University of Petroleum and Energy Studies

Dehradun

School of Engineering (SOE)

&

School of Computer Sciences (SOCS)

Department of Physics

PHYSICS LABORATORY MANUAL

Academic Year 2019-20

(Semester-I & II)

(For All B. Tech Branches)

Name...

Branch.................................Roll No.....................................

Institute...

INSTRUCTIONS FOR LABORATORY

- The objective of the laboratory is learning. The experiments are designed to illustrate phenomena in different areas of Physics and to expose you to measuring instruments. Conduct the experiments with interest and an attitude of learning.

- You need to come well prepared to the laboratory with write up and observing lab videos to perform the experiment.

- Work quietly and carefully (the whole purpose of experimentation is to make reliable measurements) and equally share the work with your group mates.

- Be honest in recording and representing your data. Never make up readings or doctor them to get a better fit for a graph. If a particular reading appears wrong repeat the measurement carefully. In any event all the data recorded in the tables have to be faithfully displayed on the graph.

- All presentations of data, tables and graphs calculations should be neatly and carefully done.

- Bring necessary graph papers for each of the experiment. Learn to optimize on usage of graph papers.

- Graphs should be neatly drawn with pencil. Always label graphs and the axes and display units.

- If you finish early, spend the remaining time to complete the calculations and drawing graphs. Come equipped with calculator, scales, pencils etc.

- Usage of electronic gadgets is strictly prohibited in the laboratory.

LIST OF EXPERIMENTS

List of Experiments (with Cycles division)

B. Tech (SOE) – All Branches

Subject: Physics Lab I **Subject Code - PHYS-**

S. No	Cycle	Experiment
1	I	Sonometer
2		Hall Effect
3		Faraday's Laws
4		Variation of Magnetic Field along the axis of a circular coil
5		Virtual Lab - Photo Electric Effect
6	II	Newton's Rings
7		Diffraction Grating – Normal Incidence
8		Solar Cell
9		Planck's constant using LEDs
10		Presentation
11	Extra	Quink's Tube- Susceptibility
12		Polarimeter/ Laser diffraction

B. Tech (SoCS) - All Branches

Subject : Physics Lab **Subject Code – PHYS 1108**

S. No	Cycle	Experiment
1	I	Sonometer
2		Hall Effect
3		Faraday's Laws
4		Variation of Magnetic Field along the axis of a circular coil
5		Virtual Lab - Photo Electric Effect
6	II	Optical Fibre
7		Laser Diffraction
8		Solar Cell
9		Planck's constant using LEDs
10		Presentation
11	Extra	Young's Modulus
12		Logic Gates

Virtual Lab Links

S. No	Virtual Lab	Title of the Experiment	Link
1	Modern physics lab	Photo Electric Effect	http://vlab.amrita.edu/?sub=1&brch=195&sim=840&cnt=1

EXPERIMENT – 1
SONOMETER

AIM
TO DETERMINE THE FREQUENCY OF A.C. MAINS BY USING A SONOMETER.

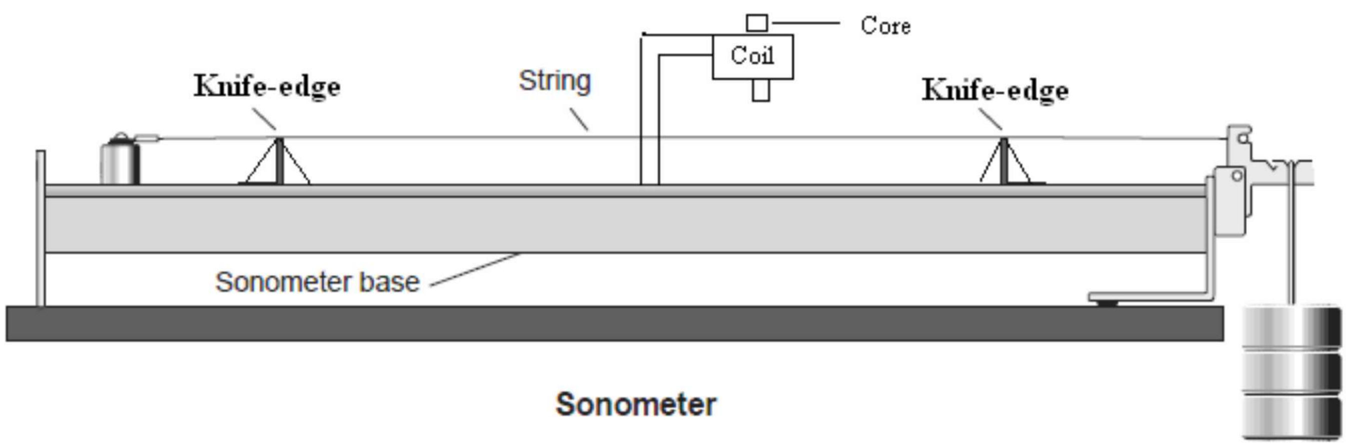
APPARATUS
Sonometer with non-magnetic(metallic) wire, step down transformer of 6-8 volts, set of weights with hanger, electromagnet.

FORMULA
The frequency (f) of A.C mains is given by

$n = 2f = \frac{1}{2L}\sqrt{\frac{T}{m}}$ Hz (when experiment is performed with a magnetic wire)

i.e $f = \frac{n}{2} = \frac{1}{4L}\sqrt{\frac{T}{m}}$ Hz

Where,
n = natural frequency of sonometer wire in Hz.
L is the resonating length of wire between the two bridges in cm.
T is the tension applied to the wire = Mg (where M is the mass suspended to wire in gms and g is the acceleration due to gravity in cm/ sec^2) (dynes)
m is the mass per unit length of the wire in gm/ cm, given by $m = \pi r^2 d\ gm/cm$
where 'r' is the radius of the wire in cm.
and 'd' is the density of the material of the wire in gm/cm^3.



Sonometer

THEORY

Sonometer is a useful apparatus for investigating the vibration of a string or wire under tension. The equipment allows the change in length of the string in accordance with the variation in the tension. Sonometer is an apparatus by which we can determine the frequency of A.C. mains in a very easy method. In this, we have a very fine arrangement for precise determination.

Sonometer is a device which consists of a thin metallic (steel) wire stretched over two bridges that are usually mounted on a soundboard and which is used to measure the vibration frequency, tension, density, or diameter of the wire, or to verify relations between these quantities also known as monochord. This set up is provided with 6V AC supply, which is applied to electromagnet.

To find the frequency of A.C. mains using an electromagnet and a sonometer, the A.C. is passed through the primary coil of a step-down transformer (220-230 volts to 4-6 volts). The two ends of the secondary coil of the step-down transformer are connected to the two ends of the windings of the electro- magnet which consists of a coil of insulated copper wire wound over a soft iron core provided with an insulated handle.

As the A.C. from the secondary coil of the step- down transformer passes through the electro-magnet it gets magnetized twice in each cycle, first with one of its faces as a north pole and then with the same face as the south pole. The electromagnet is kept close to and vertically above the sonometer steel wire. The position of the knife edges is so adjusted above that the sonometer steel wire vibrates in resonance with the A.C. supply (In India A.C. Supply is 50Hz). The wire is attracted and pulled twice in each cycle of the A.C. mains supply; once when the end of the electromagnet just above the wire is a north pole and again after half a cycle when this end is a south pole. In other words, the natural frequency (n) of the sonometer wire is double the frequency (f) of the A.C. Mains.

$$n = 2f = \frac{1}{2L}\sqrt{\frac{T}{m}}$$

or $$f = \frac{n}{2} = \frac{1}{4L}\sqrt{\frac{T}{m}}$$

PROCEDURE

1 Assembly the setup as shown in figure below.
2 Firstly tie the wire at one fixed end and other end passes over pulley and carries a hanger of weights.
3 Mount the L clamp of wires with the screws of sonometer base at a distance of 2- 3 mm above the wire.
4 The core of electromagnet should lie at the centre of coil.
5 Now connect main cord between mains and sonometer.
6 Take two patch cords and connect 6V AC supply from sonometer to the coil with polarity.
7 Now hang the weight of 500 gm to the hanger connected with one end of the steel wire.
8 Switch ON the A.C supply.
9 Now adjust the two knife edges near and far to each other so that you get the vibrations in the wire.
10 Now slowly adjust the knife edges for maximum vibrations.
11 Note the resonating length (*l*) between the two knife edges by a meter scale.
12 Also note load (M) in gm.
13 Now increase the mass in steps of 500 gm and adjust the knife edges for maximum vibrations.
14 Again note (*l*) of wire between the two knife edges.
15 Repeat the same procedure by increasing the weight of 500 gm and note down the length (*l*) for maximum vibrations.
16 Note all the values in the observation table given below.
17 Frequency of A.C mains (f) = $\frac{n}{2}$………Hz
18 Also calculate percentage error as standard frequency of A.C mains is 50Hz.

$$Percentage\ Error(in\ \%) = \frac{Standard\ Value - Calculated\ value}{Standarad\ value} \times 100$$

OBSERVATION TABLE

Length of the wire = …cm
Mass of the wire =……gm
Mass per unit length of the wire =…..gm/cm

S.No	Mass(M) gm	Tension in Newton T = M g =M x 980 Dynes	Resonating length between two knife edges (l) cm			$\frac{\sqrt{T}}{l}$ Dynes/cm	$n = \frac{1}{2L}\sqrt{\frac{T}{m}}$ Hz
			Mass increasing	Mass decreasing	Mean length cm		
1							
2							
3							
4							

Mean frequency 'n' = ………..Hz

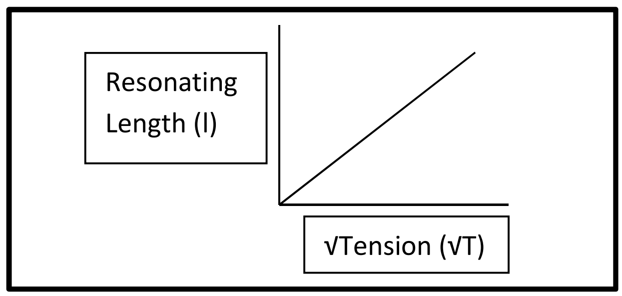
A graph is to be drawn between $\sqrt{T}$ on x-axis and resonating length (l) on Y-axis. It should be a straight line passing through origin.

From graph, $\frac{\sqrt{T}}{l}$ = ………….. dynes/ cm.

N=…………….Hz

f = $\frac{n}{2}$ = ……….. Hz

This should be approximately equal to the average value of 'n'.



VIVA-VOCE

Q. 1. What type of vibrations is produced in the sonometer wire and the surrounding air?
Q. 2. How are stationary waves produced in the wire?
Q. 3. What do you understand by resonance?
Q. 4. Is there any difference between frequency and pitch?
Q. 5. What are the positions of nodes and antinodes on sonometer wire?
Q.6. What is the frequency of D.C?
Q.7. What do you mean by Resonating Length of the wire in the experiment?
Q.8. On which principle does the ac sonometer work ?

PRECAUTIONS

1. The electromagnet should not touch the wire, it should be just above the wire.
2. Take care to see that a magnetic wire is fixed on the sonometer.
3. Determine the radius of the wire when no mass is attached to the mass hanger.
4. The length between the two bridges has to be taken accurately when the formed loop is stable.

EXPERIMENT – 2
HALL EFFECT

AIM

TO STUDY THE HALL EFFECT AND HENCE DETERMINE THE HALL COEFFICIENT (R_H) AND CARRIER DENSITY (n) OF A GIVEN SEMICONDUCTOR.

APPARATUS

Hall Probe (Ge Crystal) (thickness 0.4-0.5 mm); Hall Probe (InAs crystal), Hall Effect set-up(Digital mill voltmeter (0-200 mV) and constant current power supply, Electromagnet (Field intensity 11,000 ± 5% gauss), Constant current power supply.

FORMULA

The Hall Coefficient and Carrier Density are given by

(i) Hall Coefficient (R_H) = $\left(\frac{Z}{H_Z}\right)\left(\frac{V_H}{I}\right)$ Volt cm A^{-1}Gauss^{-1} = ……..x10^8 cm^3/coulomb

(where 'I' in Amperes, 'V' in volts, 'Z' in cm and H_z in Gauss)

(ii) Carrier density n = $\left(\frac{1}{R_H q}\right)$ cm^{-3} (where q = electronic charge = 1.6 x 10^{-19} C)

where, 'z' (in cm) is the thickness of the crystal along Z-axis, H_z is the magnetic field (in Gauss) applied along Z axis. Current 'I' (in mA) is flowing along X-axis. Hall voltage V_H is developed across the faces normal to Y-axis.

THEORY

An E.M.F. is set up transversely across a current carrying conductor when a perpendicular magnetic field is applied. This is known as the Hall Effect.

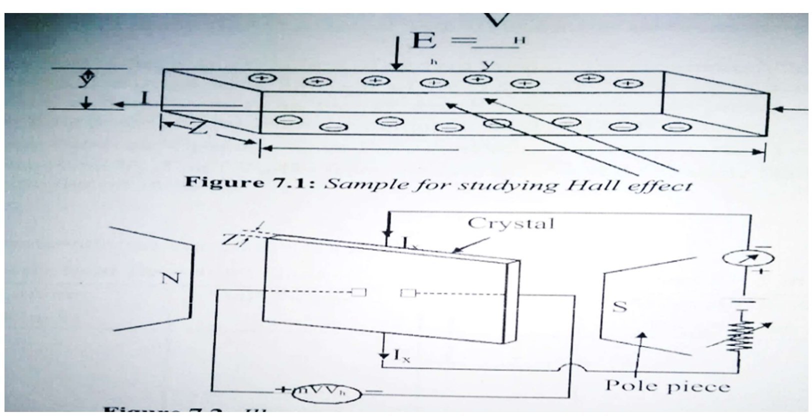


Figure 1: *Illustration of measurement of Hall Voltage*

PROCEDURE

1. Connect the widthwise contacts of the Hall Probe (with Ge crystal) to the voltage terminal and lengthwise contacts to current terminals of the Hall effect set-up. (dimensions may vary with setup).
2. Now switch 'ON' the Hall Effect set up and adjust the current to a few (mA).
3. Check the 'Zero field Potential' by changing Knob to the voltage side. This voltage is error voltage and should be subtracted from the Hall voltage reading. (i.e., when Hall probe is outside the magnetic field).
4. Now place the Hall probe in the magnetic field. This Hall probe must be fitted in the wooden stand before placing in magnetic field so that Hall probe becomes perpendicular to the magnetic field.
5. Switch on the electromagnet power supply by connecting the pole piece to the power supply.
6. Now place the Hall probe (InAs) attached with Gauss-meter between the pole pieces to measure the magnetic field.
7. Measure the Hall voltage as a function of current keeping the magnetic field constant (Table – 1).
8. Measure the Hall voltage as a function of magnetic field keeping a suitable value of current as constant (This is done by placing two probes between the pole pieces and decrease the spacing between the pole piece and measure the magnetic field and Hall voltage). (Table – 2).
9. Plot the graph between V_H and I (when H_Z = constant); V_H and H_Z (when I = constant).
10. Calculate the slope V_H/I and V_H/H_Z from the two graphs and calculate Hall coefficient in two ways and determine the mean value.

OBSERVATIONS

Thickness of the semiconductor crystal Z = 0.5 mm = 0.05 cm

Table – 1: Magnetic field Hz = 500/1000 Gauss

S. No	Current (I) (mA)	Hall Voltage (V_H) (mV)

Table – 2: Current I = 5/10 mA

S. No	Magnetic field Hz (in Gauss)	Hall Voltage (V_H) (mV)

Graph-1

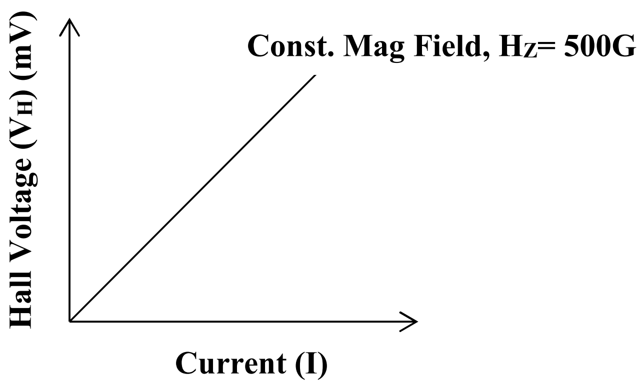


Figure 2. *Plot of V_H versus I*

Graph-2

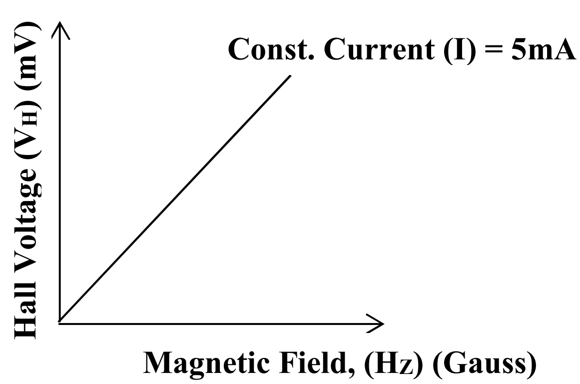


Figure 3. *Plot of V_H versus H_Z*

CALCULATIONS

Determine the slopes from two graphs to find out R_{H_1} and R_{H_2} respectively. Finally, the Hall coefficient is given by

$$R_H = (R_{H_1} + R_{H_2})/_2$$

$$Carrier\ Density\ ,\boldsymbol{n} = \left(\frac{1}{R_H q}\right) \quad = \left[\frac{1}{(\ldots\ldots\ldots cm^3/coulomb)(1.6\times10^{-19}\ coulomb)}\right]$$

RESULT

The value of Hall Coefficient (R_H) for the given semiconductor was found to be ——cm^3/coul.

The carrier density (n) = ——/cm^3.

PRECAUTIONS

1. The Hall probe is placed between the pole pieces (in magnetic field) such that maximum Hall voltage is generated.
2. Current through the Hall probe should be strictly within the limit as mentioned by the manufacturer.
3. Hall voltage developed must be measured very accurately.
4. Magnetic field is varied gradually in steps to avoid damage to the electromagnetic coils.

VIVA-VOCE

1. What is the Hall Effect?
2. On what factor, the sign of the Hall potential difference develops?
3. Why is the potential difference developed when a transverse magnetic field is applied to a current carrying conductor?
4. How will you determine the direction of the force exerted on the charge carriers?
5. What is the Hall coefficient? What are its units?

APPLICATIONS

Automotive Industry: Level/tilt measurement sensor, Throttle angle sensor automotive sensors, Crankshaftposition or speed sensor, Anti-skid sensor, Door interlock and ignition sensor Transmission mounted speed sensor, RPM sensors, Distributor mounted ignition sensor etc.

Electronic industry: Sequencing sensors, Magnetic card reader, Proximity sensors, Office machine sensors, Adjustable current sensors, Linear feedback sensor, Multiple position sensor, Microprocessor controlled sensors, Brushless DC motor sensors etc.

Aerospace Industry: Temperature or pressure sensor, Remote conveyor sensing, Remote

EXPERIMENT – 3
STUDY OF ELECTROMAGNETIC INDUCTION- FARADAY'S LAWS

AIM

1. TO STUDY THE INDUCED EMF AS A FUNCTION OF VELOCITY OF THE MAGNET PASSING THROUGH THE COIL.

2. TO STUDY THE CHARGE DELIVERED DUE TO ELECTROMAGNETIC INDUCTION.

APPARATUS

The experimental setup consists of a permanent magnet mounted on an arc of a semicircle (D shaped) of radius 40cm, measurement board consisting of voltmeter, milliammeter, resistance, condenser and diode The arc part of rigid frame of aluminum and is suspended at the center of the arc so that the whole can oscillate freely in its plane. (Fig. 1.)

