DEPARTMENT OF PHYSICS
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TORSION PENDULUM

A torsion pendulum is a mechanical system consisting of a mass suspended from a thin wire or rod that can twist or rotate about its axis. It is used to study the properties of torsional oscillations, which occur when the wire or rod is twisted and then released.

Aim

To find the rigidity modulus of the material of the given wire by using a torsional pendulum and moment of inertia of the disc about an axis passing through its centre of gravity.

Apparatus

The torsional pendulum, stop watch, meter scale, Vernier calipers, screw gauge and common balance.

Theory

Torsional pendulum consists of a heavy circular disc suspended by means of a thin long uniform wire. The top end of the wire is passed through a chuck c1 and c2 fixed at the centre of the disc. The length of the wire between the two chucks can be varied. When the circular disc is gently and slightly rotated by applying equal and opposite torque, the wire gets twisted. It is due to this twisting, an internal restoring couple due to elastic properties of the material of the wire is produced. When the body is released this restoring couple brings the disc back to the equilibrium position. But due to its kinetic energy of rotation, disc overshoots this position and the wire starts twisting in the opposite direction. A restoring couple is again set up in it arrests its motion and makes it return. The whole process is then repeated. Thus the disc oscillates in the horizontal plane about the wire as the axis. These oscillations are called torsional oscillations.

Suppose the twist at any instant at the lower end of the wire be θ.

Then the restoring couple = - Cθ where C is the twisting couple per unit twist and minus sign shows that couple is directed opposite to the twist.

This produces an angular acceleration in the disc whose moment of inertia is I and the deflecting couple (torque) is given by I $\frac{d^2\theta}{dt^2}$

According to Newtons III law,

Deflecting couple = Restoring couple

$$\text{Thus} \quad I\frac{d^2\theta}{dt^2} = -C\theta$$

$$\text{Or} \quad \frac{d^2\theta}{dt^2} = -\frac{C}{I}\,\theta$$

Since the angular acceleration is directly proportional to its angular displacement and directed towards the equilibrium, its motion is simple harmonic. Comparing the above equation with standard equation of angular S.H.M.

$$\frac{d^2\theta}{dt^2} = -\omega^2\theta$$

We get $\omega^2 = \frac{C}{I}$

So $\omega = \sqrt{\frac{C}{I}}$

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

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

Squaring and rearranging, we get

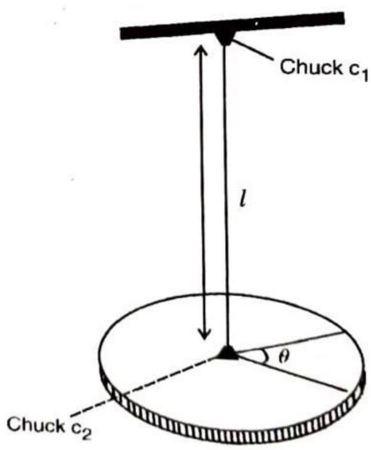
$$C = 4\pi^2 \frac{I}{T^2}$$

Using $C = \frac{\pi n r^4}{2l}$

Where n is the rigidity modulus, r is the radius of the wire and I is the length of the wire.

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

$$\therefore \quad Modulus\ of\ rigidity\ n = \frac{8\pi I}{r^4} \left(\frac{l}{T^2}\right)$$



Observations and Tabulations

Trial No.	Length of the wire (m)	Time for 20 oscillations (s)			Time period $T = \frac{t(s)}{20}$	$\frac{l}{T^2}$ (ms^{-2})
		t_1	t_2	Mean $t = \frac{t_1 + t_2}{2}$		
1	0.3					
2	0.4					
3	0.5					
4	0.6					

Mean = $\frac{l}{T^2}$ =............ ms^{-2}

Procedure

The torsional pendulum is set by clamping the wire (whose rigidity modulus is to be determined) using the chucks and stand at a particular height above the table. It is desirable that the disc may be about 10cm above the plane of the table. The length of the wire between the chucks 'l' is adjusted to have a suitable value say 0.3m by using a metre scale. A line is marked on the disc along its radius using a chalk. The stop watch is kept ready after checking errors like zero error and fly back error.

Now hold the disc with two palms of your hands and twisted to a small angle, either in the clockwise direction or anticlockwise direction, and gently released the disc. Then the disc will execute torsional oscillations. Care must be taken to prevent the oscillation of the string in the vertical plane and vowbling, precessional and mutational motion of the disc.

Using the marked line on the disc, the time taken (t) to make 20 oscillations is noted. From this time period T = $\frac{t}{20}$ is calculated. This is done once again to reduce observational errors. The mean time period is found. Then calculate $\frac{l}{T^2}$ Repeat the experiment at least four times for different values of l, each time calculate T then find The average value of $\frac{l}{T^2}$

is taken for final calculation.

I, the moment of inertia of the disc about an axis passing through its centre and perpendicular to the plane of the disc is given by I = $\frac{MR^2}{2}$ then mass M of the disc can be found out by using a weighing balance, R the radius of the disc can be found out by using Vernier calipers.

The radius of the wire ‘r’ is measured by using a screw gauge.

Knowing $\frac{l}{T^2}$ I and r ,the rigidity modulus of the material of the wire can be calculated using the formula, n = $\frac{8\pi I}{r^4}\left(\frac{l}{T^2}\right)$.

Result

Rigidity modulus of the material of wire ,n =..…$\times 10^{10}$ Nm^{-2}

The moment of inertia of the disc about an axis passing through its centre of gravity = ……….kgm^2

References

- 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**
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