Engineering Electromagnetics Practice Manual
(PH1001)
B. TECH
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– List of Experiments –

E1. Fresnel's Biprism

E2. Air wedge

E3. Lissajous figures

E4. Field along the axis of a coil

E5. Dielectric studies

E6. Quincke's method

E7. BH Curve

E8. Fraunhoffer Diffraction

E9. Optical energy loss

E10. Solar cell characteristics

{**Experiments may be arranged in a different order}

E.1 STUDY OF VARIATION OF DIELECTRIC CONSTANT OF A GEIVEN MATERIAL

AIM: To study the dielectric behavior of a ferroelectric ceramic material at various temperatures and hence, to determine the Curie temperature.

APPARATUS REQUIRED: Dielectric study set-up, temperature controlled oven, spring loaded probe and barium titanate sample ($BaTiO_3$).

PRINCIPLE: Ferroelectricity is the property of a material which exhibits the spontaneous polarization that takes place in polar crystals, which is a function of temperature. This is due to the presence of permanent dipoles in the materials. A ferroelectric material exhibits two different properties. Like ferromagnetic materials, ferroelectrics have a curie temperature. Below a particular temperature, known as curie temperature T_C it behaves as a ferroelectric and above T_C, the dielectric material behaves as a paraelectric material.

FORMULA:

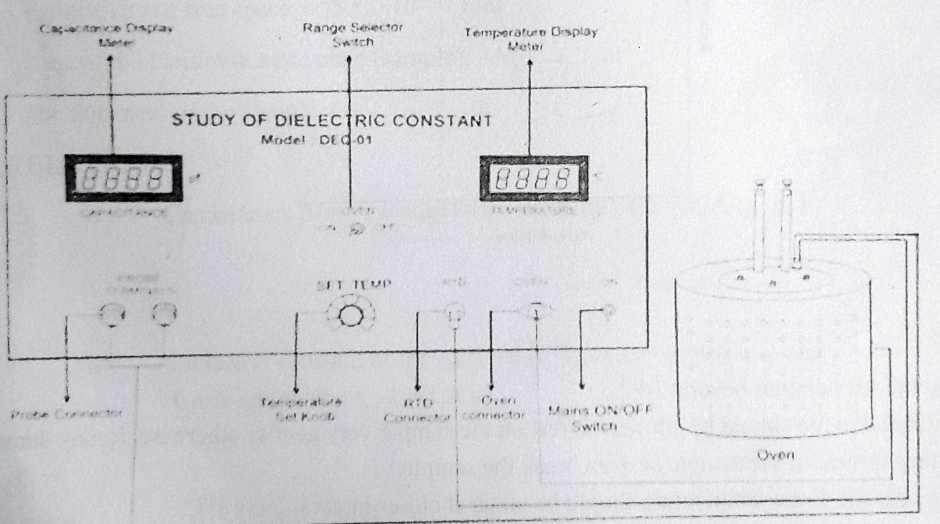
Dielectric constant of the material is $\boldsymbol{\varepsilon} = (\boldsymbol{C}/\boldsymbol{C_0})$,

where,

C – Capacitance using the material (F); $C_0 - (\varepsilon_0 A/t)$ capacitance of the capacitor with air

ε_0 – permittivity of free space $(8.85 \times 10^{-12}\ F/m)$; A – Area of the barium titanate sample (m^2)

t – Thickness of the sample (m)



Dielectric constant experimental set up

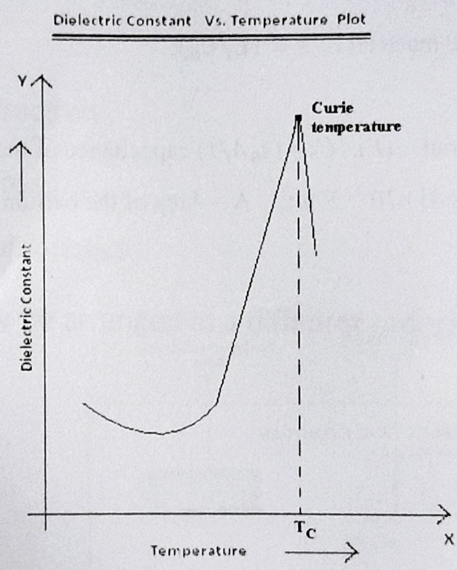
PROCEDURE:

1. Put a small piece of aluminum foil on the base plate. Pull the spring loaded probes upward, insert the aluminum foil and let them rest on it. Put the sample ($BaTiO_3$) on the foil. Again pull the top of one of the

probes and insert the sample below it and let it rest on it gently. Now one of the probes would be in contact with the upper surface of the sample, while the other would be in contact with the lower surface through aluminum foil.

2. Connect the probe leads to the capacitance meter.
3. Connect the oven to the main unit and put the oven in switch OFF position.
4. Switch ON the main unit and note the value of capacitance directly in pF (at room temperature).
5. Switch ON the oven and approximately adjust the "set temperature" knob. The green LED would light up indicating the oven is ON and temperature would start rising. The temperature of the oven in ^{0}C would be indicated by the DPM.
6. Note the capacitance at 40^{0}C and at intervals of 20^{0}C up to 120^{0}c.
7. Note the capacitance at intervals of 1^{0}C from 120^{0}C to 140^{0}C
8. Plot a graph of dielectric constant(Y – axis) versus temperature (X – axis)
9. From the graph, note the value of temperature (Curie temperature = T_C) at the turning point of the curve where the slope changes from positive to negative.

Model Graph:



PRECAUTIONS:

1. Do not raise the temperature beyond 140^{0}C
2. The spring loaded probe should be allowed to rest on the sample very gently; otherwise, it may damage the conducting surface of the sample or even break the sample.
3. The reading near the Curie temperature should be taken at closer intervals, say 1^{0}C.
4. Once you see that the value of $\boldsymbol{\varepsilon}$ had started decreasing with increasing **T,** take readings for three or four more temperatures and stop. (**No need to go upto 140^{0}C**)

TABLE 1: Variation of capacitance and hence the dielectric constant with temperature

Temperature in ^0C	Capacitance C in pF	Dielectric constant (ε)
Room temp		
40		
60		
80		
100		
120		
121		
122		
.....		
139		
140		
.		

OBSERVATIONS:

Permittivity of free space, $\varepsilon=8.85\times10^{-12}$ F/m

Area of the barium titanate plate (sample), A = ...m^2

The thickness of the sample, t = ...m.

CALCULATIONS:

i) Capacitance using vacuum as the dielectric, $C_0 = (\varepsilon_0 A/t)$ in F

=................F

ii) Dielectric constant of the material at the room temperature and Curie temperature, $\varepsilon = (C/C_0)$

=........ (No unit)

RESULTS:

The dielectric behavior of the given ferroelectric ceramic material has been studied at various temperatures.

From the graph, the curie temperature of the given ferroelectric ceramic material is=.........^0C

E2: SOLAR CELL

AIM: To draw the VI characteristics of a solar cell and to determine the maximum power generated from a solar cell, fill factor and efficiency.

APPARATUS REQUIRED: Solar cell characteristics kit, light source.

PRINCIPLE:

When light falls on a solar cell, it is absorbed and pairs of positive and negative charges, called electron-hole pairs are created. The positive and negative charges are separated because of the potential difference at the p-n junction due to space charges. The direct current produced by the metal electrodes and flows through the external load.

