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 <u>PRINCIPLE</u>: 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 (v) of the incident light that causes the emission of photoelectrons from the cathode. The dependence of V_s upon v is expressed as:

$$eV_s = hv - W \qquad (1)$$

where, $e \rightarrow$ electronic charge = 1.6×10^{-19} Coulomb.

$V_s \rightarrow$ Stopping Potential.

$h \rightarrow$ Planck's constant

$v \rightarrow$ frequency of incident light.

$W \rightarrow$ work function of the metal of the cathode.

There is a minimum frequency v_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: $W = hv_0$ (2)

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

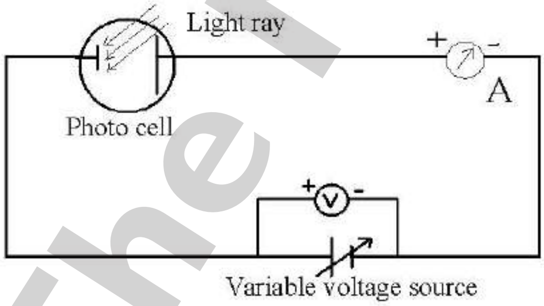
where, $c \rightarrow$ velocity of light in free space = 3×10^8 m/sec

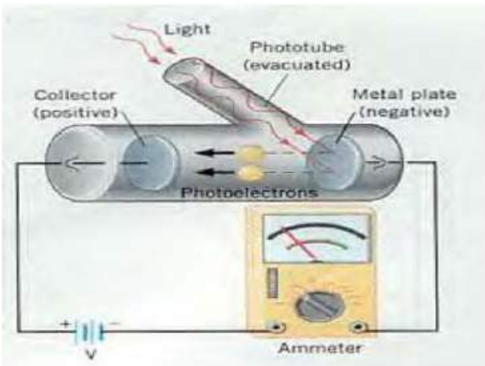
$\lambda \rightarrow$ wavelength of light (in meter)

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

$$\frac{1}{2}mv_m^2 = eV_s = hv - hv_o \qquad (4)$$

If we plot V_s versus v, we get a straight line from which we can estimate v_0 and knowing v_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 $= e \times$ 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

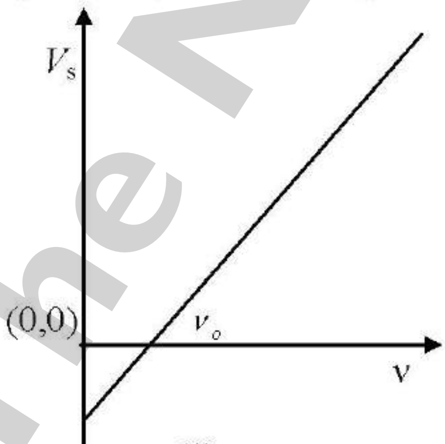
To find the intensity and frequency variation of stopping potential:

No Of Obs.	<u>Red filter</u> Frequency of filter: Red =				<u>Blue filter</u> 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								

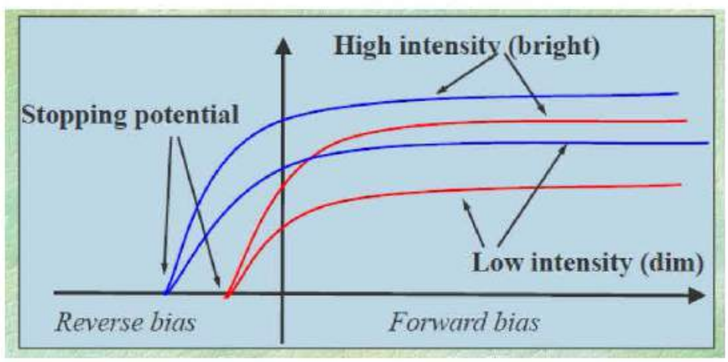
Graph: 1.We have the working formula as $eV_s = h(\nu - \nu_o)$ Or, $V_s = \frac{h\nu}{e} - \frac{h\nu_o}{e}$

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.

