

# Engineering Physics Laboratory Manual

By

**Mr.M.Srinivasa Reddy**  
**Department of Humanities & Sciences**  
**Sphoorthy Engineering College, Hyderabad.**



*Common to ECE, CSE, IT, Mech., Civil.....*

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## 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 for the experiment
- Work quietly and carefully (the whole purpose of experimentation is to make reliable measurements!) and equally share the work with your partners.
- 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 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.
- Do not fiddle idly with apparatus. Handle instruments with care. Report any breakage to the Instructor. Return all the equipment you have signed out for the purpose of your experiment.

## Bibliography

Here is a short list of references to books which may be useful for further reading in Physics or instrumentation relevant to the experiments. Also included are some references to books of general interest with regard to science and experimentation.

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## EXPERIMENT 1

### TORSIONAL PENDULUM RIGIDITY MODULUS

**Aim:** To determine the rigidity Modulus of the given wire by dynamical method.

**Apparatus:** Torsional pendulum, stop watch, screw guage, vernier calipers, scale.

**Theory:** A heavy cylindrical disc suspended from one end of a fine wire whose upper end is fixed constitutes a Torsional pendulum. The disc is turned in its old plane to twist the wire, so that on being released, it executes torsional vibrations about the wire as axis.

Let  $\theta$  be the angle through which the wire is twisted.

Then the restoring couple set up in it is equal to

$$\frac{(\pi n a^4 \theta)}{2l} = c\theta$$

Where  $\frac{(\pi a^4 n)}{2l} = c$  ----- (1) is the twisting couple  
per unit (radian) twist of the wire.

This produces an angular acceleration ( $d^2\theta/dt^2$ ) in the disc

Therefore if “I” is the moment of inertia of the disc about the wire we have

$$I \cdot \frac{d^2\theta}{dt^2} = -c\theta \qquad \frac{d^2\theta}{dt^2} = -\left(\frac{c}{I}\right)\theta$$

i.e the angular acceleration ( $\frac{d^2\theta}{dt^2}$ ) of the angular displacement( $\theta$ ) and therefore its motion is simple harmonic hence time period is given by

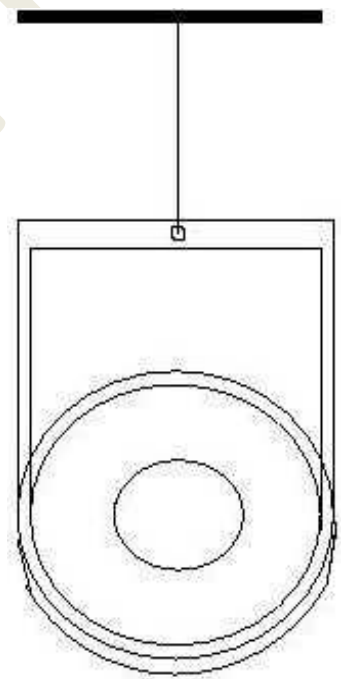


Fig. 1 Torsional Pendulum

$$T = 2\pi \sqrt{\frac{I}{c}} \quad \text{-----} \quad (2)$$

$$\text{From } (1) \quad \& \quad (2) \quad n = \frac{8\pi I}{a^4} \times \frac{l}{T^2}$$

In case of a circular disc whose geometric axes coincide with the axis of rotation. The moment of inertia “I” is given by

$$I = \frac{(MR^2)}{2}$$

where M is the mass of disc and “R” is the radius of the disc.

Plot a curve for  $l$  Vs  $T^2$  and calculate the slope.

$$n = \frac{8\pi}{a^4} \times \frac{(MR^2)}{2} \times \text{Slope} \quad \text{dynes/cm}^2$$

Sl.No	Length of Wire $l$ ( cm)	Time for 20 oscillation			Time Per one oscillation		$\frac{l}{T^2}$
		Trial1	Trail2	Mean (t)	T	$T^2$	
4	40						
2	60						
3	80						
4	100						
5	120						

### Precautions:

1. while using vernier calipers see that the readings must be taken without any parallax error
2. Measure the thickness of wire using screw guage
3. Note the disc should be rotated along with its own axis.

**Result:** The rigidity modulus of the given wire using dynamical method is  $n = 2.3 \times 10^{11}$  dynes/cm<sup>2</sup>

## EXPERIMENT 2

### Melde's Experiment

**Aim:**

To determine the frequency of AC mains by Melde's experiment.

**Apparatus:**

- Electrically maintained tuning fork, A stand with clamp and pulley, A light weight pan, A weight box, Analytical Balance, A battery with eliminator and connecting wires etc.

**Theory:**

#### STANDING WAVES IN STRINGS AND NORMAL MODES OF VIBRATION:

When a string under tension is set into vibrations, transverse harmonic waves propagate along its length. When the length of string is fixed, reflected waves will also exist. The incident and reflected waves will superimpose to produce transverse stationary waves in the string.

The string will vibrate in such a way that the clamped points of the string are nodes and the point of plucking is the antinode.

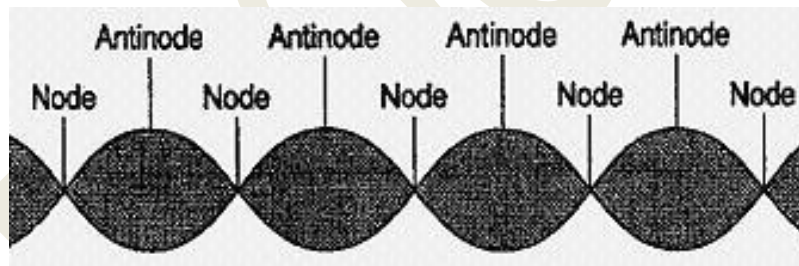


Figure 2. The Envelope of a standing waves

A string can be set into vibrations by means of an electrically maintained tuning fork, thereby producing stationary waves due to reflection of waves at the pulley. The loops are formed from the end of the pulley where it touches the pulley to the position where it is fixed to the prong of tuning fork.

(i) For the transverse arrangement, the frequency is given by

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

where 'L' is the length of thread in fundamental modes of vibrations, 'T' is the tension applied to the thread and 'm' is the mass per unit length of thread. If 'p' loops are formed in the length 'L' of the thread, then

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

(ii) For the longitudinal arrangement, when 'p' loops are formed, the frequency is given by

$$n = \frac{P}{L} \frac{\sqrt{T}}{m}$$

### Procedure:

- Find the weight of pan P and arrange the apparatus as shown in figure.
- Place a load of 4 To 5 gm in the pan attached to the end of the string
- Passing over the pulley. Excite the tuning fork by switching on the power supply.
- Adjust the position of the pulley so that the string is set into resonant
- Vibrations and well defined loops are obtained. If necessary, adjust
- The tensions by adding weights in the pan slowly and gradually. For finer adjustment, add milligram weight so that nodes are reduced to points.
- Measure the length of say 4 loops formed in the middle part of the string. If 'L' is the distance in which 4 loops are formed, then distance between two consecutive nodes is L/4.
- Note down the weight placed in the pan and calculate the tension T.
- Tension, T= (wt. in the pan + wt. of pan) g
- Repeat the experiment twine by changing the weight in the pan in steps of one gram and altering the position of the pulley each time to get well defined loops.
- Measure one meter length of the thread and find its mass to find the value of m, the mass produced per unit length.

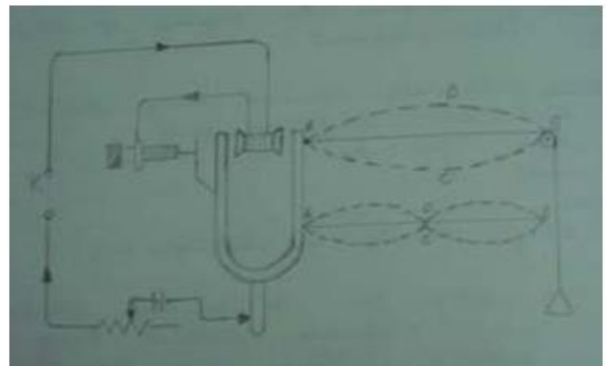
### OBSERVATIONS AND CALCULATIONS:

#### For longitudinal arrangement

Mass of the pan, w = ..... gm

Mass per meter of thread, m = ..... gm/cm

$$\text{Frequency } n = \frac{P}{L} \frac{\sqrt{T}}{m}$$





S.No.	Weight (W) gms	No. of loops (p)	Length of thread (L) cms	Length of each loop (L/P) cms	Tension (T) (W+w) gms	Frequency (n) Hzs
1						
2						
3						
4						
5						
6						

Mean frequency= ----- Hzs

### For transverse arrangement

Mass of the pan, w =..... gm

Mass per meter of thread, m =..... gm/cm

$$\text{Frequency } n = \frac{P}{2L} \frac{\sqrt{T}}{m}$$

S.No.	Weight (W) gms	No. of loops (p)	Length of thread (L) cms	Length of each loop (L/P) cms	Tension (T) (W+w) gms	Frequency (n) Hzs
1						
2						
3						
4						
5						
6						

Mean frequency= ----- Hzs

### **PRECAUTIONS:**

- The thread should be uniform and inextensible.
- Well defined loops should be obtained by adjusting the tension with milligram weights.
- Frictions in the pulley should be least possible.

## EXPERIMENT 3

### Dispersive Power of a Prism

**Aim:** To determine the dispersive power of a material of prism using Spectrometer

**Apparatus:** Spectrometer, Prism, Mercury Vapor Lamp etc.

**Theory:** A spectrometer is used to measure the necessary angles. The spectrometer consists of three units: (1) collimator, (2) telescope, and (3) prism table. The prism table, its base and telescope can be independently moved around their common vertical axis. A circular angular scale enables one to read angular displacements (together with two verniers located diametrically opposite to each other).

In the experiment, we need to produce a parallel beam of rays to be incident on the prism. This is done with the help of a collimator. The collimator has an adjustable rectangular slit at one end and a convex lens at the other end. When the illuminated slit is located at the focus of the lens (See Fig. 1), a parallel beam of rays emerges from the collimator. We can test this point, with the help of a telescope adjusted to receive parallel rays. We first prepare the telescope towards this purpose as follows:

**Setting the eyepiece:** Focus the eyepiece of the telescope on its cross wires (for viewing the cross wires against a white background such as a wall) such that a distinct image of the crosswire is seen by you. In this context, remember that the human eye has an average “least distance of distinct vision” of about 25 cm. When you have completed the above eyepiece adjustment, you have apparently got the image of the crosswire located at a distance comfortable for your eyes. Henceforth do not disturb the eyepiece.

**Setting the Telescope:** Focus the telescope onto a distant (infinity!) object. Focusing is done by changing the separation between the objective and the eyepiece of the telescope. Test for the absence of a parallax between the image of the distant object and the vertical crosswire. *Parallax effect (i.e. separation of two things when you move your head across horizontally) exists, if the cross-wire and the image of the distant object are not at the same distance from your eyes.* Now the telescope is adjusted for receiving parallel rays. Henceforth do not disturb the telescope focusing adjustment.

**Setting the Collimator:** Use the telescope for viewing the illuminated slit through the collimator and adjust the collimator (changing the separation between its lens and slit) till the image of the slit is brought

to the plane of crosswires as judged by the absence of parallax between the image of the slit and cross wires.