THEORY

Weight(A,A) have been provided on the diagonal arm, so that by altering positions the time period of oscillation can be varied from about 1.5 to 3 sec. Two coils of about 10,000 turns of copper wire loop the arc so that the magnet can pass freely through the coil. The two coils are independent and can be connected either in series or parallel. The amplitude of the swing can be read from the graduated circle by the pointer, when the magnet moves through and out of the coil the flux of the magnetic field through the coil changes, inducing the emf.

On the panel of the measurement board one voltmeter with four range 0-2.5V, 5V, 10V, 20V and one ammeter with two ranges 1mA, 2.5mA are provided. Board also has four different value condensers five resistances and two diodes and one SPST for performing experiments.

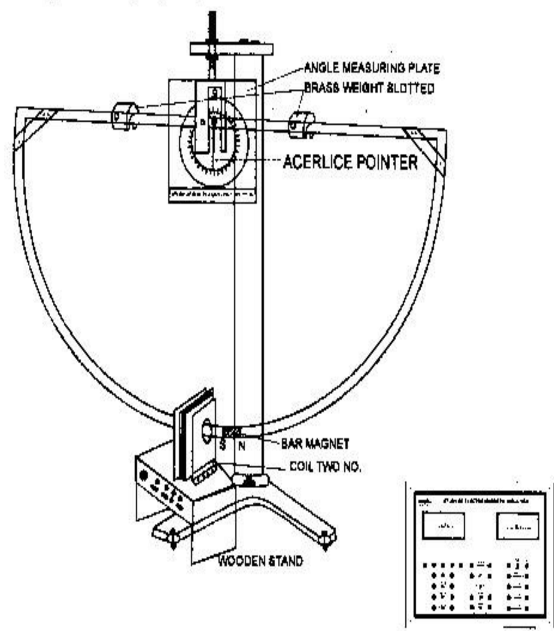


Fig. 1. Experimental setup of Faraday's law

Features

1. Mechanical part consisting of a permanent magnet mounted on an arc of semicircle of radius 40cm. The arc is part of a rigid frame of aluminum and is suspended at the centre of arc so that the whole frame can oscillate freely in its plane. Weights have been provided on the diagonal arm, so that by altering their position, the time period of oscillation can be varied from about 1.5 to 3 sec. Two coils of about 10,000 turns of copper wire loop the arc, so that the magnet can pass freely through the coil. The two coils are independent and can be connected in series or parallel.2. Measurement board consisting of voltmeter, milliammeter, resistance, condenser and diode.

BASIC PRINCIPLE

The basic principle of generation of alternating emf is electromagnetic induction discovered by Michael Faraday. The phenomenon is the production of an induced emf, V_{emf} (in volts) in a closed circuit is equal to time rate of change of magnetic flux linkage by the circuit. Faraday's law of induction tells us that the induced emf, "V_{emf}" is given by

$$V_{emf} = -\frac{d\lambda}{dt} = -N\frac{d\emptyset}{dt} \text{..........................} (1)$$

Where$\lambda = N\emptyset = flux\ linkage$ and $\emptyset$ represents flux through each turn and N is the number of turns.The negative sign shows that the induced voltage acts in such a way that it opposes the flux producing it. This is known as Lenz's law.

STUDY OF ELECTROMAGNETIC INDUCTION AND VERIFICATION OF FARADY'S LAW.

This experiment is performed in two parts.

Part 1.To study the induced emf as a function of velocity of the magnet passing through the coil.

Magnet NS pass through the coil C (by using coil 1 OR 2) with varying velocities (Fig.2.) An aluminum frame can swing about a pivot O, its period adjustable by sliding the loads A, A. If D is released from angle $\theta_0$from the equilibrium, the velocity V_{max} with which the magnet passes through the coil is given by

$$V_{max} = \frac{4\pi}{T}\sin\frac{1}{2}\theta_0 \text{......................}(2)$$

Where P is radius of D-shape arc (=40 cm).

The magnetic flux (fig.3.) through the coil (Φ) changes as the magnet NS passes through it also two pulses with opposite signs are generated in the coil for each swing. The peak E_0 corrosponds to maximum $\frac{d\Phi}{dt}$.

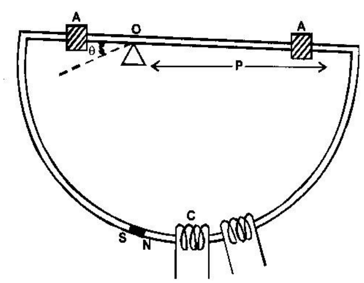


Fig.2. THE MECHANICAL PART WITH MAGNET NS PASS THROUGH COIL 'C' WITH A MEASURABLE VELOCITY

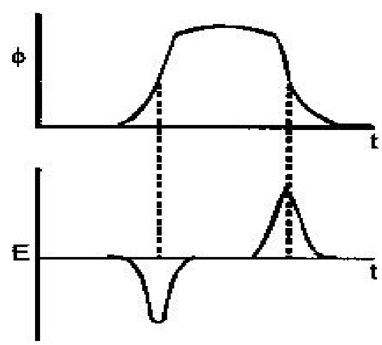


Fig. 3. Time Variation of Magnetic Flux Φ and emf E

PROCEDURE

1. Make the circuit as shown in Fig.4. Keep switch S in OFF position. C ≈ 100µF and R1 ≈ 500Ω . (here R1 represents the internal resistance of the coil and the forward resistance of the diode D.) At each swing the diode permits the capacitor to gain a charge once. The charging time RC being 50 ≈ ms. and the pulse width τ (Fig.3) being a little smaller, the capacitor reaches the E_0 value in a few swings.

2. When the milliammeter shows no more kicks, it means the capacitor C has reached the potential E_0 measure this potential by changing switch to ON position and take reading on Voltmeter.
3. Vary V_{max} by choosing different θ_0 values and measure E_0 each time.
4. Plot a graph of E_0 versus V_{max} and observe it is linear.
5. Repeat after shifting the loads A, A (Fig.2.) so that T changes. The E_0 versus V_{max} data in this set-up fall on the same graph line as in step 4.

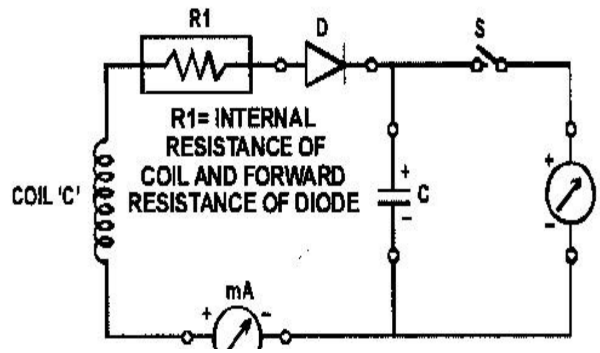
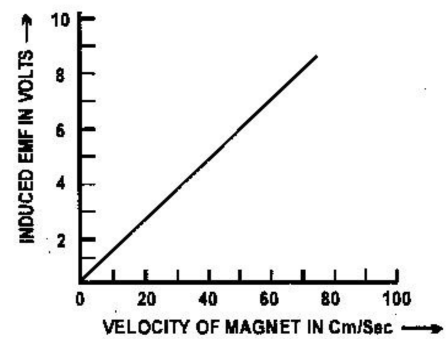


Fig. 4. Circuit Diagram for measuring v_{max}

OBSERVATION TABLE 1

S.No	Release angle θ_0 (deg)	Capacitor Potential E_0 (Volts)	$V_{max} = P\frac{4\pi}{T}\sin\frac{1}{2}\theta_0$ (cm/sec)
1			
2			
3			
4			
5			



`Fig.5. Ideal graph showing the variation of Induced emf with V_{max}

Part 2. To study the charge delivered due to electromagnetic induction

The induced emf E (eq.1) is applied in a circuit of resistance R the charge delivered is given by

$$q = \int_1^2 \frac{E}{R} dt = -\frac{1}{2}\int_1^2 \frac{d\Phi}{dt} dt = -\frac{1}{R}(\Phi_1 - \Phi_2) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(4)}$$

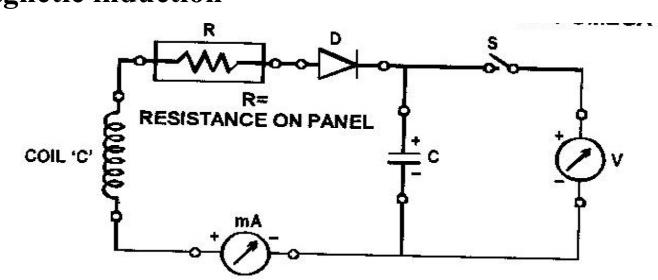


Fig. 6. Circuit Diagram for measuring Charge

When the diode in the circuit of Fig.6 the capacitor C integrates one pulse of Fig.3 and does not receive the opposite pulse. The charge collected is (1/R) times the $\int E\, dt$.

PROCEDURE:-

1 Make the connections as Fig 6. keep RC large compared with width τ by connecting resistance R (given on the panel) in the circuit (Fig 3) which is approximately given by the magnet length divided by V_{max}. With a given release angle θ_0 measure V across the capacitor for N swings taking n=1, 2, 3… by turns. (Each time hold the D by hand after n swings are completed and measure V).
2. Plot q=CV against number of swings (n). Observe the plot to be a straight line as shown in Fig 7.
3. Repeat with a different R values and observe the new q versus n curves.

OBSERVATION TABLE 2

Capacitance (C) in circuit = …….

Release angle θ_0 (deg) = ………

S.No	R1 (...)			R2 (...)		
	Swing 'n'	V (…) (Volts)	Charge Q=CV	Swing 'n'	V (…) (Volts)	Charge Q=CV
1						
2						
3						
4						
5						
6						
7						

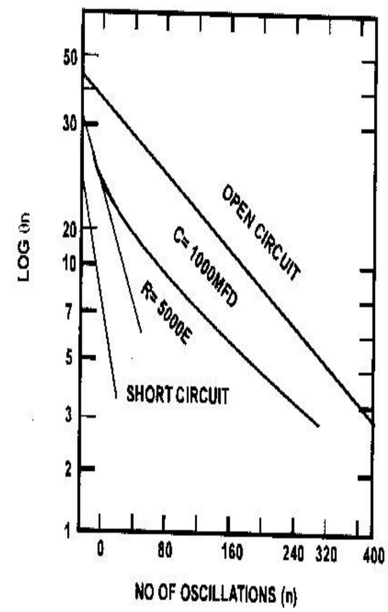


Fig.7. Graph showing the variation of Induced charge with no. of Oscillations

RESULT

To be interpreted by the student basing on the observed data.

VIVA VOCE

2. What is electromagnetic induction?
3. State Faraday's laws of electromagnetic induction.
4. Why Michael Faraday is called the father of electricity though he was not the one who discovered electricity?
5. What is damping?
6. What are eddy currents?
7. State Lenz law.

APPLICATIONS

The ground fault interrupter (gfi) is an interesting safety device that protects users of electrical appliances against electric shock. its operation makes use of faraday's law.

1. Another interesting application of faraday's law is the production of sound in an electric guitar.
2. Generators and motors.

EXPERIMENT – 4
VARIATION OF MAGNETIC FIELD WITH DISTANCE ALONG THE AXIS OF A CIRCULAR COIL

AIM

TO STUDY THE VARIATION OF MAGNETIC FIELD WITH DISTANCE ALONG THE AXIS OF A CURRENT CARRYING CIRCULAR COIL AND HENCE ESTIMATE THE RADIUS OF THE COIL.

APPARATUS

Tangent galvanometer of the Stewart and Gee type, Battery eliminator, Rheostat, Commutator, Plug key and connecting wires.

FORMULA

The magnetic field on the axis of a circular coil is given by:

$$\mathbf{B} = \frac{2\pi \mathbf{nIa}^2}{10(\mathbf{a}^2 + \mathbf{x}^2)^{3/2}}$$

Where **n** = number of turns in the coil

a = radius of the coil in cm

I = current in the coil in amperes

x = distance of the point from the centre of the coil in cm

THEORY

If we pass a current of I ampere in the coil keeping it vertical in magnetic N-S direction and place the needle at a distance x from the centre on any side of the arm, the magnetic field B acting on the needle due to the current in the coil is given by

$$\boldsymbol{B_1 = \frac{2\pi nIa^2}{10(a^2 + x^2)^{3/2}}}$$

This acts East-West in horizontal plane. The horizontal component of earth magnetic field B_H acts on the needle in N-S direction horizontally. Thus two mutually perpendicular coplanar magnetic fields act on the needle deflecting it. According to tangent law:

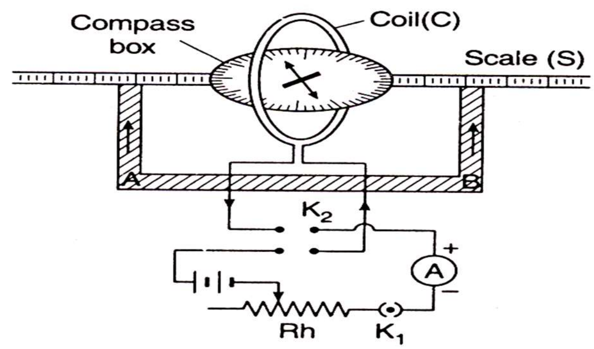
$$\boldsymbol{B_2 = B_H \tan\theta}$$

or,

$$\frac{2\pi nI\ ^{2}}{10(a^2+x^2)^{3/2}} = B_H \tan\theta$$

Hence, the variation of θ with x is studied which gives the variation of magnetic field along the axis of the circular coil.

PROCEDURE



1. The apparatus called Stewart and Gee tangent galvanometer is used to study the variation of magnetic field along the axis of current carrying circular coil and is shown in the figure.
2. Rotate the whole apparatus in the horizontal plane such that the coil lies in the magnetic meridian roughly. In this case the coil, needle and its image all lie in the same vertical plane. Rotate the compass box till the pointer ends read 0-0 on the circular scale.
3. To set the coil exactly in the magnetic meridian, send the electric current in one direction with the help of commutator and note down the deflection of the needle. Now reverse the direction of the current and again note down the deflection. If the deflections are equal then the coil is in magnetic meridian.
4. With the help of rheostat, adjust the current such that the deflection in the compass box should be 65 to 70° when it is placed at the center of the coil.
5. Displace the compass box on the bench through 2 cm. each time along the axis of the coil and for each position note down the mean deflection.
6. Repeat the measurements exactly in the same manner on the other side of the c.

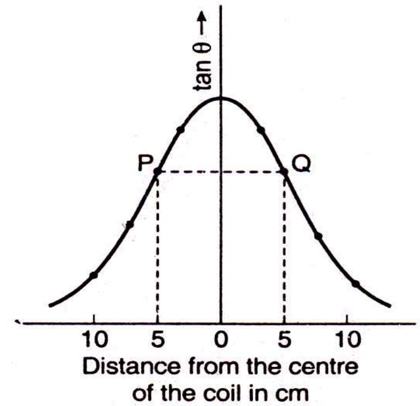
OBSERVATION TABLE

Current , I = ……Amp

S. No.	**Distance (x) (cm)**	**Deflection on Eastern Arm**						**Deflection on Western Arm**						**Mean tan θ**	**B_2 = B_H tan θ**
		Current in one direction (Direct)		**Current in other direction (Reverse)**		**Mean θ**	**tan θ**	**Current in one direction (Direct)**		**Current in other direction (Reverse)**		**Mean θ**	**tan θ**		
		θ_1	**θ_2**	**θ_3**	**θ_4**			**θ_1**	**θ_2**	**θ_3**	**θ_4**				
1.	0														
2.	2														
3	4														
4	6														

Graph

Plot a graph taking distance along X-axis and tan θ along Y-axis. Mark the points of inflection P and Q and hence the radius of the coil.



Result

(i) The graph shows the variation of Magnetic field along the axis of a Current carrying circular coil.

(ii) The radius of the coil (R_m) = ……cm

S. No	Distance (x) cm	B_1	B_2

Standard result

The radius of the coil as estimated by measuring its circumference **(R_s) =** 10 **cm**

Percentage error

(R_m -R_s) x 100/ (R_s) = ...**%**

where **R_m** and **R_s** the measured and the standard values of the radius.

PRECAUTIONS

1. The coil should be adjusted carefully in the magnetic meridian.
2. All the magnetic materials and current carrying conductors should be at a considerable distance from the apparatus.
3. The current passed in the coil should be of such a value so as to produce a deflection of nearly 65°.

4. Before reading the two ends of the pointer parallax between the pointer and its image in the plane mirror should be removed so as to record the correct value of the deflection.
5. The curve should be drawn smoothly.

VIVA-VOCE

Q. 1 : What do you mean by a uniform magnetic field?

Q. 2 : What is magnetic effect of a current?

Q. 3 : What is the Tangent law?

Q. 4 : What is magnetic meridian?

Q. 5 : How the coil is set in the magnetic meridian? How can you test this setting?

Q. 6 : What is the direction of the magnetic field produced by the coil?

Q. 7 : Why is it necessary to set the coil ion the magnetic meridian?

Q. 8 : Why both the ends of the pointer in the compass box be read.

Q. 9 : Why the readings must be repeated after reversing the current?

Q. 10 : How does the field vary along the axis of the coil?

Q. 11 : What is the magnitude of the field at the centre of the coil?

Q. 12 : Is the field uniform at the centre?

Q. 13 : Will the presence of any current carrying conductor close by, will effect the results?

Q. 14 : How do you find out the radius of the coil from x Vs $\tan\theta$ from graph?

APPLICATIONS

Motors, transformers, microphones, compasses, telephone bell ringers, television focusing controls, advertising displays, magnetically levitated high-speed vehicles, memory stores, magnetic separators etc.

EXPERIMENT- 5
NEWTON'S RINGS

AIM: Determine the wavelength of sodium light (Monochromatic Light) by Newton's rings method.

APPARATUS: Optical arrangement for Newton's rings, travelling microscope, sodium lamp, short focus convex lens, reading lens and spherometer.

PRINCIPLE & FORMULA: Consider a Plano-convex lens of large radius of curvature placed on a circular plane glass plate. A thin film of air is formed between the glass plate and the lens as shown. At the point 'O' where the lens is in contact with the glass plate, the thickness of the air film is zero and as we proceed away from O, the thickness of the film gradually increases. At the points around 'O' and at equal distance from it, the thickness of the film is same since the bottom surface of the lens is spherical.