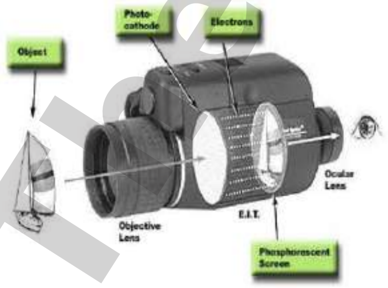
Reference

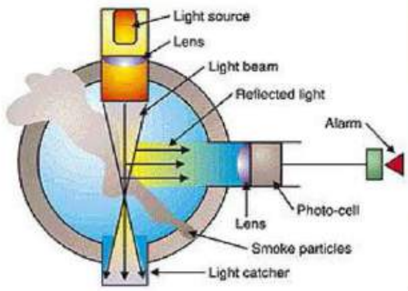
1) Physics _ Halliday and Resnick
2) Modern Physics – Kenneth Krane
3) Introduction to Modern Physics – Richtmayer, Kennard and Cooper
4) Modern Physics - Beiser

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





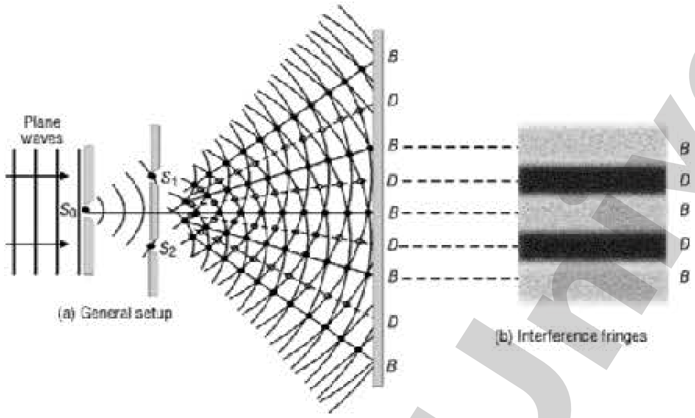
THE NEOTIA UNIVERSITY

WORK INSTRUCTION

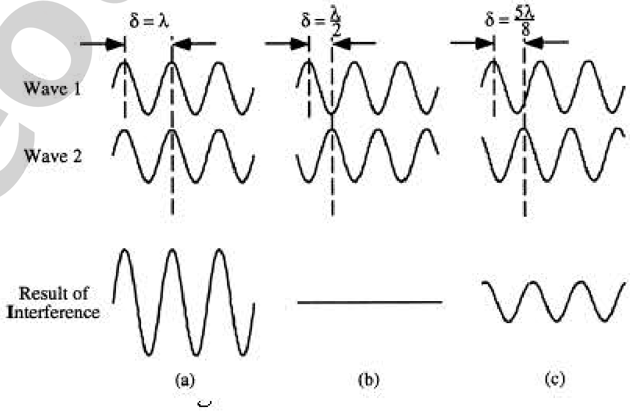
1.0 EXPERIMENT NO: BS/PHP101/05
2.0 NAME OF EXPERIMENT: Newton's Ring
3.0 0BJECTIVE: Determination of Wavelength of Light by Newton's Ring method
4.0 THEORITICAL BACKGROUND

(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.

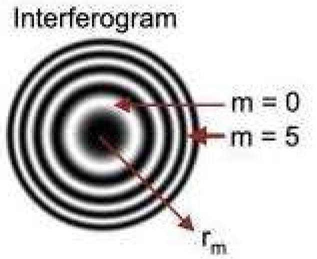


Figure 3.

(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 2μt, where 'μ' is the refractive index of the film and 't' is the thickness of the air film.

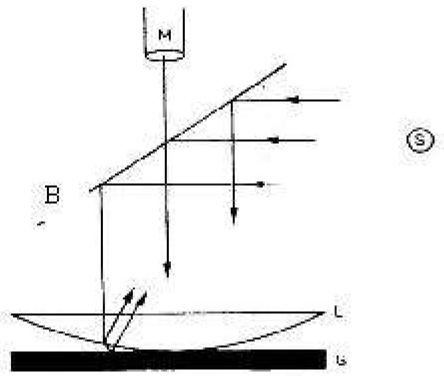


Figure 4.