FORMULA:

Maximum power generated under standard test conditions

$$P_{max} = I_{mp} \times V_{mp} \quad \text{watt}$$

Fill factor, $\quad FF = \dfrac{I_{mp}V_{mp}}{I_{sc}V_{oc}}$ (No unit)

Efficiency of the solar cell,

$$\eta = \frac{P_{max}}{A_c I_o} \times 100 \text{ Percentage}$$

where

I_{mp} – Current at maximum power (mA)
V_{mp} – Voltage at maximum power (V)
I_{sc} – Short circuit current (mA)
V_{oc} – Open circuit voltage (V)
I_o – Intensity of radiation (watt/m^2)
A_c – Area of solar cell (m^2)

here,

$$I_0 = \frac{\text{Power of the bulb}}{4\pi r^2}$$

where, r is the distance between a solar cell sample and the bulb(x or y) in cm

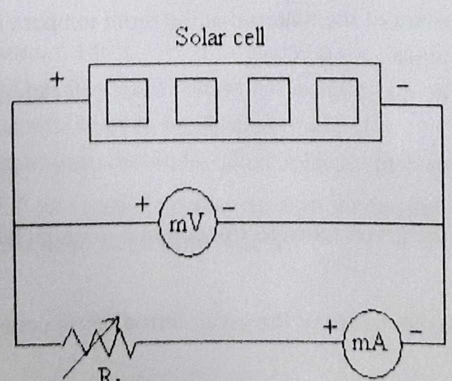


Figure 1 Study of I-V characteristics of a Solar cell

PROCEDURE:

1. Complete the circuit connections as shown in Figure 1. Then place the light source at a distance of '*x*' (=10 cm) from the solar cell.
2. Note the open circuit voltage 'V_{OC}' indicated by the millivoltmeter, by opening the connecting wire joining –ve of the milliammeter to the load (i.e., connecting +ve of the cell to the +ve of millivoltmeter and –ve of the cell to the –ve of millivoltmeter) which can be done by rotating the voltage regulator switch to 'V_{OC}'.
3. Bring load selector switch to SC (short circuit) position to short-circuit the solar cell output and note the reading in the milliammeter. If the meter shows out of scale then decrease the light intensity by increasing the distance. This maximum current is called the short circuit current 'I_{SC}'.
4. Draw 'V_{OC}' versus distance '*x*' and 'I_{SC}' versus distance '*x*' curves. Observe this curve and choose a distance '*x*' from the linear portion to get the full characteristic curve.
5. Now introduce the load resistance (R_{IN}) in the circuit (start from a low value of the resistance) and note the milliammeter and millivoltmeter readings simultaneously.
6. Repeat the same with different values of load resistances (R_{IN}) and note the corresponding milliammeter and millivoltmeter readings.
7. Repeat the experiment at another light intensity by placing the light source at '*y*' (=15 cm) from the solar cell.
8. Draw a graph between '*V*' and '*I*' as shown in Figure 2.
9. A pair of '*I*' and '*V*' for which area of the rectangle in the plot is maximum represent 'I_{MP}' and 'V_{MP}' and their product gives 'P_{max}' (Figure 2)
10. Then calculate maximum power, fill factor and efficiency using the given formulae.

Model graph:

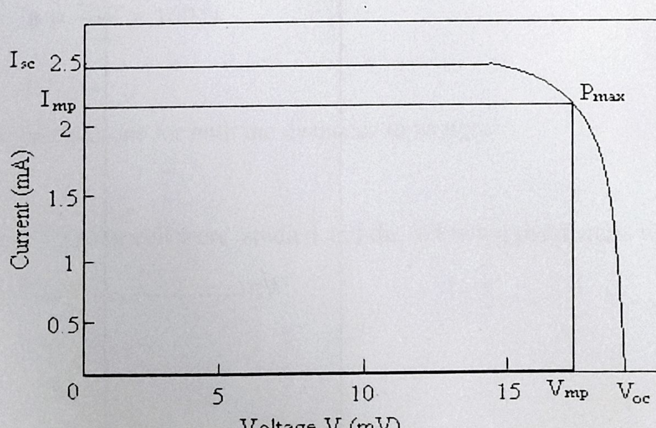


Figure 2: I-V characteristics of a Solar cell

OBSERVATIONS:

I) When the distance, x =.....cm

Maximum power P_{max} =....W

Current at maximum power I_{mp} =....A

Voltage at maximum power V_{mp} =.....V

Short circuit current I_{sc} =...A

Open circuit voltage V_{oc} =...V

Intensity of light I_o =.......W/m^2

Area of solar cell A_c =.....m^2

II) When the distance, y =.....cm

Maximum power P_{max} =....W

Current at maximum power I_{mp} =....A

Voltage at maximum power V_{mp} =.....V

Short circuit current I_{sc} =...A

Open circuit voltage V_{oc} =...V

Intensity of light I_o =.......W/m^2

Area of solar cell A_c =.....m^2

TABLE 1:

S. No	Distance x or y (cm)	Open circuit voltage V_{OC} (volt)	Short circuit current I_{SC} (mA)

I-V CHARACTERISTICS:

S. No	Distance = x cm = ... cm Intensity of light I_o = ...W/m^2			Distance = y cm = ... cm Intensity of light I_o = ...W/m^2		
	Voltage	Current	Power = V×I	Voltage	Current	Power = V×I
	V	mA	mW	V	mA	mW

CALCULATIONS:

I) Maximum power generated from a solar cell under standard test conditions is

$$P_{max} = I_{mp} \times V_{mp} \text{ watt}$$

$$P_{max} = \text{.......W}$$

II) Fill Factor(FF) $= \dfrac{I_{mp}V_{mp}}{I_{sc}V_{oc}}$

$= \text{................}$

III) Efficiency of the solar cell

$$\eta = \frac{P_{max}}{A_c I_o} \times 100\ \%$$

$\eta = \text{.....}$

(Do the calculations for both the distances separately)

RESULTS:

V-I characteristics of a solar cell were studied and the following parameters were calculated.

Power generated, P_{max} =.................mW

Fill Factor, FF =..............

Efficiency, η =.......%

(Write the results for both distances separately)

E3: AIR WEDGE

AIM: Determination of the diameter of the thin wire.

APPARATUS: Two optically flat glass plates (rectangular cross section), thin wire, microscope, sodium vapor lamp, reading lens, reading light.

THEORY: Fringe width (β) of interference pattern due to a thin wedge of a medium (here it is air) is dependent on the length of the wedge (L), height of the wedge(d) and the wavelength (λ) of the illuminating light (monochromatic) in the following way,

$$d = \frac{L\lambda}{2\beta}$$

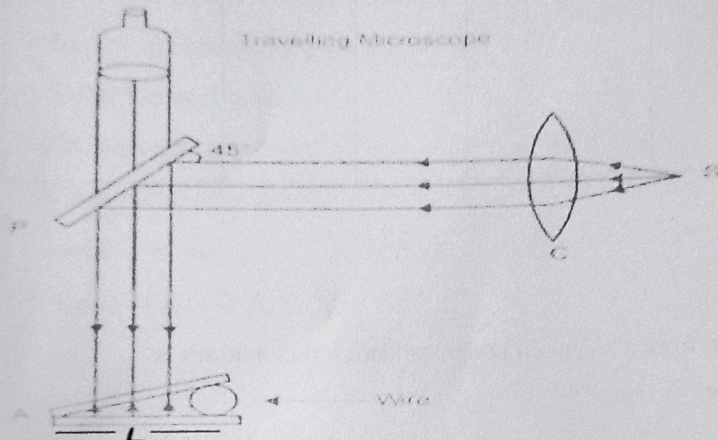


Figure 1: Set-up for band width determination

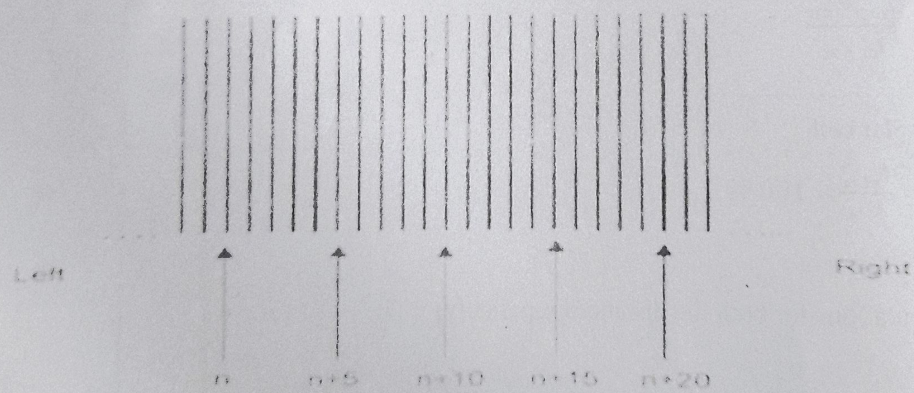


Figure 2: Fringe pattern

PROCEDURE:

1. Place the two optically flat plates one over the other so that they are in contact along one edge and are separated at the other end of the thin wire. The wire should be parallel to the edge. Under these conditions, the two plates enclose a wedge-shaped air film of thickness 'zero' at one end and the diameter of wire at the other end.

