EXPERIMENT : 1

VERNIER CALIPERS

Aim :

To measure the breadth of glass slab, using Vernier calipers.

Apparatus :

Vernier calipers and a glass slab.

Description :

As shown in Fig. 1.1 below, the Vernier calipers consists of a main scale M and a Vernier scale V. A jaw A attached to the main scale and another jaw B attached to the Vernier scale are used to hold an object whose dimension is to be measured. The Vernier can be moved along the length of the scale. It can be clamped at desired position using a screw S.

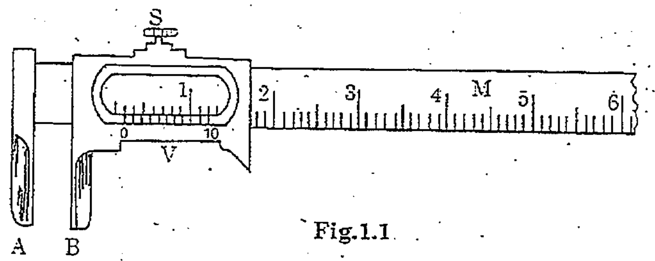


Fig.1.1

Procedure :

a. Least count : The number of divisions in one cm of main scale (M) and total number of divisions in Vernier scale (V) are noted. The zero of vernier scale is made to coincide with any division of main scale. The number of main scale divisions covered by Vernier scale is found out. For a typical Vernier calipers used in the laboratory,

10 Vernier scale divisions (v.s.d) = 9 main scale divisions (m.s.d.)

1 Vernier scale division = (9/10) main scale division

Number of main scale divisions in one cm = 10

Value of one m.s.d. = (1/10) cm

Value of one v.s.d. = (9/10) m.s.d.

The least count is defined as :

Least count= 1 main scale division – 1 Vernier scale division

i.e., L.C = 1 m.s.d. – 1 v.s.d

= 1 m.s.d. – (9/10) m.s.d.

= (1/10) m.s.d.

= (1/10) × (1/10) cm

= 0.01 cm.

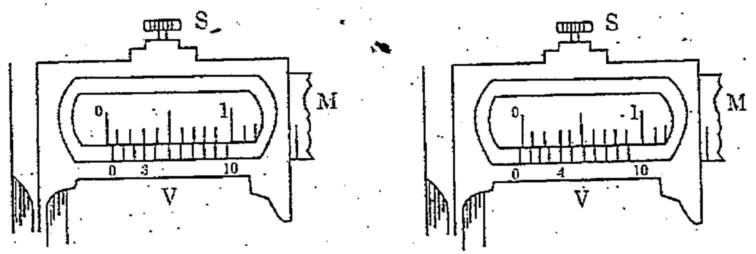
b. **Zero Error and Zero Correction :** When the two jaws of Vernier calipers are brought into contact, the zero of vernier scale should coincide with the zero of the main scale. But due to wear and tear, the Vernier zero lies either right or left of zero of the main scale.

If the Vernier zero is to the right of main scale zero, as shown in Fig.1.2a, and if x^{th} vernier scale division coincides with a main scale division, then zero error is positive and the positive error = x (Least Count) = x. LC

The zero correction is negative, equal to – x. LC

On the other hand, if vernier zero lies to the left of main scale zero as shown in Fig 1.2b, and if x^{th} vernier scale division coincides with a main scale division, then zero error is negative and the negative error = – (n-x) (Least Count) = – (n–x). LC where n is the total number of vernier scale divisions. Correspondingly, zero correction is positive and is equal to + (n – x).LC.

Illustration :



Positive zero error
a

Negative zero error
b

Fig. 1.2

In Fig. 1.2a, zero error is positive and third v.s.d. coincides with a m.s.d. Therefore,

Zero Error (Z.E.) = +3 × L.C.

Zero Correction (Z.C.) = – 3 × L.C.

In Fig.1.2 b, zero error is negative and fourth v.s.d. out of ten (n=10) coincides with a m.s.d. Therefore,

Z.E. = –(n–4) × L.C.,

= – 6 × L.C.

and Z.C. = + 6 × L.C.

The zero correction is to be added to the observed reading, taken with the Vernier Calipers.

c. **Measurement :** Given glass slab is held gently between the two jaws along its breadth. The main scale reading (MSR) in cm just before the Vernier zero is noted. The number of vernier scale division (VSD) coinciding with a main scale division is found out. The observations are repeated in various positions and readings are tabulated as given in Table 1.1.

The Observed reading is then given by :

Observed Reading (O.R.) = MSR + VSD (L.C). Now by adding zero correction to the observed reading, correct reading (C.R.) is obtained.

Observations :

Least Count (L.C) = cm, Zero Error (Z.E) = cm,

Zero Correction (Z.C) = cm

Table 1.1 : Breadth of the glass slab.

S.No.	MSR cm	Coinciding V.S.D.	Observed Reading : MSR + VSD.(L.C) cm	Correct Reading : O.R. + Z.C. cm
1.				
2.				
3.				

Mean = cm.

Note :

The result is expressed in metres.

Result :

Breadth of glass slab = m

⊛⊛⊛⊛⊛⊛

EXPERIMENT : 2

SCREW GAUGE

Aim:

To determine the diameter of a wire using screw gauge.

Apparatus :

Screw gauge and a wire.

Description :

Screw gauge, shown in Fig. 2.1, consists of a uniform screw. The screw advances through a groove, cut inside a hollow cylinder C. The cylinder is rigidly fitted into a U-shaped metallic frame F.

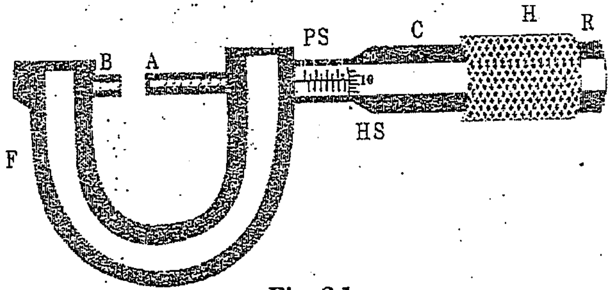


Fig. 2.1

A scale calibrated in mm, called pitch scale PS, is engraved on the cylinder parallel to its axis. The head of the screw H is attached to a sleeve. The bevelled edge of the sleeve is divided into N (50 or 100) equal parts. This is the head scale (HS) of screw gauge. The advancing end of the screw has a shaft with a perfectly plane surface A. A similar plane surface B is fixed on to the frame F, just opposite to A.

Procedure :

a. **Least Count :** To start with, the zero of head scale (HS) is adjusted to coincide with any one of the pitch scale division. The screw is then given 10 full rotations. The distance advanced by the beveled edge on pitch scale and total number of divisions on head scale are noted. The least count of the screw gauge is calculated as follows.

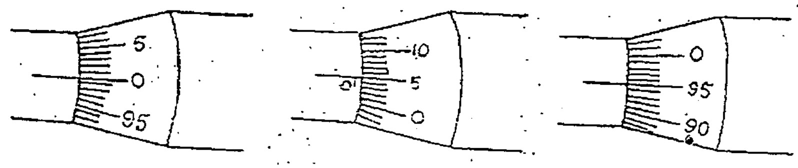
The distance advanced for ten rotations = d mm

Pitch of screw gauge p = d/10 mm

Total number of divisions on head scale = N

Therefore, Least Count (L.C.) = p/N mm

b. **Zero Error and Zero Correction :** When the plane faces A and B touch each other, the zero of head scale should coincide with the zero of pitch scale (Fig. 2.2a). If not, the screw gauge has Zero Error (Z.E.). If the zero of H.S. lies below the line of pitch scale, as shown in Fig.2.2b, the error is positive. Let x^{th} division on H.S. coincides with pitch scale line.



no zero error a　　positive zero error b　　negative zero error c

Fig. 2.2

Zero Error = $+x$ (L.C.) mm

When the Zero Error is positive, the correction to be applied is negative and is given by

Zero Correction = $-x$ (L.C.) mm

On the other hand, if the zero of H.S. (Fig. 2.2c) lies above pitch scale line, then the Zero Error becomes negative and Zero Correction, positive. Let x^{th} divisions of H.S. be coinciding on the pitch scale line. With N being total number of head scale divisions (h.s.d),

Zero Error = $-(N-x)$ (L.C.) mm

and Zero Correction = $+(N-x)$ (L.C.) mm

Illustration : In Fig.2.2b, as Z.E. is positive and fifth division falls on the line.

Zero Error = +5 (L.C.)

Zero Correction = −5 (L.C.)

Similarly, in Fig. 2.2 c, for N = 100, as Z.E. is negative and 95^{th} division coincides with pitch scale line,

Zero Error = −(100 − 95) (L.C.) = −5 (L.C.)

and Zero Correction = +5 (L.C.)

In both cases, Zero Correction must be added to the observed readings to get correct readings.

c. **Measuring the diameter of a wire :**

The given wire is held lightly between the faces, A and B. The pitch scale reading (P.S.R.) and coinciding head scale division (H.S.D.) on pitch scale line are noted accurately.

Observed reading (O.R) = P.S.R.+ (H.S.D.).(L.C.)

And therefore, correct reading (C.R) = O.R.+ Z.C.

The observations are repeated for various positions and readings are tabulated as in Table 2.1.

Observations

Least Count (L.C.) = mm

Zero Error (Z.E.) = mm

Zero Correction (Z.C.) = mm

Table 2.1 : Diameter of the wire

S.No.	P.S.R. mm	H.S.D.	O.R. = PSR + HSD (L.C) mm	C.R.= O.R.+Z.C. mm
1				
2				
3				

Mean = mm

Result :

The diameter of the given wire = m.

⊛⊛⊛⊛⊛⊛

EXPERIMENT : 3

TRAVELLING VERNIER MICROSCOPE

Aim :

To measure inner and outer diameter of a uniform capillary tube, using a Vernier microscope.

Apparatus :

Vernier microscope, capillary tube with well-cut ends.

Description :

Vernier microscope is a compound microscope, having independent horizontal and vertical movements. As shown in Fig. 3.1, the microscope can be raised or lowered by the screw S_1 along the vertical pillar P. The position is measured using the main scale M_1 and the Vernier scale V_1. Similarly it can be moved left or right horizontally by the screw S_2 and its position is measured using the main scale M_2 and the Vernier scale V_2.

The complete arrangement is on a horizontal platform, which can be leveled using base screws and spirit level. Using the screw S, the axis of microscope may be fixed at desired direction – vertically, horizontally or at any inclined position. The object is viewed through the eyepiece E. The object is focussed by adjusting the distance between the eyepiece E and the objective lens O using a screw attached to the body of microscope. The eyepiece alone can be adjusted to get a clear view of the cross wires.

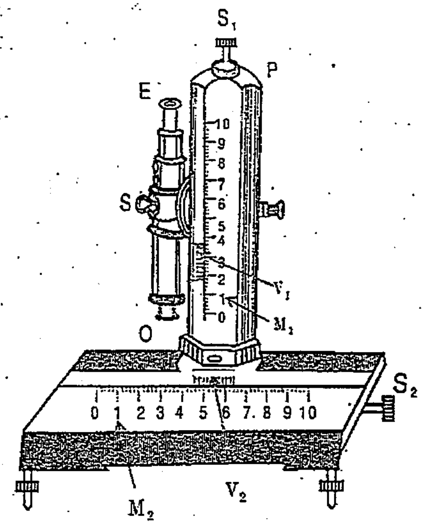


Fig. 3.1

EXPERIMENT: 4

YOUNG's MODULUS – Non Uniform Bending - I

PIN and MICROSCOPE

Aim :

To determine the Young's modulus of elasticity of the material of a beam, subjecting it to non-uniform bending using pin and microscope.

Apparatus :

A rectangular bar of uniform cross-section. Vernier microscope, two knife edges with supports, weight hanger with slotted weights, pin etc.

Procedure :

The given rectangular bar AB is placed symmetrically on two knife edges K_1 and K_2 such that $K_1A = K_2B$. Mid point C of the bar is noted and a weight hanger H, having a dead weight W is suspended from it. A pin is fixed vertically at C, with its tip upwards, as shown in Fig. 4.1a.

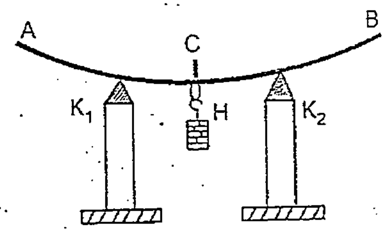


Fig. 4.1a

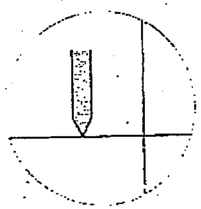


Fig. 4.1b

A Vernier microscope is conveniently placed in front of the pin in horizontal position. It is focused to see the tip of the pin. With proper adjustments along vertical scale, the horizontal cross wire is made to coincide with the tip of the pin. The image of the pin is enlarged and inverted. (Refer Fig. 4.1b) Now the reading corresponding to this position is noted using the vertical main scale and the corresponding vernier. This is the first reading with the initial dead weight W. Then weights are added to the hanger in steps of m, say, 50g. Each time, the horizontal cross wire is made to coincide with the tip of the pin and readings are taken. For convenience, including the reading for the dead weight W, eight or ten (even number of) readings can be taken while loading. The procedure is repeated by unloading the weights in steps of m.

The least count of vertical vernier of microscope is found out and readings are tabulated as in Table 4.1.

To reduce error, the shift for 4m is calculated first as shown in Table.4.1

Formula:

Consider a rectangular bar of breadth b and thickness d, placed horizontally on two knife edges separated by a distance l. When a load of mass m is applied at the mid point of the bar it produces a depression s in the bar. Then the Young's modulus (E) of the material of the bar is given by

$$E = \frac{g l^3}{4 b d^3}\left(\frac{m}{s}\right)$$

For a given rod of length l the depression s is directly proportional to the load applied. Knowing the values of l, b and d the Young's modulus E is calculated.

Table 4.1 L.C. = cm

Load	Microscope Reading		Mean	Shift for 4m
	Loading	Unloading		
kg	cm	cm	cm	cm
W			x_0	
W+ m			x_1	
W+2m			x_2	
W+3m			x_3	
W+4m			x_4	$x_4 - x_0$
W+5m			x_5	$x_5 - x_1$
W+6m			x_6	$x_6 - x_2$
W+7m			x_7	$x_7 - x_3$

Mean shift for 4m = cm

Shift for m = s = cm

The distance between the knife edges l is measured accurately.

With Vernier calipers and screw gauge, the breadth b [Table 4.2] and thickness d [Table 4.3] are measured respectively.

Table 4.2 : Breadth b – Using Vernier Calipers

S.No	MSR cm	Coinciding V.S.D.	Observed Reading : MSR + VSD.(L.C) cm	Correct Reading : O.R. + Z.C. cm
1.				
2.				
3.				

Mean = cm.

Table 4.3. : Thickness d – Using Screw gauge.

S.No.	P.S.R. mm	H.S.D.	O.R. = PSR + HSD (L.C) mm	C.R.=O.R.+Z.C. mm
1				
2				
3				

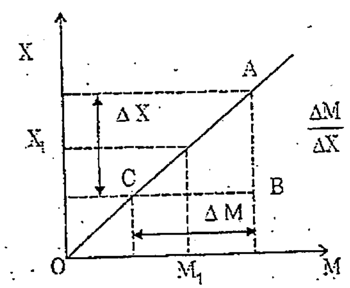
Mean = mm

Load vs depression graph:

To draw a graph of load versus depression. the microscope readings X for masses M = m, 2m,3m.... etc. are tabulated, after subtracting dead weight (W) reading from the mean reading for each load.

A graph of M versus X is drawn as schematically shown in Fig. 4.3.

M kg	X 10^{-2} m
m	
2m	
,	
Body	X_1



$$\frac{\Delta M}{\Delta X} = \frac{BC}{AB}$$

Fig. 4.2.

From the graph, ΔM/ΔX can be calculated.

Observations :

Distance between knife edges l = m

Breadth of bar b = m

Thickness of bar d = m

Acceleration due to gravity g = 9.81 ms^{-2}

Mean m/s = kg m^{-1}

From graph, ΔM/ΔX = m/s = kg m^{-1}

Young's Modulus of the rod $E = \frac{gl^3}{4bd^3}\left(\frac{m}{s}\right) =$ Nm^{-2}

Note 1:

In all bending experiments (Expt.4 to Expt.8), loading and unloading procedure is repeated two or three times with out taking any readings. This is to bring the beam to the elastic mood.

Note 2:

To determine unknown mass of a given body, the body is attached to the hanger (with dead weight W) and the corresponding scale reading is noted. Subtracting dead weight reading, the reading X_1 corresponding to given body is found out. Then from the graph [Fig. 4.2], the mass M_1 of the body is determined.

The experiment can be repeated by changing the distance between the knife edges, i.e., for different values of l.

