PHYSICS LABORATORY MANUAL

FOR 1ST SEMESTER B.E. PROGRAM

DEPARTMENT OF PHYSICS

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Experiment No. 1(a)

Aim of the experiment: To measure the length of a given object by using Vernier Caliper

Description of the measuring device

1. A vernier calipers consists of a rectangular steel bar graduated in inches on one edge and in centimeters on the other edge as shown in fig 1a.1. This is known as main scale. Over this scale slides a small scale called the vernier scale. The instrument has two jaws A and B . The jaw A is fixed at the end of the rectangular bar on the other side while the other jaw B is movable and can slide along the main scale. Each jaw is at right angles to the main scale and the movable jaw can be fixed at any position by the screw S. The two vernier scales are attached to the movable jaw as shown. Usually when two jaws are touching each other the zero of the vernier scale coincides with zero of the main scale. In some forms of the instrument the jaws project in the upper part as shown at C and D. These projecting jaws are used to measure the internal diameters of the tubes.

2. By using normal scale a minimum length of 1 mm can be measured. But least count of vernier is less than 1 mm.

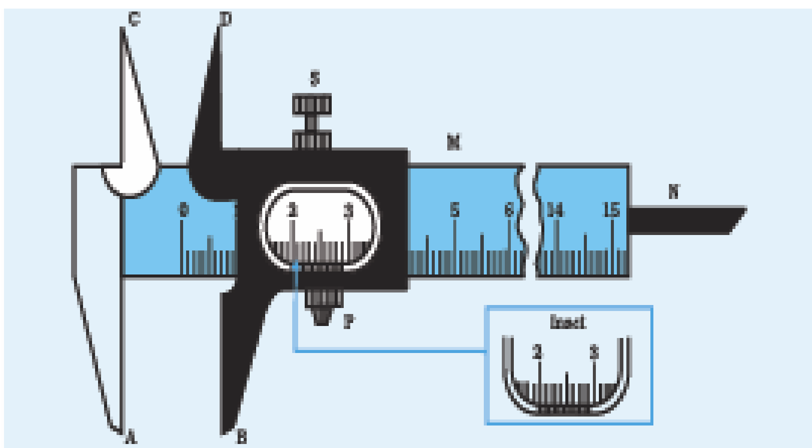


Fig. 1a.1: Vernier Caliper

Vernier Constant

(i) Find the magnitude of the smallest division on the main scale.
(ii) Count the total number of divisions on the vernier scale
(iii) Slide the movable jaw so that the zero mark (the first division) of the vernier scale couincides with any one of the main scale divisions.
(iv) Find the number of scale divisions, which coincide with the total number of vernier divisions.

Consider a vernier scale having 10 equal divisions. Let these 10 vernier divisions coincide with 9 main scale divisions. Since 10 divisions of the vernier scale coincide with 9 main scale divisions

10 vernier scale divisions = 9 main scale divisions

1 vernier scale division = 0.9 main scale division

Vernier constant = 1 main scale division – 1 vernier scale division

= (1– 0.9) main scale divisions

= 0.1 main scale division

Vernier constant (V_C) = 0.1 mm = 0.01 cm

Alternatively,

$$V_C = \frac{1MSD}{N} = \frac{1mm}{10}$$

Vernier constant (V_C) = 0.1 mm = 0.01 cm

wa**Procedure**

(a) Measuring the diameter of a small spherical or cylindrical body.

1. If the zero of main scale coincides with zero of vernier scale then there is no zero error. If zero of main scale does not coincide with the zero of vernier scale then there is some error. Note down the error.

2. Loose the movable lower jaws. Put the sample to be measured within the gap of the jaws. Tight the jaws and take the measurement.

3. Repeat the step no 2 for several times. Do the zero correction if any.

4. Calculate the mean of the corrected readings. Write the final result with proper unit.

Measuring dimensions of a given regular body (rectangular block)/ Thickness of given table top

Dimension	Sr. No.	Main Scale reading, *M* (cm/mm)	V.S.R.= V.S.D.×L.C. (mm)	T.R. (x_i)= M.S. R. + V.S.R. (mm)	$\bar{x} = \frac{\sum_i x_i}{N}$ (mm)	$(x_i - \bar{x})^2$ (mm²)	$\sigma = \sqrt{\frac{(x_i - \bar{x})^2}{N}}$ (mm)
Length (*l*)	1						
	2						
	3						
Breadth(b)	1						
	2						
	3						
Height (h)	1						
	2						
	3						

Questionnaire:

1. What do you mean by least count?
2. What is zero error? How many types of zero errors are there?
3. What are the other uses of Vernier Calipers?

Experiment No. 1(b)

Aim of the experiment: To determine the diameter of a given wire using screw gauge

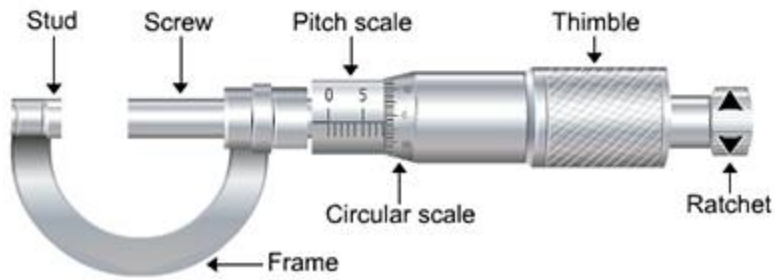


Fig. 1b.1: Physical construction of screw gauge

Description of the instrument: It consists of a U-shaped piece of solid steel, known as frame (Fig.1b.1), one arm of which carries a fixed stud with a plane face, while the other arm carries a hollow cylinder having a straight scale graduated in mm. An accurate screw, provided with a cylindrical cap, moves inside the cylinder. The beveled edge of the cylindrical cap in usually divided into 50 or 100 equal parts, known as circular scale divisions. The linear distance, by which the screw moves during its one complete revolution, is called the pitch of the screw. The pitch of the screw is usually 0.5 or 1 mm. the smallest distance, which can be measured by this screw is 0.5mm/50=0.01mm or 1mm/100=0.01mm; and this is called the least count (L.C.) of the instrument.

The front head of the screw is also perfectly plane. Usually, when the faces of the fixed and movable studs touch each other, the zeros of the linear and the circular scales coincide. If they do not, then the instrumental error comes in. The sign of this error would be positive or negative according as the readings of the circular scale corresponding to the reference level, is on the positive or negative side of its zero line. The number of the circular scale divisions by which the instrumental error occurs, has to be multiplied by the L.C. and this value has to be subtracted from the individual readings obtained by the screw gauge. The instrumental error, as stated above, is known as zero error (Z. E.) of the instrument and can be estimated as follows.

For calculating Z. E., the screw is rotated towards the stud till the screw just touches the stud and the edge of cap is on the zero mark of the main scale. When this is so, any of the following three situations can arise (Fig. 1b.2):

1. The zero mark of the circular scale coincides with the reference line. In this case, the Z.E. and the zero correction, both are nil.
2. The zero mark of the circular scale remains below the reference line and does not cross it. In this case, the zero error is positive and the zero correction is negative depending on the number of circular scale divisions above the reference line.
3. The zero mark of the circular scale is above the reference line. In this case, the Z.E. is negative and the zero correction is positive depending on the number of circular scale divisions above the reference line.

Fig. 1b.2: Analysis of zero error for a screw gauge

Exercise: To find the diameter of the given wire

If the given wire is gently fixed in between the screw and stud and the cap lies ahead of the i^{th} division of the main scale, then, main scale reading (M.S.R.) = i.

If the j^{th} division of the circular scale coincides with the '0' mark of the main scale, then circular scale reading (C.S.R.) = j x L.C. (1)

In this case, the diameter of the wire = Distance in between the stud and the screw head = Total reading (T.R.) = M.S.R. + C.S.R. ± Z.E. = i + j x L.C. (2)

A total of N=15 to 20 such readings may be recorded to finally estimate the average diameter $\bar{X}$ of the wire along with the standard deviation σ, which actually represents the uncertainty in the average measurement, as furnished in Table 1.

Procedure:

1. Estimate the zero error of the instrument by moving the Ratchet clockwise till it produces a rattling sound without placing wire in between the stud and the advancing screw.
2. Place the wire perpendicular to the screw in between the stud and the screw and move the ratchet until the rattling sound is heard.
3. Record the M.S.R. and C.S.R. and find out the T.R. using equation (2).
4. Change the position of the wire and repeat steps 2 and 3 to find out the diameter at a different location of the wire.
5. Follow the same procedure until a total 15 to 20 T.R. values are obtained.

Now record your observations as per Table 1 to obtain the final result (equation (3)).

Table 1.5: Estimation of average diameter and corresponding standard deviation of a given wire

Sr. No. (i)	Z.E. (mm)	M.S.R.(mm)	C.S.R.=C.S.D×L.C. (mm)	T.R. (x_i)(mm)	$\bar{x} = \frac{\sum_i x_i}{i_{max}}$ (mm)	$(x_i - \bar{x})^2$ (mm²)	$\sigma = \sqrt{\frac{(x_i-\bar{x})^2}{N}}$ (mm)

Result: The diameter D of the given wire can thus finally be estimated as

$$D = \bar{x} \pm \sigma \qquad (3)$$

Questionnaire:

1. Define least count and zero error of an instrument.
2. Describe negative and positive zero errors in case of a screw gauge.
3. What is the physical significance of standard deviation?
4. State a few applications of screw gauge.

Experiment No. 1(c)

Aim of the experiment: To determine the thickness of a glass plate using Spherometer

Apparatus Required: Spherometer and glass plate

Description of the instrument: A Spherometer is an instrument used for measuring very small distances. It works on the principle of a micrometer screw. It is generally used for measuring the thickness of a thin plate and for determining the radius of curvature of spherical surfaces such as lenses or mirrors.

Fig. 1c.1: Construction of Spherometer

It consists of a metal frame work supported on three fixed legs of equal length. The end of the three legs lies at the corners of an equilateral triangle. An accurately cut screw works through a threaded hole at the centre of the framework. The screw terminates at the top into a milled head and carries a large graduated disc as shown in the Figure.

The lower end of this screw forms the central leg of the instrument. A small vertical scale marked in millimeter or half millimeter is fixed at one end of the frame with its graduations close to those on the circular disc. The edge of the circular disc is divided into a large number of equal divisions generally 50 or 100.

Least Count: - The least count of a spherometer is the smallest distance that can be measured with it. *It is the distance moved by the screw when it is turned through one division on the circular scale.*

To find the least count of the Spherometer:

I. Bring the zero of the circular scale against a division mark on the mm scale.
II. Give one complete rotation to the screw and find the distance moved by it on the millimeter scale.
III. The distance travelled in one complete rotation is known as pitch.
IV. Divide the pitch by the total number of divisions on the circular scale to get the *'least count* 'of the Spherometer.

Least Count = Pitch / Total number of circular scale divisions

Procedure:

- Keep Spherometer on a glass plate whose thickness is to be measured.
- Move the micrometer screw in the anti clockwise direction.
- Ensure whether legs and micrometer screw are in proper (touching) conditions.
- The circular disc coincides with linear scale (Main Scale) gives Main Scale Reading (M.S.R.) in mm and coincidence of the circular disc with the Main Scale yields Circular Scale Reading (C.S.R.) in number.
- The procedure for the measurement for LC (Least Count) has already been mentioned.
- Total Reading is equal to M.S.R.+LC $\times$ C.S.R.. Total Reading is the thickness of the glass plate corresponding to a point on the plate. In the similar manner, keeping the pointer of the micrometer screw at different nineteen points on the glass plate yields thickness of the glass plate at different nineteen positions of the plate. Now take mean of twenty readings for the thickness of the glass plate. The mean value is the obtained thickness of the glass plate.

Table 1.6: Table for determination of thickness of a glass plate using Spherometer

Sr. No. (i)	M.S.R. (mm)	C.S.R.=C.S.D.×L.C. (mm)	T.R.(x_i) (mm)	$\bar{x} = \frac{\sum_i x_i}{i_{max}}$ (mm)	$(x_i - \bar{x})^2$ (mm^2)	$\sigma = \sqrt{\frac{(x_i - \bar{x})^2}{N}}$ (mm)

Result: The thickness of a given glass slab can thus finally be estimated as

$$T = \bar{x} \pm \sigma$$

Precaution and Sources of error:

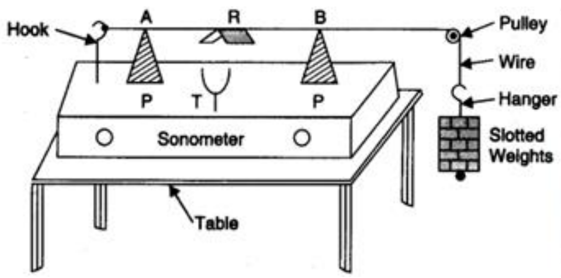
- The screw may have friction.
- Spherometer may have backlash error.
- Spherometer may also have parallax error while reading the pitch scale corresponding to the level of the circular scale.
- Non-uniformity of the divisions in the circular scale may also be present in the Spherometer.
- While setting the spherometer, screw may or may not be touching the horizontal plane surface or the spherical surface.

Experiment No. 2

Aim of the experiment: To determine the frequency of AC Mains with the help of Sonometer.

Apparatus required: Sonometer with non-magnetic wire (nichrome), step down transformer (0-10 Volts), horse shoe magnet, wooden stand for mounting the magnet, Set of 50g masses, screw gauge and meter scale (fitted with the Sonometer)

Description of the apparatus: As shown in the figure given below, an uniform nichrome (non-magnetic) wire is stretched on a hollow wooden box (Sonometer), one side of which is tied to the hook, while the other passes over a frictionless pulley. A hanger carrying masses is also attached to this end of the non-magnetic wire. A permanent strong horse shoe magnet NS is kept at the middle of the nichrome wire in such a way that it produces a magnetic field perpendicular to the direction of current, to be flown in the nichrome wire. Two moveable sharp edged bridges A and B are provided on the wooden box for stretching wire. A step down transformer (0-10 Volts) is connected across the wire.



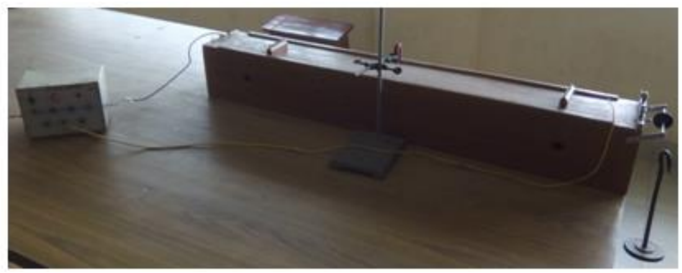


Fig. 2.1: Schematic diagram to determine frequency using Sonometer apparatus.

Working Principle: Let a Sonometer wire be stretched under a constant load, which is placed in an uniform magnetic field applied at the right angles to the Sonometer wire in the horizontal plane and let an alternating current of low voltage (by means of the step down transformer) is allowed to pass through the wire. On account of interaction, between the magnetic field and the current in the wire ($\mathbf{F} = \mathbf{i}\, \boldsymbol{l} \times \mathbf{B}$), the wire will be deflected. The direction of deflection is being given by the Fleming's left hand rule. As the current is alternating, for half cycle the wire will move upwards and for next half the wire will move downwards. Therefore the Sonometer wire will receive impulses alternately in opposite direction at the frequency of the alternating current passing through the wire. As a consequence, the wire will execute forced vibrations with a frequency of the AC mains in the Sonometer wire under the conditions of resonance.

