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WORK INSTRUCTION

1.0 EXPERIMENT NO: BS/PHP101/01

2.0 NAME OF EXPERIMENT: Young's modulus

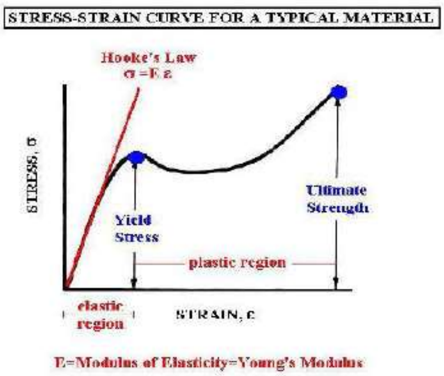
3.0 0BJECTIVE: Determination of Young's modulus by flexure method and calculation of bending moment and force at a point on the beam

4.0 TEORITICAL BACKGROUND:

Stress and Strain:

Stress is the restoring force caused due to the deformation divided by the area to which the force is applied; and strain is the ratio of the change caused by the stress to the original state of the object.

It states that within elastic limit, stress is proportional to the strain.
Thus $\frac{stress}{strain}$ is constant. The value of this constant is called modulus of elasticity.
The validity of Hooke's law is discussed below.



The first part of the curve i,e. in elastic region shows that the strain is proportional to the load per unit area or stress. Up to the point A Hooke's law holds and also up to end of first linear region we see when we unload the wire, the stretch wire shortens until its length is same as it was before the weight was given. This means that the wire is perfectly elastic up to A. When we go beyond this range we exceed what is known as elastic limit. Beyond the yield point the plastic region is started where a great extension start to act for any material.
There are different moduli of elasticity depending on the nature of the strain. We have from the following moduli of elasticity: Young's modulus, Bulk modulus, Rigidity modulus and Axial modulus. The moduli of electricity is called elastic constant of a substance.

Young's modulus, $$Y = \frac{applied\ \ load\ \ per\ \ unit\ \ cross-section}{increase\ \ in\ length\ per\ \ unit\ \ length}$$

$$Y = \frac{longitudional\ stress}{longitudional\ strain}$$

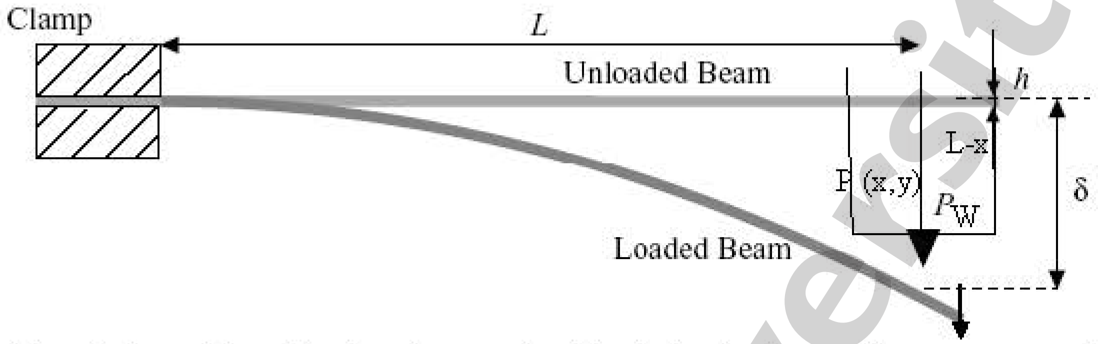
If F be the applied tensile force which causes a body of length l and cross-section A to elongate by x in the direction of force, the longitudinal stress is equal to F/A and the longitudinal strain is x/l. Hence, we express Young's modulus as

$$Y = \frac{F/A}{x/l} = \frac{Fl}{Ax}$$

In absolute C.G.S. units, F/A is expressed as in dynes/cm^2, while x/l is a pure number. Hence Young's modulus is expressed in dynes/cm^2.

Cantilever:

A cantilever is a uniform beam fixed horizontally at one end and loaded at the other end.



We consider a light cantilever fixed at clamp end and loaded at the free end by a concentrated weight *W*. Let P (x,y) be any point on the beam and *L* be the length of the beam.

The applied bending moment due to the load W about the point P which is at a distance x from the fixed end = *W (L-x)*.

Hence the bending moment equation is given by
$\frac{YAk^2}{R} = W(L-x)$ [Since the cantilever is light weight and is supposed to be weight less]
Where *A* is the sectional area of the beam and *k* is the radius of gyration.
The left-hand side of above equation represents the internal bending moment.
or, $YAk^2\frac{d^2y}{dx^2} = W(L-x)$ [when the bending is very small the curvature *1/R* at P may be taken to be equal to $\frac{d^2y}{dx^2}$.]

Note:
Radius of Gyration: We know, moment of inertia $I = \sum mr^2 = Mk^2$ (say), where M denote the mass of the whole body and k is the dimension of length. k is called radius of gyration of the body about the axis. If we consider the whole mass of the body to be concentrated at the single point such that the moment of inertia of this concentrated point mass is same as the moment of inertia of the whole body about the axis, the distance of the single point from the axis is called the radius of gyration of the body about the axis.
$\frac{YAk^2}{R}$ *is called the moment of internal resisting couple or internal bending moment.*
Yak² is called flexural rigidity of the beam and is defined as the external bending moment required producing unit radius of curvature. It measures the resistance of the beam to bending.

On integration, we have,
$YAk^2\frac{dy}{dx} = W(Lx - \frac{x^2}{2}) + C_1$, C_1 being the integration constant.
$\frac{dy}{dx} = 0$, when $x = 0$, because at the fixed end the bar remains horizontal.
So, $C_1 = 0$.
We have, $YAk^2\frac{dy}{dx} = W(Lx - \frac{x^2}{2})$.
On further integration, we have
$YAk^2 y = W(\frac{Lx^2}{2} - \frac{x^3}{6}) + C_2$, C_2 being another integration constant.
Again, $y = 0$, when $x = 0$, and therefore, $C_2 = 0$.
So, $YAk^2 y = W(\frac{Lx^2}{2} - \frac{x^3}{6})$
This gives the expression for the depression of the beam at any point.
Now at the point of loading, $x = L$ and let l be the depression of the beam. We have, then

$$YAk^2 l = W\left(\frac{L^3}{2} - \frac{L^3}{6}\right) = \frac{WL^3}{3}$$

$$\text{Or, } l = \frac{WL^3}{3YAk^2}$$

If the beam be of rectangular cross-section of breadth a and thickness b, we have

$Ak^2 = \frac{ab^3}{12}$. Hence, $l = \frac{WL^3}{3Y\frac{ab^3}{12}} = \frac{4WL^3}{Yab^3}$

Since, W = Weight $= mg$, We have $Y = \frac{gL^3m}{4bd^3l}$

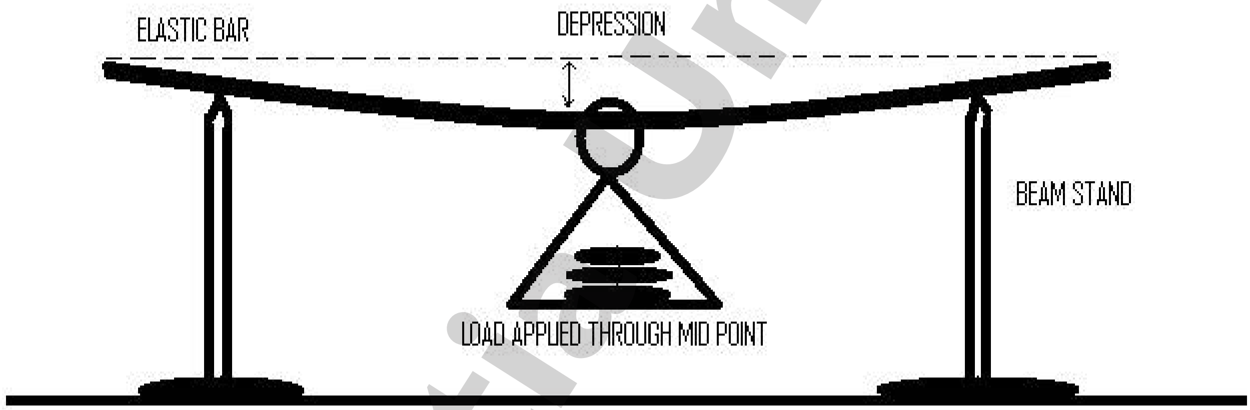
5.0 PRINCIPLE: If a light bar of breadth b and depth d is placed horizontally on two knife edges separated by a distance L, and a load of mass m , applied to the midpoint of the bar, produce a depression l of the bar, then young's modulus Y of the material of the bar is given by

$$Y = \frac{gL^3m}{4bd^3l} \qquad (1)$$

Where, g is the acceleration due to gravity. The bending moment is given by -

$$M = \frac{gL^3m}{24\,l^2+6L^2} \qquad (2)$$

The equations (1) and (2) are the working formula of the experiment.



YOUNG'S MODULUS SET-UP

6.0 TOOLS/APPARATUS REQUIRED:

- Bending bar
- Traveling microscope
- Hanger
- Two stand with knife edge
- Slotted weight
- Screw gauge
- Slide caliper
- Meter Scale

7.0 PROCEDURE: (Don't write the procedure in your Lab. Copy)

- Measure the length by a meter scale between the two points of the given bar that have to be placed on the knife edge. Mark these two points and the midpoint between them.

↓

- Determine the vernier constant of travelling microscope of travelling microscope, the vernier constant of the slide calipers, and the least count of the screw gauge, and as illustrated in respectively Table – 1, Table -2, and Table -3.

↓

- Measure the breadth of the bar by the slide caliper and depth of the bar by the screw gauge. Note down the readings for the breadth in Table – 4 and those for the depth in Table – 5.

↓

- Mount the bar on the supporting stand with the two marked points placed on the knife edge and hang a hanger that has a vertical pointer from the marked midpoint of the bar. Observe and focus the tip of the pointer of the hanger through the eyepiece of the microscope. Adjust the eyepiece vertically so that the image of the pointer touches the horizontal cross-wire of the eye-piece without any load. Note down the readings of the main scale and vernier scale attached to the vertical arm of the microscope. These readings give you the position of the pointer without any load on the hanger.

↓

- Place a load of 0.5 kg on the hanger. This will produce a depression on the bar. Again focus the tip of the pointer of the hanger through the eyepiece of the microscope and adjust the eyepiece vertically so that the image of the pointer touches the horizontal cross-wire of the eye-piece. Note down the readings of the main scale and vernier scale attached to the vertical arm of the microscope. In Table – 1 these readings give you the depressed point (x) of the pointer placed on the bar corresponding to the load of 0.5 kg.

↓

- Increase gradually the load by 0.5 kg each time and repeat the above step to determine the depressed point of the rod until load on the hanger becomes 2.5 kg.

↓

- Now start to decrease the load from the hanger. For this purpose remove the load of 0.5 kg each time and record the data until the load on the hanger becomes 0. During decreasing the load take the readings of the main scale and vernier scale attached to the vertical arm of the microscope for each time. In this way you will get the elevated position (y) of the pointer placed on the bar while the load is decreasing.

↓

- Calculate the average of x and y for each load. It will give you various values of D corresponding to different load.

↓

- From the values of D determine the depression of the rod corresponding to various loads as shown in the Table – 6.

8.0 TABULATION:

Length between the two points of the given bar placed on the knife edge (L) =

TABLE – 1A

Vernier constant ($vc1$) of travelling microscope

50 divisions (say m) of the vernier scale=49 divisions (say n) of the main scale

Value of 1 smallest main scale division (l_1) (cm)	Value of 1 division of the vernier scale $\frac{n}{m}$	Vernier constant ($vc1$) $=(1 - \frac{n}{m}) \times l_1$ (cm)

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TABLE-2
Vernier constant ($vc2$) of the slide calipers

10 divisions(say m) of the vernier scale = 9 divisions (say n) of the main scale

Value of 1 smallest main scale division (l_1) (cm)	Value of 1 division of the vernier scale $\frac{n}{m}$	Vernier constant ($vc2$) $=(1-\frac{n}{m})\times l_1$ (cm)

TABLE-3
Least count ($l.c.$) of the screw gauge

Pitch of the screw gauge is defined as the distance travelled by the circular scale for a complete rotation.

Pitch of the screw gauge p (cm)	No. of division of the circular scale n	Least count ($l.c.$) $= p/n$ (cm)

TABLE-4
Measurement of breadth (b) of the bar by slide calipers

No of obs.	Reading of the		Total reading $= m_s + v_s \times vc2$ (cm)	Mean b (cm)	Instrumental error (cm)	Correct b (cm)
	Main scale m_s (cm)	Vernier no. v_s				
1						
2						
3						

TABLE-5
Measurement of depth (d) by screw gauge

No of obs.	Reading of the		Total reading $= m_s + c_s \times l.c.$ (cm)	Mean d (cm)	Instrumental error (cm)	Correct d (cm)
	Main scale m_s (cm)	Circular scale no. c_s				
1						
2						
3						

TABLE-6
Determination of depression for various loads

No of obs.	Load m (kg.)	Microscope reading for						Avg. Microscope reading $\frac{(x+y)}{2}$ (cm)	Depression l (cm)
		Increasing load (x)			Decreasing load (y)				
		Main scale m_s (cm)	Vernier reading v_s	Total reading $= m_s + v_s \times vc1$ (cm)	Main scale m_s (cm)	Vernier reading v_s	Total reading $= m_s + v_s \times vc1$ (cm)		
1	0.0							D_0=	0.0
2	0.5							D_1=	$D_0 - D_1$=
3	1.0							D_2=	$D_0 - D_2$=
4	1.5							D_3=	$D_0 - D_3$=
5	2.0							D_4=	$D_0 - D_4$=
6	2.5							D_5=	$D_0 - D_5$=

Graph and Result

From the data of the Table – 6 plot a graph with load (m) along abscissa (x - axis) and depression (l) along vertices (y – axis). Determine the values of m and l from the graph. There from calculate the value of the Young's modulus and Bending Moment as illustrated in Table -7.

TABLE-7
Determination of Young's Modulus and Bending Moment

Value of g m/sec^2 (supplied)	Value of L (m)	Value of b (m)	Value of d (m)	Value of m from graph (kg.)	Value of l from graph (m)	Young's Modulus $Y = \frac{gL^3m}{4bd^3l}$ N/m^2	Bending Moment $M = \frac{gL^3m}{24\,l^2 + 6L^2}$ (J)	Mean Young's Modulus Y N/m^2	Mean Bending Moment M (J)

IDEAL VALUE OF ***Y*****:** in SI unit 2×10^{11} N/m^2 and in cgs unit 2×10^{12} dyne/cm^2

9.0 COMPUTATION OF PERCENTAGE ERROR:

We have the formula for

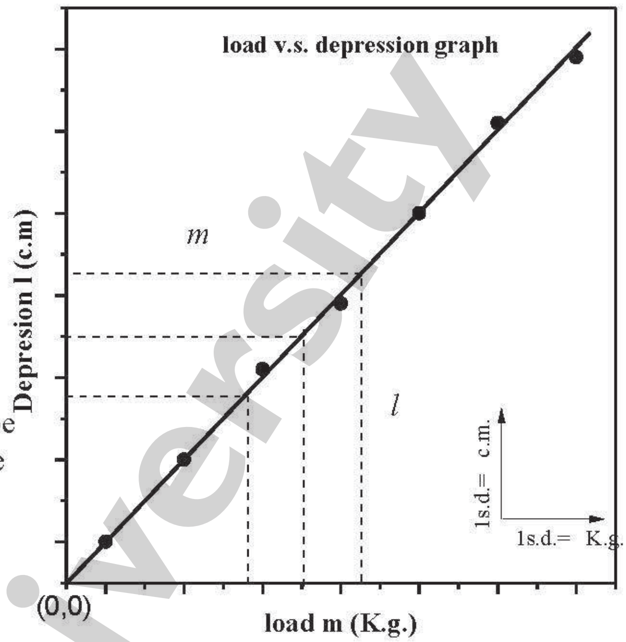
Young's Modulus as: $Y = \frac{gL^3 m}{4bd^3 l}$

Taking ln in both sides we get,

$\ln Y = \ln g + 3\ln L + \ln m - \ln 4 - \ln b - 3\ln d - \ln l$

Differential both sides we get for maximum proportional error, $\frac{\partial Y}{Y} = \frac{\partial b}{b} + \frac{3\partial d}{d} + \frac{\partial l}{l}$

(For maximum proportional error the negative signs will be converted into positive signs. As L is given, g, m and 4 are constants; they will be eliminated from the equation after differentiation.)



Now,

δb= error in measuring b

= $v.c.$ of the slide calipers ($vc2$) (because probability of making error is in one side)

δd= error in measuring d

= Least count ($l.c.$) of the screw gauge (because probability of making error is in one side)

δl= error in measuring l

= 2 × $v.c.$ of the traveling microscope ($vc1$) (because probability of making error is both sides as we are subtracting two readings)

Putting suitable values calculate the value of proportional error.