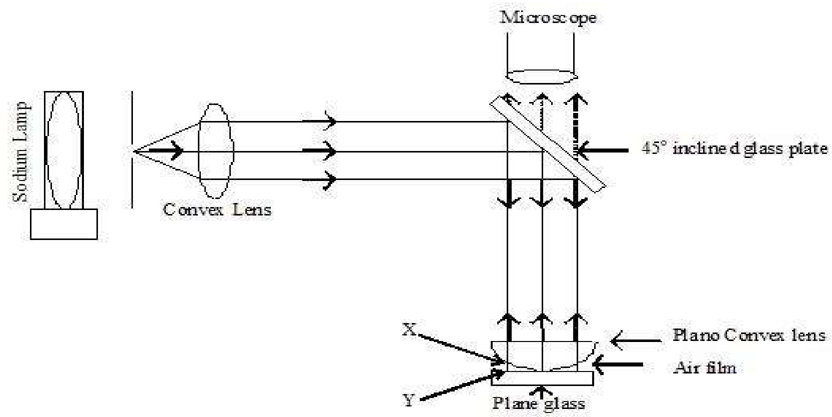


Figure 1.1

Now suppose that monochromatic light is incident normally on the air film at X at a distance of 'a' from 'O'. This light is partially reflected at the top surface of the air film at 'X' and after refraction in air partially at 'Y'. The two reflected beams will have certain path difference depending upon the thickness of the film (XY). Interference of these two reflected beams takes place which can be observed through a microscope placed vertically above the lens. The point X will be bright or dark, depending upon whether the path difference is odd or even number of half wave length of incident light. Similarly interference of light occurs at all other points of the film and a set of rings which are alternately bright and dark will be observed with a dark spot at the centre of the rings. Each ring is the locus of all points in the film which are at the same distance from the centre O of the ring system. If d_m and d_n are the diameters of the m^{th} and n^{th} dark rings respectively and R is the radius of curvature of the curved surface of the Plano-convex lens, it can be shown that the wavelength of light is given by

$$\lambda = \frac{D_m^2 - D_n^2}{4R(m-n)}$$

Thus by forming these rings called Newton's rings and by measuring their diameters, the wavelength of light can be determined.

PROCEDURE

1. Place the Plano-convex lens on the circular plane glass plate such that the convex surface of the Plano convex lens is in contact with the plane glass plate. Place this combination in the wooden box, which contain a plane glass plate inclined by 45^{o} to the incident light from the short focus convex lens. Place the wooden box under the traveling microscope and adjust it until sharp rings are seen.
2. Bring the point of the cross wires to the centre spot of the ring system. Starting from the centre of the ring system move the microscope cross wires to the left up to the 19^{th} dark ring. (This number selected arbitrarily).
3. Set the vertical cross wire tangential to the 19^{th} dark ring at the left and note the reading on the horizontal scale of the microscope. Repeat the same for alternate dark rings until cross wire reaches 1^{st} dark ring. Similarly take the readings of alternate rings at the right side starting from 1^{st} ring.
4. **Determination of radius of curvature of the convex surface of the Plano-convex lens (R)**
   Take out the lens and mark the surface which was in contact with glass plate. Place the spherometer on the convex surface of the plano-convex lens and note the reading of the spherometer (h_1) then place the spherometer on the plane glass plate and note the reading (h_2).
   Reading of the spherometer for convex surface of the lens (h_1) =……cm
   Reading of the spherometer for plane glass plate (h_2) =……cm
   Average distance between the legs of the spherometer (l) =……cm
   Height of the convex surface (h) = ($h_1 - h_2$) =……cm
   Radius of curvature of the curved surface of the Plano-convex lens

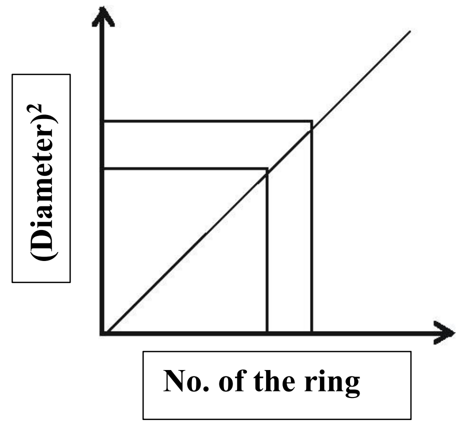
$$R = \frac{l^2}{6h} + \frac{H}{2} = \text{..................................cm}$$

TABLE

S.No.	Ring No.	Microscope Reading (cm)		Diameter D = L ~ R (cm)	D^2 (cm^2)
		Left side (L)	Right side (R)		
1	20				
2	18				
3	16				
4	14				
5	12				
6	10				
7	8				
8	6				
9	4				
10	2				

GRAPH

Draw a graph with the ring number on X-axis and (diameter)^2 on Y-axis. By joining the points a straight line passing through the origin is obtained as shown in figure 1.2.



Find the slope of the straight line, which is:

$$\frac{\left(d^2_m - d^2_n\right)}{(m-n)}$$

CALCULATIONS

Radius of curvature of the plano convex lens (R) =……cm
Diameter square of the mth ring d^2_m =……cm^2
Diameter square of the nth ring d^2_n =……cm^2
Slope of the straight line =……cm^2
Wavelength (λ) =……cm

RESULT: Wave length of Sodium light (λ) is found to be =……cm = ……. A^0

PRECAUTIONS

1. The lens surface as well as circular glass plate must be well cleaned.
2. The centre spot of the ring system should be dark.

APPLICATIONS

- **Radius of curvature of convex surface of the given lens.**
- **Refractive index of a liquid.**
- **Wavelength of a monochromatic light.**
- **Color separation scanning Equipments/ Colour scanners.**
- **Anti-Newton ring Glass in photographic industry.**

Viva Voce

1. What is Newton's Ring? How are these rings formed?
2. Why are these rings circular? If the fringes are not exactly circular what do you infer?
3. Why are you using the Plano-convex lens of large focal length?
4. Why do the rings get closer as the order of rings increases?
5. Why is the centre of these rings dark?

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2 A text book of Practical Physics – R.K Goel, Govind Ram
3 B.Sc Practical Physics – C.LArora

EXPERIMENT- 6
DIFFRACTION GRATING

AIM: To determine the wavelength of the spectral lines (Blue, Green, Yellow, Y_1, Y_2) using a diffraction grating by normal incidence method.

APPARATUS: Spectrometer, diffraction grating, sprit level, mercury vapor lamp and magnifying lens.

PRINCIPLE & FORMULA

Diffraction is the phenomenon of bending of light around the obstacle specially when passed close to sharp edges or through apertures or narrow openings. Consider a plane transmission grating with alternate opaque and transparent lines. Let a parallel beam of light rays are incident normally on the grating. Most of these rays are transmitted in the direction of the incident light through transparent portions of the grating and if a converging lens is placed in their path, they are brought to focus at O. there will be a very bright image. Some of the incident light is diffracted at the edges such as B, D and F etc., at different angles as shown in figure 2.1. If we consider these rays (bend at B and D at an angle θ from the direction of the incident light) all such rays form a parallel beam and after passing through the lens, they are brought to focus at I. The intensity at I will be maximum or minimum depending upon the path difference between the diffracted rays from B and D. If 'd' is the grating element (distance between two consecutive lines on the grating), path difference is equal to $d\sin\theta$.

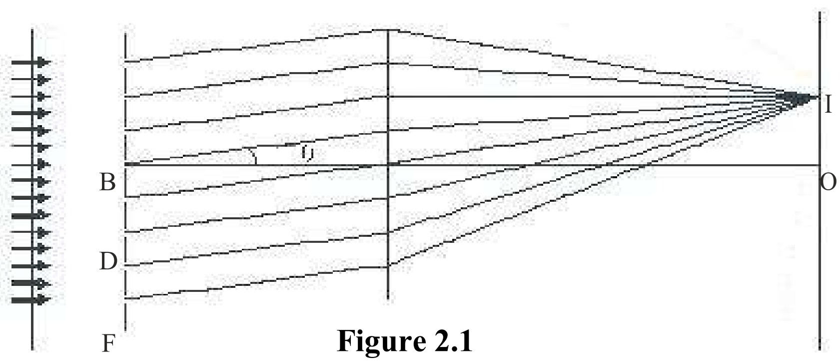

Figure 2.1

Thus if $d\sin\theta = n\lambda$ (an integral number of wave lengths) the bright images are formed in the focal plane of the lens. These are called first order, second order (n=1, 2, 3,) etc., images. Thus one set of images will be formed on one side of the central bright image at O. Also the diffraction or bending of light rays takes place to the other side of the incident direction and corresponding images of different orders are formed on the other side of the central image O. Thus in the field of view of a telescope of which the lens L forms the objective, a central bright image and the diffracted images of different orders (n=1, 2, 3, etc.) are observed. If the incident light is monochromatic, each order of diffracted image will be of the same color, but if white light (mercury) is incident on the grating, each diffracted image consists of a whole spectrum. Thus spectra of different orders are formed on either side of the central white image.

APPLICATIONS

- **Grating as filters**
- **Fiber optic telecommunication**
- **Beam splitters**

- **Optical couplers**
- **Metrological**
- **Ground-based astronomy**
- **Raman spectroscopy**
- **Colorimetry**
- **Atomic and molecular spectroscopy**
- **Fluorescence spectroscopy**

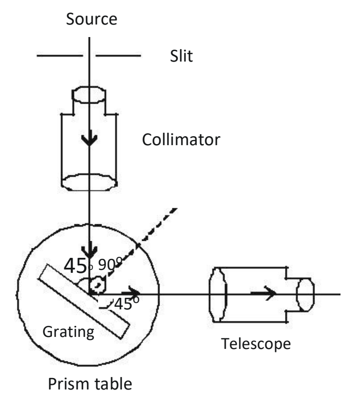

Figure 2.2

FORMULA

$$(a + b)\sin\theta = n\lambda \text{(Grating equation)}$$

Or $$\lambda = \frac{(a + b)\sin\theta}{n}$$

Where

$(a + b)$ = grating element

θ an n = angle and order of diffraction .

PROCEDURE

1. Make preliminary adjustments of the spectrometer.
2. Clamp the grating on the prism table with the help of a clamp. Adjust the grating for normal incidence position by the following method.
   I. Set the telescope for direct reading position and note the reading V_1 and V_2.
   II. Add 90^o to the above reading and rotate the telescope to this reading and fix it.
   III. Now rotate grating until the image of the slit is at cross wires of the telescope and fix the prism table. Now the incident light is making 45^o with the grating plane (See figure 2.2).
   IV. Release the vernier scale knob and rotate the vernier scale through an angle of 45^o so that the grating will be exactly normal to that of the incident light. Fix the vernier table in this position; This is called as the normal incidence position.
3. Release the telescope and rotate it to left side of the direct reading position until the first order spectrum is seen. Now coincide the vertical cross wire over the spectral lines of desired color and note down the readings in the two verniers as V_1 and V_2. Further, rotate the telescope till second order spectral lines are visible, coincide the cross wire and note down the readings in two verniers as V_1 and V_2 against 2^{nd} order.
4. Now rotate telescope to the right side of the direct reading position until the first order spectrum is seen. Now, coincide the cross wires with the same yellow spectral line and note down the readings in the two verniers as V_1' and V_2'. Rotate the telescope further until the II order spectral lines are seen, then coincide the vertical cross wires with lines and note down the readings as V_1' and V_2'. The angle of diffraction is given by half the angle between corresponding lines.

CALCULATIONS

No. of lines per cm on the grating = grating element = $(a+b) = (1/N) = 2.54/15000$

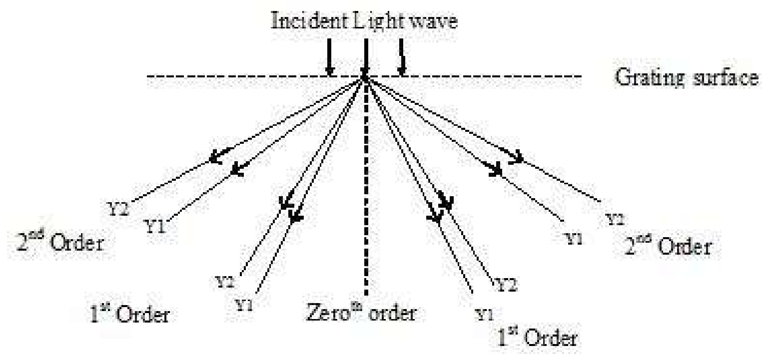

Figure 2.5

TABLE

Order of diffraction	Spectral lines	Spectrometer Readings				$2\theta = \frac{(V_1 - V_1') + (V_2 - V_2')}{2}$	θ	$\lambda = \frac{(a+b)\sin\theta}{n}$
		Left		Right				
		V_1	V_2	V_1'	V_2'			
I order	Y_2							
	Y_1							
	Green							
	Blue							
II order	Y_2							
	Y_1							
	Green							
	Blue							

RESULT: The observed wavelengths are given in table

Colour of specturl line	λ (observed)	λ (Standard)	% (Error)
Blue	....	....	....
Green	....	....	....
Yellow 1	....	....	....
Yellow 2	....	....	....

PRECAUTIONS

1. Optical adjustment of the spectrometer should be made directly.
2. The slit should be as narrow as possible.
3. Grating surface should not be touched with fingers as the slit might get damaged.
4. The grating should be exactly normal to the incident beam.
5. While taking observations, telescope and prism table should be kept fixed.

Viva Voce:

1. What is a plane transmission diffraction grating?
2. Why the grating should be kept normal to the plane of grating, then which formula should be applied?
3. What is (a+b) in the formula?
4. How many orders of spectra do you get here? Why do you not get the third order spectrum?
5. How many types of grating are known to you?
6. What is the main difference between the spectrum obtained by grating and due to prism?
7. What do you mean by dispersion of light?
8. Why a light on passing through the prism disperses into its constituent colours?
9. Define dispersive power of any material?
10. On what factors does the dispersive power depend?
11. What is the angle of deviation?

REFERENCES

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3 B.Sc Practical Physics – C.LArora
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5 A Laboratory Manual of Physics – D.P Khandelwal
6 B.Sc Practical Physics – Harnam Singh

EXPERIMENT -7
OPTICAL FIBRE

AIM: To determine the (1) Numerical Aperture (NA), (2) Power Losses due to Macro bending and adaptor of givem optical fibre.

APPARATUS: LED, NA Jig, D.M.M, scaled screen, adaptor, one and three meter length of optical fiber, mandrel.

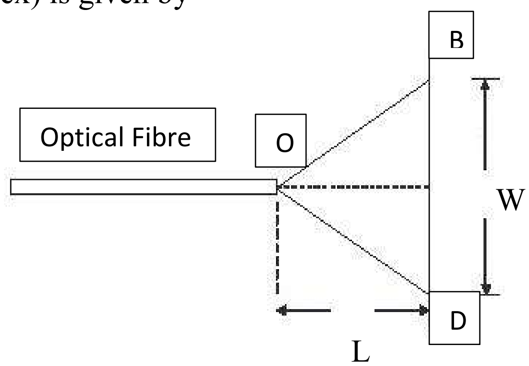
PRINCIPLE & FORMULA

The Numerical Aperture (N.A) of an optical fiber (step index) is given by

$$NA = \left[n_{core}^2 - n_{cladding}^2\right]^{1/2}$$

$$= \sin i_{max}$$

$$\text{or} \quad i_{max} = \sin^{-1}(NA)$$



n_{core} = refractive index of core,
n_{clad} = refractive index of cladding
i_{max} = acceptance angle

Figure 8.1

As shown in figure 8.1, light from the end of the optical fiber 'A' falls on the screen BD. Let the diameter of light falling on the screen BD=W, Let the distance between end of the fiber and the screen AO=L. knowing W and L, the N.A can be calculated and substituting this N.A value in Eq (2), the acceptance angle 'θ' can be calculated.

Losses of power in a fibre optic cable are mainly due to the absorption or scattering of light with an Optical fibre. Macro bending and joints between the cables (adaptor). This loss of power 'P' from input (P_o) to output (P_L) at a distance 'L' can be written as

$$P_L = P_0 e^{-\alpha L}$$

where 'α' is the attenuation coefficient in decibels (dB) per unit length, measured in dB/KM.

PROCEDURE

1. Insert one end of either one or three meter length optical fiber cable the LED and NA jig.. Switch on LED, then red light will appear at the end of the fiber on the N.A Jig. Turn SET P0/IF knob the intensity will increase. Arrange the scaled screen at a distance L, and then view the red spot on the screen. Measure the diameter of the spot (w). Note the measured values L and W in the table. Repeat the experiment with different distances and note the readings.

Tabular Form 1

S. No	L (mm)	W (mm)	$NA = \frac{W}{\lfloor 4L^2 + W^2 \rfloor^{1/2}}$	i_{max}

2. Insert one end of the three meter length plastic optical fibre cable to the FOLED and connect another end to the power meter module. Connect D.M.M test leads to Pout, red lead to red socket and black lead to black socket respectively. Set D.M.M to 2000 mV range. Switch on LED, adjust the Set Po/IF knob to set output power of the FOLED to the value -22.0 dBm(milli decibels) i.e., DMM reading will be - 220mV, note this as P_O, wind the fibre on the mandrel and note the reading as P_{OW1}, similarly for two and three turns. Note the readings as P_{OW2} and P_{OW3} respectively**.**
3. Connect one meter OF cable as given above and set D. M. M. for a constant value(~120mV) and note the reading as P_1. Similarly take P_2 by replacing one meter cable with three meter cable without disturbing set Po/If knob. Now j0in the 1m and 3m cables with the adapter as shown in the figure and note DMM reading as P_3.

Tabular Form 2

x O/P power (dbm)		Loss due to turns (dbm)
Po0	-	
Pow1	-	(Po0 – Pow1)
Pow2	-	(Po0 – Pow2)
Pow3	-	(Po0 – Pow3)

OBSERVATIONS

P_1 =

P_2 =

P_3 =

CALCULATIONS

Take P_1, P_2 and P3 as shown in Fig., without disturbing the SET Po / I_f knob.

Loss in one meter cable (X) = $(P_2 – P_1)/2$

Loss due to adopter = $P_3 – P_1 – 3X$ =

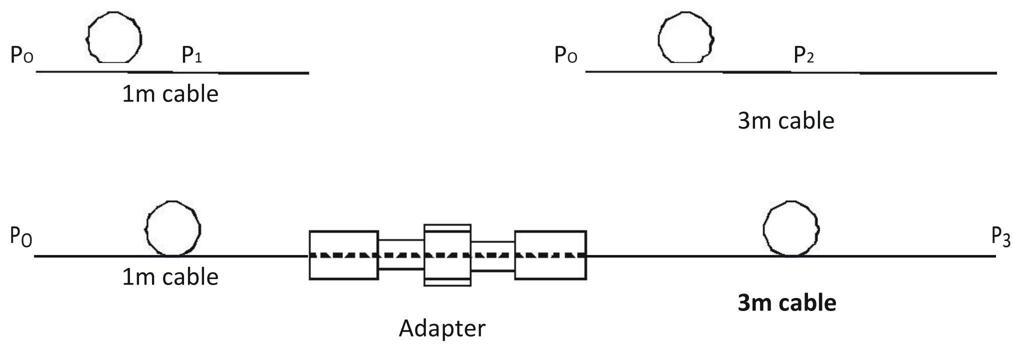


Figure 8.2

RESULT

1. N.A of given Optical fiber is ———————
2. Power loss due to one turn—————— dBm, two turns —————dBm and three turns ———dBm
3. Power loss due to one meter cable—————— dBm and due to adaptor ——— dBm

PRECAUTIONS

1. Gently insert the optical fiber cable is to LED by turning clockwise direction of its clinch nut. (until you feel the fiber touches the micro lens)
2. Do not push applying over force which may damage micro lens
3. Gently tight the clinch nut that holds the inserted fiber firmly.
4. Before taking reading check out fiber is free of all twists and strains.
5. Two cables must meet at the center of the adopter while taking P_3 reading.

VIVA-VOCE

1. What do you mean by numerical aperture?
2. On what factors the numerical aperture depends?
3. What do you mean by acceptance angle?
4. On what factors the acceptance angle of the fiber depends?
5. A fiber with high numerical aperture (NA) is preferable or not? Why?
6. What is irradiance?
7. What do you mean by bandwidth?