The frequency of AC Mains equals to the frequency of vibration of the Sonometer wire in its fundamental mode (only one loop between the two bridges A and B, i.e., having two nodes and one antinode between the two bridges) under resonance conditions is given by;

$$n = \frac{1}{2l}\sqrt{T/m} \qquad (1)$$

Where, T is the tension applied on the wire and given by T = M g, M being the total mass loaded on the wire (i.e. total mass kept on the hanger and the mass of the hanger) and g the acceleration due to gravity. Symbol l presents the length of the Sonometer wire between the two bridges. The mass per unit length of the Sonometer wire is represented by the symbol m and can be calculated in terms of the radius r of the Sonometer wire and given by;

$$m = \pi r^2 d \qquad (2)$$

where, d is the density of the material wire (nichrome)

Substitution of value of m, evaluated from the equation 2 in equation 1, gives the value of frequency of AC mains.

Procedure:

i. Measure the diameter of the wire with a screw gauge at several points along its length. Evaluate the mean radius of the Sonometer wire. [See observation table 1]

ii. Connect the step down transformer to AC mains and connect the transformer output (12 Volts connection) to the two ends of the Sonometer wire, as shown in the figure.

iii. Place the two movable sharp-edged bridges A and B at the two extreme points of the wooden box.

iv. Mount the horse shoe magnet vertically at the middle of the Sonometer wire in such a way that the wire passes freely in between the poles of the magnet and the face of the magnet is normal to the length of the wire. The direction of current flowing through the wire is normal to the magnetic field.

v. Apply a suitable tension to the wire, say by putting 500g masses on the hanger [tension in the wire = (mass of the hanger + mass kept on the hanger) × g]. Switch on the mains supply and adjust the two bridges A and B till the wire vibrates with the maximum amplitude (in the fundamental mode of resonance) between the two bridges. Measure the distance between the two bridges (l). [See observation table 2].

vi. Increasing the load M in the steps of 50g, note down the corresponding values of l for maximum amplitude (in the fundamental mode of resonance). Take six or seven such observations.

vii. Knowing all the parameter and using the relations given in equations 1 and 2 to calculate the frequency of AC mains for each set of observation separately and then take mean.

viii. Also plot the graph between the mass loaded, M along the X-axis and the square of the length l along Y-axis. This graph should be a straight line. Find the slope of this line and then use the equations 1 and 2 to calculate the frequency of AC mains from this graph. The expression of frequency for graphical solution is given as $\sqrt{[g/(4 \times slope \times m)]}$.

Observations:

Measurement of radius of Sonometer wire (r)

Least count of screw gauge = ……………………………..cm

Zero error of the screw gauge = …………………………..cm

Measurement of T, *l* and frequency (n) of AC Mains

- Mass of the hanger = 500g
- Acceleration due to gravity (g) = 980 cm/ sec^2
- Density of Sonometer wire (nichrome) = 8.18848 g/cc.

Table 2.1: Measurement of radius of Sonometer wire (r)

S. No.	Diameter of the wire along the length, including correction (cm)	Mean corrected diameter (cm)	Mean radius r (cm)
1 2 3 4 5			

Table 2.2: Measurement of T, *l* and frequency (n) of the AC Mains

S. No	Total Mass Loaded = Mass of hanger + Mass on it M (g)	Tension in wire, T = M × g (g-cm/s^2)	Position of first bridge a (cm)	Position of second bridge b (cm)	Length of wire between two bridges *l*=a-b (cm)	Frequency (Hz)
1 2 3 4 5 6 7						

- Mean value of frequency of the AC Mains = ………………………… Hz
- Calculations from the graph are also to be furnished.
- The slope of graph plotted between Mass loaded (M) and the square of length (*l*)
- Frequency of AC mains (calculated from the graph) = $\sqrt{[g/(4\times\ Slope \times\ m)]}$ Hz

Results:

The frequency of AC Mains as calculated:

A. Experimental calculation **:--------------------**Hz
B. Graphical calculation **: ----------------------**Hz (Graph is attached)
C. Standard Value **:-----------------------**50 Hz (in this country)

D. Percentage Error **:----------------------**%

Sources of errors and precautions:

1. The Sonometer wire should be uniform and without kinks.
2. The pulley should be frictionless.
3. The wire should be horizontal and pass freely in between the poles of magnet.
4. The horse shoe magnet should be place vertically at the center of the wire with its face normal to the length of wire.
5. The current should not exceed one Ampere to avoid the overheating of the wire.
6. The movement of bridges on the wire should be such that the resonance point can be found easily.
7. The diameter of the wire to be measured accurately at different points along the length of the Sonometer wire.
8. The Sonometer wire and the clamp used to hold the magnet should be non-magnetic.

Questionnaire:

1. What is resonance?
2. What is the principle of the experiment?
3. What is the use of magnet?
4. What do you understand by the frequency of AC mains?
5. Distinguish between AC and DC.
6. How does the Sonometer wire vibrate, when AC is passed through it? If you pass DC through the wire, will it vibrate?
7. What is Fleming's left hand rule?
8. What is the fundamental mode of vibration?
9. Why do we take the material of wire to be non-magnetic?
10. What are the chief sources of errors in this experiment?

Experiment No. 3

Aim of the experiment: To determine the Planck's constant using LED

Apparatus required: Planck's constant measurement apparatus PCA-01 (as shown in Fig. 3.1), consisting of a RTD sensor connected temperature regulated oven, variable voltage source, variable current source, volt meter, current meter, temperature display panel, yellow LED mounted on Teflon mount.

Fig. 3.1: Planck's constant measurement setup

Background: There are a number of proposals available for measuring the Planck's constant for didactical purposes, using the current – voltage (I-V) characteristics of a light emitting diode (LED). The outcomes of all these proposals, which are easily executable in labs yield final results within the accuracy of ±10%. The present experiment relies on diode current for $V<V_o$, using the diode law.

$I = I_o \exp [- e (V_o – V)/ \eta kT]$

where, I is forward current, I_0 is the reverse saturation current, e is electronic charge, k is Boltzmann constant, T is absolute temperature and η is material constant which depends on the type of diode, the location of recombination region, etc. The ideal method for determining the actual height of the potential energy barrier V_o is to directly measure the dependence of the forward current on the ambient temperature keeping the applied voltage V slightly below Vo. In this way the disturbance to V_o can be kept as little as possible. The slope of $\log_e$ I vs. 1/T curve gives e(Vo - V)ηk (Fig. 3.3). The constant η is determined from I-V characteristics of the diode (Fig. 3.2) at room temperature from the relation

$\eta = (e/kT_R) (\Delta V/\Delta \log_e I)$

The Planck's constant h can then be estimated using the following relation:

$h = e V_o \lambda/c$

The wavelength (λ) of the light emitted by the LED can either be measured by a plane transmission grating spectrometer normally available in the lab or may be supplied directly. The value of Plank's constant obtained from this method is within 5% of the actual value (6.62×10^{-34} Js).

Procedure:

Part A: Determination of the materials constant η

1. Keep the oven switched off. Record the room temperature T_R=…………………..K
2. Vary the diode voltage in the prescribed range, as furnished in Table 1 and the record the current in Ampere. Fill up the following table

Table 3.1: Variation of $\log_e$ I as a function of V at a constant oven-temperature

Sr. No.	Voltage (V)	Current I (A)	$\log_e$ I (A)
1	1.55		
2	1.60		
3	1.65		
4	1.70		
5	1.75		
6	1.80		

3. Draw the $\log_e$ I Vs V graph, which will be a linear fir (Fig. 3.2) with a positive slope in the fourth quadrant.

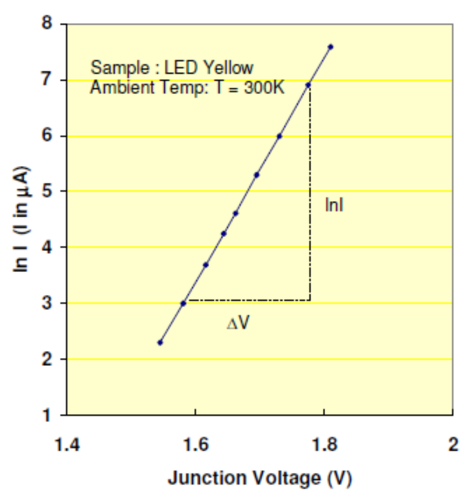


Fig. 3.2: Sample $\log_e$ I versus V curve of LED at constant oven temperature

4. Estimate the slope m_1 of this straight line (having the unit mho) and use equation (1) to estimate the value of η, which is a dimensionless constant

$$\eta = \frac{e}{kT_R} \times \frac{1}{m_1}$$ (1), where e is the electronic charge (1.602×10^{-19} C) and k is the Boltzmann Constant (1.38×10^{-23} JK^{-1})

Part B: Determination of the Planck's constant h

1. Keep the diode voltage constant at V_{C}=1.8 V and switch on the oven.
2. Vary the temperature of the oven in steps and record the diode current in Ampere. (*N. B. When the green LED attached to the oven panel is on, it means that the temperature of the oven is rising.)*
3. Fill up Table 3.2

Table 3.2: Variation of $\log_e$ I as a function of 1/T at a constant diode voltage

Sr. No.	Oven temperature T (K)	Current I (A)	$\frac{1}{T}$ (K^{-1})	$\log_e$ I (A)
1	300			
2	305			
3	310			
4	315			
5	320			
6	325			
7	330			

4. Draw the $\log_e$ I Vs 1/T graph, which will also be a linear fir (Fig. 3.3) in the fourth quadrant with a negative slope m_2.

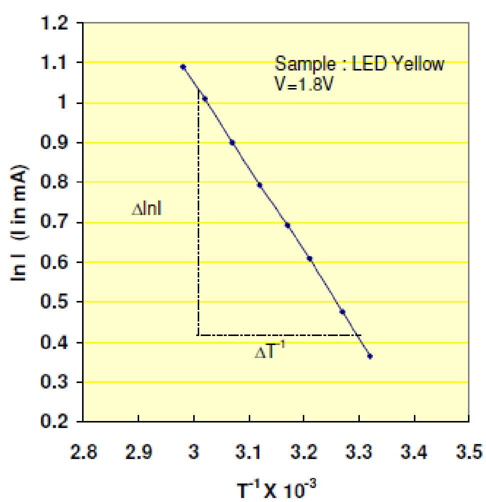


Fig.3.3: Sample $\log_e$ I versus 1/T curve of LED at constant forward bias

5. Estimate m_2.
6. Estimate the Planck's constant using the following formula

$$h = \frac{e\lambda}{c} \times (V_C - \frac{k\eta}{e} \times m_2)$$ (2), where c is the speed of light in vacuum (3×10^8 ms^{-1}) and λ is the wavelength of the yellow spectrum (5800×10^{-10} m) emitted by the LED.

Questionnaire:

1. How does an LED work?
2. Describe the forward and reverse characteristics of a diode.
3. At a constant forward bias voltage how does the diode current vary with increasing ambient temperature and why?
4. Are you aware of any other method, by which Planck's constant can be estimated?

Experiment No: 4

Aim of the experiment: Analysis of impedance and hence estimation of resonance frequency or series and parallel LCR circuit

THEORY:

For resonance to occur a circuit must contain inductance (L) and Capacitance (C). It may also (and generally does) have some Resistance. An Inductor and a capacitor can be connected to source in two different ways as shown in Fig (4.2) and Fig (4.6). The circuit of Fig (4.2) is known as Series Resonance Circuit and that of Fig (4.6) a Parallel Resonance Circuit.

Depending upon the frequency of the source voltage the circuit may behave either as inductive or as Capacitive. However, at a particular frequency, when the inductive reactance X_L equals the capacitive reactance X_C then the circuit behaves as a purely resistive circuit. This phenomenon is called Resonance and the corresponding frequency is called Resonant Frequency. $\frac{1}{j\omega C}$. If the current in the circuit is I, the relative voltage drops across the inductor, capacitor and resistor can be represented in the phasor diagram as shown in Figure 4.1

The Resonant frequency f_R is given as

The resonant frequency is

$$\omega = \omega_0 = \frac{1}{\sqrt{LC}}, \quad \text{So, } f_0 = \frac{\omega_0}{2\pi} = \frac{1}{2\pi\sqrt{LC}}$$

The quality factor is defined as

$$Q = \frac{resonant \quad frequency}{bandwidth} = \frac{f_0}{f_1 - f_2}$$

SERIES RESONANT CIRCUIT

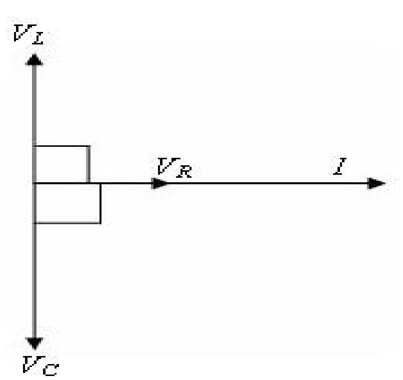


Fig. 4.1: Phasor diagram

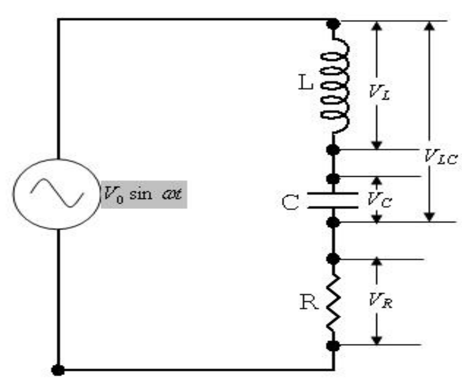


Fig. 4.2: Series LCR circuit

PROCEDURE

a) The series resonant circuit is connected as shown in Figure (4.6). The values of L, C and level of Signal Generator is so selected that we get good reading in meter.
b) Now the frequency of the Signal is varied slowly in steps and the corresponding current is watched. Note the frequency at which current is maximum. This is the Series Resonant Frequency.
c) Vary the frequency on both sides of Resonance measures the current in the circuit. Plot this current against frequency.