Hence, the percentage error is ($\frac{\partial Y}{Y}$ × 100) % (Put the values and calculate the percentage error.

DISCUSSION:

You have to write all the difficulties you faced during the experiment and their remedies. Also you have to think and to mention some way out that one should adopt during the practical for getting a better result.

References

1) GENERAL PROPERTIES OF MATTER – Sengupta & Chattrjee
2) MECHANICS – Gupta & Kumar
3) MECHANICS - Spiegel
4) ADVANCED PRACTICAL PHYSICS- Ghosh & Majumdar

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WORK INSTRUCTION

1.0 Experiment No: BS/PHP101/07

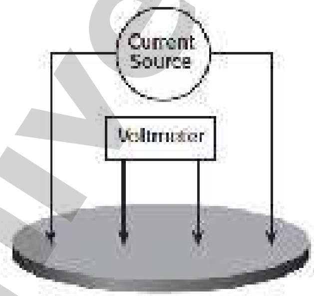
2.0 Name of Experiment: Study Band-Gap OF 'SEMICONDUCTOR'

3.0 Aim: MEASUREMENT OF RESISTIVITY BY USING A DIRECT READING POTENTIOMETER AND TO FIND BAND-GAP OF a 'SEMICONDUCTOR' SAMPLE

4.0 Principle: The crystal or sample has four individually spring loaded probes coated with Zn at tips. The probes are co-liner and equally spread. The Zn coating and individual spring ensure good electrical contacts with the sample. The probes are mounted in a Teflon bush which ensures a good electric flow between the probes. A Teflon spacer near the tips also is provided to keep the probes at stand and leads are provided for current and voltage measurement.

The resistivity of a sample in a four-probe is given by-

$$\rho_0 = \frac{V}{I} 2\pi S$$



Where, V is Potential across voltage probe
I is Constant current through sample
S is distance between probes
ρ_0 is the of resistivity of a material

If ρ be resistivity and E_g be the band gap, then for a particular temperature T, resistivity of a material is given by $\rho = Ae^{E_g/2KT}$, Where K is Boltzmann constant.

So, $\ln \rho = \ln A + E_g / 2KT$

$$E_g = \frac{2K \ln \rho}{1/T} + A$$

The slop of the graph between $\ln \rho$ vs. 1/T is equal to $\frac{E_g}{2K}$. From that E_g can be calculated.

If the two edges of the sample are at a distance of x_1 and x_2 from the probes, then the correction factor would be respectively $G_7(x_1/S)$ and $G_7(x_2/S)$.

Therefore the total correction factor for all the probes becomes

$F = G_7(w/S).G_7(x_1/S).G_7(x_2/S)$; Where w is width of the sample.

$G_7(X/S)$ can be approximated as, $G_7(X/S) = 2\frac{S}{X}\ln 2$,

Therefore, $F = 2\frac{S}{w}\ln 2 \times 2\frac{S}{x_1}\ln 2 \times 2\frac{S}{x_2}\ln 2$

With correction term we get the expression for corrected resistivity as

$$\rho = \frac{V}{I} 2\pi S \frac{1}{F} = \frac{\rho_0}{F}$$

5.0 Apparatus required:

Four probe arrangement
Semiconductor plate
Oven
Oven Controller
Digital Current Voltage Meter

6.0 PROCEDURE: (Don't write the procedure in your Lab. Copy)

Switch on the temperature and approx adjust the set temperature

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LED would light up indicating the oven is on and the temperature would rising

↓

The controller of the oven would switch on off power corresponding to set temperature

↓

Set the current. For a particular set temperature now note the reading of voltage

↓

From the experimental formula calculate the value of resistivity

↓

Draw a graph to show the variation of resistivity constant with temperature

7.0 Tabulation:

TABLE-1

Table to take temperature vs voltage reading at a constant current

Sample supplied ………..
Room temp=
Current through probe (I)= mA
S= 2.17 mm
w= 0.5 mm
x_1= 2.25 mm
x_2= 2.25 mm

Correction factor $F = 2\frac{S}{w}\ln 2 \times 2\frac{S}{x_1}\ln 2 \times 2\frac{S}{x_2}\ln 2 =$

Serial No.	Temp. (^{o}C)	Temp in (K)	1/T in ($K^{-1}x10^{-3}$)	Voltage when temperature is		Mean Voltage (mV)	Resistivity $\rho_0 = \frac{V}{I}2\pi S$ (ohm-c.m.)	Resistivity $\rho = \frac{\rho_0}{F}$ (ohm-c.m.)	$\ln\rho$
				Increasing (mV)	Decreasing (mV)				

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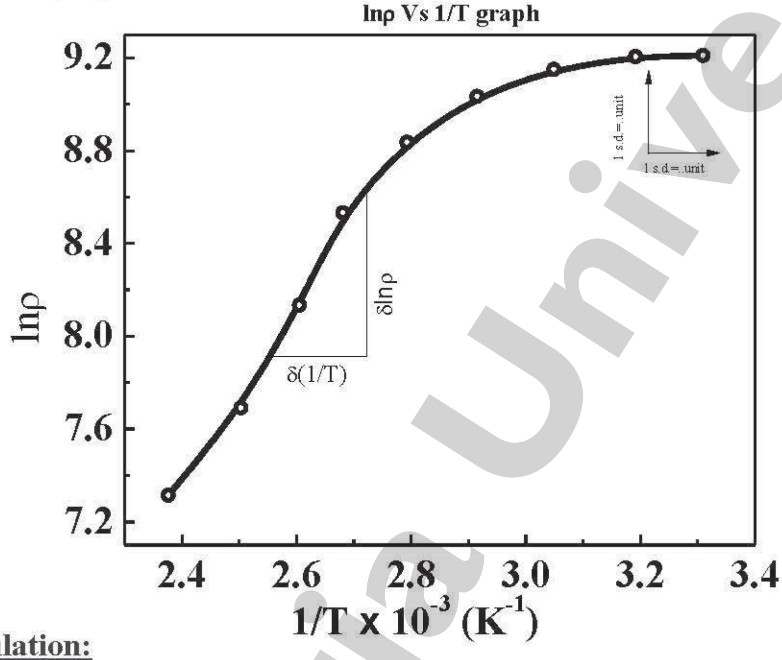
TABLE-2

DETERMINATION OF BAND GAP

Value of $\Delta \ln \rho$ from graph	Value of $\Delta(1/T) \times 10^{-3}$ from graph (K^{-1})	Value of slope (K)	Band gap $E_g = slope \times 2K$ (eV)

Graph: Draw a graph : 1/T along X-axis & $\ln \rho$ along Y-axis

lnρ Vs 1/T graph



8.0 Error calculation:

We have the experimental formula of band gap as

$$\rho = \frac{V}{I} 2\pi S \frac{1}{F}$$

Taking ln both sides we get,

$$\ln \rho = \ln V + \ln 2 + \ln \pi + \ln S + \ln 1 - \ln I - \ln F$$

After diff. we get $\frac{\delta\rho}{\rho} = \frac{\delta V}{V} + \frac{\delta I}{I}$

Other terms will vanish after diff. as they are constants

δV = error in measuring V=smallest division of the voltmeter.

δI = error in measuring I=smallest division of the ammeter

(Because probability of making error is in one side)

Hence, the percentage error is $\{\frac{\partial\rho}{\rho} \times 100\}\%$

9.0 Discussion:

You have to write all the difficulties you faced during the experiment and their remedies. Also you have to mention some way out that one should adopt during the practical to have a better result.

Viva voice: go through the chapter of Hall effect from these books.

1) Solid State Physics – S. O. Pillai
2) Solid State Physics – Kittle

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<u>WORK INSTRUCTION</u>

1.0 EXPERIMENT NO: BS/PHP101/09

2.0 NAME OF EXPERIMENT: Carey Foster Bridge

3.0 0BJECTIVE: Determination of unknown resistance by Carey Foster Bridge

4.0 THEORITICAL BACKGROUND

Post Office Box:

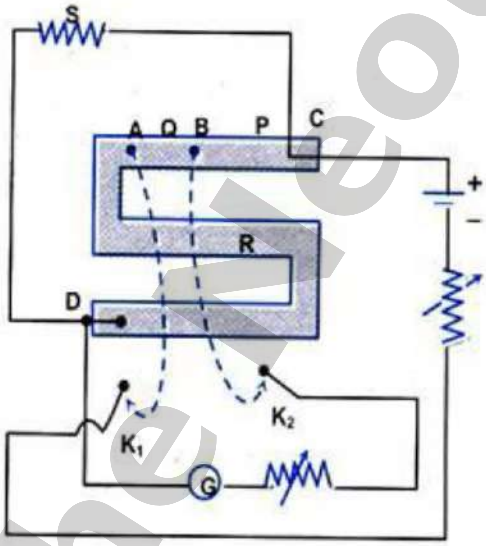
The Post Office Box was a Wheatstone bridge style testing device with pegs and spring arms to close electrical circuits and measure properties of the circuit under test. The boxes were used in the United Kingdom by engineers from the then General Post Office, who were responsible for UK telecommunications to trace electrical faults, i.e. to determine where a break occurred in a cable which could be several miles in length. It works on the principle of Wheatstone bridge to identify the resistance of wire connected and then by using wire resistivity and cross section calculating length of wire and thus determining where cable had broken.

A Post Office Box can also be used to measure an unknown resistance. It is a Wheatstone Bridge with three arms P, Q and R; while the fourth arm(s) is the unknown resistance. P and Q are known as the ratio arms while R is known as the rheostat arm.

At balance, the unknown resistance

$$S = (P/Q)\,R \qquad \ldots\ldots (1)$$

The ratio arms are first adjusted so that they carry 100 W each. The resistance in the rheostat arm is now adjusted so that the galvanometer deflection is in one direction. If $R = R_0$ (ohm) and $R = R_0 + 1$ (ohm) are the resistance in rheostat arm, for which the deflection in galvanometer is in opposite direction, then it implies that the unknown resistance 's' lies between R_0 & $(R_0 + 1)$ ohm.



Resistance-using-post-office-box

Now, the resistance in P and Q are made 100 W and 1000 W, respectively, and the process is repeated. Equation (1) is used to compute S. The ratio P/Q is progressively made 1:10, and then 1:100. Thus, the resistance S can be accurately measured.

Some points to note down:

Balance point (of a Carey Foster bridge): A point on the bridge wire that produces zero deflection in the galvanometer when the jockey knife edge is in contact with it. Also known as a **null point**.

Carey Foster Bridge: a bridge based on the principle of Wheat stone's bridge that is used to compare two nearly equal resistances and to determine values of low resistances and the specific resistance of a wire. It differs from a meter bridge because additional resistances of similar magnitudes are included at either end of the meter wire.

end correction (for a Carey Foster bridge): A small resistance that includes contributions from the finite resistance of the fixed copper strips within a Carey Foster bridge, the resistance at the junctions of the bridge wire with the copper strips and the effects of the non coincidence of the ends of the wire with the zero and one hundred division marks on the scale.

Fractional resistance box: A box containing a number of fixed small resistance coils (0.1-1.0 Ω or 0.01-0.1 Ω), so mounted that any number of these resistance coils can be connected in series.

Galvanometer: An instrument used to detect current. In the Carey Foster bridge experiments, a very sensitive galvanometer is used, with zero current corresponding to the center of the scale.

jockey: A metal knife edge mounted in plastic handle that can move along the bridge wire of a Carey Foster bridge and is used to locate the null point. Pressing on the jockey makes a point contact with the bridge wire.

low resistance: A resistance in the range of 1-5 ohm.

meter bridge: The most commonly used form of the Wheatstone's bridge. It includes a uniform 1m long wire fixed on a wooden board, and it can be used for comparison of the values of two similar resistances.

null point (of a Carey Foster bridge): A point on the bridge wire that produces zero deflection in the galvanometer when the jockey knife edge is in contact with it. Also known as a **balance point**.

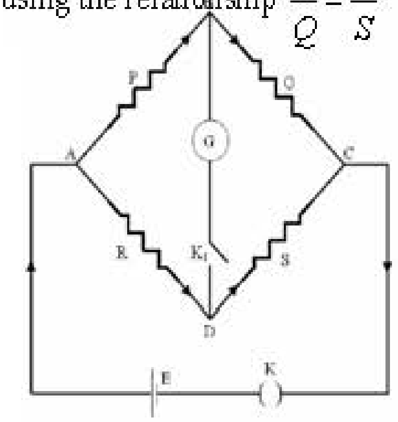
post office box: A compact form of Wheatstone's bridge in which two of the arms contain resistances of 10, 100 or 1000 Ω. A third arm contains resistances from 1-5000 Ω, and an unknown resistance can be connected in the fourth arm. Tapping keys are provided for connections to a galvanometer and battery.

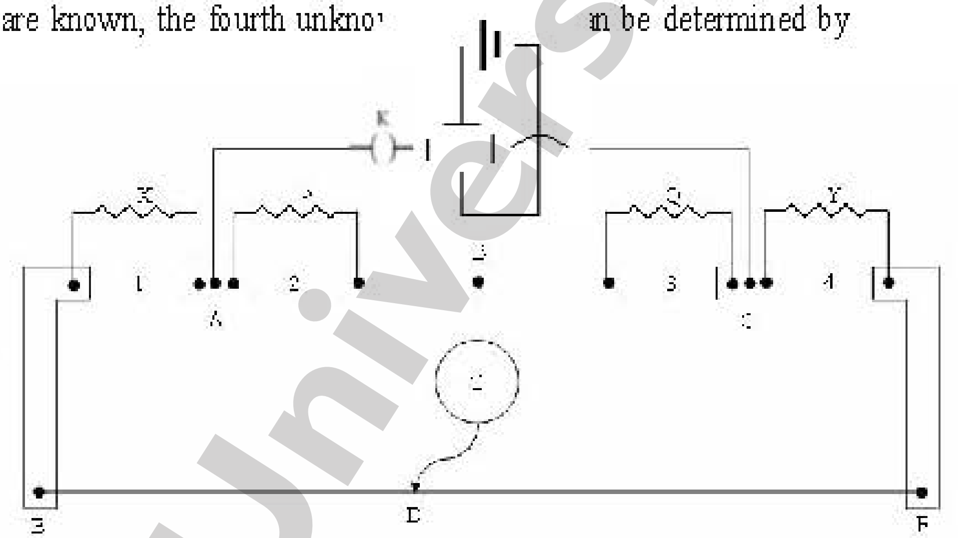
resistance: The opposition offered to the flow of current by an object. If a current I flows through an object when a potential difference V is connected across it, then the resistance R is given by $R = V/I$. The SI unit of resistance is the ohm, Ω.

specific resistance (of a wire): The resistance per unit length of the wire. In SI units, this is measured in Ω m-1.

Wheatstone's bridge: A bridge circuit (depicted in Figure 1) that comprises four resistances P, Q, R and S joined together to form a quadrilateral, with a battery connected across terminals at two opposite corners of the quadrilateral and a galvanometer between the other two corners. When the bridge is balanced (no current through the galvanometer), then $P/Q = R/S$.

5.0 PRINCIPLE: The Carey Foster Bridge is an electrical circuit that can be used to measure very small resistances. It works on the same principle as Wheatstone's bridge works. Wheatstone's bridge consists of four resistances, P, Q, R and S that are connected to each other as shown in the circuit diagram. In this circuit, G is a galvanometer. If the values of the resistances are adjusted so that no current flows through the galvanometer, then if any three of the resistances P, Q, R and S are known, the fourth unkno[illegible]n be determined by using the relationship $\frac{P}{Q}=\frac{R}{S}$





In the above circuit diagram the four points A, B, C and D of the Carey Foster bridge (right) exactly correspond to the points labeled A, B, C and D in the circuit diagram of Wheatstone's bridge (left). In this way the Carey Foster Bridge effectively works like a Wheatstone's bridge. If the balance point is located at a distance l_1 from E, then we can write the condition of balance as

$$\frac{P}{Q}=\frac{R}{S}=\frac{X+\alpha+l_1\rho}{Y+\beta+(100-l_1)\rho}$$

Where ρ is resistance per unit length of wire of the meter bridge and α and β are the end corrections at the left and right ends. These end corrections include the resistances of the metal strips to which the wire is soldered, the contact resistances between the wire and the strips, and they also allow for the non-coincidence of the ends of the wire with the zero and one hundred division marks on the scale.

If the positions of X and Y are interchanged, i.e., X is put in gap 4 and Y in gap 1, and the balance point is found at a distance l_2 from E, then the balance condition becomes,

$$\frac{P}{Q}=\frac{R}{S}=\frac{Y+\alpha+l_2\rho}{X+\beta+(100-l_2)\rho}$$

Adding 1 in both sides of each equation and equating them we get-

$$\frac{P+Q}{Q}=\frac{X+Y+\alpha+\beta+100\rho}{Y+\beta+(100-l_1)\rho}=\frac{X+Y+\alpha+\beta+100\rho}{X+\beta+(100-l_2)\rho}$$

Since the numerators are equal, we can write, $Y+\beta+(100-l_1)\rho=X+\beta+(100-l_2)\rho$

So, $\boldsymbol{\rho}=\frac{X-Y}{l_2-l_1}$ and $Y=X-\rho(l_2-l_1)$

Thus, $\boldsymbol{\rho}=\frac{\boldsymbol{X}}{\boldsymbol{l_2-l_1}}$, when Y=0

Thus if Y is short circuit (say putting a copper strip in this gap) then we can measure the value of ρ and hence any unknown resistance.