Result :

(i). Young's Modulus–by calculation E = Nm^{-2}

(ii). Young's Modulus-by graph E = Nm^{-2}

(iii). Mass of given body M_1 = kg

EXPERIMENT : 7

YOUNG'S MODULUS – Uniform Bending - I

PIN AND MICROSCOPE

Aim :

To determine Young's modulus of elasticity of the material of the beam, subjecting it to uniform bending.

Apparatus :

Long rectangular beam, two knife edges, two weight hangers with equal dead weights, two sets of slotted weights, Vernier microscope, pin etc.

Procedure :

The rectangular, uniform beam AB is placed symmetrically on the knife edges K_1 and K_2. The weight hangers H_1 and H_2 with dead weight W are suspended at C and D with equal distance from A and B respectively as show in Fig. 7.1 below.

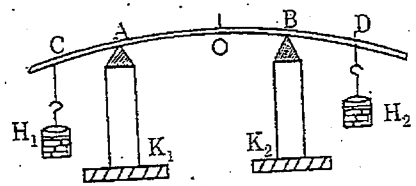


Fig. 7.1.

A pin is attached vertically at the midpoint O of the beam, with its tip pointing upward. Vernier microscope is placed nearer to the pin in horizontal position and is adjusted to focus the tip of the pin. The horizontal cross wire of the eyepiece is made to coincide with the tip of the pin. The vertical main scale reading, together with coinciding Vernier scale divisions are noted. This is the first reading with only the dead weight W on both the weight hangers. Now the loads are added to the hangers equally in the steps of m (equal to, say, 50g). Readings are taken in each case, after making the horizontal cross wire to coincide with the tip of the pin. Experiment is again performed by removing equal weights from both the hangers and readings are recorded as in Table 7.1.

To reduce error, the shift for 4m is calculated first as shown in Table.7.1

The length l of the beam between knife edges, the distance a of each weight hanger from the nearest knife edge are measured.

Table 7.1 L.C. = cm

Load	Microscope Reading		Mean	Shift for 4m
	Loading	Unloading		
kg	cm	cm	cm	cm
W			x_0	
W + m			x_1	
W + 2m			x_2	
W + 3m			x_3	
W + 4m			x_4	$x_4 - x_0$
W + 5m			x_5	$x_5 - x_1$
W + 6m			x_6	$x_6 - x_2$
W + 7m			x_7	$x_7 - x_3$

Mean shift for 4m = cm

Shift for m= s = cm

Using Vernier calipers and screw gauge, the breadth b [see Table 4.2] and thickness d [see Table 4.3] of the beam are respectively found out.

The experiments may be repeated either for different length of beam between the knife edges or for different symmetric points of suspension of the hangers.

A graph of weight M = m, 2m, 3m, ...etc. along x – axis and mean elevation X (after subtracting dead weight reading) along y – axis is drawn [Refer Fig. 4.2]. The straight line graph (elevation is directly proportional to load applied) is used to find $m/s = \Delta M / \Delta X$

Formula :

A uniform rectangular beam of width b and thickness d, placed symmetrically on two knife edges separated by a distance l, is subjected to uniform bending by a constant bending couple at all points of the beam. Thus, in uniform bending the elevation s of the midpoint of the beam due to load of mass m applied on both the end at a distance a from the nearest knife edge is given by

$$s = \frac{3}{2}\frac{gal^2}{bd^3}\left(\frac{m}{E}\right)$$

And hence the Young's Modulus of the material of the beam

$$E = \frac{3}{2}\frac{gal^2}{bd^3}\left(\frac{m}{s}\right)$$

By measuring mean elevation s for load m, the Young's modulus is determined. Further, from load versus elevation graph (straight line) one can calculate m/s .

Observations :

Distance between knife edges	l =	m
Distance between weight hanger and adjacent knife edge	a =	m
Breadth of the beam	b =	m
Thickness of the beam	d =	m
Acceleration due to gravity	g = 9.81 ms^{-2}	

Mean (m/s) = kgm^{-1}

By graph, $\Delta M/\Delta X$ = m/s = kgm^{-1}

Young's Modulus $E = \frac{3}{2}\frac{g\,a\,l^2}{b\,d^3}\left(\frac{m}{s}\right) =$ Nm^{-2}

Result :

(i). Young's Modulus by calculation = Nm^{-2}

(ii). Young's Modulus by graph = Nm^{-2}

EXPERIMENT : 8

YOUNG'S MODULUS – Uniform Bending - II

SINGLE OPTIC LEVER

Aim :

To determine Young's modulus of elasticity of the material of the beam, subjecting it to uniform bending.

Apparatus :

Uniform rectangular bar, two knife edges, two weight hangers with slotted weights, optic lever, scale and telescope etc.

Procedure :

The rectangular bar is placed symmetrically on two knife edges K_1 and K_2. The front leg of single optic lever is resting on the mid point O of the beam [Fig.8.1]. The other two hind legs are resting on a suitable support kept at same level behind the beam. The weight hangers H_1 and H_2 with dead weight W, as in previous case (Expt.7), are suspended from the points C and D of the beam as shown in Fig.8.1.

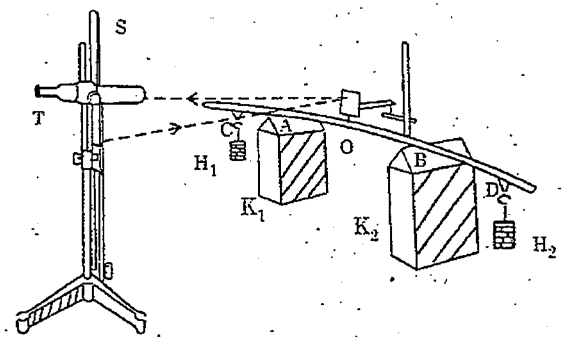


Fig. 8.1

The scale with telescope is held vertically in front of the plane mirror of optic lever. The telescope is focused to see the image of scale divisions reflected by the mirror of the optic lever. The horizontal cross wire of the telescope is adjusted to coincide with a definite division on the scale and the reading is noted.

EXPERIMENT : 13

YOUNG'S MODULUS - CANTILEVER

(STATIC METHOD- III)

SCALE AND TELESCOPE - DEFLECTION

Aim :

To determine Young's modulus of cantilever by measuring deflection of loaded free end with scale and telescope arrangement.

Apparatus :

A long rectangular beam, weight hanger with slotted weights, scale and telescope, small plane mirror etc.

Procedure :

After setting the rectangular beam with one end A rigidly fixed and other end B carrying a weight hanger H with dead weight W, a small plane mirror M is attached to the cantilever at point B, as shown in Fig.13.1.

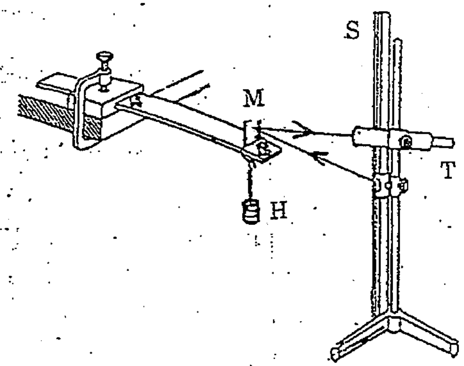


Fig.13.1

A vertical scale S with telescope T are kept in front of the mirror. Telescope is adjusted to focus the image of certain scale division reflected by the mirror and scale reading is noted for the dead weight W in the hanger. The weights are added in the steps of m (say 50 g) and correspondingly the respective scale readings are noted. The weights are gently removed one by one (in the same steps of m) and the

scale readings are noted. The readings thus obtained while loading and unloading are tabulated, as given in Table 13.1.

Note :

Before noting the readings, the cantilever is loaded to the maximum limit and the scale must be adjusted to get the image within the field of view of telescope.

The length l of cantilever from fixed end to free end is measured. The distance D between the scale and mirror is noted.

The breadth b and thickness d of the cantilever are measured by vernier calipers and screw-gauge respectively and readings are tabulated as in Table 4.2 and Table 4.3.

Experiment is repeated for different suitable lengths of the cantilever, by clamping it at various points.

Table 13.1

Load	Telescope Reading		Mean	Shift for 4m
	Loading	Unloading		
kg	cm	cm	cm	cm
W			x_0	
W + m			x_1	
W + 2m			x_2	
W + 3m			x_3	
W + 4m			x_4	$x_4 - x_0$
W + 5m			x_5	$x_5 - x_1$
W + 6m			x_6	$x_6 - x_2$
W + 7m			x_7	$x_7 - x_3$

Mean shift for 4m = cm

Shift for m= x = cm

Formula :

Let x be the shift in reading for mass m on the scale kept at a distance D from the mirror. The deflection of the cantilever from unloaded horizontal direction is

$$\theta = x / 2D$$

But the deflection of cantilever of length l, breadth b and thickness d is given by

$$\theta = \frac{6gl^2}{bd^3}\left(\frac{m}{E}\right)$$

Therefore, on substitution, the Young's modulus of the material of cantilever is

$$E = \frac{12gl^2D}{bd^3}\left(\frac{m}{x}\right)$$

A graph (see Fig. 4.2) is drawn with load M (equal to m, 2m, ...etc.) versus mean telescope reading X (subtracting dead weight reading). The value of $\Delta M / \Delta X$ is calculated.

Observations:

Length of beam from clamped end to free end	l	=	m
Distance between scale and mirror	D	=	m
Breadth of the beam	b	=	m
Thickness of the beam	d	=	m
Acceleration due to gravity	g	= 9.81 m s^{-2}	

Mean (m/x) = kg m^{-1}

By graph, $\Delta M / \Delta X$ = m/x = kg m^{-1}

Result :

(i) Young's modulus, by calculation = Nm^{-2}

(ii) Young's modulus, by graph = Nm^{-2}

EXPERIMENT : 14

YOUNG'S MODULUS – CANTILEVER
(DYNAMIC METHOD)

Aim :

To determine Young's modulus of the material of cantilever by finding the period of vertical oscillations.

Apparatus :

Cantilever (metre scale), weight hanger with slotted weights, stop clock, microscope.

Procedure :

As in previous experiment [Expt. 12], a long rectangular beam is clamped at one end A and a weight hanger H is suspended at the free end B. A small needle is fixed to the frame of the hanger [refer Fig. 12.1]. A mass M_1 (equal to, say, 50g) is added to the weight hanger so that it does not produce appreciable depression at the free end of the cantilever. A microscope, placed in front of the pin, is focused such that the horizontal cross wire just coincides with the tip of the pin.

The free end of the cantilever is slightly depressed and is then released so as to execute vertical oscillations. Taking the horizontal cross wire as the reference line, the time for, say, ten oscillations is noted using stop clock. The experiment is repeated twice and mean period of oscillation T_1 is found out. Next, with adding a mass M_2 (equal to 100g) and adjusting the cross wire, the experiment is performed to find the corresponding period of oscillation T_2. The experiment is repeated for different lengths of cantilever and readings are tabulated as in Table 14.1.

Formula :

Consider a uniform cantilever of length l, breadth b and thickness d, clamped at one end and carrying a mass M at free end. Let the cantilever be set oscillating in vertical plane. The period of oscillation is given by

$$T^2 = \frac{16\pi^2 l^3}{Ebd^3}\left(M + \frac{m}{3}\right),$$

where m is the mass of cantilever and E, the Young's modulus of the material of the cantilever.

EXPERIMENT : 18

COMPOUND PENDULUM

Aim:

To determine acceleration due to gravity and radius of gyration of a compound bar pendulum about its center of mass (gravity).

Apparatus :

A bar pendulum, stop clock, metre scale, etc.

Description :

A compound bar pendulum AB is a metallic, thick rectangular bar, one metre long, as shown in diagram Fig.18.1a. A number of small circular holes of about 5mm diameter are drilled along the length of the bar at equal distance (about 5cm) from each other. The bar pendulum can be suspended vertically from each of these holes through a horizontal knife edge K, fixed rigidly to a support on the wall.

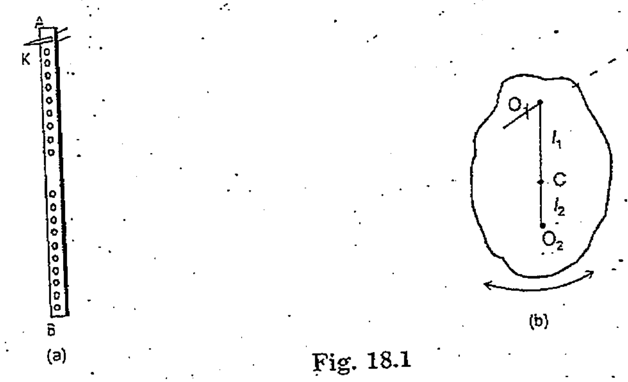


Fig. 18.1

Formula:

Consider a rigid body (compound pendulum) of center of mass (gravity) C, suspended from a point O_1, at a distance l_1 from C. For any centre of suspension O_1 there is a point O_2, called centre of oscillation, at a distance l_2 from C [Fig. 18.1 b] about which the period of oscillation is the same.

Generally, centre of suspension and centre of oscillation, lying on either side of centre of gravity are at unequal distances from it. Then $O_1O_2 = L$ is the length of equivalent simple pendulum of period T, given by,

$$T = 2\pi\sqrt{\frac{L}{g}}$$

Therefore, $$g = 4\pi^2\left(\frac{L}{T^2}\right).$$

The radius of gyration K of the rigid body about the centre of gravity is defined by

$$K^2 = l_1 l_2$$

Thus finding the period T of a compound pendulum for centre of suspension and centre of oscillation and the length L of equivalent simple pendulum, the acceleration due to gravity and radius of gyration can be determined.

Procedure :

The bar pendulum is suspended by the knife edge passing through the first hole from one end A (say). With the help of a pointer, the position of rest of the pendulum is noted. The bar is set to small oscillations about the equilibrium point. Leaving first three or four oscillations, the time taken for twenty oscillations with two trials is noted. The distance of the knife edge from the top end A is found out. The experiment is repeated by suspending the bar in each hole and the distance from A to knife edge is measured. After crossing centre of gravity, the bar is suspended upside down, but the distance of knife edge is measured from same end A of the bar. Observations are tabulated as in Table 18.1.

A graph is drawn taking distance l of knife edge along x-axis and period of oscillation T along y-axis. The graph is symmetrical about the line passing through the centre of gravity C parallel to y-axis. It consists of two similar curves on either side of C. (Fig.18.2). A line PQRS is drawn, parallel to x-axis, cutting the curve at four points P, Q, R and S. The points P and R, lying on either side of C, correspond to the centre of suspension and centre of oscillation respectively. Similarly, other pair of points is Q and S. Hence, the length L of equivalent simple pendulum is

$$L = (PR + QS)/2$$

The other such lines are drawn and corresponding periods T are noted and tabulated in Table 18.2. The acceleration due to gravity

$$g = \frac{4\pi^2 L}{T^2}$$

is determined and mean value is taken.

From the graph (Fig 18.2), we note that

PM = SM = l_1 and RM = QM = l_2 and hence the radius of gyration about the axis passing through C is given by (Table 18.3)

$$K = \sqrt{l_1 l_2}$$

The mean value of K is calculated.

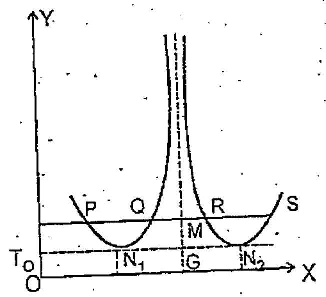


Fig. 18.2

Table 18.1 Period of Oscillation

No.of hole from end A	Distance from end A cm	Time for 20 Oscillations			Mean Period : T s
		I s	II s	Mean s	
1.					
2.					
3.					

Table 18.2 : Determination of g

Period - T s	PR cm	QS cm	Length of equivalent pendulum : L = (PR + QS) / 2 cm	L/T²

Mean L/T² = cms⁻²

Table 18.3 Determination of K

S.No	l_1=PS/2 cm	l_2 = QR/2 cm	$K = \sqrt{l_1 l_2}$ cm
1.			
2.			
3.			

Mean K = cm

Result :

(i) Acceleration due to gravity = ms^{-2}

(ii) Radius of gyration = m

Note :

For compound bar pendulum, the period is minimum (T_0) when L = 2K. Hence from the graph, Fig. 18.2, L = N_1N_2 = 2K, giving

$$K = \frac{N_1 N_2}{2}$$

and

$$g = \frac{4\pi^2 N_1 N_2}{T_0^2}$$

Table 19.1 Period of Oscillation

Face	l cm	Time for ten oscillations I s	Time for ten oscillations II s	Mean s	Period T s	l/T^2	By Expt. I kgm^2	By Calcul I kgm^2
L-B							I_1	
B-D							I_2	
L-D							I_3	

Observations:

Mass of the block	M	=	kg
Length of each string	l	=	m
Distance of separation	$2a$	=	m
Length of the block	L	=	m
Breadth of the block	B	=	m
Thickness of the block	D	=	m
Acceleration due to gravity	g	=	9.81 ms^{-2}

Result :

(i) Moments of inertia by experiment

I_1 = kg m² I_2 = kg m² I_3 = kg m²

(ii) Moments of inertia by calculation

I_1 = kg m² I_2 = kg m² I_3 = kg m²

Note :

The ratio of moments of inertia is

$I_1 : I_2 : I_3 = T_1^2 : T_2^2 : T_3^2 = (L^2 + B^2) : (B^2 + D^2) : (L^2 + D^2)$

[Keeping l and a same for all the three faces].