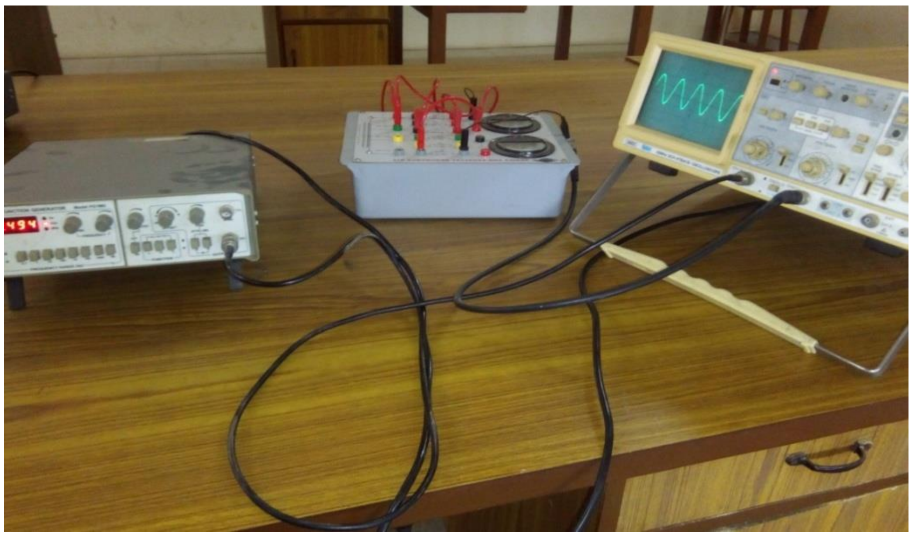


Fig. 4.3: Laboratory picture of series LCR circuit

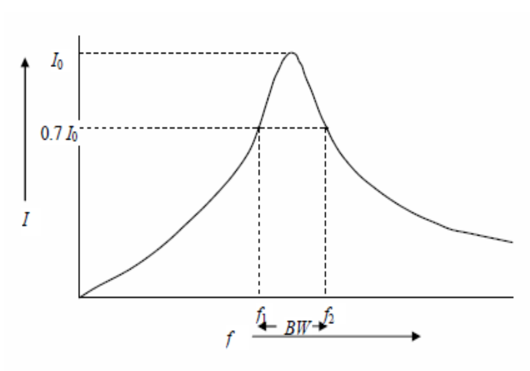


Fig.4.4: Bandwidth for a series LCR resonant circuit

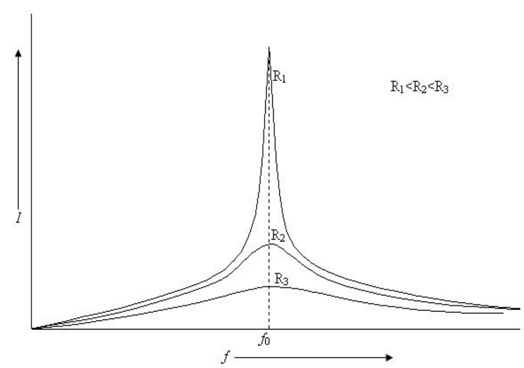


Fig. 4.5: Variation of current with frequency for different R values

Observation Table:

L = …… mH, C = …… μF

S. No.	Frequency f (Hz)	V_{R_1} (volts)	V_{R_2} (volts)	V_{R_3} (volts)	$I_1 = \frac{V_{R_1}}{R_1}$ (mA)	$I_2 = \frac{V_{R_2}}{R_2}$ (mA)	$I_3 = \frac{V_{R_3}}{R_3}$ (mA)
1							
2							
3							
4							
5							
6							

PARALLEL RESONANT CIRCUIT:

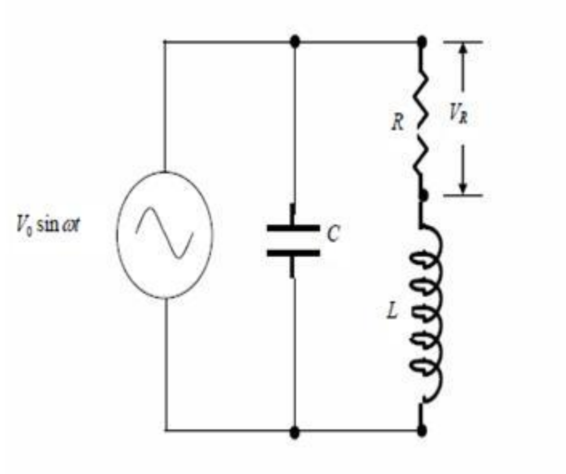


Fig. 4.6: Parallel LCR circuit

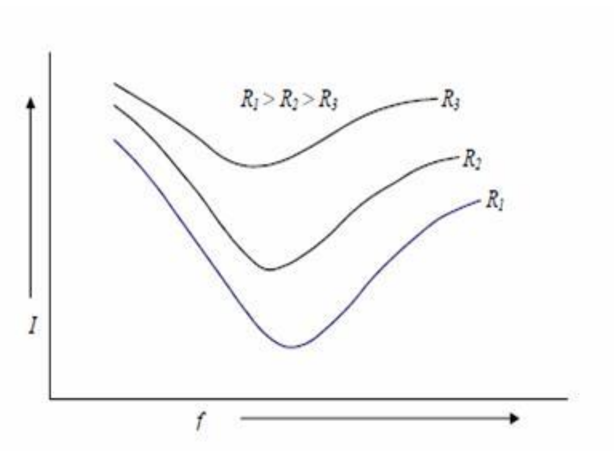


Fig. 4.7: Variation of current with frequency for different R values

Theory:

The total admittance of the LCR combination is given by

$$\frac{1}{z} = \frac{1}{1/j\omega C} + \frac{1}{j\omega L + R}$$

At resonance

$$\omega_0 C - \frac{\omega_0 L}{R^2 + \omega_0^2 L^2} = 0$$

Or, $$f_0 = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$$

The Q can be written as

$$Q = \frac{\omega_0 L}{R} = \frac{1}{\omega_0 CR} = \frac{1}{R}\sqrt{\frac{L}{C}}$$

PROCEDURE:

a) The parallel resonant circuit is connected as shown in Figure (4.6). The values of L, C and level of Signal Generator is so selected that we get good reading in meter.
b) Now the frequency of the Signal is varied slowly in steps and the corresponding current is watched. Note the frequency at which current is minimum. This is the parallel Resonant Frequency.
c) Vary the frequency on both sides of Resonance and note the current in the circuit. Plot this current against frequency.

Observation Table:

Variation of voltage across resistor with frequency for different *R* values

L = ... mH, C = ... μF

S. No.	Frequency f (Hz)	V_{R_1} (volts)	V_{R_2} (volts)	V_{R_3} (volts)	$I_1 = \frac{V_{R_1}}{R_1}$ (mA)	$I_2 = \frac{V_{R_2}}{R_2}$ (mA)	$I_3 = \frac{V_{R_3}}{R_3}$ (mA)
1							
2							
3							
4							
5							
6							

NOTE: Connect voltmeter m parallel with signal generator if required

Questionnaire:

(1) What will happen if both capacitor and inductor are connected in a circuit?

(2) What do you mean by quality factor?

(3) What do you mean impedance?

(4) What do you mean resonant frequency?

(5) What is acceptor circuit? Why the name is so?

(6) For parallel LCR circuit what is the impedance at anti-resonance?

(7) What is rejecter circuit? Why the name is so?

Experiment No. 5

Aim of the experiment: Estimation of either slit width or wavelength of He-Ne laser using single slit diffraction method

Apparatus required: He-Ne laser source, adjustable slit with stand, meter scale and graph paper.

Description of Apparatus

1. **He-Ne laser source.** He-Ne laser source of 1 mW is required for the experiment that emits intense laser beam of 632 nm wavelength.
2. **Adjustable slit.** The laser beam is incident on the adjustable slit. If the condition of diffraction ($\lambda \approx SW$) is satisfied, then diffraction pattern is obtained on the screen.
3. **Meter scale.** The main work of meter scale is to measure the distance between slit and screen.
4. **Graph paper.** The diffraction pattern is plotted on the graph paper using pencil.

Basic Understanding:

Consider a plane wave incident on a long narrow slit of width b [see Fig. 5.1]. According to geometrical optics one expects the region AB of the screen SS' to be illuminated and the remaining portion (Known as the geometrical shadow) to be absolutely dark. However, if the observations are made carefully then one finds that if the width of the slit is not very large compared to the wavelength, then the light intensity inside the geometrical shadow. Further, if the width of the slit is made smaller, larger amounts of energy reach the geometrical shadow. This spreading out of wave when it passes through a narrow opening is usually referred to as diffraction on the screen is known as the diffraction pattern (as shown in Fig. 5.2). Undeniably, since the light wavelength are very small ($\lambda \sim$ 5x10^{-5} cm), the effects due to diffraction are not readily observed.

We should point out that there is not much of diffraction between the phenomena of interference and diffraction, indeed, interference corresponds to the situation when we consider the superposition of waves coming out from a number of point sources and diffraction corresponds to the situation when we consider waves coming out from an area source like a circular or rectangular aperture or even a large number of rectangular apertures (like the diffraction grating). The diffraction phenomena are usually divided into two categories (a) Fresnel diffraction and (b) Fraunhoffer diffraction.

In the Fresnel class of diffraction the source of light and the screen are, in general at finite distance from the diffracting aperture. In the Fraunhoffer class of diffraction the source and the screen are at infinite distance from the aperture this is easily achieved by placing the source on the focal plane of a convex lens placing the screen on the focal plane of another convex lens.

Fig. 5.1: If a plane wave is incident on an aperture then according to geometrical optics a sharp shadow will be cast in the region AB of the screen.

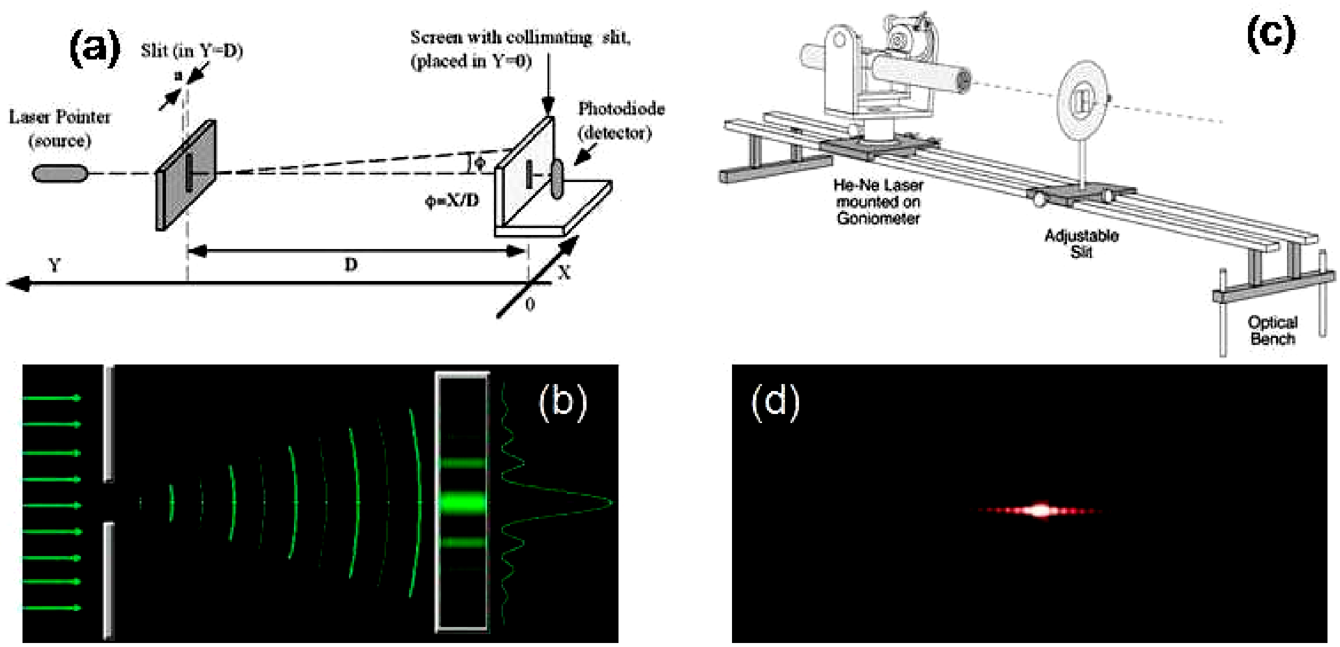


Fig. 5.2: (a) Schematic of the basic diffraction process by a single slit, (b) The intensity distribution in the diffraction pattern, (c) Experimental setup for observing single slit diffraction process and (d) The actual diffraction pattern formed by a single slit.

Procedure:

1. Switch on the He-Ne laser source. The laser beam is incident on the adjustable slit.

2. Adjust the width of the slit. If condition of diffraction is satisfied then diffraction (Fraunhoffer) takes place and diffraction pattern can be viewed on the screen.

3. The diffraction pattern is to be plotted on a graph paper. Measure the distance between slit and screen.

4. Change the distance between slit and screen for four times more. In each time, diffraction pattern is obtained on the screen and the pattern is to be plotted on the graph paper. In addition to this, corresponding to the patterns distance between slit and screen is to be noted.

Observations, Calculations and Results:

Formula for slit width:

$$\text{Slit Width} = f\lambda\left[\frac{m-m'}{x_m-x'_m}\right]$$

Where;

f is the distance between slit and screen.

λ is the wavelength of the incident laser beam whose value is $632nm$.

$(m - m')$ is the difference of orders (zero^th order to other bright orders).

$(x_m - x'_m)$ is the distance from the zero^th order centre to other bright order centers.

Table 5.1: For finding slit width

Sr. No.	Distance between slit and screen (cm)	Order (m')	Difference of orders ($m - m'$)		Distance from the Zero^th order ($x_m - x'_m$)		Slit Width (mm)
			Left	Right	Left (mm)	Right (mm)	
1		1					
		2					
2		1					
		2					
3		1					
		2					
4		1					
		2					
5		1					
		2					

Mean Slit Width = ------------ (mm)

Precautions:

1. The single slit should be adjusted to vertical position and close to the outlet of the laser beam from the laser source.
2. The slit should be narrow and close to each other because the laser beam is always very narrow.
3. The laser tube axis should be horizontal.
4. The distance of the screen from the slit should be large, so that screen should have a measurable number of orders in the diffraction pattern.
5. The laser source should be switched on only while taking the observation and immediately switched off thereafter.

Questionnaire:

1. What does the word LASER represent?
2. Distinguish between spontaneous emission and stimulated or induced emission.
3. What do you mean by population inversion?
4. What is a meta-stable state?
5. What are various types of Laser in common use?
6. What is a resonant cavity?
7. What is the function of Brewster's windows in He-Ne laser source?
8. What is the distance between two mirrors in this laser source?
9. What is the optical pumping?
10. What is the wavelength of light emitted by a He-Ne laser source?
11. What is the advantage of a He-Ne laser over a ruby laser?
12. What are various practical uses of laser?

Experiment No. 6

Aim of the experiment: To determine (i) the resistance per unit length of the bridge-wire of a Carey Foster's bridge and (ii) resistivity of the material of a given wire.

Apparatus required: Carey Foster's bridge, battery/DC regulated power supply, given wire, whose resistance and resistivity are to be determined, thick copper strip, DC galvanometer, fractional resistance box, Rheostat and jockey.

Theory: Carey Foster's bridge is a modified form of a Wheatstone bridge (Fig. 6.1(a)), where P, Q, R and S are the arm-resistances. Any such bridge is said to be balanced if the circuit is closed and the galvanometer G shows a null deflection.