6.0 TOOLS/APPARATUS REQUIRED:

- Meter Bridge
- Two Equal Resistances Of About 2 Ohms Each
- Thick Copper Strip
- Fractional Resistance Box
- Commutator
- Galvanometer/null detector
- Unknown Low Resistance
- One Way Key
- Connecting Wires

7.0 PROCEDURE:

7.1 Determination of resistance per unit length, ρ, of the Carey Foster bridge wire:

- Make the circuit connections as shown. Place a copper strip in the gape 4

↓

- Plug in the battery key so that a current flows through the bridge. Note that you should remove the battery key and make the circuit open when you are not taking any measurements.

↓

- Press down the jockey so that the knife edge makes contact with the wire, and observe the galvanometer deflection. Release the jockey.

↓

- Move the jockey to different positions along the wire to locate the position of the null point, where there is no deflection of the galvanometer. This point should be near the middle of the bridge wire when X=0

↓

- Fix a certain resistance of the fractional resistance box (X) [say 2 Ω or 1.8 Ω] and note the balancing length l_1 for direct as well as reverse current. You can change the direct current to the reverse current by using commutator. Similarly note down the balancing length l_1 for other values of X by decreasing it in steps of 0.2 Ω. Record your observations in Table – 1.

↓

- Interchange the copper strip and X, and repeat the previous step for the same set of resistances. In this case the balancing length has to be denoted by l_2. The measurement of l_2 should be done from the same side of the meter bridge. Record the values of l_2 also in the Table – 1.

7.2 Determination of an unknown low resistance Y:

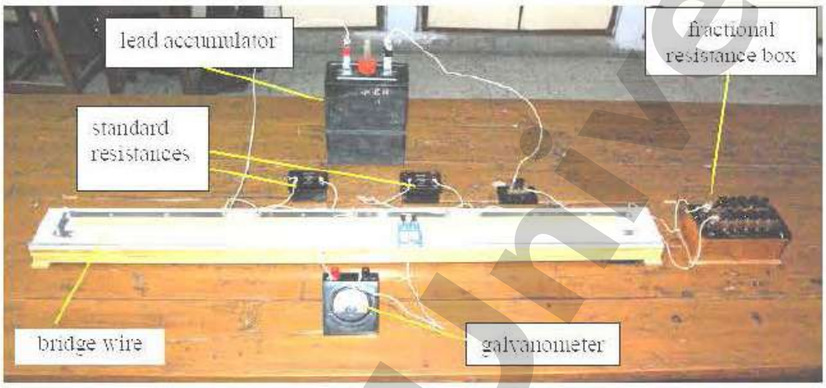
- Remove the copper strip and insert the unknown low resistance (Y) in the gap 4 and fractional resistance box (X) in the gap 1.

↓

- Repeat the step 5 of previous part. Record your observation in Table -2

↓

- Interchange Y and X, and repeat the step 6 of the previous part. Record your observation in Table -2.



8.0 TABULATION:

TABLE – 1

Determination of resistance per unit length, ρ, of the Carey Foster bridge wire:

Y = 0

No. of obs.	X in Ohm	Position of the null point when the copper strip is in						$(l_2 - l_1)$ (cm)	Value of X from graph Ohm	Value of $(l_2 - l_1)$ from graph (cm)	$\rho = \frac{X}{l_2 - l_1}$ Ohm/cm
		Extreme right gap 4 (l_1) (cm)			Extreme left gap 1 (l_2) (cm)						
		Direct current (cm)	Reverse current (cm)	Mean (cm) (l_1)	Direct current (cm)	Reverse current (cm)	Mean (cm) (l_2)				
1											
2											
3											
4											
5											

Result and Graph:

Draw a graph showing the variation of X and $(l_2 - l_1)$. Plot X along the abscissa (x-axis) and $(l_2 - l_1)$ along vertices (y-axis). Determine values of X and $(l_2 - l_1)$ from the graph and therefrom determine ρ, resistance per unit length of wire of the meter bridge.

TABLE - 2

Determination of an unknown low resistance Y:

No. of obs.	X in Ohm	Position of the null point when the unknown resistance is inserted						$(l_2 - l_1)$ (cm)	Value of X from graph Ohm	Value of $(l_2 - l_1)$ from graph (cm)	Y= $X - \rho(l_2 - l_1)$ Ohm
		Extreme right gap 4 (l_1) (cm)			Extreme left gap 1 (l_2) (cm)						
		Direct current (cm)	Reverse current (cm)	Mean (cm) (l_1)	Direct current (cm)	Reverse current (cm)	Mean (cm) (l_2)				
1											
2											
3											
4											
5											

Result and Graph:

Draw a graph showing the variation of X and $(l_2 - l_1)$. Plot X along the abscissa (x-axis) and $(l_2 - l_1)$ along vertices (y-axis). Determine values of X and $(l_2 - l_1)$ from the graph and there from determine the unknown resistance, Y.

9.0 COMPUTATION OF PERCENTAGE ERROR:

We know, $Y = X - \rho(l_2 - l_1)$

or, $Y = X - \rho \Delta l_2$

or, $Y = X - \frac{x}{\Delta l_1} \Delta l_2$

or, $Y = X(1 - \frac{\Delta l_2}{\Delta l_1})$

or, $Y = X(\frac{\Delta l_1 - \Delta l_2}{\Delta l_1})$

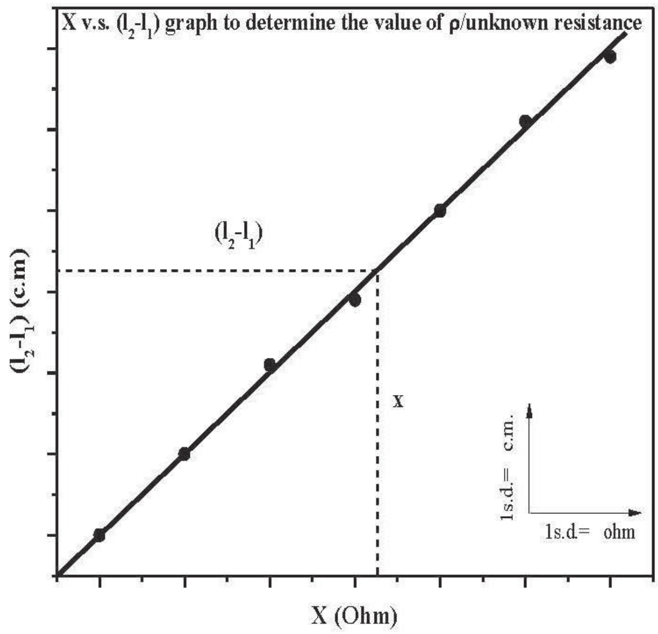
Taking logarithm on both sides

$\ln Y = \ln X + \ln(\Delta l_1 - \Delta l_2) - \ln \Delta l_1$

Differentiating both sides

$$\frac{\partial Y}{Y} = \frac{\partial X}{X} + \frac{\partial(\Delta l_1 - \Delta l_2)}{\Delta l_1 - \Delta l_2} - \frac{\partial(\Delta l_1)}{\Delta l_1}$$

As we are calculating maximum error so negative signs are made +ve



$$\frac{\partial Y}{Y} = \frac{\partial X}{X} + \frac{2\partial l + 2\partial l}{\Delta l_1 - \Delta l_2} + \frac{2\partial l}{\Delta l_1}$$

$$\frac{\partial Y}{Y} = \frac{\partial X}{X} + \frac{4\partial l}{\Delta l_1 - \Delta l_2} + \frac{2\partial l}{\Delta l_1}$$

Hence, the percentage error is $\left(\frac{\partial Y}{Y} \times 100\right)\%$

(Put the value of proportional error and calculate the percentage error)

10.0 DISCUSSION:

As stated earlier.

References

1) ELECTRICITY AND MAGNETISM - Rakshit, Chatterjee
2) ADVANCED PRACTICAL PHYSICS- Ghosh & Majumdar

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WORK INSTRUCTION

1.0 Experiment No: BS/PHP101/06
2.0 Name of Experiment: Study Dielectric Constant & Curie Temperature
3.0 Aim: Determination Dielectric Constant & Curie Temperature of Ferroelectric Ceramics
4.0 Principle: Dielectric or electrical insulating materials are understood as the materials in which electrostatic fields can persist for a long time. These materials offer very high resistance to passage of electric current under the action of applied direct current voltage and therefore sharply differ in their basic electrical properties from conductive materials. Layers of such substances are commonly inserted into capacitance to improve their performance, and the term dielectric refers specifically to this application

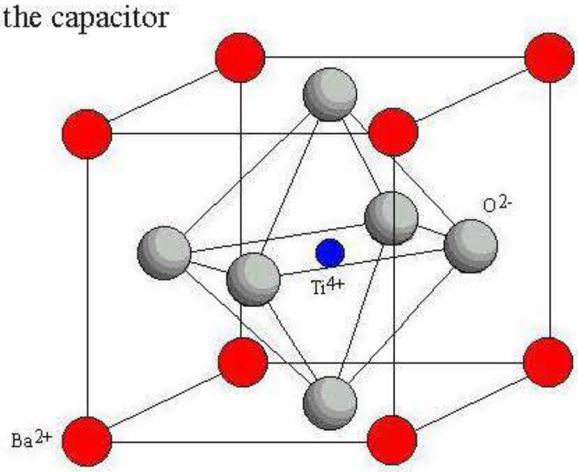
PEROVSKITE STRUCTURE
Perovskite is a family name of a group of materials and the mineral name of calcium titanate ($CaTiO_3$) having a structure of the type ABO_3. Many piezoelectric (including ferroelectric) ceramics such as Barium Titanate ($BaTiO_3$), Lead Titanate ($PbTiO_3$), Lead Zirconate Titanate (PZT), Lead Lanthanum Ziconate Titanate (PLZT), Lead Magnesium Niobate (PMN), Potassium Niobate ($KNbO_3$), etc. have a cube perovskite type structure (in the paraelectric state) with chemical formula ABO_3.

BARIUM TITANATE ($BaTiO_3$)
Barium Titanate ($BaTiO_3$) has a ferroelectric tetragonal phase below its curie point of about $120^{\circ}C$ and paraelectric cubic phase above Curie point. The temperature of the curie point appreciably depends on the impurities present in the sample and the synthesis process.

DIELECTRIC CONSTANT
The dielectric constant (ε) of a dielectric material can be defined as the ratio of the capacitance using that material as the dielectric in capacitor to the capacitance using a vacuum as dielectric.

Dielectric constant (ε) is given by $\varepsilon = \dfrac{C}{C_0}$ where $C_0 = \dfrac{\varepsilon_0 A}{t}$

C = Capacitance using the material as the dielectric in the capacitor
C_0 = Capacitance using vacuum as the dielectric
ε_0 = Permittivity of free space (8.85×10^{-12} F/m).
A = Area of the plate /sample cross section area.
t = Separation between two plates of the capacitor having vacuum as dielectric



5.0 Apparatus required:
- Two probe arrangement
- Barium Titanate ($BaTiO_3$) plate
- Oven
- Oven Controller
- Digital Capacitance Meter

<u>**6.0 PROCEDURE:**</u> (Don't write the procedure in your Lab. Copy)

- Calculate C_0 with the supplied values of A, ε_0 and t.

↓

- Switch on the heater. Rotate the temperature controlling knob by one division. The LED will be illuminated which indicates the oven is on and the temperature increases.

↓

- Note down the increasing temperatures and corresponding capacitance (C) in the Table – 1 until a certain final temperature is attained and the LED gets off. If this temperature is not appreciably high, rotate temperature controlling knob by one more division. The LED will be illuminated again and the temperature of the oven increases further.

↓

- Again start to note down the increasing temperatures and corresponding capacitance in the Table – 1. Each time from the formula calculate the value of dielectric constant

↓

- Continue the above steps until you have an appreciable high temperature (say 180°C)

↓

- Draw a graph to show the variation of dielectric constant with temperature (Temperature is along x-axis and Dielectric along y-axis.) From the graph determine the Curie temperature where the dielectric constant is maximum

7.0 <u>Tabulation:</u>

Sample: Barium Titanate ($BaTiO_3$) Area (A): 57.15 mm^2 Thickness (t): 1.67 mm
Permittivity of Space (ε_0): 8.85×10^{-12} F/m or 8.85×10^{-3} pf/mm

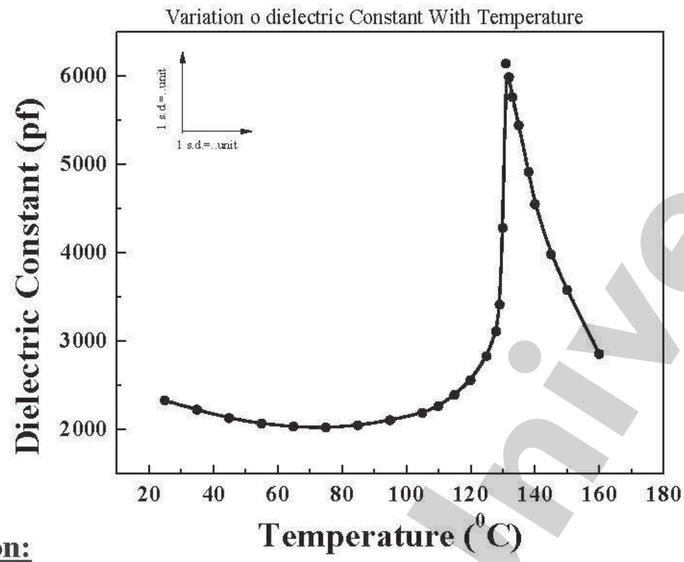
Dielectric Constant $\varepsilon = \dfrac{C}{C_0}$ where $C_0 = \dfrac{\varepsilon_0 A}{t}$ =…………………………….pf

<u>TABLE-1</u>

Temperature (°C) - Capacitance, C (pf) data

Sl.No.	Temperature (°C)	Capacitance C (pf)	Dielectric Constant (ε) = C/C_0
1	25		
2	35		
..			
..	95		
..	100		
..	105		
..			
..	125		
..	128		
..	129		
..	130		
..	..		
..	136		
..	138		
..	140		
..	145		
..	..		
..	180		

Curie temperature (From Graph) = $\quad\quad\quad\quad$ ^{o}C



8.0 Error calculation:

We have the formula for the Dielectric constant as $\varepsilon = \frac{C}{C_0}$ where $C_0 = \frac{\varepsilon_0 A}{t} = ...pf$

So, $\varepsilon = \frac{Ct}{\varepsilon_0 A}$

Taking ln in both sides we get, $\ln \varepsilon = \ln C + \ln t - \ln \varepsilon_0 - \ln A$

Differentiating we get for maximum proportional error,

$$\frac{\delta\varepsilon}{\varepsilon} = \frac{\delta C}{C}$$

(Rest of the term will be zero as t, ε_0, and A are constants and differentiation of these terms will vanish)

δC= error in measuring C
= smallest division of the capacitance meter.
(Because probability of making error is in one side)

Hence, the percentage error is $\left(\frac{\partial\varepsilon}{\varepsilon} \text{ x } 100\right)\%$

9.0 Discussion :

You have to write all the difficulties you faced during the experiment and their remedies. Also you have to mention some way out that one should adopt during the practical to have a better result.

References

1) Solid State Physics – S. O. Pillai
2) Solid State Physics – Kittle
3) Solid State Physics – Dekker
4) Feynman Lecture Vol. 2.

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WORK INSTRUCTION

1.0 EXPERIMENT NO: BS/PHP101/03

2.0 NAME OF EXPERIMENT: DISPERSIVE POWER

3.0 OBJECTIVE: DETERMINATION OF DISPERSIVE POWER OF THE MATERIAL OF A PRISM

4.0 PRINCIPLE: If A is the angle of the prism and ∂_m is the minimum deviation of a ray of monochromatic light refracted through the prism in a principle section, then the refractive index of the material of the prism μ_λ for the light of the given wavelength is expressed by

$$\mu_\lambda = \frac{\sin\frac{(A+\delta_m)}{2}}{\sin\frac{A}{2}} \quad \text{.....................} \ (1)$$

if μ_1 and μ_2 are the refractive indices of the material of the prism for lights of two given colours and μ is the refractive index of the material for the mean colour between the two given colours, then the dispersive power of the material of the prism ω between the wavelength region considered is given by

$$\omega = \frac{\mu_1 \sim \mu_2}{\mu - 1} \quad \text{.....................} \ (2)$$

Equations (1) & (2) are used as the working formula for the determination of the dispersive power of the material of a prism.