### Optical leveling of the Prism:

The prism table would have been nearly leveled before use have started the experiment. However, for your experiment, you need to do a bit of leveling using reflected rays. For this purpose, place the table with one apex at the center and facing the collimator, with the ground (non-transparent) face perpendicular to the collimator axis and away from collimator. Slightly adjust the prism so that the beam of light from the collimator falls on the two reflecting faces symmetrically (Fig. 2) When you have achieved this lock the prism table in this position. Turn the telescope to one side so as to receive the reflected image of the slit centrally into the field of view. This may be achieved by using one of the leveling screws. The image must be central whichever face is used as the reflecting face. Similarly, repeat this procedure for the other side.

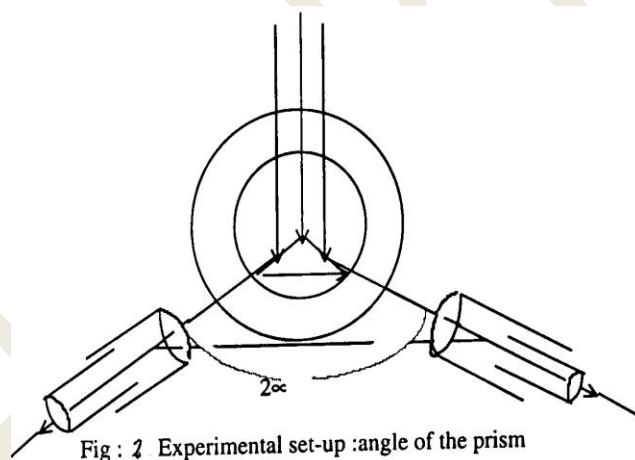


Fig : 2 Experimental set-up :angle of the prism

**Finding the angle of the prism (A):** With the slit width narrowed down sufficiently and prism table leveled, lock the prism table and note the angular position of the telescope when one of the reflected images coincides with the cross wires. Repeat this for the reflected image on the otherside (without disturbing the prism and prism table). The difference in these two angular positions gives  $2a$ .

### Finding angle of minimum deviation ( $D_m$ )

Unlock the prism table for the measurement of the angle of minimum deviation ( $D_m$ ). Locate the image of the slit after refraction through the prism as shown in Fig. 3. Keeping the image always in the field of view, rotate the prism table till the position where the deviation of the image of the slit is smallest. At this position, the image will go backward, even when you keep rotating the prism table in the same

direction. Lock both the telescope and the prism table and to use the fine adjustment screw for finer settings. Note the angular position of the prism. In this position the prism is set for minimum deviation. Without disturbing the prism table, remove the prism and turn the telescope (now unlock it) towards the direct rays from the collimator. Note the scale reading of this position. The angle of the minimum angular deviation, viz,  $D_m$  is the difference between the readings for these last two settings.

**Principle: Refractive Index ( $\mu$ ):** It is defined as

$$\mu = \frac{\text{velocity of light in vacuum}}{\text{velocity of light in air}}$$

$$\text{And } \mu = \frac{\sin i}{\sin r} = \frac{\sin\left(\frac{A + D_m}{2}\right)}{\sin \frac{A}{2}}$$

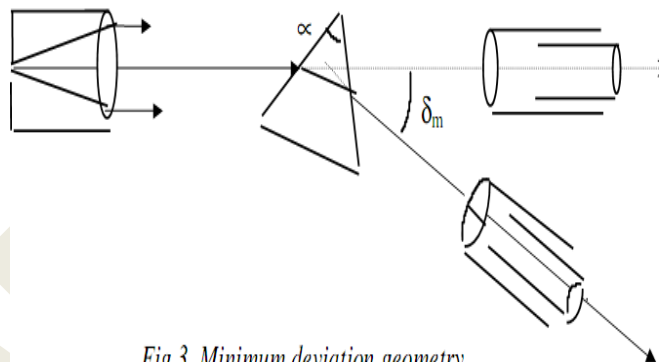


Fig 3. Minimum deviation geometry

Where  $A \rightarrow$  Angle of Prism

$D_m \rightarrow$  Angle of minimum deviation

### Observation tables:

#### 1. For angle of the prism:

Vernier A			Vernier B		
Telescope Reading	$2\alpha$	$\alpha$	Telescope Reading	$2\alpha$	$\alpha$

#### 2. For angle of minimum deviation:

Vernier A			Vernier B		
Direct Reading	Minimum Deviation	$D_m$	Direct Reading	Minimum Deviation	$D_m$

**Dispersive power ( $w$ ):** Angular rotation for a given wavelength is called dispersive power of the material of a prism

#### Readings:-

Direct ray reading = R

Green colour reading =  $R_1$

Blue colour reading =  $R_2$

Minimum deviation angle for green  $D_g = R \sim R_1$

Minimum deviation angle for blue  $D_b = R \sim R_2$

$$\therefore \mu_b = \frac{\sin\left(\frac{A + D_b}{2}\right)}{\sin\left(\frac{A}{2}\right)}, \quad \mu_g = \frac{\sin\left(\frac{A + D_g}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

$$\therefore w = \frac{\mu_b - \mu_g}{\mu_{av} - 1} \quad \text{Where} \quad \mu_{av} = \frac{\mu_b + \mu_g}{2}$$

**Speed of light in Prism:** Speed of light in prism is given by

$$v = c \left( \frac{\sin(A/2)}{\sin(A + D_m)/2} \right)$$

### Precautions:

1. Take the readings without any parallax errors
2. The focus should be at the edge of green and blue rays

**Results:** - Determined the dispersive power of a material of prism using spectrometer

$w =$

Speed of light in prism  $v =$

## Experiment 4 Newton's Rings

### Aim:

To observe Newton rings formed by the interface of produced by a thin air film and to determine the radius of curvature of a plano-convex lens.

### Apparatus:

Traveling microscope, sodium vapour lamp, plano-convex lens, plane glass plate, magnifying lens.

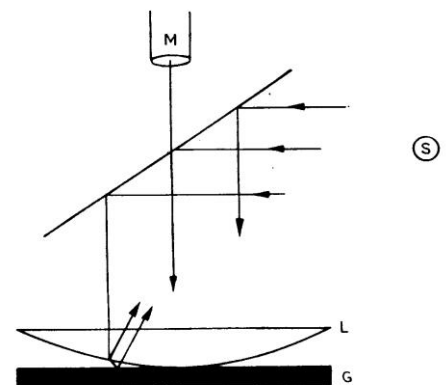
### I. Introduction:

I.1 The phenomenon of Newton's rings is an illustration of the interference of light waves reflected from the opposite surfaces of a thin film of variable thickness. The two interfering beams, derived from a monochromatic source satisfy the coherence condition for interference. Ring shaped fringes are produced by the air film existing between a convex surface of a long focus plano-convex lens and a plane of glass plate.

### I.2. Basic Theory:

When a plano-convex lens (L) of long focal length is placed on a plane glass plate (G), a thin film of air is enclosed between the lower surface of the lens and upper surface of the glass plate. (see fig 1). The thickness of the air film is very small at the point of contact and gradually increases from the center outwards. The fringes produced are concentric circles. With monochromatic light, bright and dark circular fringes are produced in the air film. When viewed with the white light, the fringes are coloured. A horizontal beam of light falls on the glass plate B at an angle of  $45^\circ$ . The plate B reflects a part of incident light towards the air film enclosed by the lens L and plate G. The reflected beam (see fig 1) from the air film is viewed with a microscope. Interference takes place and dark and bright circular fringes are produced. This is due to the interference between the light reflected at the lower surface of the lens and the upper surface of the plate G.

For the normal incidence the optical path difference Between the two waves is nearly  $2\mu t$ , where  $\mu$  is the refractive index of the film and  $t$  is the thickness of the air film. Here an



extra phase difference  $\pi$  occurs for the ray which got reflected from upper surface of the plate G because the incident beam in this reflection goes from a rarer medium to a denser medium. Thus the conditions for constructive and destructive interference are (using  $\mu = 1$  for air)

$$2t = n\lambda \quad \text{for minima; } n = 0, 1, 2, 3, \dots \dots \dots (1)$$

$$\text{and } 2t = \left(n + \frac{1}{2}\right)\lambda \quad \text{for maxima; } m = 0, 1, 2, 3, \dots \dots \dots (2)$$

Then the air film enclosed between the spherical surface of R and a plane surface glass plate, gives circular rings such that (see fig 2)

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

where  $r_n$  is the radius of the  $n^{\text{th}}$  order dark ring .

(Note: The dark ring is the  $n^{\text{th}}$  dark ring excluding the central dark spot).

Now R is the order of 100 cm and t is at most 1 cm. Therefore  $R \gg t$ . Hence (neglecting the  $t^2$  term ), giving

$$2t \approx \frac{r_n^2}{R}$$

Putting the value of “ 2 t ” in eq(1) gives  $2\lambda \approx \frac{r_n^2}{R}$

With the help of a traveling microscope we can measure the diameter of the  $n^{\text{th}}$  ring order dark ring =  $D_n$

Then  $r_n = \frac{D_n}{2}$  and hence,

$$R = \frac{D_n^2}{n} \frac{1}{4\lambda}$$

The value of  $\frac{D_n^2}{n}$  is calculated from the slope of the graph drawn in between n Vs  $D_n^2$

$$\therefore R = \frac{\text{Slope}}{4\lambda}$$

So if we know the wavelength  $\lambda$  , we can calculate R(radius of curvature of the lens).

## II. Setup and Procedure:

1. Clean the plate G and lens L thoroughly and put the lens over the plate with the curved surface below B making angle with G(see fig 1).

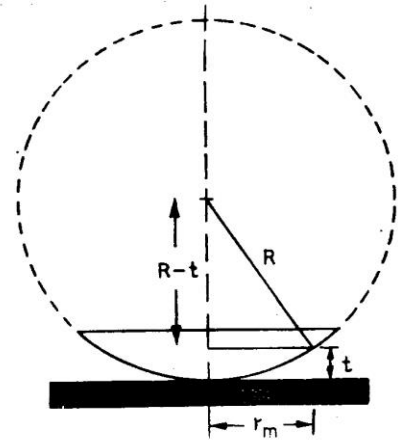


Fig.2

2. Switch in the monochromatic light source. This sends a parallel beam of light. This beam of light gets reflected by plate B falls on lens L.
3. Look down vertically from above the lens and see whether the center is well illuminated. On looking through the microscope, a spot with rings around it can be seen on properly focusing the microscope.
4. Once good rings are in focus, rotate the eyepiece such that out of the two perpendicular cross wires, one has its length parallel to the direction of travel of the microscope. Let this cross wire also passes through the center of the ring system.
5. Now move the microscope to focus on a ring (say, the 20th order dark ring). On one side of the center. Set the crosswire tangential to one ring as shown in fig 3. Note down the microscope reading .

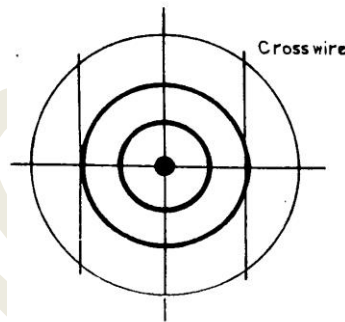


fig 3 \_

*(Make sure that you correctly read the least count of the vernier in mm units)*

6. Move the microscope to make the crosswire tangential to the next ring nearer to the center and note the reading. Continue with this purpose till you pass through the center. Take readings for an equal number of rings on the both sides of the center.

