Torsional pendulum

- **Define elasticity.**

  Elasticity is the property of a material by virtue of which they regain their original shape and size after the removal of deforming forces. Such a body is called an **elastic body**.
  Example: Metals.

- **Define plasticity.**

  It is the property of a material by virtue of which they do not regain their original shape and size after the removal of deforming forces. Such a body is called a **plastic body**.
  Example: Wet clay.

- **Define stress.**

  The ratio of deforming force F acting on a body to its area A normal to the force applied.

  $$\text{Stress} = \frac{F}{A}$$

  SI unit: Nm^{-2} or Pa.

- **What is shear stress?**

  It is the tangential force per unit area to change the shape of the body.

- **Define strain.**

  The ratio of change in dimension (length, volume, etc) of a body to its original dimension when force is applied.
  Strain has no units.

- **What is shear strain?**

  Denoted by θ.
  It is the ratio of displacement of the layer to the perpendicular distance from the fixed layer.

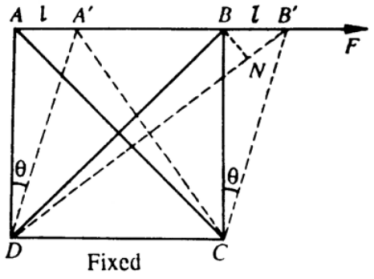

Figure 1: Depicts shear strain when tangential force is applied.

$$\theta = \frac{AA'}{AD}.$$

- **What is elastic limit?**

  The maximum value of stress above which the relationship between stress and strain is non-linear. Within elastic limits stress - strain relationship is linear, i.e., graph of stress versus strain is a straight line.

- **State Hooke's law.**

  Within the elastic limits, stress is proportional to strain.

$$\text{Stress} \propto \text{Strain}.$$

$$\frac{\text{Stress}}{\text{Strain}} = e(\text{constant}).$$

  e is the modulus of elasticity, measured in Nm^{-2}.
  e is material dependent property only.

- **Define rigidity modulus.**

  Denoted by η.
  It is the ratio of shear stress to the shear strain under elastic limit.

$$\eta = \frac{\text{Shear stress}}{\text{Shear strain}}.$$

$$\eta = \frac{F/A}{\theta}.$$

Material	η(GPa)
Aluminium	24
Brass	30-50
Copper	30-50
Steel	80-100

Table 1: Rigidity modulus of some materials (No need to memorize this table).

- **Define moment of inertia.**

  The moment of inertia I is the rotational analog of mass. Mass is the property of an object that causes the object to resist a change in its velocity.
  I of an object about an axis is that property of the object that causes it to resist a change in its angular velocity about that axis. I is sometimes called the rotational inertia.
  Moment of inertia of a rigid body about a fixed axis is also defined as the sum of the product of the masses of all the particles constituting the body and the squares of the respective distances from the axis of rotation.

$$I = \sum_i m_i r_i^2.$$

  SI unit: kgm^2.

Object	Axis of rotation	$I(\text{kgm}^2)$
Rectangular plate	Passing through its center and perpendicular to its plane	$M_1(L^2 + B^2)/12$
Rectangular plate	Passing through its length and parallel to its plane	$M_1L^2/12$
Circular disc	Passing through its center and perpendicular to its plane	$M_2R^2/2$
Circular disc	Passing through its diameter	$M_2R^2/4$

Table 2: Moment of inertia of rectangular plate and circular disc. M_1 and M_2 are masses of rectangular plate and circular disc respectively. L, B are length, breadth of rectangular plate; R radius of circular disc.

- **What is couple?**

  Pair of equal parallel forces that are opposite in direction. The only effect of a couple is to produce or prevent the turning of a body.

- **What is couple per unit twist?**

  Torque due to twisting couple per unit radian of twist.
  Denoted C.
  SI unit: Nmrad^{-1}.

- **What is the principle of torsional pendulum?**

  A torsional pendulum consists of rigid body suspended from a wire, which is then twisted and released, resulting in an oscillatory motion. The oscillatory motion is caused by a restoring torque which is proportional to the angular displacement.
  For small amplitude oscillation, the time period is

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

  I is the moment of inertia of the rigid body about the axis of rotation, C is the couple per unit twist.

- **How is the rigidity modulus determined in the experiment?**

  The rigidity modulus is related to couple per unit twist as

  $$\eta = \frac{2lC}{\pi r^4},$$

  l is length of wire,
  r is radius of wire.
  By knowing the moment of inertia of the rigid body, and measuring the time period of oscillation, we determine C. C is used to calculate the rigidity modulus of the wire after measuring l and r.

- **Why is time measured for 10 oscillations to calculate time period?**

- **What is the purpose of taking more than one trial for measuring time period?**

- **Is the quantity I/T^2 independent of the axis of rotation and the shape of the rigid body?**