APPLICATIONS

Telecommunications
Local Area Networks(LAN) and Wide Area Networks(WAN)
Factory Automation, premises. Wiring, Fiber-Optic biomedical sensors, Endoscopic Imaging, Aerospace and Military Applications, Fiber Optic Sensors.

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7 A Laboratory Manual of Physics – D.P Khandelwal
8 B.Sc Practical Physics – Harnam Singh

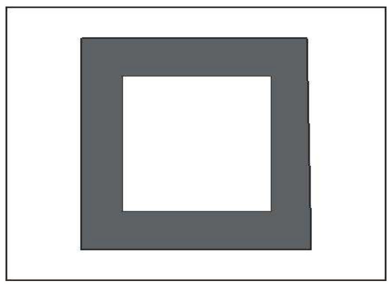
EXPERIMENT-8
LASER DIFFRACTION

AIM: To Measure the diameter of a human hair/thin wire by Laser Diffraction

THEORY: Often it is necessary to determine the diameter of a fine wire, thin thread or other object that cannot be measured by convectional means. These can be measured by using methods of diffraction and interference known as Young's Double Slit Experiment. While Young's experiment deals with the pattern of light impinging on two narrows slits separated by a small distance. The method can be applied to an object with a small diameter as well, where the diameter is within an order of magnitude of the wavelength of laser light used.

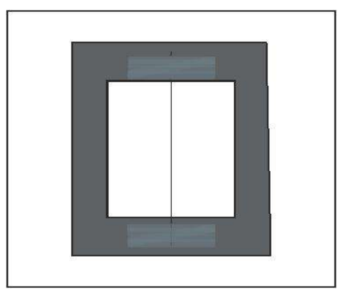
PROCEDURE

1 Take a 15 cm by 15 cm piece and make a 10 cm by 10 cm hole in the center of the cardboard piece. This is your mounting bracket.

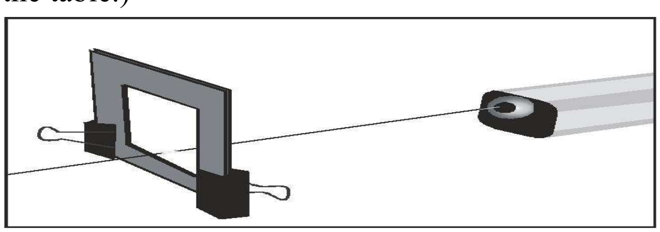


2. Select one strand of hair approximately 15-25 cm long. This hair needs to be mounted on the mounting bracket from step 1.

3 Mount the hair on the bracket using tape. Place the hair so that it bisects the mounting bracket. Make sure the hair is taut and straight.



4. Set the laser pointer (or laser) on the lab table. Positioning the laser so the beam strikes the hair in the mounting bracket. (You may use binder clips or books to position the laser source and the mounting bracket on the table.)

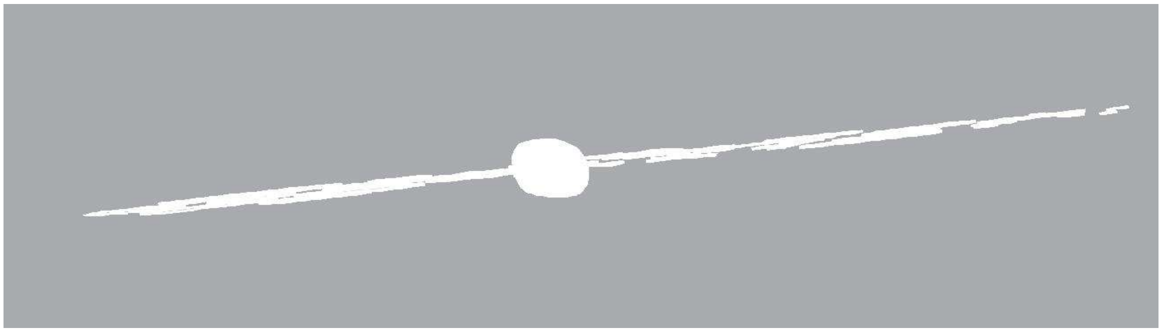


5. Make sure the laser setup and mounting bracket face a wall or screen.

6. Record the following key parameters on the data sheet provided. Record the wavelength of the laser

as λ . In some case it may be necessary to average the wavelength values given on the laser's label. Typical value of wavelength for a red He-Ne Laser is 632-634 nm.
Red laser pointers have a typical range between 630 nm –680 nm. Record the distance (D) between the mounting bracket and screen or wall. (If you are using a wall for a screen it might be prudent to tape a piece of white paper on the wall to use as a background.)

7. Examine the pattern striking the screen. It should appear similar to the image below. (You may need to darken the work area or room to see the faint higher order bands.)



8. Carefully measure the bright bands by measuring from the center of the bright central band to the starting edge of first bright band on the left. Record this value as y_{1i}, under the y_{mi} column. (You may find a bring spot in the center of the central band. This point can be used as reference.) Measure from the center of the central band again to the end of the first bright band on the left. Record this as y_{1f}, under the y_{mf} column. The average of these two measurements is the distance between the central bright band and the 1st order maximum (m=1) on the left side. Record this on the data table as y_1 avg under the y_m avg column on the data sheet. Repeat the steps for the 2nd, 3rd, 4th and 5th order bands. If you can see the bands beyond m = 5, measure those as well. Make sure you measure from the middle of the central band to the beginning and the end of each of the mth order bands.
(You may have to darken the room to see all the bands.)

9. After measuring all the bands on the left. Proceed to measure the mth order bands on the right side of the central band using the same techniques outlined in step 8. This should yield a total set of at least ten measurements.

10. For each y_m avg calculate the diameter of the human hair (d) using:

$$d = (\lambda\ m\ D) / y_m \text{ avg}$$

11. After determining the ten values of d calculate the average diameter of a human hair and the standard error (α_d) in the measurement of d. where the standard error is the standard deviation of d divided by the square root of the number of measurements taken. $\alpha_d = S_d / N^{1/2}$

EXAMPLE CALCULATIONS

Example for the 1st order (m = 1) band for a He-Ne laser wavelength λ = 633 nm, and screen distance of D = 1.5 m.

$$d_1 = \left(633\times10^{-9}\ \text{m}\right)(1)(1.5)/(0.02\text{m}) = 4.75\times10^{-5}\ \text{m or } 47\mu\text{m}$$

Example for the 4th order (m = 4) band for a He Ne laser wavelength = 633 nm, and screen distance of D = 1.5 m. $d_4 = \left(633\times10^{-9}\text{ m}\right)(4)(1.5)/(0.0575\text{m}) = 6.61\times10^{-5}$ m or 66μm

The same experiment can be tried out on a needle or pin.

Viva Voce:

1. What is the range of values for human hair?
2. Average the range of values of human hair. What is the percent difference between your average value and the average accepted value from different sources of information such as books or internet?
3. What other items could you measure using this technique?
4. What is He-Ne laser? How it works?
5. Why we can't measure human hair diameter using screw gauge?
6. What is diameter of dust particle (floating in air)?

Diameter of a human hair Data sheet					
Laser wavelength λ=					
m	**| m |**	Y_{mi}	Y_{mf}	$Y_{m\,avg}$	**Calculated Diameter**
+7	7				
+6	6				
+5	5				
+4	4				
+3	3				
+2	2				
+1	1				
0	N/A			N/A	N/A
-1	1				
-2	2				
-3	3				
-4	4				
-5	5				
-6	6				
-7	7				
			Average Diameter		
			Error		

Some examples of diameter of human hair

Bibliographic entry	Result	Standardized Result
Piezo Technology. Epson (UK) Ltd	"45 microns, 2 times smaller than the diameter of a human hair and close to the limit of resolution for the human eye"	90 µm
Denny R's Homepage. Denny & Gayle Rossbach. Palmdale, CA	"Diameter of a human hair inches: 0.001; centimeters: 0.00254"	25.4 µm
Why ChooseAWater Treatment System?Aqua-Fresh Drinking Water Systems, Inc	"Particulate contaminants including asbestos, rust, sediment, dirt, and scale as small as 0.2 microns (1/300th diameter of a human hair)."	60 µm
Hair - Important Facts About Hair. CAQTI Cosmetics, Inc.	"Flaxen hair is the finest, from 1/1500 to 1/500 of an inch in diameter … and black hair is the coarsest, from 1/450 to 1/140 of an inch."	17 - 50 µm (flaxen) 51 - 181 µm (black)

EXPERIMENT – 9
SOLAR CELL CHARACTERISTICS

AIM

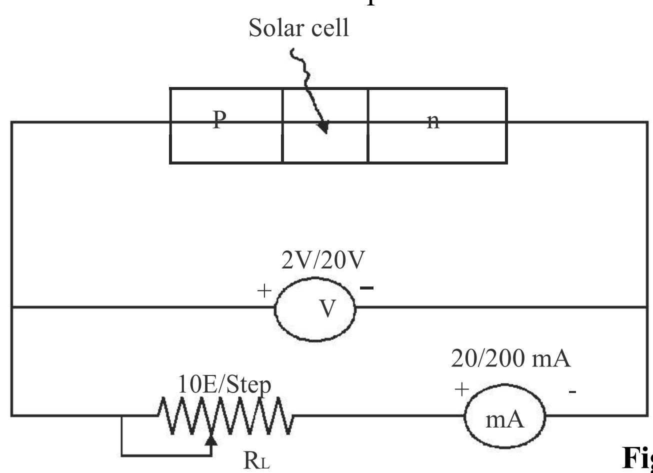
STUDY OF BOTH THE CURRENT - VOLTAGE CHARACTERISTIC AND THE POWER CURVE TO FIND THE MAXIMUM POWER POINT (MPP) AND EFFICIENCY OF A SOLAR CELL.

APPARATUS

Solar Panel Consist of 6 solar Cells, Table lamp, Digital/Analog D.C ammeter and voltmeter.

THEORY

A solar cell or photovoltaic cell is a device that converts light energy into electrical energy. Sometimes the term solar cell is reserved for devices intended specifically to capture energy from sunlight, while the term photovoltaic cell is used when the light source is unspecified. Fundamentally, the device needs to fulfill only two functions: photo generation of charge carriers (electrons and holes) in a light-absorbing material, and separation of the charge carriers to a conductive contact that will transmit the electricity. This conversion is called the *photovoltaic effect*, and the field of research related to solar cells is known as photovoltaic.



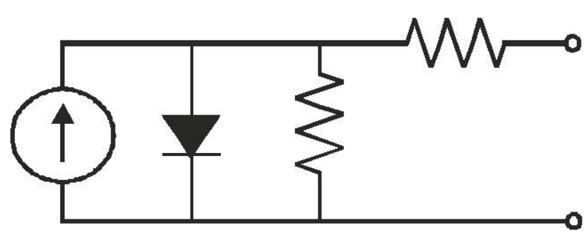
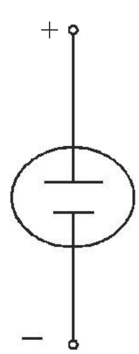
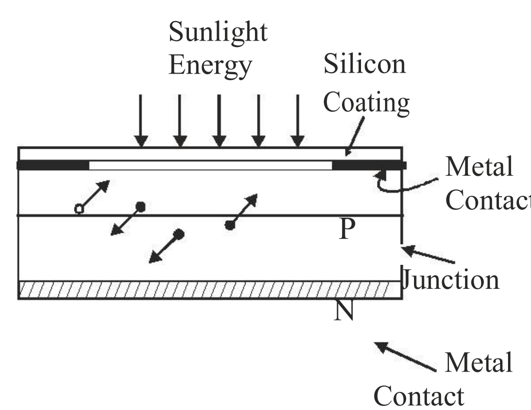


Figure 1



(A) Circuit Symbol



(B) Cross-section

Figure 2: *Solar cell*

SIMPLE EXPLANATION

1. Photons in sunlight hit the solar panel and are absorbed by semiconducting materials, such as silicon.
2. Electrons (negatively charged) are knocked loose from their atoms, allowing them to flow through the material to produce electricity. The complementary positive charges that are also created (like bubbles) are called holes and flow in the direction opposite of the electrons in a silicon solar panel.
3. An array of solar panels converts solar energy into a usable amount of direct current (DC) electricity.

PHOTO GENERATION OF CHARGE CARRIER

When a photon hits a piece of silicon, one of three things can happen:

1. The photon can pass straight through the silicon this (generally) happens for lower energy photons,
2. The photon can reflect off the surface,
3. The photon can be absorbed by the silicon which either generates heat or generates electron-hole pairs, if the photon energy is higher than the silicon band gap value.

CHARGE CARRIER SEPARATION

There are two main modes for charge carrier separation in a solar cell:

1. **Drift** of carriers, driven by an electrostatic field established across the device
2. **Diffusion** of carriers from zones of high carrier concentration to zones of low carrier concentration (following a gradient of electrochemical potential).

In the widely used *p-n junction* designed solar cells, the dominant mode of charge carrier separation is by *drift*. However, in *non-p-n junction* designed solar cells (typical of the third generation of solar cell research such as dye and polymer thin-film solar cells), a general electrostatic field has been confirmed to be absent, and the dominant mode of separation is via charge carrier *diffusion*.

PROCEDURE

1. Take the Solar Energy Trainer NV6005 along with Solar Panel.

2. Place the solar panel in the stand and adjust the panel at an angle of about 45º with the ground. Direct the sunlight
straight at the solar panel (angle of 90º).

Note: *If sunlight is not properly available then any source of light like lamp can be used.*

3. With the DB15 connector connect the Solar Energy Trainer NV6005 with Solar Panel. Then wait for 1 minute to avoid errors due to temperature fluctuations.

4. Set the potentiometer to maximum resistance i.e. at fully clockwise position and measure and record its resistance into the Observation Table.

5. Connect the solar cell as shown in the following circuit diagram as shown in figure 3.

- **a.** Connect positive terminal of solar cell to P1 terminal of the potentiometer.
- **b.** Connect other end of potentiometer i.e. P2 to positive terminal of ammeter.
- **c.** Connect negative terminal of ammeter to negative terminal of solar cell.
- **d.** Now connect the positive terminal of voltmeter to P1 and negative terminal of voltmeter to P2.

6. Record the values of corresponding voltage and current into the observation Table.

7. Now gradually move the potentiometer in anti- clockwise direction so that the resistance of the potentiometer decreases. Now measure the resistances at successively smaller values and record the

corresponding values of voltages and current in the Observation Table below.

Note: *Always to measure the resistance of potentiometer at any position, first remove the patch cords from P_1andP_2 and measure resistance by multi meter. Reconnect these connections again for further measurements.*

OBSERVATION TABLE

S.No.	Resistance, R	Voltage, V (Volt)	Current, I (mA)	Power Calculated P = V.I (watt)
1				
2				
3				
4				
5				
6				
7				
8				

8. Plot the V-I characteristics from the measurements recorded in the table, to show how the photoelectric current depends on the photoelectric voltage and to find maximum power point.

Fillfactor Calculation

Fill factor is the ratio of maxmium useful power to ideal power: Maximum useful power is area of largest rectangle that can be formed under V-I curve. V_m and I_m are values of voltage and current for these conditions.

Maximum useful power □V_m□I_m

And Ideal power □V_{OC}□I_{SC}

where I_{SC} = maximum value of saturation current

V_{OC} = emfgenrated by photovoltaic cell in open circuit.

Fill factor □ $\dfrac{V_m \square I_m}{V_{OC} \square I_{SC}}$

From V-I characteristics you can easily find the maximum power point (MPP). MPP occurs where the product of voltage and current is greatest.

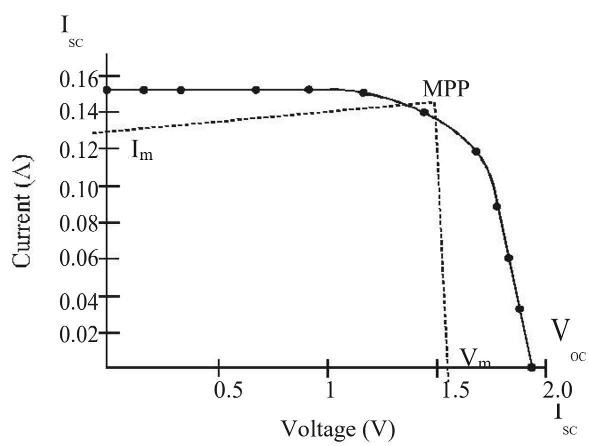


Figure 4: *Current voltage characteristicof the solar cell*

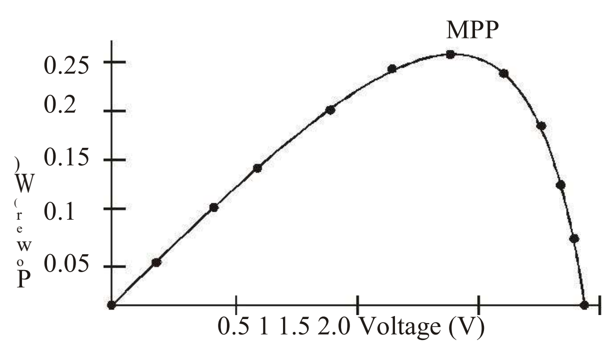


Figure 6: *Power curve of the solar cell as a function of voltage*

9. Plot the curve of power as a function of voltage from the measurements recorded in the table.

Expected Power - Voltage curve is as shown in figure 11.6.

The maximum power point (MPP) is the maximum value of power in the above curve.
The resistance, RMPP, at which the output power is at a maximum, can be calculated using the following formula:

$$R_{MPP} = \frac{V_{MPP}}{I_{MPP}}$$

TO CALCULATE THE EFFICIENCY (η) OF SOLAR CELL

The efficiency of the solar cell is the ratio of produced electrical power (Pout) and the incident radiant power (Pin).
Efficiency of solar cell, $\eta = \frac{P_{Out}}{P_{In}}$

Where P_{out} is the output electrical power (maximum power point).
Pin is calculated by multiplying approximated irradiance ("irradiance" means radiant power of the light incident per unit area) by the effective area of the solar cell on the panel.
This method used the fact that the practical value of the current (maximum photoelectric current measured) is proportional to the photons (radiation) striking the solar cell. This current is therefore proportional to the incident radiant power of the light.
The open circuit voltage depends on the semiconductor material of which solar cell is made. It is not proportional to the incident radiant power and therefore cannot be used for this measurement.