### Observations and results:

1. Least count of vernier of traveling microscope = \_\_\_\_\_ mm
2. Wave length of light = \_\_\_\_\_ m



**Table 1: Measurement of diameter of the ring**

S.No	Order of the ring (n)	Microscope reading						Diameter	
		Left side			Right side				
		MS	VS	Net(cm)	MS	VS	Net(cm)	D(cm)	D <sup>2</sup> (cm <sup>2</sup> )
1	20								
2	18								
3	16								
4	14								
5	12								
6	10								
7	8								
8	6								
9	4								
10	2								

**Calculations:**

Plot the graph of  $D^2$  Vs n and draw the straight line of best fit.

Give the calculation of the best fit analysis below. Attach extra sheets if necessary.

From the slope of the graph, calculate the radius of curvature R of the plano convex lens as

$$R = \frac{\text{Slope}}{4\lambda} = \text{_____ cm.}$$

**Results:** ... ..

(One graph paper required).

**Precautions:**

Notice that as you go away from the central dark spot the fringe width decreases. In order to minimize the errors in measurement of the diameter of the rings the following precautions should be taken:

- The microscope should be parallel to the edge of the glass plate.
- If you place the cross wire tangential to the outer side of a perpendicular ring on one side of the central spot then the cross wire should be placed tangential to the inner side of the same ring on the other side of the central spot. (See fig 3)
- The traveling microscope should move only in one direction.

## Experiment 5

### Diffraction Grating - Minimum deviation Method

**Aim:** To determine the wavelength of a given light using a plane diffraction grating in minimum deviation position.

**Apparatus:** Spectrometer, Sodium Vapour Lamp, Grating (15000<PI>), Grating holder

**Principle:** When a light passes through a small aperture whose dimensions are comparable with the  $\lambda$  of light then light deviates from its rectilinear path and bends round the corner of the placed aperture of its geometrical shadow, this phenomenon is called diffraction. Because the source and the screen are placed effectively at infinite distance from the diffracting element it forms a class of fraunhofer diffraction

An arrangement consisting of a large number of parallel slits equal opaque space is called diffraction grating. The distance between the centers of two successive slits is called the grating element. If “a” is width of the slit and “b” is the distance between the two slits. Then (a+b) is called the grating element or grating construction.

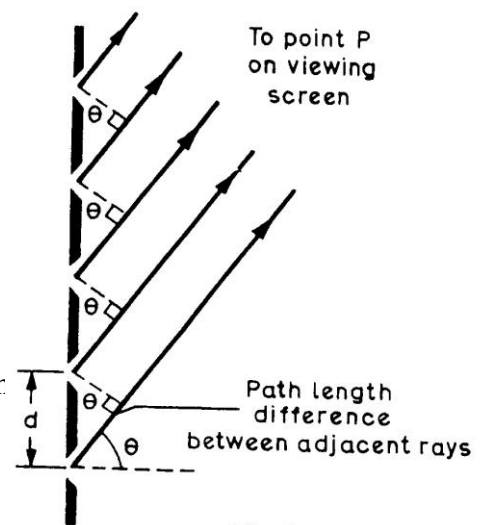
When a wave front is incident on a grating surface light is transmitted through the slits and abstracted by the opaque portions such a grating is called a transmission grating. In a transmission grating the grooves scatter light and so are opaque while the unruled surfaces transmit and act like slits. Typically a high quality grating (used for studying spectra in the visible range) has about 15000 grooves per inch, which gives a slit spacing of the order of a micron.

The condition for maximum intensity is

$$2(a+b) \sin\left(\frac{\theta}{2}\right) = n\lambda \quad \text{if } a+b = d$$

$d \rightarrow$  Distance between lines on grating =  $1/N$

$N \rightarrow$  Number of lines on the grating = 15000 lines per inch



$$\frac{2 \sin\left(\frac{\theta}{2}\right)}{N.n} = \lambda$$

$$\lambda = \frac{2 \sin \theta / 2}{N.n} A^\circ$$

$n \rightarrow$  the Order of the Spectrum

$\theta \rightarrow$  the angle of diffraction

### Procedure:

1. Adjust telescope for parallel rays i.e. focus telescope on the object at infinity. Here we can adjust telescope on an object which is at very large distance. Level the spectrometer and prism table on which grating is mounted using a spirit level. Fig. 5 schematically shows the arrangement of the grating and the spectrometer.

Diagram:

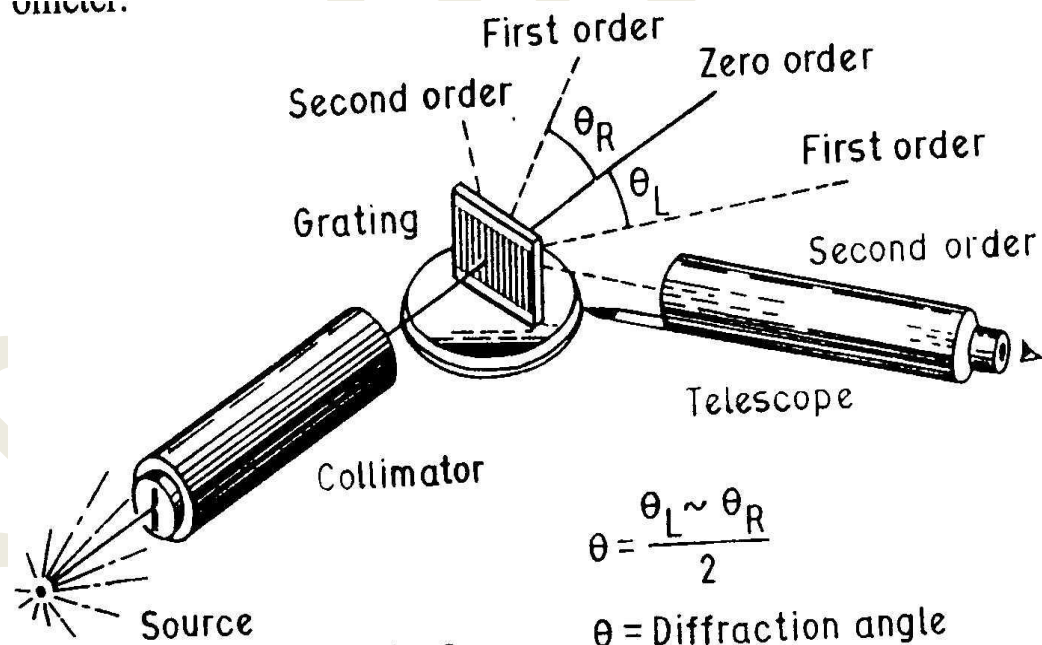


Fig. 5

2. Switch on the power supply for spectral lamp.
3. Place the grating on the prism table such that the surface of the grating is approximately perpendicular to the collimator of the spectrometer (i.e. perpendicular to the incident slit falling on the grating). Fix the prism table in this position. With the Hg source observe first order spectrum on left hand side and right hand side. Measure the angle of diffraction of each line by rotating telescope so that cross-wire coincides with particular spectral line. Note down each measurement on the observation table I. The diffraction angle

is equal to difference between LHS and RHS observation divided by two for a particular spectral line.

(See Fig. 5).

4. In first order spectrum of sodium measure the angular position  $\theta_L$  of yellow 1 (D1) on the left side. Use the micrometer screw to turn the telescope to align the crosswire at the second yellow line (D2) and read its angular position  $\theta_L$

5. Likewise measure  $\theta_R$  on the RHS for D1 and D2.

### Method to make light fall normal to the grating surface:

- First mount grating approximately normal to the collimator. See the slit through telescope and take reading from one side of vernier window. Note down the reading.
- Add or subtract (whichever is convenient)  $90^\circ$  from reading taken in step (a) and put telescope to this position. In this position telescope is approximately perpendicular to the collimator.
- Now rotate prism table until the slit is visible on the cross-wire of the telescope. At this position the incident light from the collimator falls at an angle  $45^\circ$  with the plane of the grating. Note down this reading.
- Next add or subtract  $45^\circ$  to step (c) reading and rotate the prism table so as to obtain this reading on the same window. In this situation, light incident in the grating surface is perpendicular.

### Observations and Results:

S.No	Spectral Line	Wavelength in A <sup>0</sup>	Position of Telescope						$\theta = \frac{\theta_L - \theta_R}{2}$	Sinθ
			Left Side θ <sub>L</sub> (degree)			Right side θ <sub>R</sub> (degree)				
			Main	Vernier	Total	Main	Vernier	Total		
1	D1									
2	D2									

### Precautions:

- The experiment should be performed in a dark room.
- Micrometer screw should be used for fine adjustment of the telescope. For fine adjustment the telescope should be first licked by means of the head screw.

3. The directions of rotation of the micrometer screw should be maintained otherwise the play in the micrometer spindle might lead to errors.
4. The spectral lamps (mercury source) attain their full illuminating power after being warmed up for about 5 minutes, observation should be taken after 5 minutes.
5. One of the essential precautions for the success of this experiment is to set the grating normal to the incident rays (see below). Small variation on the angle of incident causes correspondingly large error in the angle of diffraction. If the exact normality is not observed, one finds that the angle of diffraction measured on the left and on the right are not exactly equal. Read both the verniers to eliminate any errors due to non coincidence of the center of the circular scale with the axis of rotation of the telescope or table.

**Result:** Determined the  $\lambda$  of a given light using a plane diffraction grating in minimum deviation position.

$$D1 = \text{deviation position } \lambda = 5.89 \times 10^{-5} \text{ cm}$$

$$D2 = \text{deviation position } \lambda = 5.896 \times 10^{-5} \text{ cm}$$

## Experiment 6

### Diffraction at a Single and Double slit (LASER)

**Aim:** To determine slit width of single and double slit by using He-Ne Laser.

**Apparatus:** He-Ne laser, Single Slit, Double Slit, Screen, Scale, tape etc.

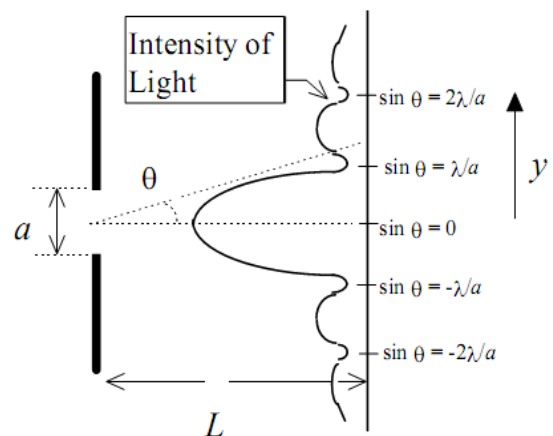
**Theory:** If the waves have the same sign (are *in phase*), then the two waves constructively interfere, the net amplitude is large and the light intensity is strong at that point. If they have opposite signs, however, they are *out of phase* and the two waves destructively interfere: the net amplitude is small and the light intensity is weak. It is these areas of strong and weak intensity, which make up the interference patterns we will observe in this experiment. Interference can be seen when light from a single source arrives at a point on a viewing screen by more than one path. Because the number of oscillations of the electric field (wavelengths) differs for paths of different lengths, the electromagnetic waves can arrive at the viewing screen with a *phase difference* between their electromagnetic fields. If the Electric fields have the same sign then they add *constructively* and increase the intensity of light, if the Electric fields have opposite signs they add *destructively* and the light intensity decreases.

**Diffraction at single slit** can be observed when light travels through a hole (in the lab it is usually a vertical *slit*) whose width,  $a$ , is small. Light from different points across the width of the slit will take paths of different lengths to arrive at a viewing screen (Figure 1). When the light interferes destructively, intensity minima appear on the screen. Figure 1 shows such a diffraction pattern, where the intensity of light is shown as a graph placed along the screen.