EXPERIMENT : 20

SURFACE TENSION

DROP WEIGHT METHOD

Aim:

To determine the surface tension of (i) water (ii) liquid (Kerosene oil) and interfacial surface tension between liquid and water.

Apparatus :

A glass funnel with vertical stand, a short glass tube of suitable diameter, rubber tubing, beaker, pinch clip, Hare's Apparatus, etc..

Description :

As shown in Fig.20.1, a short glass tube is connected to the lower end of funnel through a rubber tube. The funnel is held vertical with a rigid support. The flow of liquid through the glass tube can be adjusted by means of pinch clip, provided with the rubber tubing.

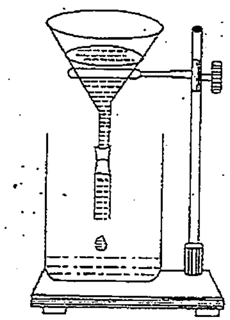


Fig. 20.1

Procedure :

To start the experiment, pure clean water is poured into the funnel. The pinch clip is adjusted so that drops are formed slowly and steadily at the open end of the glass tube. A dry, clean weighed beaker [weighing is done by electronic balance] is taken and, say, fifty drops of water are collected. The mass of beaker with 50 drops is measured. The experiment is repeated by collecting drops in steps of 50 and in each case, after deducting the mass of empty beaker, one can determine the mass of single drop. Hence mean mass of single drop of water is calculated. The readings are recorded as in Table 20.1.

Formula :

From Rayleigh Formula, the surface tension of water is given by

$$T = \frac{mg}{3.8\, r}$$

where, m is the mass of one drop of water, r is the radius of glass tube and g is the acceleration due to gravity.

Note :

The dropping end of the glass tube should be flat. The glass tube should be kept vertical. The pinch cock is adjusted so that the liquid drops are formed slowly, say at the rate of about eight drops per minute. In the case of a liquid which wets glass (like water), the value of r used is the external radius of the tube. For waxed tubes, the value of r is the internal radius which has to be found out by measuring the internal diameter of the tube using a vernier microscope. (Refer. Expt.3).

Table 20.1 : Drop weight - water : m_1

Object	Mass g	Mass of 50 drops g	Mass of single drop m_1 g
Empty Beaker	w_1		
Beaker + 50 drops	w_2	$(w_2 - w_1)$	
Beaker + 100 drops	w_3	$(w_3 - w_2)$	

Mean mass of one drop m_1 = g.

Surface Tension of liquid (Kerosene):

To find the surface tension of the liquid (kerosene), the funnel and glass tube are dried thoroughly and is filled with the kerosene oil. A dried and weighed beaker is taken to collect liquid drops in steps of fifty and after each collection, the mass of beaker with liquid drops is noted. The mean mass of single liquid drop m_2 is calculated. Use the same table as Table 20.1.

Interfacial Surface Tension:

To find interfacial surface tension of water in a lighter liquid (kerosene oil), sufficient quantity of kerosene is taken in the beaker. Mass of beaker with liquid is noted. By dipping the end of the glass tube in the liquid, water drops are formed within the liquid. The water drops are formed slowly within the liquid, say about six drops per minute. As in previous case, mass of water drops in steps of fifty is noted. From these readings the mean mass of single water drop in kerosene m_3 is calculated [Table 20.2].

Table 20.2 : Interfacial Drop weight : m_3

Object	Mass g	Mass of 50 drops g	Mass of single drop m_3 g
Beaker + Liquid	w_1	———	———
Beaker + Liquid + 50 drops of water	w_2	$(w_2 - w_1)$	———
Beaker + Liquid + 100 drops of water	w_3	$(w_3 - w_2)$	———

Mean mass of one drop m_3 = g.

The interfacial surface tension of water of density ρ_1 in a liquid of density ρ_2 is given by

$$T_{WL} = \frac{m_3 g}{3.8\, r}\left[1 - \frac{\rho_2}{\rho_1}\right]$$

m_3 being the mass of a drop of water in liquid.

The density of the liquid is determined using Hare's apparatus. It is an inverted U-tube of uniform area of cross section, with the bent part connected to a rubber tube, as shown in Fig.20.2. Both the limbs of U-tube are dipped in water and liquid respectively. By means of rubber tube, water and liquid raise in respective limbs.

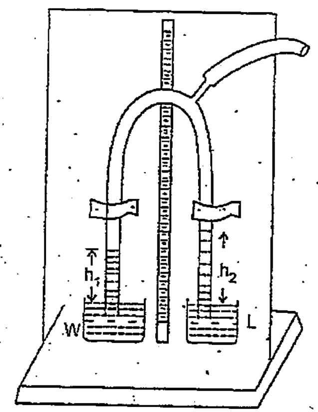


Fig. 20.2

The readings corresponding to beaker level and limb level both for water and liquid are noted on a metre scale provided with the apparatus. The heights of water (h_1) and liquid (h_2) columns are calculated and hence the density of liquid [Table 20.3] is determined.

Table 20.3 – Hare's Apparatus : ρ_2 / ρ_1

S.No	Water Readings cm		Height of water column h_1 cm	Liquid Readings cm		Height of liquid column h_2 cm	$\rho_2 / \rho_1 = h_1/h_2$
	Beaker Level	Limb level		Beaker Level	Limb level		

Mean $\rho_2 / \rho_1 = h_1 / h_2$ =

As the water and kerosene wet the glass, the outer radius (r) of the glass tube must be used. It is measured by using screw gauge at different diametrically opposite points. [Refer Expt.2.]

Observations :

Mass of one drop of water	m_1 =		kg
Mass of one drop of liquid	m_2 =		kg
Mass of one drop of water in liquid	m_3 =		kg
Acceleration due to gravity	g =	9.81	$m\ s^{-2}$
Ratio of density of liquid ρ_2 to that of water ρ_1	(ρ_2 / ρ_1) =	h_1 / h_2	
Mean radius of glass tube	r =		m
surface tension of water	T_w =		Nm^{-1}
Surface tension of liquid (kerosene)	T_L =		Nm^{-1}
Interfacial surface tension of water	T_{WL} =		Nm^{-1}

Result :

Surface tension of water	=	Nm^{-1}
Surface tension of liquid	=	Nm^{-1}
Interfacial surface tension	=	Nm^{-1}

❂❂❂❂❂❂

EXPERIMENT : 21

SURFACE TENSION

CAPILLARY RISE

Aim:

To find the surface tension of liquid (water) by capillary rise method.

Apparatus :

Capillary tube of uniform bore, a beaker with given liquid, a pointer, a vernier microscope, etc.

Procedure :

A well cleaned, sufficiently long uniform capillary tube is taken and is passed through a cork. The cork is clamped to a rigid support so as to keep the tube vertical. One end of the tube is attached to a rubber tubing. The free end of the tube is dipped in a beaker containing the liquid.

A pointer is fixed through the same cork, close to the capillary tube. The pointer is adjusted so that the tip of it just touches the surface of liquid in the beaker, as shown in Fig.21.1. The liquid rises in the tube due to capillarity and by repeatedly pressing and releasing the rubber tube, a continuous liquid column is formed. Care should be taken to remove any air bubbles or breaks along the length of the column. The pointer is checked to make the tip just touching the surface of the liquid.

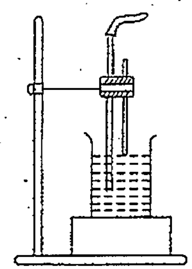


Fig.21.1

A microscope in horizontal position is focused to see the meniscus of the liquid. The horizontal cross wire is made tangent to the concave part of the meniscus as shown in diagram [Fig. 21.2a]. The vertical main scale reading and corresponding coinciding vernier scale divisions are noted. Now the beaker is removed carefully and the microscope is adjusted to focus the tip of the pointer. The horizontal cross wire should just touch the tip and readings of microscope in vertical scale are taken. [Table.21.1]. The difference in readings gives the height h of the liquid column in the capillary tube. Experiments are repeated by changing the level of

Table 20.3 – Hare's Apparatus : ρ_2 / ρ_1

S.No	Water Readings cm		Height of water column h_1 cm	Liquid Readings cm		Height of liquid column h_2 cm	$\rho_2 / \rho_1 = h_1/h_2$
	Beaker Level	Limb level		Beaker Level	Limb level		

Mean $\rho_2 / \rho_1 = h_1 / h_2 =$.

As the water and kerosene wet the glass, the outer radius (r) of the glass tube must be used. It is measured by using screw gauge at different diametrically opposite points. [Refer Expt.2.]

Observations :

Mass of one drop of water	m_1	=		kg
Mass of one drop of liquid	m_2	=		kg
Mass of one drop of water in liquid	m_3	=		kg
Acceleration due to gravity	g	=	9.81	$m\,s^{-2}$
Ratio of density of liquid ρ_2 to that of water ρ_1	(ρ_2 / ρ_1)	=	h_1 / h_2	
Mean radius of glass tube	r	=		m
surface tension of water	T_w	=		Nm^{-1}
Surface tension of liquid (kerosene)	T_L	=		Nm^{-1}
Interfacial surface tension of water	T_{WL}	=		Nm^{-1}

Result :

Surface tension of water	=	Nm^{-1}
Surface tension of liquid	=	Nm^{-1}
Interfacial surface tension	=	Nm^{-1}

EXPERIMENT : 21

SURFACE TENSION

CAPILLARY RISE

Aim:

To find the surface tension of liquid (water) by capillary rise method.

Apparatus :

Capillary tube of uniform bore, a beaker with given liquid, a pointer, a vernier microscope, etc.

Procedure :

A well cleaned, sufficiently long uniform capillary tube is taken and is passed through a cork. The cork is clamped to a rigid support so as to keep the tube vertical. One end of the tube is attached to a rubber tubing. The free end of the tube is dipped in a beaker containing the liquid.

A pointer is fixed through the same cork, close to the capillary tube. The pointer is adjusted so that the tip of it just touches the surface of liquid in the beaker, as shown in Fig.21.1. The liquid rises in the tube due to capillarity and by repeatedly pressing and releasing the rubber tube, a continuous liquid column is formed. Care should be taken to remove any air bubbles or breaks along the length of the column. The pointer is checked to make the tip just touching the surface of the liquid.

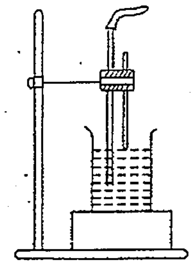


Fig.21.1

A microscope in horizontal position is focused to see the meniscus of the liquid. The horizontal cross wire is made tangent to the concave part of the meniscus as shown in diagram [Fig. 21.2a]. The vertical main scale reading and corresponding coinciding vernier scale divisions are noted. Now the beaker is removed carefully and the microscope is adjusted to focus the tip of the pointer. The horizontal cross wire should just touch the tip and readings of microscope in vertical scale are taken. [Table.21.1]. The difference in readings gives the height h of the liquid column in the capillary tube. Experiments are repeated by changing the level of

liquid in the beaker and subsequently adjusting the tip of the pointer to touch it. Mean value of height h is determined.

The radius r of the bore of capillary tube is found out by measuring inner diameter using vernier microscope [see Expt.3]. The tube is fixed horizontal and microscope is focused to the cross-section of the bore. Working on the horizontal movement of the vernier, the point of intersection of the cross wires is made to coincide at points A and B of horizontal diameter AB, shown in Fig.21.2b.

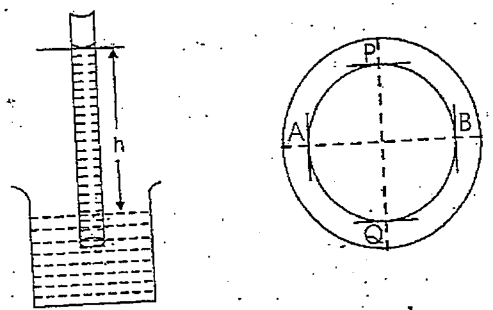


Fig. 21.2

Readings are taken in horizontal scale and are recorded as in Table.21.2. The difference in reading gives the diameter 2r of the bore. The experiment is performed on vertical movement of the vernier and readings are noted corresponding to the points P and Q of vertical diameter PQ [Fig.21.2b]. Thus the mean diameter and hence the radius of the bore is determined.

The density ρ of the liquid is determined using Hare's apparatus, as described in previous case [Expt.20]. The density of water is taken to be 1000 kg m^{-3}.

Formula :

Let h be the height of liquid column in a capillary tube of radius r. If ρ is the density of the liquid, then the surface tension T of the liquid is given by

$$T = \frac{r}{2}\left(h + \frac{r}{3}\right)\rho g$$

where g is the acceleration due to gravity.

Table 21.1 : Height of capillary rise : L.C. = 0.001 cm

S.No.	Reading of meniscus			Reading of the tip			Height
	MSR cm	coinciding VSD	O.R. cm	MSR cm	coinciding VSD	O.R cm	h cm
1.							
2.							
3.							
4.							

Mean height h = cm

Tabe 21.2 : Radius of the bore r : L.C. = 0.001cm.

Horizontal scale Readings : 2r		Diameter 2r = A ~ B	Vertical Scale Readings : 2r		Diameter 2r = P ~ Q	Mean 2r
Left (A) cm	Right (B) cm	cm	Up (P) cm	Down (Q) cm	cm	cm

Mean diameter 2r = cm

Mean radius r = cm

Observations :

Mean height of liquid column h = m

Mean radius of the bore r = m

Density of the liquid ρ = Relative density × 10^3 kg m^{-3}.

[For water, ρ = 1000 kg m^{-3}]

Acceleration due to gravity $g = 9.81\ ms^{-2}$

Surface tension of the liquid $T = \quad Nm^{-1}$

Result :

Surface tension of given liquid $= \quad Nm^{-1}$

⊛⊛⊛⊛⊛⊛

Note :

(i) Comparison of surface tensions of two liquids :

For narrow capillary tube, r<<h, and hence $T = \frac{rh\rho g}{2}$

Let T_1 and T_2 be the surface tensions of two liquids of densities ρ_1 and ρ_2 respectively.

$$T_1 = \frac{rh_1\rho_1 g}{2} \quad \text{and} \quad T_2 = \frac{rh_2\rho_2 g}{2}$$

$$\text{Therefore, } \frac{T_1}{T_2} = \frac{h_1\rho_1}{h_2\rho_2}$$

Performing the experiment by taking same capillary tube with two different liquids, (h_1/h_2) is determined. Using Hare's apparatus, $\rho_1 / \rho_2 = H_2 / H_1$ is found. H_1 and H_2 are heights of two liquid columns in Hare's apparatus respectively. Hence the ratio of surface tensions can be determined.

(ii) Comparison of radii of two tubes.

With same given liquid, the experiment is repeated by taking two capillary tubes of radii r_1 and r_2 respectively. If h_1 and h_2 are the respective heights of liquid column, then

$$T = \frac{r_1 h_1 \rho g}{2} = \frac{r_2 h_2 \rho g}{2}$$

$$\text{Therefore, } \frac{r_1}{r_2} = \frac{h_2}{h_1}$$

Hence the ratio of radii of two tubes can be determined.

⊛⊛⊛⊛⊛⊛

EXPERIMENT : 22

VISCOSITY OF LIQUID

BURETTE METHOD

Aim :

To determine coefficient of viscosity of a liquid (water).

Apparatus :

Uniform, long capillary tube, ungraduated burette, beaker, rubber tubing with pinch clip, stop clock, etc.

Procedure :

An ungraduated burette is held vertically by a retort stand. The marks A, B, C, D, ... etc. are labelled along the length of the burette. A uniform capillary tube of sufficient length is fixed to the lower end of the burette through a rubber tubing with pinch clip arrangement. The burette is filled with given liquid, say, water. The capillary tube is placed horizontally on a support so that liquid is allowed to flow freely through it [Fig.22.1]

A clean empty beaker is taken and its weight is found using electronic balance. When the liquid comes to the level A, the stop clock is started and simultaneously the liquid through the tube is collected in weighed beaker. When the liquid level reaches the mark B, the flow is stopped using pinch clip, time taken is noted and mass of the beaker with liquid is determined.

The heights h_1 and h_2 of the marks A and B respectively from the horizontal level of capillary tube are measured. The effective pressure head h for the steady flow then is $h = (h_1+h_2) / 2$.

