Mechanics Laboratory Manual

(B.Sc. Physics I Sem.)

Department of Pure & Applied Physics

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B.Sc. Physics First Sem.
Mechanics Lab.

List of Experiments

Experiment – 1 To determine the length, height, or diameter of the given workpiece by using vernier caliper, screw guage, and travelling microscope.

Experiment – 2 To determine the restoring force per unit extension or spring constant of a spiral spring by statistical method.

Experiment – 3 To determine the moment of inertia of a flywheel.

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Experiment – 5 To determine the elastic constants of a wire by Searle's method.

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EXPERIMENT – 01

1. Aim – To determine the length, height, or diameter of the given workpiece by using Vernier Caliper, Screw Guage, and Travelling Microscope.

2. Appratus required – 1. Vernier Caliper,

2. Screw Guage

3. Travelling Microscope, Workpieces

For the measurement of length usually meter scales are used with accuracy up to millimeter. But for the measure length say 1/100 th of the centimeter (c.m.) or 1/100th of a millimeter, it is not possible to measure accurately using meter scale. Hence, the following instruments are used for more accuracy.

A.)VERNIER CALIPER

A.1. Description of the Vernier caliper.

A vernier caliper is defined as a measuring device that is used for the measurement of linear dimensions. It is also used for the measurement of diameters of round objects with the help of the measuring jaws. French mathematician Pierre Vernier invented the vernier scale in 1631. The main use of the vernier calliper over the main scale is to get an accurate and precise measurement. Vernier caliper has two scales– one main scale and a Vernier scale, which slides along the main scale. The main scale and Vernier scale are divided into small divisions though of different magnitudes.

1. The main scale is graduated in cm and mm. It has two fixed jaws, A and C, projected at right angles to the scale. The sliding Vernier scale has jaws (B, D) projecting at right angles to it and also the main scale and a metallic strip (N). The zero of main scale and Vernier scale coincide when the jaws are made to touch each other. The jaws and metallic strip are designed to measure the distance/ diameter of objects. Knob P is used to slide the vernier scale on the main scale. Screw S is used to fix the vernier scale at a desired position.

2. The least count of a common scale is 1mm. It is difficult to further subdivide it to improve the least count of the scale. A vernier scale enables this to be achieved.

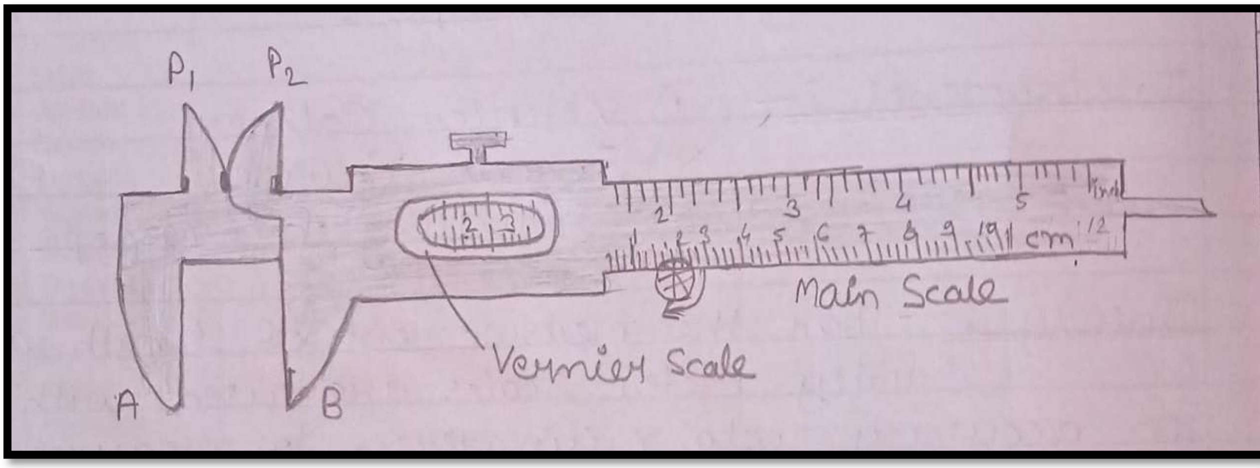


Fig. 1.1 Vernier Calliper

<u>A.2. Principle (Theory)</u> - The difference in the magnitude of one main scale division (M.S.D.) and one vernier scale division (V.S.D.) is called the least count of the instrument, as it is the smallest distance that can be measured using the instrument. Formulas Used

(a) Least count of vernier calipers =

$$\frac{\text{The magnitude of the smallest division on the main scale.}}{\text{The total number of small divisions on the vernier scale.}}$$

A.3. Procedure

1. Keep the jaws of Vernier Calipers closed. Observe the zero mark of the main scale. It must perfectly coincide with that of the vernier scale. If this is not so, account for the zero error for all observations to be made while using the instrument.

2. Look for the division on the vernier scale that coincides with a division of main scale. Use a magnifying glass, if available and note the number of division on the Vernier scale that coincides with the one on the main scale.

3. Gently loosen the screw to release the movable jaw. Slide it enough to hold the sphere/cylindrical body gently (without any undue pressure) in between the lower jaws AB. The jaws should be perfectly perpendicular to the diameter of the body. Now, gently tighten the screw so as to clamp the instrument in this position to the body.

4. Carefully note the position of the zero mark of the vernier scale against the main scale. Usually, it will not perfectly coincide with any of the small divisions on the main scale. Record the main scale division just to the left of the zero mark of the vernier scale.

5. Start looking for exact coincidence of a vernier scale division with that of a main scale division in the vernier window from left end (zero) to the right. Note its number (say) N, carefully.

6. Multiply 'N' by least count of the instrument and add the product to the main scale reading noted in step 4. Ensure that the product is converted into proper units (usually cm) for addition to be valid.

7. Repeat steps 3-6 to obtain the diameter of the body at different positions on its curved surface. Take three sets of reading in each case.

8. Record the observations in the tabular form [Table E 1.1(a)] with proper units. Apply zero correction, if need be.

9. Find the arithmetic mean of the corrected readings of the diameter of the body. Express the results in suitable units with appropriate number of significant figures

A.4. Calculations and Observations.

(i) Least count of Vernier Calipers (Vernier Constant)

1 main scale division (MSD) = 1 mm = 0.1 cm

Number of vernier scale divisions, N = 10

$$\text{Vernier constant} = \frac{1\text{MSD}}{\text{N}} = \frac{1\text{ mm}}{10}$$

Vernier constant (V_C) = 0.1 mm = 0.01 cm.

(ii). Zero error : It is defined as the condition in which the measuring device registers a reading when there should not be any reading. The zero error of the vernier caliper is calculated as:

Actual reading = Main scale + Vernier scale – (Zero error)

OBSERVATION TABLE – 01

Vernier constant (V_C) = 0.1 mm = 0.01 cm.

S.no	Main Scale reading, M (cm/mm)	Number of coinciding vernier division, N	Vernier scale reading, V = N × VC (cm/mm)	Measured diameter, M + V (cm/mm) (For spherical object.)
1				
2				
3				
4				

Dimension {For rectangular workpiece}	*S. No*	Main Scale reading, M (cm/mm)	Number of coinciding vernier division, N	Vernier scale reading, V = N × VC (cm/mm)	Measured demension, M + V (cm/mm
Length					
Length					
Breadth					
Breadth					
Height					
Height					

Dimension {For cylinderical workpiece}	*S. No*	Main Scale reading, M (cm/mm)	Number of coinciding vernier division, N	Vernier scale reading, V = N × VC (cm/mm)	Measured demension, M + V (cm/mm

A.5. Result

(a) Diameter of the spherical/ cylindrical body, D = ... × 10^{-2}m.

(b) The dimension of the given rectangular block.

Length= _______× 10^{-2} m. , Breadth =_____× 10^{-2}m. , Height = _________×10^{-2}m. .

(c) The dimension of the given rectangular block.

Diameter= ______×10^{-2} m., Depth= _____×10^{-2} m.,

A.6. PRECAUTIONS

1. If the vernier scale is not sliding smoothly over the main scale, apply machine oil/grease.

2. Screw the vernier tightly without exerting undue pressure to avoid any damage to the threads of the screw.

3. Keep the eye directly over the division mark to avoid any error due to parallax.

4. Note down each observation with correct significant figures and units.

B.) Screw gauge

B.1. Description of the instrument.