Efficiency of solar cell, $\eta = \frac{P_{Out}}{P_{In}}$
Where P_{out} (Output Electrical Power) = Maximum Power Point (MPP)
P_{in} (Incident radiant power) = Approximated IrradiancexArea of solar cell
$= F \times I_P \times A$, Here A = Area of a solar cell (Length x Breadth) m^2
I_p= Practical value of current (maximum photoelectric current measured) indicated on the ammeter,

F is a constant and is given by

$$F = \frac{Maximum\ Solar\ Irradiance(\ specified\ by\ Manufacturer)\text{or (the power of the source used)}}{Maximum\ Value\ of\ Current}$$

The maximum irradiance in summer is approx. 1000 W/m^2 (or the power of the source used).. The maximum value of the current specified by the manufacturer is achieved at this value i.e. 150mA in the given solar cells. (The parameters of the solar cell/panel are related to the standard test conditions of 1000W/m^2 and cell temperature of 25º C.)

$$F = \frac{1000\ \text{W/m2}}{150\text{mA}}$$

$$F = 6.67\ \frac{W}{m^2.mA}$$

Multiplying the practical value of current (Ip) indicated on the ammeter by the factor gives an approximation of the radiant power per unit area (irradiance) striking the solar cell.

$$F = 6.67\ \frac{W}{m^2.mA}$$

The efficiencies of solar cells lie between 12 to 15 %. If efficiency is slightly less than determined value then it is due to measuring errors and inaccuracies in determining the incident radiant power. Furthermore, the efficiency of solar panel is less than that of their separate constituent cells. This is caused by losses that arise in matching solar cells that do notall have exactly the same properties. If the solar cells are connected in series to generate desired voltage, the maximum power point may not be same for all cells. Solar cell losses arise as not all photons striking the solar cell can be converted into charge carriers. Part of the light is reflected as soon as it hits the surface and the metal contacts cast shadows. Since the photon energy does not correspond to the energy gap, less than half of the incident energy is used. Recombination of charge carriers (atomic rebinding of electrons) and electrical losses caused by internal resistances (ohmic losses in the semiconductor) of the solar cell and its contacts also arise.

RESULT

The efficiency of the given Solar Cell is …..%

PRECAUTIONS

1. Do not make inter connections on the board with mains switched ON.
2. All the connections should be tight.
3. Switch off after taking the readings.

VIVA-VOCE

1. What is solar cell?
2. Why solar cell is also called photovoltaic cell?
3. What are the uses of solar cell?
4. What do you mean photoelectric effect?
5. On what factors does the photocurrent depend?
6. Define the efficiency of Solar Cell?
7. How does temperature effect efficiency of solar cell/photo voltaic cell.
8. What happens to the current when Photo voltaic cells are connected in series and in parallel.
9. What is the order of current in photo voltaic cell?
10. Define a fill factor of a photo voltaic cell.

APPLICATIONS

- Telecommunication systems: Radio transceivers on mountain tops or telephone boxes in the country can often be solar powered.
- Remote monitoring and control: scientific research stations, seismic recording, weather stations, etc. use very little power which, in combination with a dependable battery, is provided reliably by a small PV module.
- Ocean navigation aids: many lighthouses are powered by solar cells.
- Water Pumping/Rural Electrification/Domestic supply
  Health Care/Lighting, Electronic industry and Electric Power Generation in Space.

EXPERIMENT – 10
PLANCK'S CONSTANT

AIM
STUDY OF PLANCK'S CONSTANT BY USING LEDs.

APPARATUS
0-5V DC at 2mA, D.C Voltmeter, D.C Ammeter, Different color LEDs.

FORMULA & THEORY
Max Planck first proposed the idea that light was emitted in discrete packets or quanta in order to avoid the infamous ultra-violet catastrophe. With one problem resolved other question soon follows. Primarily, how big was a given packet? It was subsequently determined that the energy of given photon is given by the equation:

$$E = h\upsilon$$

where E is the energy of the photon υ is its frequency, and h is the Planck's constant.
The objective of this experiment is to determine Planck's constant using light emitting diodes (LED's) by observing the 'reverse photo-electric effect'. In case of the photoelectric effect, an electron is emitted from metal if the energy of the photon is greater than the work function of the metal. If the energy of the said photon is greater than the work function of the given material then the electron emitted possesses a voltage, which equals the difference in these energies. In case of an LED, 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 is first observed is the 'turn-on voltage'. This effect is not normally observed in metals and other typical substances because the photons emitted are outside the range of visible light, usually somewhere in infrared. In addition, the materials in question are rarely transparent to the photons which they emit. Fortunately many years of research have been put forth to develop LEDs that work well and are relatively cheap, making the materials relatively simple to acquire.

Planck's Constant:
Planck's constant is the fundamental constant in modern physics. It relates the energy of a photon to its frequency. To determine this constant we use Light Emitting Diodes (LED). Diodes emitting different colors of light are available in today's market. Each color is achieved by having a slightly different semiconductor material. This experiment has being carried out in many manners with a variety of LEDs. We choose to do the experiment using a number of LEDs, with different colors including Blue, Green, Red and Orange.
The experiment is based on the fact that the energy of the photon relates to its frequency as:
$E = h\upsilon$, Where, E is the energy of photon, h is the Planck's constant and υ is the frequency of the emitted photon. When the diode first emits light the voltage across the diode, V_0 is just enough to give energy to electrons to jump between two energy levels.
Therefore
$E = h\,\upsilon = hc/\lambda$ and $E = eV_0$
$h\,\upsilon = eV_0$
$hc/\lambda = eV_0$
$h = eV_0\,\lambda/c$
where,
h is Planck's Constant,
e is the electronic charge,

V_0 is Threshold voltage,
λ is wavelength of LED and
c is the velocity of light
If the threshold voltage V_0, is measured for several diodes of different colour (and different maximum wavelength λ), a graph of V_0 Vs $(1/\lambda)$ should be linear. The slope (= hc/e) of linear curve can be used to compute the experimental value of Plank's constant 'h'.

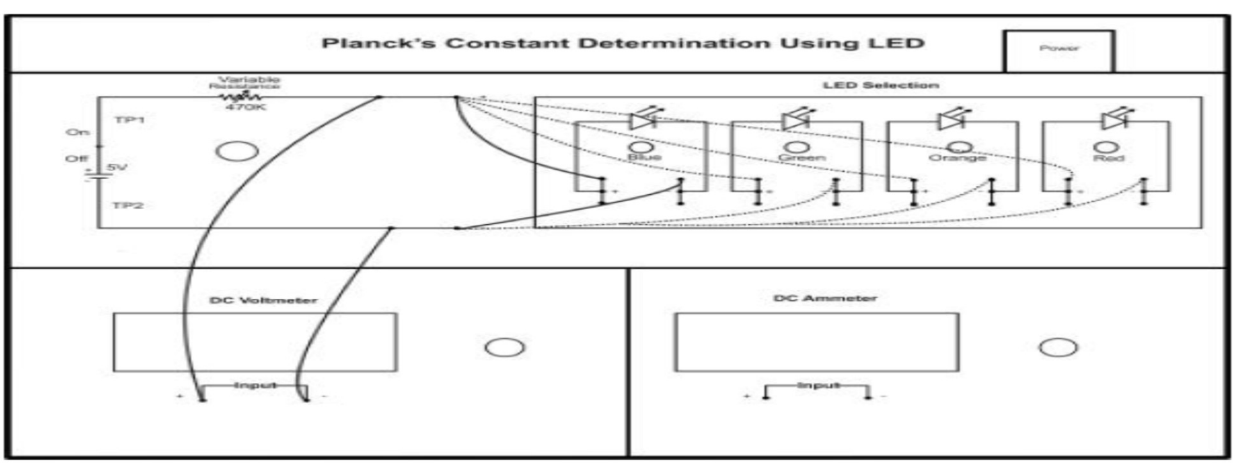
Dirac Constant:
The Dirac Constant or the "reduced Planck Constant", $\hbar = h/2\pi$. The Planck's Constant is stated in SI units of measurement, joules per hertz, or joules per (cycle per second), while the Dirac Constant is the same value stated in joules per (radian per second). In essence, the Dirac Constant is a conversion factor between phase (in radians) and action (in joule-seconds) as seen in the Schrodinger equation. The Planck Constant is similarly a conversion factor between phase (in cycles) and action. All other uses of Planck's constant and Dirac's Constant follow from that relationship.

Significance of the size of Planck's Constant
Expressed in the SI units of joule seconds (J·s), the Planck Constant is one of the smallest constants used in physics. The significance of this is that it reflects the extremely small scales at which quantum mechanical effects are observed, and hence why we are not familiar with quantum physics in our everyday lives in the way that we are with classical physics. Indeed, classical physics can essentially be defined as the limit of quantum mechanics as the Planck Constant tends to zero. In natural units, the Dirac Constant is taken as 1 (i.e., the Planck Constant is 2π), as is convenient for describing physics at the atomic scale dominated by quantum effects.

LED's Wavelengths
Blue:470 nm   Green:560 nm Yellow:580 nm   Orange:630 nm   Red:700 nm

1. DETERMINATION OF PLANCK'S CONSTANT USING LIGHT EMITTING DIODE (LED).

PROCEDURE:
1. Connect + ve terminal of DC power supply to + ve terminal of any one LED and +ve terminal of DC voltmeter.
2. Now connect - ve terminal of DC power supply to -ve terminal of LED and - ve terminal of DC



voltmeter.
3. Set the range of DC voltmeter at 20 mV. Connect the mains cord and switch 'On' the power supply.

4. Now vary the DC voltage slowly by variable resistance pot and see the LED connected in circuit.
5. When the LED is just starts to emit light note the value of applied voltage by DC voltmeter.
6. Now switch 'Off' the DC power supply and break the LED connection.
7. Again make same connection for another color of LED and repeat the experiment for different colors of LEDs.
8. Now use the formula given below and put the value of all parameters used in formula and calculate the value of Planck's constant for different LEDs.

$$h = eV_0 \lambda/c$$

Take mean value of h calculated for different LEDs.

DETERMINATION OF PLANCK'S CONSTANT BY PLOTTING A CURVE BETWEEN THRESHOLD VOLTAGE AND WAVELENGTH OF LEDS.

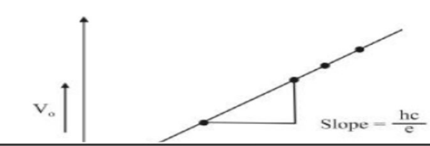
Plot a graph between Threshold voltage (V_o) and reciprocal of wavelength ($1/\lambda$) for different LEDs. The plot is as shown below. Find the slope (S) from the graph, which is equal to (hc/e).
Put the values of S, c and e and solve for Planck's constant (h).

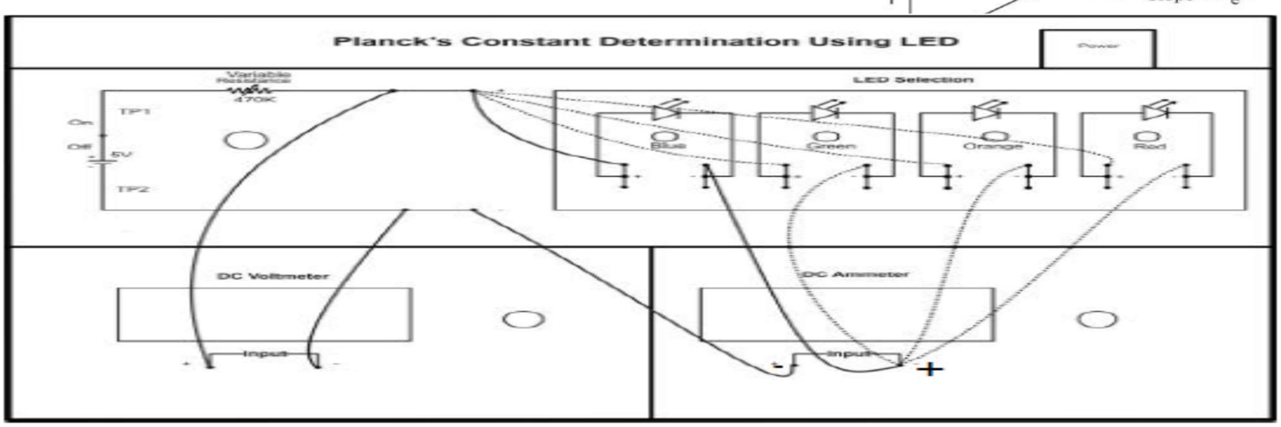
OBSERVATION TABLE 1

S.No	**LED colour**	**Voltage V(volts)**	**Wavelength λ (nm)**	**Frequency(Hz) f = c / λ**	**Energy (J) E = qV**	**h = eVλ /c (J-s)**
1						
2						
3						
4						
5						

Plot a graph between $\frac{1}{\lambda}$ on X-axis and voltage on Y-axis.

2. **DRAW THE V-I CHARACTERISTIC FOR LIGHT EMITTING DIODE (LED'S) AND DETERMINE THE VALUE OF PLANCK'S CONSTANT.**





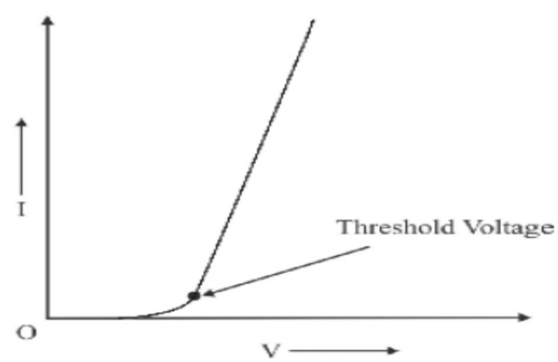
PROCEDURE

1. Now take another patch cord and connect + ve of power supply to + ve of any one LED.
2. Connect - ve of power supply to - ve of ammeter and connect +ve of ammeter to - ve of selected LED.
3. Connect + ve terminal of power supply to + ve terminal of DC voltmeter and –ve terminal to - ve terminal of DC voltmeter.
4. Set the voltmeter at the range of 20 V and ammeter at the 200 mV.
5. Connect the mains cord and switch 'On' the power supply and increase the DC voltage at the fix interval of 0.1 volt or 100 mV.
6. Note the corresponding current by DC ammeter and tabulate the readings.

OBSERVATION TABLE 2

S.No	LED (violet)		LED (green)		LED (red)	
	V (…)	I (…)	V (…)	I (…)	V (…)	I (…)
1						
2						
3						
4						
5						

Plot a graph between current on X-axis and voltage on Y-axis. Note the reading of voltage at which the current flow suddenly through the LED, at this point the graph suddenly change their direction. This voltage is the knee voltage or threshold-voltage. Put this value in given formula and calculate the Planck's constant. Do this exercise for different LEDs and find the average experimental value of Plank's constant.



VIVA-VOCE

- What is a Light emitting diode?
- What is the relation between energy and wavelength?
- What is Knee voltage?
- What is wavelength corresponding to red, yellow, blue, green colours?
- What is infrared radiation? What is the range of wavelength?
- What is value of Planck's constant? What is the energy of quanta?

APPLICATIONS

- Photomultipliers
- Image sensors
- The gold-leaf electroscope
- Photoelectron spectroscopy
- Spacecraft
- Moon dust
- Night vision devices

PRECAUTIONS

1. Record the initial value for voltage very precisely.
2. Avoid loose connections in the circuit.

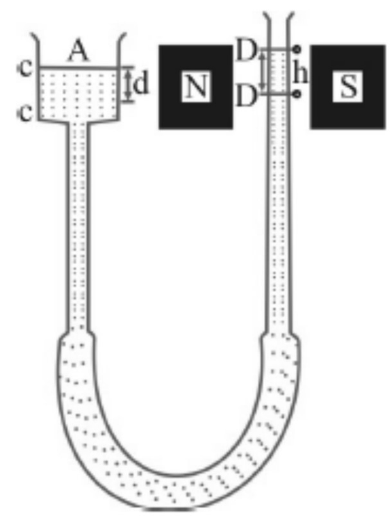
EXPERIMENT – 11
MEASUREMENT OF SUSCEPTIBILITY

AIM

MEASUREMENT OF SUSCEPTIBILITY OF FERRIC CHLORIDE ($FeCl_3$) OR MANGANESE SULPHATE ($MnSO_4$) PARAMAGNETIC SOLUTION.

APPARATUS

1. Quinck's tube with stand
2. Ferric chloride sample
3. Electromagnet
4. Guass and Tesla meter
5. InAs Probe
6. Constant current power supply
7. Magnifying viewer
8. Travelling Microscope (Optional)
9. Graduated cylinder



FORMULA:

$$\chi = \frac{2(\rho - \sigma)gh}{H^2}$$

where ρ is the density of the liquid
σ is density of air
g acceleration due to gravity.
h is net rise of the liquid column in narrow tube.
H is applied magnetic field strength between the pole pieces.

THEORY

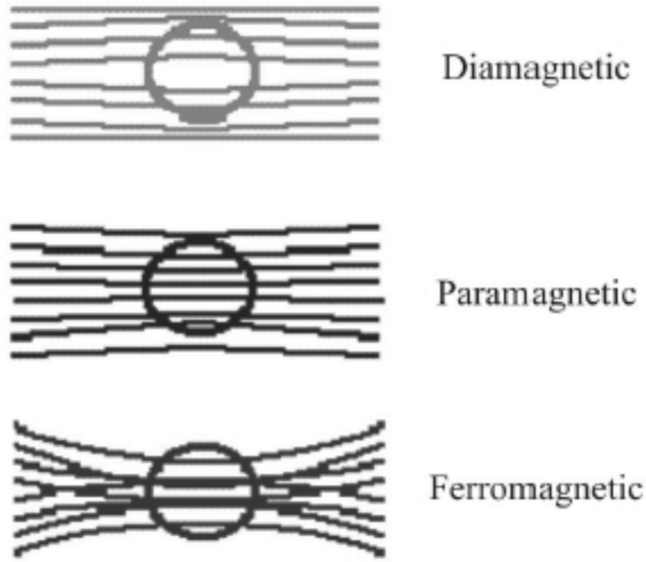
Basic Principles of Magnetic Behaviour:

Magnetism is a fundamental property of matter. Based on their magnetic properties, all substances can be classified into one of three groups:
Diamagnetic, Paramagnetic, and Ferromagnetic.

Diamagnetic substances

Outside a magnetic field, Diamagnetic substances exhibit no magnetic properties. When placed in a magnetic field, diamagnetic substances will exhibit a negative interaction with the external magnetic field. In other words they are not attracted to, but rather slightly repelled by the magnetic field i.e. those repelled by a strong magnetic field. These substances are said to have a negative magnetic susceptibility.

Paramagnetic substances:

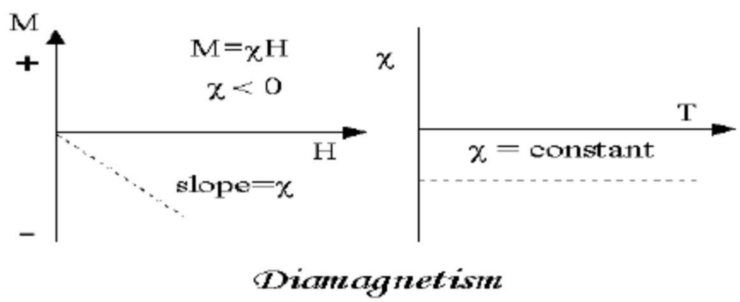


Paramagnetic substances also exhibit no magnetic properties outside a magnetic field. When placed in a magnetic field, however, these substances exhibit a slight positive interaction with the external magnetic field and are slightly attracted. The magnetic field is intensified within the sample causing an increase in the local magnetic field i.e. those attracted by a strong magnetic field. These substances are said to have a positive magnetic susceptibility.

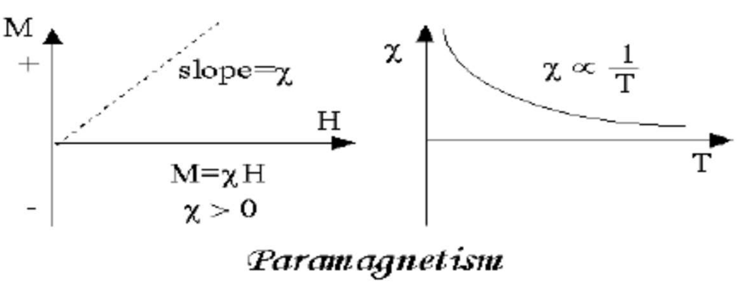
Ferromagnetic substances:

Finally, the most recognized class Ferro-magnetic; Ferro-magnetic substances are quite different. When placed in a magnetic field they exhibit an extremely strong attraction to the magnetic field. The local magnetic field in the center of the substance is greatly increased. These substances (such as iron) retain magnetic properties when removed from the magnetic field. Ferro-magnets are able to retain a permanent magnetic field since their free electrons are in close proximity and remain aligned even after the external magnetic field is removed. Unlike the Ferro-magnets, the magnetic properties of the Diamagnetic or Paramagnetic materials could only be observed and measured when these samples are held within a magnetic field applied externally.