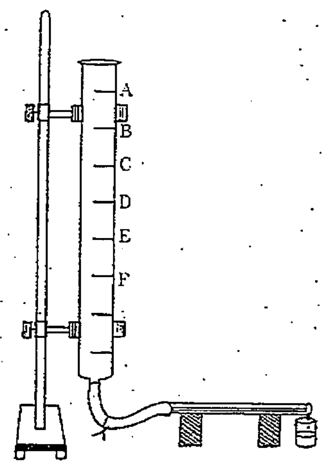


Fig.22.1

EXPERIMENT : 45

PLANE TRANSMISSION GRATING.

NORMAL INCIDENCE METHOD.

Aim:

To determine the number of lines (rulings) per metre of the grating and to find the wave lengths of prominent spectral lines of mercury spectrum by normal incidence method, using spectrometer.

Apparatus :

Spectrometer, plane transmission grating, sodium vapour lamp, mercury vapour lamp, etc.

Procedure :

(i) Normal Incidence :

After making the initial adjustments of the spectrometer, the slit of the collimator is illuminated by sodium light (monochromatic light). The telescope is adjusted to focus the slit directly and by finer adjustment, the vertical cross wire is made to coincide with the fixed edge of the image of the slit. The telescope is clamped at this position. The verniers are adjusted to read 0° and 180° and are fixed rigidly.

Now, the telescope is turned through 90° as in Fig. 45.1. The plane transmission grating, G is mounted vertically on the prism table using a grating holder. The ruled surface should face the collimator. By slowly rotating the prism table, the fixed edge of the reflected image of the slit is made to coincide with the vertical cross wire of the telescope. At this position, the angle of incidence of a parallel ray of light on the grating surface becomes equal to 45°.

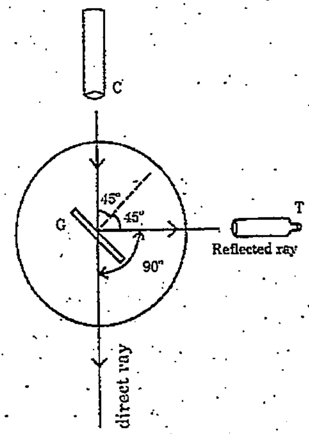


Fig.45.1

Therefore, to make the angle of incidence is equal to zero, that is, to make the ray of light normal to the surface, the vernier with prism table is rotated through 45° towards the collimator, so that incident light is normal to the grating. The vernier is clamped rigidly at this position.

(ii). Determination of number of lines per metre N. :

Now, the telescope is released and brought to view the direct image. On either side of direct image, one can observe image of first order diffraction and second order. The telescope is turned to observe first order diffracted image to the left of direct image. The vertical cross wire is made to coincide with the image, the corresponding readings of the verniers V_1 and V_2 are noted.

Now the telescope is rotated to the right of the direct ray and the first order image is observed. The vertical cross wire is made to coincide with the image, the corresponding readings of the verniers V_1 and V_2 are noted. Refer Fig.45.2

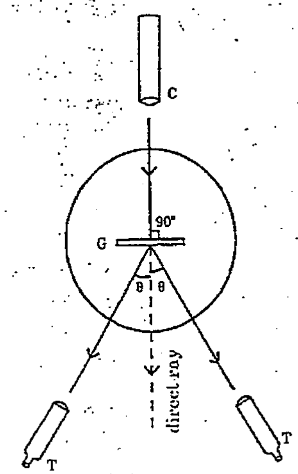


Fig. 45.2

(The experiment can be repeated for second order diffraction also).

The readings are tabulated as in Table 45.1. The difference between left and right readings of the first order diffraction, gives twice the angle of diffraction θ. Knowing the wave length λ of monochromatic light (for sodium light, λ = 589.3nm), the number of lines per metre N of the grating is determined by

$$\sin\theta = Nm\lambda,$$

where m is the order of diffraction, equal to one for first order, two for second order etc. Therefore, $N = \frac{\sin\theta}{\lambda}$ is calculated.

Table 45.1. : Determination of N L.C. = 1' $\lambda = 589.3 \times 10^{-9}$ m

Diffracted Image				2θ		Mean 2θ	Mean θ	$N = \frac{\sin\theta}{\lambda}$
Left		Right						
V_1	V_2	V_1	V_2	V_1	V_2			

N = m^{-1}.

(iii). Mercury Spectrum : The sodium vapour lamp is removed and the slit is illuminated by mercury vapour lamp. On either side of direct image, mercury line spectrum is observed due to first order (m = 1) diffraction. (Refer Fig. 45.2) As the wave length of spectral line is proportional to sin θ, the least deviated line is violet, followed by blue, green, yellow and red. The prominent spectral lines of mercury in increasing order of wavelengths are violet 1 (fairly bright). Violet 2 (faint), blue (bright), bluish green 1 (bright), bluish green 2 (faint), green (very bright), yellow 1 and yellow 2 (very bright) and red (fairly bright). As discussed in case (ii), the angle of diffraction θ for each line is determined and the readings are recorded [Table 45.2]. Using the formula

$$\lambda = \frac{\sin\theta}{N}$$

the wave length λ of prominent lines of mercury spectrum are determined.

TABLE 45.2 : Determination of λ : Hg Spectrum L.C. = 1'

Mercury Spectral Lines	Diffracted Image				2θ		Mean 2θ	Mean θ	$\lambda = \frac{\sin\theta}{N}$
	Left		Right						
	V_1	V_2	V_1	V_2	V_1	V_2			
Violet 1									
Violet 2									
Blue									
Bl. Green									
Green									
Yellow 1									
Yellow 2									
Red									

Observations :

Wave length of Na line λ = 589.3 nm = 589.3×10^{-9}m

Number of lines per metre on grating N = m^{-1}

Result :

(i) The number of lines per metre on grating =

(ii) The wave lengths of prominent lines of mercury spectrum are determined.

******

Note :

DISPERSIVE POWER of grating :

Dispersive power of grating is defined to be the ratio of change in angle of diffraction dθ to the change in wavelength dλ for any pair of spectral lines. It is not a constant, but depends on the region of spectrum. Now, for grating, under normal incidence, let θ_1 and θ_2 be the angles of diffraction of spectral lines λ_1 and λ_2 respectively. Then,

$$\text{Dispersive power} \quad P = \frac{(\theta_2 - \theta_1)}{(\lambda_2 - \lambda_1)}$$

From the Table 45.3, the dispersive power is calculated by taking spectral lines pair wise. (Violet 1 & Yellow 1 pair shown in the table).

Table 45.3. Dispersive power

Spectral lines	θ	λ	$(\theta_2 - \theta_1)$	$(\lambda_2 - \lambda_1)$	$P = \frac{(\theta_2 - \theta_1)}{(\lambda_2 - \lambda_1)}$
Violet 1	θ_1	λ_1			
Blue					
Green					
Yellow 1	θ_2	λ_2			
Yellow 2					
Red					

The dispersive power of grating for various spectral region of mercury spectrum is determined.

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Observations :

Wavelength of sodium light $\lambda = 5.893 \times 10^{-7}$m

Microscope reading for cross wire coinciding with the edge of contact $X_1 =$ m

Microscope reading for cross wire coinciding with the wire $X_2 =$ m

Distance of the wire from the edge of contact : $l = X_1 - X_2 =$ m

Mean fringe width $\beta =$ m

Diameter of the wire $d = \frac{l\lambda}{2\beta} =$ m

Table 51.1 : Microscope readings L.C. = 0.001cm

No.of dark fringes	Microscope Readings			Width of 12 fringes cm	Fringe width β cm
	MSR cm	VSD	O.R= MSR+(VSD) L.C.		
n			x_1		
n + 3			x_2		
n + 6			x_3		
n + 9			x_4		
n + 12			x_5	$x_5 - x_1$	
n + 15			x_6	$x_6 - x_2$	
n + 18			x_7	$x_7 - x_3$	
n + 21			x_8	$x_8 - x_4$	

Mean β = cm

Result :

The diameter of the wire = m

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Note :

Thickness of insulation : First, with the insulation of enamel coating, the diameter d_1 of the wire is determined as described above. Next, the coating is removed uniformly and the experiment is repeated to find the diameter d_2 of the wire without insulation. Then, the thickness of the insulation is given by $(d_1 - d_2) / 2$.

EXPERIMENT : 52

NEWTON'S RINGS

Refractive index of convex lens

Aim :

To determine radii of curvature of a double convex lens by forming Newton's rings and to calculate refractive index of the material of the lens.

Apparatus :

Convex lens, glass plates, sodium vapour lamp, 45° slot, Vernier microscope, etc..

Procedure :

A large focal length (1 metre or more) convex lens L is placed on a glass plate P, kept on the bed plate of microscope, as shown in Fig. 52.1. Rays of light from sodium vapour lamp S, incident horizontally on a glass plate G inclined at 45° are reflected vertically downward and are incident normally on the air film enclosed between the lens and glass plate. Due to interference between the light reflected from top and bottom surface of air film, the alternate dark and bright concentric rings can be observed through the microscope. At the point of contact of lens with the plate, the thickness of air film is zero. Therefore, the center of concentric rings appears dark. As one moves away from the point of contact, the thickness of air film increases symmetrically and hence, alternate bright and dark rings are obtained. These rings are called Newton's rings , Fig.52.2

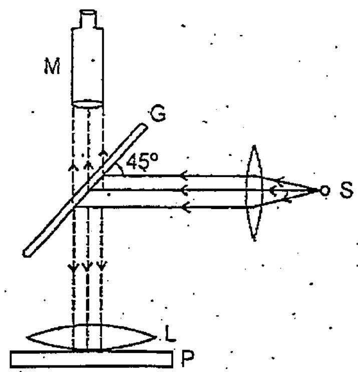
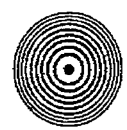


Fig. 52.1



(Enlarged view)

Fig. 52.2

Let the first clear dark ring be nth ring. The microscope is moved slowly to the left side by working its screw to cover, say, twenty seven dark rings. The rings are counted as n, n+3, n+6 etc upto n+27. The vertical cross wire is made tangent to $(n+27)^{th}$ dark ring and the reading in horizontal scale is noted. By working on horizontal screw of the vernier, the vertical cross wire is made tangent to $(n+24)^{th}$, $(n+21)^{th}$, - - - n^{th} ring on the left side and respective readings on the scale are noted. Now moving the microscope in same direction,[i.e., moving to the right of the centre to avoid error due to back-lash], the cross wire is made tangential to n^{th}, $(n+3)^{rd}$, $(n+6)^{th}$, - - -, $(n+27)^{th}$ dark ring on other side (right side) of the center. The corresponding readings are taken and are tabulated as in Table.52.1. The difference in readings between two sides of a particular ring gives the diameter of that ring. For example d_n is the diameter of n^{th} Newton's dark ring.

Table 52.1 L.C. = 0.001 cm

Order of ring.	Microscope Readings		d_n $\times 10^{-2}$ m	d_n^2 $\times 10^{-4}$ m^{-2}	$(d^2_{n+m} - d_n^2)$ (m = 15)
	Left : cm	Right : cm			
n	↑	↓		x_1	
n + 3				x_2	
n + 6				x_3	
n + 9				x_4	
n + 12	↑	↓		x_5	
n + 15				x_6	$x_6 - x_1$
n + 18				x_7	$x_7 - x_2$
n + 21				x_8	$x_8 - x_4$
n + 24	↑	↓		x_9	$x_9 - x_4$
n + 27				x_{10}	$x_{10} - x_5$

For R_1; Mean $(d^2_{n+m} - d^2_n)$ = $\times 10^{-4}$ m^2

As shown in Table.52.1 ten sets of readings are taken and d_n and d_n^2 are calculated. Dividing the table in the middle $(d^2_{n+m} - d_n^2)$ is obtained in the last column keeping m = 15.

Let us take the mean value of the last column as C_A.

That is $$C_A = d^2_{n+m} - d^2_n$$

(We will be using this constant in the next part of the experiment).

The convex lens is reversed and the experiment is repeated and the radius of curvature, R_2 of the second face is determined.

Formula :

Let d_n and d_{n+m} be the diameter of n^{th} and $(n+m)^{th}$ dark Newton's rings respectively. If λ is the wavelength of monochromatic light and R is the radius of curvature of the lens, then,

$$d^2_n = 4Rn\lambda$$

$$d^2_{n+m} = 4R(n+m)\lambda$$

Therefore, $$R = \frac{(d^2_{n+m} - d^2_n)}{4m\lambda} = \frac{C_A}{4m\lambda}$$

By taking $\lambda = 589.3 \times 10^{-9}$ m, radii of curvature R_1 and R_2 can be determined.

The focal length of the convex lens (focal length more than 100 cm) is determined using telescope method. Refer Expt.39.

The refractive index μ of the lens of focal length f is given by

$$\mu = 1 + \frac{R_1 R_2}{f(R_1 + R_2)}$$

Observations :

Wavelength of sodium light λ = 589.3×10^{-9} m

Radius of curvature R_1 = m

Radius of curvature R_2 = m

Focal length of lens f = m

Refractive index $\mu = 1 + \frac{R_1 . R_2}{f(R_1 + R_2)}$ =

Result :

Refractive index of material of double convex lens =

******

Note :

Refractive index of transparent liquid (water)

The refractive index of the given liquid can be determined by forming thin liquid film between convex lens and glass plate and forming Newton's rings.

A large drop of liquid is placed on the plate and the lens is kept on it, so that same face touching the plate. Newton's rings are formed [fewer in numbers and less in intensity]. The procedure is the same as with the air film.

For air film we have the constant

$$C_A = d^2_{n+m} - d^2_n$$

and hence the wave length of monochromatic light in air is given by

$$\lambda_A = \frac{C_A}{4m\,R}$$

For liquid film let the corresponding constant be C_L.

The wave length of monochromatic light in liquid is given by

$$\lambda_L = \frac{C_L}{4m\,R}$$

Now the refractive index of liquid is given by

$$\mu = \frac{\lambda_A}{\lambda_L} = \frac{C_A}{C_L}$$

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EXPERIMENT : 53

FEBRY PEROT ETALON

Aim :

To determine the thickness of air film by forming interference using Febry Perot Etalon and hence to calculate fine structure spread of spectral line.

Apparatus :

Spectrometer, Febry Perot Etalon, Sodium vapour lamp, scale and telescope arrangements, etc...

Procedure:

A Febry Perot Etalon consists of two semi silvered optically plane glass plates held parallel to each other, enclosing a thin air film. Silvered faces of plates are facing each other. The complete arrangement is enclosed in a cell having circular openings on both the opposite faces. The plates are made exactly parallel, and vertical by means of three leveling screws.

The Febry Perot Etalon is mounted vertically on leveled prism table of spectrometer. The collimating lens from collimator is removed and the slit is made as wide as possible. The slit is then illuminated uniformly using sodium vapour lamp. The light incident on front face of Etalon, undergoes multiple reflection through the air film and by interference, alternate bright and dark concentric circular fringes with central spot are formed. By focusing the telescope and adjusting it, the interference pattern can be observed.

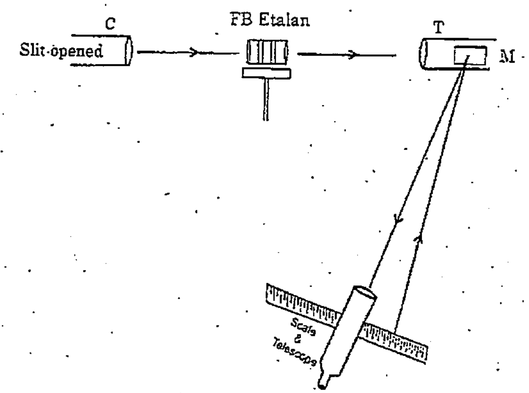
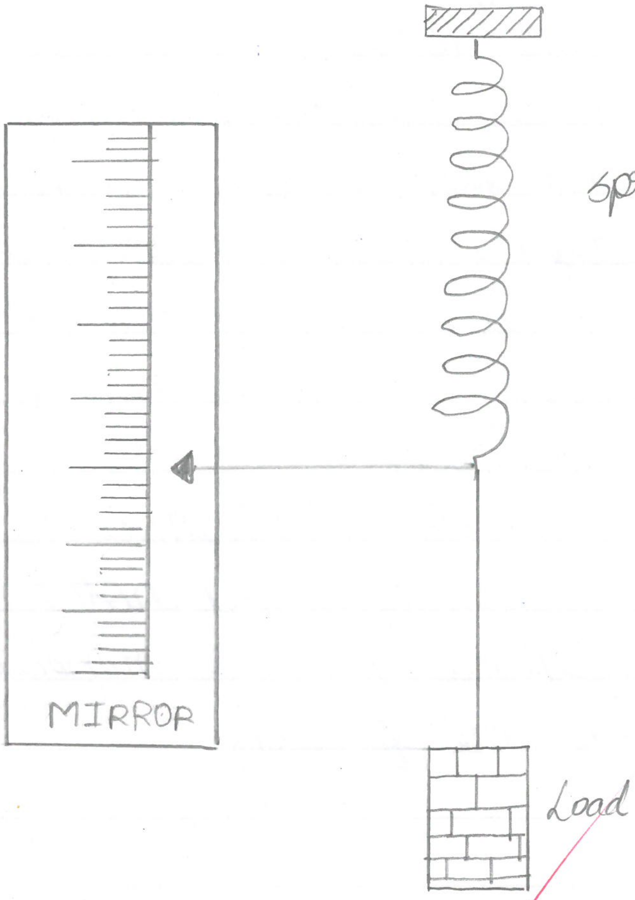
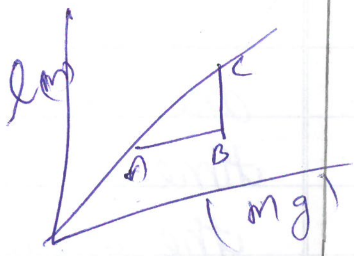


Fig. 53.1





from graph $K = \frac{AB}{BC} \times g$

Spring Const $K = \frac{\text{Restoring force}}{\text{Extension}}$

$$T = 2\pi\sqrt{\frac{M}{K}}$$

$$T = 2\pi\sqrt{\frac{M_0+M}{K}}$$

$$T_1 = 2\pi\sqrt{\frac{M_0+m_1}{K}}$$

$$T_2 = 2\pi\sqrt{\frac{m_0+m_2}{K}}$$

$$K = \frac{4\pi^2(m_1-m_2)}{(T_1^2 - T_2^2)}$$

$T = \frac{t}{n}$ (t → mean time, n → no. of oscillation)

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.08.18

SPRING CONSTANT

* AIM:-

To determine the spring constant of a spring by static method.