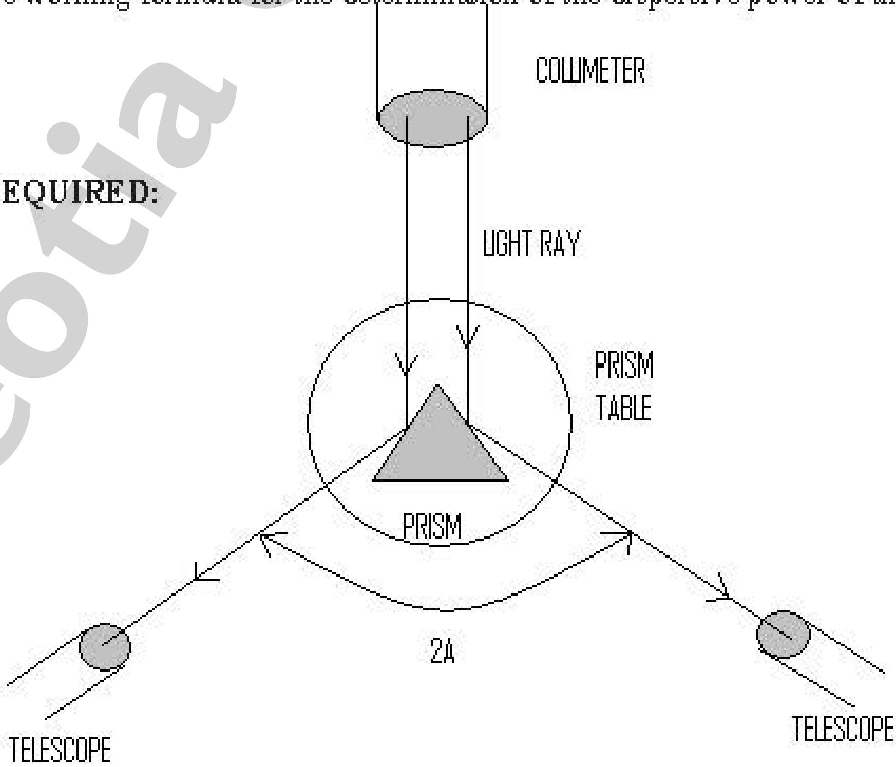
5.0 TOOLS/APPARATUS REQUIRED:

5.1 Spectrometer

5.2 Mercury lamp

5.3 Prism

5.4 Sprit level



DISPERSIVE POWER SET - UP

Procedure :

Using spirit level, level the base of the spectrometer, prism table, telescope and collimator.

↓

At the minimum deviation position of prism for yellow line, adjust the telescope and collimator for parallel rays

↓

Determine the vernier constant (V.C.) of the spectrometer

↓

Place the prism perpendicular to the collimator axis

↓

There will be two refracted images in two sides of the prism

↓

Touching the cross-wire on the image in both sides and take the reading of two vernier position
Determine the angle (A) of the prism from tab. 2

↓

Place the prism at the minimum deviation position and take the reading of two vernier position for three different colours

↓

Take direct reading of the telescope

↓

Determine the angle of minimum deviation from tab. – 5

↓

Determine the refractive index of three different colours

↓

Determine the dispersive power of the material of the prism using equn. – 2

Tabulation:

TABLE-1

Determination of vernier constant (V.C.) of the spectrometer

…… divisions(say m) of the vernier scale=…… divisions (say n) of the main scale

Value of 1 smallest circular scale division (l_1) (min/sec)	Value of 1 division of the vernier scale $\frac{n}{m}$ (min/sec)	Vernier constant of the spectrometer v.c. $(1-\frac{n}{m}) \times l_1$ (min/sec)

TABLE-2

Determination of the angle (A) of the prism

Vernier scale	Reading of the 1^{st} position of the telescope			Reading of the 2^{nd} position of the telescope			2A = (a ~ b) (deg)	Mean 2A (deg)	Angle (A) of the prism (deg)
	Main scale reading m_s (deg)	Vernier no. v_s	Total $m_s + v_s$ x v.c (deg). (a)	Main scale reading m_s (deg)	Vernier no. v_s	Total $m_s + v_s$ x v.c (deg). (b)			
1^{st} Vernier									
2^{nd} Vernier									

TABLE-3

Reading of the telescope at the position of minimum deviation :

Colour of the line	Vernier scale	No. of obs.	Main scale reading m_s (deg)	Vernier no. v_s	Total $m_s + v_s$ x v.c (deg).	Mean reading (deg).
Red	1^{st} Vernier	1				d_1
		2				
		3				
	2^{nd} Vernier	1				d_2
		2				
		3				
Yellow	1^{st} Vernier	1				d_3
		2				
		3				
	2^{nd} Vernier	1				d_4
		2				
		3				
Blue	1^{st} Vernier	1				d_5
		2				
		3				
	2^{nd} Vernier	1				d_6
		2				
		3				

TABLE-4

Direct reading of the telescope:

Vernier scale	No. of obs.	Main scale reading m_s (deg)	Vernier no. v_s	Total $m_s + v_s$ x v.c (deg).	Mean reading (deg).
1^{st} Vernier	1				d_7
	2				
	3				
2^{nd} Vernier	1				d_8
	2				
	3				

TABLE-5

Determination of angle of minimum deviation:

Colour of the line	Angle of minimum deviation δ_m (deg).		Mean δ_m (deg).
	1^{st} Vernier	2^{nd} Vernier	
Red	$d_1 \sim d_7$	$d_2 \sim d_8$	
Yellow	$d_3 \sim d_7$	$d_4 \sim d_8$	
Blue	$d_5 \sim d_7$	$d_6 \sim d_8$	

TABLE-6

Determination of dispersive power of the material of the prism:

Angle (A) of the prism (deg	Colour of the line	δ_m (deg).	Refractive index	Dispersive power $\omega = (\mu_1 \sim \mu_2)/(\mu-1)$
	Red		μ_1	
	Yellow		μ	
	Blue		μ_2	

Discussion:

You have to write all the difficulties you faced during the experiment and their remedies. Also you have to mention some way out that one should adopt during the practical to have a better result.

Viva voice: go through the chapter of young's modulus and elasticity from these books.

1) OPTICS - Ghatak
2) OPTICS – K. G. Majumdar
3) ADVANCED PRACTICAL PHYSICS- Ghosh & Majumdar
4) PRACTICAL PHYSICS- Rakshit, Chatterjee & Saha

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WORK INSTRUCTION

1.0 EXPERIMENT NO: BS/PHP101/04
2.0 NAME OF EXPERIMENT: Laser Diffraction
3.0 OBJECTIVE: Determination of wavelength of monochromatic light by laser diffraction method
4.0 THEORITICAL BACKGROUND:

(A) **What is diffraction?**

When a light passes through a small aperture whose dimensions are comparable with the 'λ'(wavelength) of light then light deviates from its rectilinear path and bends round the corner of the placed aperture of its geometrical shadow, this phenomenon is called ***diffraction***.

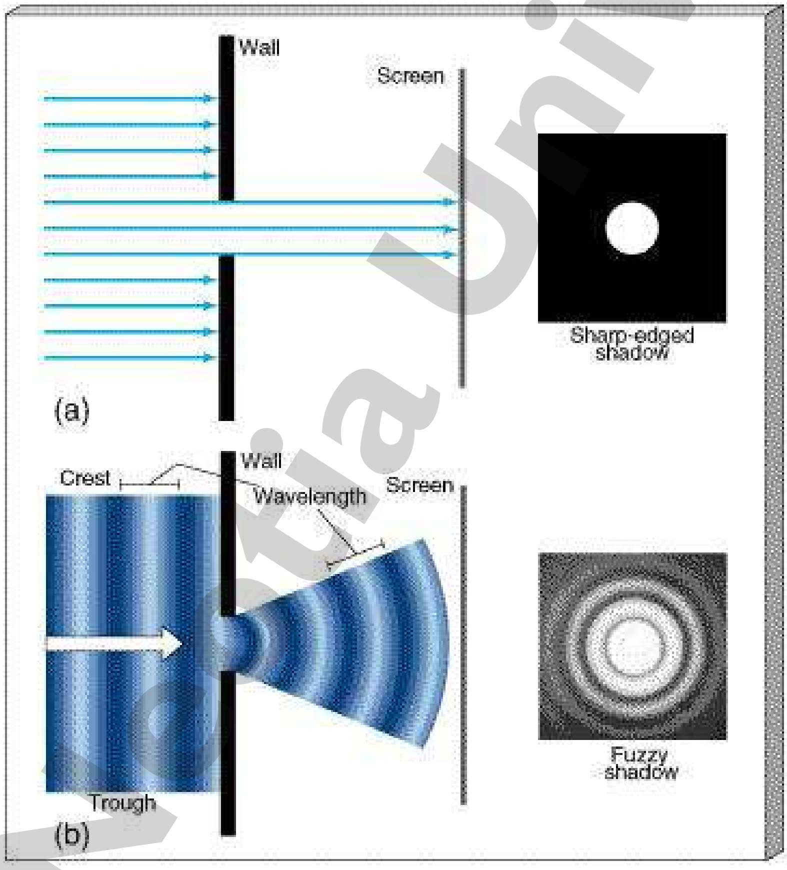


Figure 1.

If the source and the screen are placed effectively at infinite distance from the diffracting element it forms a class of **Fraunhoffer** diffraction and if the source and screen are placed at finite distance then **Fresnel**'s class observed.

(B) What is grating?

A diffraction grating consists of a number of closely spaced parallel lines ruled on a glass surface. A diffraction grating can be simply thought of as a set of identical and equally spaced slits separated by opaque strips. In reality gratings are made by ruling fine grooves by a diamond point either on a plane glass surface to produce a transmission grating or on a metal mirror to produce a reflection grating (see figure 2). In a transmission grating the grooves scatter light and so are opaque while the unruled surfaces transmit and act like slits. Typically a high quality grating (used for studying spectra in the visible range) has about 15000 grooves per inch, which gives a slit spacing of the order of a micron.

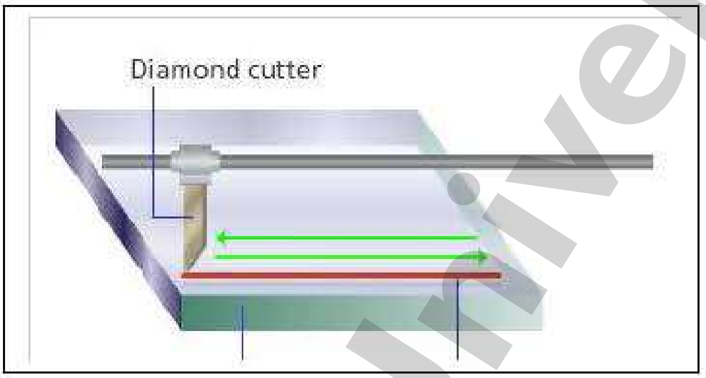


Figure 2: Construction of grating

It is a useful device for separating out the various wavelengths in a spectrum. It has the same effect as a prism but with greater resolving power (see fig. 3).

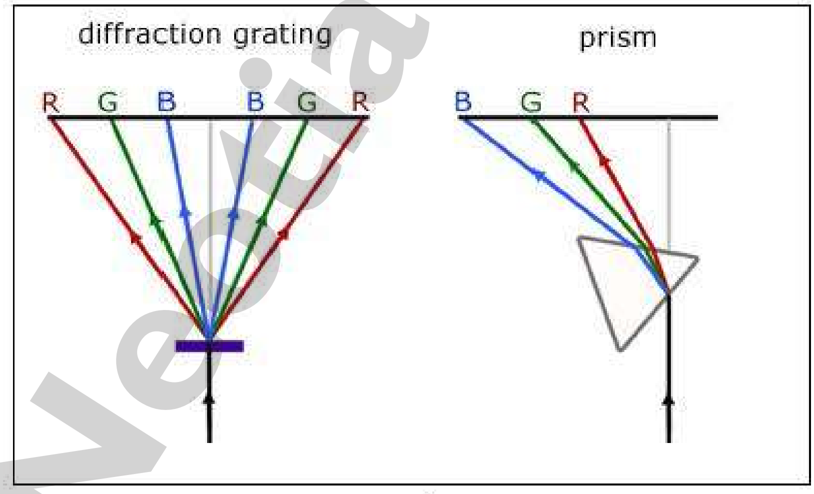


Figure 2.

(C) LASER :

(D) A **laser** (from the acronym *Light Amplification by Stimulated Emission of Radiation*) is an optical source that emits photons in a coherent beam. Laser light is typically near-monochromatic, i.e., consisting of a single wavelength or color, and emitted in a narrow beam. This is in contrast to common light sources, such as the incandescent light bulb, which emit incoherent photons in almost all directions, usually over a wide spectrum of wavelengths (see fig 3.).

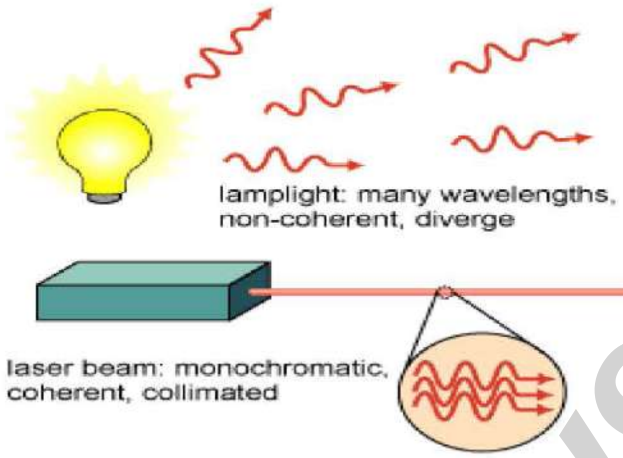


Figure 3

Lasers are finding ever increasing military applications -- principally for target acquisition, fire control, and training. These lasers are termed rangefinders, target designators, and direct-fire simulators. Lasers are also being used in communications, laser radars (LIDAR), landing systems, laser pointers, guidance systems, scanners, metal working, photography, holography, and medicine.

Basic operation of a HE-Neon LASER:

Any LASER have three components

- Lasing material (crystal, gas, semiconductor, dye, etc...)
- Pump source (adds energy to the lasing material , e.g. flash lamp, electrical current to cause electron collisions, radiation from a laser, etc.)
- Optical cavity consisting of reflectors to act as the feedback mechanism for light amplification

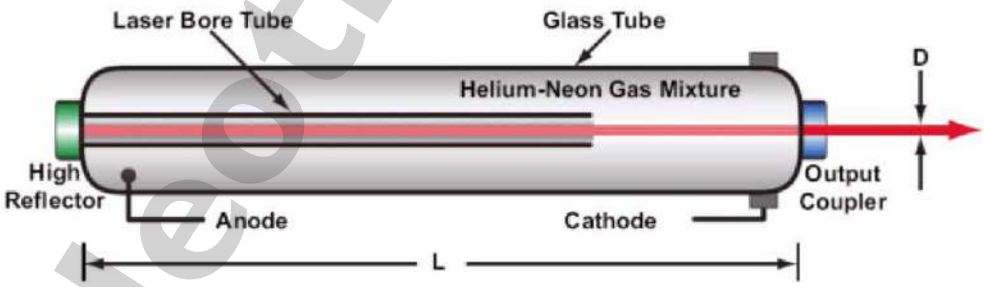
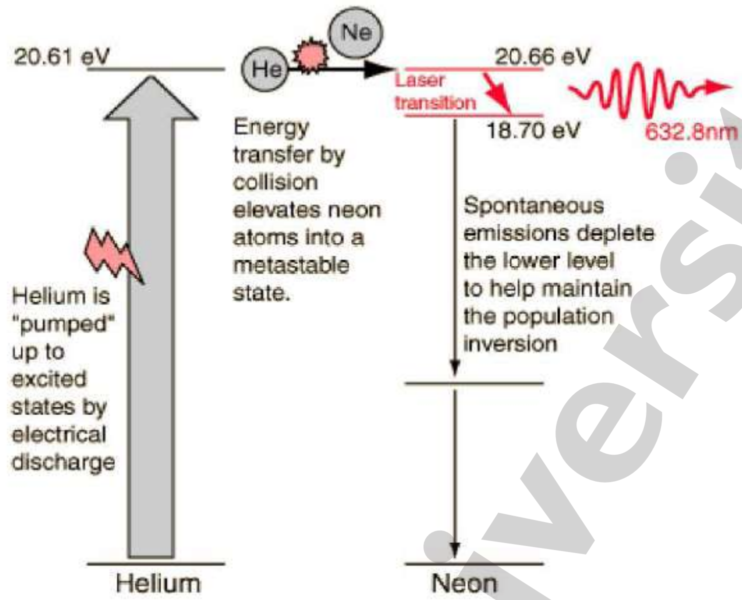


Figure 3: Typical construction of a He-Neon Laser

Basic operation of a helium Neon Laser has been shown in the figure below



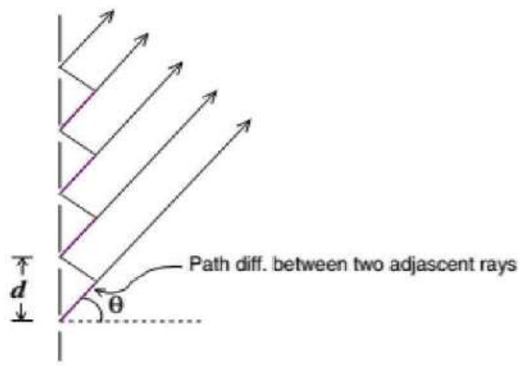
Types of Lasers

There are many different types of lasers. The laser medium can be a solid, gas, liquid or semiconductor. Lasers are commonly designated by the type of lasing material employed:

- **Solid-state lasers**- have lasing material distributed in a solid matrix such as the ruby or neodymium:yttrium-aluminum garnet "Yag" lasers.
- **Gas lasers**- have lasing material as gas such as Helium and helium-neon, CO_2 lasers.
- **Excimer lasers** use reactive gases, such as chlorine and fluorine, mixed with inert gases such as argon, krypton or xenon. When electrically stimulated, a pseudo molecule (dimer) is produced.
- **Dye lasers** use complex organic dyes, such as rhodamine 6G, in liquid solution or suspension as lasing media.
- **Semiconductor lasers**, sometimes called diode lasers, are not solid-state lasers. These electronic devices are generally very small and use low power. They may be built into larger arrays, such as the writing source in some laser printers or CD players.