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 μ = 1 for air)

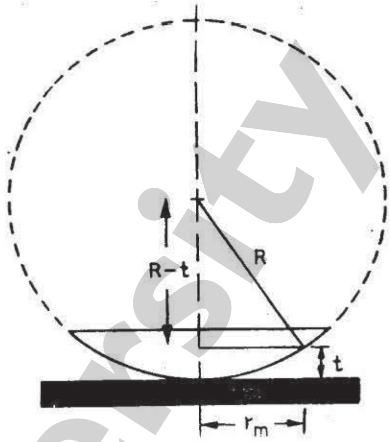


Figure 3.

$2t = n\lambda$ 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 .

(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

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

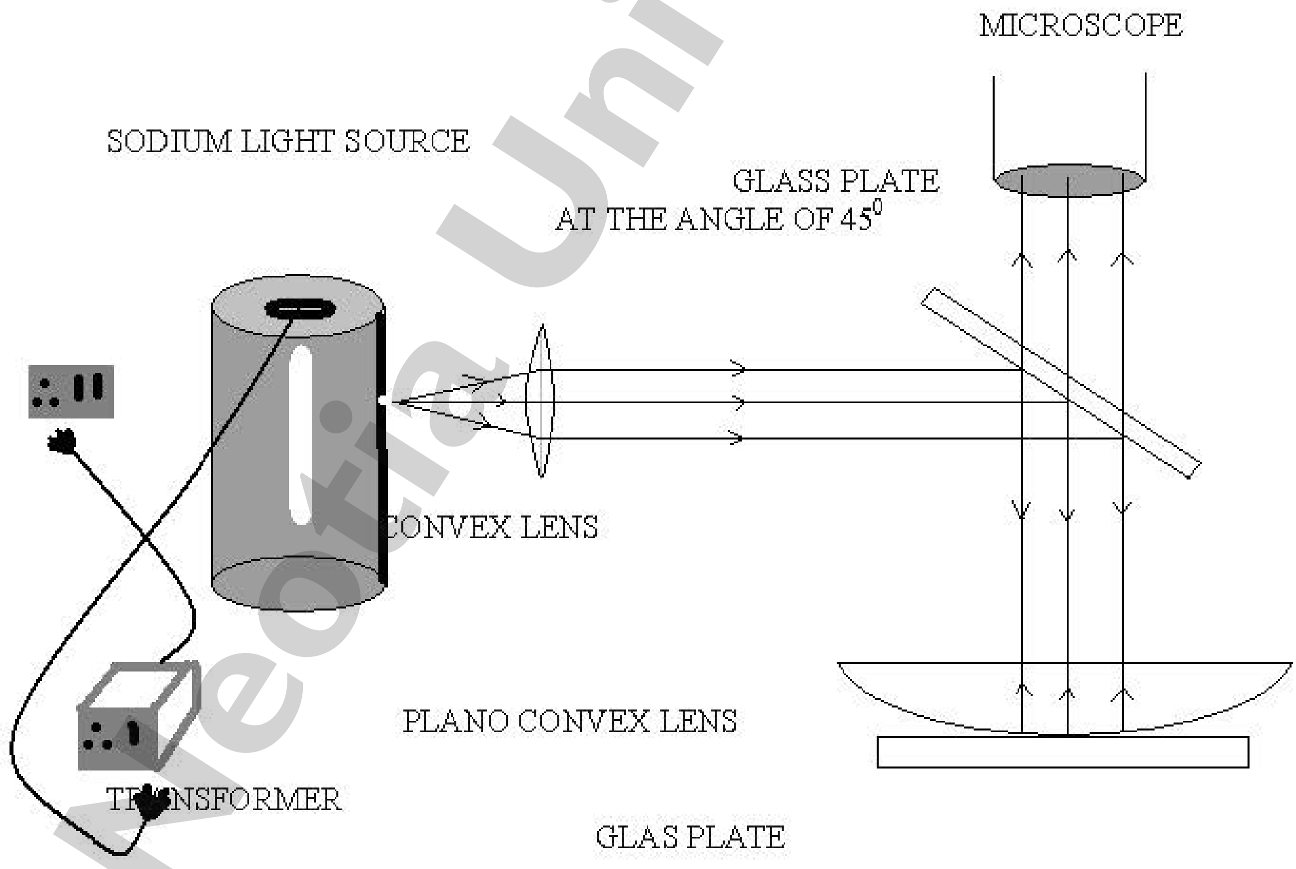
So if we know the R(radius of curvature of the lens), we can calculate wavelength λ and vice-versa. Also we can determine refractive index of any unknown liquid.