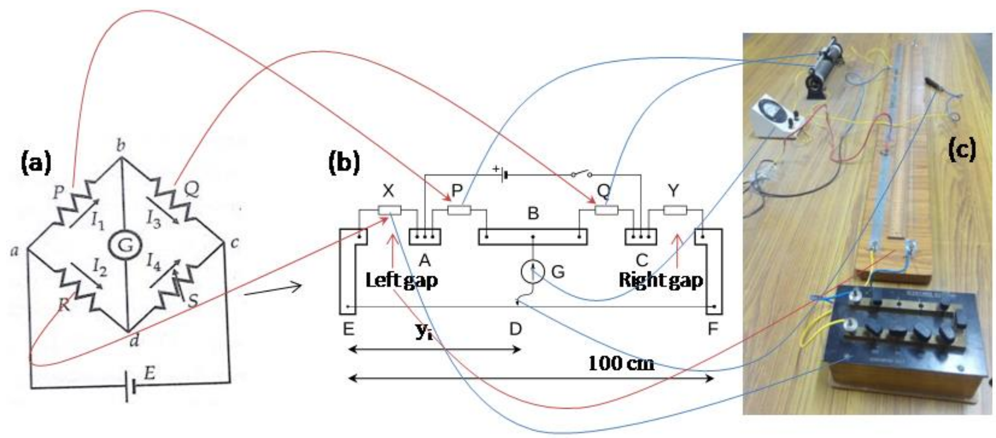


Fig. 6.1: Schematics of the (a) Wheatstone bridge and (b) Carey Foster's bridge, (c) actual experimental setup

Thus, in case of a Wheatstone bridge (Fig. 6(a)), balanced condition refers to $I_G = 0 \Rightarrow I_1 = I_3 \; and \; I_2 = I_4 \Rightarrow V_b = V_d \Rightarrow I_1 P = I_2 R \; and \; I_1 Q = I_2 S \Rightarrow \frac{P}{Q} = \frac{R}{S}$. In a similar way, in case of a Carey Foster's bridge, using Fig. 6.1(b) we obtain

$$\frac{P}{Q} = \frac{Resistance \; of \; the \; path \; A \to E \to D}{Resistance \; of \; the \; path \; C \to F \to D} = \frac{X + \sigma(\lambda_a + y_i)}{S + \sigma(\lambda_b + L - y_i)} \quad (1)$$

Here, X is the resistance of the fractional resistance box, S is the given unknown resistance, y_i is position of the galvanometer null point on the bridge wire (i.e. point D in Fig. 6.1(b)), measured from the point E, σ is the resistance per unit length of the bridge wire, λ_a and λ_b are the fractional lengths of the bridge wire consumed due to winding at the points E and F in Fig. 6.1(b) and L=100 cm is the total measurable length EF of the bridge wire. Here P and Q are the resistances of the two halves of the Rheostat separated by the rheostat-jockey.

Now, using (1), we get,

$$\frac{P+Q}{Q} = \frac{X + S + \sigma(\lambda_a + \lambda_b + L)}{S + \sigma(\lambda_b + L - y_i)} \quad (2)$$

If we interchange X and S in the circuit Fig. 6(b), equation (2) yields

$$\frac{P+Q}{Q} = \frac{X + S + \sigma(\lambda_a + \lambda_b + L)}{X + \sigma(\lambda_b + L - y_j)} \quad (3)$$

Here, y_j represents the position of the new null point measured from the point E.

Now comparing equations (2) and (3) we get

$$S + \sigma(\lambda_b + L - y_i) = X + \sigma(\lambda_b + L - y_j)$$

$$\Rightarrow \ \sigma(y_j - y_i) = X - S \quad (4)$$

If both X and S are shunted, ideally we expect $y_j = y_i$. However, this never happens, because in reality, both X and S can never be reduced to zero. Therefore, from equation (4) we get

$$\delta y_o = (y_j - y_i)_{X,S=0} \quad (5)$$

Here, the quantity δy_o is known as the zero error of the instrument.

Combining (4) and (5) therefore we finally get,

$$y_j - y_i - \delta y_o = y = \frac{1}{\sigma}X - \frac{S}{\sigma} \quad (6)$$

Procedure:

(a) Determination of δy_o

i. Connect the fractional resistance box at the left gap (Fig. 6.1(b)). Plug in all the keys tightly

ii. Connect copper strip (i.e. S=0) to the right gap. Switch on the power supply.

iii. Place the jockey connected to the galvanometer at 50 cm mark (measured from the left). Here $(y_i)_{S,X=0}=y_1$.

iv. Adjust the Rheostat galvanometer jockey to set the galvanometer deflection to zero.

v. Switch off the power supply. Interchange the positions of the fractional resistance box and the copper strip.

vi. Switch on the power supply and moving the jockey on the bridge wire find out the point at which galvanometer deflection is zero. The distance of this null point measured from the left is $y_2=(y_j)_{S,X=0}$

vii. Estimate δy_o by using the formula $\delta y_o = (y_i - y_j)_{X,S=0} = y_1 - y_2$. *Take care of the sign*.

(b) Estimation of the unknown resistance and resistivity

i. After determining the zero error of the instrument, do not disturb the Rheostat by moving its jockey.

ii. Switching off the power supply, connect fractional resistance box to the left gap and the unknown resistance to the right gap of Carey Foster's bridge. Keep the copper strip aside. Its function is over.

iii. Take out 1Ω key from the fractional resistance box. By the moving the jockey on the meter bridge wire, find out the null point on the wire. Record this position from the *left* of the wire. (Note that, as long as the fractional resistance box is connected to the left gap, all the positions as measured on the bridge wire from the left, will be denoted by y_i. On the other hand, if the fractional resistance box is connected to the right gap, all the positions as measured on the bridge wire from the *left*, will be denoted by y_j.) By this way, you have actually measured y_i corresponding to X=1Ω. Similarly estimate the y_i values corresponding to X=2Ω, 3 Ω and 4Ω.

iv. Switch off the power supply. Plug in all the keys in the fractional resistance box and interchange the positions of this box and the unknown resistance. Now record the values of y_j corresponding to X=1Ω, 2Ω, 3 Ω and 4Ω. All these values are to be measured from the left of the bridge wire.

v. Fill up the following tables

Table 6.1: Variation of y with X

	y_1 (cm)	y_2 (cm)	δy_o (cm)		X (Ω)	y_i (cm)	y_j (cm)	$y = y_j - y_i - \delta y_o$ (cm)
X=0Ω								
S=0 Ω				S≠0 Ω				

Table 6.2: Determination of radius of cross-section of the unknown resistance (to be measured using a screw gauge)

Least count (L.C.) of the screw gauge: ……………………………

Zero error δ(mm)	Sr. No.	M.S.R. (mm)	C.S.R. (mm)	Total reading r= M.S.R. + C.S.R. ± δ (mm)	<r> (mm)
	1				
	2				
	3				
	4				
	5				

Calculations and results:

Plot y Vs X using a linear least square fit, i.e. a straight line as per equation (6). A typical such pot is furnished below.

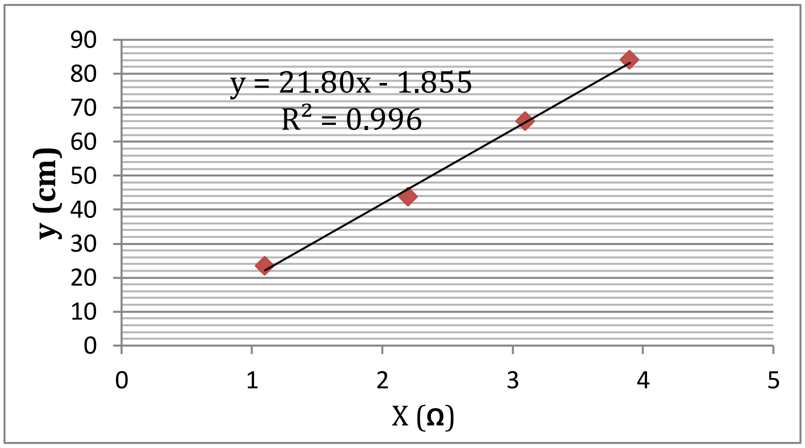


Fig. 6.2: Representative sample experimental data validating equation (6).

From the slope and the intercepts of this straight line, determine the unknown quantities, as mentioned in the aim of the experiment. From the graph of Fig. 6.2, it is clear that

(a) The slope (in Fig. 6.2 which is 21.8 cm/Ω)of the straight line=$\frac{1}{\sigma}$

(b) And the intercept of the straight line (in Fig. 6.2 which is -1.885 cm)=$\frac{-S}{\sigma}$

If the unknown wire has a uniform circular cross-sectional area of radius r and resistivity ρ, then we have

$\pi r^2 \rho = S$ (7).

Using equation (7) determine the value of ρ.

Precautions:

1. Clean the surface of the copper strip with the help of sand paper before the experiment.
2. Tighten all the electrical connections before measurement.
3. Tighten all the keys of the fractional resistance box before every measurement.
4. While recording the galvanometer null point, press the jockey firmly on the Carey Foster's bridge wire.

Questionnaire:

1. What do you mean by end-correction in case of Carey Foster's bridge? What is the necessity of this correction?
2. How to determine the range of the resistance of the unknown wire that can be accurately measured using a Carey Foster's bridge?
3. How can you compare two resistances of slightly different values using a Carey Foster's bridge?
4. During the Carey Foster's bridge experiment, if you observe that the intercept of the y Vs X straight line is not negative, then what probable errors can you think of that can lead to correct results?

Experiment No. 7

Object: Estimation of refractive index and study of dispersion relation of a given prism using a spectrometer

Apparatus Required: Spectrometer, prism, mercury vapour lamp, spirit level and reading lens.

Formula Used: The refractive index μ of the prism is given by the following formula:

$$\mu = \frac{\sin(\frac{A+\delta_m}{2})}{\sin(\frac{A}{2})}$$

Where A = angle of the prism, δ_m = angle of minimum deviation.

Procedure:

1. Set the spectrometer and find the angle of the prism by the rotating telescope method.
2. Place the prism with its centre coinciding with the centre of the prism table and set it approximately in the position of minimum deviation, so that light falls on the face AB and emerges out form the face AC as shown in Fig. 7.1.Clamp the table.
3. Turn the telescope to receive the emergent light and adjust its position, so that the image of the slit is formed on the cross-wire. Clamp the telescope and note its reading on both the verniers V_1 and V_2.
4. Now the turn the telescope to receive the reflected light from the face AB as shown in Fig.7.1. Adjust the position of telescope till the image of the slit falls on the vertical cross-wire. Clamp it and note the reading on both the verniers.
5. Bring the telescope beck to receive the deviated ray. Turn the prism table without disturbing the circular scale in the clockwise direction so that the deviated ray is displaced by about one degree. Adjust the telescope so that the image is formed on the vertical cross-wire again. Note the reading on both the vernier scales.
6. Turn the telescope again to receive the reflected light from the face AB. Make the necessary adjustments and note the reading on the both the vernier scales.
7. Turn the table in the clockwise direction again and take three or four observations as explained.
8. Rotate the prism table back to its starting position so that the prism is again in the minimum deviation position approximately. Turn the table in the anti-clockwise direction and take four observations.
9. Remove the prism and turn the telescope so that the direct light is received and the image of slit falls on the vertical cross-wire. Note the reading of both the verniers.

Note: - *If θ is the angle between the direct and the reflected rays, then the angle of incidence is given by*

$$i = \frac{180-\theta}{2}$$

The angle of deviation D is given by the difference between the reading of deviated ray and direct ray.

10. Plot a graph between i and D and from the graph find the angle of minimum deviation.

Basic description of a Spectrometer

See experiment no 8

Graphical procedure to find D_m for light from a sodium lamp

Level the spectrometer base, prism table, telescope and collimator, using procedures explained elsewhere. Adjust the telescope and collimator for parallel rays as described elsewhere. Place the prism so that its center coincides with the center of the prism table (use the circles on the prism table to centre the prism). Adjust the prism so that light from the given source passes through the collimator and falls on one of the refracting faces of the prism and emerges out of the other refracting face after refraction. An image of the slit or the spectrum of light from the source is obtained, and may be viewed either directly by your eye or through the telescope.

Now remove the prism and bring the telescope in the line of the collimator. Observe the slit directly through the telescope and rotate the telescope so that the vertical crosswire coincides with the image of slit. Note the reading of any one of the two verniers –V_1 say and continue to use only this one vernier scale throughout the experiment. Let the direct ray be D_o.

Place and centre the prism on the prism table. Facing the slit, keep the frosted surface of the prism to the left and the refracting edge to the right. Switch on the monochromatic light source – sodium vapour lamp. Now take the readings for angle of incidence I on the prism and corresponding angle of deviation in the following way. Starting from the direct reading position D of telescope, rotate the telescope anti-clockwise by about 60^o and then while looking through the telescope rotate the prism clockwise (so that the refracting edge moves towards you), until the image of the slit comes into view. Make accurate adjustments and take the reading P. Obviously 2I + (D~P) = 180 and *I* can be calculated. Now without disturbing the prism, rotate the telescope clockwise and find the deviated ray. Take the reading *R*. Obviously *Do~ R = D*. Additional values of *I* and corresponding *D* may be taken by rotating the telescope in steps through $60^o + 2x$ from direct position (so that *I* increases by x, where x = 10o say), and finding the corresponding *R* and *D*.

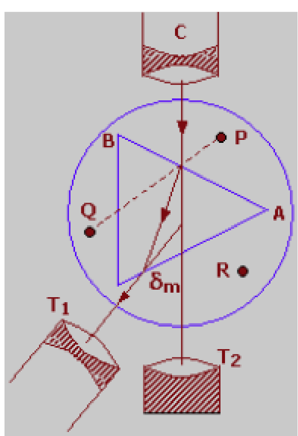


Fig. 7.1: Arrangement to determine

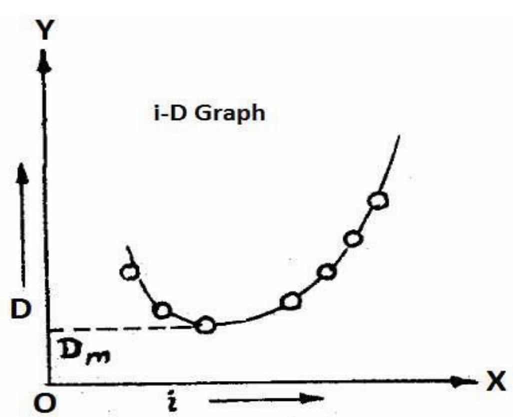


Fig. 7.2: Graph of angle of deviation vs angle of incidence the angle of minimum deviation

While rotating the prism table note down the different angles from the vernier and read as angle of deviation and calculate the angle of incidence using the equation $i = A + D_m / 2$

1. Plot a graph (*i* vs *D*) taking angle of incidence i along the X-axis and angle of deviation *D* along the Y-axis. The nature of the graph is shown in Fig.7.2.

2. Draw a horizontal line as a tangent to the lowest point of the curve. Intersection of this horizontal line on Y-axis gives the angle of minimum deviation D_m (Fig.7.2).

The refractive index μ of the prism is given by the following formula:

$$\mu = \frac{\sin(\frac{A+\delta_m}{2})}{\sin(\frac{A}{2})}$$

Where *A* = angle of the prism, δ_m = angle of minimum deviation.

Fig. 7.2: Laboratory picture of Prism experiment

Observation Table:

Vernier V_1 Direct reading =						Vernier V_2 Direct reading =				
Sl. No	Telescope reading		θ	$i = \frac{180-\theta}{2}$	D	Telescope reading		θ	$i = \frac{180-\theta}{2}$	D
	Dev.	Refl.				Dev.	Refl.			
1										
2										
3										
4										
5										
6										
7										
8										

Questionnaire:

(1)What do you mean by Angular Dispersion?

(2) What is Dispersive power of the prism?

(3)What is Refractive index?

(4)What is Spectrometer?

(5)What is the function of Collimator?

(6)What u meant by Angle of Prism?

(7)Which color in the spectrum is having more refractive index?