(E) Determination of wavelength of monochromatic light by Laser diffraction method

Consider a plane wavefront incident on a grating surface. Portions of the wavefront falling on the slits will be transmitted through the grating. Now each point on a wavefront falling on a slit will act as a source of secondary wavefront.



Rays coming out from these points interfere with each other producing a diffraction pattern on a viewing screen placed behind the grating. Moreover, beams coming from different slits also interfere with each other producing a net intensity distribution of light which is resultant of both the diffraction effect due each single slit and interference effect due to all the N slits. Now consider a setting in which the viewing screen is placed at 'large distance' from the grating (Fraunhoffer diffraction class) so that the interfering rays can be considered almost parallel (Fig. 1). Consider parallel rays emerging at an angle θ with the horizontal line from identical points in each slit as shown in Fig. 1. The path difference between two such adjacent rays will be 'd sinθ', where 'd' is the distance between two slits. It can shown that the intensity of the resultant wave obtained as a result of superposition of all such rays (emerging from all points from all slit wavefronts) is given by,

$$I = I_0 \frac{\sin^2\beta}{\beta^2} \frac{\sin^2 N\gamma}{\sin^2\gamma}$$

Where I_0 is a constant and β

$$\beta = \frac{\pi b \sin\theta}{\lambda}, \quad \gamma = \frac{\pi d \sin\theta}{\lambda}$$

where 'b' is the slit width and 'λ'is the wavelength of light used. Thus the intensity, I will vary as a function of angle θ. For very large N , points of highest intensity, called principal maxima will be obtained when $\gamma = n\pi$ that is when, $d\sin\theta_m = m\lambda$, m = 0; ±1; ±2;::: (principal maxima)……………….(1)

The maxima for m = 0; ±1; ±2 are called zeroth order, first order, second order maxima and so on, respectively. If 'y_m' is the distance of the m^{th} principal maxima from the central maximum, and 'D' is the distance between the grating and the screen, then the corresponding diffraction angle can be estimated using

$$\theta_m = \tan^{-1}\left(\frac{y_m}{D}\right)$$ (see figure 4.)

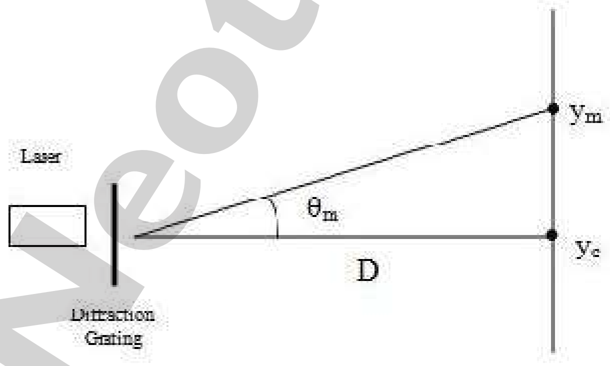


Figure 4.

Using (1) and (2) wavelength of the monochromatic light can be determined from the following formula

$$\lambda = \frac{\sin\theta_m}{nN}$$

Where $N=1/d$ is the number of lines per unit length of the grating.

5.0 PRINCIPLE: Let a parallel beam of light of wavelength λ coming from laser source fall normally on a plane transmission grating. Diffraction maxima of different orders would be formed on the other side of the grating at different angles with the incident beam. The angle of diffraction (θ) for any order can be measured from the central maximum and n-th order secondary maximum of the diffraction pattern.
If d is the distance of n-th order secondary maximum from central maximum and D is the distance of the screen from the grating, then the angle of diffraction for n-th order is

$$\theta = \tan^{-1}\left(\frac{d}{D}\right) \qquad (1)$$

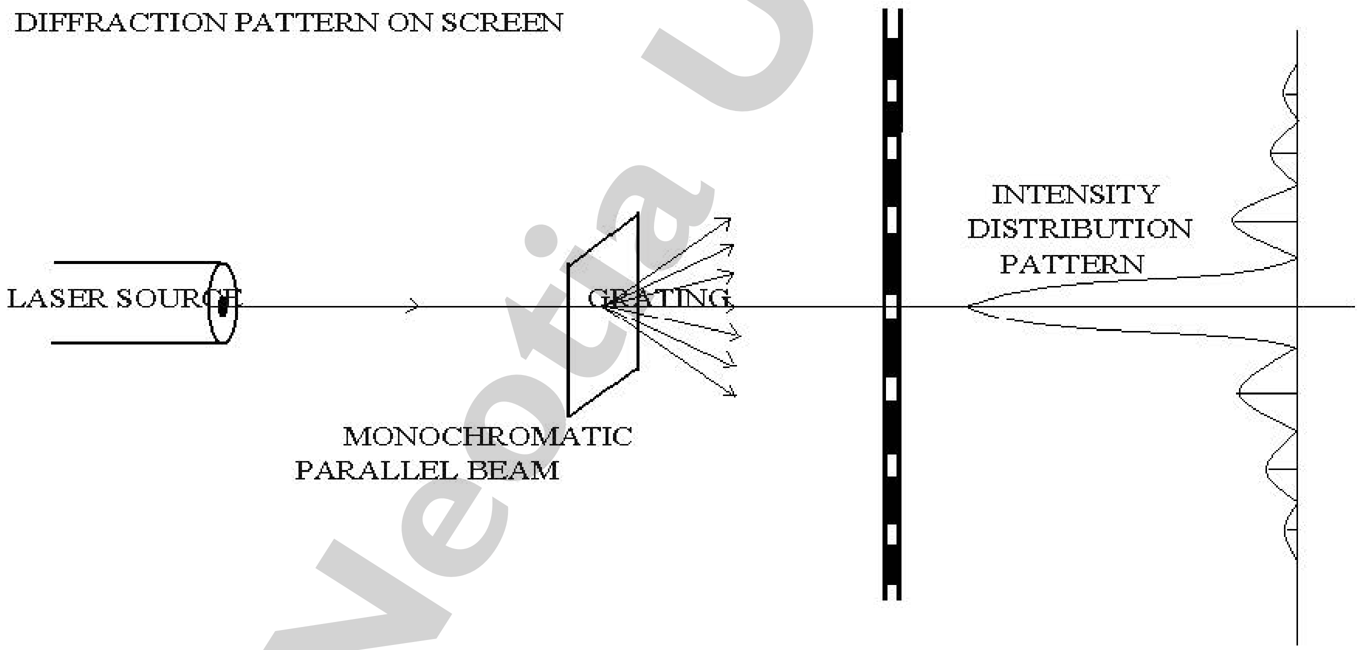
Knowing θ the wavelength of the monochromatic light can be determined from the following formula

$$\lambda = \frac{\sin\theta}{nN}, \qquad (2)$$

where N is the number of lines per unit length of the grating.

6.0 TOOLS/APPARATUS REQUIRED:

- Laser Source
- Screen
- Plane Transmission Grating
- Scale



7.0 PROCEDURE: (don't write the procedure in your Lab. Copy)

- Switch on the Laser Source

↓

- Place the transmission grating on the grating stand keeping it perpendicular to the source

↓

- Diffraction spots are seen on the screen

↓

- Measure the distance (D) of the screen from the grating.

↓

- Measure the distance (d) of different secondary maxima from the central maximum by a meter scale.

↓

- Repeat the above step for two more different values of D.

8.0 TABULATION:

TABLE-1

Determination the angle of diffraction

Distance of the screen from the grating (D)=……….. cm.

Order no.	Distance from the central spot (in cm)			Angle of diffraction $\theta = \tan^{-1}(d/D)$ (deg)
	Left d_1	Right d_2	Mean (d) $=(d_1 + d_2)/2$	
1				
2				
3				
4				
5				
6				
7				
8				

Draw Table – 2 and Table – 3 by repeating the Table-1 for two other distances (D) of screen from the grating.

TABLE-4

Table for drawing order no. vs. angle of diffraction data

Order no.	Angle of diffraction θ From Table-1 (deg)	Angle of diffraction θ From Table-2 (deg)	Angle of diffraction θ From Table-3 (deg)	Mean Angle of diffraction(θ) (deg)
1				
2				
3				
4				
5				
6				
7				
8				

Graph and Result

Draw graph of order number (n) vs. angle of diffraction by plotting order number (n) along abscissa (x-axis) and angle of diffraction (θ) along vertices (y-axis). Then determine the wavelength of laser as per instruction given in the Table – 5.

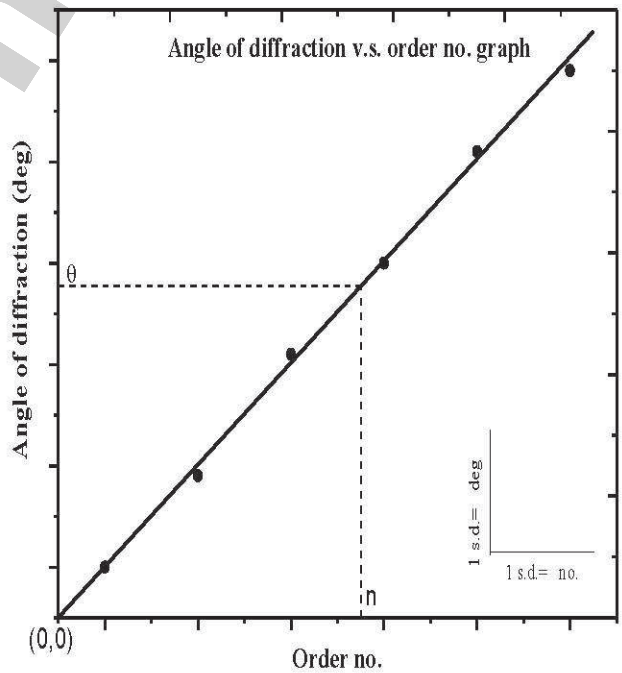
TABLE-5

Determination of wavelength of laser beam:

Order of diffraction (n) (From graph)	Angle of diffraction of corresponding order no. (θ) (deg) (From graph)	Number of lines/cm (N) (Supplied)	Wave length of laser $\lambda = \sin\theta / nN$ (Å)
		1000	

8.0 COMPUTATION OF PERCENTAGE ERROR:

We have the formula for the Determination of wavelength of monochromatic light by diffraction with a laser as $\lambda = \sin\theta / nN \approx \tan\theta / nN$, if θ is small.



$$\text{So, } \lambda = \frac{d/D}{nN} = \frac{d}{DnN}$$

Where, θ is the angle of diffraction,
n is order no. and N is number of lines/cm.
Taking ln in both sides we get,

$\ln\lambda = \ln d - \ln D - \ln n - \ln N$

Differentiating we get for maximum proportional error,

$$\frac{\partial\lambda}{\lambda} = \frac{\partial d}{d} + \frac{\partial D}{D} + \frac{\partial n}{n}$$

(Rest of the term will be zero as N is constant and differentiation of this term will vanish)

$\delta d = \delta D$=error in measuring d or D
= 2 x minimum division of the scale used
(because probability of making error is in both sides)
δn = error in measuring n
= 1 (because probability of making error is in one side)

Putting suitable values calculate the value of proportional error.

Hence, the percentage error is $\left(\frac{\partial\lambda}{\lambda} \times 100\right)\%$

9.0 DISCUSSION :

You have to write all the difficulties you faced during the experiment and their remedies. Also you have to mention some way out that one should adopt during the practical to have a better result.

References

1) OPTICS - Ghatak
2) OPTICS – K. G. Majumdar
3) ADVANCED PRACTICAL PHYSICS- Ghosh & Majumdar
4) PRACTICAL PHYSICS- Rakshit, Chatterjee & Saha

THE NEOTIA UNIVERSITY

WORK INSTRUCTION

1.0 EXPERIMENT NO: BS/PHP101/05

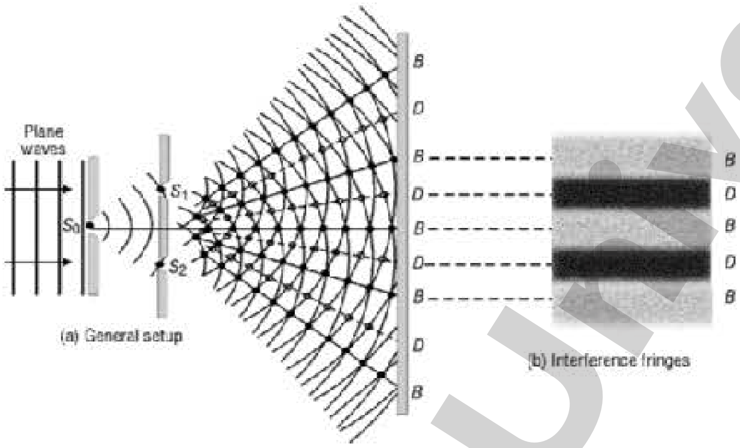
2.0 NAME OF EXPERIMENT: Newton's Ring

3.0 0BJECTIVE: Determination of Wavelength of Light by Newton's Ring method

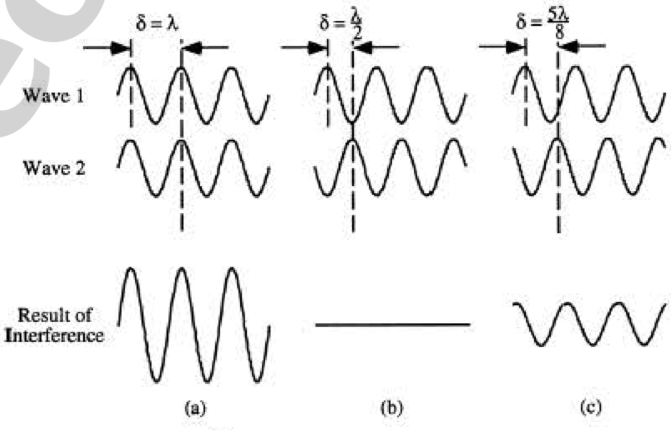
4.0 THEORITICAL BACKGROUND

(A) Interference:

Interference is caused by coherent waves interacting with each other as they intersect, causing waves to either add together (constructive interference) or cancel (destructive interference).



- ***Constructive interference*** is the point of intersection between two light waves where their interaction combine together to give rise to a larger wave (Amplified), but the wavelength stays the same. The resultant of constructive interference is a bright band of light.
- ***Destructive interference*** is the point of intersection between two light waves where their interaction will cancel each other out to give a null point with zero amplitude i.e. dark band of light.



In general, ordinary light waves are usually *in-coherent* because they produce well-phased light for only about 10^{-8} sec and also have random change in relative phase. Thus we can not see the usually sustained interference pattern with ordinary light. But coherent sources such as LASER, Na-Vapour lamp can produce sustained interference.

(B) Newton's Ring

The phenomenon of Newton's rings is an illustration of the interference of light waves reflected from the opposite surfaces of a thin film of variable thickness. The two interfering beams, derived from a monochromatic source satisfy the coherence condition for interference.

Ring shaped fringes are produced by the air film existing between a convex surface of a long focus plano-convex lens and a plane of glass plate.

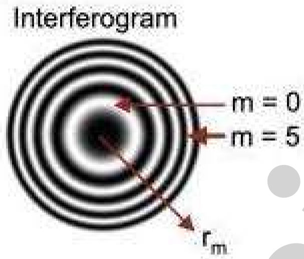


Figure 3.