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).

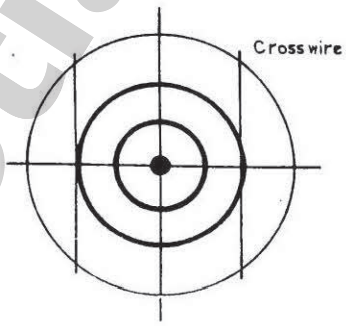


Figure 2.

- 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. *To avoid the backlash error circular scale should be rotated in one direction*.

↓

- 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

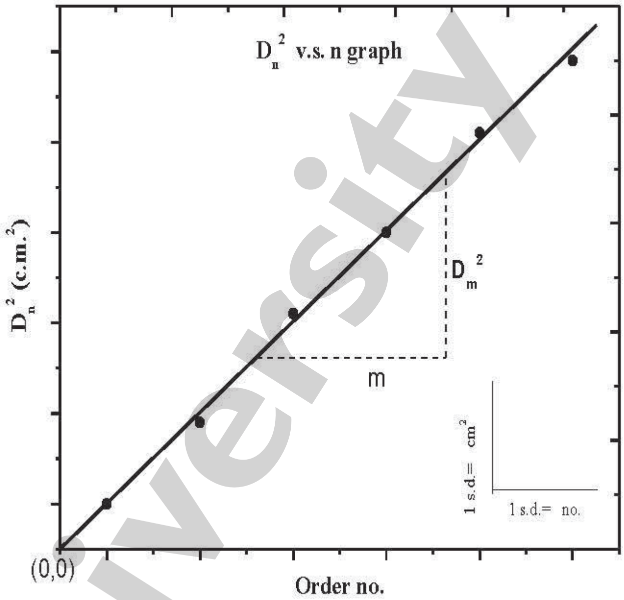
From the data of the Table – 2 plot a graph with n along abscissa (x - axis) and D_n^2 along vertices (y – axis). Determine the values of n and D_n^2 from the graph. Therefrom calculate the value of the wavelength of light as illustrated in Table -3.

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. $2 \times l.c.$. the error in Dn^2 or $D_{m+n}{}^2$ is, therefore $4 \times l.c.$ The error in obtaining $D_{m+n}{}^2 - D_n{}^2$ is $8 \times l.c.$)

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 $\left(\frac{\partial\lambda}{\lambda} \text{ x } 100\right)\%$

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

WORK INSTRUCTION

1.0 EXPERIMENT NO: BS/PHP101/02

2.0 NAME OF EXPERIMENT: Rigidity Modulus

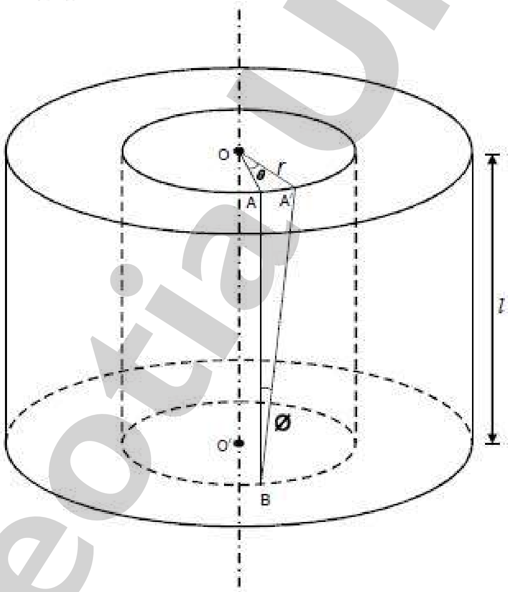
3.0 0BJECTIVE: determination of Rigidity Modulus of the material of an wire by dynamical method