Experiment No. 8

Aim of the experiment: Estimation of wavelengths of a CFL using plane transmission grating and optical spectrometer

Apparatus required: Spectrometer, CFL, transmission grating, reading lamp and reading lens.

Description of Apparatus:

1. **Spectrometer**. This is an arrangement for producing pure spectrum. The essential parts of a spectrometer include collimator, prism table, and telescope (See figure).

2. **Collimator**. The collimator provides a narrow parallel beam of light. It consists of a horizontal, cylindrical, metallic tube fitted with an achromatic convergent lens at one end and a short coaxial tube at the other end. The short coaxial tube, which is provided with a vertical slit of adjustable width at the outer end, can be moved inside the main tube with the help of a rack and pinion arrangement. The slit is illuminated by the sources of light, whose spectrum is to be examined and the distance between the slit and the convergent lens is so adjusted that the slit lies in the first focal plane of the lens. Under this condition, the rays of light emerging from the collimator are parallel. Usually in a spectrometer, the collimator is rigidly fixed with its axis horizontal, but in same instruction, it can be rotated about the vertical passing through the center of instrument.

3. **Prism Table.** It is a circular table supported horizontally on a vertical rod at the center of the spectrometer. It can be rotated independently of the collimator and telescope about the vertical axis passing through instrument's center of a circular scale graduated in half degrees carried by the telescope (See figure), the rotation of the prism table can be read with the help of two diametrically opposite verniers attached to it and sliding over the circular scale. The prism table can be clamped to the main body of instrument in any desired position with the help of a clamping screw and then a fine rotation can be given to it with the help of a tangent screw provided at the base. The prism table can be raised or lowered and may be clamped at any desired height with the help of a clamping screw provided for it. It is also provided with the three leveling screws (See figure) so that the refracting faces of the prism can be adjusted parallel to the line joining any two of the leveling screws are drawn on the surface of the prism table, which help in placing the prism in proper position during the experiment.

4. **Telescope**. It is simple astronomical telescope consists of a horizontal and cylindrical metallic tube fitted with an achromatic convergent lens (called the objective) at one end and a short coaxial tube called eyepiece tube at the end. The eyepiece tube (provided with the cross-wires and Ramsden eyepiece) can be moved inside the main tube with the help of rack and pinion arrangement. Pulling or pushing the eyepiece in eyepiece tube by hand can also change the distance between the cross-wires and the eyepiece. Thus the telescope can be adjustable to receive parallel rays and to form a clear image upon the cross-wires, which in their turn are distinctly visible through the eyepiece. The telescope can be rotated about the central axis of the instrument. It is also provided with a clamping and a tangent screw at the base by which a slow rotation can be given to it. The main circular scale is attached with the telescope so that when the telescope is rotated, it can be

measured by reading the position of the Verniers attached to the prism table and sliding over the main scale.

5. **Plane Transmission Grating**. An arrangement, which is equivalent in its action to a large number of parallel slits of same width separated by equal opaque spaces, is called diffraction grating. It is constructed by ruling fine equidistant parallel lines on a optically plane glass plate with the help of a sharp diamond point of an automatically plane transmission grating. If the ruling is made on a metallic surface, the grating is called reflection grating. The number of ruled lines in a grating varies from 15000 to 30000 per inch and the ruled surfrace varies from 2" to 6". The grating available in our BIT Physics laboratory is having 15000 ruled lines per inch and the ruled surface is of around 2".

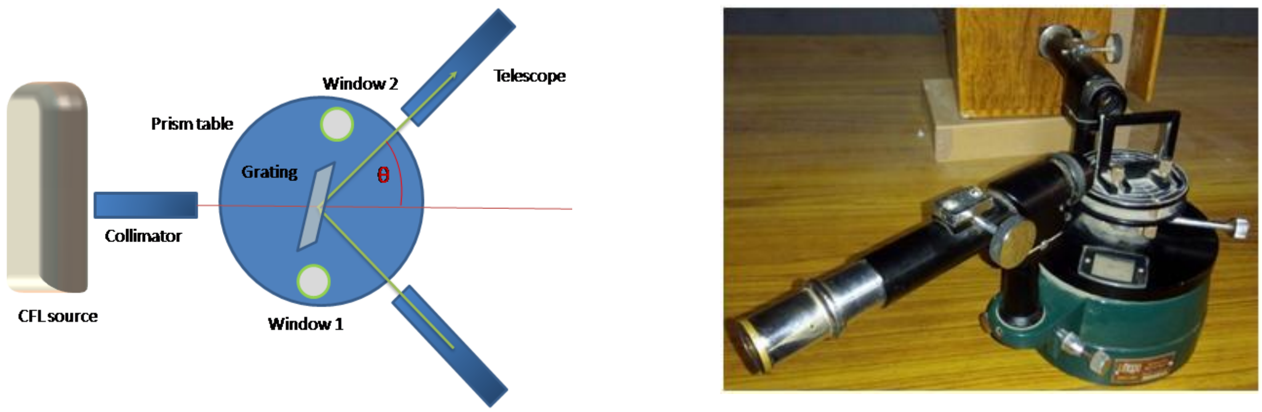


Fig. 8.1: (a) Schematic of the grating spectrometer and (b) real image of the same

The construction of a grating requires a great amount of labor and skilful operation. Further, the ruling process takes some time and during the period the temperature must be maintained constant within a fraction of a degree to avoid an even spacing of lines. An original grating (called the master grating) is therefore very expensive and hence, for useful laboratory work, replicas of the master grating are prepared. The commercial process to prepare a replica is to pour a solution of celluloid in amylacetate on the master grating and allow it to dry to thin strong film, which posses the impression of the grating is then detached from it and mounted in between two optically glass plates. Thus a replica, which we use in laboratories, is prepared.

Grating Elements: **The distance between** the centers of any consecutive ruled lines or transparent spaces acting as a slit is called grating element. Let 'a' be the width of the transparent space and b be the width of ruled space, then the grating = (a + b).

Measurement of angles with help of spectrometer

The spectrometer scales are angle measuring utilities for the positions of the telescope which can be rotated about the central axis of the instrument. The main circular scale is attached with the telescope so that when the telescope is rotated, the main circular scale also rotates with it. The angle, through which the telescope is rotated, can be measured by reading the positions of the vernier attached to the prism table and sliding over the main scale. In a spectrometer there are two sets of main circular scales (fitted with the telescope) and vernier scale (attached with the prism table). Both sets are diagonally (left hand and right hand sides) fixed in the instrument and measures angle for particular telescope position with a difference of 180 degrees (See figure). These scales can be used in a similar manner as a simple vernier calliper or travelling microscope is used. The vernier calliper or travelling microscope is used to measure small distance in centimeters and fractions whereas spectrometer scales are used to measure small angular displacements (in degree, minutes and seconds) { 1 degree is equal to 60 minutes, and is equal to 60 seconds; (1"=60' and 1'=60") }

Least Count of the spectrometer Scale:

BIT, Physics Laboratory has two types of spectrometers in which

30 divisions of Vernier Scale are equal to 29 divisions of the Main Scale.

Now, we will find out the least count in first case which 30 divisions of vernier scale are equal to 29 divisions of the main scale. The method is as follows:

1. Value of one division of circular main scale = 0.5^o = 30' (as 1^o =60')
2. Value of one division of sliding vernier scale = (29/30) X 0.5^o
3. Least count of spectrometer scale = Value of 1 div. of main scale – Value of 1 div. of vernier
   = 0.5^o – [(29/30) X 0.5^o]
   = [0.5 x 1/30] ^{o} =$(1/60)^o$ =1' = 60" (Sixty seconds)

Taking Readings on the Spectrometer Scales:

Following is an illustration for taking observation reading using the left hand side set of the circular main scale (attached with the telescope) and the corresponding vernier scale (sliding over the circular main scale and attached with the prism table). Assuming that we are using the spectrometer in which 30 divisions of vernier scale are equal to 29 divisions of the main scale.

The 0^{th} division of the vernier scale precedes the circular main scale division whose value is 234^o and 30'. Therefore the main sale division reading is 234^o32'.

Let 13^{th} division of vernier scale coincides completely with a main scale division. Therefore the vernier scale reading would be = 13 x Least count of vernier scale.

=13 x 30" = 390" = 6'30"

Total Spectrometer Scale Reading = Circular Main scale Reading + Vernier Reading = 234^o38'30"

Reading of the right hand side scale can be similarly observed. The readings taken from left hand side and right hand side should ideally differ by 180^o

Formula Used: The wavelength λ of any spectral line using plane transmission grating can be calculated from the formula (a + b) sinθ = n λ, where (a + b) is the grating element, θ is the angle of diffraction, and n is the order of the spectrum. If there are N lines per inch ruled on the grating surface then the grating element is given by (a+b) = 2.54 / N cm. Hence, (2.54 / N) sinθ = n λ or λ = 2.54 sinθ /nN cm.

Procedure

The whole experiment is divided into two parts (i) Adjustments, and (ii) Measurement of the diffraction angle θ

(i) Adjustment

Adjustment of the Spectrometer:

Before doing any measurement with the spectrometer, the following adjustment exactly in the sequence given below must be made:

- The axis of the collimator and the telescope must intersect at the perpendicular to the common axis of the prism table and the telescope (usually being made by the manufacturer)
- The eyepiece should be focused on the cross-wires. For dong it turns the telescope towards a white wall and adjust the distance between the objective and eyepiece of the telescope with the help of rack and pinion arrangement such that the field of view appears bright. Now alter the distance between eyepiece and the cross-wires by pulling or pushing the eyepiece tube, till the cross-wires are distinctly visible. This focuses the eyepiece on the cross-wires.

The best method to focus eyepiece without any strain is to see the cross-wires through the eyepiece with one eye and wall directly by the other eye so that there is no parallel between the two. This focusing of the eyepiece may be different for persons of different eyesight. If a second observer cannot see the cross-wires distinctly, he or she may have to move the eyepiece in or out in the eyepiece tube suit his or her eyesight.

- The collimator and the telescope must be adjusted respectively for emitting and receiving parallel rays of light. This can be done in the following manner.

a) Illuminate the slit of the collimator with the source of light, whose spectrum is to be analyzed (CFL lamp in this experiment). Bring the telescope in line with the collimator with the help of rack and pinion arrangement such that the image of the collimator slit as seen through the telescope slit as narrow as possible (of course with a clear appearance through the telescope).

b) Mount the prism on the prism table such that its center coincides with the center or the prism and adjust the height of the prism table such that the prism is in level with the collimator and the telescope.

c) Rotate the prism table in such that a way that one of the polished surfaces of the prism faces towards the collimator. Turn the telescope towards the second polished and observes the spectrum.

d) Now rotate the prism table in such a direction that the spectrum begins to move towards the collimator axis. Rotate the telescope also so as to keep the spectrum always in the field of view. Continue the rotation of the prism table in the same direction till spectrum becomes stationary for a moment. This corresponds to the position of minimum deviation of the prism. Any further rotation of the prism table in the same direction will cause the spectrum to move in the opposite direction.

e) Keeping the prism table in minimum deviation position, adjust the collimator and telescope with the help of rack and pinion arrangements to get the spectrum well focused and sharp.

f) Rotate the prism table slightly through 4^{o} and 5^{o} from the position of the minimum deviation such that the refracting edge of the prism moves towards to collimator. The spectrum will shift away from the collimator axis and in general becomes blurred. Now focus the collimator on the spectrum with the help of its rack and pinion arrangement to make the spectrum as sharp as possible.

If necessary, the telescope may be slightly turned to keep the spectrum in the field of view but its (telescope) focusing arrangement is not to be disturbed while focusing collimator. Now rotate the prism table slightly through 4° or 5° from the position of the minimum deviation such that the refracting edge of the prism moves towards the telescope. Focus the telescope on the spectrum with the help of its rack and pinion arrangement to make the spectrum as sharp as possible. The time does not disturb the precious arrangement of the collimator.

1. Repeat this process of alternate focusing the collimator and telescope, till the rotation of the prism table in either direction from the position of minimum deviation, does not cause the spectrum to go out of focus. When this is the case, the collimator and the telescope both will be focused for parallel rays. This process of focusing the collimator and the telescope can be very easily remembered by the following rule:
    a) Rotate the prism table such that the refracting edge of the prism is brought
    b) Towards the collimator – Adjust the collimator
    c) Towards the telescope – Adjust the telescope

2. The prism table must be optically leveled. For it, proceed as follows;
3. Mount the prism on the prism table with its refracting edge at the center of prism table and of its polished surface perpendicular to the line joining the two screws, as shown in the figure.
4. Rotate the prism table such that the refracting edge faces towards the collimator and the light from the collimator falls simultaneously on both the polished prism surfaces. Clamp the prism table.
5. Turn the telescope towards the face of the prism till the image of the slit formed due to reflection from this face is received in the field of view of the telescope. Adjust the two leveling screws to bring the image in the center of the field of view, i.e., the image should be bisected at the point of intersection of cross-wires.
6. Next, turn the telescope towards the face of the prism till the reflected image of slit from this face is received in the field of view of telescope. Adjust the screw along to bring the image in the center of field of view.
7. Repeat the procedure of alternate adjustments till the two images formed by the reflections from the faces of the prism are seen exactly in the center of field of view of the telescope. The prism table is then said to be optically leveled.

Adjustment of the grating for normal incidence:

For this proceed as follows:

- Bring the telescope in line with the collimator such that the direct image of the slit falls on the vertical cross wire of the telescope. Note the reading on both spectrometer scales.
- Rotate the telescope through 90° from this position and then clamp it. The axis of the telescope will now be perpendicular to the axis of collimator.

- Mount the grating on the prism table such that its ruled surface passes through the center of the prism table and is also perpendicular to the line joining the two leveling screws. The prism table is now rotated till the reflected image of the slit from the grating surface falls on the vertical cross-wire. Adjust the screws if necessary to get the image in the center of the field of view. The grating surface is now inclined at an angle of 45^o with the incident rays. Note the readings of both the spectrometer scales.
- Rotate the prism table through 45^o or 135^o as the case may be so that the ruled surface of the grating becomes normal to the incident rays and faces the telescope. *Now clamp the prism table.*
- The ruling of the grating should be parallel to the main axis of the instrument;
  For this unclamp the telescope and rotate. The diffracted images of the slit or the spectral lines will be observed in the field of view of the telescope. Adjust the leveling screw, if necessary, to get these images at the center of the cross wires. When this is done, the rulings of the grating will be parallel to the main axis of the instrument.
- The slit should be adjusted parallel to the rulings of the gratings. For this rotate the slit in its own plane till the diffracted images of the spectral lines becomes as bright as possible. The observations may now be taken.

(ii) Measurement of the Angle of Diffraction:

To measure the angle of diffraction, proceed as follows;

- Rotate the telescope to one side (say left) of the direct image of the slit till the spectrum of the first order (n=1) is visible in the left of view of telescope. Clamp the telescope and then move it slowly by tangent screw till the vertical cross wire coincides with the red line of the spectrum. Note the readings (main scale reading + vernier scale reading) from left window. Thus go on moving the telescope so that the vertical cross wire coincides in turn with the different spectral lines namely, yellow, green, violet, etc. Each time note the readings from left window.
- Unclamp the telescope and rotate it to the other side (say right) of the direct image till the first order spectrum is again visible in the field of view. Clamp the telescope and use the tangent screw to coincide the vertical cross wire on various spectral lines in turn and each time note the readings from left window.
- Find the difference in the readings of the same kind for the same spectral line in two settings. This gives an angle equal to twice the angle of diffraction for that spectral line in the first order (n=1). Half of it is will give the angle of diffraction. Similarly, calculate the angle of diffraction for other spectral lines. The number of lines per inch on the grating surface is usually written on the grating. Note it.