Screw gauge is a mechanical tool that allows precise measurement of the diameter, radius, or thickness of a thin wire or a thin metal sheet. It is also known as a micrometer screw gauge. It includes two scales, a Pitch scale, and a Circular scale. Micrometer gauges are highly accurate for measurement in comparison to the Vernier Caliper Scale. Screw gauge measurement can be done using a Micrometer and an Inch Micrometer. A screw gauge is used for the precise measurement of a cylindrical or a spherical object. The screw gauge consists mainly of a U-shaped frame and a spindle (or a screw) attached to the thimble.

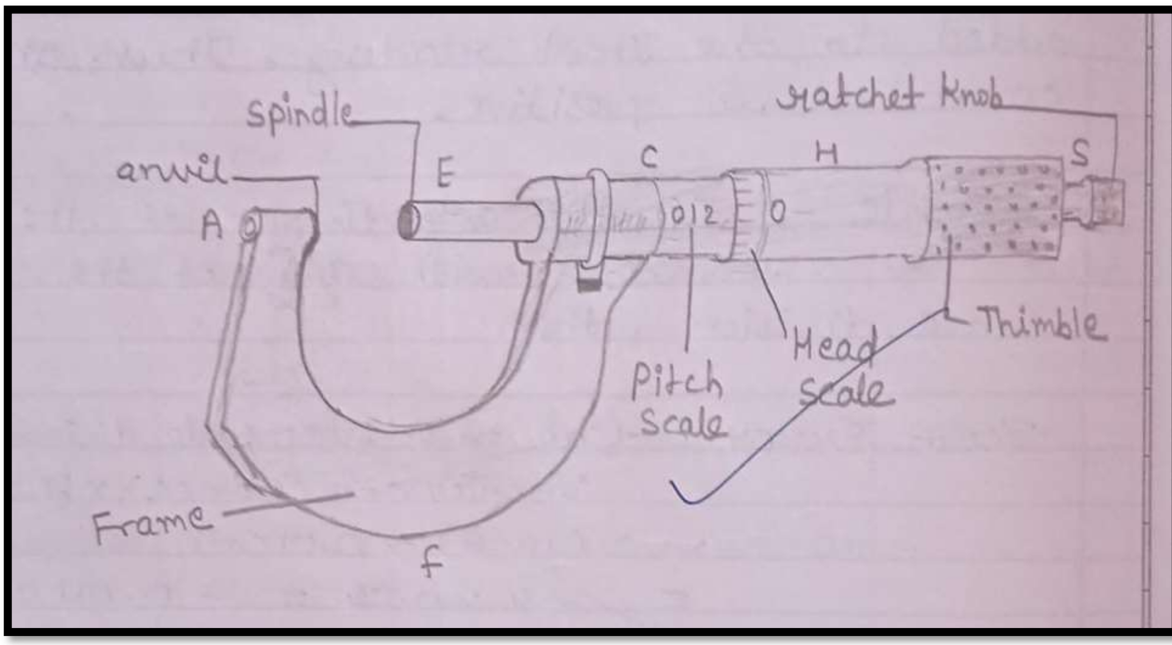


Fig. 1.2. Screw Gauge

B.2. Principle

The linear distance moved by the screw is directly proportional to the rotation given to it. The linear distance moved by the screw when it is rotated by one division of the circular scale, is the least distance that can be measured accurately by the instrument. It is called the least count of the instrument.

B.3. Procedure

1. Take the screw gauge and make sure that the rachet R on the head of the screw functions properly.

2. Rotate the screw through, say, ten complete rotations and observe the distance through which it has receded. This distance is the reading on the linear scale marked by the edge of the circular scale. Then, find the pitch of the screw, i.e., the distance moved by the screw in one complete rotation. If there are n divisions on the circular scale, then distance moved by the screw when it is rotated through one division on the circular scale is called the least count of the screw gauge.

3. Insert the given wire between the screw and the stud of the screw gauge. Move the screw forward by rotating the rachet till the wire is gently gripped between the screw and the stud. Stop rotating the rachet the moment you hear a click sound.

4. Take the readings on the linear scale and the circular scale and obtain the diameter of the wire.

5. The wire may not have an exactly circular cross-section. Therefore. it is necessary to measure the diameter of the wire for two positions at right angles to each other and it is also necessary to measure the diameter at several different places and obtain the average value of diameter as the wire may not be truly cylindrical.

6. Take the mean of the different values of diameter so obtained and subtract zero error, if any, with proper sign to get the corrected value for the diameter of the wire.

B.4. Calculation and observations

(i) Least count of Vernier Calipers (Vernier Constant)

As the number of divisions on main scale are 10 to a centimeter, so the smallest division on main scale will be 1mm and it will be the pitch (p) of the screw gauge. The number of circular divisions is n = 100.

The least count of a screw gauge is L.C. =

$$\frac{pitch}{No.\ of\ divisions\ on\ the\ circular\ scale}$$

= 1mm/100

= 0.01m.m.= (0.01/10) cm= 0.001cm =10^{-3}cm.

OBSERVATION TABLE – 02

The least count of a screw gauge is L.C. = 0.01m.m.= (0.01/10) cm= 0.001cm =10^{-3}cm.

1. Reading along one direction.

S.no	Linear scale reading M (mm)	Circular scale reading (n)	Diameter d1 = M + n × L.C. (mm)

2.Reading along perpendicular direction.

S.no	Linear scale reading M (mm)	Circular scale reading (n)	Diameter d1 = M + n × L.C. (mm)

B.5. Result

The diameter of the given wire as measured by screw gauge is ... mm.

B.6.Precautions

1. Rachet arrangement in screw gauge must be utilised to avoid undue pressure on the wire as this may change the diameter.

2. Move the screw in one direction else the screw may develop “play”.

3. Screw should move freely without friction.

4. Reading should be taken atleast at four different points along the length of the wire.

C.) Travelling Microscope

C.1. Description of the instrument.

It is a compound microscope attached to a graduated vertical pillar, which is mounted on rigid platform (Fig. 1). The platform is provided with three leveling screws. The microscope can be set with its axis either in the vertical or the horizontal position. The microscope can be moved in the vertical or horizontal direction by means of a screw arrangement attached to it. The distance through which the microscope is moved is read on the scale. There are two scales one for horizontal movement and the other for the vertical movement. Each scale has a main scale (M1, M2) and a vernier scale (V1, V2). The vernier moves with the microscope. As in the spectrometer, there is a set of main screw and fine adjustment screw, for the horizontal and the vertical movements. One set is fixed to the pillar for vertical movement and the other set is fixed to the platform for horizontal movement. The eyepiece of the microscope is provided with cross-wires. The image of an object is focused by the microscope using a side screw (focusing screw) attached to the microscope

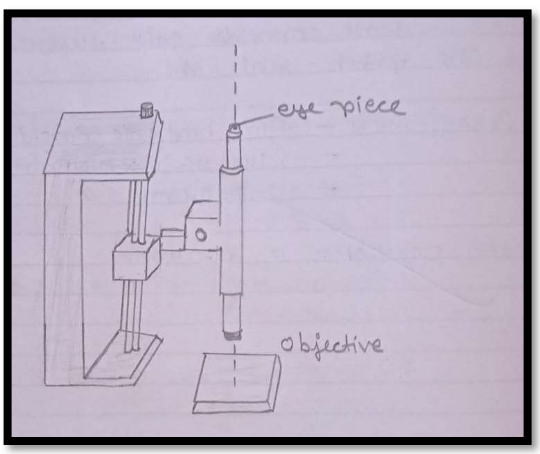


Fig.1.3. Traveling microscope

C.2.Procedure

1. When the microscope is clamped by the main screw or fine adjustment screw at any position, the reading is taken in the vertical scale or in the horizontal scale according to the requirement.

2. The Image of the object can be focused by adjusting the side screw attached to the microscope.

3. The cross wire mark on the eyepiece of microscope must be arranged in such a way that it may come in between the first line.

4.The readings of main and vernier scale must be measured and added and also same steps are repeated for the second line .

5. The Depth is counted by subtracting reading of first line and second line.

C.3. Calculation and observations

1 main scale division (MSD) = 0.05 cm

Number of vernier scale divisions, N = 50

Least count of traveling microscope = 0.05cm /50 = 0.001cm

OBSERVATION TABLE – 03

Least count of traveling microscope = 0.001cm

S.no	Main Scale reading, M (cm)	Number of coinciding vernier division, N	Vernier scale reading, V = N × VC (cm)	Measured diameter, M + V (cm) (For circular object.)
1				
2				
3				
4				

C.4. Result:

The parts and functions of the travelling microscope are studied and a few readings are taken.

EXPERIMENT No 2

Aim : The aim/objective of this experiment is to determine the restoring force per unit extension or spring constant of a spiral spring by statistical method.