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)

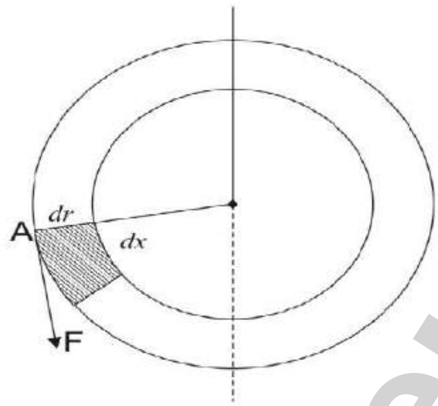


Now due to the elastic property of the material the relative turnung of the co-axial disc gives rise to a restoring torque which tends to prevent the twisting of the cylinder.

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

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

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

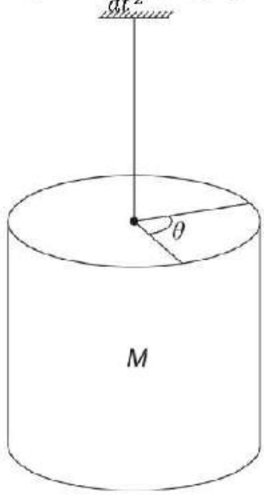
The total restoring torque that comes to play during the twisting of the entire cylinder of radius r is $\Gamma = \frac{2\pi\eta\varphi}{l}\int_0^r r^3 dr = \frac{2\pi\eta\varphi}{l}\frac{r^4}{4} = = \frac{\pi\eta\varphi\, r^4}{2l}$ ………………(3)

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

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 velocity ω. We imagine that the body is made up of a large number of particles of masses $m_1, m_2, m_3, \ldots$, 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

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

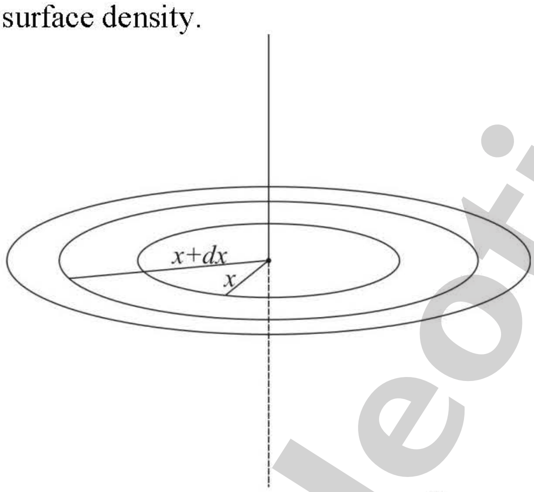
$= \frac{1}{2}\omega^2(m_1 r_1^2 + \frac{1}{2} m_2 r_2^2 + \frac{1}{2} m_3 r_3^2 + \ldots\ldots\ldots\ldots)$

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

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:

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

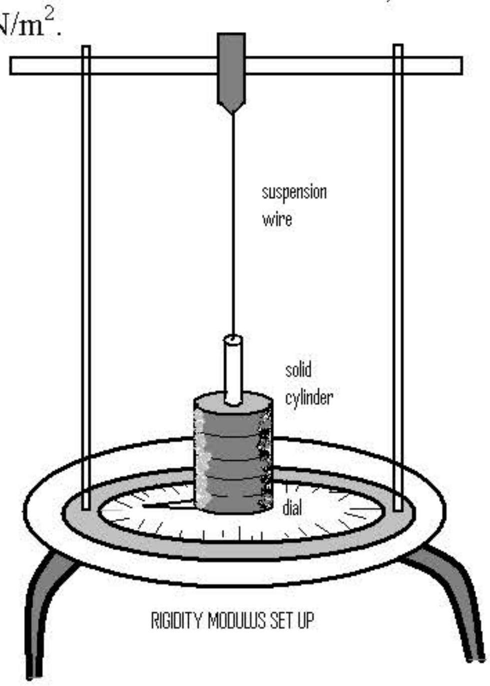
If we suspend a solid cylinder as the bob of the torsion pendulum, then by calculating I and measuring l, r, and T experimentally, we can determine the modulus of rigidity (η) of the wire from the following equation.