2. Place this arrangement on the platform of the microscope so that length of the plate is parallel to the horizontal traverse of the microscope.

3. Illuminate the system by monochromatic light (sodium light) reflected from a glass plate, held at 45° to the vertical, just above the wedge.

4. Adjust the eyepiece of the microscope so that the cross wire appears sharp (i.e., focusing is done).

5. With the microscope vertically, above the inclined glass plate, view the air wedge and focus the microscope till the parallel, equispaced interference bands are clearly seen. Note that the bands will be parallel to the wire. If every setting is correct a large number of interference bands could be seen.

6. Keep the intersection of the cross wires on one of the dark bands near to one end of the air wedge (where the wire is placed). Note the reading (n) on the horizontal scale of the Vernier microscope.

7. Shift the microscope, by rotating the appropriate screw, over 05 dark bands. Note the reading on the horizontal scale.

8. Repeat this process for n + 5, n + 10, n + 15, ... etc to get *about* ten (10) such readings.

9. Use the centimeter scale, to find out the distance between the wire and the other end of glass plate, where the two plates are in contact. Note the reading of the distance,'L' in m.

10. Calculate the diameter of the wire,'d' from the equation given above and β obtained from the observation table.

11. Write down your inferences.

TABLE 1: TO FIND THE FRINGEWIDTH (β):

LC=

Number of the fringes	Microscope reading			Number of the fringes	Microscope reading			Width of the 30 fringes $\lvert R_{n+15} - R_n \rvert$	Band width (β)
	MSR	VSC	TR* (R_n)		MSR	VSC	TR* (R_n)		
	cm	div	cm		cm	div	cm	cm	cm
n				n +15					
n +5				n +20					
n + 10				n +25					
......				.....					
Mean band width (β)=									

OBSERVATIONS:

Distant between the wire and the one edge of the tied glass end (A), L= -------------- m

The wavelength of the sodium light, $\lambda = 5893\times10^{-10}$m. (given)

CALCULATION: Use Table 1 and the formula given in the theory to calculate ,

d = ---------------- m

In order to verify the result from interference pattern (Air wedge), measure the diameter of the wire by a screw gauge.

TABLE 2: TO DETERMINE THE DIAMETER OF THE WIRE BY A SCREW GAUGE:

Zero Error = LC=

S.No	PSR (mm)	HSC (div)	HSR (HSC×LC) (mm)	TR=PSR+HSR (mm)	CR= TR±ZE (mm)
1. 2. 3.					

Mean (d)= mm.

RESULT:

The diameter of the thin wire is determined to be, (d)

i) Measured from interference phenomenon=……m. [with error calculated]
ii) Obtained by using a screw gauge =……m.
iii) Write your comment:

E4: FIELD ALONG THE AXIS OF A COIL

AIM: To plot the graph showing the variation of magnetic field with distance along the axis of a circular coil carrying current.

APPARATUS REQUIRED: Coil attached to a bench, compass box, DC power supply, rheostat, commutator, plug key, ammeter and connecting wires.

FORMULA: The field along the axis of a coil is given by

$$F = \frac{\mu_0 n r^2 I}{2(x^2 + r^2)^{3/2}}$$

where,

n = number of turns of the coil (turns),

r = radius of the coil (m),

I = current in amperes flowing in the coil (ampere),

x = distance of the point from the center of the coil (m),

μ_0 = magnetic permeability of the vacuum (Hm^{-1}).

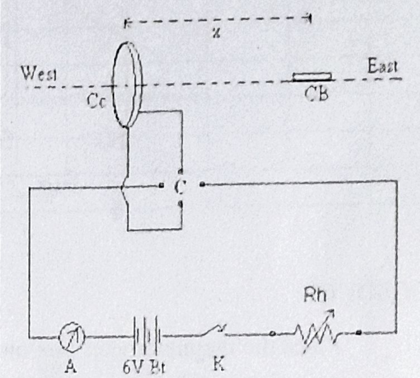


Fig1. Field along the axis of a coil- Determination of H
Cc - circular coil   CB - Compass box
C - Commutator   A- Ammeter
6V Bt- 6V Battery   K- Plug key R_h -Rheostat

If '*F*' is made perpendicular to '*H*' earth's horizontal magnetic field, the deflection θ of the needle is given by

$$F = H \tan\theta \,.$$

Thus

$$H = \frac{\mu_0 n r^2 I}{2(x^2+r^2)^{3/2}} \frac{1}{\tan\theta} \quad \text{tesla}$$

where,

$\mu_0 = 4\pi \times 10^{-7}$ is the permeability of free space in *henry/meter.*

DESCRIPTION OF THE APPARATUS:

The circuit is made as shown in the Fig.1. It consists of a circular coil of many turns of insulated thin copper wire. It is fixed with its plane vertical on a horizontal bench. The coil has four connecting terminals with marking as 2, 5 and 50. The connection between first and second terminals gives 2 turns. And second and third gives 5 turns and third and fourth gives 50 turns. A magnetometer compass box is placed inside the coil such that it can slide on the bench in such a way that the center of the needle always lies on the axis of the coil. The distance of the needle from the center can be read on the graduated scale fixed on the arms of the magnetometer.

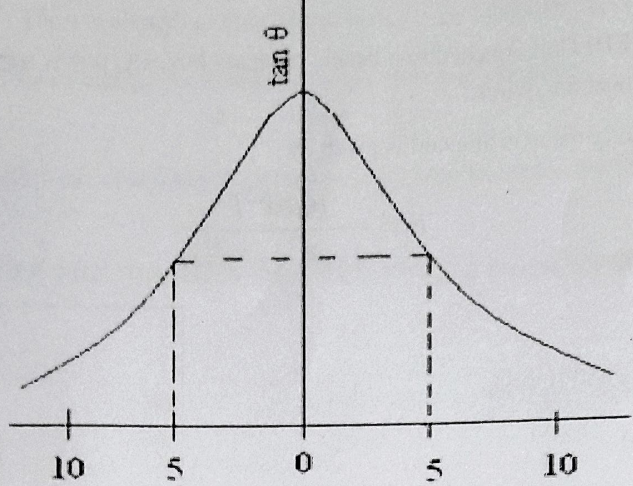


Fig 2 Distance from the centre of the coil **X** in mm

PROCEDURE:

(i) Place the magnetometer box on the sliding bench such that its magnetic needle is at the center of the coil. By rotating the whole apparatus in the horizontal plane, set the coil in the magnetic meridian. In this case, the coil, needle, and its image all lie in the same vertical plane. Rotate the compass box until the pointer ends read 0°-0° on the circular scale.

(ii) To set the coil exactly in the magnetic meridian set up the electrical connections as in the Fig.1. Pass the current in one direction by the help of commutator. Note the readings of the ends of the magnetometer pointer. Reverse the current direction. Again note the readings. If both readings are the same then the coil is in the magnetic meridian. Otherwise adjust again.

(iii) Using the rheostat adjust the current such that the deflection of 40°-60° is produced in the compass needle at the center of the coil. Read both ends of the pointer. Reverse the direction of the current and again note the readings. The mean of the four readings give the mean deflection at x=0.