Apparatus required: Highly elastic and light spring, meter scale, hanger with a pointer and slotted weights.

Theory: The spring constant of a spring is defined as the force required to produce unit extension or compression in it. It is also known as the force constant or restoring force per unit extension.

Statical method: Consider a highly elastic spring of spring constant 'k' is suspended from a rigid support. The weight 'Mg' due to the load 'M' attached at the lower end of the spring produces an extension 'l' in the spring, which can be measured by the scale. Restoring force exerted by the spring is

$$F = -kl$$

Negative sign shows that the restoring force exerted is in the opposite direction of the elongation. The elongation is directed in the downward direction while the force is exerted in the upward direction.

Formula to be used:

We know that the restoring force exerted by the spring is equal to the weight on the spring due to the load 'M' attached to the lower end of the spring. And these two forces are in equilibrium.

$$F + Mg = 0$$

$$kl = Mg \quad , \qquad [\, F = -kl \,]$$

$$k = Mg/l$$

The spring constant of the spring can also be determined if the extension 'l' for known load 'M' is measured. It can be determined graphically by plotting a graph between the load 'M' along x-axis and the extension 'l' along the y-axis. The graph is a straight line where the slope is l/M.

Now, we get k = g/slope.

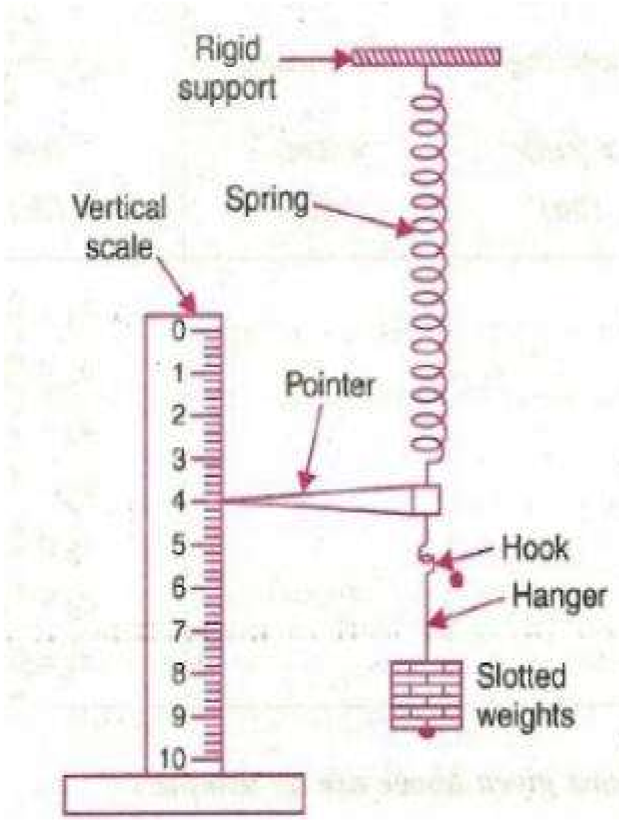


Fig: Experimental Setup

Statical method procedure:

1. Hang the spring vertically from rigid support, the lower end of the spring should have a hanger with a pointer attached to it. Set a meter scale vertically in such a way that it does not touch the spring.
2. With no load on the hanger, note the reading of the pointer.
3. Gently place a load of approximately 10gm in the hanger, note the corresponding reading of the pointer.
4. Gradually increase the loads in steps of approximately 10gm and note down the pointer readings.
5. Now, gradually decrease the loads in steps of approximately 10gm and note down the pointer readings.
6. Find mean extension 'l' for each load.
7. Plot a graph between the load 'M' along the x-axis and the extension 'l' along the y-axis.

Observations:

Pointer reading with no load on the hanger, x_1 = ... cm.

Observation table:

S No.	Load mass 'M' (cm)	Pointer reading, load increasing 'x' (cm)	Pointer reading, load decreasing 'y' (cm)	Average pointer reading (cm) $x' = x + y/2$	Extension (cm) $l = x' - x_1$.
1.					
2.					
3.					
4.					

Precautions and sources of error:

1. The axis of spring should be vertical.
2. The scale should be placed vertically and should not touch the spring.
3. The load placed on the hanger should not be greater than 200gm.

Result:

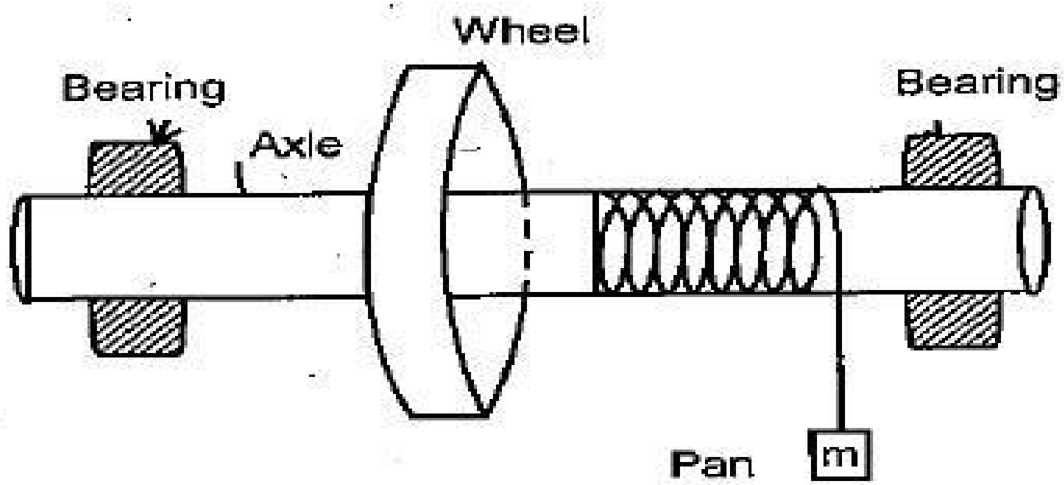
The spring constant of the given spring is ....N/m.

Experiment no. 03

Aim: To determine the moment of inertia of a flywheel.

Apparatus required: The flywheel, slotted weight, strong thread, meter scale, vernier caliper, sand bed, stopwatch.

Theory: Flywheel is a heavy metallic wheel with long axle which when properly supported in wearing may remain in rest in any position. i.e is it Centre of gravity lies on the excess of rotation. Its moment of inertia can be determined experimentally by setting in rotational motion with non amount of energy. The flywheel is mounted with its access horizontal and at a suitable height from ground a string careers suitable mass at its one end and having a length less than the height of the axle from the ground is graft completely and evenly around the axle.



Moment of inertia is defined as the product of mass and radius of gyration (square). it is a tensor of rank 1 having SI unit of KG meters with dimension formula MLs .it depends on mass and its distribution about its axis of rotation. it is a addictive in nature whatever it is the role of mass in linear motion, same in the role of movement of inertia in rotational motion.

In the experiment of flywheel, when mass is released, the string unwind itself does set rotational motion in the wheel. The result mass descends further and the axle of rotation of the wheel goes on increasing till it become maximum then the string leaves the excel and the mass drops off. potential energy of the hanging weight changes into its kinetic energy and this kinetic energy act as a talk for rotation of axis of fly wheel.

Let h be the height followed by the mass before the string leaves the axle and the mass drop of and let v be the linear velocity of the mass and w be the angular velocity of the wheel it instant mass is dropped when mass the sense a distance h. it lose it loses potential energy mgh which is used as follow:

1. Partly and providing kinetic energy of translation mvs/2.

2. Partially in providing kinetic energy of rotation Iws/2 to the fly wheel where I is the moment of inertia of fly wheel about axle.

3. Partially doing work against the friction.

If the work done against the friction is F per rotation and if the number of rotations made by the wheel till the mass detaches itselfis equal to n_1 the work done against the friction is equal to n_1F hands by principal of conservation of energy we have:

$$mgh = mvs/2 + Iws/2 + n_1F \qquad (1)$$

After the mass the detached, the fly wheel continues to rotate for a considerable time t before it come to the rest by the fraction. If it makes and n_2F before it comes to rest then the work done against the friction is n_2F and evidently equal to the kinetic energy of the fly will it the instance mass is dropped off. Thus,

$$n_2F = Iws/2$$

$$F = Iws/2n_2$$

Or substituting the value of F in eq. (1) we get,

$$Mgh = mvs/2 + Iws/2 + (1+n_1/n_2)$$

Or. $I=(2mgh-mvs)/(w(1+n_1/n_2))$ .... (2)

If r is radius of the flywheel, v=rw

$$I=(2mgh-mrsws)/[ws(1+n_1/n_2)]$$

$I= m((2gh/ws)-rs)/(1+n_1/n_2)$ .... (3)

After the mass has detected, its angular velocity decreases on account of friction and after sometime t, the fly wheel come to rest if at the time of detachment of the mass angular velocity of the fly wheel is w which become zero after rest. Hence if the force of friction is steady, the motion of the fly wheel is uniformly retarded and the average angular velocity during this interval is equal to w/2.Thus,

$$w/2= 2\pi n_2/t$$

$$w=4\pi n_2/t$$

Then observing the time t and counting the number of rotations n_1 and n_2 made by the wheel its moment of inertia can be calculated.