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

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



RIGIDITY MODULUS SET UP

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)

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.

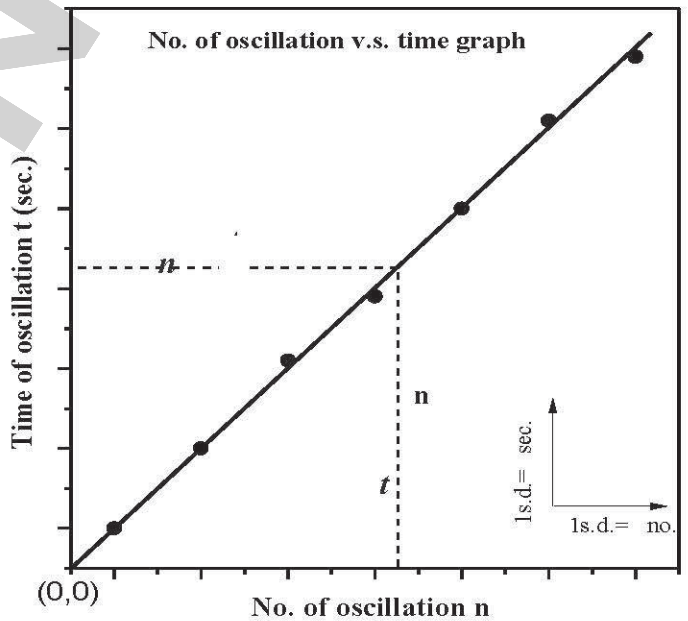


TABLE-6
Determination of Modulus of Rigidity (η)

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 η =ln L +ln M +2ln R – 2ln T – 4ln 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: ($\frac{\partial\eta}{\eta}$ x 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,

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

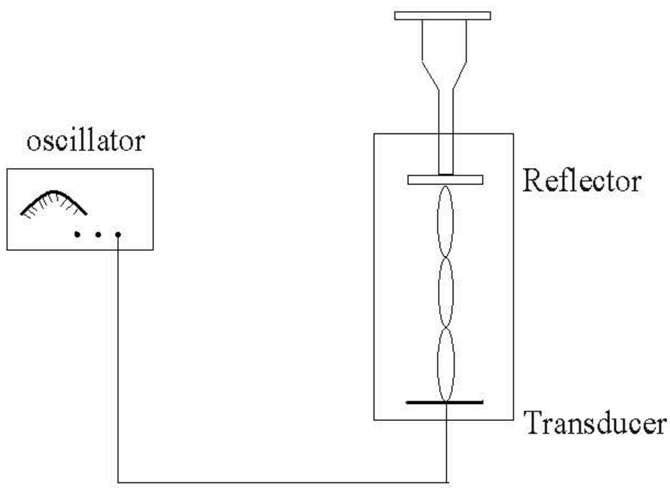
From the knowledge of wavelength (λ), the velocity (V) can be obtained by the relation

$$V = \lambda \times f$$

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.)
	0			d_0=	0.0			
	4			d_1=	$d_0 - d_1$=			
	8			d_2=	$d_0 - d_2$=			
Water	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.