Observations, Calculations and Results:

Least count of the spectrometer scale:

Value of 1 division of main scale =……………………,

Division of main scale are equal to divisions of vernier scale.

Value of 1 division of vernier scale =………………………

Least count of spectrometer scale = value of 1 division of main scale - 1division of vernier scale

N be number of lines ruled per inch on the grating

Grating element (a+b) = 2.54" / N

Table 8.1: Determination of angle of diffraction

Color of the spectral line	Spectrum of the left to the direct image			Spectrum of the right to the direct image			$2\theta = \theta_1 - \theta_2$ (°)	θ (angle of diffraction) (°)
	M.S.R. (°)	V.S.R. (°)	T.R. (θ_1) (°)	M.S.R. (°)	V.S.R. (°)	T.R. (θ_2) (°)		
Violet								
Blue								
Green								
Yellow								
Red								

Where, V.S.R. = V.S.D. ×L.C.

Table for the measurement of the angle of diffraction of θ for first order

For first order, n=1, $\lambda = (a+b)\sin\frac{\theta}{2}\,cm$

λ for Violet color = ………………………Å.
Calculate λ for all visible spectral lines also.

Sources of Errors and Precautions

1. The axes of the telescope and the collimator must intersect at perpendicular to the main axis of the spectrometer.
2. The collimator must be so adjusted as to give out parallel rays.
3. The telescope must be so adjust as to receive parallel rays and form a well defined slit on the cross wire.
4. The prism table must be optically leveled.
5. The grating should be so mounted on the prism table that its ruled lines are parallel to the main axis of the spectrometer.
6. The plane of the grating should be normal to the incident light and its ruled surface must face the telescope so that the error due to nonparallelism of the incident rays is minimum.
7. The slit should be as narrow as possible and parallel to the ruled surface of the grating.
8. While handling the grating, one should not touch its faces but hold it between the thumb
9. and the fingers by edges only.
10. While taking observations of the spectral lines, the prism table must remain clamped.

Table 8.2: Estimation of percentage error.

Color of the Spectral line	Wavelength as obtained by experiment (Å)	Standard value of wavelength (Å)	Percentage error (%)
Violet		4047	
Blue		4358	
Green		5461	
Yellow		5770	
Red		6234	

Sample Questions

- What do you understand by diffraction of light?
- How does it differ from interference of light?
- What is a diffraction grating? How is it constructed?
- What is grating element?
- What are the necessary adjustments?
- How do you adjust telescope and collimator for parallel rays?
- How do you set the grating for normal incidence?
- Why the ruled surface of grating face should forwards the telescope?
- How many orders of spectra are you getting with the grating?
- How do you measure the wavelength of light using grating?
- Why do you not get more order?
- What is the difference between a prism spectrum and a grating spectrum?
- What are the various series of lines observed in hydrogen spectrum?
- What is Rydberg constant?

Experiment No. 9

Aim of the experiment: To measure the excitation potentials of atoms by Franck Hertz experiment

Background: Franck and Hertz, in 1914, performed a series of experiments to measure the excitation potential of atoms of different elements. These experiments showed directly that in an atom discrete energy levels do exist. Their apparatus is schematically represented in Fig.9.1.

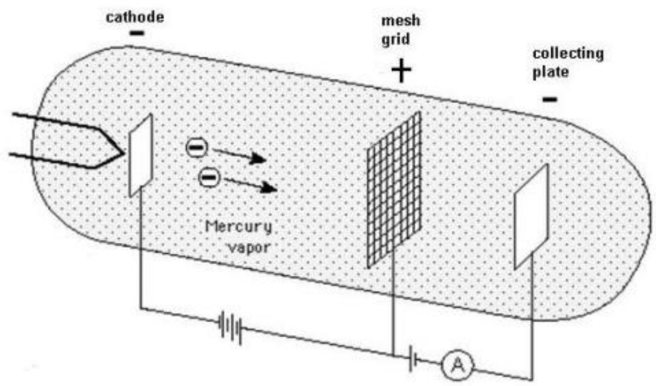


Fig. 9.1: Schematic of the Franck Hertz experimental setup

It consists of a glass tube, in which are mounted a filament, a grid and a plate as shown. The filament is heated by a battery. An accelerating potential V is applied in between the filament and the grid and a fixed retarding potential V_0 (about 0.5V) in between the grid and the plate. The gas of the element, whose atoms are to be studied, is introduced in the tube at about 1mm Hg pressure.

The electrons emitted from the hot filament are accelerated in between the filament and the grid by a potential V, and retarded between the filament and the grid by the potential V_0. Thus, only electrons having energies greater tan eV_0 at the grid are able to reach the plate. The current to the plate is determined by an ammeter connected to it.

The current is plotted against the accelerating potential V, which is gradually increased from zero. The curve, thus obtained, shows a series of regularly spaced peaks, as shown in Fig. 9.2.

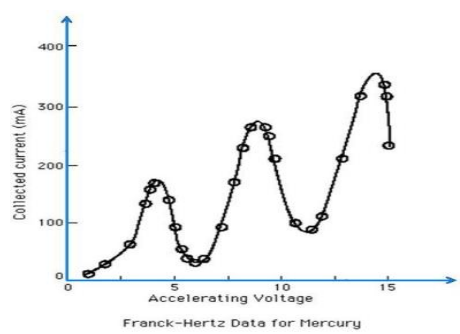


Fig. 9.2: Experimental outcome of Franck Hertz experiment

Interpretation of the curve:

Electrons are emitted from the filament with a range of small energies. In the beginning, they acquire a small additional energy eV on reaching the grid. Those electrons, whose energy is now greater than eV_0

reach the plate and a current is obtained. As the accelerating potential V is increased, more and more of the electrons arrive at the plate and the current rises. Between filament and grid the electrons collide with the gas atoms. However, since the electron energies are insufficient to excite the atoms, the electrons do not lose energy in these elastic collisions.

When accelerating potentials V becomes equal to the first excitation potential V_e of the gas atoms, the electron energy at the grid is eV_e. The electrons can now suffer inelastic collisions with the gas atoms near the grid and excite them to an energy level above their ground state. The electrons, which do so, lose their energy and are unable to reach the plate the way they were previously reaching overcoming the retarding potential. The plate current thus drops sharply. The position of the first peak in Fig. 9.2 gives the first excitation potential V_e of the gas atoms.

As the accelerating potential v is increased further, the electrons suffer inelastic collisions nearer and nearer the filament, so that, when they reach the grid, once again they acquire enough energy to reach the plate thereby increasing the plate current. When V becomes equal to $2V_e$, a second inelastic collision occurs near the grid and the plate current drops again. This process repeats as V is further increased.

The first peak occurs at a potential slightly less than V_e. This is because, the electrons emitted from the filament with a finite velocity and hence with some energy. The true excitation potential Ve is obtained by measuring the difference in between two successive peaks.

Limitations:

Atoms have more than one excitation potential and also an ionization potential. Therefore, in an actual experiment, the curve obtained, is quite complicated and we cannot distinguish between which are excitation and which are ionization potentials.

Demonstrations of the existence of discrete energy levels:

The experiment shows that electrons transfer energy to the atoms in discrete amounts. And that they cannot excite atoms if their energy is less that eV_e. Franck and Hertz demonstrated it directly by observing the spectrum of the gas during electron collisions. They showed that a particular spectral line does not appear until the electron energy reaches a threshold value. For example, in case of mercury vapor, they found that a minimum electron energy of 4.9 eV was required to obtain the 2536Å line of mercury and a photon of 2536Å light has an energy of just 4.9eV. This shows that discrete energy level do exist in an atom and the electrons of the atoms can exist only in these levels.

Experimental setup:

The Franck-Hertz experiment setup model no. FH 3001 from SES Instruments Pvt. Ltd. is used. The setup as depicted in the user manual for FH 3001 is shown in Fig. 9.3. The circuit diagram for the setup is shown in Fig. 9.4.

Fig. 9.3: Experimental setup for Franck Hertz experiment (FH 3001)

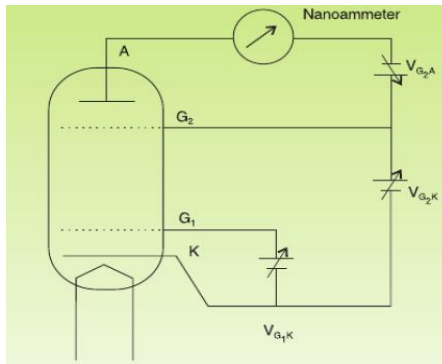


Fig. 9.4: Circuit diagram of FH 3001 unit

The FH3001 setup consists of

a. Tetrode filled with Ar
b. Filament voltage: 2.6-3.4V
c. Grids voltages: V_{G1K}: 1.3-5V, V_{G2A}: 1.3-12 V, V_{G2K}: 0-95 V
d. Digital Ammeter (with range multipliers: 10^{-7}, 10^{-8} and 10^{-9})

Experimental Procedure

1. Ensure that the Electrical power is 220V ± 10%, 50 Hz.
2. Before the power is switched 'ON' make sure all the control knobs are at their minimum position and Current Multiplier knob at 10^{-7} position.
3. Switch on the Manual-Auto Switch to Manual, and check that the Scanning Voltage Knob is at its minimum position.
4. Turn the Voltage Display selector to V_{G1K} and adjust the V_{G1K} Knob until voltmeter reads 1.5 V.
5. Turn the voltage Display selector to V_{G2A} and adjust the V_{G2A} Knob until the voltmeter read 7.5 V.
6. Before proceeding to the next step check that the initial parameters are Filament Voltage: 2.6V (minimum position) V_{G1K}: 1.5 V, V_{G2A}: 7.5V, V_{G2K}: 0V, Current Amplifier: 10^{-7}
7. These are suggested values for the experiment. The experiment can be done with other values also.
8. Rotate V_{G2K} knob and observe the variation of plate current with the increase of V_{G2K}. The current reading should show maxima and minima periodically. The magnitude of maxima could be adjusted suitably by adjusting the filament voltage and the value of current multiplier.

9. Now take the systematic readings, V_{G2K} versus plate Current. For better resolution and observation of the maxima / minima V_{G2K} is varied from 0-80 V in the increments of 0.1V or 0.01 V. Increments of 0.1 will be used for the data set away from the peak or the dip. The interval 0.01V may be chosen to finer the observation near maxima or minima.
10. Plot the graph with output current on Y- axis and Accelerating Voltage V_{G2K} at X-axis (similar to one, as shown in Fig. 9.2).

Table 9.1: Data for accelerating voltage versus plate current

<table>
<tr><td rowspan="5">Least count of Voltmeter = 0.1 V
Least count of Ammeter=10^{-9}A
V_{G1K}: 1.5 V
V_{G2A}: 7.5 V</td><td>Sr. No.</td><td>Accelerating voltage V_{G2K} (V)</td><td>Plate current I_A (nm)</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
</table>

Table 9.2: Estimation of ionization potential

<table>
<tr><td>V_{G2K} at maximum plate current (V)</td><td>Difference from the preceding maximum (V)</td><td>Average difference between the consecutive maxima (V)</td></tr>
<tr><td></td><td></td><td rowspan="4"></td></tr>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
</table>

Results and Discussion:

As seen from the curve between the current and V_{G2K} graph the electrons can excite the atoms of the buffer gas (Ar) only if they are accelerated by a specific collector voltage or its integer multiples. This verifies the discrete atomic energy levels of Ar atoms. A significant decrease in plate current is observed whenever the potential on grid 2 is increased by approximately (11± 2) eV, which indicates that the fed electrical energy is converted in quanta of (11±2) eV only. The average value of spacing between the consecutive peaks, in the experimental output, is ~11eV compared to the first excited state of Ar atom i.e. 11.83eV observed from the spectroscopic evidences.

Precautions:

1. Before taking the systematic readings, gradually increase the value of V_{G2K} to a maximum. Adjust the filament voltage if required such that maximum readings are about 10.00 on x 10-8 range. This will ensure that all the readings could be taken in the same range.
2. During the experiment (manual), when the voltage is over 60V, please pay attention to the output current indicator, IF the ammeter reading increases suddenly decrease the voltage at once to avoid the damage of the tube.
3. Whenever the filament voltage is changed, allow 2/3 minutes for its stabilization.
4. When the Franck-Hertz Tube is already in the socket, make sure the following before the power is switched 'ON' or 'OFF', to avoid damage to the tube.

i. Manual-Auto switch is on Manual and Scanning and Filament Voltage knob at its minimum position (rotate it anticlockwise) and current multiplier knob at 10^{-7}.

ii. V_{G1K}, V_{G2A}, and V_{G2K} all three knobs are at their minimum position.

Questionnaire:

1. What do you mean by energy quantization?
2. What do you mean by atomic energy levels?
3. What are the different mechanisms of emission of electrons by a cathode?
4. What is the typical pressure maintained inside the Franck Hertz tube and why?
5. How can one identify a collision of a moving electron with an atom to be inelastic?

Experiment No. 10

Aim of the experiment: Determination of the wavelength of sodium light by Newton's rings

Apparatus required: Sodium lamp, wooden box with slit, plano-convex lens fitted in Newton's rings setup

Brief description of the apparatus: Newton's rings apparatus consists of a plano-convex lens C, whose convex surface (having a large radius of curvature R~1m) is placed in contact with a plane glass plate P as depicted in Fig. 1. This lens-plate combination is enclosed in a cylindrical case provided with three leveling screws. The inside of the case is painted black, while the top of the case is open and is provided with a screw cap by which suitable pressure can be uniformly applied on the rim of the lens. Another glass plate, known as beam splitter, is kept above the top of the case by making an angle of 45° with the vertical. Light from a sodium lamp, kept inside a wooden box with an aperture in front of it, is made parallel by a convex lens and is made to get incident on the beam splitter at an angle of 45°, thereby making the beam to enter the C-P combination normal to the plane surface of the plano-convex lens. The reflected light falls normally on the air-film trapped in between C, and the glass plate P. The light reflected from the upper the lower surfaces of the air film produce interference fringes. At the center the lens is in contact with the glass plate and the thickness of the air film is zero. The center will be dark as a phase change of π radians is introduced due to reflection at the lower surface of the air film (as the refractive index of glass plate P (μ = 1.5)) is higher than that of the air film (μ = 1).

Theory: When a parallel beam of monochromatic light of wavelength λ is made incident on a wedge shaped thin film of air enclosed in between C and the convex surface of P with a large radius of curvature, each incident ray on the air-film will give rise to two reflected rays front the front and back surfaces of the air-film. These two reflected rays, being coherent in nature, interfere by virtue of interference by division of amplitude, and produce alternate bright and dark concentric rings, having darkness at the common center. The interference fringes are in the forms of concentric circles, the diameter of which can be measured with a travelling microscope (which has a screw gauge attached to it). The experimental set-up is shown in Fig.10.1.