(C) Calculation of diameters of Newtons Ring:

When a plano-convex lens (L) of long focal length is placed on a plane glass plate (G) , a thin film of air I enclosed between the lower surface of the lens and upper surface of the glass plate.(see fig 4). The thickness of the air film is very small at the point of contact and gradually increases from the center outwards. The fringes produced are concentric circles. With monochromatic light, bright and dark circular fringes are produced in the air film(see fig 3). *When viewed with the white light, the fringes are colored.*

A horizontal beam of light falls on the glass plate B at an angle of 45^0. The plate B reflects a part of incident light towards the air film enclosed by the lens L and plate G. T the air film is viewed with a microscope. Interference takes place and dark and bright circular fringes are produced. This is due to the interference between the light reflected at the lower surface of the lens and the upper surface of the plate G.

For the *normal incidence* the optical path difference Between the two waves is nearly $2\mu t$, where 'μ' is the refractive index of the film and 't' is the thickness of the air film.

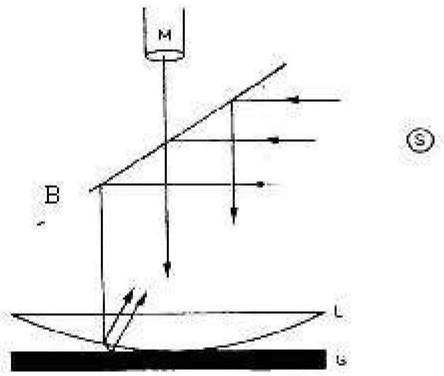
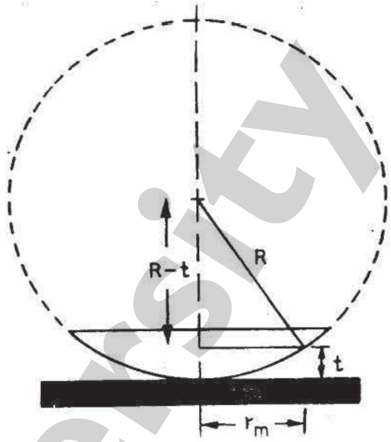


Figure 4.

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



$2\,t = n$ □ for minima; n = 0, 1, 2, 3… … … …**(1)**

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

Then the air film enclosed between the spherical surface of R and a plane surface glass plate, gives circular rings such that (see fig 3)

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

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

Figure 3.

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

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

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

Putting the value of " 2 t" in eq(1) gives $n\lambda = \frac{r_n^2}{R}$

With the help of a traveling microscope we can measure the diameter of the n^{th} ring order dark ring (D_n)

Then $r_n = D_{n/2}$ and hence,

$$D_n^2 = 4Rn\lambda \qquad (1)$$

we can also measure the diameter of the m^{th} ring order dark ring and would obtain

$$D_{m+n}^2 = 4R(m+n)\lambda \qquad (2)$$

Using (1) and (2) we obtain

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

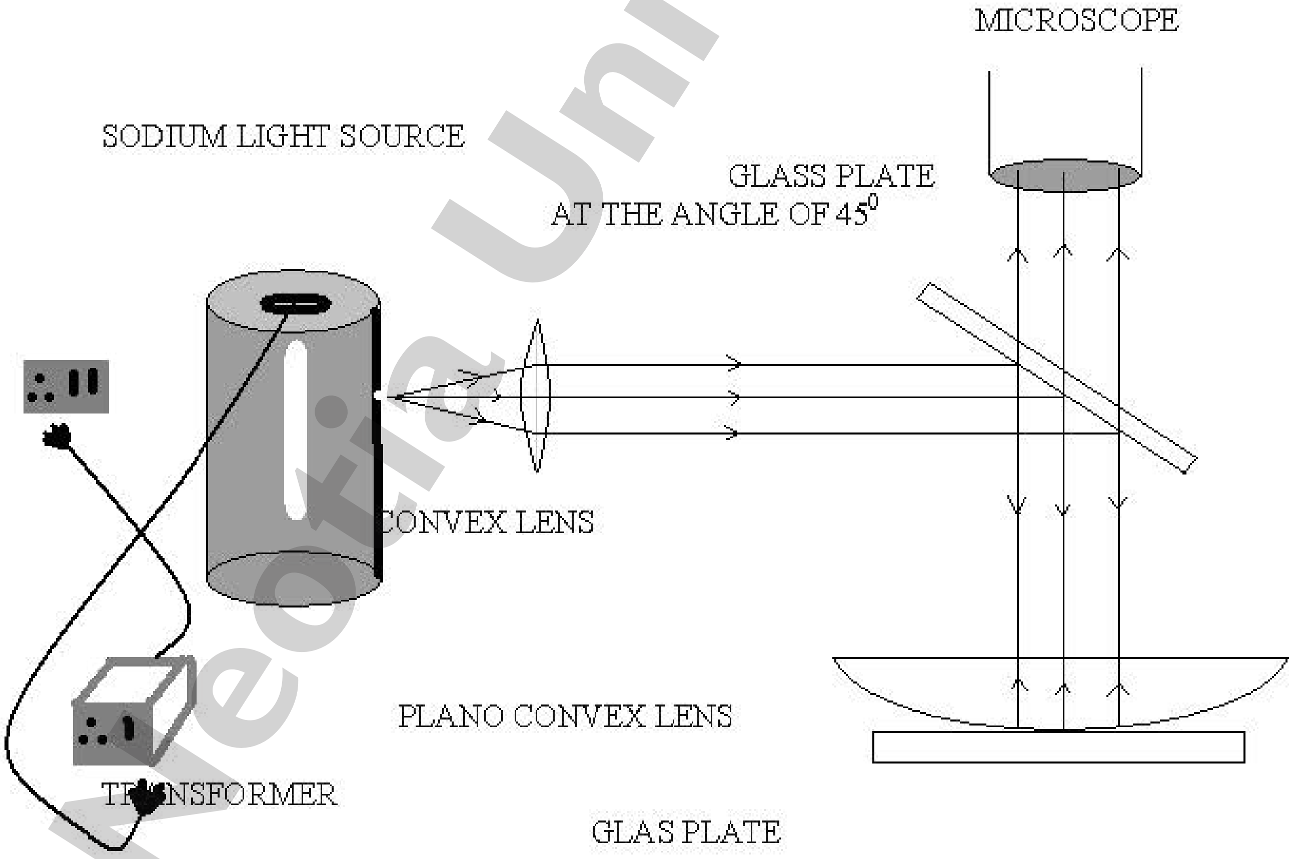
So if we know the R(radius of curvature of the lens), we can calculate wavelength λ and vice-versa. Also we can determine refractive index of any unknown liquid.

5.0 PRINCIPLE: When a parallel beam of monochromatic light of wavelength λ is made incident on the wedge shaped air- film (between glass) plate and convex surface of a plan convex lens for each incident ray we get two reflected rays shown as in figure below. These two rays will interfere and will produce alternate bright and dark concentric rings, the central spot is dark.

If D_m and D_{m+n} be the diameters of m^{th} and $(m+n)^{th}$ bright or dark rings, then the wavelength λ of the incident monochromatic light is:

$$\lambda = \frac{D_{m+n}{}^2 - D_n{}^2}{4Rm}$$

D_m= diameter of the m^{th} bright/dark ring
D_{m+n}=diameter of $(m+n)^{th}$ bright/dark ring
R= radius of curvature of convex surface of the Plano convex lens.



NEWTON'S RING SET – UP

6.0 TOOLS/APPARATUS REQUIRED:

- Microscope
- Sodium Lamp
- Convex Lens
- A Glass Plate
- Plano Convex Lens

7.0 PROCEDURE: (Don't write the procedure in the worksheet)

- Determine the least count of the circular scale of the travelling microscope.

↓

- Switch on the monochromatic light source. This sends a parallel beam of light. This beam of light gets reflected by the plate falls on the lens.

↓

- Look down vertically from above the lens and see whether the center is well illuminated. On looking through the microscope, a spot with rings around it can be seen on properly focusing the microscope.

↓

- Once good rings are in focus, rotate the eyepiece such that out of the two perpendicular cross wires, one has its length parallel to the direction of travel of the microscope.

↓

- Now move the microscope to focus on a ring (say, the 20th order dark ring on your left hand side).

↓

- Set the crosswire tangential to the ring as shown in fig 2. Note down the microscope readings (both main scale and circular scale).

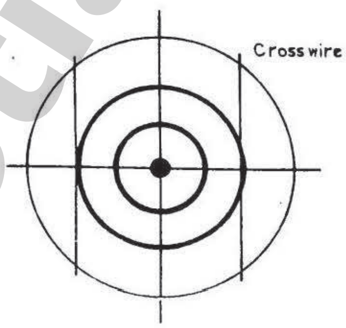


Figure 2.

- Move the microscope to make the crosswire tangential to the next ring nearer to the center(say 19^{th}) and note the reading. Continue with this purpose till you reach to the 20^{th} ring (say) on your right hand side. <u>*To avoid the backlash error circular scale should be rotated in one direction*</u>.

↓

- Calculate diameters of each ring.

↓

- Plot a graph with 'n' *(order number)* along abscissa (x - axis) and D_n^2 along vertices (y – axis).

↓

- Find the slope of the curve from the graph and find the wavelength of the light.

8.0 TABULATION:

TABLE-1

To determine the least count (*l.c.*) of the travelling microscope

Pitch of the travelling microscope is defined as the distance travelled by the circular scale for a complete rotation.

Pitch of the travelling microscope p (mm)	No. of division of the circular scale n	Least count ($l.c.$) $= p/n$ (mm)

TABLE-2

To measure the diameters of Newton's ring

No. of Rings (n)	Microscope reading						Diameter $D_n =$ (x - y) (cm.)	D_n^2 in (cm^2)
	Left of central point (x)			Right of central point (y)				
	Main. Scale Reading (mm) (L)	Circular scale reading (K)	Total (mm) $x = L + K \times l.c.$	Main. Scale Reading (mm) (L)	Circular scale reading (K)	Total $y = L + K \times l.c.$ (mm)		

Graph and Result

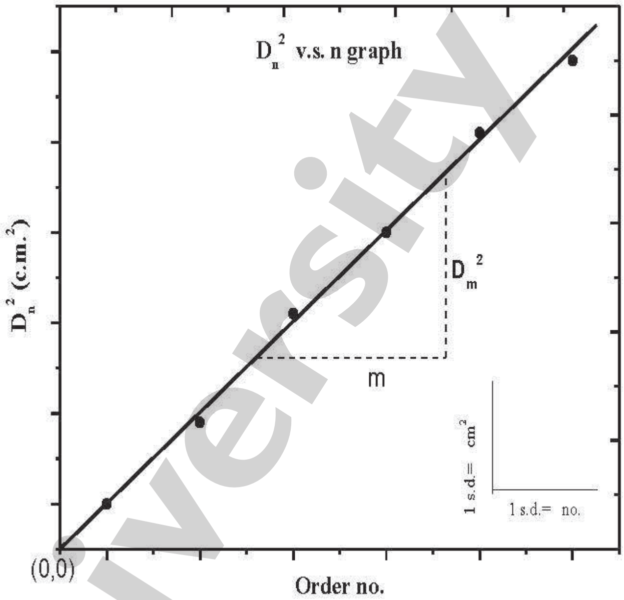
From the data of the Table – 2 plot a graph with n along abscissa (x - axis) and D_n^2 along vertices (y – axis). Determine the values of n and D_n^2 from the graph. Therefrom calculate the value of the wavelength of light as illustrated in Table -3.

TABLE-3

Determination of wavelength of monochromatic light

Value of R (cm.) (Supplied)	Value of D_n^2 or $(D_{m+n}^2 - D_n^2)$ from graph (cm^2)	m from graph	Value of $\lambda = \frac{D_{m+n}{}^2 - D_n{}^2}{4Rm}$ in Å
64			

9.0 COMPUTATION OF PERCENTAGE ERROR:



We have the formula for the Determination of wavelength of monochromatic light by Newton's ring

as $$\lambda = \frac{D_{m+n}^{\ 2} - D_n^{\ 2}}{4Rm}.$$

Where, R is the radius of curvature of the lens.
Taking 'ln' in both sides we get,

$$\ln \lambda = 2\ln D_m - \ln 4 - \ln R - \ln m$$

Differentiating we get for maximum proportional error,

$$\frac{\delta\lambda}{\lambda} = \frac{\delta(D_{m+n}^{\ 2} - D_n^{\ 2})}{D_{m+n}^{\ 2} - D_n^{\ 2}} + \frac{\delta m}{m}$$

(Rest of the term will be zero as R is constant and differentiation of this term will vanish)

$\delta(D_{m+n}^{\ 2} - D_n^{\ 2})$ = error in measuring $(D_{m+n}^{\ 2} - D_n^{\ 2})$
= 8 x minimum division of the scale (*l.c.*);

$(D_{m+n}^{\ 2} - D_n^{\ 2}$ is measured by taking the difference between the two readings of a scale provided with a vernier, the maximum error in measuring each of these quantities is twice the vernier constant i.e. 2 × *l.c.*. the error in Dn^2 or $D_{m+n}^{\ 2}$ is, therefore 4 × *l.c*. The error in obtaining $D_{m+n}^{\ 2} - D_n^{\ 2}$ is 8 × *l.c.*)

δm = error in measuring m
= 1 (because probability of making error is in one side)

Putting suitable values calculate the value of proportional error.

Hence, the percentage error is $\left(\frac{\partial\lambda}{\lambda} \times 100\right)\%$

9.0 DISCUSSION :

You have to write all the difficulties you faced during the experiment and their remedies. Also you have to mention some way out that one should adopt during the practical to have a better result.

References

1) OPTICS - Ghatak
2) OPTICS – K. G. Majumdar
3) ADVANCED PRACTICAL PHYSICS- Ghosh & Majumdar

Work Instruction

1.0 NAME OF THE EXPERIMENT: Studies on Photoelectric Effect.

2.0 OBJECTIVE: Determination of Planck's constant, Stopping Potential and Work Function.

4.0 PRINCIPLE: Einstein first proposed the correct explanation of photoelectric phenomenon by an extension of the quantum idea of Planck. This extension is known as Einstein's light quantum hypothesis. According to the theory of Photo electric effect, when light from an external source is incident on the cathode of a photo cell, we get a photo current recorded by the ammeter shown in the circuit diagram bellow. Here the applied voltage opposes electron emission from the cathode of the photo cell and this electric field opposes electron towards the anode of the photocell. The photo current decreases as the voltage V increases and at a particular value of this voltage, known as stopping potential (V_s), the current becomes zero. Stopping potential (V_s) increases with the frequency (ν) of the incident light that causes the emission of photoelectrons from the cathode. The dependence of V_s upon ν is expressed as:

$$eV_s = h\nu - W \qquad (1)$$

where, $e \rightarrow$ electronic charge = 1.6×10^{-19} Coulomb.
$V_s \rightarrow$ Stopping Potential.
$h \rightarrow$ Planck's constant
$\nu \rightarrow$ frequency of incident light.
$W \rightarrow$ work function of the metal of the cathode.

There is a minimum frequency ν_0 below which no photoelectric emission occurs from a given metal. This particular frequency is known as threshold frequency. W can be defined as in term of threshold frequency as: $W = h\nu_0$ (2)

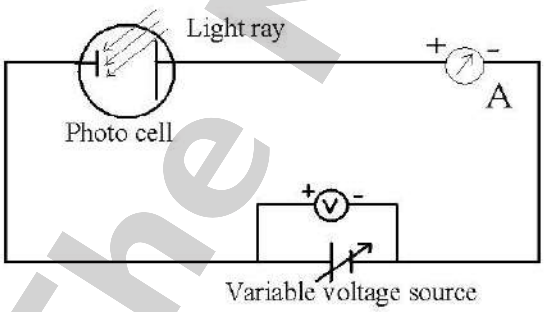
The frequency of the light can be written as: $\nu = \frac{c}{\lambda}$ (3)

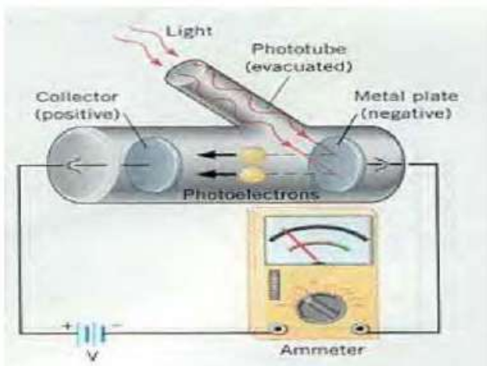
where, $c \rightarrow$ velocity of light in free space = 3×10^8 m/sec
$\lambda \rightarrow$ wavelength of light (in meter)

If v_m is the maximum velocity attained by the photo electrons, then from eqn. (1) we get

$$\frac{1}{2}mv_m^2 = eV_s = h\nu - h\nu_o \qquad (4)$$

If we plot V_s versus ν, we get a straight line from which we can estimate ν_0 and knowing ν_0 we determine the Planck's constant h from eqn. (4).





5.0 Apparatus required: variable voltage source, volt meter, ammeter, light Source, colour filter, photo cell, etc

6.0 PROCEDURE: (Don't write the procedure in your Lab. Copy)

- Connect the photocell with the Planck constant set up that contains variable voltage source, voltmeter (V), and miliameter (mA).