These three properties are illustrated in figure



Diamagnetism



Paramagnetism

MAGNETIC SUSCEPTIBILITY:

Quantitative measure of the extent to which a material may be magnetized in relation to a given applied magnetic field. The magnetic susceptibility of a material, commonly symbolized by χ_m , is equal to the ratio of the magnetization *M* within the material to the applied magnetic field strength *H*, or

$$\chi_m = \frac{M}{H}$$

This ratio, strictly speaking, is the volume susceptibility.

Magnetic susceptibility is the degree to which a material can be magnetized in an external magnetic field. If the ratio of the magnetization is expressed per unit volume, volume susceptibility is defined as,

$$\chi_v = M / H,$$

Where M is the volume magnetization induced in a material of susceptibility k by the applied external field H. Volume susceptibility is a dimensionless quantity. Mass, or specific, susceptibility is defined as

$$\chi = M \text{ c} = \text{k} / \text{r},$$

Where r is the density of the material. The dimensions of mass susceptibility are therefore m^3/kg.

There are two other measures of susceptibility, the mass magnetic susceptibility (χ_{mass} or χ_g, sometimes χ_m), measured in $m^3 \cdot kg^{-1}$ in SI or in $cm^3 \cdot g^{-1}$ in cgs and the molar magnetic susceptibility (χ_{mol}) measured in $m^3 \cdot mol^{-1}$ (SI) or $cm^3 \cdot mol^{-1}$ (cgs) that are defined below, where ρ is the density in $Kg \cdot m^{-3}$ (SI) or $g \cdot cm^{-3}$ (cgs) and M is molar mass in $Kg \cdot mol^{-1}$ (SI) or $g \cdot mol^{-1}$ (cgs).

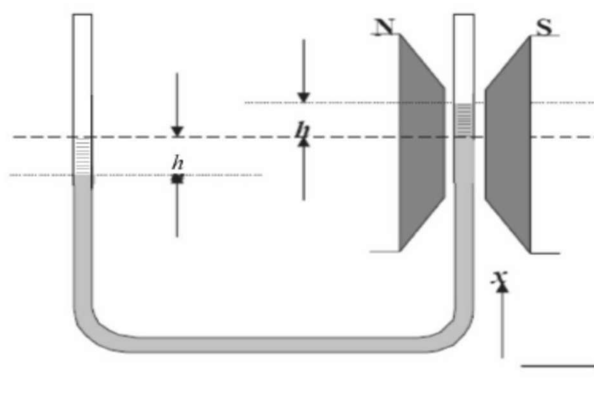
$$\chi_{mass} = \chi_v / \rho$$

$$\chi_{mol} = M.\chi_{mass} = M.\chi_v / \rho$$

Variant forms of susceptibility			
Name	**Equation**	**Symbol**	**SI Units**
Bulk susceptibility	M / H	χ, χ_v or κ	dimensionless
Mass susceptibility	χ_v / ρ	χ_ρ	$m^3\ Kg^{-1}$
Molar susceptibility or molar mass susceptibility	$\chi_v \times$ Wa / ρ	χ_M	$m^3\ mol^{-1}$

PROCEDURE

1. Take Guass and Tesla meter.
2. Connect InAs probe and switch on the Gauss and Tesla meter.
3. Adjust zero reading on display by zero adjust potentiometer and keep range selector switch at X1 position.



Paramagnetic liquid in a uniform magnetic field

4. Now take Constant Current Power Supply and set the current Adjust potentiometer at fully anticlockwise position. Connect electromagnet is in series i.e. the direction of current in both the coil of electromagnet is in the series i.e. the direction of current in both the coils should be same otherwise little or no magnetic field would results.
5. Switch on the Power Supply and set some low value of current.

6. Keep Hall probe (InAs) between electromagnet such that the flat face (Inner part of shielded probe) of the probe is kept perpendicular to the direction of magnetic field. Note the strength of magnetic field.
7. Increase the current from the Constant Current Power Supply and note the value of corresponding magnetic field. If magnetic field is greater than 2K guass then meter will indicate the over range. For its measurement keep the selector switch at X10 position and note the value of magnetic field.
8. Multiply the display reading by 10 to get the magnetic field strength in both gauss and tesla.
9. You get result that magnetic field increase with increasing current of electromagnet.
10. Now switch off the Constant Current Supply and Gauss and Tesla meter, as it is ready for measurement.
11. Now for preparing the solution of ferric chloride, take distilled water, graduated cylinder and ferric chloride power.
12. Fill the graduated cylinder with 10ml distilled water, now dissolve $FeCl_3$ by step of 1-1gm and make saturated solution (solution in which the maximum amount of solvent has been dissolved. Any more solute added will sit as crystals on the bottom of the container). Note total mass of $FeCl_3$ Powder which is dissolve in water.
    m = ……………gm
    Note: Stirring the solution continuously.
13. Mount the Quinck's tube on its stand.
14. Thoroughly clean the Quinck's tube and fill it with $FeCl_3$ solution with wide limb such that the liquid meniscus lies in the central region of the pole pieces. Note the remaining volume (r) of solution, so that volume of solution inserted into U-tube will be
    $v = (10–r)$ ml
    So density of liquid or solution $\rho=m/v$ and density of air $\sigma =1$
15. Insert the narrow limb of U-tube vertically between the pole pieces of the electromagnet.
16. Transfer some of solution to the U-tube so that the meniscus is in the center of the pole pieces if necessary.
17. Take care to ensure that the surface of the liquid between the poles of the magnet is in the region where the field is greatest and reasonably uniform.
18. Take magnifier viewer note the reading of the lower meniscus of the liquid (as shown in below figure) by the graduated scale on the limb and put into the observation table given below, when no current is passing through electromagnet. Illuminate the meniscus with an electric lamp (if necessary).
19. Now switch on the Constant Current Supply and Guass and Telsa meter and observe rise in level of liquid for 1amp current. Note the reading of the lower meniscus of the liquid and put into the below table.
20. Repeat the experiment for different values of magnetizing current.

21. Now remove the U-shape tube and place InAs probe between the electromagnet as describe above and note magnetic field (H) in below table.

OBSERVATIONS

S.No	Magnetizing current I amp	Magnetic field H	H^2	Position of liquid meniscus		Height of liquid column h = a-b	Susceptibility $\chi = \frac{2(\rho - \sigma)gh}{H^2}$
				Without field (a)	With field (b)		
1							
2							
3							

RESULT

Mean susceptibility χ =…………

PRECAUTIONS

Don't touch powder or solution, chemical gloves recommended.

VIVA-VOCE

1. What do you mean by magnetic susceptibility?

Ans: The magnetic susceptibility χ is a dimensionless proportionality constant that indicates the degree of magnetization of a material in response to an applied magnetic field.

2. What is magnetization and magnetic intensity?

Ans: The magnetic dipole moment per unit volume of the magnetized substance is called magnetization (M). Magnetic field intensity (H) refers to the strength of applied magnetic field.

3. What is the relation between magnetic flux density, magnetic intensity and magnetization?

Ans: The relation is

$B= \mu_0(H+M)$

Where B = magnetic flux density, H = Magnetic field intensity, M = magnetization and μ_0 = permeability of free space.

4. What is permeability?

Ans: The magnetic permeability (μ) deals with the degree of concentration of lines of force in a specimen. It is the ratio of the number of lies of force passing per unit area (held perpendicular to the lines of force) in the specimen to the lines of force that would exist there due to the field in the absence of specimen. In the other way, it is the inductance per unit length. In SI units, permeability is measured in henrys per metre ($H \cdot m^{-1} = J/(A^2 \cdot m) = N\ A^{-2}$).

5. How the magnetic permeability is related with magnetic susceptibility?

Ans: The relation is given as $\mu = \mu_0(1+ \chi)$

where μ is magnetic permeability of the medium, μ_0 is magnetic permeability of free and χ magnetic susceptibility of the material. Also relative magnetic permeability (μ_r) of the medium is represented by $\mu_r = \mu / \mu_0$

6. What are paramagnetic substances or paramagnetic salts?

Ans: Paramagnetic substances are slightly attracted by a magnetic field and the material does not retain the magnetic properties when the external field is removed. These have a small, positive susceptibility to magnetic fields. Paramagnetic properties are due to the presence of some unpaired electrons, and from the realignment of the electron paths caused by the external magnetic field. Paramagnetic materials include magnesium, molybdenum, lithium, and tantalum.

Similarly, a paramagnetic salt is a salt that has free paramagnetic ions. In the absence of a strong magnetic field these ions or magnetic dipoles are randomly aligned, thus giving a net value of zero for the magnetization of the salt.

7. What are diamagnetic and ferromagnetic substances?

Ans: A substance which when placed in the magnetic field gets feebly magnetized in the direction opposite to the applied magnetic field, is called diamagnetic substance eg. Al, Mn, $CuCl_2$, O_2 etc.

The ferromagnetic substances are those substances which when placed in the magnetic field, become strongly magnetized in the direction of the field eg. Fe, Ni, Co etc.

8. How will you distinguish paramagnetic, diamagnetic and ferromagnetic substances in the light of susceptibility?

Ans: Ferromagnetic substances have large positive susceptibility. Sometimes in some cases may as high as 10^5. Paramagnetic substances have a small, positive susceptibility. The diamagnetic substances exhibit small, negative magnetic susceptibility of the order of 10^{-5}.

APPLICATIONS

- Magnetic susceptibility is used mostly as a relative proxy indicator for changes in composition that can be linked to paleoclimate-controlled depositional processes.
- The high precision and sensitivity of susceptibility loggers makes this measurement extremely useful for core-to-core and core-down hole log correlation.
- The physical link of magnetic susceptibility to particular sediment components,
- Ocean or wind current strength and direction, or provenance, usually requires more detailed magnetic properties studies in a specialized shore based laboratory.
- Geoarchaeology Mineral exploration

EXPERIMENT – 12
ABSORPTION COEFFICIENT OF A LIQUID

AIM

DETERMINATION OF ABSORPTION COEFFICIENT OF A LIQUID OR SOLUTION (WATER, $KMNO_4$) WITH THE HELP OF A PHOTOVOLATIC CELL.

APPARATUS

1 A wooden box with the following built in items

- 1.1 source of light
- 1.2 convex lens
- 1.3 glass vessel graduated
- 1.4 photovoltaic cell.
- 1.5 potentiometer

2 Micro ammeter having 50 μA ranges.

FORMULA

The absorption coefficient is given by

$$\mathbf{a = \frac{2.3026}{t} \log_{10} \frac{I_0}{I}} \quad \text{cm}^{-1}$$

Where
t = thickness of absorbing medium
I_0= intensity of incident light
I = intensity of light emerging from the absorbing medium.

If θ_0 and θ be the deflections in galvanometer corresponding to intensities I and I_0, then

$$a = \frac{2.3026}{t} log_{10} \frac{\theta_0}{\theta}$$

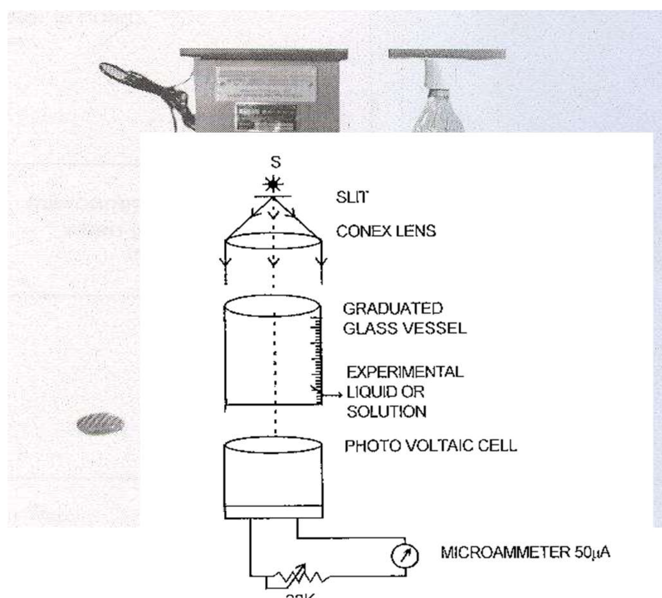


FIG. 1.

Using this formula, the absorption coefficient of the liquid or solution can be calculated.

PROCEDURE

1. The experimental arrangement is made as shown in fig. 1. Remove the glass vessel and cover of the photovoltaic cell and switch on the bulb, adjust the pot in such a way that the reading of micro ammeter does not exceed 50 micro amp.
2. The empty graduated glass vessel is placed between the source of light and photovoltaic cell. Now the light from the source passing through glass vessel falls on photovoltaic cell. This produces a steady deflection θ_0 on the scale corresponding to intensity I_0. The value of θ_0 is noted.
3. The experimental liquid or solution (water or $KMnO_4$) is filled inside the vessel. The thickness t of liquid or solution is recorded on the scale provided on the vessel. Some light is absorbed by this liquid. Hence the deflection in the microammeter reduces. In this case the steady deflection θ corresponding to thickness of liquid t is noted.
4. The thickness t of the experimental liquid or solution is increased in steps and the corresponding steady deflection θ of the microammeter is noted.

OBSERVATION TABLE

Microammeter deflection (θ_0) = ……

S. No	**Thickness of liquid t (cm)**	**Micro ammeter deflection when glass vessel is filled θ**	$\frac{\theta_0}{\theta}$	**log** $_{10}\frac{\theta_0}{\theta}$	**Absorption Coefficient (a) cm^{-1}**
1					
2					
3					

Mean value of

Absorption coefficient = ………. **cm^{-1}**

Graph

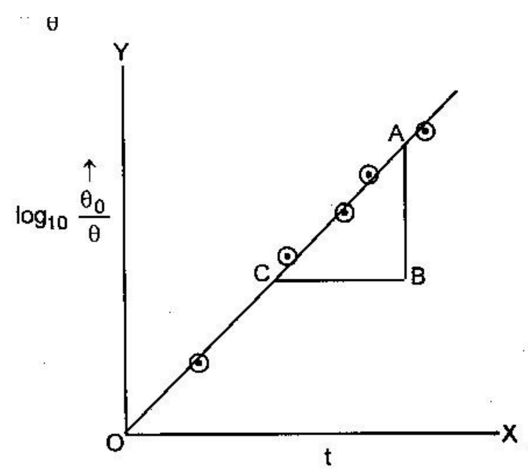


Fig. 2

A graph is drawn between thickness (t) on X- axis and **log** $_{10}\frac{\theta_0}{\theta}$ on Y-axis**.** The plot should be a straight line passing through origin as shown in fig 2.

CALCULATIONS

slope from the graph, m = tan θ = AB/BC = $\frac{log_{10}\frac{\theta_0}{\theta}}{t}$.

Substituting the values of AB and BC from the graph the value of ‘a’ can be calculated.

and hence the Absorption coefficient is given by a = 2.3026 (slope) = ….. cm^{-1}.

The mean value of absorption coefficient of the given absorbing medium = … cm^{-1}.

PRECAUTIONS:

1. The photovoltaic cell should not be exposed to light for long time continuously. The cover of the photocell should be opened only when the observations are made.
2. The voltage applied to lamp must remain constant throughout the experiment so that the illuminating power of the source may not get changed.

VIVA-VOCE

1. What do you mean by absorptive power?
2. What is a photo-voltaic cell?
3. What are the advantages of photo-voltaic cell over photo cell?
4. On what principle a photo- conductive cell is based?
5. On what factors does the absorption of light through a solution depend?
6. When light passes through a solution, its intensity diminishes due to absorption as well as view of inverse square law. How have you accounted for the second factor in your experiment?
7. What is the color of $KMnO_4$ and why this color?

EXPERIMENT – 13
YOUNG'S MODULUS

AIM
DETERMINATION OF YOUNG'S MODULUS OF ELASTICITY OF THE GIVEN SAMPLE MATERIAL BY BENDING.

APPARATUS
1. Sample Stand
2. Weights of 500 gm
3. Samples (Iron, Aluminum, Brass)
4. DC Adaptor
5. Weight Holder
6. Spherometer Stand with Buzzer

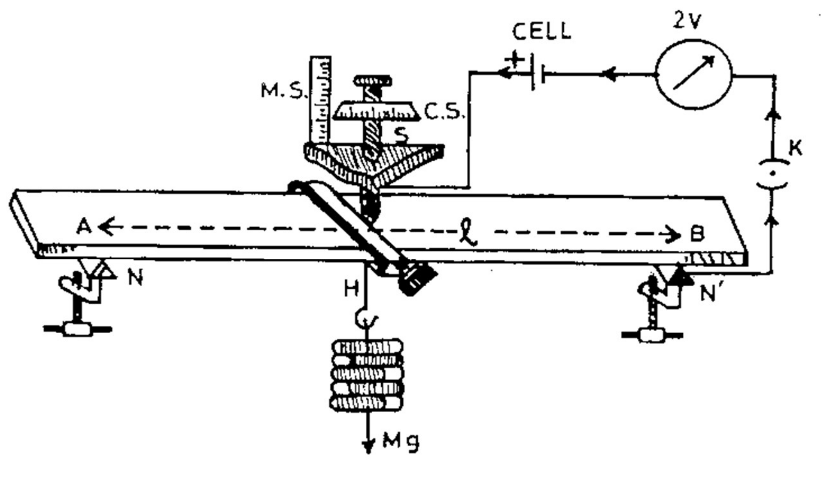


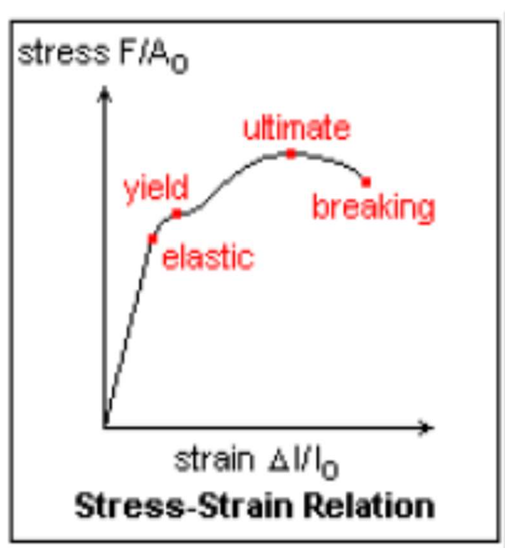
FIG. 1 BENDING OF BEAM APPARATUS

FORMULA

$$Y = \frac{mgl^3}{4bd^3\,e}\,\frac{dynes}{cm^2}$$

where
Y – Young's modulus of the material of beam.
m - Load (in gm);
l – length of beam (cm);
g – gravitational acceleration. (cm/sec^2)
b – Breadth (cm); d – thickness (cm);
e– depression of the beam produced by load(cm).

