DEPARTMENT OF PHYSICS
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STATIC TORSION – RIGIDITY MODULUS

Aim

To determine the rigidity modulus of a material in the form of a rod using static torsion apparatus.

Apparatus

The static torsion apparatus, weight hanger with slotted weights (each 100g), a mirror strip, scale and telescope arrangement and a screw gauge.

Static torsion apparatus consists of a stout metal frame with the experimental rod whose rigidity modulus is to be found and is fixed horizontally. The end A is firmly fixed to the frame. The other end B is tightly held by a chuck C at the centre of a wheel. The chuck is attached to the wheel through ball bearing so that it can turn easily to either side - clockwise or anti clockwise by rotating the wheel. To rotate the wheel a metal wire is attached to the groove on the wheel. This wire can be wound on the wheel clockwise or anti clockwise. A weight hanger is suspended from the free end of the metal wire. The angles of twist of the rod at two different distance (say D and E) from the fixed end A of the rod, are measured with the help of pointers used as the accuracy is very low. To measure the angle of twist we fix a small mirror P_1 and P_2 which move on the scales S_1 and S_2. This measurement is not normally in front of the mirror at a convenient distance to view the reflected image of the at the position were twist is to be found out. A scale and a telescope is arranged shifts from position. By noting the shift in the reflected image the angle of twist can graduated scale. When the rod twists the mirror also twists, then the reflected image be calculated.

Theory

If m is the mass attached to the metal wire hanging and R is the radius of the wheel. Then the external torque on the experimental rod fixed to the centre of the wheel is

$$r = mgR \text{ (Torque = force × perpendicular distance)}$$

This torque produces a twist θ in the rod. At equilibrium this external torque will be equal to the restoring torque developed within the rod given by $\frac{\pi n^4 \theta}{2l}$, where n is the rigidity modulus of the material of the rod r is the radius of the rod, L is the length of the rod measured from the fixed end A to the position where twist is found out.

Thus we get $\quad mgR = \frac{\pi n^4 \theta}{2l}$

Or $\quad n = \frac{mgR.2l}{\pi r^4.\theta}$

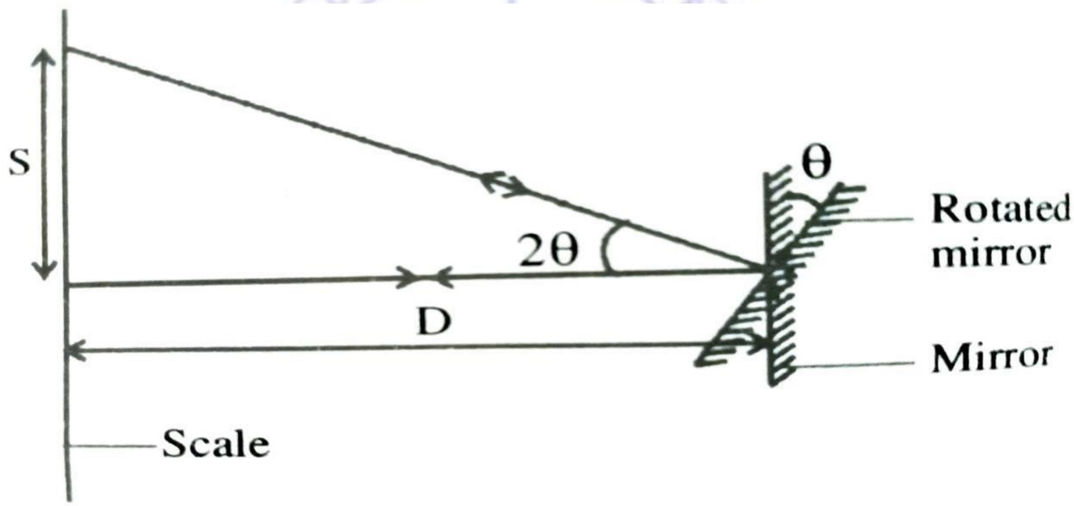
When the rod twists an angle θ, the mirror also twists at the same angle but the reflected image will rotate an angle 2θ. Let S be the shift produced in the reflected image and D be the distance between the mirror and the scale.