Procedure:

I. Take a string of length less than the height from the floor. make a loop it its one and tie a suitable mass at the other end slip on the loop to the small peg projecting on the axle of wheel.

II. Sometimes instead of peg there is a whole on the axel in which a brass pain can be fitted which serve the purpose of peg. To facilitate counting of rotations on the rim of the wheel of a reference mark is made on a rim. opposite to the horizontal pointer fixed to the structure on which the fly wheel is mounted.

III. Let the mass be released. Count the number of rotations n_1 the fly wheel makes before the loop come of the peg and the mass drops off. The number n_1 must be equal to the number of turns of thread around the axle. carefully start the stopwatch at the moment mass is detached and also continues to count the number of rotation n_2 the flywheel make before it comes to rest. stop the stopwatch when thefly will come to rest.

IV. Measure by meter scale the length of the string between the loop and the mark it the other end which gives h. distance descended by the mass. With the help of the vernier caliper measure the diameter of the axel of the flywheel.

V. Repeat the experiment with different mass and string of different length and take at least three sets of reading and in each case for the same value of mass and height, take at least three set of observation, for n_1, n_3 and t. if these values differ slightly for the same values of m and h calculate their mean. Calculate the moment of inertia of the fly wheel for each set of observation separately and then find out the mean value of moment of inertia.

Observation:

Measurements of h, n_1, n_2 and t Least count of Stop watch= ....sec

Table 1: Measurements of h , n_1 , n_2 and t (fixed the value of mass m and vary the height h from the from which mass will be released).

Sn o.	m (gm)	h (cm)	n_1	n_2	t (sec)	I'	I' (Av)

Table 2 :Measurement of h , n_1 , n_2 and time t (fixed the value of height h and vary mass m to be released).

Sn o.	m (gm)	h (cm)	n_1	n_2	t (sec)	I''	I'' (Av)

Table 3 :Measurement of diameter of the axle.

Sno.	Reading along any diameter		Tot a	Reading along any perpendicular diameter		Tot b	(a+b)/2
	Main	Vernier		Main	Vernier		

Calculation:

Mean corrected radius of the axel=.........cm

$$w = 4\pi n_2/t \text{ sec}$$

$I' = m((2gh/ws)-rs)/(1+n_1/n_2)$=.........kg ms

$I'' = m((2gh/ws)-rs)/(1+n_1/n_2)$=.........kg ms

$I = (I'+I'')/2$

Result:

The moment of inertia of the flywheel about its axis of rotation is=……………….Kg ms

Precautions:

1. Ball bearing should be properly lubricated.
2. Axle of the fly wheel should be horizontal.
3. Mass should not be oscillating while it is falling down.
4. Mass should land in the sand bed only.
5. Number of rotations of the wheel should be properly counted.

EXPERIMENT – 4

AIM: To determine rigidity modulus of the material of a wire by using Maxwell's needle (Dynamic method).

APPARATUS REQUIRED: (1) Maxwell needle,

(2) Stop watch,

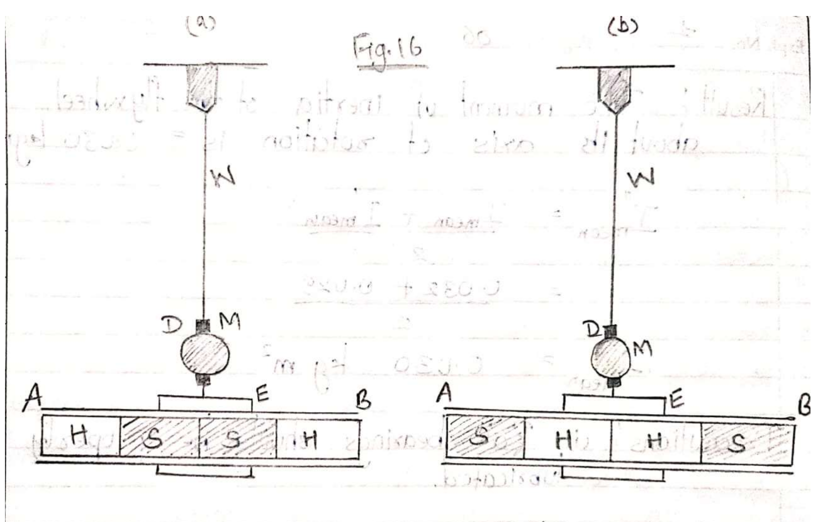
(3) Screw gauge,

(4) Lamp and scale arrangement,

(5) Balance and weight box or telescope,

(6) Clamp with stand.

DESCRIPTION: A Maxwell's needle consists of a brass tube AB (Fig. 16) fitted symmetrically into another short brass tube E to which is attached centrally a stout wire D carrying a small mirror M. The system is suspended by a wire R of the material under test, the upper end of W being rigidly fixed. Two similar hollow (H and H) and two similar solid (S and S) metal cylinders of equal length and diameter can fit into the tube AB and fill it up completely when put end to end. Thus, the length of each piece is 1/4th of AB.



Maxwell Needle

THEORY: The experiment consists in arranging the solid pieces (S, S) in the inner positions and the hollow ones (H, H) in outer positions as shown in Fig. 16(a) and determining the time period T_1 of the torsional oscillations in the usual way.

The next step is to interchange the positions of solid and hollow cylinders as shown in Fig. 16(b) and the time period of torsional oscillation T_2 is determined again.

We have,

$$\eta = \frac{32\pi \, L \, a^2 (M - m)}{r^4 \left(T_2^2 - T_1^2\right)}$$

where, M is the mass of each solid piece

m is the mass of each hollow piece,

a is the length of each piece (*i.e AB*/4)

L is the length of the wire W

and r is the radius of the wire W

PROCEDURE: Suspend the Maxwell's needle from a clamp. If a lamp and scale arrangement is not available, a telescope can be used. Put a chalk mark at the middle and focus the mark by telescope coinciding with vertical cross wire.

Arrange the inner cylinders with solid cylinders in side and hollow cylinders at the ends. Note the time for 20 oscillations. Repeat it three times and calculate mean T_1. Interchange the positions of the cylinders, taking solid ones to the ends and hollow ones to the middle. Note the time for oscillation for 20 oscillations. Repeat it three times and calculate mean T_2.

Measure the mass of each solid cylinder. Calculate its mean, M. Measure the mass of each hollow cylinder. Take its mean, m.

Measure the radius, r of the wire W by screw gauge. Measure the length AB by scale, $1/4^{th}$ of it is a . Measure the length L, of the wire W by a scale.

OBSERVATIONS:

Mass of solid cylinder, $\frac{M_1+M_2}{2}$ = M = ………………gm.

Mass of hollow cylinder $\frac{m_1+m_2}{2}$ = m = ……………..gm.

Length of the wire W, L = …………………………cm.

Radius of the wire W, r = …………………………..cm.

Length of each cylinder, AB/4 = a = …………………..cm.

TABLE – 1

Observation for radius of wire W by screw gauge

Least count of screw gauge (LC) = ………………. cm

S.NO.	MSR (cm)	CSD	CSD×LC	Total (cm) MSR+CSD×LC	Mean (cm)
1.					
2.					
3.					
4.					
5.					

Diameter of wire = ………………………cm.

Radius of wire = $\frac{Diameter}{2}$ = ………………. cm.

TABLE – 2

Calculation of time period

Condition of cylinders	Time for 20 oscillations in sec				Time Period (sec)
	t_1	t_2	t_3	Mean	
Hollow cylinders at the ends					T_1 = ……………………sec
Solid cylinders at the ends					T_2 = …………………… sec

CALCULATION:

$$\eta = \frac{32\pi\, L\, a^2 (M - m)}{r^4\left(T_2^2 - T_1^2\right)}$$

$$\eta = \frac{32 \times 3.14 \times 0.235 \times (0.1125)^2 \times (0.280 - 0.026)}{(10^{-3})^4 \times \left((62.66)^2 - (38)^2 \right)}$$

$$\eta = 3.058 \times 10^7 \text{ N/m}^2$$

RESULT: The modulus of rigidity of wire is 3.058×10^7 N/m^2.