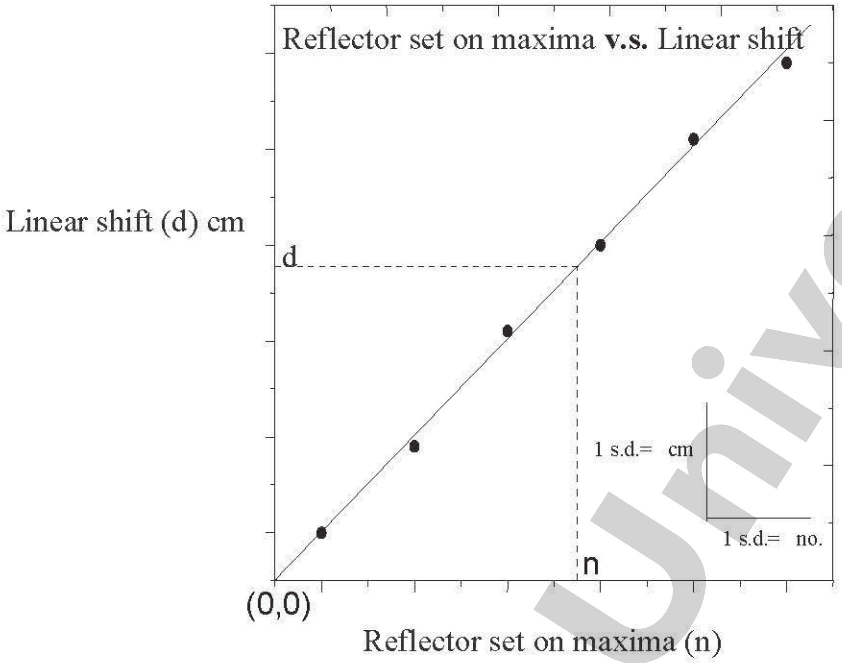


TABLE-3

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)

l

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.

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WORK INSTRUCTION

1.0 EXPERIMENT NO: BS/PHP101/01

2.0 NAME OF EXPERIMENT: Young's modulus

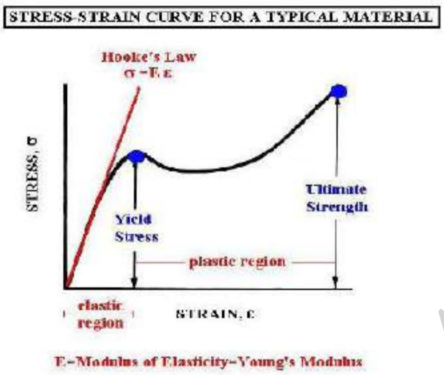
3.0 0BJECTIVE: Determination of Young's modulus by flexure method and calculation of bending moment and force at a point on the beam

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

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

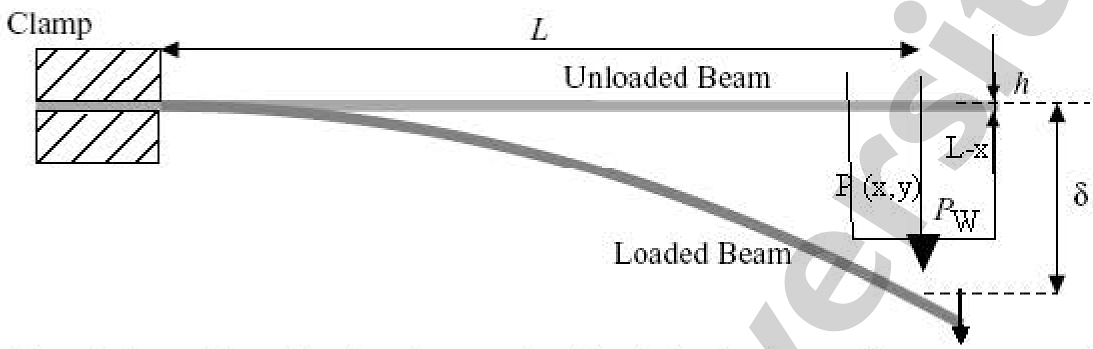
If F be the applied tensile force which causes a body of length l and cross-section A to elongate by x in the direction of force, the longitudinal stress is equal to F/A and the longitudinal strain is x/l. Hence, we express Young's modulus as

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

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.*
Yak^2 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 $Y = \frac{gL^3m}{4bd^3l}$