For a rectangular slit it can be shown that the minima in the intensity pattern fit the formula

$$a \sin \theta = m \lambda$$

where  $m$  is an integer ( $\pm 1, \pm 2, \pm 3, \dots$ ),  $a$  is the width of the slit,  $\lambda$  is the wavelength of the light and  $\theta$  is the angle to the position on the screen. The  $m^{\text{th}}$  spot on the screen is called



**Figure 1: Diffraction by a slit of width  $a$ . Graph shows intensity of light on a screen.**

the  $m^{\text{th}}$  order minimum. Diffraction patterns for other shapes of holes are more complex but also result from the same principles of interference.

**Two-slit Diffraction:** When laser light shines through two closely spaced parallel slits (Figure 2) each slit produces a diffraction pattern. When these patterns overlap, they also interfere with each other. We can predict whether the interference will be constructive (a bright spot) or destructive (a dark spot) by determining the path difference in traveling from each slit to a given spot on the screen.

Intensity maxima occur when the light arrives *in phase* with an integer number of wavelength differences for the two paths:  $d \sin \theta = m\lambda$  where  $m = \pm 0, \pm 1, \pm 2, \dots$  and the interference will be destructive if the path difference is a half-integer number of wavelengths so that the waves from each slit arrive *out of phase* with opposite signs for the electric field.

$$d \sin \theta = \left[ m + \frac{1}{2} \right] \lambda \quad \text{where } m = \pm 0, \pm 1, \pm 2, \dots$$

**Small Angle Approximation:** The formulae given above are derived using the *small angle approximation*. For small angles  $\theta$  (given in *radians*) it is a good approximation to say that  $\theta \approx \sin \theta \approx \tan \theta$  (for  $\theta$  in radians). For the figures shown above this means that  $\theta \approx \sin \theta \approx \tan \theta = \frac{y}{L}$

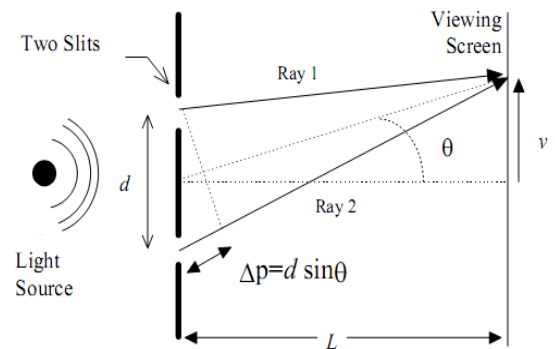
### Procedure:

#### Part A: Diffraction at single slit

The diffraction plate has slits etched on it of different widths and separations. For this part use the area where there is only a single slit.

For two sizes of slits, examine the patterns formed by single slits. Set up the slit in front of the laser. Record the distance from the slit to the screen,  $L$ . For each of the slits, measure and record a value for  $y$  on the viewing screen corresponding to the center of a dark region. Record as many distances,  $y$ , for different values of  $m$  as you can. Use the largest two or three values for  $m$  which you are able to observe to find a value for  $a$ . The He-Ne laser has a wavelength of 633 nm.

#### Part B: Two-slit Diffraction



**Figure 2: Interference of light from two slits. A maximum occurs when  $\Delta p = m\lambda$  and a minimum when  $\Delta p = (m + 1/2)\lambda$ , where  $m=0,1,2,\dots$**

Using the two-slit templates, observe the patterns projected on the viewing screen. Observe how the pattern changes with changing slit width and/or spacing.

For each set of slits, determine the spacing between the slits by measuring the distances between minima on the screen. (The smaller spacings give are from the two slits patterns interfering, if they get too small to measure accurately, just make your best estimate.) You will need to record distances on the screen  $y$  and the distance from the slits to the screen,  $L$ .

**Precautions:** Look through the slit (holding it very close to your eye). See if you can see the effects of diffraction. Set the laser on the table and aim it at the viewing screen. **DO NOT LOOK DIRECTLY INTO THE LASER OR AIM IT AT ANYONE! DO NOT LET REFLECTIONS BOUNCE AROUND THE ROOM.**

Pull a hair from your head. Mount it vertically in front of the laser using a piece of tape. Place the hair in front of the laser and observe the diffraction around the hair. Use the formula above to estimate the thickness of the hair,  $a$ . (The hair is not a slit but light diffracts around its edges in a similar fashion.) Repeat with observations of your lab partners' hair.

**Observations:**

**Table 1: Single slit**

$L = \dots\dots$

$\lambda = \dots\dots\dots$

Diffraction Order, $m$	Distance, $y$	$y/L$	Angle $\theta$ in radians	$\sin \theta$	$a$ $\left( = \frac{m\lambda}{\sin \theta} \right)$



**Result : Slit width = .....**

**Table 2: Double slit**

**L = .....**

**$\lambda$  = .....**

Diffraction Order, $m$	Distance, $y$	$y/L$	Angle $\theta$ in <i>radians</i>	$\sin \theta$	$a$ $\left( = \frac{m\lambda}{\sin \theta} \right)$

**Result : Slit width = .....**

## Experiment 7

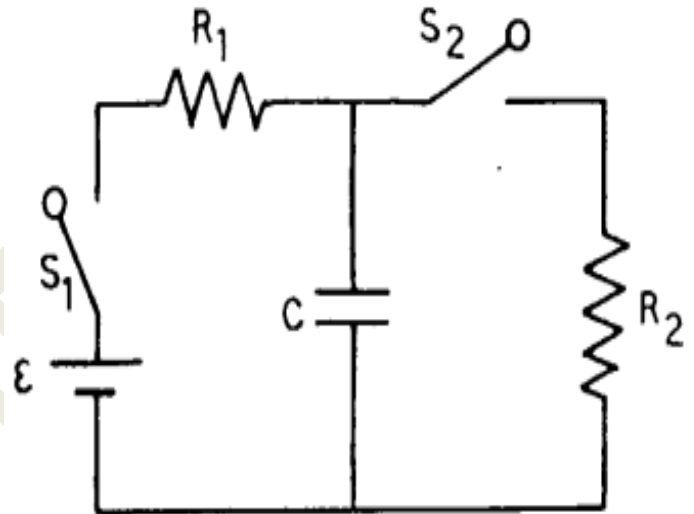
### Time Constant of RC Circuit

**AIM:** To determine the time constant ' $\tau$ ' of the circuit by charging and discharging

**APPARATUS:** D.C.Voltage source, resistors, a capacitor, digital micro ammeter, Charge and discharge key.

#### PROCEDURE:

**I.1** The basic circuit for charging and discharging a capacitor is shown in fig 1. If switch  $S_1$  is closed keeping  $S_2$  open, then the battery charges the capacitor and current flows through the resistor  $R$  until the capacitor is fully charged. If the charge on the capacitor at time  $t$  is  $q(t)$ , then the voltage across the capacitor  $C$  is  $q/C$  and the current through  $R_1$  is  $i = dq/dt$ . By applying Kirchhoff's second law.



$$iR_1 + (q/C) = \varepsilon \rightarrow R_1(dq/dt) + (q/C) = \varepsilon \quad \dots\dots\dots(1)$$

which has the solution

$$q(t) = C\varepsilon(1 - e^{-t/R_1C}) = q_0(1 - e^{-t/R_1C}) \quad \dots\dots\dots(2)$$

Where  $q_0 = C\varepsilon$

The quantity  $\tau = R_1C$  is the charging time constant which characterizes the rate at which charge is deposited on the capacitor. As  $t \rightarrow \infty$ , eq (2) shows that  $q \rightarrow C\varepsilon = q_0$ . In Practice the Capacitor charges to its maximum value  $q_0$  after a time interval equal to a few time constants. Once the capacitor is fully charged then the current  $i$  through the resistor become zero.

**I.2** At this point if the switch  $S_1$  is opened and  $S_2$  is closed the charge in the capacitor discharges through the resistor  $R_2$

By Kirchhoff's second law

$$R_2\left(\frac{dq}{dt}\right) + \left(\frac{q}{C}\right) = 0$$

with solution (taking  $q = q_0$  at  $t = 0$ )

$$q(t) = q_0 e^{-t/R_2C}$$

Thus the charge on the capacitor decays exponentially with time. In fact after a time  $t=R_2C$  (equal to the discharging time constant) the charge drops from its initial value  $q_0$  by a factor of  $e^{-1}$ .

### Observations and results :

#### Part A: Measurement of time constant for discharging of a capacitor

$R_2 =$  \_\_\_\_\_

$C =$  \_\_\_\_\_

S.No.	Dicharging time (t) Secs	Current (I) $\mu A$
1	0	
2	10	
3	20	
4	30	
5	40	
6	50	
7	60	
8	70	
9	80	
10	90	

#### GRAPH:

Plot a graph time in seconds on the x-axis and current in  $\mu A$  on y-axis and find the time for a fall to  $0.37 \times I_{\max}$ . Let this be  $= \tau$

#### Results:

The value of time constant measured  $\tau =$  \_\_\_\_\_ sec

The value of time constant calculated  $\tau = R_2C =$  \_\_\_\_\_ sec

**Part B: Measurement of time constant for charging of a capacitor** $R_1 =$  \_\_\_\_\_ $C =$  \_\_\_\_\_

S.No.	charging time (t) Secs	Current (I) $\mu A$
1	0	
2	10	
3	20	
4	30	
5	40	
6	50	
7	60	
8	70	
9	80	
10	90	

**GRAPH:**

Plot a graph time in seconds on the x-axis and current in  $\mu A$  on y-axis and find the time for a rise to  $0.63 \times I_{\text{max}}$ . Let this be  $= \tau$

**Results:**

The value of time constant measured  $\tau =$  \_\_\_\_\_ sec

The value of time constant calculated  $\tau = R_1 C =$  \_\_\_\_\_ sec

## Experiment 8

### Resonance in LCR circuit

**Aim:** To study resonance effect in series and parallel LCR circuit and quality factor. *This experiments also enables study of forced damped oscillation.*

**Apparatus:** A signal generator, inductor, capacitor, ammeter, resistors, AC milli voltmeter.

#### Basic methodology:

In the series LCR circuit, an inductor (L), capacitor (C) and resistance(R) are connected in series with a variable frequency sinusoidal emf source and the voltage across the resistance is measured. As the frequency is varied, the current in the circuit (and hence the voltage across R) becomes maximum at the resonance frequency  $f_r = \frac{1}{2\pi\sqrt{LC}}$ . In the parallel LCR circuit there is a minimum of the current at the resonance frequency.