PRECAUTION:

(1) As the fourth power of r enters into calculation, measure it carefully.
(2) Limit the amplitude of oscillation to 4˚. The reference mark should always remain in the field of view of the telescope.

(3) See that there is no linear oscillation and only torsional oscillation is present when time period is noted.
(4) Avoid fan or wind at the place of observation.

Experiment - 5

1: Aim:

To determine Young's modulus, Modulus of rigidity, and Poisson's ratio of the material of given wire by Searl's dynamical method.

2: Apparatus required:

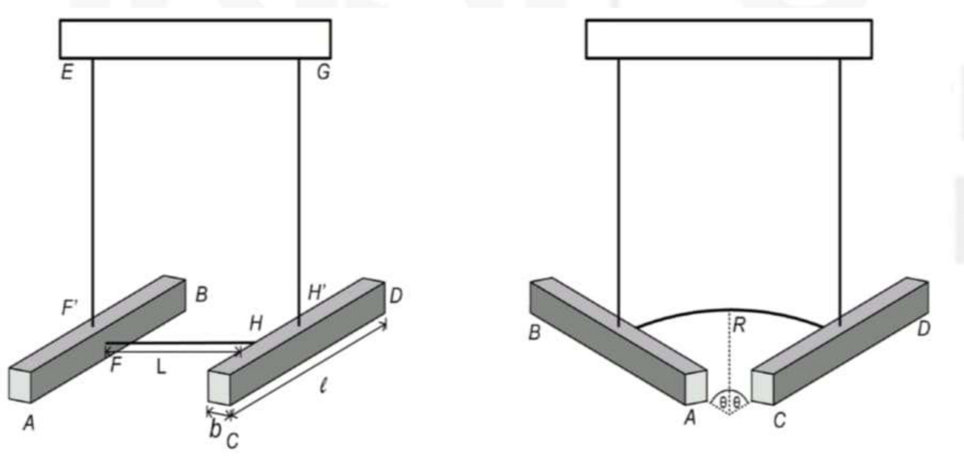
Two identical bars, given wire, stop watch, screw gauge, slide calipers, balance, candle, and the match box.

3: Description of the apparatus:

Two identical rods AB and CD of square cross section connected together at their mid points by the specimen wire are suspended by two silk fibers from a rigid support such that the plane passing through these rods and the wire is horizontal as shown.

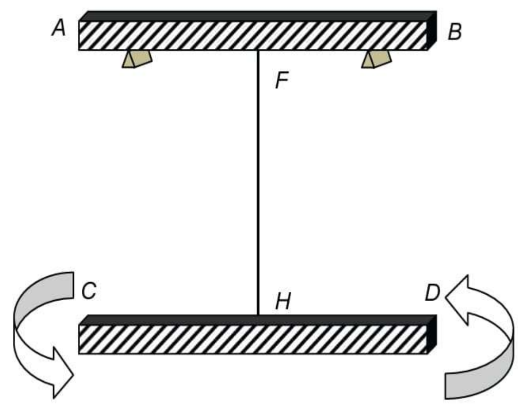
4: Theory:

Young's modulus (Y) is defined as the ratio of linear stress to the linear strain, while Poisson's ratio (σ) represents ratio of the lateral strain to the longitudinal strain. Bulk modulus (K) is known as the ratio of the normal stress to the volume strain. Relation among Y, σ and K is $Y=3K(1-2\sigma)$. Modulus of rigidity (η) is defined as the ratio of shearing stress to the shearing strain. And the relation among η, Y and σ is $Y=2\eta(1+\sigma)$. Two equal inertia bars AB and CD of square section are joined together at their centers by a short and moderately thin wire GG' of the material whose elastic coefficient is to be determined, and the system is suspended by two parallel torsion less threads, so that in the equilibrium position the bars are parallel to each other with plane ABCD horizontal If the two bars be centered through angles in opposite directions and be then set free , the bars will execute flexural vibrations in horizontal plane with same time period about their supporting threads.



(a) (b)

Experiment - 5



(c)

Fig 1 Experimental setup of Searl's Method

When the amplitude of vibration is small, the wire is only slightly bent and distance GG' between the ends of the wire measured along the straight line will never differ perceptibly from the length of the wire so that the distance between the lower ends of the supporting threads remains practically constant and hence the thread remains vertical during the oscillation of the bars, and there is no horizontal component of tension in the thread acting on the wire.

The mass of the wire is negligible as compared with that of wire so that motion of G and G' at right angles to GG' may be neglected. Further, since the horizontal displacement of G and G' are very small compared with the length of the supporting threads, the vertical motion of G and G' may be neglected. The center of gravity of the bars, therefore at rest and hence the section of the wire on either bars and vice Versa is simply a couple which by symmetry must be the vertical axis. The moment of this couple called the "bending moment" is same at every point of the wire and thus the neutral filament if the wire is bent into n circular arc.

If the radius of the arc, Y the Young's modulus for the material of the wire, and l the geometrical moment of inertia of the cross section of the wire about an axis through the centroid of the area and perpendicular to the plane of bending, the bending moment is given the equation $G=YI/p$. If L is the length of the wire and θ be the angle turned through either bar. $p = L/20$ and $G = 2YI\theta/L$; and if $d^2\theta/dt^2$ is the angular acceleration of each bar towards the equilibrium position and K the moment of inertia of the bar about a vertical axis passing

Experiment - 5

through its C.G., the torque due to inertial reaction is K d0/dP. Hence equating the sum of these torques to zero, we get from Newton's third law, the equation

$$K \frac{d^2\theta}{dt^2} + 2YI\theta/L = 0$$

Therefore, assuming the motion of the bars as S.H.M., the time period of the flexural vibrations is given by

$$T_1 = 2\pi\sqrt{\frac{KL}{2YI}}$$

$$Y = \frac{2\pi^2 KL}{T_1^2 I} \qquad \text{.....................} \ (1)$$

Where $I = \frac{1}{4}\pi r^2$ and $K = M\left(\frac{a^2+b^2}{12}\right)$

Where M=Mass of the bar, a = length of the bar, and b= breadth of the bar.

Putting the value of I in equation (1), we have

$$Y = \frac{8\pi KL}{T_1^2 r^4} \qquad \text{....} \ (2)$$

Now the suspensions of the bars are removed and one bar is fixed horizontally on a suitable support, while the other is suspended from given wire. If the wire is twisted through an angle and the bar is allowed to execute torsional oscillations, the time period of oscillations is given by

$$T_2 = 2\pi\sqrt{\frac{K}{C}} \ .$$

where $C = \frac{\eta\pi r^4}{2L}$. and η = modulus of rigidity of the material of wire.

Experiment - 5

$$\eta = \frac{8\pi KL}{T_2^2 r^4} \qquad \ldots\ldots (3),$$

from equation (2) and (3),

$$\frac{T_2^2}{T_1^2}$$

Now, Y=2η(1+σ) where σ = Poisson's ratio. Hence

$$\sigma = \frac{T_2^2}{2T_1^2} - 1$$

5: Observation table:

Table 1

Calculation of time period T_1 for oscillation in horizontal plane .

s.no	Time for 10 oscillations(sec)	Time for 1 oscillation	Average(T_1)

Table 2

Calculation of the time period T_2 for oscillation in vertical plane.

s.no	Time for 10 oscillations(sec)	Time for 1 oscillation	Average(T_2)

Experiment - 5

Table 3

Calculation for the breadth of the given bar

Mass of either rod =

Length of the either bar =

Least count of slide calipers =

Least count of slide calipers =

s.no	Main scale(cm)	Vernier scale(mm)	Total(cm)	Mean(cm)

Table 4

Calculation for the diameter of the given wire

Least count of screw gauge =

Error of the screw gauge =

s.no	Main scale(cm)	Screw gauge(mm)	Total(cm)	Mean(cm)

6: Calculation:

$$I = M\left(\frac{a^2+b^2}{12}\right) \quad \ldots\ldots\ldots KG/$$

$$Y = \frac{8\pi KL}{T_1^2 r^4} \quad \ldots\ldots\ldots\ldots\ N/m^2$$

Experiment - 5

$$\eta = \frac{8\pi K}{T_2^2 r^4} \quad \text{………… N/m}^2$$

$$\sigma = \frac{T_2^2}{2T_1^2} - 1 \quad \text{……………}$$

7: Results:

The values of elastic constants for the material of the wire are

Y=……………N/m^2. With percentage error…………

η =……………… N/m^2. with percentage error……………

σ =……………………With percentage error=…………

8: Precautions:

1. The amplitude of oscillation should be small.

2.Bars should oscillate in a horizontal plane.