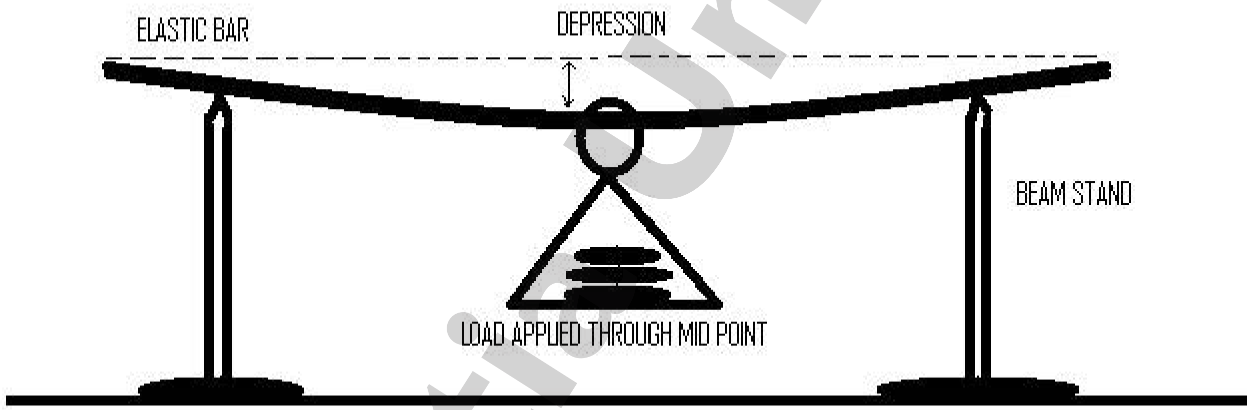
5.0 PRINCIPLE: If a light bar of breadth b and depth d is placed horizontally on two knife edges separated by a distance L, and a load of mass m , applied to the midpoint of the bar, produce a depression l of the bar, then young's modulus Y of the material of the bar is given by

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

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 Increasing load (x): Main scale m_s (cm)	Increasing load (x): Vernier reading v_s	Increasing load (x): Total reading $= m_s + v_s \times vc1$ (cm)	Decreasing load (y): Main scale m_s (cm)	Decreasing load (y): Vernier reading v_s	Decreasing load (y): Total reading $= m_s + v_s \times vc1$ (cm)	Avg. Microscope reading $\frac{(x+y)}{2}$ (cm)	Depression l (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 $2\text{x}10^{11}$ N/m^2 and in cgs unit $2\text{x}10^{12}$ dyne/cm^2

9.0 COMPUTATION OF PERCENTAGE ERROR:

We have the formula for

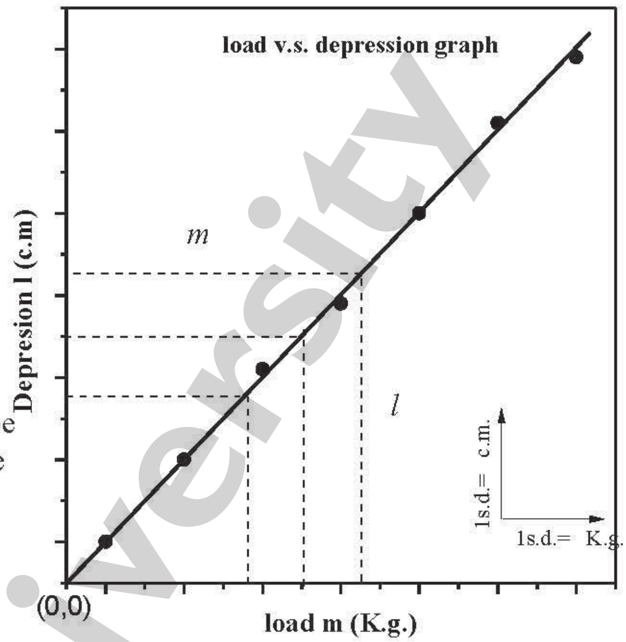
Young's Modulus as: $Y = \dfrac{gL^3 m}{4bd^3 l}$

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, $\dfrac{\partial Y}{Y} = \dfrac{\partial b}{b} + \dfrac{3\partial d}{d} + \dfrac{\partial l}{l}$

(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 ($\dfrac{\partial Y}{Y}$ × 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