(iv) Now shift the compass box through 2cm from the center to one side of the coil and repeat the experiment. Thus for different distances do the experiment for the same current in the coil.

(v) Repeat the experiment shifting the compass box to the other side of the coil.

(vi) Plot a graph taking distance along the X-axis and $tan\theta$ along the Y-axis with the center of the coil as the origin.

(vii) Repeat the experiment for one more value of current in the coil.

(viii) Calculate the magnetic field (H) along the axis of the coil.

TABLE 1: TO FIND HORIZONAL COMPONENT OF THE EARTH'S MAGNETIC FIELD

Current (I) = ---------- ampere

S. No	Distance x (cm)	Magnetometer to east deflections in deg				Mean θ (deg)	tan θ (deg)	*H*	Magnetometer to west deflections in deg				Mean θ (deg)	tan θ (deg)	*H*	*F*
		Direct		Reverse					Direct		Reverse					
		1	2	1	2				1	2	1	2				
	00															
	02															
	04															
	06															
	08															
	10															
	13															
	16															
	20															
Mean																

RESULT:

Thus, the horizontal component of earth's magnetic field is, H=____________ *tesla.*

E5: FRAUNHOFER DIFFRACTION FROM A SINGLE SLIT

AIM: To determine the width of the slit using Fraunhofer diffraction pattern

APPARATUS: Laser, A Slit, Optical bench, Screen with graph paper, scale, Microscope, and laser.

THEORY: If we allow monochromatic (laser beam) light to fall on a single slit whose width *'a'* is of the order of magnitude of the wavelength λ (632.8 nm) of the light, a **diffraction pattern** appears consisting of a broad intense central band, a series of narrower (less intense) bands (called **secondary maxima**) and a series of dark bands, or **minima**.

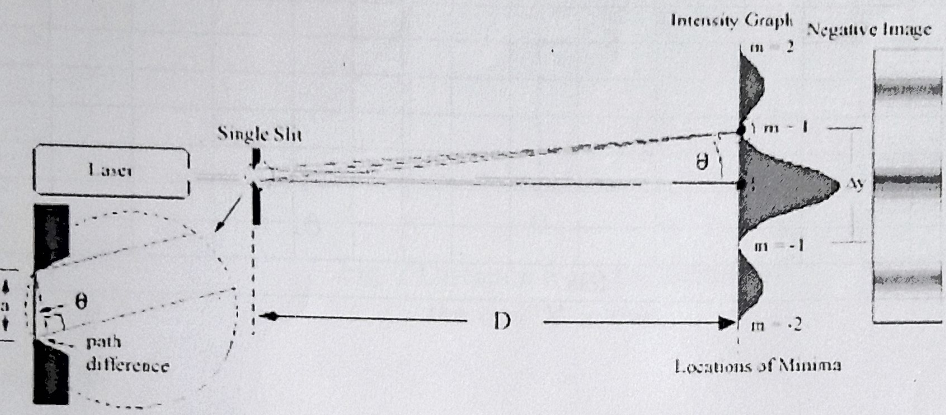


Figure 1 Single-slit diffraction

The explanation of single-slit diffraction analogous to Young's double-slit interference experiment by describing the single slit of width '*a*' as two slits each with a width of ***a***/2. Waves from one side of the slit will destructively interfere with the waves from the other side of the slit when

$$a \sin \theta_m = m\lambda; \; m = \pm 1, \pm 2, \pm 3, \ldots \qquad (1)$$

where θ_m is the angle subtended from the normal line of the slit to the radial direction of the m^{th} dark band and both the wavelength λ and the slit width 'a' must be measured in the same units.

PROCEDURE:

1. Put the screen (with a graph sheet attached to it) on one end of the Optical bench.
2. The laser has to be on the other end of the Optical bench.
3. Mount a slit with a VERY small aperture on the Optical bench near to the laser.
4. Illuminate the slit with the laser beam and adjust the width with the screw attached to it till a sharp fringe pattern (distinct spots of red light). Notice how the intensity (brightness) of the pattern fades with distance from the center. The dark spots are labeled by their order ***m***, with ***m*** starting at ***1*** on each side of the center; these are the ***"first-order minima"***. The maxima are similarly labeled. Notice that the center of the pattern, referred to as the ***"zeroth-order"*** maximum, is always bright.
5. Mark the various positions of the **minima's**, on the white/graph paper screen, with the help of pen/pencils.

6. Measure the distance between the marked positions with the help of scale. Let *'Y_m'* be the distance of the minima of m^{th} order from the central maxima and ***'D'*** is the distance between the slit and the screen.
7. Use the Eq.(1) to calculate the width of the slit.
8. Take the slit in front of the light source and measure its width with the help of a traveling microscope.

TABLE 1: DETERMINATION OF THE ANGLE FOR DIFFERENT ORDERS OF THE MINIMA'S:

Order m	Y_m (cm)	D(cm)	$\tan\theta_m = Y_m/D \approx \sin\theta_m$	λ(m)	$a = m\lambda/\sin\theta_m$
-3					
-2					
-1					
0					
1					
2					
3					

Average value of slit width = $(\sum a)/6$

Repeat it for another value of D and take the average value.

MEASUREMENT OF THE SLIT WIDTH BY A MICROSCOPE:

Take the saddle, with slit, mounted on it, out from the optical bench and place it on a table. Illuminate one side of the slit with a white light source and observe the light emanating from the other side. Focus the microscope on the slit so as to see the two edges of slit distinctly. Focus the cross point of the cross wire on one edge of the slit and take the reading in your notebook. Move the cross wire so that it reaches to the other end of the slit and again note down the observation. In the similar fashion, one should take at least four different sets of observations in the notebook. Differences of this observations/reading corresponding to the two edges of the slit provide us the value of slit width.

TABLE 2: DETERMINATION OF THE SLIT WIDTH BY A MICROSCOPE:

S. No.	Reading corresponding to the RHS edge of the slit X_1 (mm)			Reading corresponding to the LHS edge of the slit X_2 (mm)			Difference $a_i = \lvert X_2 - X_1 \rvert$
	MSR	CSR	Total	MSR	CSR	Total	
1							
2							
3							
4							

Average value of measured slit width = $(\sum a)/4$

CALCULATION:

%age error in slit width = $\dfrac{|\text{Experiment al value} - \text{Measured value}| \times 100}{\text{Measured value}}$

Theoretical width of the central maxima = 2D*632.8/slit width

Measured width of the central maxima = $|Y_{-1} - Y_1|$

RESULT:

The width of the single slit is measured by,

i. Fraunhoffer diffraction =________________m.

ii. Microscopic Observation =________________m.

E6: MAGNETIC SUSCEPTIBILITY-QUINCKE'S METHOD

AIM: To determine the magnetic susceptibility (χ) of the given solution by Quincke's method.

APPARATUS REQUIRED: Constant current power supply unit, Electromagnet (i.e. coil unit), Quincke's tube, microscope, $FeCl_3$/ $MnSO_4$ solution, etc.

PRINCIPLE: Magnetic susceptibility of a material is the ratio of the intensity of magnetization produced in the sample to the magnetic field intensity which produces the magnetization.