3.Two bars should be identical.

4.Length of the two threads should be the same.

5. The radius of wire should be measured very accurately.

Experiment-06

Aim: To determine the value of acceleration due to gravity with Kater's pendulum.

Apparatus Required: Kater's pendulum, a stop watch and a meter rod.

Theory: Kater's pendulum, shown in Fig. 1, is a physical pendulum composed of a metal rod 1.20 m in length, upon which are mounted a sliding metal weight W1, a sliding wooden weight W2, a small sliding metal cylinder w, and two sliding knife edges K1 and K2 that face each other. Each of the sliding objects can be clamped in place on the rod. The pendulum can suspend and set swinging by resting either knife edge on a flat, level surface. The wooden weight W2 is the same size and shape as the metal weight W1. Its function is to provide as near equal air resistance to swinging as possible in either suspension, which happens if W1 and W2, and separately K1 and K2, are constrained to be equidistant from the ends of the metal rod. The centre of mass G can be located by balancing the pendulum on an external knife edge. Due to the difference in mass between the metal and wooden weights W1 and W2, G is not at the centre of the rod, and the distances h1 and h2 from G to the suspension points O1 and O2 at the knife edges K1 and K2 are not equal. Fine adjustments in the position of G, and thus in h1 and h2, can be made by moving the small metal cylinder w.

Formula: The following formula is used for the determination of acceleration due to gravity 'g':

$$g = \frac{8\pi^2}{\frac{T_1^2 + T_2^2}{l_1 + l_2} + \frac{T_1^2 - T_2^2}{l_1 - l_2}}$$

Here, T1: time periods of the oscillating pendulum from knife-edge K1

T2: time periods of the oscillating pendulum from knife-edge K2

l1: distances between knife-edges K1 and CG of the pendulum

l2: distances between knife-edges K2 and CG of the pendulum

When T1 and T2 are very close to each other (difference less than 1 percent), the above expression becomes as:

$$g = \frac{8\pi^2}{\dfrac{T_1^2 + T_2^2}{l_1 + l_2}}$$

Figure

Precedure:

1. Fix the weights as shown in figure. i.e.
   {one end→M→K1→m→w→K2→W→other end)

2. Make sure that the distances from big masses to ends and big masses to knife edges should be symmetrical.
3. Balance the pendulum on a sharp wedge such that the smaller weights are at symmetrical distant from CG. Now mark the position of its center of gravity and measure the distance of the knife-edges K1 and K2 CG. This will give you value of l1 and l2.
4. Suspend the pendulum with the knife-edge K1 and set it to oscillate with small amplitude. Note the times for 15, 20 and 25 oscillations respectively.
5. Now suspend the pendulum with the knife-edge K2 and set it to oscillate with small amplitude. Note the times for 15, 20 and 25 oscillations respectively.
6. The oscillations should be seen with the help of a telescope for accuracy.

Observation:

1. Least count of stop watch=.......sec
2. Distance between K1 and CG (l1)=… .... cm
3. Distance between K2 and CG (l2)=… .... cm
4. Table for time period T1(oscillation about K1):

Sr. No.	*Number of Oscillation n*	*Time of Oscillation t_1(sec)*	*Time Period $T_1=t_1/n$*	*Mean T_1 (sec)*
1.	*15*			
2.	*20*			
3.	*25*			

5. Table for time period T2(oscillation about K2):

Sr. No.	Number of Oscillation (n)	Time of Oscillation T_2(sec)	Time Period $T_2=t_2/n$	Mean T_2(sec)
1.	15			
2.	20			
3.	25			

Calculation: Using equation (1) or (2) {depending on value of T1 and T2} calculate the value of g.

Result: Acceleration due to gravity 'g'=... ...... m/s^2

Standard value of 'g' = ...m/s^2

Percentage error:

$$\frac{\Delta g}{g} \times 100 = \frac{g_{s\tan dard} - g_{measured}}{g} \times 100. = ...\%$$

Precaution:

1. The two knife-edges should be parallel to each other.
2. The amplitude of vibration should be small so that the motion of the pendulum satisfies the condition of simple harmonic motion.
3. To avoid any irregularity of motion the time period should be noted after the pendulum has made a few oscillations.
4. To avoid friction there should be glass surface on rigid support.

Experiment - 7

Aim: To determine coefficient of viscosity of given liquid (glycerine) by using Stokes law.

Introduction: This laboratory investigation involves determining the viscosity of glycerine using Stokes' Law. Viscosity is a fluid property that provides an indication of the resistance to shear within a fluid. Specifically, a fluid column will be used as a viscometer. Time taken by the steel ball to travel a distance in the fluid will be measured using the Intelligent Timer.

Apparatus Required –

I. A jar of glycerine

II. Balls of different radii

III. Screw gauge

IV. Stop watch

V. Meter Scale

Theory:

George Gabriel Stokes, an Irish-born mathematician, worked most of his professional life describing fluid properties. Perhaps his most significant accomplishment was the work describing the motion of a sphere in a viscous fluid. This work lead to the development of Stokes' Law, a mathematical description of the force required to move a sphere through quiescent, viscous fluid at specific velocity.

A body moving in a fluid is acted upon by a frictional force in the opposite direction to its direction of travel. The magnitude of this force depends on the geometry of the body, velocity of the body, and the internal friction of the fluid. A measure for the internal friction is given by the dynamic viscosity η. For a sphere of radius r moving at velocity v in an infinitely extended fluid of dynamic viscosity η, the frictional force according to Stokes' law is given as:

$$F1=6.\pi.\eta.r.v \qquad (1)$$

If the sphere is allowed to fall vertically in the fluid, after a time, it will move at a constant velocity v, and all the forces which are acting on the sphere will be in equilibrium: the

$$F_2 = \frac{4\pi r^3 \rho_1 g}{3} \qquad (2)$$

$$F_3 = \frac{4\pi r^3 \rho_2 g}{3} \qquad (3)$$

Where, ρ_1 is the density of the fluid
ρ_2 is the density of the sphere
g is the acceleration due to gravity

frictional force F1 which acts upwards, the buoyancy force F2 which also acts upwards and the downward acting gravitational force F3, shown in free body diagram. The latter two forces are given by:

And the equilibrium between these three forces can be described by:

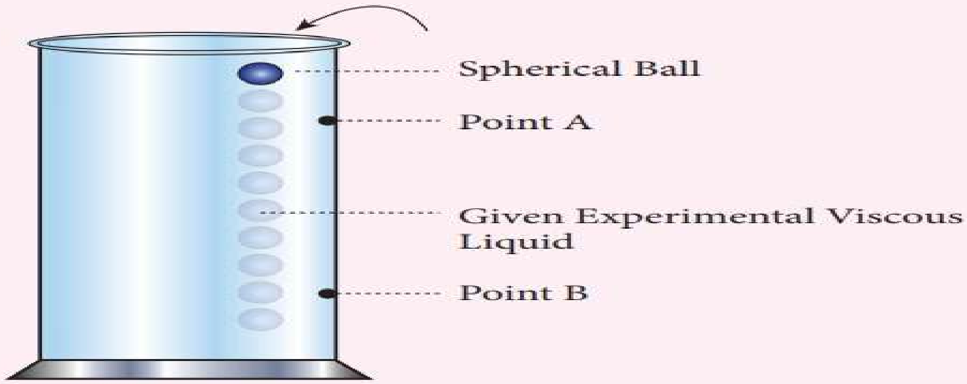
$$F1 + F2 = F3 \qquad (4)$$

The viscosity can, therefore, be determined by measuring the rate of fall v:

$$\eta = \frac{2}{9} \cdot r^2 \cdot \frac{(\rho_2 - \rho_1) \cdot g}{v} \qquad (5)$$

Where, v can be determined by measuring the fall time t over a given distance s. The equation 5 can be written as

$$\eta = \frac{2}{9} \cdot r^2 \cdot \frac{(\rho_2 - \rho_1) \cdot g \cdot t}{s} \qquad (6)$$



EXPERIMENTAL SET UP OF MEASURING VISCOSITY BY STOKE'S METHOD

In practice, equation 1 has to be corrected since the assumption that the fluid extends infinitely in all directions is unrealistic and the velocity distribution of the fluid particles relative to the surface of the sphere is affected by the finite dimensions of the fluid. For a sphere moving along the axis of a cylinder of fluid of radius R, the frictional force is:

$$F_1 = 6\pi\eta v r\left(1+2.4.\frac{r}{R}\right) \quad (7)$$

$$\eta = \frac{2}{9}\cdot r^2\cdot\frac{(\rho_2-\rho_1)\cdot g\cdot t}{s}\cdot\frac{1}{\left(1+2.4.\frac{r}{R}\right)} \quad (8)$$