* APPARATUS REQUIRED:-

A spring, a hanger with a light aluminium pointer, a small scale etched on a plane mirror strip, weights, a timer.

* THEORY:-

STATIC METHOD:

consider a spring hanging from a rigid support. when a load m is suspended from the free end of the spring, an external, text, acts on the spring in the download direction. The support applies on equal force in the upward direction. Thus the spring has a balanced system of forces acting on it and it is in Equilibrium. The length of the spring increases and an internal force. Find is developed in the spring increased

TABLE:

S.NO	Load m and the hanger	Position of the pointer (x)		Average(x)
		Load	unloading	
1.	W	13.6	13.6	13.6
2.	W+50	18.6	18.6	18.6
3.	W+100	24.4	24.4	24.4
4.	W+150	29.7	29.7	29.7
5.	W+200	35.4	35.4	35.4

Mean = 0.89285 N/m

due to the elasticity of the spring. This internal force tends to bring the spring back to its original length when the external force are with drawn. Note that. Fint and Fext are Equal in magnitude, According to Hooki law,

Fint is directly proportional to x, the change in the length of the string,

Thus, $F_{int} = -kx$

Here K is the constant of proportionality, known as the spring constant of force constant. The minus(-) sign Indicates that Fint and x are in opposite directions.

Obviously,

$F_{ext} = kx$

Equation (1) and (2) Indicates that the spring constant K is numerically equal to the force, required to change the length of the spring by 1 unit.

If the load on the spring is M and MP is the sum of the mass of the hanger and the effective sum of the spring, $F_{ext} = (m+mg)g$. In this experiment Values of x for a number of values of fext are determined from this slope of the graph.

DP

CALCULATION:-

$$k = \frac{(m_2 - m_1)g}{x_2 - x_1}$$

$$= \frac{(200-150) \times 10^{-3}}{(29.7 - 24.1) \times 10^{-2}}$$

$$= \frac{50}{5.6 \times 10^{-1}}$$

$$= 8.92857 \times 10^{-1}$$

$$= 0.89285 \text{ N/m}$$

* PROCEDURE :-

(a) STATIC METHOD :-

1. Arrange the apparatus as shown in the Figure. Make sure that the alminium pointer is close to the mirror on which the scale is etched but it does not touch the mirror.

2. Read the position of the pointer on the scale. Avoid the parallel error. This is done by reading the position of the pointer is hidden behind the pointer.

3. Increase the lead on the spring in equal steps and read the position of the pointer each time. This fill out the first two columns of the first table of the data sheet.

4. Now gently pull the load down through about 0.5 cm. Release it gently and let it come to rest take the reading of the position of the pointer and enter, it in the last row of column 3 of the table.

EXPERIMENT : 7

YOUNG'S MODULUS – Uniform Bending - I

PIN AND MICROSCOPE

Aim :

To determine Young's modulus of elasticity of the material of the beam, subjecting it to uniform bending.

Apparatus :

Long rectangular beam, two knife edges, two weight hangers with equal dead weights, two sets of slotted weights, Vernier microscope, pin etc.

Procedure :

The rectangular, uniform beam AB is placed symmetrically on the knife edges K_1 and K_2. The weight hangers H_1 and H_2 with dead weight W are suspended at C and D with equal distance from A and B respectively as show in Fig. 7.1 below.

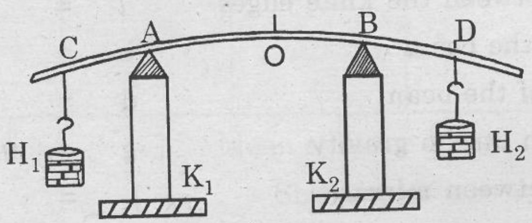

Fig. 7.1.

A pin is attached vertically at the midpoint O of the beam, with its tip pointing upward. Vernier microscope is placed nearer to the pin in horizontal position and is adjusted to focus the tip of the pin. The horizontal cross wire of the eyepiece is made to coincide with the tip of the pin. The vertical main scale reading, together with coinciding Vernier scale divisions are noted. This is the first reading with only the dead weight W on both the weight hangers. Now the loads are added to the hangers equally in the steps of m (equal to, say, 50g). Readings are taken in each case, after making the horizontal cross wire to coincide with the tip of the pin. Experiment is again performed by removing equal weights from both the hangers and readings are recorded as in Table 7.1.

To reduce error, the shift for 4m is calculated first as shown in Table.7.1

The length l of the beam between knife edges, the distance a of each weight hanger from the nearest knife edge are measured.

Table 7.1 L.C. = cm

Load	Microscope Reading		Mean	Shift for 4m
	Loading	Unloading		
kg	cm	cm	cm	cm
W			x_0	
W + m			x_1	
W + 2m			x_2	
W + 3m			x_3	
W + 4m			x_4	$x_4 - x_0$
W + 5m			x_5	$x_5 - x_1$
W + 6m			x_6	$x_6 - x_2$
W + 7m			x_7	$x_7 - x_3$

Mean shift for 4m = cm

Shift for m= s = cm

Using Vernier calipers and screw gauge, the breadth b [see Table 4.2] and thickness d [see Table 4.3] of the beam are respectively found out.

The experiments may be repeated either for different length of beam between the knife edges or for different symmetric points of suspension of the hangers.

A graph of weight M = m, 2m, 3m, ...etc. along x – axis and mean elevation X (after subtracting dead weight reading) along y – axis is drawn [Refer Fig. 4.2]. The straight line graph (elevation is directly proportional to load applied) is used to find m/s = ΔM /ΔX

Formula :

A uniform rectangular beam of width b and thickness d, placed symmetrically on two knife edges separated by a distance l, is subjected to uniform bending by a constant bending couple at all points of the beam. Thus, in uniform bending the elevation s of the midpoint of the beam due to load of mass m applied on both the end at a distance a from the nearest knife edge is given by

$$s = \frac{3}{2}\frac{gal^2}{bd^3}\left(\frac{m}{E}\right)$$

And hence the Young's Modulus of the material of the beam

$$E = \frac{3}{2}\frac{gal^2}{bd^3}\left(\frac{m}{s}\right)$$

By measuring mean elevation s for load m, the Young's modulus is determined. Further, from load versus elevation graph (straight line) one can calculate m/s .

Observations :

Distance between knife edges	l	=	m
Distance between weight hanger and adjacent knife edge	a	=	m
Breadth of the beam	b	=	m
Thickness of the beam	d	=	m
Acceleration due to gravity	g	= 9.81 ms^{-2}	

Mean (m/s) = kgm^{-1}

By graph, $\Delta M / \Delta X$ = m/s = kgm^{-1}

$$\text{Young's Modulus } E = \frac{3}{2}\frac{g\,a\,l^2}{b\,d^3}\left(\frac{m}{s}\right) = \quad Nm^{-2}$$

Result :

(i). Young's Modulus by calculation = Nm^{-2}

(ii). Young's Modulus by graph = Nm^{-2}

❁❁❁❁❁❁

***EXPERIMENT* : 8**

YOUNG'S MODULUS – Uniform Bending - II

SINGLE OPTIC LEVER

Aim :

To determine Young's modulus of elasticity of the material of the beam, subjecting it to uniform bending.

Apparatus :

Uniform rectangular bar, two knife edges, two weight hangers with slotted weights, optic lever, scale and telescope etc.

Procedure :

The rectangular bar is placed symmetrically on two knife edges K_1 and K_2. The front leg of single optic lever is resting on the mid point O of the beam [Fig.8.1]. The other two hind legs are resting on a suitable support kept at same level behind the beam. The weight hangers H_1 and H_2 with dead weight W, as in previous case (Expt.7), are suspended from the points C and D of the beam as shown in Fig.8.1.

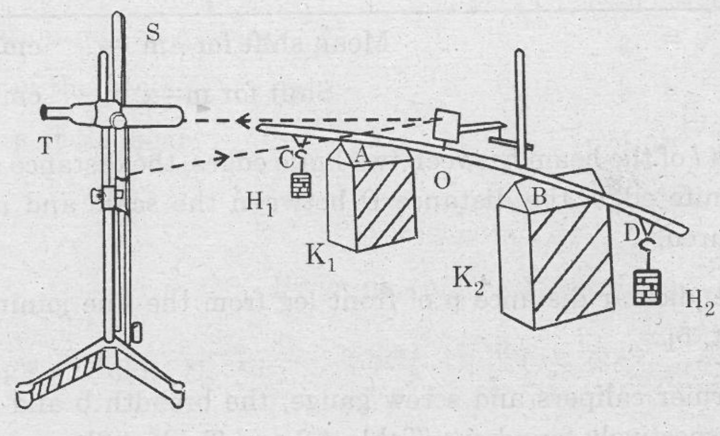

Fig. 8.1

The scale with telescope is held vertically in front of the plane mirror of optic lever. The telescope is focused to see the image of scale divisions reflected by the mirror of the optic lever. The horizontal cross wire of the telescope is adjusted to coincide with a definite division on the scale and the reading is noted.

EXPERIMENT : 11

YOUNG'S MODULUS – CANTILEVER
(STATIC METHOD- I)

PIN AND MICROSCOPE - DEPRESSION

Aim :

To determine Young's modulus of the material of cantilever, by measuring the depression produced at the free end, using pin and microscope arrangement.

Apparatus :

A long rectangular beam (a metre scale), weight hanger, slotted weights, pin, microscope etc.

Procedure :

The given uniform rectangular beam (a metre scale) AB is clamped rigidly at A along the edge of a table using a G-clamp. A suitable length AB of the beam is projecting outside (Fig. 11.1). At free end B of the cantilever, a weight hanger H with dead weight W is suspended. A pin is attached upward at the point of loading, B. A microscope in horizontal position is adjusted to focus the tip of the pin in the field of view of the eye piece.

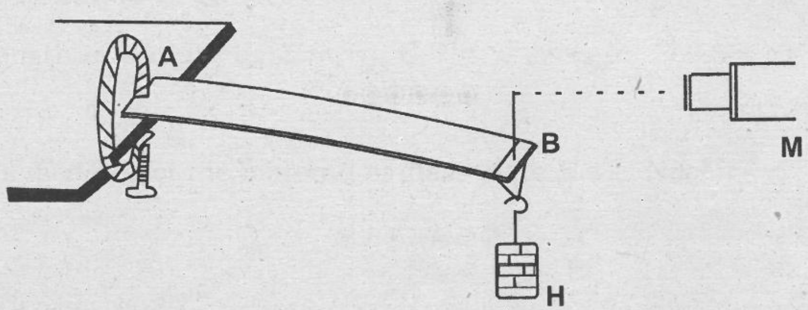

Fig. 11.1

By working on the vertical screw, the horizontal cross wire is made to coincide with the tip of the pin. The reading in vertical main scale and coinciding vernier divisions are noted. Weights are added to the hanger in the steps of m,

equal to 50g and readings are taken, each time making the horizontal cross wire to coincide with the tip of the pin. Similarly, readings are noted while unloading in same steps of m. As in the earlier bending experiments, eight (or ten) readings are taken so that the depression can be calculated first for 4m and then for m. Observations are tabulated as in Table 11.1.

Using vernier calipers and screw gauge, the breadth b and thickness d of the cantilever are measured respectively (see Table 4.2 and Table 4.3).

Formula:

A cantilever is a rectangular beam of breadth b and thickness d, rigidly clamped at one end. A load due to mass m is applied at the free end of cantilever of length l. Let s be the depression produced at the point of loading. The Young's modulus of the material of the cantilever is given by

$$E = \frac{4gl^3}{bd^3}\left(\frac{m}{s}\right)$$

Table 11.1 L.C. = cm

Load	Microscope Reading		Mean	Shift for 4m
	Loading	Unloading		
kg	cm	cm	cm	cm
W			x_0	
W + m			x_1	
W + 2m			x_2	
W + 3m			x_3	
W + 4m			x_4	$x_4 - x_0$
W + 5m			x_5	$x_5 - x_1$
W + 6m			x_6	$x_6 - x_2$
W + 7m			x_7	$x_7 - x_3$

Mean shift for 4m = cm

Shift for m= s = cm

A graph is drawn taking the load M = m, 2m . . . etc. along x axis and mean microscope reading X (after subtracting dead weight reading) along y- axis (See Fig. 4.2). From the slope of straight line graph, $\Delta M / \Delta X$ is calculated.

Observations :

Length of cantilever	l	=	m
Breadth of cantilever	b	=	m
Thickness of cantilever	d	=	m
Acceleration due to gravity	g	= 9.81	ms^{-2}
	Mean (m/s)	=	$kg\ m^{-1}$
	By graph, $\Delta M / \Delta X$ = m/s	=	$kg\ m^{-1}$

$$\text{Young's modulus } E = \frac{4gl^3}{bd^3}\left(\frac{m}{s}\right) = \text{Nm}^{-2}$$

Result :

(i) Young's modulus, by calculation = Nm^{-2}

(ii) Young's modulus, by graph = Nm^{-2}

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EXPERIMENT : 12

YOUNG'S MODULUS – CANTILEVER

(STATIC METHOD- II)

OPTIC LEVER - DEPRESSION

Aim:

To determine Young's modulus of the material of cantilever, by measuring the depression produced at the free end, using single optic lever arrangement.

Apparatus :

A long rectangular beam (a metre scale), weight hanger, slotted weights, optic lever, scale and telescope etc.

Procedure :

The given uniform rectangular beam (a metre scale) AB is clamped rigidly at A along the edge of a table using a G-clamp. A suitable length AB of the beam is projecting outside. At free end B of the cantilever, a weight hanger H with dead weight W is suspended. The depression of loaded free end of cantilever can be measured more accurately by single optic lever method, using scale and telescope arrangement. The front leg of lever resting on the point of loading and two hind legs on separate rigid support, as shown in Fig.12.1. The loading is done in steps of m and the telescope readings are noted. Readings are taken while unloading also. As in all the bending experiments eight or ten readings are taken to reduce error.

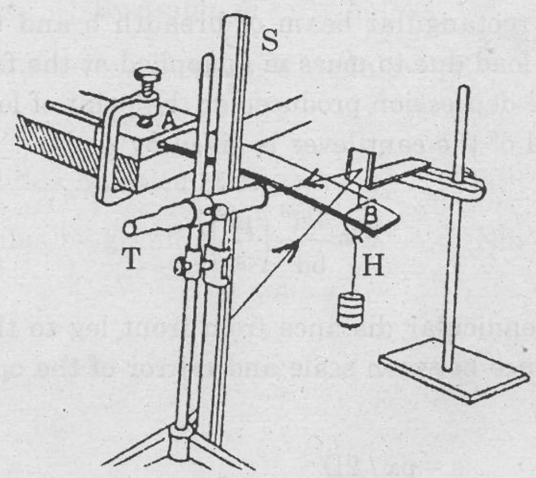

Fig.12.1

EXPERIMENT : 13

YOUNG'S MODULUS – CANTILEVER

(STATIC METHOD- III)
SCALE AND TELESCOPE – DEFLECTION

Aim :

To determine Young's modulus of cantilever by measuring deflection of loaded free end with scale and telescope arrangement.

Apparatus :

A long rectangular beam, weight hanger with slotted weights, scale and telescope, small plane mirror etc.