Thus we have

$$2\theta = \frac{S}{D} \quad (\text{Angle} = \frac{Arc}{Radius})$$

$$\text{Or} \qquad \theta = \frac{S}{2D}$$

$$\therefore \qquad n = \frac{4mgR}{\pi r^4}(\frac{lD}{S})$$



Procedure

The mirror strip is fixed on the experimental rod at a suitable distance (say 30 cm) / from the fixed end A. Dont fix the mirror strip at a large distance from end A, this may make the reflected image out of the scale. The scale and telescope arrangement is kept at a distance of about one metre from the mirror. The mirror strip is adjusted so that the plane is parallel to the scale and telescope arrangement. The image of the scale reflected from the mirror is viewed through the telescope. For this look at the mirror through just above the telescope to ensure that scale is in the mirror. If not adjust the scale to get it. Then looking through the telescope and adjust the rack and pinion arrangement of the telescope to view clear image.

After this slotted weights are loaded and unloaded a few times to bring the rod in the elastic mood. Then maximum weight is loaded by winding the wire in the clock- wise direction first then in the anti clock wise direction. In both cases ensure that the scale readings are clearly visible through the telescope. If not the scale position is moved up or down to get this. Now all the weights are removed. To start with a dead load (W_0) is suspended on the metallic wire by winding the wire in the clockwise direction. Then the reading corresponding to this is noted through the telescope. The horizontal cross wire coincidence is taken as the reading. This is then repeated by adding weights one by one till maximum weight has been loaded. After this weights are removed from the hanger one by one till dead load is reached. The readings are tabulated and the average reading for each weight is found out. The whole process is repeated for the anti clockwise direction. If the reading corresponding to a particular mass in the clockwise direction is S_1, and that in the anti clockwise direction is S_2, Then $S_2 \sim S_1$, give us the shift correspond to an angle of rotation 2θ of the mirror. From this shift corresponding to θ is $\frac{S_2-S_1}{2}$.

The shift corresponding to a particular load m (say 4m) can be found out. Then shift for 'm' can be calculated. The distance of the mirror strip from the scale is then measured as D. Thus we may find the value of $(\frac{lD}{S})$ which is found to be a constant. The radius of the wheel is found out by measuring its circumference (C) using a twine. From the radius of the wheel $R = \frac{C}{2\pi}$ is calculated .The diameter of the experimental rod is measured by using screw gauge half of this gives the radius r. Knowing all the quantities the rigidity modulus of the material of the rod is evaluated using,

$$n = \frac{4mgR}{\pi r^4}\left(\frac{lD}{S}\right)$$

The experiment may be repeated for different distances l.

Observations and Tabulations

To find $(\frac{lD}{S})$

Length of the rod l in metre	Distance D in metre	Load in wt. hanger in kg.	Tel. Reading clockwise in metre			Tel. Reading Anti clockwise in metre			Mean shift $\frac{S_2 \sim S_1}{2}$	Shift for a load 4 m	Mean shift for a load 4 m	Mean shift for a load m (S)	$\frac{lD}{S}$
			On loading	On unloading	Means S_1	On loading	On unloading	Means S_2					
		W_0							x_0				
		,, + m							x_1				
		,, + 2m							x_2				
		,, + 3m							x_3				
		,, + 4m							x_4	$x_4 - x_0$			
		,, + 5m							x_5	$x_5 - x_1$			
		,, + 6m							x_6	$x_6 - x_2$			
		,, + 7m							x_7	$x_7 - x_3$			

Mean $(\frac{lD}{S})$ = ……….

<u>To find the radius of the wheel</u>

Circumference of the wheel, C = …… cm

Radius of the wheel ,R = $\frac{C}{2\pi}$ =................. cm

= ....m

<u>Screw gauge Observation</u>

Distance moved for 10 rotations x =.......... mm

Pitch of the screw, P = $\frac{x}{10}$ = ...mm

Number of divisions on the head scale, N = ...

Least count = $\frac{P}{N}$ = ...mm

Zero error = $\pm$ ....divisions

Zero correction = $\mp$.............divisions

To find the radius of the rod ‘r’

Trial No.	P.S.R. (mm)	H.S.R.	C.H.S.R.	Total reading = PSR + CHSR × LC	Mean diameter d (mm)
1					
2					
3					
4					
5					

Radius of the rod, r = $\frac{d}{2}$….cm = …. m

Mass m =............ kg

Rigidity modulus n = $\frac{4mgR}{\pi r^4}\left(\frac{lD}{S}\right)$ = …………..

n = ...× 10^{10} Nm^{-2}

Result

The rigidity modulus of the material of the rod

n = … .× $10^{10}Nm^{-2}$

Reference

Experimental Physics – I, For First, Second, Third and Fourth Semester, BSc Degree Programme, Dr.P.Sethumadhavan, Prof. K.C. Abraham, Prof .Sunil John, **Manjusha Publications**