↓

- Switch on the set up. It will show some current in the mA. Using the zero-adjustment knob, make the current zero. Verify whether the reverse bias voltage is at zero.

↓

- Switch on the light source. The light is incident on the photocell. Note that the distance between the light source and photocell remains constant throughout the experiment.

↓

- Place the color filters in front of the source one by one.

↓

- When the light is incident on the photocell, the electrons emit and they are attracted by the anode. We get a current shown in the mA. Increase the reverse voltage of the variable voltage source. It reduces the current. In the Table – 1 note down the voltage and current at regular interval for each color filter until the current becomes zero. The voltage for which the current is zero is known as stopping potential.

↓

- Draw the graph plotting the frequency of the filter along abscissa (x-axis) and stopping potential along vertices (y-axis).

↓

- From the graph determine the slope, intersect on x -axis and intersect on y –axis. There from calculate the Planck's constant as indicated in the Table – 2.

↓

- Now repeat the procedure Tab-1 for two different colors by varying the intensity for both and record the data in Tab-3.

↓

- Draw a graph as V vs. I for different colors, each with different intensities to show that the stoping potential does not depend upon incident intensity.

6.0 Tabulation:

TABLE-1

To find the stopping potential:

No Of Obs.	Red filter Frequency of filter: Red =		Yellow filter Frequency of filter: yellow =		Green filter Frequency of filter: green=		Blue filter Frequency of filter: blue=		Orange filter Frequency of filter: Orange=	
	Voltage (mV)	Current (mA)	Voltage (mV)	Current (mA)	Voltage (mV)	Voltage (mV)	Voltage (mV)	Current (mA)	Voltage (mV)	Current (mA)
1										
2										
3										
4										
5										
6										

TABLE-2

Determination of Plank's constant (h) and Work function (W)

Value of intersect on x-axis Threshold frequency ν_o (Hz)	Value of the slope h/e (J-s/coulomb)	Value of h = e × slope (J-s)	Intersect on y-axis $\frac{h\nu_o}{e}$ (V)	Value of h $= \frac{e}{\nu_o} \times$ intersect (J-s)	Mean value of the h (J-s)	Value of the Work function (W) (eV)

TABLE-3

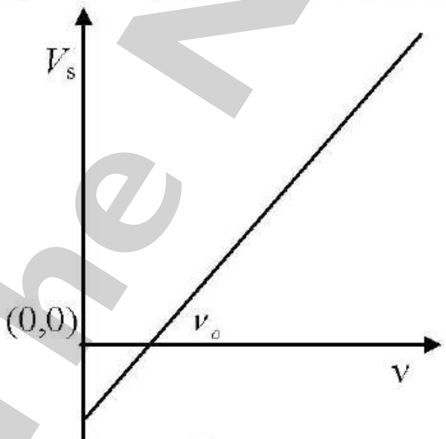
To find the intensity and frequency variation of stopping potential:

No Of Obs.	Red filter Frequency of filter: Red =				Blue filter Frequency of filter: yellow =			
	High Intensity		Low intensity		High Intensity		Low intensity	
	Voltage (mV)	Current (mA)	Voltage (mV)	Current (mA)	Voltage (mV)	Current (mA)	Voltage (mV)	Current (mA)
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

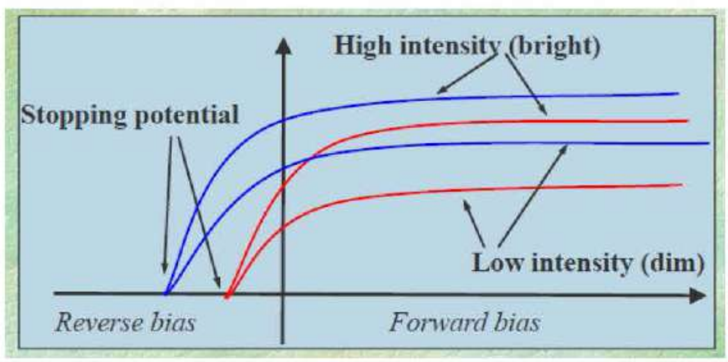
Graph: 1.We have the working formula as $eV_s = h(\nu - \nu_o)$ Or, $V_s = \frac{h\nu}{e} - \frac{h\nu_o}{e}$

Now a graph will be plotted between stopping potential (V_s) (along y-axis) vs. ν (along x –axis)

2. A graph will be plotted between potential (V) (along x-axis) vs. current I (along y –axis) form Tab-3



(1)



(2)

7.0 Error calculation:

We have the formula for the Determination of Plank's constant as $eV_s = h(\nu - \nu_o)$

$$\text{or, } h = \frac{eV_s}{\nu - \nu_o}$$

Where, e = electronic charge,

Vs = stopping potential.

ν = frequency of the filter,

ν_0 = Threshold frequency.

Taking ln in both sides we get, $\ln h = \ln e + \ln V_s - \ln(\nu - \nu_0)$

Differentiating we get for maximum proportional error,

$$\frac{\delta h}{h} = \frac{\delta V_s}{V_s}$$

(Rest of the term will be zero as e and υ are constants and differentiation of these terms will vanish)

δV_s = error in measuring V_s

= smallest division of the voltmeter. (Because probability of making error is in one side)

Hence, the percentage error is $\left(\frac{\partial h}{h} \times 100\right)$ %

8.0 Discussion:

You have to write all the difficulties you faced during the experiment and their remedies. Also you have to mention some way out that one should adopt during the practical to have a better result.

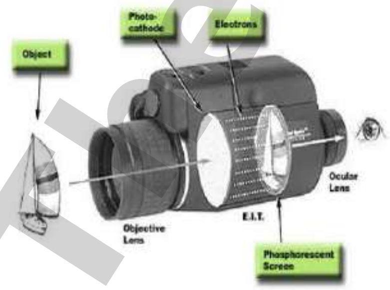
Reference

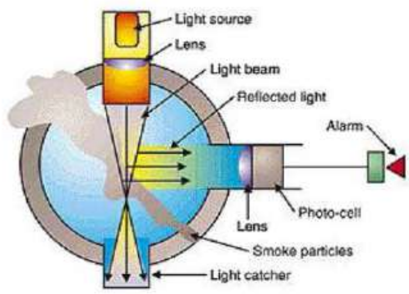
1) Physics _ Halliday and Resnick
2) Modern Physics – Kenneth Krane
3) Introduction to Modern Physics – Richtmayer, Kennard and Cooper
4) Modern Physics - Beiser

9.0 Applications:

The Photoelectric effect has numerous applications, for example night vision devices take advantage of the effect. Photons entering the device strike a plate which causes electrons to be emitted, these pass through a disk consisting of millions of channels, the current through these are amplified and directed towards a fluorescent screen which glows when electrons hit it. Image converters, image intensifiers, television camera tubes, and image storage tubes also take advantage of the point-by-point emission of the photocathode. In these devices an optical image incident on a semitransparent photocathode is used to transform the light image into an "electron image." The electrons released by each element of the photoemitter are focused by an electron-optical device onto a fluorescent screen, reconverting it in the process again into an optical image.

Popular three applications are-1. Night Vision Device 2. Smoke Detector 3. Solar panels





THE NEOTIA UNIVERSITY

WORK INSTRUCTION

1.0 EXPERIMENT NO: BS/PHP101/02

2.0 NAME OF EXPERIMENT: Rigidity Modulus

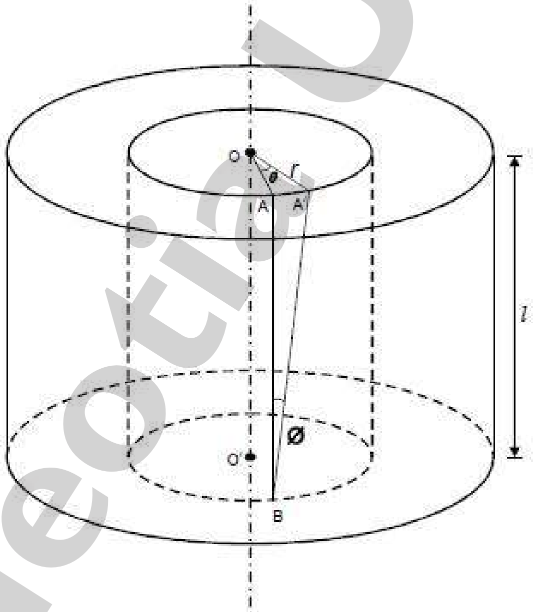
3.0 0BJECTIVE: determination of Rigidity Modulus of the material of an wire by dynamical method

4.0 THEORITICAL BACKGROUND:

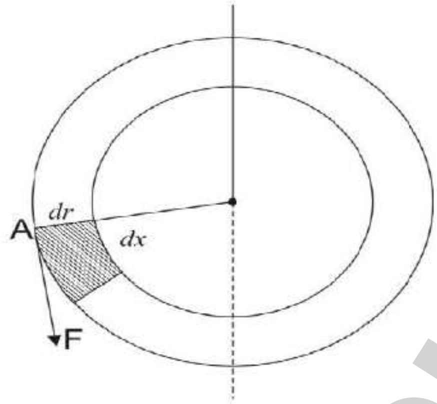
Torsion of a wire:

We assume the shape of the wire as a cylinder of length l and radius a. Let it's one end be clamped and at the other end a torque is applied.As a result of the torque the cylinder is twisted through a certain angle.We imagine the cylinder in question is divided up into a number of co-axial discs, then due to this twist these discs will turn relative to one another about the axis of the cylinder and the amount of turning of a disc will depend on it's position from the fixed end. The disc which is far from the fixed end will turn more about the axis than the one nearer to the fixed end. To measure this turn, we consider an imaginary co-axial cylinder of radius r. A straight line AB is considered over the surface of this cylinder, parallel to the axis OO'. After twisting the line gets inclined (as A'B) to the original line. The angle between AB and A'B (i.e φ) is the angle of shear. AA' represents the amount of turn of the line OA which is on the surface of the cylinder. Arc length AA' is equal to rθ, where r is radius of the imaginary cylinder and $\angle AOA' = \theta$ (angle of twist) and arc length AA' is also l φ, Therefore rθ=l φ.

Hence $\varphi = \frac{r\theta}{l}$ ……………….(1)



Now due to the elastic property of the material the relative turnung of the co-axial disc gives rise to a restoring torque which tends to prevent the twisting of the cylinder.
To calculate the restoring torque we proceed in the following way:
We imagine the cylinder to be divided into a number of co-axial cylindrical shells. We take into consideration one such shell of radius r and thickness dr. On the face of this shell at the position A we imagine an element of length dx, whose breadth is dr. Over this element let F be the tangential force that comes to play due to relative turning.
Tangential stress= $\frac{F}{dr\ dx}$



So rigidity modulus $\eta = \frac{\frac{F}{dr\ dx}}{\theta}$ (From 1)

$= = \frac{F\ l}{dr\ dx\ r\ \varphi}$

Hence $F = \frac{\eta\ \varphi\ r\ dr\ dx}{l}$ ………………(2)

The moment of this force about the axis of the cylinder is given by

$F.r = \frac{\eta\ \varphi r^2\ dr\ dx}{l}$

Therefore the restoring torque over the entire surface of the annulus is given by

$\delta\Gamma = \frac{\eta\ \varphi r^2\ dr\ \sum dx}{l} = \frac{\eta\ \varphi r^2\ dr\ 2\pi r}{l}$ $(\sum dx = 2\pi r)$

$= \frac{2\pi\eta\ \varphi r^3\ dr}{l}$

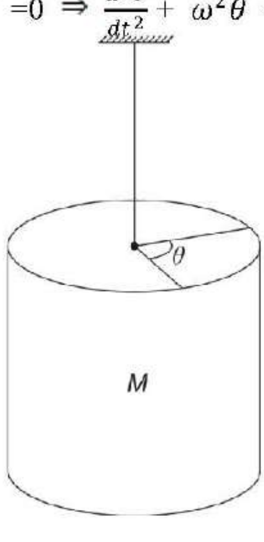
The total restoring torque that comes to play during the twisting of the entire cylinder of radius r is $\Gamma = \frac{2\pi\eta\varphi}{l}\int_0^r r^3 dr = \frac{2\pi\eta\varphi}{l}\frac{r^4}{4} = = \frac{\pi\eta\varphi\, r^4}{2l}$ ………………(3)

Tortional rigidity or tortional constant is restoring torque per unit twist

$C = \frac{\Gamma}{\varphi} = \frac{\pi\eta r^4}{2l}$ …………………………(4)

Tortional Pendulum : In this pendulum a wire is fixed at one end and has a bob in the form of a solid cylinder of mass M at the bottom. Giving a slight rotation to M, the wire is twisted at the free end and the system is made to oscillate about he wire as axis.If θ be the angle of twist imparted to the wire then the deflecting couple is $I\frac{d^2\theta}{dt^2}$. I belng the moment of inertia of the solid cylinder of mass M about the wire.The restoring torque must be $C\theta$, where C is the restoring torque per unit twist or tortional rigidity.

$I\frac{d^2\theta}{dt^2} = -C\,\theta \Rightarrow \frac{d^2\theta}{dt^2} = -\frac{C}{I}\theta \Rightarrow \frac{d^2\theta}{dt^2} + \frac{C}{I}\theta = 0 \Rightarrow \frac{d^2\theta}{dt^2} + \omega^2\theta = 0$, where $\omega^2 = \frac{C}{I}$



The motion is simple harmonic motion with time period $T = \frac{2\pi}{\omega} \Rightarrow T = 2\pi\sqrt{\frac{I}{C}}$

I= $\frac{MR^2}{2}$ and C = $\frac{\pi\eta r^4}{2l}$ ⇒T =2π $\sqrt{\frac{MR^2/2}{\frac{\pi\eta r^4}{2l}}}$ ⇒ $T^2 = 4\pi^2 \frac{MR^2}{2}\frac{2l}{\pi\eta r^4}$

Therefore $\eta = 4\pi\frac{MR^2 l}{T^2 r^4}$ ……………(5)

What is moment of inertia?

Let us consider a rigid body rotating about the axis AB with uniform angular velocityω. We imagine that the body is made up of a large number of particles of masses m_1, m_2, m_3,…., situated at distances r_1, r_2, r_3, etc respectively from the axis of rotation. The angular velocity of different particles is same (ω) but their linear velocities are different due to their different linear positions with respect to the axis. Hence the kinetic energy of the rigid body

$E = \frac{1}{2} m_1 \omega^2 r_1^2 + \frac{1}{2} m_2 \omega^2 r_2^2 + \frac{1}{2} m_3 \omega^2 r_3^2 + \ldots\ldots\ldots\ldots\ldots\ldots$

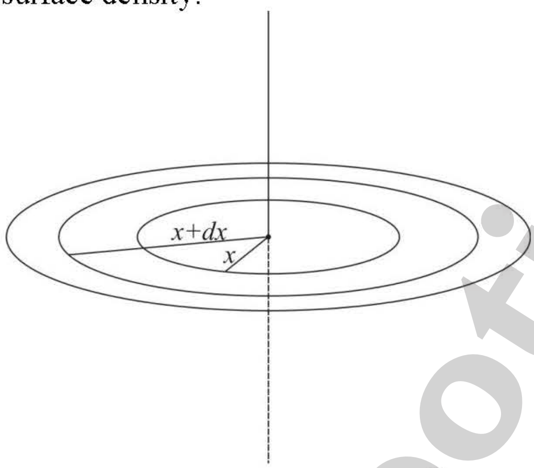
$= \frac{1}{2}\omega^2(m_1 r_1^2 + \frac{1}{2} m_2 r_2^2 + \frac{1}{2} m_3 r_3^2 + \ldots\ldots\ldots\ldots\ldots)$

$= \frac{1}{2} I\omega^2$

Where $I = \sum mr^2$ = moment of inertia of the body about the axis in question

Moment of inertia of a cylinder

To find the moment of inertia of a cylinder, we will find out the moment of inertia of a disc about an axis passing through its centre and perpendicular to its plane. In the diagram the moment of inertia of a ring whose inner radius is x and outer radius is x+dx is $\sigma[\pi(x+dx)^2 - \pi x^2]$ x^2 $=2\pi x\, dx\, \sigma x^2$, where σ is the surface density.