Procedure :

After setting the rectangular beam with one end A rigidly fixed and other end B carrying a weight hanger H with dead weight W, a small plane mirror M is attached to the cantilever at point B, as shown in Fig.13.1.

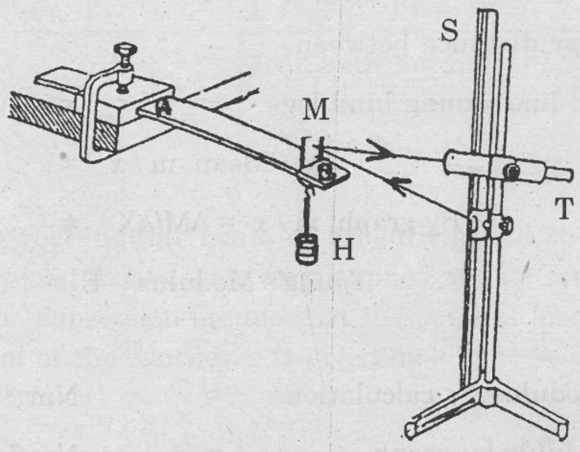

Fig.13.1

A vertical scale S with telescope T are kept in front of the mirror. Telescope is adjusted to focus the image of certain scale division reflected by the mirror and scale reading is noted for the dead weight W in the hanger. The weights are added in the steps of m (say 50 g) and correspondingly the respective scale readings are noted. The weights are gently removed one by one (in the same steps of m) and the

scale readings are noted. The readings thus obtained while loading and unloading are tabulated, as given in Table 13.1.

Note :

Before noting the readings, the cantilever is loaded to the maximum limit and the scale must be adjusted to get the image within the field of view of telescope.

The length l of cantilever from fixed end to free end is measured. The distance D between the scale and mirror is noted.

The breadth b and thickness d of the cantilever are measured by vernier calipers and screw-gauge respectively and readings are tabulated as in Table 4.2 and Table 4.3.

Experiment is repeated for different suitable lengths of the cantilever, by clamping it at various points.

Table 13.1

Load	Telescope Reading		Mean	Shift for 4m
	Loading	Unloading		
kg	cm	cm	cm	cm
W			x_0	
W + m			x_1	
W + 2m			x_2	
W + 3m			x_3	
W + 4m			x_4	$x_4 - x_0$
W + 5m			x_5	$x_5 - x_1$
W + 6m			x_6	$x_6 - x_2$
W + 7m			x_7	$x_7 - x_3$

Mean shift for 4m = cm

Shift for m= x = cm

Formula :

Let x be the shift in reading for mass m on the scale kept at a distance D from the mirror. The deflection of the cantilever from unloaded horizontal direction is

$$\theta = x / 2D$$

But the deflection of cantilever of length l, breadth b and thickness d is given by

$$\theta = \frac{6gl^2}{bd^3}\left(\frac{m}{E}\right)$$

Therefore, on substitution, the Young's modulus of the material of cantilever is

$$E = \frac{12\,gl^2D}{bd^3}\left(\frac{m}{x}\right)$$

A graph (see Fig. 4.2) is drawn with load M (equal to m, 2m, ... etc.) versus mean telescope reading X (subtracting dead weight reading). The value of $\Delta M / \Delta X$ is calculated.

Observations:

Length of beam from clamped end to free end	l	=	m
Distance between scale and mirror	D	=	m
Breadth of the beam	b	=	m
Thickness of the beam	d	=	m
Acceleration due to gravity	g	=	$9.81\ m\,s^{-2}$

Mean (m/x) = $kg\ m^{-1}$

By graph, $\Delta M / \Delta X = m/x$ = $kg\ m^{-1}$

Result :

(i) Young's modulus, by calculation = Nm^{-2}

(ii) Young's modulus, by graph = Nm^{-2}

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EXPERIMENT : 14

YOUNG'S MODULUS – CANTILEVER

(DYNAMIC METHOD)

Aim :

To determine Young's modulus of the material of cantilever by finding the period of vertical oscillations.

Apparatus :

Cantilever (metre scale), weight hanger with slotted weights, stop clock, microscope.

Procedure :

As in previous experiment [Expt. 12], a long rectangular beam is clamped at one end A and a weight hanger H is suspended at the free end B. A small needle is fixed to the frame of the hanger [refer Fig. 12.1]. A mass M_1 (equal to, say, 50g) is added to the weight hanger so that it does not produce appreciable depression at the free end of the cantilever. A microscope, placed in front of the pin, is focused such that the horizontal cross wire just coincides with the tip of the pin.

The free end of the cantilever is slightly depressed and is then released so as to execute vertical oscillations. Taking the horizontal cross wire as the reference line, the time for, say, ten oscillations is noted using stop clock. The experiment is repeated twice and mean period of oscillation T_1 is found out. Next, with adding a mass M_2 (equal to 100g) and adjusting the cross wire, the experiment is performed to find the corresponding period of oscillation T_2. The experiment is repeated for different lengths of cantilever and readings are tabulated as in Table 14.1.

Formula :

Consider a uniform cantilever of length l, breadth b and thickness d, clamped at one end and carrying a mass M at free end. Let the cantilever be set oscillating in vertical plane. The period of oscillation is given by

$$T^2 = \frac{16\pi^2 l^3}{Ebd^3}\left(M + \frac{m}{3}\right),$$

where m is the mass of cantilever and E, the Young's modulus of the material of the cantilever.

EXPERIMENT : 18

COMPOUND PENDULUM

Aim :

To determine acceleration due to gravity and radius of gyration of a compound bar pendulum about its center of mass (gravity).

Apparatus :

A bar pendulum, stop clock, metre scale, etc. .

Description :

A compound bar pendulum AB is a metallic, thick rectangular bar, one metre long, as shown in diagram Fig.18.1a. A number of small circular holes of about 5mm diameter are drilled along the length of the bar at equal distance (about 5cm) from each other. The bar pendulum can be suspended vertically from each of these holes through a horizontal knife edge K , fixed rigidly to a support on the wall.

Fig. 18.1

Formula:

Consider a rigid body (compound pendulum) of center of mass (gravity) C, suspended from a point O_1, at a distance l_1 from C. For any centre of suspension O_1 there is a point O_2,called centre of oscillation, at a distance l_2 from C [Fig. 18.1 b] about which the period of oscillation is the same.

Generally, centre of suspension and centre of oscillation, lying on either side of centre of gravity are at unequal distances from it. Then $O_1O_2 = L$ is the length of equivalent simple pendulum of period T, given by,

$$T = 2\pi\sqrt{\frac{L}{g}}$$

Therefore, $$g = 4\pi^2\left(\frac{L}{T^2}\right).$$

The radius of gyration K of the rigid body about the centre of gravity is defined by

$$K^2 = l_1 l_2$$

Thus finding the period T of a compound pendulum for centre of suspension and centre of oscillation and the length L of equivalent simple pendulum, the acceleration due to gravity and radius of gyration can be determined.

Procedure :

The bar pendulum is suspended by the knife edge passing through the first hole from one end A (say). With the help of a pointer, the position of rest of the pendulum is noted. The bar is set to small oscillations about the equilibrium point. Leaving first three or four oscillations, the time taken for twenty oscillations with two trials is noted. The distance of the knife edge from the top end A is found out. The experiment is repeated by suspending the bar in each hole and the distance from A to knife edge is measured. After crossing centre of gravity, the bar is suspended upside down, but the distance of knife edge is measured from same end A of the bar. Observations are tabulated as in Table 18.1.

A graph is drawn taking distance l of knife edge along x-axis and period of oscillation T along y-axis. The graph is symmetrical about the line passing through the centre of gravity C parallel to y-axis. It consists of two similar curves on either side of C. (Fig.18.2). A line PQRS is drawn, parallel to x-axis, cutting the curve at four points P, Q, R and S. The points P and R, lying on either side of C, correspond to the centre of suspension and centre of oscillation respectively. Similarly, other pair of points is Q and S. Hence, the length L of equivalent simple pendulum is

$$L = (PR + QS)/2$$

The other such lines are drawn and corresponding periods T are noted and tabulated in Table 18.2. The acceleration due to gravity

$$g = \frac{4\pi^2 L}{T^2}$$

is determined and mean value is taken.

From the graph (Fig 18.2), we note that

PM = SM = l_1 and RM = QM = l_2 and hence the radius of gyration about the axis passing through C is given by (Table 18.3)

$$K = \sqrt{l_1 l_2}$$

The mean value of K is calculated.

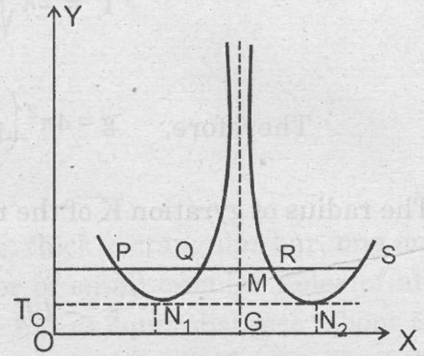

Fig. 18.2

Table 18.1 Period of Oscillation

No.of hole from end A	Distance from end A cm	Time for 20 Oscillations I s	II s	Mean s	Mean Period : T s
1.					
2.					
3.					

Table 18.2 : Determination of g

Period T s	PR cm	QS cm	Length of equivalent pendulum : L = (PR + QS) / 2 cm	L/T²

Mean L/T² = cms⁻²

Table 18.3 Determination of K

S.No	l_1=PS/2 cm	l_2 = QR/2 cm	K = $\sqrt{l_1 l_2}$ cm
1.			
2.			
3.			

Mean K = cm

Result :

(i) Acceleration due to gravity = ms^{-2}

(ii) Radius of gyration = m

Note :

For compound bar pendulum, the period is minimum (T_o) when L = 2K. Hence from the graph, Fig. 18.2, L = N_1N_2 = 2K, giving

$$K = \frac{N_1N_2}{2}$$

and

$$g = \frac{4\pi^2 N_1 N_2}{T_0^2}.$$

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EXPERIMENT : 46

PLANE TRANSMISSION GRATING.

MINIMUM DEVIATION METHOD

Aim :

To determine the number of lines (rulings) per metre of the grating and to find the wave lengths of prominent spectral lines of mercury spectrum by minimum deviation method, using spectrometer.

Apparatus :

Spectrometer, plane transmission grating, sodium vapour lamp, mercury vapour lamp, etc.

Procedure :

As in previous experiment, after the initial adjustments of spectrometer, the slit is illuminated by mercury vapour lamp. The grating is mounted vertically at the center of prism table. The grating is placed almost normal to the incident ray from collimator. The telescope is adjusted to view the direct image of the slit and the vertical cross wire is made to coincide with the image. After clamping the telescope, two verniers are adjusted to the direct readings of 0° and 180°. Verniers are clamped firmly at this position. The telescope is now turned left of direct ray and mercury spectrum is observed due to first order diffraction [Fig. 46.1].

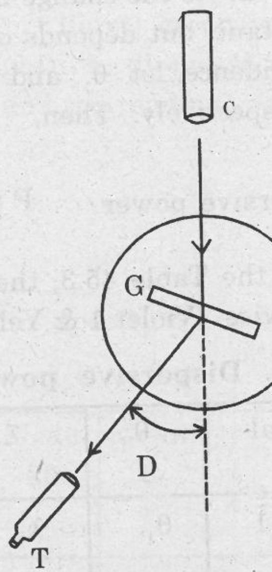

Fig. 46.1

The telescope is now adjusted to focus the bright green line of the spectrum. Rotating prism table alone, such that the green line moves towards the direct image side till it reaches the minimum deviation position. Further slight rotation of the table, makes the line to move in opposite direction, away from direct image side. At this position, fixing the prism table, the grating is set into minimum deviation position. Now making the vertical cross wire to coincide with each and every prominent lines of spectrum, starting from violet, the vernier readings are noted. The telescope is now taken to other side of direct ray. By rotating the prism table alone, grating is set in minimum deviation position for green line. Experiment is repeated and the vernier readings for all colors are tabulated, as shown in Table 46.1. The difference between diffracted ray reading corresponding to minimum deviation position and the direct ray readings gives the angle of minimum deviation D for a spectral line of wavelength λ. Using the formula for minimum deviation position,

$$\lambda = \frac{2\sin\left(\frac{D}{2}\right)}{mN}$$

where m (=1) is the order of diffraction and N is the number of rulings per metre, the wave length of prominent lines of mercury spectrum can be determined. The number of lines per metre N is found out using sodium light either by normal incidence or by minimum deviation method.

Observations :

Wave length of sodium light λ = 589.3 nm = 5.893×10^{-7} m

Number of lines per metre of grating N =

Table 46.1 Minimum Deviation D **L.C. = 1′**

Direct Readings : V_1 = V_2 =

Spectral lines	Readings Left		Minimum Deviation D		Readings Right		Minimum Deviation D		Mean D / 2	$\lambda = \frac{2\sin\left(\frac{D}{2}\right)}{N}$
	V_1	V_2	V_1	V_2	V_1	V_2	V_1	V_2		nm
Violet 1										
...										
...										
...										
Red										

Result :

The wavelengths of prominent mercury spectral lines are determined by minimum deviation method.

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Observations :

Wavelength of sodium light $\lambda = 5.893 \times 10^{-7}$m

Microscope reading for cross wire coinciding with the edge of contact $X_1 =$ m

Microscope reading for cross wire coinciding with the wire $X_2 =$ m

Distance of the wire from the edge of contact : $l = X_1 - X_2 =$ m

Mean fringe width $\beta =$ m

Diameter of the wire $d = \dfrac{l\lambda}{2\beta} =$ m

Table 51.1 : Microscope readings L.C. = 0.001cm

No.of dark fringes	Microscope Readings M S R cm	V S D	O.R = MSR+(VSD) L.C.	Width of 12 fringes cm	Fringe W idth β cm
n			x_1		
n + 3			x_2		
n + 6			x_3		
n + 9			x_4		
n + 12			x_5	$x_5 - x_1$	
n + 15			x_6	$x_6 - x_2$	
n + 18			x_7	$x_7 - x_3$	
n + 21			x_8	$x_8 - x_4$	

Mean $\beta =$ cm

Result :

The diameter of the wire = m

******

Note :

Thickness of insulation : First, with the insulation of enamel coating, the diameter d_1 of the wire is determined as described above. Next, the coating is removed uniformly and the experiment is repeated to find the diameter d_2 of the wire without insulation. Then, the thickness of the insulation is given by $(d_1 - d_2) / 2$.

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EXPERIMENT : 52

NEWTON'S RINGS

Refractive index of convex lens

Aim :

To determine radii of curvature of a double convex lens by forming Newton's rings and to calculate refractive index of the material of the lens.

Apparatus :

Convex lens, glass plates, sodium vapour lamp, 45° slot, Vernier microscope, etc..

Procedure :

A large focal length (1 metre or more) convex lens L is placed on a glass plate P, kept on the bed plate of microscope, as shown in Fig. 52.1. Rays of light from sodium vapour lamp S, incident horizontally on a glass plate G inclined at 45° are reflected vertically downward and are incident normally on the air film enclosed between the lens and glass plate. Due to interference between the light reflected from top and bottom surface of air film, the alternate dark and bright concentric rings can be observed through the microscope. At the point of contact of lens with the plate, the thickness of air film is zero. Therefore, the center of concentric rings appears dark. As one moves away from the point of contact, the thickness of air film increases symmetrically and hence, alternate bright and dark rings are obtained. These rings are called Newton's rings , Fig.52.2

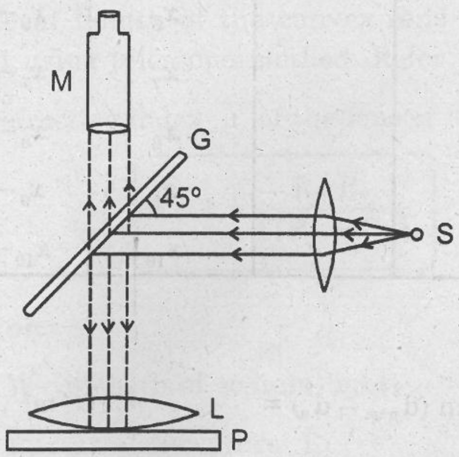

Fig. 52.1

(Enlarged view)

Fig. 52.2

Let the first clear dark ring be nth ring. The microscope is moved slowly to the left side by working its screw to cover, say, twenty seven dark rings. The rings are counted as n, n+3, n+6 etc upto n+27. The vertical cross wire is made tangent to $(n+27)^{th}$ dark ring and the reading in horizontal scale is noted. By working on horizontal screw of the vernier, the vertical cross wire is made tangent to $(n+24)^{th}$, $(n+21)^{th}$, - - - n^{th} ring on the left side and respective readings on the scale are noted. Now moving the microscope in same direction,[i.e., moving to the right of the centre to avoid error due to back-lash], the cross wire is made tangential to n^{th} $(n+3)^{rd}$, $(n+6)^{th}$, - - -, $(n+27)^{th}$ dark ring on other side (right side) of the center. The corresponding readings are taken and are tabulated as in Table.52.1. The difference in readings between two sides of a particular ring gives the diameter of that ring. For example d_n is the diameter of n^{th} Newton's dark ring.