THEORY
Elasticity:
An important property of many structural materials is their ability to regain their original shape after a load is removed. These materials are called elastic. Steel, glass and rubber are elastic; putty or modeling clay are not elastic. Each of these materials is elastic to varying degrees; steel and glass are both more elastic than rubber. The degree of elasticity or "stiffness" of a material is called its Modulus of Elasticity (E). Using the modulus of elasticity, possible deformations can be calculated for any material and loading.



Stress-Strain Relation

Elastic body:
A body which regains its original shape when the deformation force is removed is called an elastic body.
Inelastic or Plastic body:
A body which cannot regain its original shape, when the deformation force is removed is called a plastic body. Elasticity is molecular property of the matter. Elasticity is the property of an object or material which causes it to be restored

to its original shape after distortion. It is said to be more elastic if it restores itself more precisely to its original configuration. A rubber band is easy to stretch, and snaps back to near its original length when released, but it is not as elastic as a piece of piano wire. The piano wire is harder to stretch, but would be said to be more elastic than the rubber band because of the precision of its return to its original length.

PROCEDURE

1. Mount the setup by fixing two long round rods with U-type brackets.
2. Tighten the sample (Iron) on Sample stands.
3. Place it horizontally on the smooth surface.
4. Tighten the Weight holder at the center of sample with the help of screw.
5. Place the spherometer stand, beyond the center of sample (Iron).
6. Adjust the spherometer height with the help of screw according to the sample.
Note: Spherometer leg must be in contact by rotating the Circular Scale with the center of the sample.
7. Connect buzzer with adaptor and connect patch cord with banana terminal, provided on the sample for buzzer connection.
8. Switch 'On' the supply for adaptor.
9. Buzzer blows because at this stage spherometer leg is in contact with the sample.
10. Consider spherometer Main Scale divisions 1 to 20 mm from top to bottom.
11. Note Pitch Scale (P.S) reading and Circular Scale reading (C.S) i.e., no. of divisions * 0.01mm (least count) reading in Observation Table 1 and find total reading M.S + C.S x lc
Note: This time there is no load on the sample it is said to be initial reading.

Increment of the Loads

12. Now place the 500 gm weight on the Weight holder with the help of T – Pin, at this stage buzzer stops blowing because spherometer leg is not in contact with sample owing to bending of rod.
13. Rotate the Circular Scale of spherometer (clock wise direction) till the buzzer blows (because when it touches the sample, circuit becomes complete and buzzer starts blowing).
14. Again note the readings of M.S. and C.S. * 0.01mm (least count) in Table 1, and then evaluate the total reading.
15. Depression of sample is determined by x_n-x_0. Tabulate the reading in observation Table 1.
16. Place one more 500 gm weight on the Weight holder, total 1 kg weight is hanging, at this time again buzzer stop blowing because spherometer leg is not in contact with sample.
17. Rotate the Circular Scale of spherometer till the buzzer blows (because when it touches the sample, circuit becomes complete and buzzer starts blowing).
18. Again note the readings of M.S. and C.S. * 0.01 (least count) in Table 1, and then evaluate the total reading.
19. Depressions of sample is determined by x_n-x_0. Tabulate the reading in observation Table 1.
20. Place 500 gm weights one by one on the Weight holder i.e., total weight will be1.5kg, 2kg, 2.5kg and 3.0kg. For these different weights position, repeat the steps 16 to 19 and tabulate the readings.
21. Tabulate all the readings in the given Observation Table 1.

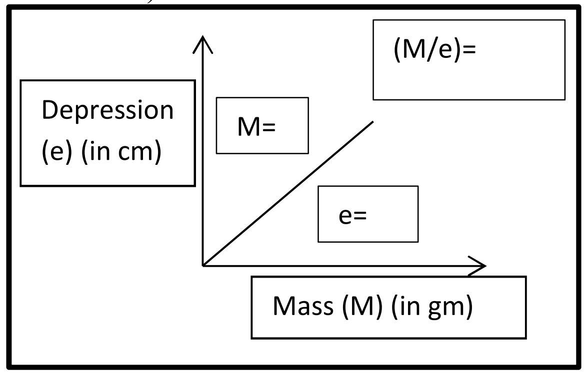
Decrement of the Loads

22. At 0 gm load decreasing, spherometer reading is same as 3kg increasing load.
23. Now remove 500 gm weight from the Weight holder (i.e., decreasing of 0.5 kg load from sample) and again note main scale reading (M.S), circular scale reading (C.S) i.e., no of divisions * 0.01mm (least count) and find total reading.
Note: Before removing the weights rotate the spherometer fully anticlockwise.

24. Depression of sample is $X_n \sim X_{11}$. Tabulate the reading in Observation Table 1.

25. Now again remove 500 gm. weight from the Weight holder (i.e., decreasing of1kg load from sample) and again note main scale reading (M.S), circular scale reading (C.S) i.e., no of divisions * 0.01mm (least count) and find total readingi.

26. Remove 500 gm weights one by one from the Weight holder i.e., decrement of load will be 1.5kg, 2kg, 2.5kg and 3kg respectively. For these different weights position, repeat the steps 25 and 26 and tabulate the readings.



28. Tabulate all the readings in the given Observation Table 1 in the load decreasing column.

29. Take the mean of depressions individually d1 = (x1+x10)/2, d2 = (x2+x9)/2 ...and so on.

30. In Observation Table 2, insert all the values of individual Mean of depressions d1, d2, d3........

31. Take the length, breadth, depth of a given material of sample.

32. Length, Breadth, Depth all are in cm. Change it into meter.

OBSERVATION TABLE 1

S. No	Mass(M) in gm	Spherometer Reading When Load Increasing(in mm)				Spherometer Reading When Load Decreasing(in mm)				Depression (e) in cm	M/e gm/cm
		PSR a (mm)	HSC x l.c b (mm)	TR=a+b (in mm)	Depression d = $X_n \sim X_0$ (in cm)	PSR a (mm)	HSC x l.c b (mm)	TR=a+b (in mm)	Depression d $=X_n \sim X_{11}$ (in cm)		
1	0			X_0				X_{11}			
2	500			X_1	d_1			X_{10}	d_1	e_1	500/ e_1
3	1000			X_2	d_2			X_9	d_2	e_2	1000/ e_2
4	1500			X_3	d_3			X_8	d_3	e_3	1500/ e_3
5	2000			X_4	d_4			X_7	d_4	e_4	2000/ e_4
6	2500			X_5	d_5			X_6	d_5	e_5	2500/ e_5

Avg value of (M/e) = ……gm/cm

l =.................. (in meter) 1 m = 100cm
b =................. (in meter) 1 m = 1000mm
d =.................. (in meter)

33. Put all the readings in given formula, where Y is elastic constant or Young's Modulus of elasticity.

$$Y = \frac{gl^3}{4bd^3}\left(\frac{M}{e}\right) \text{ dynes/ cm}^2$$

where 'm' is mass (in gm), g = 980 cm/sec^2, length (l)(cm), breadth (b) (cm),, depth (d) (cm),, depression(e) (cm) and Elastic Constant (Y) is in dynes/cm^2.

Draw a graph between Mass (M) on X-axis and Depression (e) on Y-axis, the plot should be a straight line passing through origin as shown. Find reciprocal of the slope from the graph and find the value of Young's Modulus.

RESULT

The value for Y from average value of (M/e) = ……….. dynes/ cm^2

The value for Y from graph value of (M/e) = ……….. dynes/ cm^2

The standard value of Young's Modulus for a given material = ………….. dynes/ cm^2

The error % = --------

PRECAUTIONS

1. The 'Beam' must be symmetrically placed on the knife edges K_1 and K_2.
2. The hanger must always be suspended at the centre of gravity of the beam.
3. To avoid backlash error spherometer should be rotated in one direction.
4. Special care should be taken in observing the thickness 'd' and depression 'e'
5. The elasticity of Aluminum and Brass samples is less so doesn't exceed weight more than 1.5kg on Weight holder.

APPLICATIONS

The elastic property of the material is useful while studying materials for industrial applications such as construction of bridges, railway wagons etc.

VIVA – VOCE

1. What is Hook's law?

Ans: Hooke's law of elasticity was discovered by the English scientist Robert Hooke in 1660, which states that, for relatively small deformations of an object, the displacement or size of the deformation is directly proportional to the deforming force or load. Under these conditions the object returns to its original shape and size upon removal of the load. Elastic behaviour of solids according to Hooke's law can be explained by the fact that small displacements of their constituent molecules, atoms, or ions from normal positions is also proportional to the force that causes the displacement.

Mathematically, Hooke's law states that the applied force F equals a constant k times the displacement or change in length x, or **F = kx**. The value of k depends not only on the kind of elastic material under consideration but also on its dimensions and shape.

2. What is modulus of elasticity?

Ans: An elastic modulus, or modulus of elasticity, is the mathematical description of an object or substance's tendency to be deformed elastically (i.e., non-permanently) when a force is applied to it. The elastic modulus of an object is defined as the slope of its stress–strain curve in the elastic deformation region.

$$\lambda = \frac{stress}{strain}$$

where lambda (λ) is the elastic modulus; stress is the restoring force caused due to the deformation divided by the area to which the force is applied; and strain is the ratio of the change caused by the stress to the original state of the object. If stress is measured in pascals, since strain is a dimensionless quantity, then the units of λ are pascals as well.

3. What is young’s modulus?

Ans: Young's modulus (Y) describes tensile elasticity, or the tendency of an object to deform along an axis when opposing forces are applied along that axis; it is defined as the ratio of the longitudinal stress to the longitudinal strain. It is often referred to simply as the elastic modulus.

$$\mathrm{Y} = \frac{longitudinal\ stress}{longitudinal\ strain}$$

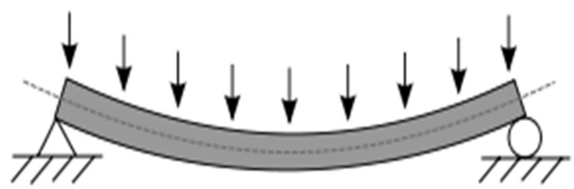
4. What is a beam?

Ans: When the length of the rod of uniform cross-section is very large compared to its breadth such that the shearing stress over any section of the rod can be neglected, the rod is called a beam.

Beams are traditionally descriptions of building or civil engineering structural elements, but smaller structures such as truck or automobile frames, machine frames, and other mechanical or structural systems contain beam structures that are designed and analyzed in a similar fashion.

5. What is the change produced in depression when the thickness is doubled?

Ans: If thickness is doubled, then the depression is reduced to 1/8 of its previous value.



6. What is the change produced in depression when the breadth is doubled?

Ans: If breadth is doubled, then the depression is reduced to l/2 of its previous value.

7. What is the change in Young’s modulus when the thickness and breadth of the bar is doubled?

Ans: Young’s modulus does not change.

8. How are longitudinal strain and stress produced in your experiment?

Ans: Due to depression, the upper or the concave side of the beam becomes smaller than the lower or the convex side of the beam. As a result, longitudinal strain is produced.The change in length will be due to the force acting along the length of the beam. These forces will give rise to longitudinal stress.

Elastic Properties of different Materials

Material	Rigidity * $10^{10}N/m^2$	Young's Modulus * 10^{10} N/m^2	Poison's ratio
Steel	7.9 – 8.9	19.5 – 20.6	0.28
Aluminium	2.67	7.50	0.34
Copper	4.55	12.4 – 12.9	0.34
Iron (Wrought)	7.7 – 8.3	19.9 – 20.0	0.27
Brass	3.5	0.7 – 10.2	0.34 – 0.38

EXPERIMENT – 14
LOGIC GATES

OBJECT:

TO STUDY THE VARIOUS LOGIC GATE CIRCUITS.

APPARATUS:

Logic gates are the basic part of digital electronics. To understand the concept of digital circuits one must be familiar with the behavior of Logic gates. These logic gates are special purpose devices to process the digital signals and to perform different operations over them.

A **logic gate** performs a logical operation on one or more logic inputs and produces a single logic output. The logic normally performed is Boolean logic and is most commonly found in digital circuits. Logic gates are primarily implemented electronically using diodes or transistors, but can also be constructed using

Electromagnetic relays, fluidics, optics, or even mechanical elements.

APPLICATION:-

- **Every digital product, like computers, mobile, calculators even digital watches, contains logic gates.**
- **The adder which is of great importance in your computer processor and also in many more applications is basically built from the logic gates.**

THEORY:

Logic Gate is a digital circuit with one or more input but only one output. AND, OR, NAND, NOR, NOT, EX-OR Gates are some examples of Logic Gates. Each Gate has one or two binary input variable designated by X & Y and one binary output variable Z. The logic diagram and Truth Table of Logic Gates is shown in experiment section.

OR Gate: The OR gate has two or more than two inputs and one output. This operation is represented by a plus sign eg. X +Y= Z is read X or Y is equal to Z meaning that Z=1 if X=1 or if Y=1 or if both X=1 & Y=l. If both X=0 & Y=0 then Z=0.The output voltage of OR Gate is high if any or all of the input voltages are high that is +5 V or 1 (TTL level is used). Logic equation is Z = X + Y (X & Y are inputs & Z is output.)

AND Gate: It has two or more than two inputs. This operation is represented by a dot or by absence of an operator eg. X.Y=Z or XY=Z is read X AND Y is equal to Z. The logical operation AND is interpreted to mean that Z=l if and only if X=l and Y=l otherwise Z=0

NOT Gate: It has one input and one output. This operation is represented by prime (bar). For example X= Z is read X not equal to Z" meaning that Z is what X is not. In other words if X=l, then Z=0 but if X= 0 then Z=l.

NAND Gate: It has two inputs & one output. NAND function is compliment of AND functions. The bubble on output represents inversion after AND ing. The logic equation is Z = (X.Y)'. The output is high if any of the input is low.

NOR Gate: It has two or more than two inputs and one output. The NOR function is complement of OR function .The output is low if any input is high.

EX-OR Gate: Exclusive OR Gate has two inputs and one output. The output is high if and only if the two inputs i.e. X & Y are different i.e. If X=l & Y=0 or X=0 & Y=l otherwise output will be low.

The logic equation is XY' + X'Y = XÅY=Z.

Note: Refer Truth Tables and logic diagrams shown in experiment section.

Logic gates :

A logic gate is a combination of different electronic components that takes one or more logic-level inputs and produces a single logic-level output. Because the output is also a logic level, an output of one logic gate can connect to the input of one or more other logic gates.

In electronic logic, a logic level is represented by a certain voltage (which depends on the type of electronic logic in use). Each logic gate requires power so that it can source and sink currents to achieve the correct output voltage. In logic circuit diagrams the power is not shown, but in a full electronic schematic, power connections are required. There are 7 positive logic gates and each gate has two laws or rules.

Truth table: A truth table is a table that describes the behavior of a logic gate. It lists the value of the output for every possible combination of the inputs and can be used to simplify the number of logic gates and level of nesting in an electronic circuit.

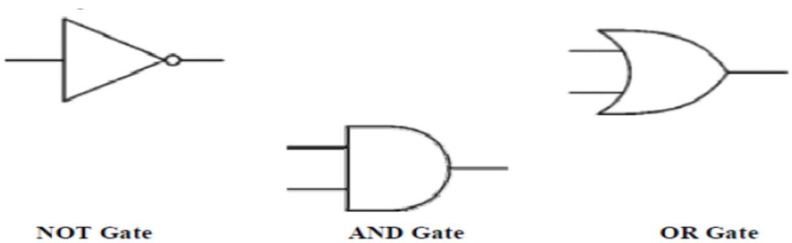


Figure 1

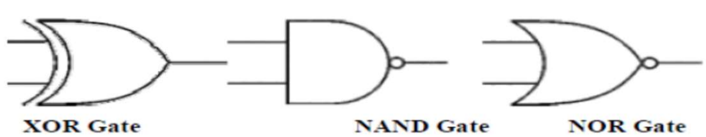
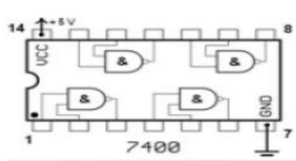
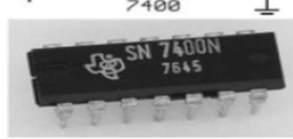


Figure 2





List of logic gate Ics :

The 7400 series has several ICs that contain just two-input logic gates :

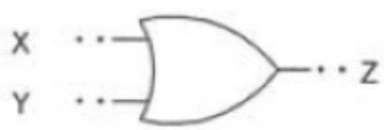
IC No.	Gate
7400	NAND
7402	NOR
7404	NOT
7408	AND
7432	OR
7486	XOR

STUDY OF THE OPERATION OF OR/AND/NOT/NAND/NOR/XOR/XNOR GATE AND TO VERIFY ITS TRUTH TABLE.

Logic Diagram & Truth Table :

(Logic 1 = +5 V & Logic 0 = GND)

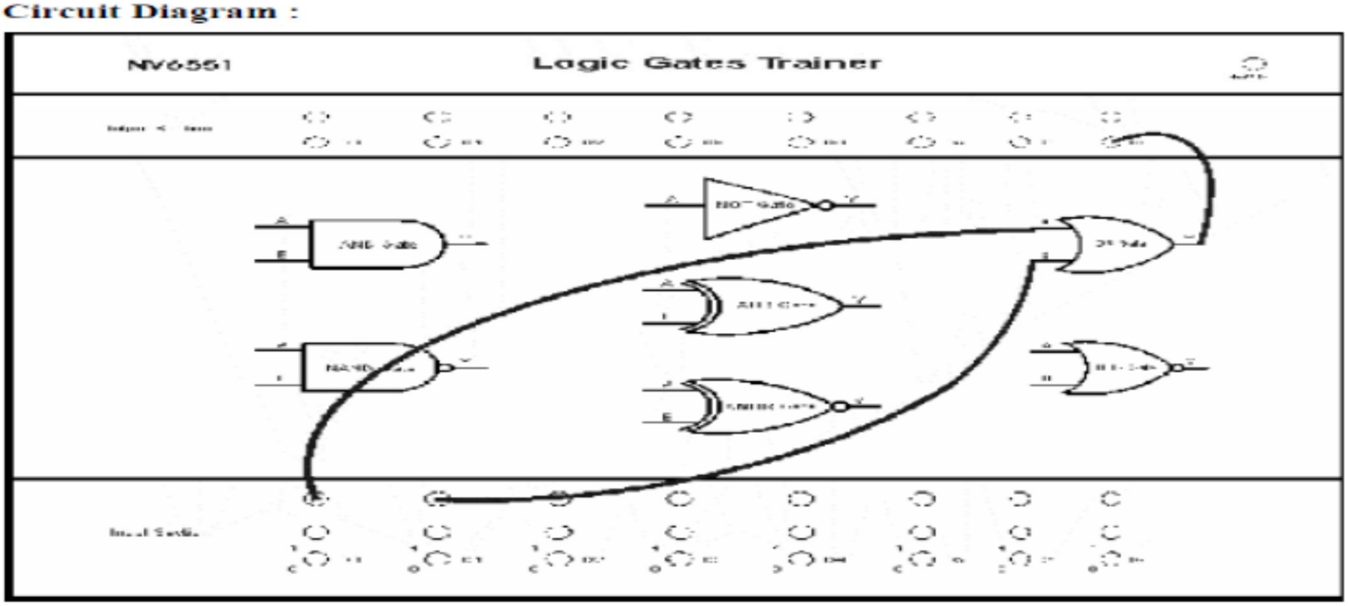
Truth Table :



X	Y	Z
0	0	0
0	1	1
1	0	1
1	1	1

OR Gate

Circuit Diagram :



Procedure :

1. Connect inputs D0 and D1 as inputs of OR gate, A and B, and connect output Y to the D7 of output section LED.
2. Plug in the +5V DC adaptor into the trainer and switch on the power supply.
3. Now set switch D0 and D1 of input section to OFF, this will show logic 00 and observe the output Y at D7's LED.
4. Record your observation into the observation table.
5. Similarly set different combinations of A and B like AB=01, AB=10 and AB=11 and record the corresponding outputs into the observation table.