If the finite length L of the fluid cylinder is taken into account, a further correction of the order r/L is necessary.

$$\eta = \frac{2}{9}\cdot r^2\cdot\frac{(\rho_2-\rho_1)\cdot g\cdot t}{s}\cdot\frac{1}{\left(1+2.4.\frac{r}{R}\right)\quad(1+3.3\,\frac{r}{L})} \quad (9)$$

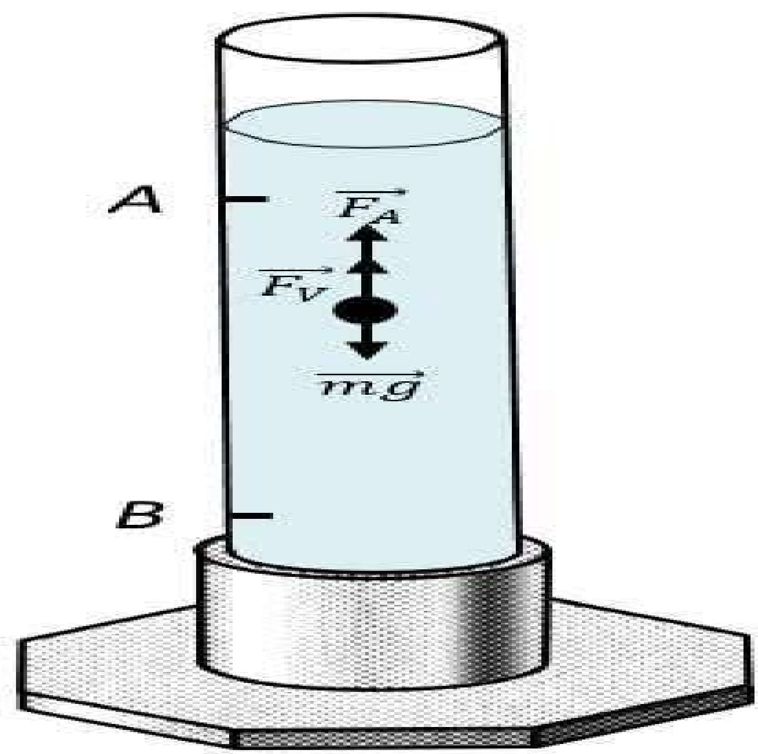
Procedure

Set up

1. Clamp the stand rod on the ‘A’ shaped Base and then clamp the Glass tube using Boss head and Universal finger clamp such that the tube is held vertical. Level the apparatus with the help of levelling screws of the ‘A’ shaped Base.

2. Clamp the Electromagnet assembly on the stand rod using Bosshead such that the core of the electromagnet lies along the axis of the tube.

3. Fill the glass tube with glycerine such that about 2cm of the tube is empty.



4. Connect the electromagnet to the 4mm sockets provided on the Intelligent Timer (Marked as solenoid) using flexible plug leads and switch on the electromagnet.

5. Hold the steel ball with the electromagnet and make a trial to ensure that when the Start Switch is pressed the electromagnet release the ball immediately, if it doesn't then turn the iron core a bit upward.

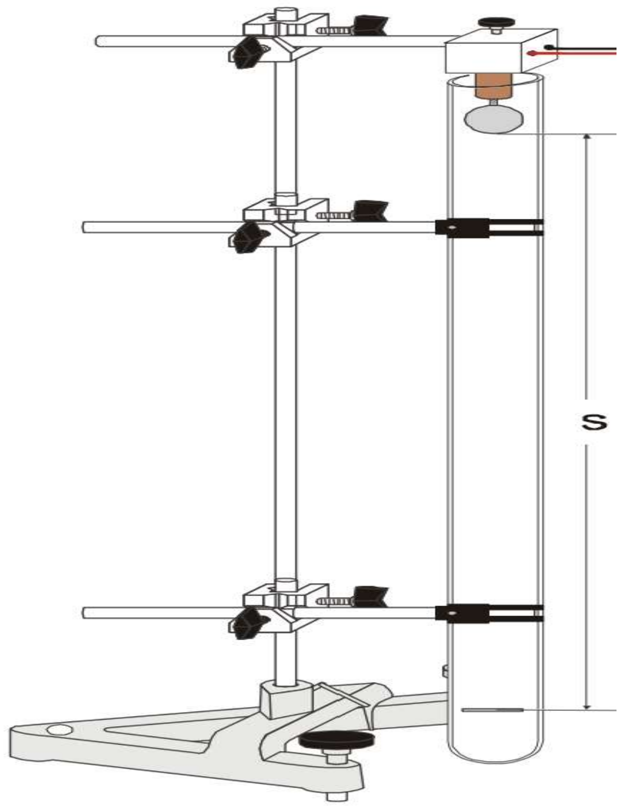


Fig : Experimental Setup

6. Position the holding magnet with the steel ball above the fluid column in a way that the steel ball is on concentres with the cylinder axis and completely dipped in.

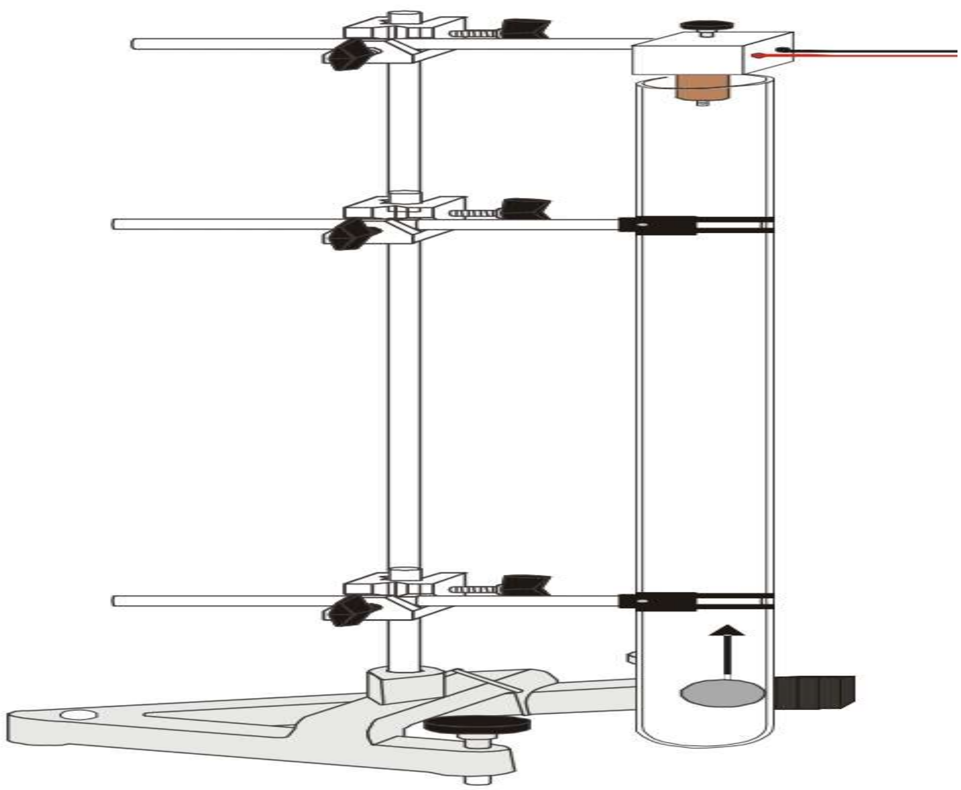
7. Mark the position of the steel ball on the tube itself and from that position, mark another position at 80 cm (say).

8. Press the Start/Stop switch to release the ball and again press the Start/Stop switch when the ball reaches the marked position.

9. Note down the time.

10. Using three ferrite magnet combination return the steel ball to the electromagnet as shown in the adjacent figure.

11. Repeat the experiment several times and take out the mean value to find out the speed and hence, the coefficient of viscosity for glycerine at that temperature.



Observations:

ρ1 = 1260 kgm-3 Density of Glycerine

ρ2 = 7790 kgm-3 Density of Iron Bal

Distance between two marks AB h (cm)	Radius of the ball r (cm)	r^2	Time taken by the ball distance AB t (s)	Terminal velocity of the ball v=h/t (Cm/s)

Calculation -

Result –

The coefficient of viscosity of glycerin is deduced to be ___________ dyne s/cm^2

Precautions-

I) The ball bearing should be small size in order.
II) The ball bearing should be properly wetted in the experiment liquid {glycerine}.
III) The ball should be fall centrally into the experimental liquid.
IV) The radius of the ball must be measured twice and accurately.