FORMULA:

Magnetic susceptibility is given by,

$$\chi = 2\rho g(h/H^2) \text{ (no unit)}$$

$B = \mu H$ (B is in Gauss and H in Oe)

$\mu = 1$ in CGS units (air)

$1\,Oe = 1\,G$ in air

$$\chi = 2\rho g(\textit{slope of h vs } H^2 \textit{ curve})$$

ρ – Density of the given solution (g/cm³)

g- Acceleration due to gravity (980cm/s²)

h - Difference in height levels ($h=h_1-h_0$) (cm)

h_0 – Height of the liquid without magnetic field (or with residual field only) (cm)

h_1 –Height of the liquid with magnetic field (cm)

$H = H_1 - H_0$ (Oe) [Given in the calibration table]

H_1- Magnetic field including residual field (Oe)

H_0- Residual magnetic field when the magnetizing current is OFF (Oe)

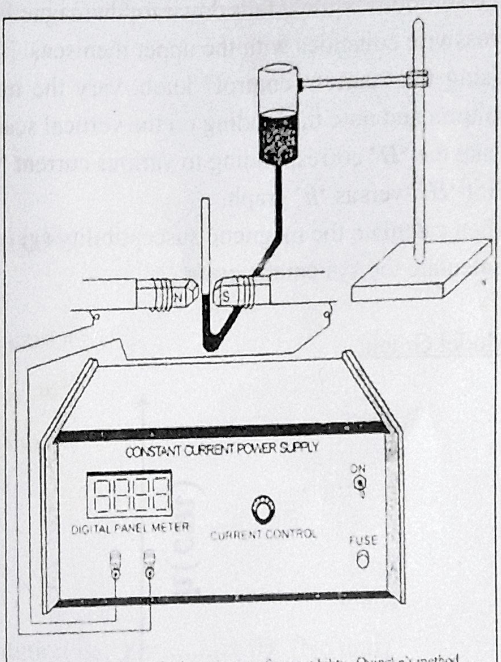


Figure 1: Set-up for determination of susceptibility - Quincke's method

PROCEDURE:

1. Arrange the apparatus as shown in Figure 1.
2. Fill the Quincke's tube with the experimental liquid and place it in such a way that the meniscus of the liquid at the narrow limb of the tube is exactly at the center of the magnetic field between the flat pole faces of an electromagnet.
3. Move and place the microscope horizontally in such a way that the objective of the microscope is in front of the liquid meniscus in the narrow limb.
4. On looking through the microscope adjust the distance between the liquid meniscus and the objective of the microscope using the screw until a clear, well defined, inverted image of the liquid (upper i.e., inverted image) meniscus is seen. Fix the microscope here and adjust the vertical tangential screw until the horizontal cross – wire coincides with the upper meniscus. Note the readings on the vertical scale. Do not disturb the microscope till you complete the experiment.
5. Switch ON the constant (magnetizing) current power supply unit.
6. Rotate the Current – Control knob provided for varying the current (i.e., magnetic field) and set the current value as 1.00A.
7. Now you can observe either rise or fall of the liquid level in the tube (It rises up for paramagnetic liquids and solutions while it falls down for diamagnetic). Adjust the vertical tangential screw until the horizontal crosswire coincides with the upper meniscus. Note the reading on the vertical scale.
8. Using the "current control" knob, vary the magnetizing current in steps as mentioned in the tabular column and note the reading on the vertical scale of the microscope.
9. Take the ***'H'*** corresponding to various current ***'I'*** values from the calibration table (to be given).
10. Plot ***'H²'*** versus ***'h'*** graph.
11. Then calculate the magnetic susceptibility (χ) of the given solution using the formula.
12. Calculate the systematic error.

<u>Model Graph:</u>

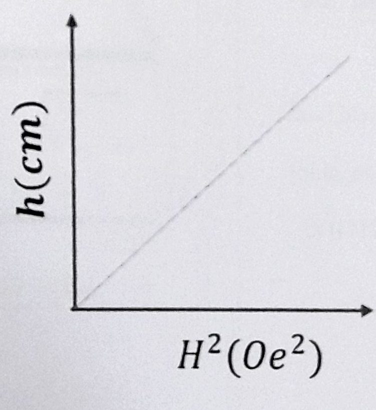


TABLE: TO DETERMINE MEAN (h/H^2):

LC=..................

S.No	Current (I)	Magnetic field (H)	H^2	Microscopic Reading						Difference in Liquid levels
				Without Current			With Current			
				MSR	VSC	*TR (h_i)	MSR	VSC	TR (h_f)	$h=h_i-h_f$

	A	Oe	Oe^2	cm	Div	cm	cm	Div	cm	cm
1.	0									
2.	0.3									
3.	0.6									
4.	0.9									
5.	1.2									
6.	1.5									
7	1.8									
8	2.1									
9	2.4									
10	2.7									
11	3.0									

*TR=MSR+(VSC×LC)

OBSERVATIONS:

χ = ... (from graph).

Mean (h/H^2) value = __________ cm/Oe^2.

Density of the given solution ρ = __________ g/cm^3.

Acceleration due to gravity g = __________ cm/s^2.

χ = ...

RESULT:

The mean magnetic susceptibility of the given solution is, χ = ...± $\delta\chi$ (No unit)

E7: B-H CURVE USING CRO

AIM: To determine the hysteresis loss in the transformer core using B-H curve unit.

APPARATUS REQUIRED: Analog CRO, B-H Curve unit kit, and Patch cords.

FORMULA:

$$\textit{Energy loss} = \frac{N_1}{N_2} \times \frac{R_2}{R_1} \times \frac{C}{AL} \times S_V \times S_H \times \textit{area of the loop} \quad \text{joule cycle}^{-1}\ \text{m}^{-3}$$

where

N_1 – Number of turns in the primary coil

N_2 – Number of turns in the secondary coil

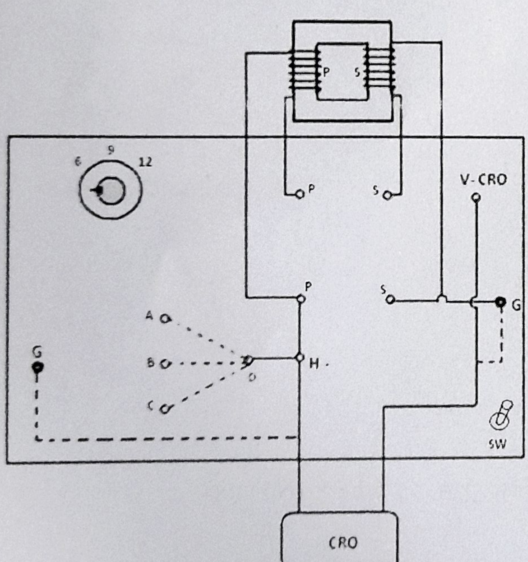
A – Area of cross section of the core (m^2)

L – Total length of the core material (l+b) (m)

C – Capacitance of the capacitor (F)

S_V – Vertical sensitivity of the CRO (V/m)

S_H – Horizontal sensitivity of the CRO (V/m)



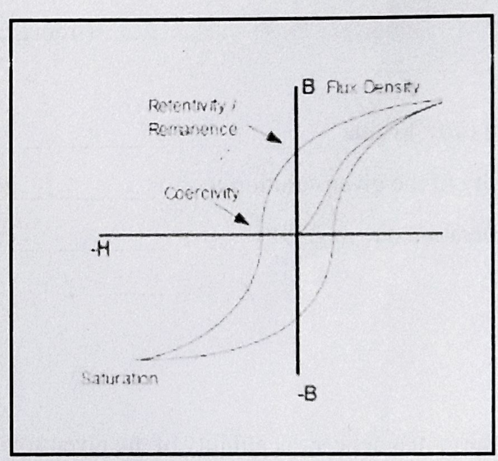


Figure 1 B-H Curve Unit

DESCRIPTION:

The specimen used to make the core of the transformer. There are two windings on the specimen (primary and secondary). The primary is fed to low AC voltage (50 Hz). This produces a magnetic field (H) in the specimen. It is connected to the input of the CRO (horizontal input). The magnetic field is proportional to the voltage across R_1 (resistance connected in series with primary). The alternating magnetic field induces a voltage in the secondary coil. The voltage induced is proportional to dB/dt.

This voltage is applied to the passive integrating circuit. The output of the integrator is proportional to B and fed to the vertical input of the CRO.