Moment of inertia of the disc $=\int_0^R 2\pi\sigma x^3 dx = 2\pi\sigma\frac{R^4}{4} = m\frac{R^2}{2}$, where $m=\pi\sigma R^2$ =mass of the disc. Hence the moment of inertia of the whole cylinder can be obtained by summing the moment of inertia of all the discs which made the cylinder. $I=\sum m\frac{R^2}{2} = M\frac{R^2}{2}$

5.0 PRINCIPLE: The time period (T) with which the bob of a torsion pendulum oscillates, about the suspension wire as axis is given by

$$T = 2\pi\sqrt{\frac{I}{C}} \qquad \text{Or} \qquad C = \frac{4\pi^2 I}{T^2}$$

Where I is the moment of inertia of the bob of mass M and radius R of the torsion pendulum about the suspension wire as its own axis to be given by

$$I = \frac{1}{2}\,MR^2$$

And C represents the resting couple exerted by the suspension wire of length l for one radian twist at its free end and is given by, $C = \dfrac{\eta\pi r^4}{2l}$

Where (η) is the rigidity of modulus of the material of the wire, while l and r are respectively the length and radius of the suspension wire. Hence we can write:

$$\eta = \frac{8\pi I l}{T^2 r^4}$$

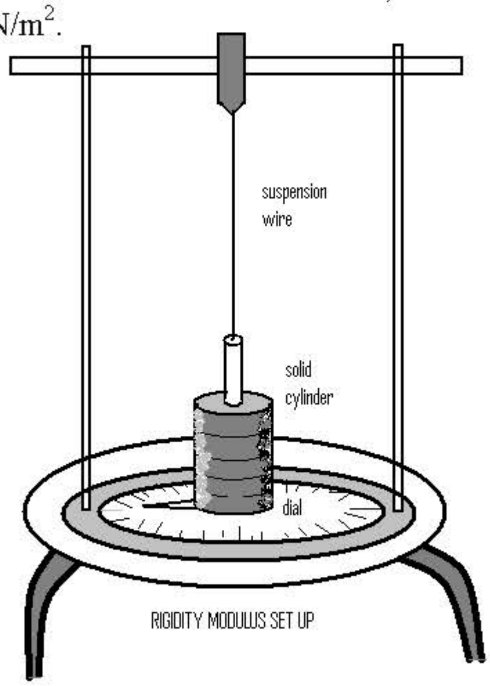
If we suspend a solid cylinder as the bob of the torsion pendulum, then by calculating I and measuring l, r, and T experimentally, we can determine the modulus of rigidity (η) of the wire from the following equation.

$$\eta = \frac{8\pi l}{T^2 r^4}\left(\frac{1}{2}\mathrm{MR}^2\right)$$

M and R are the mass and radius of the cylinder respectively. If l, r and R are measured in meters, M is measured in kg and T is measured in second then the unit of η will be N/m^2.

6.0 TOOLS/APPARATUS REQUIRED:

- Rigidity modulus set-up
- Measuring tape
- Slide calipers
- screw gauge
- Stop watch



7.0 PROCEDURE: (don't write the procedure in your Lab. Copy)

- Determine the vernier constant of the slide caliper (in Table – 1) and measure the radius (R) of the cylinder by the slide caliper as per instructions given in Table – 2.

↓

- Determine the least count of the screw gauge (in Table – 3) and measure the radius (r) of the suspension wire by the screw gauge as per instructions given in Table – 4.

↓

- Give a small twist to the suspension wire and determine the time taken for a certain number of torsional oscillations of the cylinder by a stop watch. Repeat this process for a number of times (say 5 – 6). Every time record the number of oscillations and its corresponding time in Table – 5. Plot a graph with number of oscillations (n) along the abscissa (x - axis) and time (t) taken for the oscillations along the vertices (y – axis). Determine the time period (T) from the graph as shown in Table – 5.

↓

- Measure length of suspension wire from the point of suspension to the point where the cylinder is attached and have the mass of the cylinder and then calculate the value of rigidity modulus of the wire as illustrated in Table – 6.

8.0 TABULATION:

Supplied, L= cm.

M = 1980 gm.

7.0 TABULATION:

TABLE-1

Vernier constant (*v.c.*) of the slide calipers

10 divisions (say m) of the vernier scale = 9 divisions (say n) of the main scale

Value of 1 smallest main scale division (l_1) (cm)	Value of 1 division of the vernier scale $\frac{n}{m}$	Vernier constant (*v.c.*) $(1-\frac{n}{m}) \times l_1$ (cm)

TABLE-2

Measurement of the radius (R) of the cylinder

No of obs.	Reading of the		Total reading (cm) $m_s + v_s \times v.c.$	Mean diameter D (cm)	Instrumental error (cm)	Correct D (cm)	Radius $R = D/2$ (cm)
	Main scale m_s (cm)	Vernier no. v_s					
1							
2							
3							

TABLE-3

Least count (*l.c.*) of the screw gauge

Pitch of the screw gauge is defined as the distance travelled by the circular scale for a complete rotation.

Pitch of the screw gauge p (cm)	No. of division of the circular scale n	Least count (*l.c.*) = p/n (cm)

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TABLE-4
Measurement of radius (r) of the suspension wire by screw gauge

No of obs.	Reading of the		Total reading (cm) $m_s + c_s \times l.c.$	Mean diameter d (cm)	Instrumental error (cm)	Correct d (cm)	Radius $r = d/2$ (cm)
	Main scale m_s (cm)	Circular scale no. c_s					
1							
2							
3							

TABLE-5
Determine the time period (T) of the torsional oscillation of the cylinder

No of obs.	No of oscillation (n)	Total time taken for the oscillation (t) (sec.)	Value of an oscillation from graph (n_g)	Corresponding time for that oscillation from graph (t_g) (sec.)	Time Period (T) $= t_g/n_g$ (obtained from graph) (sec.)
1					
2					
3					
4					
5					
6					

Graph and Result

From the data of the Table – 5 plot a graph with number of oscillation (n) along the abscissa (x - axis) and time (t) taken for the oscillations along the vertices (y – axis). Determine the time period (T) from the graph. Therefrom calculate the value of the modulus of rigidity of the wire as illustrated in Table -6.

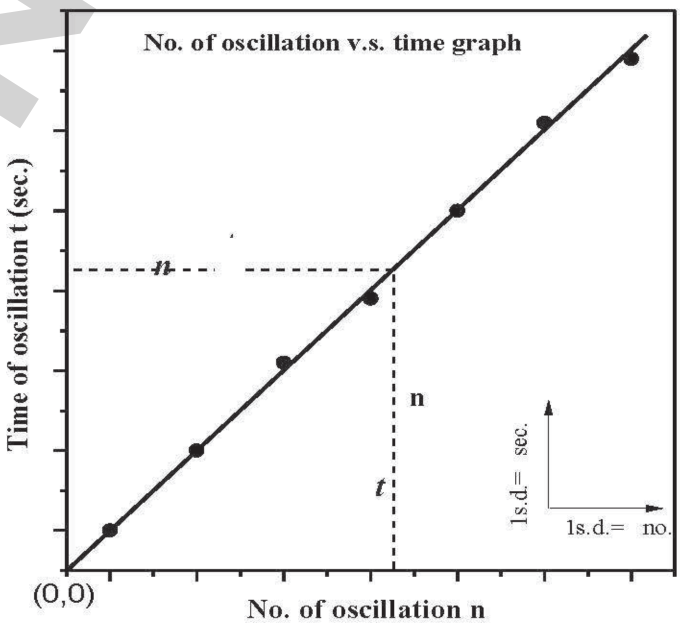

TABLE-6
Determination of Modulus of Rigidity (η)

L = m.
M = kg.

Value of R from TABLE - 2 (m)	Value of r from TABLE - 4 (m)	Value of T from TABLE - 5 (sec.)	Moment of inertia $I = \frac{1}{2}MR^2$ (kg-m^2)	Value of $\eta = \frac{8\pi L}{T^2 r^4} I$ (N/ m^2)

Ideal value of η (in SI unit): (7 ~ 9) ×10^{10} N/m^2

9.0 COMPUTATION OF PERCENTAGE ERROR:
We have the formula for the

Rigidity modulus is: $\eta = \frac{8\pi L}{T^2 r^4}(\frac{1}{2}MR^2)$

Taking 'ln' in both sides we get: $\ln \eta = \ln L + \ln M + 2\ln R - 2\ln T - 4\ln r$

Differentiating both sides, we get for maximum proportional error, $\frac{\partial\eta}{\eta} = \frac{\partial L}{L} + \frac{2\partial R}{R} + \frac{2\partial T}{T} + \frac{4\partial r}{r}$

(For maximum proportional error the negative signs will be converted into positive signs. As M is given it will be eliminated from the equation after differentiation.)

δL= error in measuring L
= 2 × smallest division of the scale used (because probability of making error is in both sides)
δR= error in measuring R
= *v.c.* of the slide calipers (because probability of making error is in one side)
δT= error in measuring T
= one smallest division of stop watch (because probability of making error is in one side)
δr= error in measuring r
= *l.c.* of the screw gauge (because probability of making error is in one side)

By putting suitable values of L, R, T, and r calculate proportional error $\frac{\partial\eta}{\eta}$

Hence, the percentage error is: $(\frac{\partial\eta}{\eta} \times 100)$ %

DISCUSSION:
You have to write all the difficulties you faced during the experiment and their remedies. Also you have to think and to mention some way out that one should adopt during the practical for getting a better result.

References
1) GENERAL PROPERTIES OF MATTER – Sengupta & Chatterjee
2) MECHANICS – Gupta & Kumar
3) MECHANICS - Spiegel

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WORK INSTRUCTION

1.0 EXPERIMENT NO: BS/PHP101/08

2.0 NAME OF EXPERIMENT: ULTRASONIC INTERFEROMETER

3.0 0BJECTIVE: DETERMINATION OF VELOCITY OF ULTRASONIC WAVE IN WATER

4.0 PRINCIPLE:

The ultrasonic interferometer consist of transducer crystal at the bottom of the cell, which is driven by a crystal controlled oscillator fixed frequency.

Ultrasonic wave is transmitted to the liquid in contact with the transducer and reflected back from the metal plate, placed at a distance from the transducer in the liquid. The reflective wave is received by the same transducer and a meter indicates the position of the metal reflector is at node or anti node. Stationary wave is formed in the liquid.

An Ultrasonic Interferometer is a simple and direct device to determine the ultrasonic velocity in liquids with a high degree of accuracy. The principle used in the measurement of velocity (V) is based on the accurate determination of the wavelength (λ) in the medium. If the separation between these two plates is exactly a whole multiple of the sound wavelength, standing waves are formed in the medium. This acoustic resonance gives rise to an electrical reaction on the generator driving the quartz plate and the anode current of the generator becomes a maximum. If the reflector is set now on two successive maxima or minima, the difference between the micrometer readings will be $\lambda/2$. If the reflector is set at m^{th} and $(n+m)^{th}$ maxima, then the difference between the micrometer reading,

$$d = n\frac{\lambda}{2} \qquad \text{So, } \lambda = \frac{2d}{n}$$

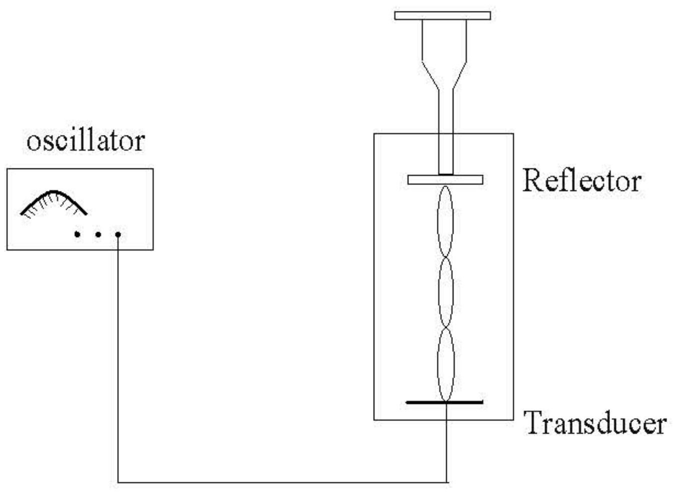
From the knowledge of wavelength (λ), the velocity (V) can be obtained by the relation

$$V = \lambda \times f$$

5.0Procedure: (don't write the procedure in your Lab. Copy)

1. Adjustments of ultrasonic interferometer:

Insert the cell in the square base socket and clamp to it with the help of a screw provide on one of its side. Unscrew the knurled cap of cell and lift it away from double walled construction of the cell. In the middle portion of it pour experimental liquid and screw the knurled cap. Two chutes in double wall construction are provided for water circulation to maintain desired temperature. Connect the High frequency Generator with cell by co-axial cable provided with the instrument. For initial adjustment two knobs are provided on high frequency generator, one is marked 'Adj' and the other with 'Gain'. With knob marked 'Adj' the position of the needle on the Ammeter is adjusted and the knob marked 'Gain' is used to increase the sensitivity of the instrument for greater deflection if desired. The meter is used to notice the number of maximum deflections while micrometer is moved up and down in liquid. The micrometer is slowly moved till the anode current on the meter on the High Frequency Generator shows a maximum. Note the anode current and the micrometer reading.



6.0 TOOLS/APPARATUS REQUIRED:

1) ULTRASONIC INTERFEROMETER
2) Signal generator

7.0 Tabulation:

TABLE-1
Determination of the least count of the micrometer screw

No. of div. in circular scale n	pitch x (mm)	Least count L.C.=x/n (cm)

TABLE-2
Determination of Velocity of Ultrasonic Wave:
Frequency of Ultrasonic Wave = 2×10^6 Hz

Liquid used	Reflector set on maxima (n)	Linear scale reading (cm)	Circular scale reading	Total reading (cm)	Linear shift d (cm)	Wave length $\lambda = \frac{2d}{n}$ (cm)	Mean λ (Meter)	Velocity Of Ultrasonic Wave $V = \lambda \times f$ (Meter/sec.)
Water	0			d_0=	0.0			
	4			d_1=	$d_0 - d_1$=			
	8			d_2=	$d_0 - d_2$=			
	12			d_3=	$d_0 - d_3$=			
	16			d_4=	$d_0 - d_4$=			
	20			d_5=	$d_0 - d_5$=			

Graph and Result

From the data of the Table – 2 plot a graph with Reflector set on maxima (n) along abscissa (x - axis) and Linear shift (d) along vertices (y – axis). Determine the values of *n* and *d* from the graph. There from calculate the value of the velocity of ultrasonic wave in water in Table -3.

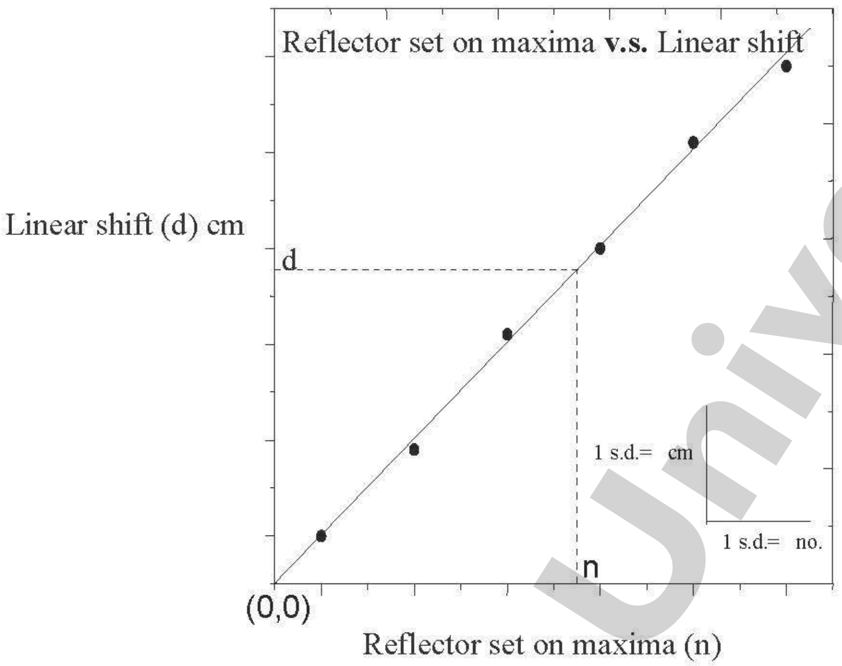


TABLE-3

Determination of Velocity of Ultrasonic Wave:
Frequency of Ultrasonic Wave = 2×10^6 Hz

Reflector number (n) (From graph)	Linear shift (d) cm ((From graph)	Wave length $\lambda = \frac{2d}{n}$ (cm)	Velocity Of Ultrasonic Wave $V = \lambda \times f$ (Meter/sec.)

8.0 Error calculation

9.0 COMPUTATION OF PERCENTAGE ERROR:

We have the formula for

$$\lambda = \frac{2d}{n}$$

Taking ln in both sides we get,

$\ln \lambda = 2\ln d - \ln n$

Differential both sides we get for maximum

proportional error, $\frac{\partial\lambda}{\lambda} = \frac{2\partial d}{d} + \frac{\partial n}{n}$

(For maximum proportional error the negative signs will be Converted into positive signs)

Now,
δd= error in measuring d
= Least count (*l.c.*) of the screw gauge (because probability of making error is in one side)
δn= error in measuring *n*
Putting suitable values calculate the value of proportional error.

Hence, the percentage error is ($\frac{\partial\lambda}{\lambda} \times 100$) % (Put the values and calculate the percentage error).

9.0 Discussion :
You have to write all the difficulties you faced during the experiment and their remedies. Also you have to mention some way out that one should adopt during the practical to have a better result.