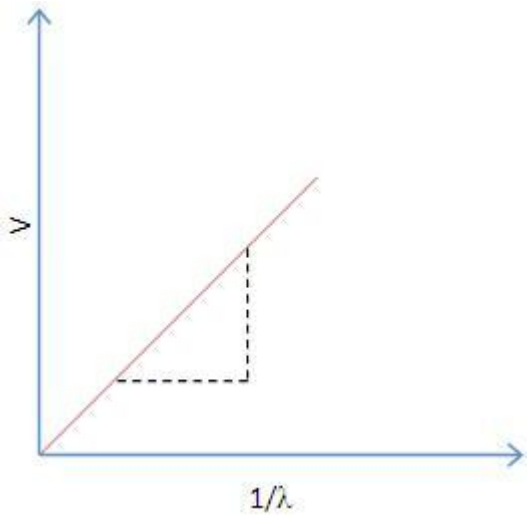
Equating (1) and (2), we get

$$eV = \frac{hc}{\lambda} \qquad (3)$$

The knee voltage V can be measured for LED's with different values of λ (wavelength of light).

$$V = \frac{hc}{e}\left(\frac{1}{\lambda}\right) \qquad (4)$$

Now from equation (4), we see that the slope s of a graph of V on the vertical axis vs. 1/λ on the horizontal axis is



$$s = \frac{hc}{e} \qquad (5)$$

To determine Planck's constant h, we take the slope s from our graph and calculate

$$h = \frac{e}{c}s$$

using the known value

$$\frac{e}{c} = 5.33 \times 10^{-28}\frac{Cs}{m}$$

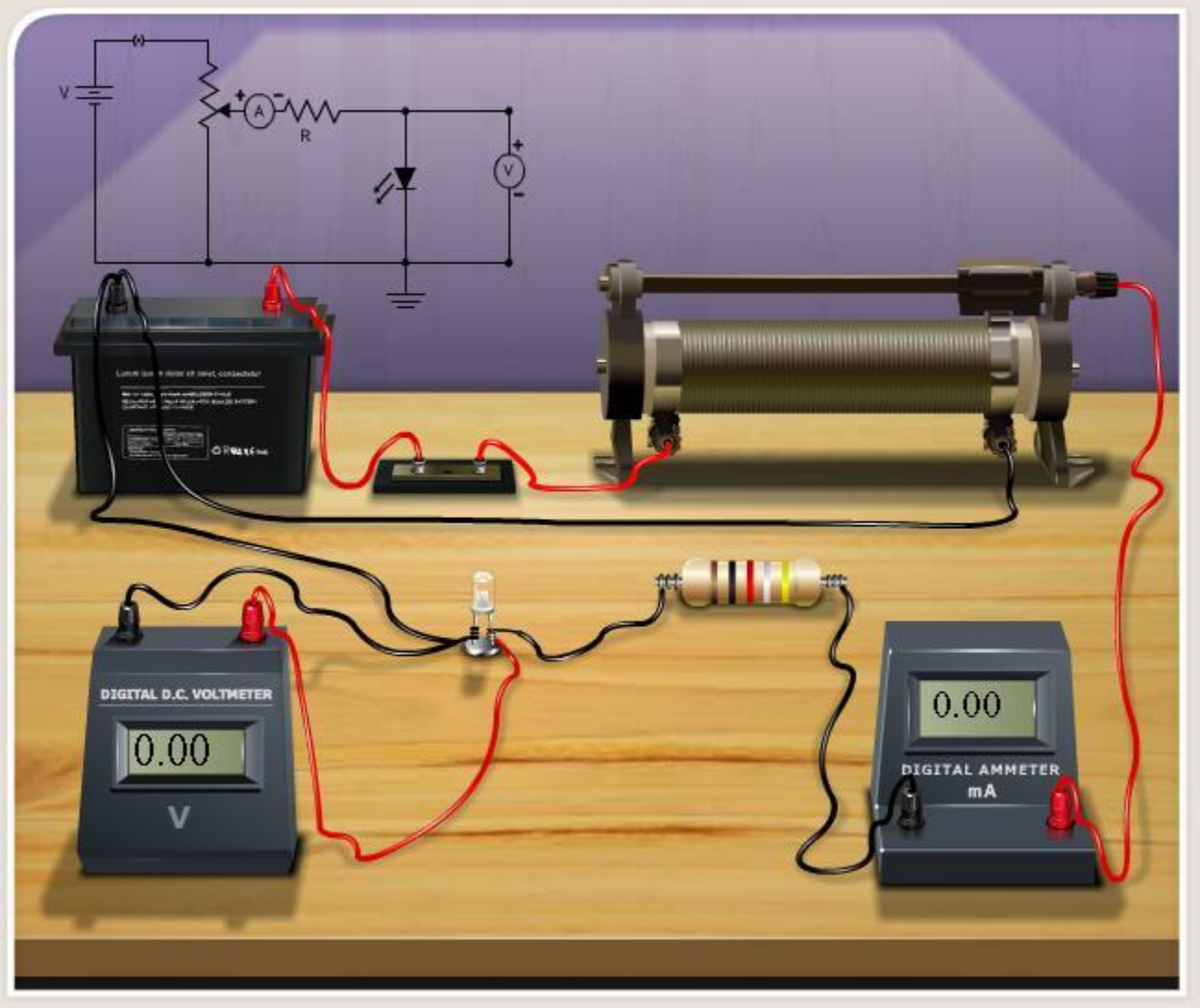
Alternatively, we can write equation (3) as

$$h = \frac{e}{c}\lambda V$$

calculate h for each LED, and take the average of our results.

Procedure for Simulation

Place the mouse pointer over the components and click to drag wire.