#### Power Resonance:

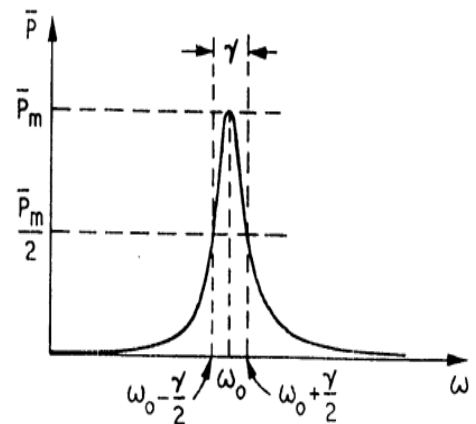
The power dissipated at the resistor is  $P = I V = I^2 R = V^2 R$

The average power dissipated over one cycle is  $\bar{p} = \frac{I_0^2 R}{2}$

Fig 4 shows graph of  $\bar{p}$  as a function of the driving frequency  $f_r$

The maximum power value  $\bar{P}_m$  occurs at the resonating frequency

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$



It can be shown that to a good approximation, which the power falls to half of the maximum value,  $\bar{P}_m/2$  at  $f = f_r \pm \frac{\gamma}{2}$ . Here  $\gamma$  is related to damping in the electrical circuit and is given by  $\gamma = R/L$ . The width or

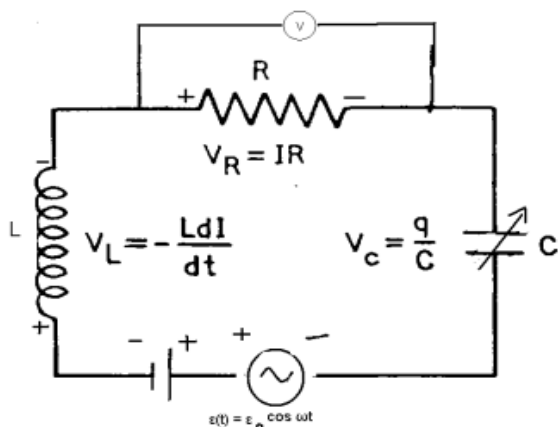
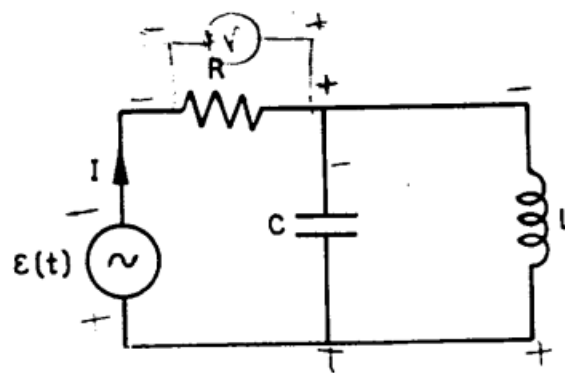
range of  $f$  over which the value of  $\bar{p}$  falls to half the maximum at the resonance is called the Full Width Half Maximum (FWHM). The FWHM is a characteristic of the power resonance curve and is related to the amount of damping in the system. Clearly  $\text{FWHM} = \gamma = R/L$ . One also defines the quality

factor Q as  $Q = \frac{f_r}{\gamma} = \frac{1}{R} \sqrt{\frac{L}{C}}$  which is also measure damping. Large Q (small R) implies small damping

while small Q (large R) implies large damping. Clearly we have  $\text{FWHM} = \gamma = R/L$ . Thus, the quality factor Q can be determined from the FWHM of the power resonance graph.

**Procedure:**

1. The series and parallel LCR circuits are to be connected as shown in fig 1 & fig 2.
2. Set the inductance of the variable inductance value and the capacitances the variable capacitor to low values ( $L \sim 0.01\text{H}$ ,  $C \sim 0.1 \mu\text{F}$ ) so that the resonant frequency  $f_r = \frac{1}{2\pi\sqrt{LC}}$  is of order of a few kHz.
3. Choose the scale of the AC milli voltmeter so that the expected resonance occurs at approximately the middle of the scale.
4. Vary the frequency of the oscillator and record the voltage across the resistor.
5. Repeat (for both series and parallel LCR circuits) for three values of the resistor (say  $R = 100, 200$  &  $300 \Omega$ ).

**I.1. Series LCR circuit : Circuit Diagram;****I.2. Parallel LCR circuit: Circuit Diagram;****Fig 3****Observations and results:****Part A: Series LCR Circuit.**

$L =$  \_\_\_\_\_ mH

$C =$  \_\_\_\_\_  $\mu\text{F}$ .

S.No.	Frequency (v) kHz	$R_1 =$ _____ $\Omega$		$R_2 =$ _____ $\Omega$		$R_3 =$ _____ $\Omega$	
		V	$\bar{p} = \frac{V^2}{R}$	V	$\bar{p} = \frac{V^2}{R}$	V	$\bar{p} = \frac{V^2}{R}$
1							
2							
3							
4							
5							
6							

**Part B: Parallel LCR Circuit.**

L = \_\_\_\_\_ mH

C = \_\_\_\_\_  $\mu$ F.

S.No.	Frequency ( $\nu$ ) kHz	R <sub>1</sub> = _____ $\Omega$		R <sub>2</sub> = _____ $\Omega$		R <sub>3</sub> = _____ $\Omega$	
		V	$\bar{p} = \frac{V^2}{R}$	V	$\bar{p} = \frac{V^2}{R}$	V	$\bar{p} = \frac{V^2}{R}$
1							
2							
3							
4							
5							
6							
7							
8							

**Calculations and Results:**

- Plot the graph of frequency ( $\nu$ ) vs  $\bar{p}$  (average power) for series and parallel cases.
- Read off the resonant frequency  $f_r = \frac{1}{2\pi\sqrt{LC}}$  by locating the maxima / minima in the graphs
  - Resonance frequency for series LCR circuit = \_\_\_\_\_ kHz
  - Resonance frequency for parallel LCR circuit = \_\_\_\_\_ kHz
  - Calculate the value of resonance frequency = \_\_\_\_\_ kHz

**Results :**

Estimated value of Q for series resonance from graph : (1) (2) (3)

Calculated value of  $Q = \frac{f_r}{\gamma} = \frac{1}{R} \sqrt{\frac{L}{C}}$  (1) (2) (3)

% errors in Q (1) (2) (3)

## Experiment 9

### Magnetic field along the axis of a coil (Stewart & Gees method)

**Apparatus:** Circular coil, Power supply, Switching keys, Magnetic needle, Sliding compass box etc.

**Objective:** To measure the magnetic field along the axis of a circular coil and verify Biot-Savart law.

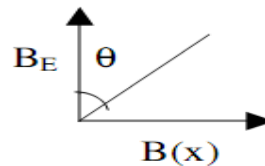
**Theory:** For a circular coil of  $n$  turns, carrying a current  $I$ , the magnetic field at a distance  $x$  from the coil and along the axis of the coil is given by

$$B(x) = \frac{\mu_0 n I R^2}{2} \frac{1}{(R^2 + x^2)^{3/2}}$$

Where  $R$  is the radius of the coil.

In this experiment, the coil is oriented such that plane of the coil is vertical and parallel to the north-south direction. The axis of the coil is parallel to the east-west direction. The net field at any point  $x$  along the axis, is the vector sum of the fields due to the coil  $B(x)$  and earth's magnetic field  $B_E$  (Fig 1)

$$\therefore \tan \theta = \frac{B(x)}{B_E}$$



**Fig 1.**

### Procedure:

The apparatus consists of a coil mounted perpendicular to the base. A sliding compass box is mounted on aluminum rails so that the compass is always on the axis of the coil.

1. Orient the apparatus such that the coil is in the north-south plane
2. Adjust the leveling screws to make the base horizontal. Make sure that the compass is moving freely.
3. Connect the circuit as shown in the figure.
4. Keep the compass at the center of the coil and adjust so that the pointers indicate 0-0
5. Close the keys  $K$  and  $KR$  (make sure that you are not shorting the power supply) and adjust the current with rheostat,  $RH$  so that the deflection is between 50 to 60 degrees. The current will be kept fixed at this value for the rest of the experiment



6. Note down the readings  $\theta_1$  and  $\theta_2$ . Reverse the current and note down  $\theta_3$  and  $\theta_4$ .
7. Repeat the experiment at intervals of 1 cm along the axis until the value of the fields drops to 10% of its value at the center of the coil. Repeat on both sides of the coil.
8. Draw following graphs:

.B(x) as a function of x.

.log(B(x)) as a function of  $\log(R^2 + X^2)$

Find slope and y-intercept from the graph and results with the expression for B(x).

### Observations/Calculations:

#### Parameters and constants

Least count for x measurement=

Least count for  $\theta$  measurement=

No of turns of the coil, n=

Radius of the coil, R= 10 cm

Current in the coil, I= ...

Permeability of air,  $\mu_0 = 4\pi \times 10^{-7} \text{ N / A}^2$

Earth's magnetic field,  $B_E = .39 \times 10^{-4} \text{ T}$

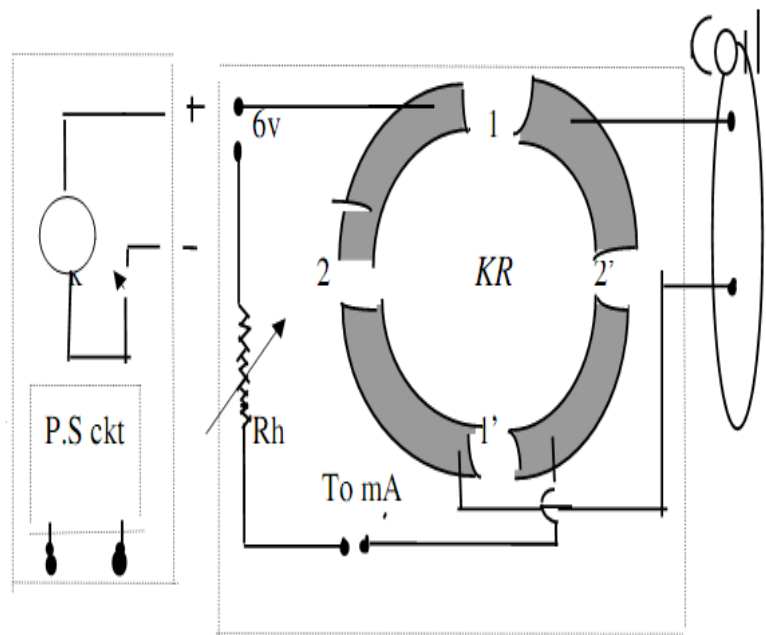


Fig 2.

Table I

$x_{cm}$	$\theta_1$	$\theta_2$	$\theta_3$	$\theta_4$	$\theta$ (average)	$\tan\theta$	$\log(\tan\theta)$	$\log(R^2 + X^2)$	$B(x) = B_E \tan \theta$ (T)( $10^{-4}$ )	LogB (x)
1										
2										
3										
4										

5										
...										
....										

**Table II**

For other side of the scale.....

$x_{cm}$	$\theta_1$	$\theta_2$	$\theta_3$	$\theta_4$	$\theta(\text{average})$	$\tan\theta$	$\log(\tan\theta)$	$\log(R^2 + X^2)$	$B(x) = B_E \tan \theta$ $(T)(10^{-4})$	$\text{LogB}(x)$
1										
2										
3										
4										
5										
....										
.....										

**Calculation:**

From the graph of  $B(x)$  vs.  $\log(R^2 + X^2)$ , find the slope and intercept from regression analysis. Slope should be -1.5 according to Biot-Savart law, and intercept value should match with the value calculated using  $\mu_o$ ,  $n$ ,  $I$ , and  $R$ .

**Results:**

Experimental value of exponent (slope) =

Theoretical value of slope= -1.5

Experimental value of intercept=

Theoretical value of intercept=.....

