PHYSICS

CLASS NOTES FOR CBSE

Chapter 10. Mechanical Properties of Solids

01. Elastic and Plastic Behaviours of Solids

Sometimes, a force acting on a body, instead of producing a change in its state of rest or of uniform motion, produces a change in the shape of the body. Such a force is called ***deforming force***

A rigid body can be noticeably stretched, compressed, bent or twisted by applying a suitable force. That a body can be deformed by a force, can be easily shown by stretching a rubber band or by loading a spring. Delicate measurements indicate that deformations do take place, even when small forces are applied to the rigid bodies.

Elastic Body

A body that returns to its original shape and size on the removal of the deforming force (when deformed within elastic limit), is called an elastic body.

Actually, this concept of an elastic body is an idealisation and no materials behave as perfectly elastic body. Thus, all bodies are elastic ; the difference lies only in degree.

Elasticity

The property of matter by virtue of which it regains its original shape and size, when the deforming forces have been removed is called elasticity.

Contrary to the concept of elasticity in daily life ; in physics, elasticity stands for opposition to change. Qualitatively, more rigid a body, more elastic it is said to be. for this reason, steel is more elastic than rubber.

Plastic body

A body that does not return to its original shape and size on the removal of deforming force, however small the magnitude of deforming force may be, is called a plastic body.

02. Hooke's Law

It is the basic law in elasticity. It states that *the extension produced in a wire is directly proportional to the load attached to it.*

Thus, according to Hooke's law,

$$\text{extension} \propto \text{load}$$

However, this proportionality holds good upto certain limit, called the ***elastic limit.***

Hooke's law can be easily verified by suspending a long metallic wire of uniform area of cross-section from a rigid support and noting the extension (increase in its length) on loading it. The extension is always directly proportional to the load.

In 1807, English physicist Thomas Young pointed out that the load and the extension are more scientifically described in terms of stress and strain respectively. Thus, Hooke's law may be stated that *stress is directly proportional to strain.*

According to the modified form of Hooke's law,

$$\text{stress} \propto \text{strain}$$

or $$\text{stress} = \text{constant} \times \text{strain}$$

or $$\frac{\text{stress}}{\text{strain}} = \text{constant} \qquad \text{...(i)}$$

This constant of proportionality is called ***modulus of elasticity or coefficient of elasticity*** of the material. Its value depends upon the nature of the material of the body and the manner in which the body is deformed. There are three modulii of elasticity namely ***Young's modulus (Y)***, ***bulk modulus (K)*** and ***modulus of rigidity*** (η) corresponding to the three types of the strain.

03. Stress

We known that when a body is deformed, the restoring forces are developed uniformly inside the body.

Stress

It is defined as the restoring force per unit area set up in the body, when deformed by the external force. Thus,

$$\text{stress} = \frac{\text{restoring force}}{\text{area}}$$

As the restoring force set up in the body is equal and opposite to the external deforming force (so long as no permanent deformation is produced *i.e.* within elastic limit), *The stress may be measured as the external force acting per unit area i.e.*

$$\text{stress} = \frac{\text{external force applied}}{\text{area}} = \frac{F}{a}$$

Stress is of the following two types :

(a) ***Normal Stress***

The deforming force acting per unit area normal to the surface of the body is called normal stress. For example, when a wire is pulled by a force, the force acts along the length of the wire and normal to its cross-section. The stress so produced is called the normal stress.

(b) ***Tangential Stress***

The deforming force acting per unit area tangential to the surface is called tangential stress. For example, a body being sheared (when force is applied parallel to the surface of the body) is under the tangential stress.

04. Strain

When a deforming force acts on a body, it undergoes change in its dimensions and the body is said to be deformed or strained.

Strain

The ratio of change in dimension of the body to its original dimension is called strain.

Since a body can have three types of deformations *i.e.* in length, in volume or in shape, likewise there are following three types of strains :

(a) ***Longitudinal Strain***

It is defined as the increase in length per unit original length, when deformed by the external force. It is also called ***linear strain or tensile strain***.

$$\text{Thus, longitudinal strain} = \frac{\text{change in length}}{\text{original length}} = \frac{l}{L},$$

where L is the original length and l, the increase in length.

(b) ***Volumetric Strain***

It is defined as change in volume per unit original volume, when deformed by the external force.

$$\text{Thus, volumetric strain} = \frac{\text{change in length}}{\text{original length}} = \frac{\Delta V}{V},$$

where V is the original volume and ΔV, the change in volume.

(c) **Shear Strain**

When change takes place in the shape of the body, the strain is called the shear strain. *It is defined as the angle θ (in radian), through which a line originally perpendicular to the fixed face gets turned on applying tangential deforming force.*

The angle, through which the reference line turns, is called the ***angle of shear***.

When force is applied parallel to the surface of a solid body, then the change takes place only in the shape of the body. The body remains in equilibrium as there is no net force or net torque acting on the body. Such a shear is called ***pure shear***. It can happen only in case of a solid. If a force is applied parallel to the surface of a fluid, it will begin to flow in the direction of applied force.

05. Young's Modulus (Stretching of a wire)

It is defined as the ratio of normal stress to the longitudinal strain. It is denoted by Y. Thus, in accordance with the equation (i),

$$Y = \frac{\text{normal stress}}{\text{longitudinal strain}} \qquad \text{...(ii)}$$

Consider a wire (or a rod) of length L and area of cross-section a fixed at one end [shown in fig. below]. Suppose that a normal force F is applied to the free end to the wire and its length increases by l. Then,