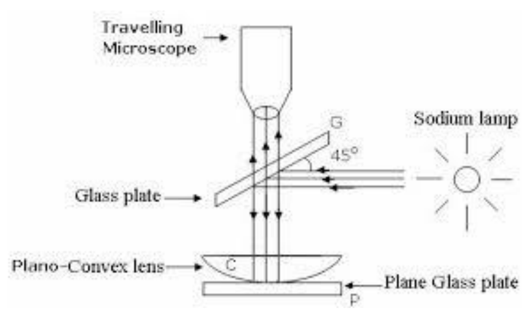


Fig. 10.1: Schematic of the experimental setup for the Newton's rings experiment.

Let r_m be the radius of the m^{th} order dark ring, which can be measured with the microscope. Also, let the corresponding thickness of the air gap at the point P be t. (Fig. 10.2)

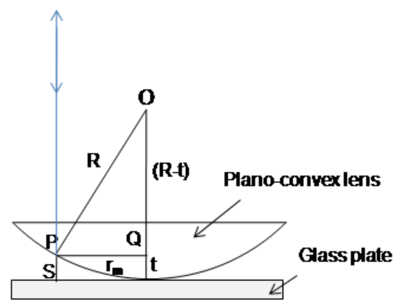


Fig. 10.2: Relationship of *t* with the radii of Newton's rings.

The optical path difference between the beams reflected from the lower surface of C and upper surface of P is given by

$\delta_{PS}=2\mu t\cos 0^{\circ}=2t$ (1)

for perpendicular incidence (i.e. angle of reflection=0°) of the beam (shown in blue in Fig. 10.2) and μ= refractive index of the medium in between the points P and S= refractive index of air=1

Now the phase of the wave reflected at P is changed by 180° on reflection due to Stoke's law, the corresponding difference in optical path being mλ, where m is an integer. Hence the actual optical path difference between the rays reflected from the points P and S will be rectified to

$\delta_{PS} = 2t \pm m\lambda$ (2)

From triangle OPQ (Fig. 10.2) we have,

$r_m^{\ 2} = t(2R-t)$ (3)

The value of radius of curvature *R* (100cm) of the lower surface of the plano-convex lens is much greater than the thickness of the air film *t*. In view of this, equation (3) reduces to

$t = \dfrac{r_m^{\ 2}}{2R}$ (4)

Combining equations (2) and (4) we get,

$\delta_{PS} = \dfrac{r_m^{\ 2}}{R} \pm m\lambda$ (5)

Now, from the theory of interference it is well-known that the two rays reflected from the point P and S will interfere destructively if

$\delta_{PS} = (2m \pm 1)\dfrac{\lambda}{2}$ (6)

Therefore, if m represents the m^{th} order dark ring, equations (5) and (6) may be compared to yield

$$\frac{r_m^{\ 2}}{R} = m\lambda \qquad (7)$$

On the other hand, the condition of constructive interference, i.e. bright rings leads to

$$\frac{r_m^{\ 2}}{R} = (2m \pm 1)\frac{\lambda}{2} \qquad (8)$$

Let us now concentrate at the dark Newton's rings. If we want to estimate the radius of the n^{th} order dark ring, then it can be evaluated using equation (7) by replacing *m* with *n*, i.e.

$$\frac{r_n^{\ 2}}{R} = n\lambda \qquad (9)$$

Subtracting equation (7) from equation (9) and readjusting we get

$$\lambda = \frac{r_n^{\ 2} - r_m^{\ 2}}{R(n-m)} = \frac{\Delta r_m^{\ 2}}{\Delta m} \times \frac{1}{R} \qquad (10)$$

Equation (10) is the experimental formula using which wavelength λ of sodium light can be evaluated.

Now, following equation (10) it is readily understood that, if we consider $r_n^{\ 2} - r_m^{\ 2}$ as a Y axis variable and estimate it as a function of (*n*-*m*), taken as X axis variable, a straight line is obtained, the slope of which is *R* times the value of λ.

n and *m* being arbitrary numbers, can be varied independently. However, for the sake of simplicity let the value of *n* be fixed at *n*=12 (say) and *m* be varied from 12 to 2 at a step of 2. If we do so, (*n*-*m*) will assume values given by 0, 2, 4, 6, 8 and 10. Corresponding to these values, the numerators of equation (10) can be evaluated. Hence the value of λ can be estimated as the final quantity.

Procedure:

1. Adjust the angle of the beam splitter (tilted glass plate as shown in Fig. 10.1) and X, Y and Z axis adjustment screws attached to the travelling microscope to get a clear *inverted* image of the Newton's rings that can be viewed through the microscope.

   N. B. As the image of the Newton's rings is inverted, the readings in going from point 1 to 6 decreases continuously.

2. Move the horizontal axis (X axis) screw of the microscope to set the junction of the cross wire to the extreme left point (point '1' of Fig. 10.3) of the 2^{nd} innermost ring (i.e. *m*=2). Record the corresponding main scale reading (M.S.R.), circular scale reading (C.S.R.) and hence the total reading (TR).

3. Now gradually moving the same screw move the cross-wire junction to the right and scan the positions 2, 3, 4, 5, 6 etc. (as shown Fig. 10.3) sequentially corresponding to *m*=2, 4, 6, 8, 10 etc.

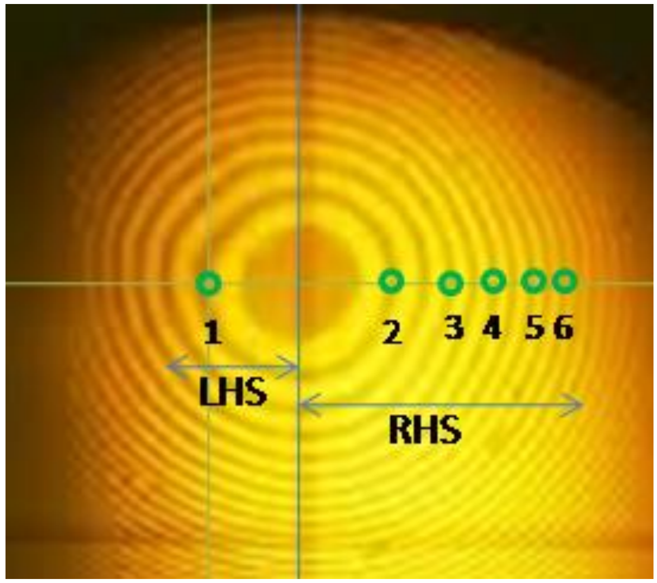


Fig. 10.2: Real image of the Newton's rings as viewed through the travelling microscope.

Calculations and results:

1. Fill up the following table.

   L.C. of the micrometer screw gauge: ……………………………………

Table 10.1: Relationship in between the order numbers and radii of Newton's rings

m	*LHS*			*m*	*RHS*			*Coordinate of the center X_c $=X_2'-(X_2-X_2)/2$ $=(X_2'+X_2)/2$ (mm)*	*r_m= X_c-X_m (mm)*	*r_m^2 (mm²)*	Δm	Δr_m^2 *(mm²)*
	M.S.R. (mm)	*CSD*	*TR (X_2')= M.S.R. +CSD×LC (mm)*		*M.S.R. (mm)*	*CSD*	*TR (X_m) =M.S.R. +CSD×LC (mm)*					
2			X_2'=	2							10	
				4							8	
				6							6	
				8							4	
				10							2	
				12							0	

2. Draw $\Delta r_m^{\ 2}$ Vs Δm graph, which will be a straight line that may or may not pass through the origin (as shown in Fig. 10.3).

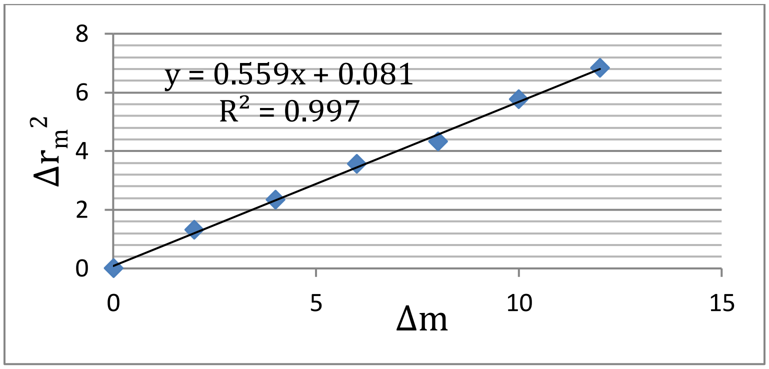


Fig. 10.3: Sample data plot of Newton's rings experiment.

3. Estimate the slope of this straight line and then using equation (10) find out the value of λ.

N. B. For filling up the values of $\Delta r_m^{\ 2}$*, subtract all the values of* $r_m^{\ 2}$ *from* $r_{12}^{\ 2}$.

Precautions:

1. By adjusting the screws attached on the plane surface of the plano-convex lens ensure that the Newton's rings are perfectly circular.
2. Adjust the positions of the light source and the beam splitter so that the illumination of the rings is uniform and you can clearly differentiate in between the adjacent bright and dark fringes.
3. While recording the M.S.R. and C.S.R. ensure that your measurements are free from parallax error.
4. While recording the data, move the screw gauge only in the clockwise direction. Moving the screw in the reverse direction in course of measurement for fine adjustments may add up to the percentage error of the experiment.

Questionnaire:

1. What is the optical process responsible for the formation of Newton's rings?
2. What are experimental steps required to improve the clarity of Newton' rings?
3. If the upper surface of the glass plate on which the plano-convex lens is placed for the Newton's rings experiment is fully silvered, what will happen to your observation?
4. How can you determine the refractive index of a fluid using Newton's rings experiment?

Experiment No. 11

Aim of the experiment: To estimate the wavelength of Sodium light by Fresnel's bi-prism experiment.

Apparatus used: Optical bench with uprights, sodium lamp, bi-prism, convex lens, slit and micrometer eye piece are already fitted on the optical bench.

Formula used: The wavelength λ of the sodium light is given by the formula in case of bi-prism experiment.

$\lambda = \beta\, 2d / L$

Where β = fringe width,

2d = distance between the two virtual sources,

L = distance between the slit and screen.

Again $2d = \sqrt{(d_1 d_2)}$, where d_1 = distance between the two virtual images of the slit formed by the convex lens posited closer to the slit and d_2 = distance between the same two images when the convex lens is moved closer to the eye-piece.

Description of the Apparatus:

Two coherent sources, from a single source, to produce interference pattern are obtained with the help of a Bi-prism. A bi-prism may be regarded as made up of two prisms of very small refracting angles placed base to base. In actual practice a single glass plate is suitably grinded and polished to give a single prism of obtuse angle about 170° leaving remaining two acute angles of 30° each. The optical bench used in the experiment consists of a heavy cast iron base supported on four leveling screws. There is a graduated scale along its one arm. The bench is provided with four uprights which can be clamped anywhere and the position can be read by means of vernier attached to it. Each of the uprights is subjected to the following motions:

i) Motion along bench

ii) Transverse motion

iii) Rotation about the axis of the upright.

iv) With the help of the tangent screw, the slit and bi-prism can be rotated in their own vertical planes.

The bench arrangement is shown in the Fig. 11.1.

Fig. 11.1: Experimental setup for Fresnel's bi-prism

Action of bi-prism:

The action of the bi-prism is shown in the Fig. 11.2. Monochromatic light from source S falls on two points of the prism and is bent towards the base. Due to the division of wavefront, the refracted light appears to come from S_1 and S_2 as shown Fig.11.2. The waves from two sources unite and give interference pattern.

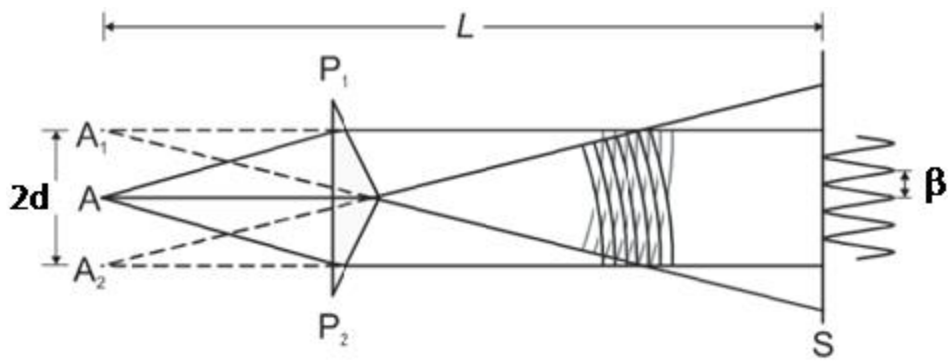


Fig. 11.2: Mechanism of formation of interference fringes by Fresnel's bi-prism

The fringed are hyperbolic. However, due to high eccentricity they appear to be straight lines in the focal plane of eyepiece as shown in Fig. 11.3.

Fig. 11.3: Interference pattern formed by Fresnel's bi-prism.

Background theory:

If a rectangular aperture, illuminated by a monochromatic light source with wavelength λ, is placed in front of the apex of a bi-prism, two virtual images (A_1 and A_2) of the slit are formed on the side opposite to the flat edge of the bi-prism, as depicted in Fig. 11.2. Let the separation in between the two images be 2d. Light rays coming from A_1 and A_2 being coherent, can interfere with each other to form sustained interference patterns on a screen S, a distance L away from the virtual sources.

The optical path difference in between the two rays reaching the point S from A_1 and A_2 is given by:

$\delta = 2d\sin\theta$ (1),

where θ is the angle of deviation with respected to the horizontal line. It is well known from the basics of interference that if

$\delta = n\lambda \ (n \epsilon I)$ (2)

the rays coming from A_1 and A_2 interfere constructively and the corresponding order of interference is n. Let the position of this maxima from the central maxima be Y_n.

If $2d << L$, θ will be a small quantity and the following approximations will be valid.

$\sin\theta \simeq \theta \simeq \tan\theta = Y_n/L$ (3)

Combining (1)-(3) we get,

$n\lambda = 2dY_n/L$ (4)

Similarly, for $(n\pm1)^{th}$ order maxima, we can write

$(n\pm1)\lambda = 2dY_{(n\pm1)}/L$ (5)

Subtracting (4) from (5) are rearranging finally we get,

$Y_{(n\pm1)} - Y_n$=distance between two consecutive maxima=fringe width=$\beta = \lambda L/2d$ or

$\lambda = 2d\beta/L$ (6).

Equation (6) is the experimental formula using which we can estimate the value of λ. In the experiment, therefore, we have to measure three unknown quantities: (i) β, (ii) 2d and (iii) L. In the following sections we will discuss how to measure these quantities.

Procedure:

i) With the help of spirit level and leveling screws make the optical bench perfectly horizontal.

ii) The slit, bi-prism and eye-piece are to be maintained at the same height. Make the slit and the cross wire of eye piece perpendicular to the optical bench.

iii) The eye piece is to be focused on the cross wire.

iv) The light from the sodium lamp is allowed to fall on the slit and the bench is adjusted in such a way that light comes straight along its length. Precautions are to be taken to avoid the loss of light intensity for the interference pattern.

v) Place the bi-prism upright near the slit and move the eye piece sideways. See the two images of the slit through bi-prism. In case they are not distinctly seen, move the upright of bi-prism right angle to the bench till they are obtained. Make the two images parallel by rotating bi-prism parallel to its plane face.

vi) Bring the eye piece near to the bi-prism and rotate it at 90° to the bench to obtain a patch of light containing the interference fringes provided that the edge of the prism is parallel to the slit.

vii) Rotate the bi-prism with the help of tangent screw attached to it till the edge of the bi-prism parallel to the slit and a clear interference pattern is obtained.

viii) The line joining the centre of the slit and the upper surface of the bi-prism should be parallel to the bed of the bench. Otherwise, there will be a lateral shift and its removal is very important for the accurate measurement of the wavelength.