Experiment - 8

Experiments Using Compound Pendulum

Two types of compound pendulum-Bar pendulum and Kater's pendulum are used for determination of g in the laboratory. We will discuss them here.

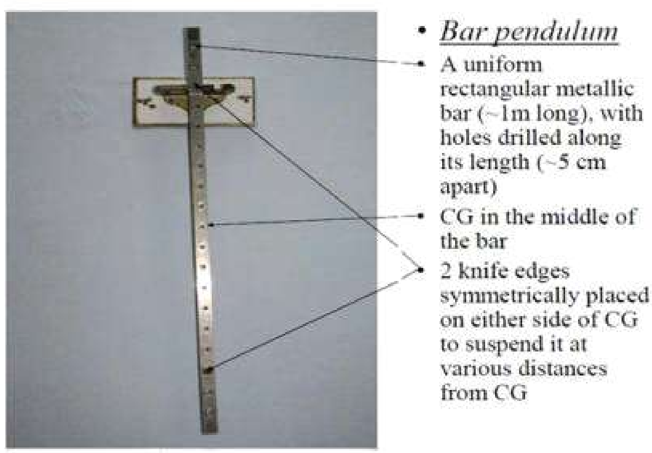
Aim.:-

To determine g using Bar pendulum.

APPARATUS REQUIRED:-

(1) Bar pendulum, (2) Stop watch-1/10th second and wall bracket, (3) Reading Telescope

Description of a bar pendulum. Primarily it is a rectangular metallic rod AB of length 1 metre. Holes are drilled at intervals of 5 cm over its entire length. The straight line joining the center of these holes also pass through the c.g. of the rod. Hence when the rod is sus- pended by putting a knife-edge K through any of the holes, it remains vertical.



A bracket is usually attached to the wall and its plane is kept horizontal. The knife-edge remains over the plane surface of the bracket. Both ends of the rod, A and B, are pointed to facilitate focussing by the telescope. With flat ends two pins may be attached by wax.

Theory. If the distance between the c.g. and centre of oscillation of a bar pendulum is 1, then time period,

$$T=2\pi\sqrt{(k^2+l^2)/lg}$$

OR

$$g=4\pi L/T^2$$

It can be shown that on the same side of the c.g., there are two points of centre of oscillation for the same value of T. Correspondingly, on the other side of the c.g. there are two points of centre of suspension.

As the centre of suspension and centre of oscillation of a pendulum are interchangeable, there shall be four points of ×centre of suspension on one side of c.g. and the farther centre of suspension on the other side of c.g. (which is the centre of oscillation for the former) is called equivalent length, L, of the pendulum and

$$g=4\pi L/T^2$$

Distance of the holes can be measured from one ne end of the bar pendulum and time period about each hole can be experimentally determined. A graph plotted for length versus time period can be used to determine L. Using this value g can be calculated using eqn. (ii)

Procedure. (1) Put the knife-edge in the nearest hole to one end of the bar pendulum and suspend it from the bracket.

(2) If the lower end is not pointed, fix a pin at the end along the length using bee's wax.

(3) Keep a telescope at a distance of atleast 3metres and focus to the pin at the end of the pendulum. See that the pin coincides with the vertical cross-wire of the telescope.

(4) Pull the pendulum slightly to one side and leave. The pendulum will start oscillating. See that the plane of oscillation is vertical. If not, the knife-edge might be loose, tighten it.

(5) View the oscillating pendulum in the telescope. The amplitude of oscillation should be such that the pin does not go beyond the field of view of the telescope ($\theta < 4°$). Note the time for 20 oscillations with the stop watch and calculate the time period.

Repeat these two more times and calculate the average T. Remove the knife- edge and measure the distance from the upper end.

(6) Fix the knife-edge in the next hole and determine the time period as done in step (5). Repeat it for all the holes on the same side of the c.g.

(7) After completing the observations for all holes on one side of the middle (c.g.) turn the pendulum upside down. Le the end B becomes the upper end. Put the knife-edge in the hole nearest to B and determine T us done in step (5). But measure the distance from the end A.

Likewise, measure the time period for all holes on this side of c.g. But in all cases measure the distance from the end A.

Note that it is not necessary to locate the position of c.g. which will be in the middle-hole. So starting from one end, you can measure time period about the hole immediately before the middle-hole, it is not possible to keep the pendulum vertical when the knife-edge is fixed to the middle hole coinciding with g.

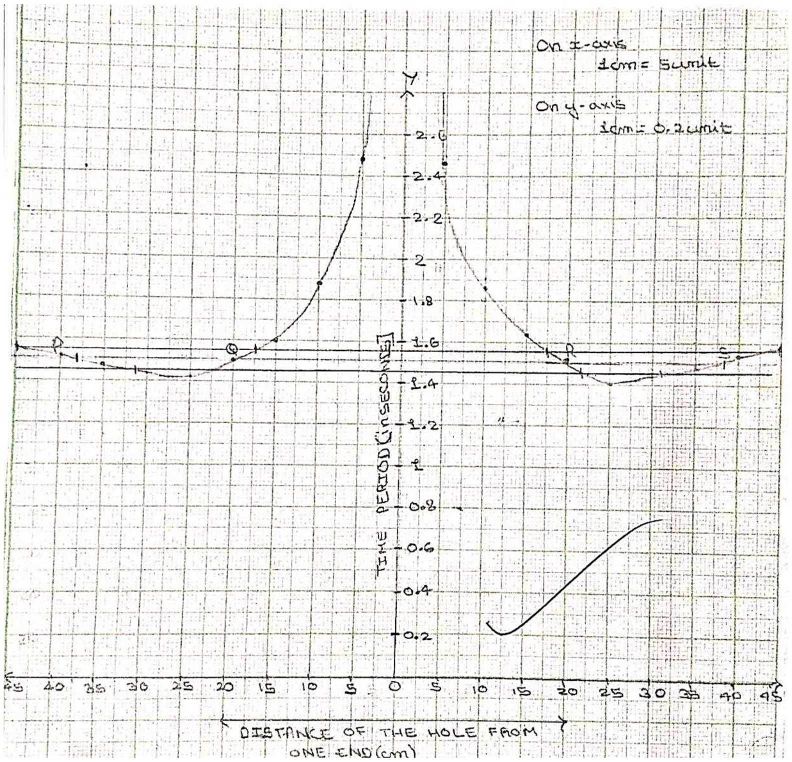
OBSERVATION TABLE (FOR SIDE A) OF BAR PENDULUM

No. of observation	Distance of the hole to Center of gravity(cm)	Time for 20 oscillations in sec.			Time period (sec)
		T1(s)	T2(s)	MEAN(s)	
1.	45				
2.	40				
3.	35				
4.	30				
5.	25				
6.	20				
7.	15				
8.	10				
9.	5				

MAKE SAME OBSERVATION TABLE FOR (SIDE B) OF BAR PENDULUM.

Plotting of graph and calculation. Plot a graph taking the distance of the holes from the end A along the X-axis and corresponding time period along the Y-axis. The nature of the graph is shown the Fig. 4. Draw a line parallel to the X-axis so that it intersects the curve at four points P, Q, R and S. Note the distance PR and QS from the graph.

Equivalent length L = PR + QS The time period T, for this length can be had 2 from the point of intersection of the line on the Y-axis With this value of L and T, calculate g using equation.



It is necessary to determine the value of g at least 3 times. For this purpose, you can should draw three lines parallel to X-axis ,estimate L and T in each case. The value of g is to be calculated separately and the average be taken.

TABLE 2

CALCULATIONS of g

NO. of observations	PR(cm)	QS(cm)	L=PR+QS/2(cm)	T(s)	g cm/s^2	MEAN g cm/s*2
1)						
2)						
3)						

Result. The value of g determined experimentally = Standard value = 981 cm/s^2. cm/s2

% of error = ((g’-g)/g) ×100

Probable errors and precautions.

(1) All equations used in this equation are derived on the assumption of a small amplitude of oscillation (0 < 4°). Hence, amplitude should be small and T should be determined accurately. It is however, observed that with amplitude as large as 30°, no perceptible difference in time for 10 osc. is noticed by using an ordinary stopwatch. May be a more sensitive time recording device is necessary.

(2) The knife-edge should be clamped rigidly.

(3) The wall-bracket used for suspension of the pendulum should be perfectly horizontal.

(4) The pendulum should be fixed away from any fan or near the window so as not to be affected by wind.