Now match your observation table with the Truth table of OR gate.

Observation Table :

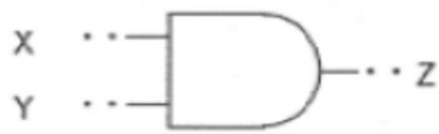
A(D0)	B(D1)	Y(D7)

AND Gate:

Logic Diagram & Truth Table :

(Logic 1 = +5 V & Logic 0 = GND)

Truth Table



X	Y	Z
0	0	0
0	1	0
1	0	0
1	1	1

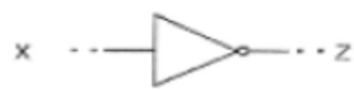
NOT Gate:

Logic Diagram & Truth Table:

(Logic 1 = +5 V & Logic 0 = GND)

Truth Table :

X	Z
0	1
1	0

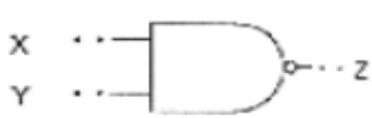


NAND Gate:

Logic Diagram & Truth Table:

(Logic 1 = +5 V & Logic 0 = GND)

Truth Table :



X	Y	Z
0	0	1
0	1	1
1	0	1
1	1	0

NAND Gate :

NOR Gate:

Logic Diagram & Truth Table :

(Logic 1 = +5 V & Logic 0 = GND)

Truth Table :

X	Y	Z
0	0	1
0	1	0
1	0	0
1	1	0

NOR Gate

XOR Gate:

Logic Diagram & Truth Table :

(Logic 1 = +5 V & Logic 0 = GND)

Truth Table

X	Y	Z
0	0	0
0	1	1
1	0	1
1	1	0

XNOR Gate:

Logic Diagram & Truth Table :

(Logic 1 = +5 V & Logic 0 = GND)

Truth Table

XNOR Gate

X	Y	Z
0	0	1
0	1	0
1	0	0
1	1	1

VIVA VOCE

- What are the Truth Table for OR, NOR, AND, NAND gates?
- Write the decimal values of 11001, 1111 binary numbers?
- What are universal Gates?
- Explain the applications of Logic Gates? What do you understand by Flip-Flop?

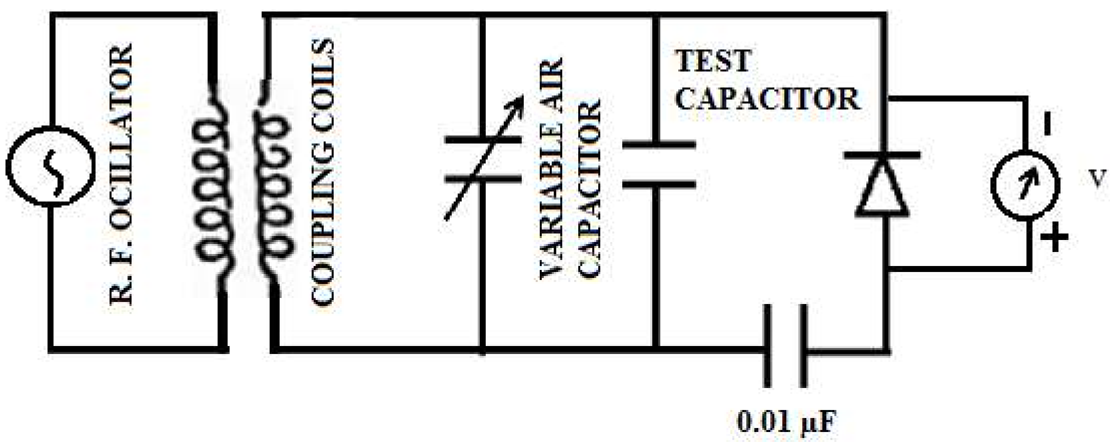
EXPERIMENT – 15
DIELECTRIC CONSTANT

AIM

TO FIND THE DIELECTRIC CONSTANT OF A SUBSTANCE.

APPARATUS

1. Dielectric Constant App. consists of R.F. Generator (9-10 MHz approx).
2. Micro ammeter (Range: 0-50 μA)
3. Potentiometer for sensitivity selection.
4. Fixed capacitor (Metal).
5. Variable Gang capacitor.
6. Sockets for test capacitor and variable capacitor brought out at front panel.
7. One solid Bakelite plate to be inserting in gap of test capacitor.



CIRCUIT DIAGRAM

THEORY

A dielectric is a material having low electrical conductivity in comparison to that of a metal. It is characterized by its dielectric constant. Dielectric constant is measured as the ratio of the capacitance C of an electrical condenser filled with the dielectric to the capacitance C_0 of the evacuated condenser i.e.

$$\epsilon = \frac{C}{C_0}$$

PROCEDURE

METHOD-1

1. Switch ON the instrument using ON/OFF toggle switch provided on the front panel.
2. Connect the variable/Gang capacitor and test Capacitor plug to the sockets indicated on the front panel.
3. Set the sensitivity pot to 30 μA.
4. Keep test capacitor without dielectric and vary capacity variable/gang capacitor air capacitor so that the deflection in micrometer reaches the resonance point.Let this value of variable/ gang capacitor be C_1.

A. TO FIND THE DIELECTRIC CONSTANT FOR SOLIDS.

5. For measuring dielectric of solids e.g. Bakelite Plate, connect the variable/gang capacitor in parallel with the test capacitor.
6. Put the dielectric (solids) plates in between the gap of capacitor.
7. Start varying the variable/gang capacitor to the anti-clock wise direction. There is a decrease in the micrometer to the resonance point and note down the capacity of variable/gang capacitor C_2.

METHOD -2

1. Switch ON the instrument using ON/OFF toggle switch provided on the front panel.
2. Connect the variable/Gang capacitor and test Capacitor plug to the sockets indicated on the front panel.
3. Set the sensitivity pot to 30 μA.
4. Keep test capacitor without dielectric and vary capacity variable/gang capacitor air capacitor so that the deflection in micrometer reaches the resonance point. Let this value of variable/ gang capacitor is C_1.

B. TO FIND THE DIELECTRIC CONSTANT FOR LIQUIDS

5. For measuring the dielectric of liquids e.g. kerosene oil, fill the variable/gang capacitor with dielectric.
6. Vary the capacity of variable/gang capacitor so that the deflection in micrometer reaches to the resonance point. Let this value of variable/gang capacitor be C_2.

OBSERVATION TABLE

For Sensitivity = 30 μA				For Sensitivity = 40 μA			
No. of Plates	**C_1**	**C_2**	**Dielectric Constant (K_1)**	**No. of Plates**	**C_1**	**C_2**	**Dielectric Constant (K_2)**
Single							
Double							

Mean value of Dielectric constant K is given by $\mathbf{K = (K_1 + K_2)/2 =}$

OBSERVATIONS

Capacity of test capacitor C_0=…27…..pF (Standard)

Capacitor of variable/gang capacitor C_1=………pF

Capacity of variable/gang capacitor C_2=……….pF

CALCULATION:

Dielectric constant K is given by,

$$K = 1 + \frac{C_1 - C_2}{C_0}$$

C_0: Capacity of test capacitor without dielectric.

C_1: Capacity of variable air capacitor for maximum deflection in micro-ammeter when test capacitor is without dielectric.

C_2: Capacity of variable capacitor for maximum deflection in micro-ammeter when capacitor is filled with dielectric (Solid or liquid)

PRECAUTIONS:

1) Set the sensitivity pot to 30 μA maximum.

2) After the liquids dielectric experiment gang capacitor should be dry for further experiments.

VIVA-VOCE

Q.(1). What is Dielectric?

Ans: Dielectric is an electrical insulator that can be polarized by an applied electric field. When a dielectric is placed in an electric field, electric charges do not flow through the material as they do in a conductor, but only slightly shift from their average equilibrium positions causing dielectric polarization.

Q.(2). What is the difference between dielectric materials and metals?

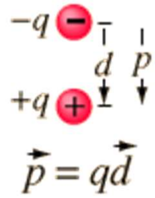
Ans: The conductivity of dielectrics is negligible in comparison to that of metals. For dielectrics the specific resistance ρ is on the order of 10^8-10^{17} ohm-cm; for the metals, ρ is in the range of 10^{-6}-10^{-4} ohm-cm.

Q.(3). What is electric dipole?

Ans: An electric dipole is combination of two equal and opposite electric charges.

Q.(4). What is electric dipole moment?

Ans: The electric dipole moment for a pair of opposite charges of magnitude q is defined as the magnitude of the charge times the distance between them and the defined direction is toward the positive charge.



Q.(5). What is electric polarization?

Ans: Electric polarization is the slight relative shift of positive and negative electric charge in opposite directions within an insulator, or dielectric, induced by an external electric field. Polarization occurs when an electric field distorts the negative cloud of electrons around positive atomic nuclei in a direction opposite the field. This slight separation of charge makes one side of the atom somewhat positive and the opposite side somewhat negative.

Q.(6). What is the effect of electric field on dielectric materials?

Ans: When a dielectric is placed in an electric field, electric charges do not flow through the material as they do in a conductor, but only slightly shift from their average equilibrium positions causing dielectric polarization. Because of dielectric polarization, positive charges are displaced toward the field and negative charges shift in the opposite direction. This creates an internal electric field which reduces the overall field within the dielectric itself.

Q.(7). Define dielectric constant of a material?

Ans: The dielectric constant (K) of a material is the ratio of its permittivity ε of that material to the permittivity of vacuum εo, so $K = \varepsilon/\varepsilon o$. The dielectric constant is therefore also known as the relative permittivity of the material. Since the dielectric constant is just a ratio of two similar quantities, it is dimensionless.

Given its definition, the dielectric constant of vacuum is 1. Any material is able to polarize more thanvacuum, so the K of a material is always > 1.

Q.(8). Where the various dielectric materials find their applicability?

Ans:A low-K dielectric is a dielectric that has a low permittivity, or low ability to polarize and hold charge. Low-K dielectrics are very good insulators for isolating signal-carrying conductors from each other. Thus, low-K dielectrics are a necessity in very dense multi-layered IC's, wherein coupling between very close metal lines need to be suppressed to prevent degradation in device performance.

A high-K dielectric, on the other hand, has a high permittivity. Because high-K dielectrics are good at holding charge, they are the preferred dielectric for capacitors. High-K dielectrics are also used in memory cells that store digital data in the form of charge.

Q.(9). Define time constant of a RC circuit?

Ans: It is the time required to charge (or discharge) the capacitor through the resistor. The RC is the time constant (in seconds) of an RC circuit, is equal to the product of the circuit resistance(in ohms) and the circuit capacitance (in farads), i.e. = R * C.

Q.(10). What is electrolytic capacitor?

Ans: An electrolytic capacitor is a capacitor that uses an electrolyte (an ionic conducting liquid) as one of its plates to achieve a larger capacitance per unit volume than other types. Or in an electrolytic capacitors one or both of the "plates" is a non-metallic conductive substance, an electrolyte. Electrolytes have lower conductivity than metals, so are only used in capacitors when metallic plate is not practical, such as when the dielectric surface is fragile or rough in shape or when ionic current is required to maintain the dielectric integrity.

The electrolytic solvent has to have high dielectric constant, high dielectric strength, and low resistivity; a solute of ionic conductivity facilitators is mixed within. The electrolyte is usually boric acid or sodium borate in aqueous solution, together with various sugars or ethylene glycol which are added to retard evaporation.

APPLICATIONS

1. A major use of dielectrics is in fabricating capacitors. These have many uses including storage of energy in the electric field between the plates, filtering out noise from signals as part of a resonant circuit, and supplying a burst of power to another component.

2. Some applications of dielectrics rely on their electrically insulating properties rather than ability to store charge, so high electrical resistivity and low dielectric loss are the most desirable properties here. The most obvious of these uses is insulation for wires; cables etc., but there are also applications in sensor devices. For example, it is possible to make a type of strain gauge by evaporating a small amount of metal onto the surface of a thin sheet of dielectric material.

ERPERIMENT 16
POLARIMETER

AIM: To determine the specific rotation of cane sugar with the help of a polarimeter.

APPARATUS: Half-shade/Bi-quartz polarimeter, light source (Sodium/Mercury vapor lamp), sugar, measuring flask, beaker, analytical balance and a weight box.

PRINCIPLE & FORMULA

If a beam of unpolarised light is viewed through two crossed Nicol prisms (when the principal planes of the two are perpendicular to each other) the field of view is completely dark. The first Nicol is called the polariser and the second is called the analyzer. If the sugar solution is introduced between the two crossed Nicols, it is found that light is restored in the field of view. To extinguish the light, the analyzer has to be rotated through a finite angle depending on the concentration of the sugar solution. This experiment shows that the substance introduced between the Nicols has rotated the plane of polarization. Such substances are called optically active substances and the phenomenon is called 'Optical activity'. If the plane of polarization is rotated clockwise, the substance is called dextro-rotatory (right handed) and if it is rotated anti-clockwise, the substance is called levo-rotatory (left handed).

The angle θ by which the plane of polarization is rotated is directly proportional to the length of the path traveled by the light in the substance (*l*), the concentration of the substance (c). It also depends on the temperature and wavelength of light. Thus for a particular wavelength and temperature

$$\theta \propto l\,c \quad \text{or} \quad \theta = S\,l\,c \quad \text{or} \quad S = \frac{\theta}{l \times c} = \frac{\theta \times v}{l \times m}$$

Where, S = specific rotation or specific rotatory power of the substance θ = rotation produced in degree
m = mass of sugar in gm. dissolved in
water v = volume of sugar solution
l = length of the tube in decimeter

Specific rotation, for a given wavelength at a given temperature, is defined as the rotation produced by one decimeter length of the solution having a concentration of 1 gm/cc.

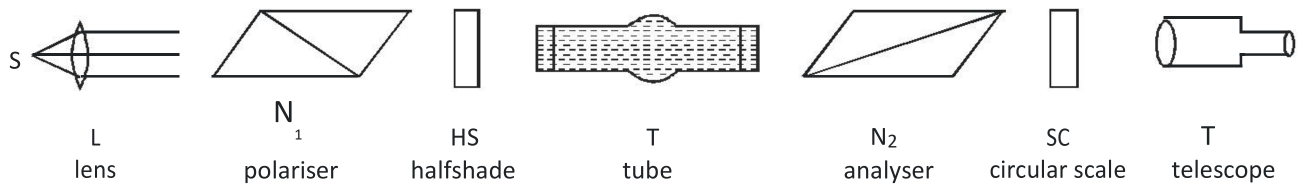
APPLICATIONS

- **Sugar Industry**
- **Chemical Industry**
- **Pharmaceutical Industry**
- **Flavours, Fragrances and Essential Oils**

LAURENT'S HALF - SHADE POLARIMETER

Laurent's half-shade polarimeter is an instrument used for finding the specific rotation of certain optically active solutions. The essential parts of a Laurent's half-shade polarimeter are shown in the figure. 'S'is unpolarised/ ordinary source of light and L is a convex lens which renders the incident light into a parallel beam. N_1 and N_2 are two Niclo prisms. N_1 acts as polariser while N_2 acts as analyzer. N_2 can be rotated about a common axis of N_1 and N_2. The rotation of analyzer (N_2) can be read in a graduated circular scale (S.C.).

The vernier is also provided to read the fraction of a degree. Light after passing through polariser becomes plane polarized with its vibrations in the principal plane of the Nicol (N_1). The plane polarized light now passes through a half-shade device (H.S.) and then through a tube 'T' containing the optically active substance. Usually 'T' is a hollow glass tube having a large diameter in the middle so that no air bubble may be in the path of light when filled with a liquid. The emergent light on passing through analyzer N_2 is viewed through a telescope T. The telescope is focused on the half shade.



PROCEDURE

1. Weight exactly 4 gms of sugar and dissolve it in 100 c.c. of distilled water in a measuring flask; make the solution exactly 100 c.c.

2. If the polarimeter is employing a half shade device, a monochromatic source is used and if a biquartz device is used than white light is to be used. Clean the tube such that it is free from dust and fills it with distilled water and close the ends. Place the tube in position inside the polarimeter.

3. Look through the telescope and rotate the analyzer till the two halves of the field of view appear equally bright. Take the reading of main scale as well as vernier scale and find out the total reading **(θ_1).**

4. Take out the tube and fill it completely with the sugar solution so that there are no air bubbles in it. ***(DoNot Over Tight the Cap It May Break the Tube)*** Close the tube, place it in its position in the polarimeter and look through the telescope. Again set the field of view as explained in step-3. Note the reading of the analyzer on the circular scale **(θ_2).**

5. Repeat step 4 of the experiment for different concentrations of the solution and tabulate the observations.

OBSERVATIONS

Least count of the vernier of circular = ……. °

Length of the cylindrical tube (l)= …….cm

Mass of the sugar dissolved (x) =……. gm

Volume of the solution (v) =……. cc.

Temperature of the solution (t) (room temperature) =……. °C

Tabular Form:

S.No	Concentration of solution (x/v) gm/cc	Reading on circular scale when two halves are of equal intensity x_n	Angle of rotation of plane of polarization $\theta = x_n - x_1$	$S = (10.\theta.\ v)/l.x$
1	Distilled water	x_1		
2	4/100	x_2		
3	8/100	x_3		
4	12/100	x_4		

GRAPH

Plot a graph between concentration of the solution (c) on the X-axis and angle of rotation of the plane of polarization of plane polarized light (θ) on the Y-axis. You get a straight line passing through the origin.

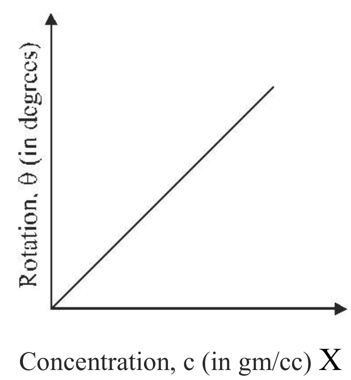
CALCULATIONS

$$\text{slope} = \frac{\theta}{c}$$

$$S = \frac{\text{slope} \times 10}{l}$$

Where l is the length of the tube in cm

Reading with distilled water, say $\theta_1 = \ldots\ldots$



RESULTS: The specific rotation of glucose solution at …°C for the given weight is ________________degree/unit concentration/unit length

PRECAUTIONS

1. The window cap of the tube containing the solution should be gently tight, so that there will be no leakage.
2. There should be no air bubble in the solution contained in the polarimeter tube.
3. The temperature of the solution must be recorded (room temperature).
4. Having set the analyzer in correct position w.r.t the polarizer, turn the former through 180° and again make a similar setting.
5. Under no circumstances the polarizer should be touched during one complete set of observation.
6. Use sodium light for half shade, and white light for bi-quartz.

Viva Voce:

1. What do you mean by polarization of light?
2. How does polarized light differ from ordinary light?
3. What is angle of polarization?

4. What are the plane of polarization and plane of vibration?
5. What is Polaroid?
6. What are the uses of Polaroid's in daily life?
7. What is Brewster's law?
8. What is the polarizing angle for the air-glass?

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