Experiment Name: To determine the modulus of rigidity of a wire by the method of oscillations
(dynamic method).

Theory: Within the elastic limit of a body, the ratio of the shearing stress to shearing strain is called rigidity modulus of elasticity. If a heavy body be supported by a vertical wire of length l and radius **r** , so that the axis of the wire passes through its centre of gravity and if the body be turned through an angle and released, it will execute torsional oscillations about a vertical axis. If at any instant the angle of twist be θ, the moment of the torsional couple exerted by the wire will be

$$C = \frac{\eta \pi r^4 \theta}{2l}$$

When $\theta = 1$ radian,

Then, $$C = \frac{\eta \pi r^4}{2l} \quad \ldots\ldots\ldots\ldots\ (1)$$

Where, η is the modulus of rigidity of the material of the wire.
Therefore the motion is simple harmonic and of the fixed period.

$$T = 2\pi\sqrt{\frac{I}{C}}$$

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

$$\text{Or, } C = \frac{4\pi^2 I}{T^2} \quad \ldots\ldots\ldots\ldots\ (2)$$

Where **I** is the moment of inertia of the body .

And $$I = \frac{1}{2} Ma^2$$

Where, **M** = Mass of the cylinder , **a** = radius of the Cylinder.

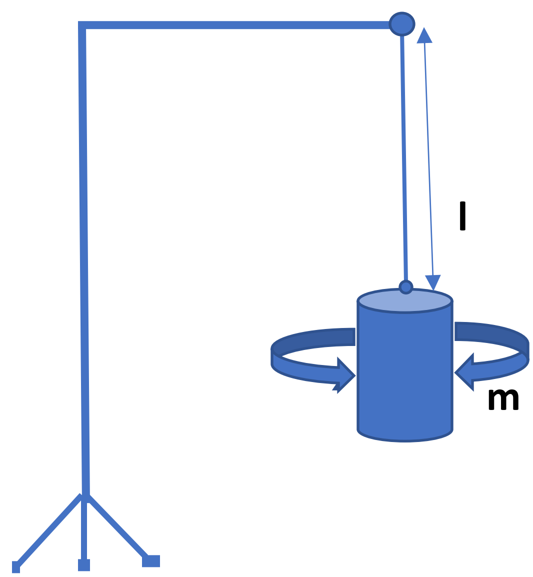
From equation **(1)** and **(2)**, we get

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

Or, $\eta = \frac{4\pi^2 I}{T^2} \times \frac{2l}{\pi r^4}$

Or, $\eta = \frac{8\pi I l}{T^2 r^4}$ **dynes/ sq.cm ....(3)**

Putting the value of **I**, l, **r** and **T** ,we can calculate **η.**



Apparatus :

(i). A uniform wire

(ii). A disc or cylindrical bar

(iii). A suitable clamps

(iv). A stop-watch

(v). A screw gauge

(vi). A slide calipers

(vii). A metre scale

(viii). A balance etc.

Procedure :

(i). We detached the cylinder from the suspension and weigh it with a balance. Also we measured its diameter be means of a pair of slide calipers at three different places. Then we calculated the moment of inertia of the cylinder from its mass **M** and radius **a** using the relation, $I = \frac{1}{2} Ma^2$.

(ii).We measured the diameter of the wire by means of a screw gauge at three different points along the length of the wire , taking two mutually perpendicular readings at each position.
(iii).We suspended the cylinder with the experimental wire from the rigid support so that it rotates about the axis of the wire.

(iv). We measured the length of the wire from the point of support and the point at which the wire is attached to the cylinder with a rod and metre scale.

(v). We put a vertical chalk mark on the surface of the cylinder and when it is at rest , place a pointer facing the vertical line. In reference to this pointer, oscillations are counted. Alternately a telescope is to be focused from a distance on the vertical line on the cylinder so that it may remain coincident (without parallax) with the vertical line of the cross-wire of the telescope.

(vi).We gave a little twist to the cylinder from its position of rest through a certain angle so that it begins to oscillate about its axis of suspension. With the help of a stop-watch, note the time for 20 complete oscillations. When the vertical line on the cylinder is going towards the right, crossing the tip of the pointer or the vertical line of the cross-wire of the telescope, a stop-watch is started. The cylinder will perform one complete oscillation when the line on it crosses the pointer or the vertical line of the cross-wire again in the same direction.

(vii).We repeated the operations three times and from these observations calculate the mean period of oscillation.

Data Collection:

(A). Length of the wire , l = cm

Calculation of the least count.

Pitch (P) = $\frac{\text{The distance moved by plane of the disc along vertical scale}}{\text{Number of full rotations given to the circular scale}}$

$= \frac{1}{1}$ mm

= 1 mm

Number of total divisions in the circular scale, n = 100

Least count (L.C) = $\frac{\text{pitch}}{\text{Number of divisions of circular scale}}$

$= \frac{\mathbf{1}}{\mathbf{100}}$ mm

= 0.01 mm

= 0.001 cm

(B). Reading for the radius of the wire (r)

No. of obs.	**Linear Scale Reading (x) cm**	**Circular Scale Divisions (C.D)**	**Least Count (L.C) cm**	**Diameter d = x +(C.D × L.C) cm**	**Mean Diameter (d) cm**	**Mean Radius r = d/2 cm**
01						
02						
03						

(C). Reading for the radius of the cylinder (a)

No. of obs.	Main Scale Reading (x)	Vernier Scale Division (V.D)	Vernier Constant V.C	Diameter D= x +(V.D×V.C)	Mean Diameter D	Mean Radius a=D/2
	cm		cm	cm	cm	cm
01						
02						
03						

(D). Reading for the time period T:

No. of obs.	Time for 20 Oscillations (t)	Time Period T= (t/20)	Mean Time Period T
	sec	sec	sec
01			
02			
03			
04			
05			

Calculation :

Mass of the cylinder, M = gm.

Moment of inertia of the cylinder , I = $\frac{1}{2}$ M a²

$$= \frac{\qquad\qquad\qquad}{2} \text{ gm-cm}^2.$$

$= \qquad$ gm-cm^2.

From data collection,

$\boldsymbol{l}$ **=** cm, r = cm , T = sec, I = gm-cm^2

So, we get From equation (3)

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

$= \underline{\qquad\qquad\qquad\qquad}$ dynes/ sq.cm

$= \underline{\qquad\qquad}$ dynes/ sq.cm

$= \qquad$ dynes/ sq.cm

Result: The Modulus of rigidity of a wire is= ______________________ dynes/ sq.cm

Precautions & Discussions:

(i) There should be no knot in the wire.

(ii) The amplitude of vibration / oscillation should be small so that wire is not twisted beyond the elastic limit.

(iii) To avoid the backless error, the circular scale of screw gauge should also be measured very carefully.

(iv) The radius of the suspension wire occurs in 4th power and hence it should be measured very carefully.