PROCEDURE:

1. The unit, one to force the B-H loop (hysteresis) of a ferromagnetic specimen using a CRO is shown in Figure1. A measurement of the area of the loop leads to the evaluation of energy loss in the specimen. The top view of the unit is shown in the Figure1. The value of R_I can be selected connecting terminals D to B (or C or A)
2. A is connected to D. The primary terminals of the specimen are connected to (P-P) and secondary to (S-S) terminals. The CRO has to be calibrated and it is adjusted to work on external mode ***XY mode*** (the time base is switched OFF). The horizontal and vertical position controls are adjusted such that the spot is at the center of the CRO screen.
3. The terminal marked GND is connected to the ground of the CRO. The terminal ***'H'*** is connected to the horizontal input (CH_1) of the CRO. The terminal ***'V'*** is connected to the vertical input (CH_2) of the CRO. The power supply of the unit is switched ON. The hysteresis loop is formed. The horizontal and vertical gains (voltage sensitivity knobs in CRO) are adjusted such that the loop occupies a maximum area on the screen of the CRO. Once this adjustment is made, the gain controls should not be disturbed. The loop is traced on a translucent graph paper. The area of the loop is estimated.
4. The connection of vertical input of the CRO is removed without disturbing the connection of the horizontal input and the gain controls. One horizontal line will appear. The horizontal sensitivity of the CRO is determined by applying a known input AC voltage **say V volt** (peak to peak i.e., applied input voltage V_{RMS}).
5. If the spot stretches horizontally (where vertical deflection is off) by $\boldsymbol{x}$ cm (where for V volt, the horizontal sensitivity is $S_H = V/x \times 10^{-2}$ (volt/m). Similarly, the vertical sensitivity of the CRO can be measured ($S_V = V/y \times 10^{-2}$ volt/m where, $\boldsymbol{y}$ is the deflection of the spot along vertical direction).

TABLE 1:

S.No	R_I (Ω)	V_{RMS} (V)	Size of the loop	x (m)	V_H (V/div)	S_H (V/m)	y (m)	V_V (V/div)	S_V (V/m)	Area of the loop	Energy loss
1.											
2.											
3.											
4.											
5.											

OBSERVATIONS:

Number of turns in the primary coil, N_1 = 200

Number of turns in the secondary coil, N_2 = 400

C = 4.7 μF

R_2 = 4.7 Kohm

R_1	= Resistance between D to A (or D to B or D to C)	=	ohm
A	= Area of cross section ($w \times t$)	=	m^2
w	= width of transformer core	=	m
t	= thickness of the specimen	=	m
L	= length of the specimen =2(l+b)	=	m
l	=mean length of the core	=	m
b	=mean breadth of the core	=	m
S_H	= horizontal sensitivity of CRO	=	Vm^{-1}
S_V	= vertical sensitivity of CRO	=	Vm^{-1}

CALCULATION:

Area of the loop = m^2

$$\text{Energy loss} = \frac{N_1}{N_2} \times \frac{R_2}{R_1} \times \frac{C}{A\,L} \times S_V \times S_H \times \text{Area of the loop}$$

RESULT:

Energy loss of the given specimen is measured =........................joules cycle^{-1} m^{-3}

E8: MEASUREMENT OF ENERGY-LOSSES OF THE OPTICAL FIBER

AIM: Measurement of the energy loss during the transmission of light through an optical fiber with various configurations.

APPARATUS REQUIRED: Optical fiber Trainee Tool Kit, Fiber optic cables of different lengths (1m, 3m), CRO

Theory:

LOSSES IN OPTICAL FIBER:

Optical fibers are available in different variety of materials. These materials are usually selected by taking into account their absorption characteristics for different wavelengths of light. In the case of optical fiber, since the signal is transmitted in the form of light, which is completely different in nature as that of electrons, one has to consider the interaction of matter with the radiation to study the losses in fiber. Losses are introduced in fiber due to various reasons. As light propagates from one end of fiber to another end, part of it is absorbed in the material exhibiting absorption loss. Also, part of the light is reflected back or in some other directions from the impurity particles present in the material contributing to the loss of the signal at the other end of the fiber. In general terms it is known as propagation loss. Whenever the condition for the angle of incidence of the incident light is violated the losses are due to refraction of light. This occurs when the fiber is subjected to bending. Lower the radius of curvature more is the loss. Other losses are due to the coupling of the at LED & photo detector ends

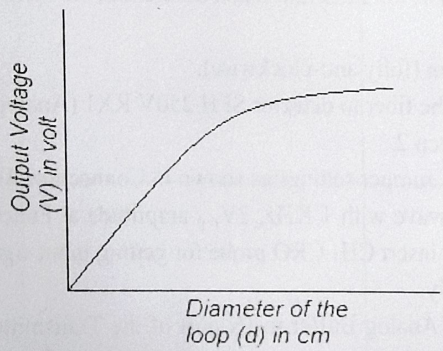
Mathematically the overall loss (attenuation) α is given by,

$$\alpha = \left(\frac{10}{L_1 - L_2}\right) \log_{10}(V_2/V_1) \quad dB$$

V_1- the voltage corresponding to the fiber length L_1

V_2 – is the same for the fiber length L_2

MODEL GRAPH: Bending Loss:



CALCULATION OF LOSSES:

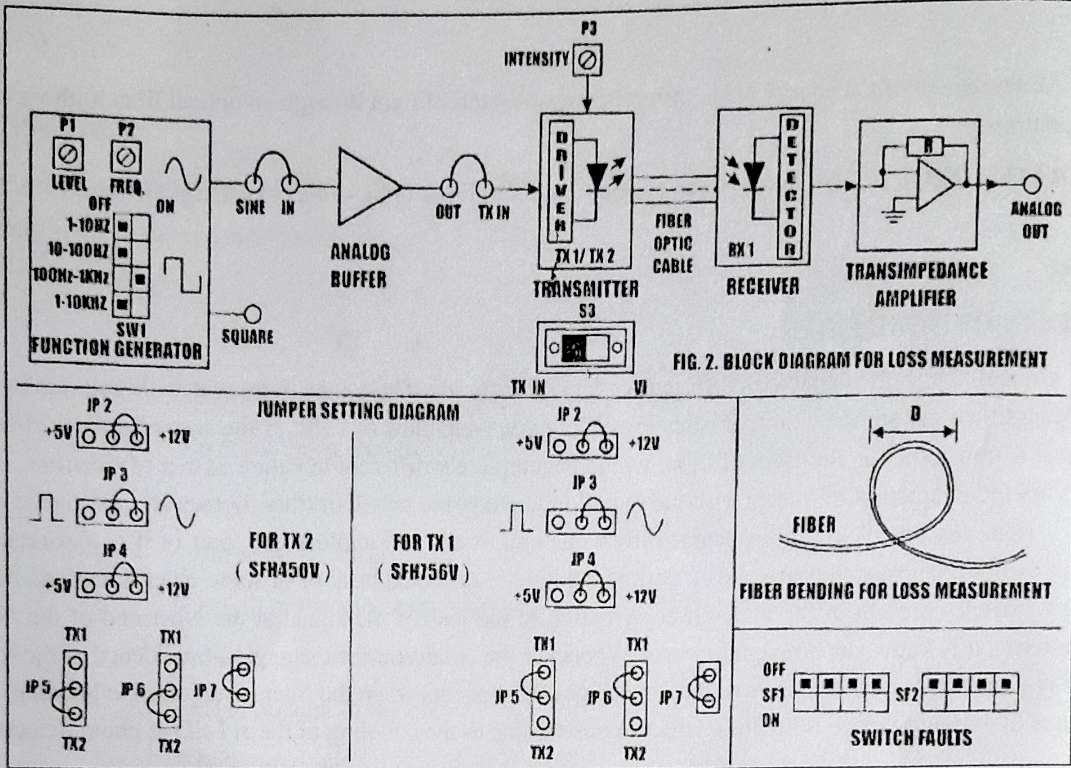


FIG. 2. BLOCK DIAGRAM FOR LOSS MEASUREMENT

PROCEDURE:

1. Connect the power supply cables with proper polarity to the kit. While connecting this, ensure that the power supply is OFF.
2. Slightly unscrew the cap of IR LED SFH 450V (950nm). Do not remove the cap from the connector, loose the cap and insert one end of the fiber into it and assure that the fiber is properly fixed. Now tight the cap by screwing it back.
3. Keep pot P3 at a minimum (fully anti-clockwise).
4. Connect the other end of the fiber to detector SFH 250V RX1 (Analog Detector) very carefully as per the instructions are given in step 2.
5. Make the connections and Jumper settings as shown in Connection Block diagram (Fig1).
6. Set the input signal Sine wave with 1 KHz, $2V_{p\text{-}p}$ amplitude at Function generator and connect it to IN port of Analog Buffer and insert CH_1 CRO probe for getting input signal.
7. Switch on the power supply.
8. Connect the OUT port of Analog Buffer to IN port of the Transmitter (TX IN) and connect CH_2 CRO probe to Analog OUT for getting the output signal from RECEIVER TRANSIMPEDENCE AMPLIFIER. (Transmitter and Receiver Transimpedence amplifier are internally connected). Negative ports of CH_1 and CH_2 should be grounded with Function Generator negative port.
9. Observe the reproduction of the originally transmitted output signal in CRO by adjusting INTENSITY pot P3. Note this amplitude level as V_1.
10. Replace the Fiber Optical Cable (with different lengths) without disturbing any of the settings. Measure this amplitude level V_2.

11. Now repeat the experiment with transmitter LED SFH 756V (660nm).
12. Make the Jumper settings as shown in connection Block diagram 2.
13. Measure V_1 & V_2 as given in step 11.
14. Compare the values of 'α' and find out the LED wavelength, which has less attenuation in the Fiber Optic Cable.
15. Repeat all the above procedure for bending the fiber into a loop of various diameters (3cm, 3.5cm, 4cm, 4.5cm, and 5cm). Record the output voltage for each loop of different diameters and plot a graph.

*** Don't bend the Optical Fiber Cable into a Loop having a diameter less than 4 cm.**

TABLE 2: MEASUREMENT OF ATTENUATION (α):

S.No	LED	Length of Fiber (cm)	Output Voltage (V)	*α (dB)*
1.	*SFH 450V*	L_1=	V_1=	
2.		L_2=	V_2=	
3.	*SFH 756V*	L_1=	V_1=	
4.		L_2=	V_2=	

TABLE 3: MEASUREMENT OF BENDING LOSS

S.No	LED	Diameter of the Loop ***d*** (cm)	Output Voltage ***V*** (volt)
1.			
2.			
3.	*SFH 450V*		
4.			
5			
6.			
7.			
8.	*SFH 756V*		
9.			
10			

RESULT:

The energy loss of the fiber optic cable with different configurations is measured as: .....

E9: LISSAJOUS PATTERNS – SUPERPOSITION OF TWO WAVES

AIM: To know how to use a CRO to measure voltage and frequency of a signal and to study the superposition of two waves from Lissajous pattern

APPARATUS REQUIRED: A cathode ray oscilloscope (CRO), frequency generators (FNG), digital multi meter (DMM), Variable Resistance box, Variable Capacitance box.

GENERAL DESCRIPTION OF A CRO: In a cathode ray oscilloscope, a beam of electrons produced by the electron gun is accelerated by an anode and focused onto a fluorescence screen. This beam can be deflected horizontally or vertically by applying a suitable voltage across the CH_1 (*X* plate) or CH_2 (*Y* plates) respectively. A linear time – base of any desired frequency can be applied across the X plates, under whose influence the electron beam travels back and forth horizontally. These X and Y inputs can also be amplified internally to make it clearly visible.

I. Measurement of AC voltage and study of wave shapes:

1. Switch the CRO power 'ON'.
2. Keep intensity of the CRO **low** so that the trace on the screen is just visible. ***High intensities may spoil the screen's coating material.***
3. Keep the VOLT/DIV knobs on both channels [$CH_1(X)$ and $CH_2(Y)$] at the same position (say at 0.2 volts/div).
4. Adjust the X – position control and the Y – position control knobs to place the trace at the center of the screen.
5. Switch the FUNCTION GENERATOR (FNG) ON. Keep the frequency of the FNG at around 1 KHz.
6. Connect the output of the FNG to the input of $CH_1(X)$ of the CRO using the BNC connector.
7. Keep to the function switch corresponding sine wave is switched ON in FNG.
8. Adjust the Amplitude control knob (voltage gain control knobs) at around 2V position in CRO channels.
9. Vary it (knob) to see a vertical line traced by the electron beam with a length of about 4 large divisions (square boxes) on the screen.

The applied sine wave on the Y plates keeps changing polarity 1000 times per second in a sinusoidal fashion and hence the electron beams also, being negatively charged keep moving up and down at this frequency. Hence due to the persistence of vision we see a continuous line. If you reduce the frequency of the applied sine wave to very low values (say 0.1Hz) then you can follow the beam movement.

10. The magnitude of the line is proportional to the peak-to-peak voltage of the applied wave (V_{pp}). Calculate the peak voltage of the sinusoidal wave using the formula,

$$\underline{V_p = \text{(Number of divisions x Voltage sensitivity)/2 in Volts}}$$

The voltage sensitivity is read from the knob position of $CH_1(X)$ in volt/div or mV/div

11. Calculate $V_{RMS} = V_P/\sqrt{2}$ for sine wave.
12. In the digital multimeter (DMM) set the function dial to AC voltage and the range to 20V (say). Read the output voltage from the FNG directly.
13. Repeat such measurements for two more such values.
14. Release and adjust the Time/Div such that you observe some two or three complete sine waves within the screen. This is possible because now the time base (sweep voltage) is applied to the X Plates.
15. Set the function selection knob of FNG to the **first square and then to the triangle** and observe the shape on the CRO screen changes one after another. As before, do it for different voltages applied from

the FNG in these Square/Triangle modes and calculate the V_{RMS} voltages using both the CRO and the DMM measurements and tabulate the results.

$$V_{RMS} = \frac{V_P}{\sqrt{2}} \text{ for sine wave}$$

$$V_{RMS} = V_P \text{ for square wave}$$

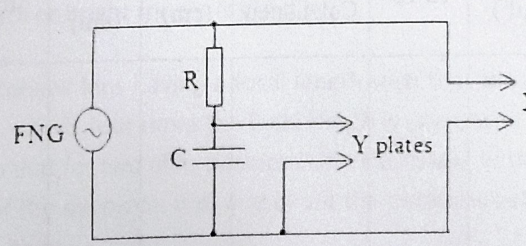
$$V_{RMS} = \frac{V_P}{\sqrt{3}} \text{ for triangular wave}$$

TABLE 1: MEASUREMENT OF AC VOLTAGE

No.	Shape of wave	Voltage applied (volt)	No of divisions	V_P (volt)	V_{RMS} Measured CRO (volt)	V_{RMS} measured DMM (volt)
1. 2.	Sine					
1. 2. 3.	Square					
1. 2. 3.	Triangle					

II. Phase Measurement Using CRO:

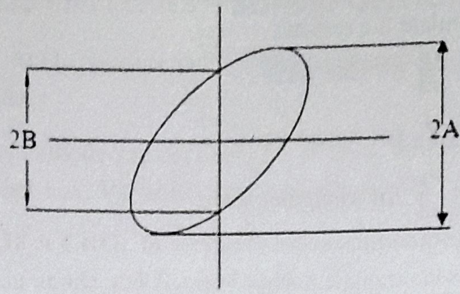
Fig 1



$$\tan(\varphi) = \omega CR$$

$$\omega = 2\pi f$$

Fig 2



$$\boxed{\sin\varphi = \frac{B}{A}}$$

1. We know when an AC voltage is applied to an RC combination it introduces a phase shift.
2. Use one FNG only and connect its output to the R & C combination connected in series across its output as shown in Fig.1. The output from the FNG is also connected to $CH_2(X)$ and the output across the capacitors and resistors is connected to $CH_1(Y)$
3. Set the output frequency to be 1 KHz as before and the amplitude to about 1.0 volt.
4. Use 'XY-mode' in CRO.
5. Now you would observe an ELLIPSE on the screen. Adjust the position of the ellipse such that it is properly centered on the screen as shown in Fig. 2.
6. Measure 2A and 2B as shown in Fig.2 and calculate $sin\phi = (B/A)$.
7. Also, calculate $tan\phi = \omega CR$ from the known values, R and C connected in the circuit ($\omega = 2\pi f$)
8. Tabulate and compare the phase differences calculated with the two formulae. Interpret the results and comment on the discrepancy, if any in the readings.