## Experiment 10

### Study of Characteristics of LED and LASER sources

#### CHARACTERISATION OF 660 & 850 NM LEDs:

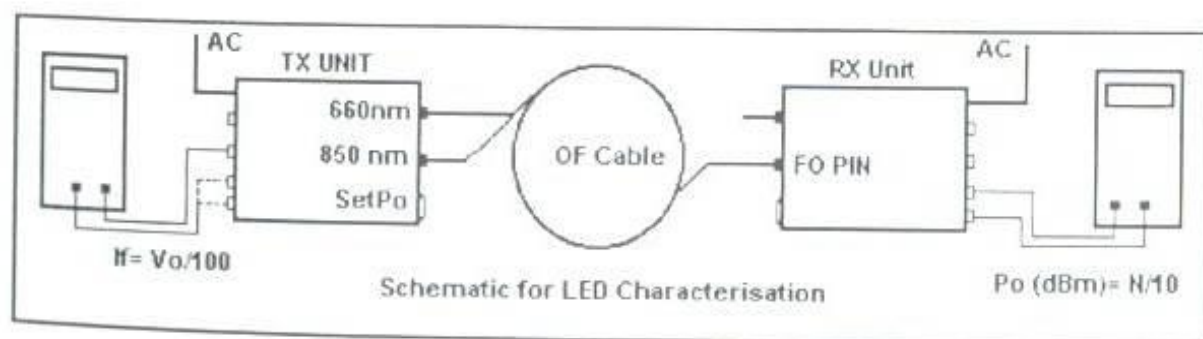
**AIM:** The aim of the experiment is to study the relationship between the **LED dc forward current** and the **LED optical power output** and determine the linearity of the device at **660nm** as well as **850nm**. The conversion efficiencies of the two LEDs will also be compared.

**EQUIPMENT:** 1.Fiber optic analog transmission Kit TNS 20EA-TX 2.Fiber optic analog transmission Kit TNS 20EA-RX 3.One meter PMMA fiber patch card 4.Inline SMA adaptors

**THEORY:** LEDs and laser diodes are the commonly used sources in optical communication systems, whether the system transmits digital or analogue signals. In the case of analogue transmission, direct intensity modulation of the optical source is possible, provided the optical output from the source can be varied linearly as a function of the modulating electrical signal amplitude. LEDs have a linear optical output with relation to the forward current over a certain region of operation. It may be mentioned that in many low-cost, short-haul and small bandwidth applications, LEDs at 660 nm, 850 nm and 1300nm are popular. While direct intensity modulation is simple to realize, higher performance is achieved by fm modulating the base-band signal prior to intensity modulation.

The relationship between an LED optical output  $P_o$  and the LED forward current  $I_F$  is given by  $P_o = K.I_F$  (over a limited range), where  $K$  is a constant.

#### BLOCK DIAGRAM:



**PROCEDURE:**

The schematic diagram for characterization of the LED is shown below and is self explanatory.

The step by step procedure is given here:

**Step1:** Connect one end of Cable 1 to the **660nm** LED port of TNS20EA TX and the other end to the **FO PIN** (power meter) port of TNS20EA-RX.

**Step2:** Set DMM 1 to the 2000mV range and connect it to the terminals Po (**Po1 & Po2**) on the RX unit.

The power meter is ready for use. **Po = (Reading)/10 dBm**

**Step3:** Set DMM2 to the 200.0 mV range and connect it between the **Vo1** and **Gnd** terminals in the TX unit. **If1 = Vo1 (mv)/100** in ma.

**Step4:** Adjust the **SET Po** knob on the TX unit to the extreme anticlockwise Position to reduce **If1** to 0. The reading on the power meter should be out of range.

**Step 5:** Slowly turn the **SET Po** knob clockwise to increase If1. The power meter should read -30.0dB approximately. From here change If1 in suitable steps and note the power meter readings, Po. Record up to the extreme clock-wise position.

**Step 6:** Repeat the complete experiment for 850nm LED and tabulate the Readings for **Vo2** (between terminals **Vo2** and **Gnd**) & **Po**. **If2=Vo2(mv)/100** in ma. Apply the correction of **2.2 dB** discussed in Experiment1 for the **850nm LED**.

**OBSERVATIONS FOR 660nm**

Sl No	V01 (mV)	If1=Vo1/100(ma)	Po(dBm)
1			
2			
3			
4			
5			
6			

**OBSERVATIONS FOR 850 nm**

Sl No	$V_{o2}(\text{mV})$	$I_{f2}=V_{o2}/100(\text{ma})$	$P_o(\text{dBm})$	$P_o(\text{dBm})$ Corrected
1				
2				
3				
4				
5				
6				

**RESULT:**

Studied the relationship between the LED dc forward current and the

LED optical power output and determined the linearity of the device at 660nm and 850nm. The conversion efficiencies of the two LEDs are compared.

**CHARACTERISTICS OF LASER DIODES**

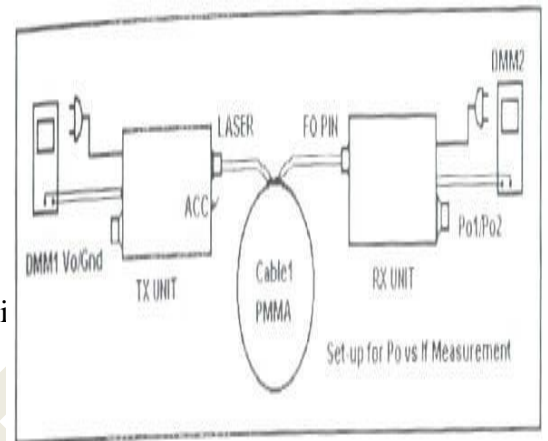
**AIM:** The aim of the experiment is to study the Optical Power ( $P_o$ ) of a Laser Diode vs Laser Diode Forward Current ( $I_F$ )

**EQUIPMENT:** 1. Laser Diode Design Module TNS 20EL-TX 2.Laser Diode Design Module TNS 20EA-RX 3.Two meter PMMA fiber patch card 4.Inline SMA adaptors

**THOERY:** Laser Diodes (LDs) are used in telecom, data communication and video communication applications involving high speeds and long hauls. Most single mode optical fiber communication systems use lasers in the 1300nm and 1550 nm windows. Lasers with very small line-widths also facilitate realization of wavelength division multiplexing (WDM) for high density communication over a single fiber. The inherent properties of LDs that make them suitable for such applications are, high coupled optical power into the fiber (greater than 1 mw), high stability of optical intensity, small line-widths (less than 0.05 nm in special devices), high speed (several GHz) and high linearity (over a specified region suitable for analogue transmission). Special lasers also provide for

regeneration/amplification of optical signals within an optical fiber. These fibers are known as erbium doped fiber amplifiers. LDs for communication applications are commonly available in the wavelength regions 650nm, 780nm, 850nm, 980nm, 1300nm and 1550nm.

### BLOCK DIAGRAM



### PROCEDURE:

The schematic diagram for study of the LD Po as a function of LD forward current IF is shown below and is self explanatory.

**Step1:** Connect the 2-metre PMMA FO cable (Cab1) to TX Unit of TNS20EL and couple the laser beam to the power meter on the RX Unit as shown. Select ACC Mode of operation.

**Step2:** Set DMM 1 to the 200 mV range and connect it to the **Vo/Gnd terminals**. This will monitor **if in ma**, given by **Vo (mV)/100**. Set DMM2 to 2000 mV range and connect it to the **Po1/Po2 terminals**. This will provide Po in dBm when divided by 10.

**Step3:** Adjust the **SET Po** knob to extreme counterclockwise position to reduce IF to 0 ma. The power meter reading will normally be below – 50 dBm or outside the measuring limits of the power meter.

**Step4:** Slowly turn the **SET Po** Knob clockwise to increase IF and thus Po. Note IF and Po readings. Take closer readings prior to and above the laser threshold. Current, Po will rapidly increase with small increase in IF.

### OBSERVATIONS (ACC Mode/PMMA Cable)

Sl No	Vo(mV)	IF=Vo/100(ma)	Po (dBm)
1			
2			
3			
4			

**RESULT:** Studied the Optical Power (**Po**) of a Laser Diode vs Laser Diode Forward Current (**IF**) Characteristics

## Experiment 11

### Evaluation of Numerical Aperture of a given fiber

**AIM:** The aim of the experiment is to determine the numerical aperture of the optical fibers available

**EQUIPMENT:** 1.Laser Diode Design Module TNS 20EL-TX 2.Laser Diode Design Module TNS 20EA-RX 3.Two meter PMMA fiber patch card 4.Inline SMA adaptors 5.Numerical Aperture Measurement Jig

**THEORY:** Numerical aperture of any optical system is a measure of how much light can be collected by the optical system. It is the product of the refractive index of the incident medium and the sine of the maximum ray angle.

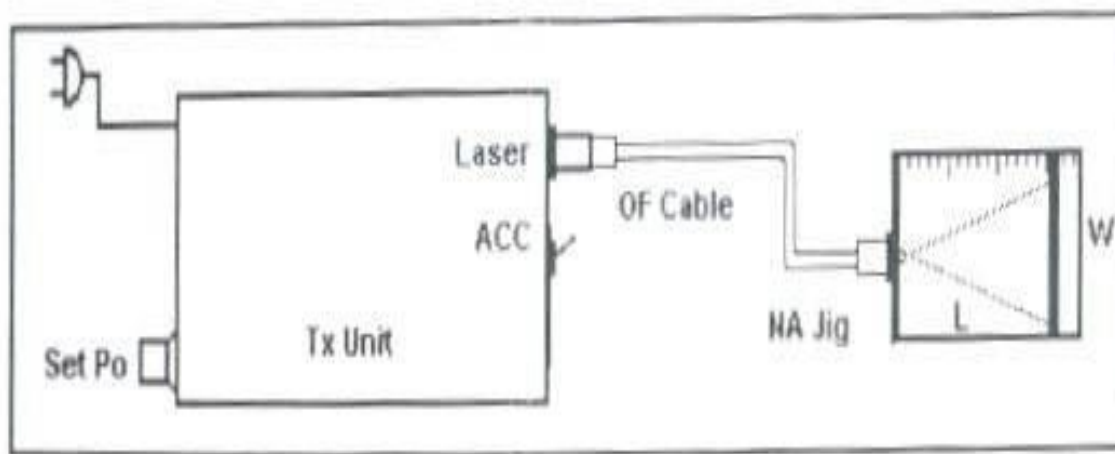
$$NA = n_i \sin \theta_{\max}; n_i \text{ for air is } 1, \text{ hence } NA = \sin \theta_{\max}$$

For a step-index fibre, as in the present case, the numerical aperture is given by  $NA = (n_{\text{core}}^2 - n_{\text{cladding}}^2)^{1/2}$

For very small differences in refractive indices the equation reduces to

$NA = n_{\text{core}} (2\Delta)^{1/2}$ , where  $\Delta$  is the fractional difference in refractive indices. I and record the manufacture's NA,  $n_{\text{cladding}}$  and  $n_{\text{core}}$ , and  $\theta$ .

#### BLOCK DIAGRAM:



## PROCEDURE:

The schematic diagram of the numerical aperture measurement system is shown below and is self explanatory.

**Step1:** Connect one end of the PMMA FO cable to Po of TNS20EL TX Unit and the other end to the NA Jig, as shown.

**Step2:** Plug the AC mains. Light should appear at the end of the fiber on the NA Jig. Turn the Set Po knob clockwise to set to maximum Po. The light intensity should increase.

**Step 3:** Hold the white scale-screen, provided in the kit vertically at a distance of 15 mm (L) from the emitting fiber end and view the red spot on the screen. A dark room will facilitate good contrast. Position the screen-cum-scale to measure the diameter (W) of the spot. Choose the largest diameter.

**Step: 4** Compute NA from the formula  $NA = \sin\theta_{\max} = W/(4L^2 + W^2)^{1/2}$ . Tabulate the reading and repeat the experiment for 10mm, 20mm, and 25mm distance.