1. After the connections are completed, click on 'Insert Key' button.
2. Click on the combo box under 'Select LED' button.
3. Click on the 'Rheostat Value' to adjust the value of rheostat.
4. Corresponding voltage across the LED is measured using a voltmeter,which is the knee voltage.
5. Repeat, by changing the LED and note down the corresponding knee voltage.

$$h = \frac{e\lambda V}{c}$$

6. Calculate 'h' using equation

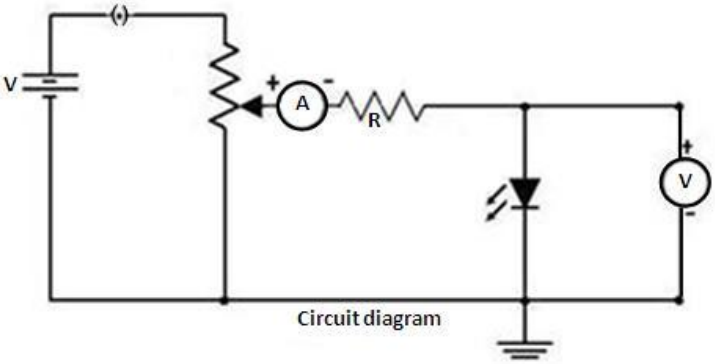
$$\lambda = \frac{hc}{eV}$$

7. The wave length of infrared LED is calculated by using equation,

Observations

Colour of LED	Wavelength (λ) nm	Knee voltage (V) volt	λxV	h = eλV/c

Procedure for Real lab



1. Connections are made as shown in circuit diagram.
2. Insert key to start the experiment.
3. Adjust the rheostat value till the LED starts glowing, or in the case of the IR diode, whose light is not visible, until the ammeter indicates that current has begun to increase.
4. Corresponding voltage across the LED is measured using a voltmeter,which is the knee voltage.
5. Repeat, by changing the LED and note down the corresponding knee voltage.
6. Using the formula given,find the value of the Planck's constant.

Results

Planck's constant = Js.
Wavelength of IR LED = nm.

What is the value of knee voltage for a Yellow LED light?

2. Calculate the value of Planck's constant for blue LED, for its knee voltage.

3. Calculate the wavelength of IR LED by comparing with Red LED at their corresponding knee voltage.

4. Calculate the value of IR LED by comparing with Green LED at their corresponding knee voltage.

5. Calculate the wavelength of IR LED by drawing a graph between voltage and wavelength.

6. What happens when an LED is directly connected to a power supply? Which is the most suitable value of resistor if a power supply of 0-12 V is used?

7. Which LED has the largest energy gap?

Aim:

1. To determine the Hall voltage developed across the sample material.
2. To calculate the Hall coefficient and the carrier concentration of the sample material.

Apparatus:

Two solenoids, Constant current supply, Four probe, Digital gauss meter, Hall effect apparatus (which consist of Constant Current Generator (CCG), digital milli voltmeter and Hall probe).

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

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

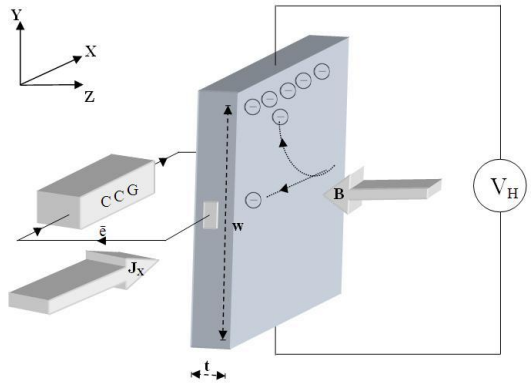


Fig.1 Schematic representation of Hall Effect in a conductor.
CCG – Constant Current Generator, J_X – current density
$\bar{e}$ – electron, ***B*** – applied magnetic field
t – thickness, ***w*** – width

V_H – Hall voltage

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 V_H and this effect is called Hall Effect.

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, $F_m = q(vxB)$ 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

$$eE = evB \tag{2}$$

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,

$$I = neAv \tag{3}$$

Where 'n' is the number density of electrons in the conductor of length l ,breadth 'w' and thickness 't'.

Using (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 eq(4) we get

$$R_H = \frac{V_H * t}{I * B} \qquad (5)$$

Where R_H is called the Hall coefficient.

$$R_H = 1/ne \qquad (6)$$

Procedure:

- Connect 'Constant current source' to the solenoids.
- Four probe is connected to the Gauss meter and placed at the middle of the two solenoids.
- Switch ON the Gauss meter and Constant current source.
- Vary the current through the solenoid from 1A to 5A with the interval of 0.5A, and note the corresponding Gauss meter readings.
- Switch OFF the Gauss meter and constant current source and turn the knob of constant current source towards minimum current.
- Fix the Hall probe on a wooden stand. Connect green wires to Constant Current Generator and connect red wires to milli voltmeter in the Hall Effect apparatus
- Replace the Four probe with Hall probe and place the sample material at the middle of the two solenoids.
- Switch ON the constant current source and CCG.
- Carefully increase the current I from CCG and measure the corresponding Hall voltage $\boldsymbol{V_H}$. Repeat this step for different magnetic field $\boldsymbol{B}$.
- Thickness $\boldsymbol{t}$ of the sample is measured using screw gauge.
- Hence calculate the Hall coefficient $\boldsymbol{R_H}$ using the equation 5.
- Then calculate the carrier concentration $\boldsymbol{n}$. using equation 6.

Specification of Hall Probe (p-type)

Thickness(t)= 0.50mm

Result

Hall coefficient of the material = ... (15.8×10^3 cm^3 /C)

Carrier concentration of the material =..... cm^{-3} (~10^{14})