Table 52.1 L.C. = 0.001 cm

Order of ring	Microscope Readings Left : cm	Right : cm	d_n $\times 10^{-2}$ m	d_n^2 $\times 10^{-4}$ m^{-2}	$(d^2_{n+m} - d_n^2)$ (m = 15)
n	↑	↓		x_1	
n + 3				x_2	
n + 6				x_3	
n + 9				x_4	
n + 12	↑	↓		x_5	
n + 15				x_6	$x_6 - x_1$
n + 18				x_7	$x_7 - x_2$
n + 21				x_8	$x_8 - x_4$
n + 24	↑	↓		x_9	$x_9 - x_4$
n + 27				x_{10}	$x_{10} - x_5$

For R_1, Mean $(d^2_{n+m} - d^2_n)$ = , $\times 10^{-4}$ m^2

As shown in Table.52.1 ten sets of readings are taken and d_n and d_n^2 are calculated. Dividing the table in the middle $(d^2_{n+m} - d_n^2)$ is obtained in the last column keeping m = 15.

Let us take the mean value of the last column as C_A.

That is $$C_A = d^2_{n+m} - d^2_n$$

(We will be using this constant in the next part of the experiment).

The convex lens is reversed and the experiment is repeated and the radius of curvature, R_2 of the second face is determined.

Formula :

Let d_n and d_{n+m} be the diameter of n^{th} and $(n + m)^{th}$ dark Newton's rings respectively. If λ is the wavelength of monochromatic light and R is the radius of curvature of the lens, then,

$$d^2_n = 4Rn\lambda$$

$$d^2_{n+m} = 4R(n+m)\lambda$$

Therefore, $$R = \frac{(d^2_{n+m} - d^2_n)}{4m\lambda} = \frac{C_A}{4m\lambda}$$

By taking $\lambda = 589.3 \times 10^{-9}$m, radii of curvature R_1 and R_2 can be determined.

The focal length of the convex lens (focal length more than 100 cm) is determined using telescope method. Refer Expt.39.

The refractive index μ of the lens of focal length f is given by

$$\mu = 1 + \frac{R_1 R_2}{f(R_1 + R_2)}$$

Observations :

Wavelength of sodium light λ = 589.3×10^{-9} m

Radius of curvature R_1 = m

Radius of curvature R_2 = m

Focal length of lens f = m

Refractive index $\mu = 1 + \frac{R_1 R_2}{f(R_1 + R_2)}$ =

Result :

Refractive index of material of double convex lens =

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Note :

Refractive index of transparent liquid (water)

The refractive index of the given liquid can be determined by forming thin liquid film between convex lens and glass plate and forming Newton's rings.

A large drop of liquid is placed on the plate and the lens is kept on it, so that same face touching the plate. Newton's rings are formed [fewer in numbers and less in intensity]. The procedure is the same as with the air film.

For air film we have the constant

$$C_A = d^2_{n+m} - d^2_n$$

and hence the wave length of monochromatic light in air is given by

$$\lambda_A = \frac{C_A}{4m\,R}$$

For liquid film let the corresponding constant be C_L.

The wave length of monochromatic light in liquid is given by

$$\lambda_L = \frac{C_L}{4m\,R}$$

Now the refractive index of liquid is given by

$$\mu = \frac{\lambda_A}{\lambda_L} = \frac{C_A}{C_L}$$

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EXPERIMENT : 53

FEBRY PEROT ETALON

Aim :

To determine the thickness of air film by forming interference using Febry Perot Etalon and hence to calculate fine structure spread of spectral line.

Apparatus :

Spectrometer, Febry Perot Etalon, Sodium vapour lamp, scale and telescope arrangements, etc...

Procedure:

A Febry Perot Etalon consists of two semi silvered optically plane glass plates held parallel to each other, enclosing a thin air film. Silvered faces of plates are facing each other. The complete arrangement is enclosed in a cell having circular openings on both the opposite faces. The plates are made exactly parallel, and vertical by means of three leveling screws.

The Febry Perot Etalon is mounted vertically on leveled prism table of spectrometer. The collimating lens from collimator is removed and the slit is made as wide as possible. The slit is then illuminated uniformly using sodium vapour lamp. The light incident on front face of Etalon, undergoes multiple reflection through the air film and by interference, alternate bright and dark concentric circular fringes with central spot are formed. By focusing the telescope and adjusting it, the interference pattern can be observed.

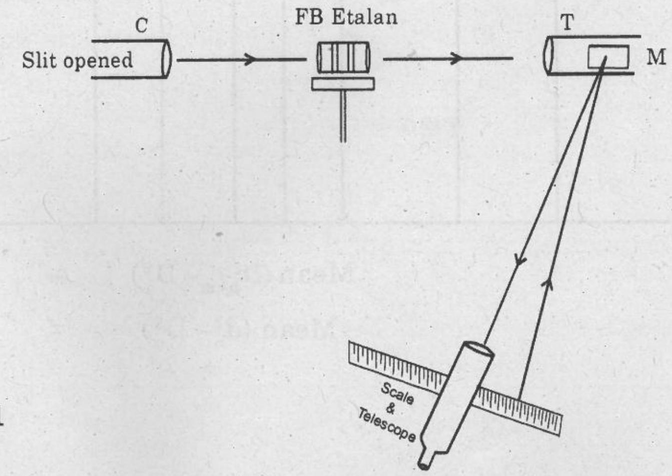

Fig. 53.1

EXPERIMENT : 41

SPECTROMETER - PRISM.

Aim :

To determine refractive Index of the material of solid prism (glass) using spectrometer by measuring the (i) Angle of the prism (ii) Angle of minimum deviation. .

Apparatus :

Spectrometer, glass prism, sodium vapour lamp, etc.

Description :

A spectrometer essentially consists of three components as shown in Fig. 41.1. (i). Collimator. (ii). Telescope and (iii). Prism Table.

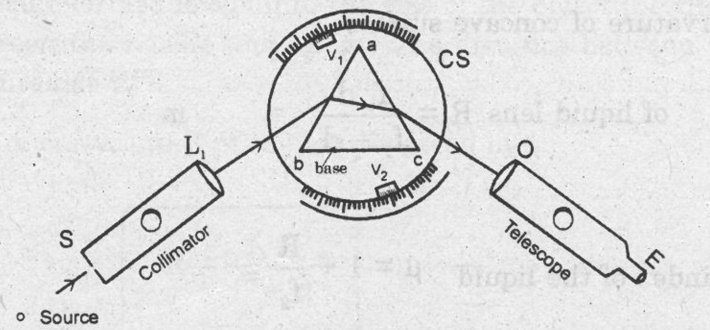

Fig. 41.1

Collimator is an arrangement of two coaxial tubes. There is a vertical adjustable slit, S at one end and a convex lens L_1 at the other end. The narrow slit of the collimator is illuminated by a source of light . The distance between the slit and the lens is adjusted using a rack and pinion arrangement to focus the slit. The rays of light through the slit, after refraction by the lens are rendered parallel. This procedure is usually referred as adjusting the collimator to produce parallel rays. The collimator is fixed to a rigid stand.

An astronomical telescope with its axis in same horizontal plane as that of collimator, consists of on objective O and an eye piece E. The distance between the objective and eye piece can be adjusted using a rack and pinion arrangement. In front of the eye piece, a horizontal and vertical cross wires are fixed. The telescope

is attached to a circular scale CS and can be rotated about a vertical axis, passing through the center of circular scale. The telescope can be fixed at any position by means of radial screw and fine adjustments are done using a tangential screw. The scale is graduated in degrees from 0° to 360°. Each division of the scale corresponds to half a degree.

A prism table P with adjustable height is provided with three leveling screws. It can be rotated about same vertical axis as that of telescope. The prism table can be raised or lowered and fixed at any position using a long screw.

The position of prism table can be read with the help of two verniers V_1 and V_2. Each vernier scale is divided into thirty divisions.

Procedure :

(a). Least Count of Verniers :

The value of each division in circular scale is found. The number of divisions in vernier scale V_1 or V_2 is noted. The zero of vernier scale is made to coincide with any one of main scale divisions and total number of main scale divisions required to cover complete vernier scale is determined. The Least Count (L.C.) of the vernier can be calculated as follows :

The value of 1 MSD = 1/2 ° = 30′

Number of divisions in vernier scale = 30 VSD

Number of MSD to cover V.S. = 29 MSD

30 VSD = 29 MSD

Hence, 1 VSD = 29/30 MSD

Therefore, Least Count (L.C.) of the vernier

L.C. = 1 M.S.D – 1 V.S.D

= 1/30 MSD = 1′

(b). Preliminary Adjustments :

(i). The eye piece of the telescope is adjusted to see the vertical and horizontal cross wires clearly and distinctly.

(ii). The telescope is then turned towards a distant object. The distance between the eye piece and the objective is adjusted using the rack and pinion arrangement to get a clear and well defined image of the distant object. The image will be a diminished and inverted image. **Once the telescope is adjusted (focussed for the distant object), the rack and pinion adjustment screw should not be disturbed.**

(iii). The spectrometer is placed in front of a source of monochromatic light (Sodium vapour lamp). The slit of collimator is opened narrowly. Telescope is brought on line with collimator. The lens of collimator is then adjusted so that the clear, well defined image of narrow slit obtained and coincides with the vertical cross wire without parallax. The collimator also need not be disturbed hereafter.

(iv). Levelling of prism table – Optical Method - The initial levelling of the table is done by using spirit level and three levelling screws. Prism is placed on the table with its edge nearer to the collimator and base at right angles to it. One of the refracting faces of the prism, say, ac must be perpendicular to the line joining any two of the leveling screws (A and B), as shown in Fig.41.2.

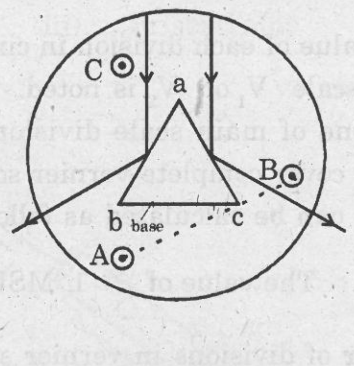

Fig. 41.2

The rays from collimator are get reflected from both the faces ab and ac. The image of the slit due to reflection is formed on each face. Now, after locating the image from face ac, the telescope is turned to view this image. By working on the leveling screws A and B , the image is bought to the centre of the field of view of eye piece. Next, the image from the face ab is centralized in the field of view by adjusting the third screw C. By these adjustments, the prism table is leveled.

c). Measurement of the Angle of Prism A :

The prism is placed on the prism table and mounted vertically with a prism holder. The edge of the prism is facing the collimator, so that parallel rays of light fall almost equally on two refracting faces ab and ac, as shown in Fig. 41.3.

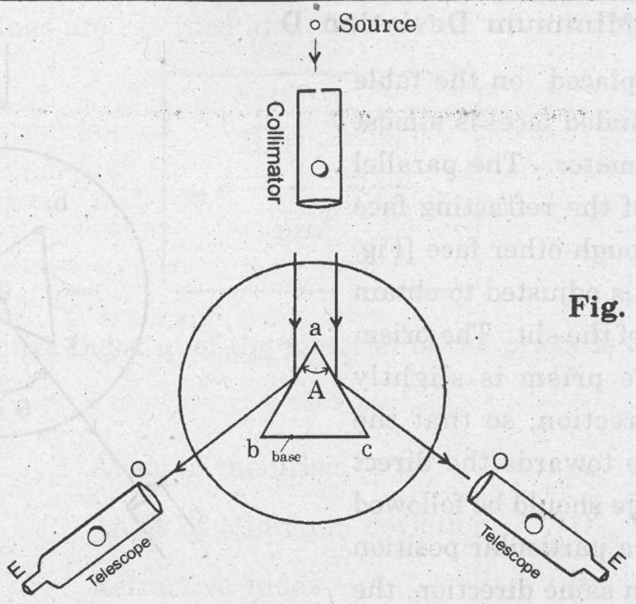

Fig. 41.3

The telescope is turned towards one of the faces (ab) and the reflected image from the face is observed through the telescope. Using tangential screw, the vertical cross wire is made to coincide with the image. The positions of prism table, vernier and telescope are fixed. The main scale (circular scale) readings and coinciding vernier scale divisions are noted for both the verniers V_1 and V_2. Now, releasing the telescope, it is tuned towards other face ac, experiment is performed and corresponding readings are noted. Observations are tabulated as in Table 41.1. The difference in readings between I and II face gives twice the angle of prism A.

Table 41.1 : Angle of the prism A L.C. = 1'

Image	Vernier V_1			Vernier V_2		
	MSR	VSD	O.R.	MSR	VSD	O.R.
Reflected image from I Face						
Reflected image from II Face						
Difference 2A						

Mean 2A =

Mean A =

(d). Angle of Minimum Deviation D :

The prism is placed on the table so that its base (grounded face) is almost in line with the collimator. The parallel rays falling on one of the refracting face ab are refracted through other face [Fig. 41.4]. The telescope is adjusted to obtain this refracted image of the slit. The prism table and hence the prism is slightly rotated in either direction, so that the image tends to move towards the direct image side. The image should be followed by the telescope. In a particular position for further rotation in same direction, the image just turns back in opposite direction. This corresponds to **minimum deviation** of the prism.

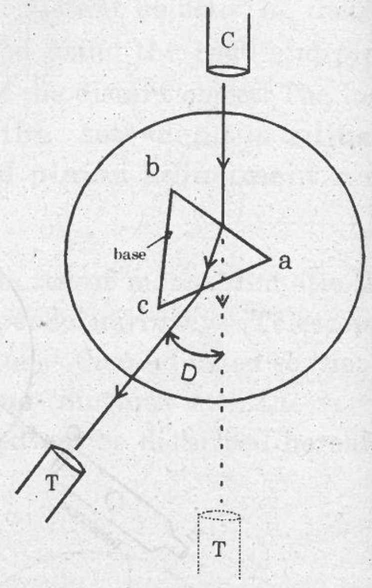

Fig. 41.4

The prism is fixed in this position and with finer adjustment using tangential screw, the vertical cross wire at the center of field of view is made to coincide with the image. Telescope is fixed and readings of verniers V_1 and V_2 are noted. The prism then is removed, telescope is released and is brought in line with the collimator, the direct readings of verniers are taken. The difference between these two readings for each vernier gives the angle of minimum deviation D and hence the mean D is calculated.

Table 41.2 Angle of Minimum Deviation D **L.C. = 1′**

Image	Vernier V_1			Vernier V_2		
	M S R	V S D	O.R.	M S R	V S D	O.R.
Refracted image						
Direct image						
Difference D						

Mean D =

The readings are recorded as in Table.41.2. Now using the formula,

$$\mu = \frac{\sin\left(\frac{A+D}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

the refractive index μ of the material of the prism is determined.

Observations :

Angle of the prism A =

Angle of Minimum deviation D =

Refractive index μ =

Result :

(i). Refractive index of the material of solid prism =

******

Note :

HOLLOW PRISM

Refractive index of liquid

The refractive index of a transparent liquid (water, glycerine) can be determined with same experimental procedure as in the case of solid glass prism. A hollow prism is filled with the given liquid, say, water. Two faces (refracting faces) of hollow prism are made up of optically plane, thin parallel sided glass plates. The angle of prism A and the angle of minimum deviation D are determined [see Table 41.1 and Table 41.2]. The refractive index μ of the liquid is calculated from the formula

$$\mu = \frac{\sin\left(\frac{A+D}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

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Table 19.1 Period of Oscillation

Face	l cm	Time for ten oscillations I s	Time for ten oscillations II s	Mean s	Period T s	l/T^2	By Expt. I kgm²	By Calcul I kgm²
L-B							I_1	
B-D							I_2	
L-D							I_3	

Observations:

Mass of the block	M	=	kg
Length of each string	l	=	m
Distance of separation	2a	=	m
Length of the block	L	=	m
Breadth of the block	B	=	m
Thickness of the block	D	=	m
Acceleration due to gravity	g	=	9.81 ms^{-2}

Result :

(i) Moments of inertia by experiment

I_1 = kg m² I_2 = kg m² I_3 = kg m²

(ii) Moments of inertia by calculation

I_1= kg m² I_2= kg m² I_3 = kg m²

Note :

The ratio of moments of inertia is

$$I_1 : I_2 : I_3 = T_1^2 : T_2^2 : T_3^2 = (L^2 + B^2) : (B^2 + D^2) : (L^2 + D^2)$$

[Keeping l and a same for all the three faces].

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***EXPERIMENT* : 20**

SURFACE TENSION

DROP WEIGHT METHOD

Aim :

To determine the surface tension of (i) water (ii) liquid (Kerosene oil) and interfacial surface tension between liquid and water.