**Step5:** In case the fiber is under filled, the intensity within the spot may not be evenly distributed. To ensure even distribution of light in the fiber, first remove twists on the fiber and then wind 5 turns of the fiber on to the mandrel as shown. Use an adhesive tape to hold the windings in position. Now view the spot. The intensity will be more evenly distributed within the core.

## OBSERVATIONS:

Sl. No	L (mm)	W(mm)	NA	$\theta$ (degrees)
1	10	10	0.447	26.5
2	15	14	0.423	25.0
3	20	20	0.447	26.5
4	25	24	0.432	25.64
5	30	-	-	-

**RESULT:** Numerical aperture of the available optical fibers is Determined



## Experiment 12

### Losses in Optical fibers

**AIM:** The aim of the experiment is to study various types of losses that occur in optical fibers and measure **losses in dB** of two **optical fiber patch cords** at two wavelengths, namely, **660nm** and **850nm**. The **coefficients of attenuation per meter** at these **wavelengths** are to be computed from the results.

**EQUIPMENT:** 1.Fiber optic analog transmission Kit TNS 20EA-TX 2.Fiber optic analog transmission Kit TNS 20EA-RX 3.One meter& two meter PMMA fiber patch card 4.Inline SMA Adaptors

**THOERY:** Attenuation in an optical fiber is a result of a number of effects. This aspect is well covered in the books referred to in Appendix II. We will confine our study to measurement of attenuation in two cables (**Cable1** and **Cable2**) employing and SMA-SMA In-line-adaptor. We will also compute loss per meter of fiber in dB. We will also study the spectral response of the fiber at 2 wavelengths, 660nm and 850 and compare with the plot in Appendix II.

The optical power at a distance, L, in an optical fiber is given by  $P_L = P_o 10^{-\alpha L/10}$  where  $P_o$  is the launched power and  $\alpha$  is the attenuation coefficient in decibels per unit length. The typical attenuation coefficient value for the fiber under consideration here is **0.3 dB** per meter at a wavelength of **660nm**. Loss in fibers expressed in decibels is given by  $-10\log (P_o/P_F)$  where,  $P_o$  is the launched power and  $P_F$  is power at the far end of the fiber. Typical losses at connector junctions may vary from 0.3 dB to 0.6 dB.

Losses in fibers occur at **fiber-fiber joints** or splices due to axial displacement, angular displacement, separation (air core), mismatch of cores diameters, mismatch of numerical apertures, improper cleaving and cleaning at the ends. The loss equation for a simple fiber optic link is given as:

**$P_{in}(dBm) - P_{out}(dBm) = L_{J1} + L_{FIB1} + L_{J2} + L_{FIB2} + L_{J3}(dB)$** : where,  $L_{J1}(dB)$  is the loss at the LED-connector junction,  $L_{FIB1}(dB)$  is the loss in cable1,  $L_{J2}(dB)$  is the insertion loss at a splice or in-line adaptor,  $L_{FIB2}(dB)$  is the loss cable2 and  $L_{J3}(dB)$  is the loss at the connector-detector junction.

**PROCEDURE:** The schematic diagram of the optical fiber loss measurement system is shown below and is self explanatory. The step by step procedure is given here:

**Step 1:** Connect one end of **Cable1** to the **660nm** LED

port of the TNS20EA-TX and the other end to the **FO PIN** port (power meter port) of TNS20EA-RX.

**Step2:** Set the DMM to the 2000 mV range. Connect the **terminals** marked **Po** on TNS20EA-RX to the DMM the power meter is now ready for use.

**Step3:** Connect the optical fiber patchcord, **Cable1**

securely, as shown, after relieving all twists and strains on

the fibre. **While connecting the cable please note that minimum force should be applied. At the same time ensure that the connector is not loosely coupled to the receptacle.** After connecting the optical fibre cable properly, adjust **SET Po** knob to set power of **660nm** LED to a suitable value, say, -15.0dBm (the DMM will read 150 mV). Note this as **P<sub>01</sub>**

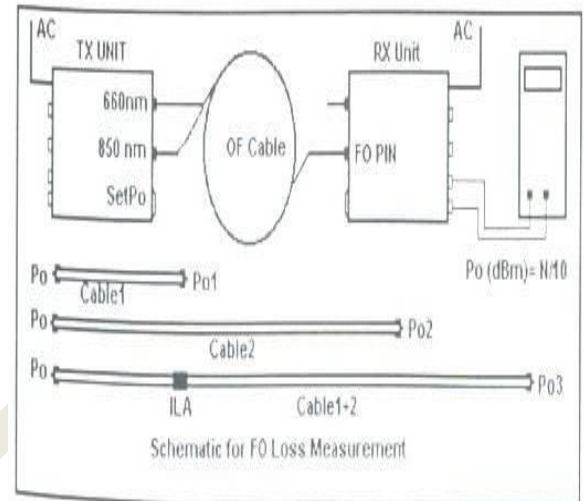
**Step 4:** Wind one turn of the fiber on the mandrel, and note the new reading of the power meter **P<sub>02</sub>**. Now the loss due to bending and strain on the plastic fiber is **P<sub>01</sub>-P<sub>02</sub>dB**. For more accurate readout set the DMM to the 200.0mV range and take the measurement. Typically the loss due to the **strain** and **bending** the fiber is 0.3 to 0.8 db.

**Step5:** Next remove the mandrel and relieve **Cable1** of all twists and strains. Note the reading **P<sub>01</sub>**. Repeat the measurement with **Cable2** (5 meters) and note the reading **P<sub>02</sub>**. Use the **in-line SMA adaptor** and connect the **two cables** in series as shown. Note the measurement **P<sub>03</sub>**.

**Loss in Cable1=P<sub>03</sub>-P<sub>02</sub>-Lila Loss in Cable2=P<sub>03</sub>P<sub>01</sub>-Lila**

Assuming a loss of 06 to **1.0dB** in the **in-line adaptor (Lila=1.0dB)**, we obtain the loss in each cable. The difference in the losses in the two cables will be equal to the loss in **4 meters of fiber** (assuming that the losses at connector junctions are the same for both the cables). The experiment may be repeated in the higher sensitivity range of 200.0mV. The experiment also may be repeated for other **Po** settings such as -20dBm, -25 dBm, -30dBm etc.

### BLOCK DIAGRAM



**OBSERVATIONS FOR 660nm**

Sl No	Po1 (dBm)	Po2 (dBm)	Po3 (dBm)	Loss in Cable 1 (dB)	Loss in Cable2 (dB)	Loss in 4 metres fibre (dB)	Loss per metre (dB) at 660nm
1	-15.0						
2	-20.0						
3	-25.0						
4							

Step6: Repeat the entire experiment with **LED2** at **850nm** and tabulate in 1.4.2

**NOTE:**

The power meter has been **calibrated** internally to read power in **dBm at 660nm**. However the calibration has to be redone manually for measurements at **850nm**. The PIN has a **66% higher** sensitivity at 850nm as compared to 660nm for the **same input optical power**. This corresponds to a sensitivity that is **higher by 2.2dB**. To calibrate the power meter at **850nm**, **deduct 2.2dB** from the measured reading. In computing losses in cables and fibers this gets eliminated while solving the equations.

**OBSERVATIONS FOR 850nm**

Sl No	Po1 (dBm)	Po2 (dBm)	Po3 (dBm)	Loss in Cable 1 (dB)	Loss in Cable2 (dB)	Loss in 4 metres fibre (dB)	Loss per metre (dB) at 850nm
1	-15.0						
2	-20.0						
3	-25.0						
4							

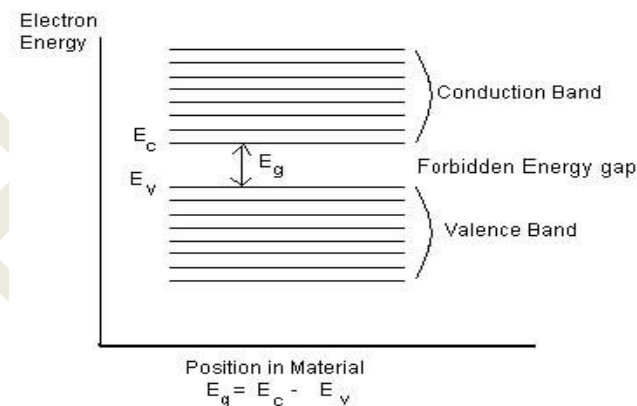
**RESULT:** Studied the various types of losses that occur in optical fibers and measured the **losses in dB** of two **optical fiber patch cords** at two wavelengths, namely, **660nm** and **850nm**. The **coefficients of attenuation per meter** at these **wavelengths** are computed from the results.

## Experiment 13

### Energy gap of a material of p-n junction

**Aim:** The objective of this lab is to determine the forbidden energy gap of a germanium semiconductor. This will be accomplished by measuring the resistance of an intrinsic semiconductor sample as a function of temperature.

**Theory:** In an atom electrons occupy distinct energy levels. When atoms join to make a solid, the allowed energy levels are grouped into bands. The bands are separated by regions of energy levels that the electrons are forbidden to be in. These regions are called forbidden Energy gaps or bandgaps. Energy bands and the forbidden energy gap is illustrated in figure 1. The electrons of the outermost shell of an atom are the valence electrons. These occupy the valence band. Any electrons in the conduction band are not attached to any single atom, but are free to move through the material when driven by an external electric field.

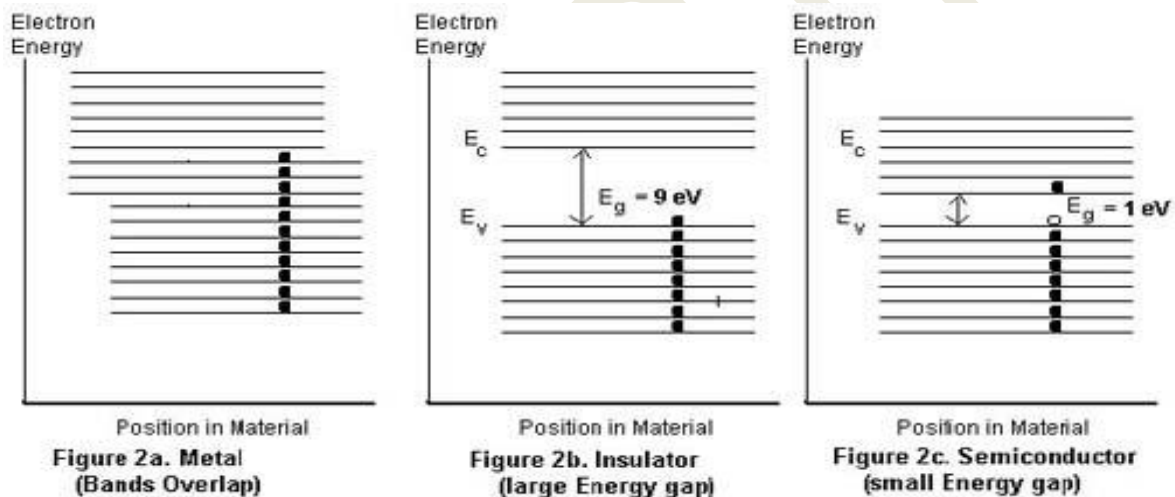


**Figure 1**

In a metal such as copper, the valence and conduction bands overlap as illustrated in figure 2a. There is no forbidden energy gap and electrons in the topmost levels are free to absorb energy and move to higher energy levels within the conduction band. Thus the electrons are free to move under the influence of an electric field and conduction is possible. These materials are referred to as conductors.