(a) For setting the apparatus for no lateral shift, the eyepiece is first slowly moved away from bi-prism. The fringes will thus move either to right or left. By turning the base screw provided with bi-prism, the bi-prism can be moved at right angle to the bench in such a direction so that the fringes are always back to their original position.

(b) Followed by this, move the eye piece towards or away from the bi-prism. The fringe system will once again move laterally. However, this time, they are brought to their original position by turning the screw of attached to the eye piece.

Measurements:

(A) Estimation of the fringe width (β):

i) Find out the least count of the micrometer screw.

ii) Place the micrometer screw at such a distance from bi-prism, where fringes are distinct, bright and widely spaced, say 100 cm.

iii) The cross wire is moved on one side of the fringes to avoid backlash error. Now the cross wire is fixed at the centre of a bright fringe.

iv) The crosswire is now moved and fixed at the centre of every second fringe. The micrometer readings are noted. From these observations β can be calculated.

**** There is a very common mistake that is often encountered while taking the micrometer readings. The main scale of the micrometer is graduated in mm from -10 mm to + 10mm having 0 at the center. The readings on the positive side are similar to those recorded by an ordinary screw gauge. However, on the negative side the M.S.R. and the C.S.R. are to be recorded using the following relations.*

Actual M.S.R.= M.S.R. observed-1 (take care of the sign)

Actual C.S.R.= (C.S.D. observed-100)×L.C. (take care of the sign)

(B) Measurement of L:

The distance between the slit and eyepiece is L, the value of which is corrected taking into account the bench error.

(C) Measurement of 2d:

For measuring 2d, we use a simple principle of ray optics of imaging of an object with the help of a bi-convex lens, as schematically depicted in Fig. 11.4(b). The distance 2d between the two virtual sources can be measured with the help of Fig.11.4.

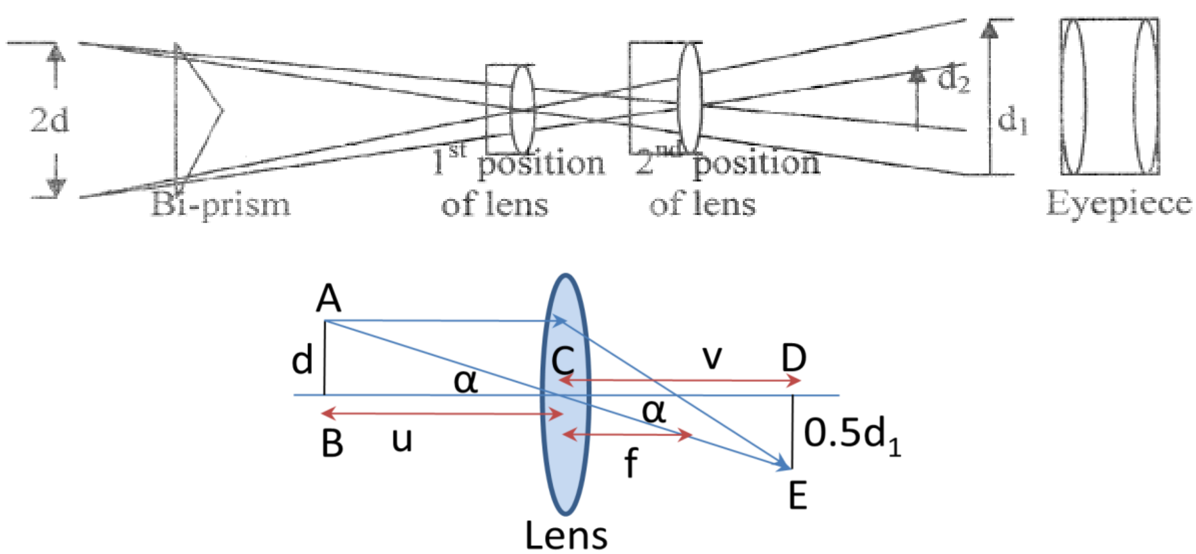


Fig. 11.4: (a) Distance between two virtual sources as a function of the position of the convex lens. (b) Principle of image magnification by a bi-convex lens.

Suppose half of the distance between the two virtual (i.e. AB=d) sources is above the line BD passing through the center of the lens C. If u is the object distance of the lens for which we obtain an image DE at a distance v from the lens, we see that ΔABC and ΔCDE are similar.

∴ $\tan\alpha = AB/BC=DE/CD$

⇒ $d/u = d_1/2v$

⇒$v/u= d_1/2d$ (6)

Now, following the principle of reversal of track of light, if the lens is moved to a distance v from the source, a second image of the source will form at a distance u from the lens. So, following the same procedure as above, we get

$d/v = d_2/2u$

⇒$v/u= 2d/d_2$ (7)

Combing equations (6) and (7) we finally obtain

$d_1/2d= 2d/d_2$

∴$2d=\sqrt{(d_1 d_2)}$ (8)

i) To obtain the value of 2d, the positions of slit and bi-prism uprights are kept unaltered.

ii) A convex lens is introduced between the bi-prism and the eye-piece and moved in between to obtain the second position where again two sharp and focused images are obtained. The distance between two images is noted. In the first position the distance is d_1.

iii) The lens is again moved towards the eye-piece to obtain the second position where again two sharp and focused images are obtained. The distance in this case is denoted by d_2. Knowing d_1 and d_2, 2d can be calculated by using the formula:

$2d = \sqrt{(d_1\, d_2)}$

Result: Wavelength of sodium light λ = ………………………………Å

Standard value of λ = ………………………………Å

% Error = ………………………………%

Observations:

Pitch of the screw = ……………………..mm

No. of divisions on the micrometer screw = ………………………mm

L.C. of micrometer screw = …………………..mm

Table 11.1: Determination of fringe-width β

Fringe No.	Micrometer reading (a)			Fringe No.	Micrometer reading (b)			Diff. of 20 fringes (b-a)	Mean of 20 fringes (<20β>) (mm)	Fringe Width β= <20β>/20 (mm)
	M.S.R. (mm)	C.S.R (mm)	T.R (mm)		M.S.R. (mm)	C.S.R (mm)	T.R (mm)			
1				21						
3				23						
5				25						
7				27						
9				29						
11				31						
13				33						
15				35						
17				37						

(2) Measurement of L:

Position of upright carrying slit = ….mm

Position of upright carrying the eyepiece = ….mm

Observed value of L = ….mm

Value of L for bench error = ….mm

Measurement of 2d:

Table 11.2(a): Measurement of d_1

Image No.	Micrometer reading				d_1 $(<x_2>-<x_1>)$ (mm)
	1[st] position of the lens				
I	M.S. R. (mm)	C.S.R. (mm)	T.R. (x_1) (mm)	Average value of x_1 $<x_1>$/mm	
II	M.S. R. (mm)	C.S.R. (mm)	T.R. (x_2) (mm)	Average value of x_2 $<x_2>$/mm	

Table 11.2(b): Measurement of d_2

Image No.	Micrometer reading				d_2 $(<x_2>-<x_1>)$ (mm)
	2[nd] position of the lens				
I	M.S. R. (mm)	C.S.R. (mm)	T.R. (x_1) (mm)	Average value of x_1 $<x_1>$ (mm)	

II	M.S. R. (mm)	C.S.R. (mm)	T.R. (x_2) (mm)	Average value of x_2 $<x_2>$ (mm)	

Hence $2d=\sqrt{d_1 d_2}$=……………………………mm

Calculations:

$\lambda = \beta.2d/L$ = …………..Å

Precautions and Sources of Error:

i) The setting of uprights at the same level is essential.

ii) The slit should be vertical and narrow.

iii) Fringe shift should be removed.

iv) Bench error should be taken into account.

v) Crosswire should be fixed in the center of the fringe while taking observations for fringe width.

vi) The micrometer screw should be rotated only in one direction to avoid backlash error.

vii) The fringe width should be measured at a fairly large distance.

viii) Convex lens of shorter focal length should be used (f = 25 cm approx)

ix) Motion of eyepiece should be perpendicular to the lengths of the bench.

Questionnaire:

1. What do you mean by interference of light?
2. Is there any loss of energy in the interference phenomenon?
3. What are the different types of interference?
4. What are interference fringes?
5. What is a Bi-prism?
6. Why are the refracting angles of the two prisms made so small?

7. What is the purpose of the Bi-prism?
8. What is the effect of changing the distance between the slit and bi-prism on the fringe–width?
9. How o you measure 2d?
10. 0 How will you locate zero order fringes in b-prism experiment?
11. 1 How can you measure the thickness of mica sheet?
12. Are the bi-prism fringes perfectly straight?
13. 3 What is the construction of sodium lamp?

Experiment No. 12

Aim of the experiment: To measure of Peak to Peak Voltage and frequency of a given AC signal using CRO.

Introduction:

The cathode ray oscilloscope (CRO) is a versatile laboratory instrument used for the visual observation, measurement, and analysis of waveforms. With the help of transducers, many physical quantities like pressure, strain, temperature, acceleration etc. Can b converted into voltage which can be displayed on CRO. Thus many dynamic phenomena can be studied by means of CRO.

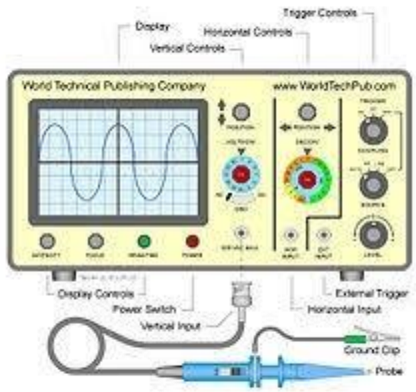


Fig. 12.1: Different parts of CRO

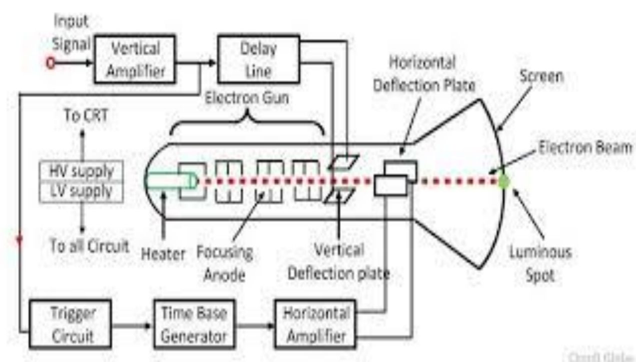


Fig. 12.2: Different components of CRO

The heart or the major component of the oscilloscope is the cathode ray tube (CRT). The rest of the CRO consists of circuitry to operate the CRT.

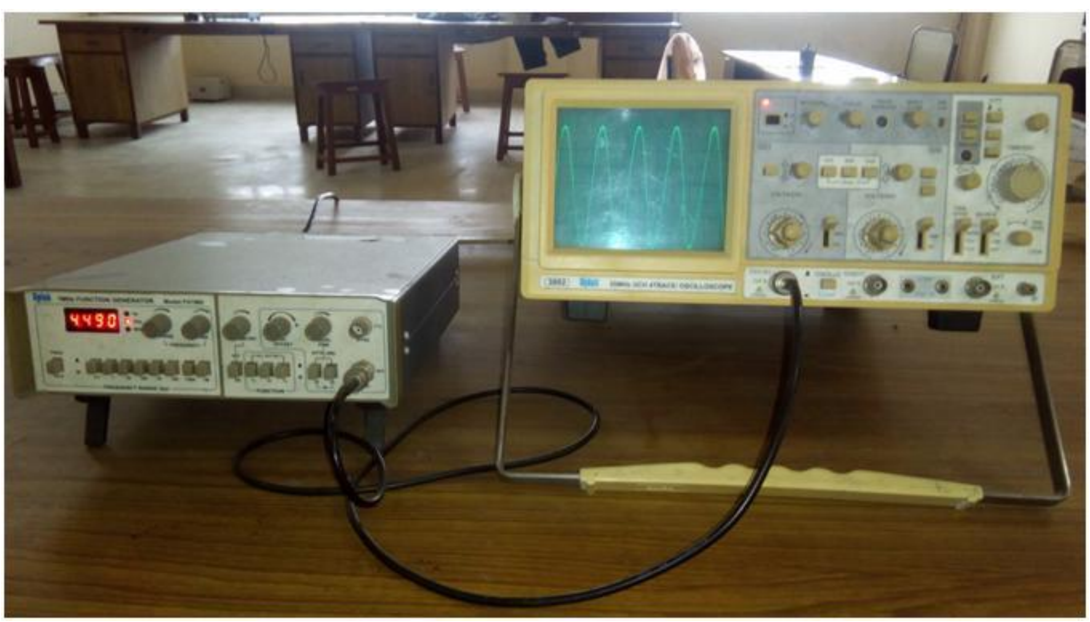


Fig. 12.3: Laboratory picture of CRO experiment

Application of CRO:

a) **Visual display and qualitative study of signal waveforms**: To display a signal on the CRT screen, the signal is applied to the vertical input terminals. The time variation of the signal is visualized by means of the sweep generator displacing the spot in proportion to time in the horizontal direction. The nature of the signal cab be qualitatively studied from the trace on the CRT screen. For example, one can get a visual impression if the signal is sinusoidal or rich in harmonics.

b) Measurement of voltage: The calibration of the vertical scale gives the voltage corresponding to the vertical deflection of the spot on the CRT screen. Thus the magnitude of an applied dc voltage or the voltage at different times of a time- varying signal can be measured.

c) Measurement of frequency:

I. Using the time base: The calibration of the horizontal scale, i.e. the time base helps to determine the frequency of a time-varying signal displayed on the CRT screen. If N complete cycles of the ac signal are found to appear in a time interval t, the time period of the signal is T = t/N. The frequency is f = 1/T = N/t.

II. Using Lissajous figures: The patterns generated on the CRT screen upon simultaneous application of sine waves to the horizontal and the vertical deflection plates, are known as Lissajous figures. Various patterns are obtained depending on the relative amplitudes, frequencies and phases of the waveforms. Using Lissajous figure frequency of a wave form can be determined.

Table 12.1: Measurement of Frequency

Sl.No.	Frequency of Function Genetor F_{in} (Hz)	Frequency Measurement using CRO F_o in (Hz)				Ratio F_o/F_{in}
		Value of Time-base (Time/Div.)	No. Of Div.	T(s)	F_o (1/T)	

Table 11.2: Measurement of Voltage by CRO

Sl.No.	Voltage from Sources $(V_{p-p})_{in}$ (V)	V_{p-p} Measured by CRO			Ratio $(V_{p-p})_{out} / (V_{p-p})_{in}$
		Y-amplifier setting (V/div.)	Vertical Scale No. of Div.	$(V_{p-p})_{out}$ (V)	

Questionnaire:

1. What is Cathode ray oscilloscope (CRO)?
2. What are the basic components of a CRO?
3. What is the function of probe in CRO?
4. How many types of probe used in CRO?
5. What is the function of Attenuator in CRO?
6. Which device is used for the source of emission of electrons in a CRT?
7. What is the function of electron gun used in CRT?
8. For what vertical and horizontal plates are provide in a CRO?