Apparatus :

A glass funnel with vertical stand, a short glass tube of suitable diameter, rubber tubing, beaker, pinch clip, Hare's Apparatus, etc..

Description :

As shown in Fig.20.1, a short glass tube is connected to the lower end of funnel through a rubber tube. The funnel is held vertical with a rigid support. The flow of liquid through the glass tube can be adjusted by means of pinch clip, provided with the rubber tubing.

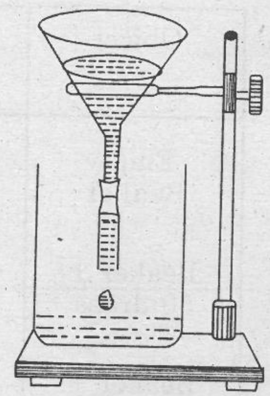

Fig. 20.1

Procedure :

To start the experiment, pure clean water is poured into the funnel. The pinch clip is adjusted so that drops are formed slowly and steadily at the open end of the glass tube. A dry, clean weighed beaker [weighing is done by electronic balance] is taken and, say, fifty drops of water are collected. The mass of beaker with 50 drops is measured. The experiment is repeated by collecting drops in steps of 50 and in each case, after deducting the mass of empty beaker, one can determine the mass of single drop. Hence mean mass of single drop of water is calculated. The readings are recorded as in Table 20.1.

Formula :

From Rayleigh Formula, the surface tension of water is given by

$$T = \frac{mg}{3.8\,r}$$

where, m is the mass of one drop of water, r is the radius of glass tube and g is the acceleration due to gravity.

Note :

The dropping end of the glass tube should be flat. The glass tube should be kept vertical. The pinch cock is adjusted so that the liquid drops are formed slowly, say at the rate of about eight drops per minute. In the case of a liquid which wets glass (like water), the value of r used is the external radius of the tube. For waxed tubes, the value of r is the internal radius which has to be found out by measuring the internal diameter of the tube using a vernier microscope. (Refer. Expt.3).

Table 20.1 : Drop weight - water : m_1

Object	Mass g	Mass of 50 drops g	Mass of single drop m_1 g
Empty Beaker	w_1		
Beaker + 50 drops	w_2	$(w_2 - w_1)$	
Beaker + 100 drops	w_3	$(w_3 - w_2)$	

Mean mass of one drop m_1 = g.

Surface Tension of liquid (Kerosene):

To find the surface tension of the liquid (kerosene), the funnel and glass tube are dried thoroughly and is filled with the kerosene oil. A dried and weighed beaker is taken to collect liquid drops in steps of fifty and after each collection, the mass of beaker with liquid drops is noted. The mean mass of single liquid drop m_2 is calculated. Use the same table as Table 20.1.

Interfacial Surface Tension:

To find interfacial surface tension of water in a lighter liquid (kerosene oil), sufficient quantity of kerosene is taken in the beaker. Mass of beaker with liquid is noted. By dipping the end of the glass tube in the liquid, water drops are formed within the liquid. The water drops are formed slowly within the liquid, say about

six drops per minute. As in previous case, mass of water drops in steps of fifty is noted. From these readings the mean mass of single water drop in kerosene m_3 is calculated [Table 20.2].

Table 20.2 : Interfacial Drop weight : m_3

Object	Mass g	Mass of 50 drops g	Mass of single drop m_3 g
Beaker + Liquid	w_1	———	———
Beaker + Liquid + 50 drops of water	w_2	$(w_2 - w_1)$	———
Beaker + Liquid + 100 drops of water	w_3	$(w_3 - w_2)$	———

Mean mass of one drop m_3 = g.

The interfacial surface tension of water of density ρ_1 in a liquid of density ρ_2 is given by

$$T_{WL} = \frac{m_3 g}{3.8\, r}\left[1 - \frac{\rho_2}{\rho_1}\right]$$

m_3 being the mass of a drop of water in liquid.

The density of the liquid is determined using Hare's apparatus. It is an inverted U-tube of uniform area of cross section, with the bent part connected to a rubber tube, as shown in Fig.20.2. Both the limbs of U-tube are dipped in water and liquid respectively. By means of rubber tube, water and liquid raise in respective limbs.

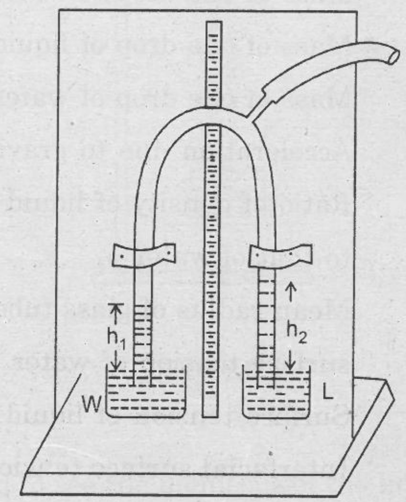

Fig. 20.2

The readings corresponding to beaker level and limb level both for water and liquid are noted on a metre scale provided with the apparatus. The heights of water (h_1) and liquid (h_2) columns are calculated and hence the density of liquid [Table 20.3] is determined.

Table 20.3 – Hare's Apparatus : ρ_2 / ρ_1

S.No	Water Readings cm		Height of water column h_1 cm	Liquid Readings cm		Height of liquid column h_2 cm	$\rho_2 / \rho_1 = h_1/h_2$
	Beaker Level	Limb level		Beaker Level	Limb level		

Mean $\rho_2 / \rho_1 = h_1 / h_2$ =

As the water and kerosene wet the glass, the outer radius (r) of the glass tube must be used. It is measured by using screw gauge at different diametrically opposite points. [Refer Expt.2.]

Observations :

Mass of one drop of water	m_1	=	kg
Mass of one drop of liquid	m_2	=	kg
Mass of one drop of water in liquid	m_3	=	kg
Acceleration due to gravity	g	=	9.81 $m\ s^{-2}$
Ratio of density of liquid ρ_2 to that of water ρ_1	(ρ_2 / ρ_1)	=	h_1 / h_2
Mean radius of glass tube	r	=	m
surface tension of water	T_w	=	Nm^{-1}
Surface tension of liquid (kerosene)	T_L	=	Nm^{-1}
Interfacial surface tension of water	T_{WL}	=	Nm^{-1}

Result :

Surface tension of water	=	Nm^{-1}
Surface tension of liquid	=	Nm^{-1}
Interfacial surface tension	=	Nm^{-1}

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***EXPERIMENT* : 21**

SURFACE TENSION

CAPILLARY RISE

Aim:

To find the surface tension of liquid (water) by capillary rise method.

Apparatus :

Capillary tube of uniform bore, a beaker with given liquid, a pointer, a vernier microscope, etc.

Procedure :

A well cleaned, sufficiently long uniform capillary tube is taken and is passed through a cork. The cork is clamped to a rigid support so as to keep the tube vertical. One end of the tube is attached to a rubber tubing. The free end of the tube is dipped in a beaker containing the liquid.

A pointer is fixed through the same cork, close to the capillary tube. The pointer is adjusted so that the tip of it just touches the surface of liquid in the beaker, as shown in Fig.21.1. The liquid rises in the tube due to capillarity and by repeatedly pressing and releasing the rubber tube, a continuous liquid column is formed. Care should be taken to remove any air bubbles or breaks along the length of the column. The pointer is checked to make the tip just touching the surface of the liquid.

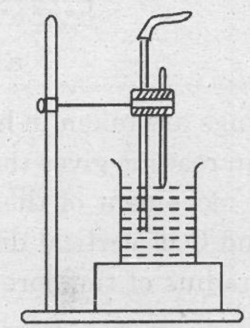

Fig.21.1

A microscope in horizontal position is focused to see the meniscus of the liquid. The horizontal cross wire is made tangent to the concave part of the meniscus as shown in diagram [Fig. 21.2a]. The vertical main scale reading and corresponding coinciding vernier scale divisions are noted. Now the beaker is removed carefully and the microscope is adjusted to focus the tip of the pointer. The horizontal cross wire should just touch the tip and readings of microscope in vertical scale are taken. [Table.21.1]. The difference in readings gives the height h of the liquid column in the capillary tube. Experiments are repeated by changing the level of

Hence, $\sigma = \frac{ms}{\pi r^2(T_3^4 - T_0^4)}\left(\frac{\beta}{\alpha}\right)$ W m^{-2} K^{-4}.

Observations :

Mass of silver disc m = kg

Radius of silver disc r = m

Specific heat capacity of silver s = 235 J Kg^{-1} K^{-1}.

Room temperature T_1 = °C

Steady temperature of steam chamber $T_3 = T_3$° C + 273 = K.

Temperature difference at knee point T_K = °C

Temperature of silver disc To = $T_K + T_1 + 273$ = K

Slope of θ versus T plot, α = dθ / dT = AB / BC =

Slope of the tangent at knee point β = dθ /dt = PR / QR =

Rate of temperature raise at To K = (dT / dt) = (β / α) = K s^{-1}.

Stefan's Constant $\sigma = \frac{ms}{\pi r^2(T_3^4 - T_0^4)}\left(\frac{\beta}{\alpha}\right)$ = W m^{-2} K^{-4}.

Result :

Stefan's Constant σ = W m^{-2} K^{-4}.

EXPERIMENT : 87

SPECIFIC CHARGE OF ELECTRON

THOMSON METHOD

Aim :

To determine e/m of electron by J.J.Thomson method, using a cathode ray tube and a pair of bar magnets.

Apparatus :

Cathode ray tube, power supply, wooden frames with scales, bar magnets (two), deflection magnetometer, etc.

Description :

A cathode ray tube (CRT) is a highly evacuated, funnel shaped glass tube G. It consists of a cathode K, ring type anode A , a mica disc D with central small hole and two closely spaced horizontal parallel plates Y , Y′ and a graduated fluorescent screen S as shown in Fig. 87.1. When the power is switched on, a narrow beam of electron passing through A and D strikes the screen S at zero division of the scale, graduated in centimetre, if there is no deflecting voltage and if the tube is kept along the magnetic meridian.

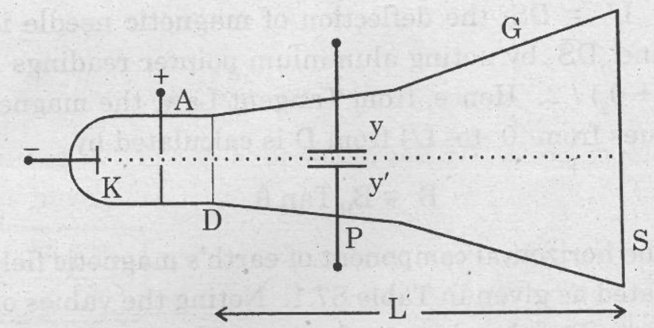

Fig. 87.1

The deflection magnetometer consists of a magnetic needle pivoted at the center of circular scale. The scale is divided into four quadrants, each quadrant is graduated in degrees (0° – 90°). A light long aluminum pointer is attached at right angles to the needle.

Procedure :

Keeping all magnets and magnetic materials away, using compass needle, mark a line along magnetic meridian (North – South) and another at right angles (East – West) to it. The CRT is placed with its length along the magnetic meridian. Now CRT is switched on and after few minutes, a spot is observed at the central zero scale division on the screen. The intensity and sharpness of the spot are adjusted by working on the controlling switches. Now a voltage about 10 V to 20 V is applied to deflect the electron beam between the plates Y and Y′. The light spot on the screen is now deflected either up or down by a few scale divisions. The deflection Y of the spot is measured. The deflecting voltage V is noted.

Next, a pair of bar magnets with their opposite poles facing each other is placed symmetrically on the opposite sides of CRT along East – West line, at right angles to the magnetic meridian. By suitably adjusting the positions of both the magnets, without disturbing the symmetric conditions, the light spot is brought back to the original position. That is, the deflection produced by electric field is nullified by that due to magnetic field. The positions of the disc D and the screen S are marked on wooden base. Then, without disturbing the magnets, the CRT is removed. A straight line DS is drawn.

The compass box of the magnetometer, with initial adjustments of aluminium pointer readings 0° – 0° when placed along magnetic meridian, is used to find the magnetic field at various points along the line DS. Taking x as the distance of a point from D and L′ = DS, the deflection of magnetic needle is determined at various points on line DS by noting aluminium pointer readings θ_1 and θ_2 and hence mean $\theta = (\theta_1 + \theta_2)/2$. Hence, from Tangent Law, the magnetic field B at a point x (taking values from 0 to L′) from D is calculated by

$$B = B_H \tan\theta$$

where B_H is the horizontal component of earth's magnetic field. The readings are noted and tabulated as given in Table 87.1. Noting the values of the distance L between the mid point P of the plates and screen, the length p of deflecting plate and the distance of separation d of plates from the manual of the apparatus, using the formula, the specific charge e/m of electron can be calculated.

Theory :

Let an electron of charge e and mass m moving along magnetic meridian with velocity v enters a region of perpendicular electric field E between the parallel plates, each of length p and separation d. Let V be the voltage applied,

such that E = V/d. IF Y_1 is the deflection of electron on the screen S, then,

$$Y_1 = \frac{e\,V\,p\,L}{m\,d\,v^2}$$

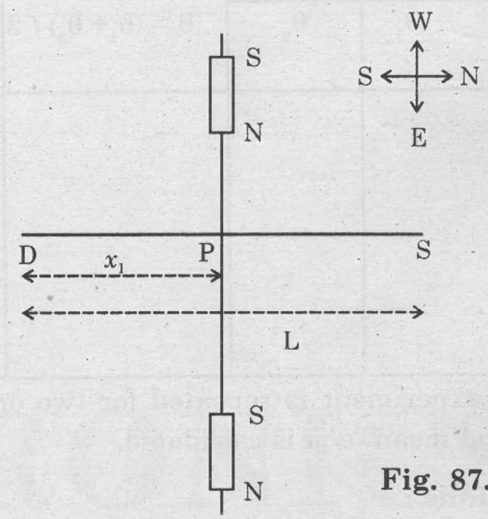

Fig. 87.2

When only a magnetic field B, at right angles to both E and the direction of electron motion, is acting on the electron, then, the deflection Y_2 on the screen is, with x_1 = DP , [as shown in Fig. 87.2],

$$Y_2 = \frac{e}{m}\,\frac{1}{v}\int_{x_1}^{L'} dx \left[\int_{x_1}^{x} B\,dx\right]$$

$$= \frac{e}{m}\,\frac{1}{v}\,A$$

where $$A = \int_{x_1}^{L'} dx \left[\int_{x_1}^{x} B\,dx\right] = \int_{x_1}^{L'} (L' - x)B\,dx$$

When the electric field and the magnetic field oppose and produce zero deflection, then,

$$Y_1 = Y_2$$

and hence ,

$$v = \frac{VpL}{Ad}$$

Now substituting v in the expression for deflection in electric field alone, taking Y_1 = Y, we have ,

$$\boxed{\frac{e}{m} = \frac{VpLY}{d\,A^2}}$$

The value of A is determined graphically by taking x along x–axis and $(L' - x)B$ along y-axis, as shown in Fig.87.3 Let the curve attains maximum at $x = x_1$. Then the value of A is the area under the curve from $x = x_1$ to $x = L'$, the shaded region in Fig. 87.3.

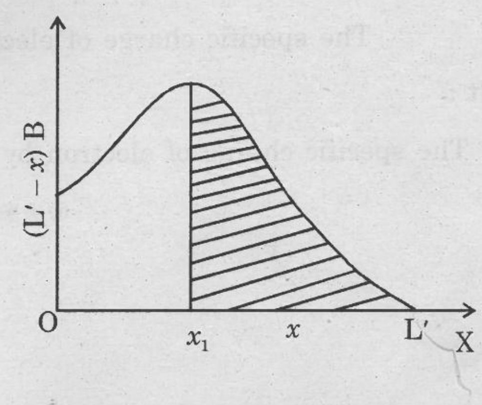

Fig. 87.3

Table 87.1 $B_H = 4.066 \times 10^{-5}$ T, L′ = DS = m

x m	Deflection θ_1	θ_2	$\theta = (\theta_1 + \theta_2) / 2$	Mag. Field $B = B_H \tan\theta$ T	$(L' - x)$ m	$(L' - x)B$ mT

The experiment is repeated for two or three different values of deflecting voltage and mean e/m is calculated.

observations :

The distance between mid-point of plates and screen L = m

The length of each deflecting plate p = m

The distance of separation of plates d = m

The deflecting voltage V = V

The deflection due to electric field alone Y = m

Horizontal component of Earth's magnetic field $B_H = 4.066 \times 10^{-5}$ T

The distance between disc and screen L′ = m

Area under the curve A = Tm^2

The specific charge of electron e/m = Ckg^{-1}

Result :

The specific charge of electron by Thomson method = Ckg^{-1}.

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ELECTRONICS EXPERIMENTS

"Electronics is an art and a science, you will have to learn to use approximations instead of exact answers"

Malvino