In an insulator such as silicon dioxide ( $\text{SiO}_2$ ), the conduction band is separated from the valence band by a large energy gap of 9.0 eV. All energy levels in the valence band are occupied and all the energy levels in the conduction band are empty. It would take 9.0 eV to move an electron from the valence band to the conduction band and small electric fields would not be sufficient to provide the energy, so  $\text{SiO}_2$  does not conduct electrons and is called an insulator. Notice the large energy gap shown in figure(2b).

Semiconductors are similar to the insulators insofar as they do have an energy gap only the energy gap for a semiconductor is much smaller ex. Silicon's energy gap is 1.1 eV and Germanium's energy gap is 0.7 eV at 300 °K. These are pure intrinsic semiconductors. Observe the energy gap in figure 2 c.



For finite temperatures, a probability exists that electrons from the top of the valence band in an intrinsic semiconductor will be thermally excited across the energy gap into the conduction band. The vacant spaces left by the electrons which have left the valence band are called holes which also contribute to the conduction because electrons can easily move into the vacancies. If an electric field is applied, the electrons flow in one direction and the holes move in the opposite direction. The holes act as a positive charge (deficiency of negative charge) so the direction of current (effective positive charge) is in the same direction. For pure silicon at 300 °K, the number of electrons residing in the conduction band as a result of thermal excitement from the valence band is  $1.4 \times 10^{10} / \text{cm}^3$ .

Semiconductors have a conduction band and a valance band separated by a forbidden region called the energy gap. If the lowest energy in the conduction band is designated,  $E_c$ , and the highest energy level of the valance band is called,  $E_v$ , then the energy gap between them would be:  $E_g = E_c - E_v$ . The conductivity of a material is directly proportional to the concentration of electron in the conduction band, hence the resistivity,  $\rho$ , of a material would be inversely proportional to the concentration of electrons in the conduction band. The concentration of electrons increases with temperature. The resistivity decreases with temperature according to the following equation:

resistivity  $= C_0 T^{-3/2} \exp(E_g / 2kT)$  where  $C_0$  is a constant and  $T$  is temperature in degrees Kelvin,  $E_g$  is the energy gap, and  $k$  is the Boltzman's constant. Since  $E_g$  is small for a semiconductor on the order of  $1 \text{ eV} = 1.6 \times 10^{-19} \text{ joules}$ ,  $k = 1.38 \times 10^{-23} \text{ J/mole } ^\circ\text{K}$  and  $T$  is about  $350 ^\circ\text{K}$ , the resistivity,  $\rho$ , varies almost linearly with  $(1/k T)$ . So the resistivity can be described for small temperature range as:

$$\rho = C_1(T) \exp(E_g / 2kT) \text{ where } C_1 \text{ is a slowly varying function of temperature.}$$

The resistance of a sample of material would thus be:

$$R(T) = C_2(T) \exp(E_g / 2kT) \text{ at temperature, } T.$$

At an initial temperature,  $T_0$ , it would be:

$$R(T_0) = C_2(T_0) \exp(E_g / 2kT_0) \text{ where } C_2(T) = C_2(T_0).$$

Dividing the two equations and taking the natural logarithm of both sides yields:

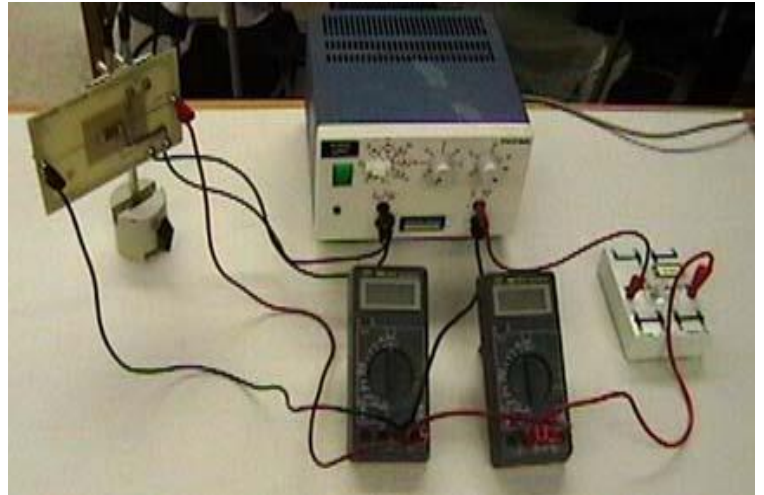
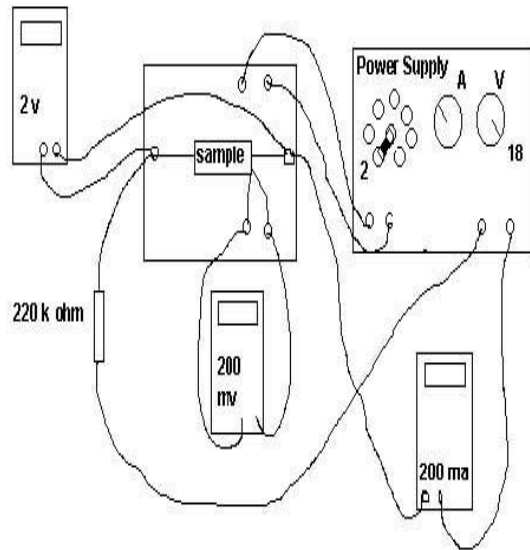
$$\ln(R_T/R_0) = (E_g/2) (1/kT) - (E_g/2) (1/kT_0) \text{ where } E_g/2 \text{ is the slope of the linear equation}$$

and  $(E_g/2) (1/k T_0)$  is the y-intercept.

By plotting  $\ln(R_T/R_0)$  vs.  $(1/k T)$ , the value of  $E_g$  can be found from the slope.

**Procedure:** The [sample of germanium](#) should be connected in the circuit as shown in the diagram. Initial measurements of the room temperature, and the thermocouple's voltage should be made before the [power supply](#) has been turned on. The voltage across the sample and the current through the sample should be read and recorded for every **0.2 mv** increase in the thermocouple's voltage. The values should be recorded in Table 1. The thermocouple's voltage can be converted to temperature by:  **$T = V/0.04 + T_0$** . The Resistance of the sample is given by Voltage/Current in the sample. All calculated values should be recorded in table 1 using Excel. A [graph of the data](#) should be made using MS Excel, use the

trendline feature to obtain the slope. Compare with the actual value of 0.67 eV.



### Result & Calculations:

Initial measurements:

temperature: \_\_\_\_\_

Thermocouple voltage \_\_\_\_\_ (mv)

**Table I:**

S.No.	Current (mA)	Voltage (mV)	Resistance (ohms)	Thermocouple (mV)	Temperature (T) K	1/kT	$R_T/R_0$	$\ln(R_T/R_0)$

By plotting  $\ln(R_T/R_0)$  vs.  $(1/kT)$ , the value of  $E_g$  can be found from the slope.



## EXPERIMENT 14

### Air wedge: Interference of light

#### AIM:

To measure the diameter of a given thin wire using interference patterns formed using an extended source, at the air wedge between two glass plates.

#### Apparatus:

Glass plate, thin wire, beam splitter, light source, traveling microscope etc.

#### Theory:

Interference effects are observed in a region of space where two or more coherent waves are superimposed. Depending on the phase difference, the effect of superposition is to produce variation in intensities which vary from a maximum of  $(a_1 + a_2)^2$  to a minimum of  $(a_1 - a_2)^2$  where  $a_1$  and  $a_2$  are amplitude of individual waves. For the interference effects to be observed, the two waves should be coherent. Interference patterns can be observed due to reflected waves from the top and bottom surfaces of a thin film medium. Because of the extended source, the fringes are localized at or near the wedge.

Fig (1) shows the cross sectional view of the two flat glass plates kept on each other and separated by a wire at the rightmost end. There is a thin air film between the two glass plates due to the wire kept at the right end.

The path difference between the two rays  $r_1$  and  $r_2$  is  $2t \cos r$ , where ' $t$ ' is the air thickness as shown in the figure.

The condition for dark band is,

$$2t \cos r = m\lambda$$

If the incident ray is close to normal ,

$$2t = m\lambda \dots\dots\dots(1)$$

For  $m = N$ , the maximum order of the dark band the path difference will be maximum and this correspond to the position where the wire is kept . Moreover, here the fringes are equal thickness fringes.

So eqn (1) can be written as

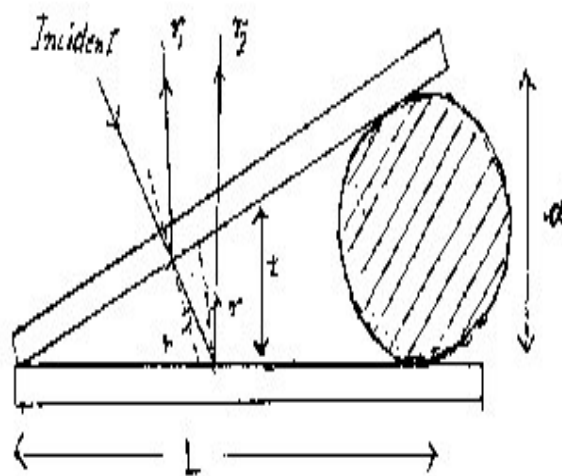


Fig.1 AirWedge



$$2d = N\lambda \dots\dots\dots (2)$$

The length 'L' shown in the figure can be written as

$$L = N\beta \dots\dots\dots (3)$$

where  $\beta$  is the fringe width. From eq (2) and (3),

$$d = L\lambda/2\beta \text{ -----}(4)$$

### Procedure:

- Place the two optically flat glass plates one over the other, so that they touch each other at the left end and are separated at the right end by the given thin wire. The length of the wire should be perpendicular to the length of the glass plate.
- Place this assembly on the platform of the microscope such that the length of the glass plate is parallel to the horizontal traverse of the microscope.
- Illuminate the assembly by sodium light. Adjust the glass plate G, such that incident light is almost normal to the glass plate wire assembly.
- Focus the microscope to observe the interference patterns
- Measure the horizontal positions of the dark bands in the order of say, m, m+5, m+10,..... by traversing the microscope horizontally.
- Determine the length 'L' with the help of microscope.
- Plot a graph of horizontal positions versus order of dark band. Find out the mean fringe width b from the graph and calculate the thickness of the given wire.

### Results:

**Thickness of the wire =** ... ..

(One graph paper required).

**Wavelength of the source: 5893 Å**

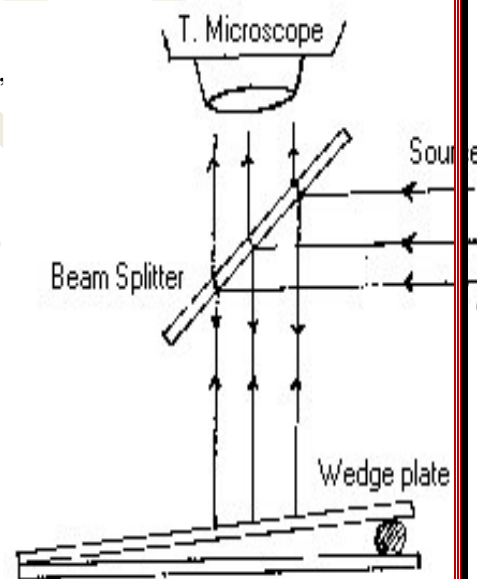


Fig. 2 Experimental setup