TABLE 2: MEASUREMENT OF PHASE DIFFERENCES

S. No.	Frequency (Hz)	R (Ω)	C (μF)	$tan\phi$	ϕ Calculated	A (cm)	B (cm)	$\sin\phi$	ϕ Measured

RESULT: Write your comment about what you have found/observed in this experiment.

E10: FRESNEL BIPRISM: Use of interference phenomenon of light

AIM: To measure the wavelength (λ) of an unknown monochromatic light using biprism.

APPARATUS: A Sodium Lamp, An optical bench, a slit, a bi-prism, an eye-piece with micrometer scale, and convex lens.

THEORY: The Fresnel biprism is a prism which has one of its angles slightly less than two right angles and two equal small base angles. It acts like two very thin prisms placed base to base. When rays from a slit, S, illuminated by a monochromatic light, such as sodium light are made to be incident on the plane face of the biprism (PQR), the emergent rays from the two halves of the biprism appear to diverge from two coherent virtual sources, S1 and S2 (Figure. 1). If a screen (AB) is placed with its plane perpendicular to the plane containing the slit and the common base of the biprism, the emergent beams of light overlap on the screen producing alternate dark and bright fringes.

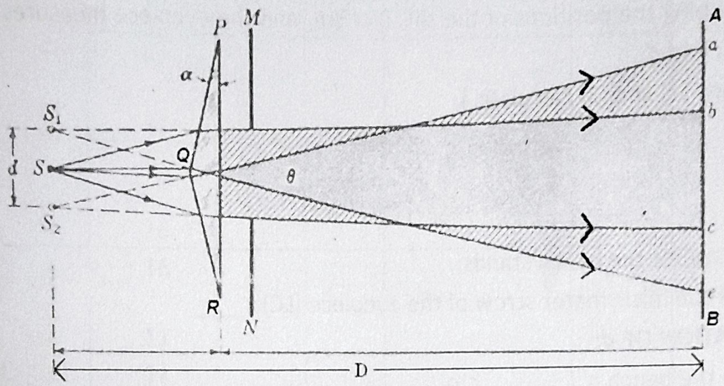


Figure 1 Diagram of Fresnel's biprism experiment

If '*d*' is the distance between the two virtual sources S_1 and S_2, **D** is the distance between the slit and the screen, and 'λ' is the wavelength of the monochromatic radiation, then the fringe width '*x*, i.e., the distance between two consecutive dark or bright fringes is given by

$$x = \frac{D}{d}\lambda$$

To determine 'd', a convex lens having a focal length such that the distance between the slit and the focal plane of the eyepiece exceeds four times the focal length is interposed between the biprism and the eye-piece. The lens is adjusted so that for two of its positions the real images of the two virtual sources S_1 and S_2 are focused on the focal plane of the eyepiece. If d_1 and d_2 are the distances between the real images of S_1 and S_2 for two positions of the lens, then

$$d = \sqrt{d_1 d_2}$$

PROCEDURE:

1. Mount the gadgets on the optical bench.
2. Study all the movements on each stand.
3. Ensure that all the pieces are aligned at roughly the same height

4. Remove the stand with the convex lens from the optical bench.
5. Bring the eyepiece close to the biprism.
6. Looking through the eyepiece you will see a bright vertical patch of light. A slight rotation of the biprism in its own plane will break up this patch into vertical equidistance fringes.
7. Adjust the slit width to get the best compromise between brightness and sharpness of the fringe pattern.
8. Move the eyepiece slowly away from the biprism along the optical bench to a distance of about 100cms. Keeping the fringe pattern all the time in the field of view. Take care of proper alignment during this process.
9. Keeping eyepiece at a distance of 100 cm from the slit, measure the fringe width by measuring the distance traversed by the eyepiece in crossing about 5 fringes using the scale (main and circular) on the eye-piece.
10. Interpose the convex lens between the biprism and the eyepiece making sure that $D>4f$.
11. Move the lens along the optical bench till you locate two conjugate positions of the lens at which you can see real images of the double slit in the field of view of the eyepiece.
12. Without disturbing the positions of the slit, biprism, and the eyepiece measures the double-slit image separations d_1 and d_2.
13. Using equations (2) and (3) calculate λ.

OBSERVATIONS:

Vernier Constant for the bench stands:

Least count of the micrometer screw of the eyepiece (LC) =____

TABLE 1: DETERMINATION OF *d*:

Position of the slit on the bench = _________cm.
Approximate focal length of the lens = _________cm
Position of the biprism on the bench = _________cm
Position of the eye-piece on the bench = ________cm

No.of Observations	Position of the lens on the bench	Direction movement of crosswire of eyepiece	Readings of the micrometer eye piece (mm)						Distance (mm) Between the images $\lvert R_1 - R_2 \rvert$	$d_1 d_2$ in (mm)	Mean $d = \sqrt{d_1 d_2}$ (mm)
			Left image			Right image					
			LSR	CSC	TR (R_1)	LSR	CSC	TR (R_2)			
1.	....	l→r								= d_1	
		r→l									
2.	....	l→r								= d_2	
		r→l									

TABLE 2: MEASUREMENT OF FRINGE-WIDTH:

i. Position of the slit on the bench = ________cm.
ii. Position of the biprism on the bench = ________cm.
iii. Position of the eye-piece on the bench = ________cm.

Apparent distance between the slit and the eyepiece (cm)	Direction of the eyepiece movement	Eyepiece set at the fringes	Readings (mm) of micro-meter scale			Width for 5 fringes R (mm)	Mean R (mm)	Mean fringe width $x=R/5$ (mm)
			LSR (mm)	CSC (div)	TR=LSR+CSR (mm)			
D_1	L→R	1 6						x_1
		6 11						
		11 16						
	R←L	16 11						
		11 6						
		6 1						
D_2	L→R	1 6						x_2
		6 11						
	R←L	11 6						
		6 1						

TABLE 3: DETERMINATION OF THE WAVELENGTH (λ):

Fringe width 'x' (cm)	Distance, 'd' (cm)	Distance 'D' (cm)	$\lambda = \frac{x}{D}d$ (m)

Discussion:

(i) In the measurement of the distance (d) between the two virtual sources S1 and S2, the distance between the slit and the screen should be nearly equal to 4.5 times the focal length of the convex lens so that d_1 and d_2 do not differ largely. This will reduce the error in measuring d.

(ii) While using the micrometer screw, care should be taken to avoid backlash error arising from the misfit between the micrometer screw and the nut in an old instrument. To do this, the eyepiece should be moved beyond the image concerned before reversing its direction of movement from left to right, or vice versa. One can also find the distance from the initial and final readings of the screw and count the number of complete turns, without depending on the linear scale.

(iii) While measuring d_1 and d_2, the images may be distorted due to spherical aberration. To avoid this distortion, a top with a passage of light through the central portion of the lens may be used.

Result:

The wavelength of the monochromatic light is measured, (λ) = ______ (nm) [*with the error estimated*]