SHORT ANSWER QUESTIONS

Q.1. What is deforming force ?

Ans. If a force applied on a body changes the configuration of the body in length, volume or shape, then the force is called a deforming force.

Q.2. What is plasticity ?

Ans. The property of materials by virtue of which they offer resistance to the tendency of regaining their orginal configuration after the removal of the deforming force is called plasticity.

Q.3. What is elastic fatigue ?

Ans. The property by virtue of which a substance exhibits delay in regaining its original configuration for a longer time is called elastic fatigue.

Q.4. What is elastic potential energy ?

Ans. When a body is deformed, some work is done against the internal restoring forces acting between the particles of the body. This work done appears as elastic potential energy in the body.

Q.5. Why is a spring made of steel and not of copper ?

Ans. A spring will be a better one as a large restoring force is set up in it on deformation. This depends on the elasticity of the material. Since Young's modulus of steel is more than that of copper, so steel is preferred in making springs.

Q.6. Why are the bridges declared unsafe after long time ?

Ans. A bridge undergoes alternating strains for a large number of times during its use. When a bridge is used for a long time, it loses its elastic strength. As a result, the amount of strain in a bridge will become more for a given stress and the bridge may collapse. So the bridges are declared unsafe after long use.

Q.7. A wire is broken into two parts. How will Young's modulus of elasticity be affected ?

Ans. As Young's modulus of a material is constant, so it will remain constant.

Q.8. Which is more elastic, steel or rubber ?

Ans. The substance which has greater modulus of elasticity is more elastic. When equal forces are applied to equal lengths of steel and rubber wires of same cross-section, extension of steel is less. Hence modulus of elasticity of steel is more than that of rubber. Therefore, steel is more elastic than rubber.

Q.9. What is breaking stress ?

Ans. Breaking load per unit area of cross-section is called breaking stress.

$$\text{Breaking stress} = \frac{\text{Breaking load}}{\text{Area of cross-section}}.$$

Q.10. Why can a wire of greater diameter support more weight ?

$$\text{Breaking stress} = \frac{\text{Breaking load}}{\text{Area of cross-section}}$$

$$\therefore \quad \text{Breaking load} = \text{Breaking stress} \times \text{Area of cross-section.}$$

As breaking stress of a particular material is constant, so greater area of cross-section can support greater weight.

Q.11. Stress and pressure are both forces per unit area. Then in what respect does stress differ from pressure ?

Ans. Pressure is the external force per unit area while stress is the internal force within a strained body acting normally per unit area of the body.

Q.12. Is elastic limit a property of the material of the wire ?

Ans. No, It depends on the radius of the wire also.

Q.13. Among solids, liquids and gases, which one can have all the moduli of elasticity ?

Ans. Only solids. Liquids and gases have only bulk modulus of elasticity.

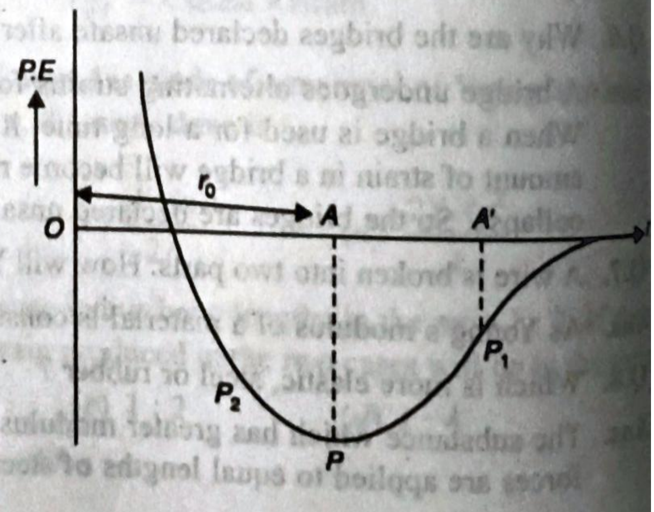
Q.14. Are elastic forces always conservative ?

Ans. Elastic forces are not always conservative. Elastic forces are conservative so long as the loading and unloading are coincident, even if the curves are not linear.

LONG ANSWER TYPE QUESTIONS

Q.1. What is elasticity ? Explain the elastic property of matter on the basis of molecular forces.

Ans. ***Elasticity*** : The property of a material body by virtue of which it tends to regain its original size or shape after the removal of deforming force is called elasticity.



Reason of elasticity : The presence of intermolecular forces accounts for the potential energy of the molecules as shown in the figure. When the distance between two molecules is $OA = r_0$, the molecule at A possesses minimum potential energy. If the body is stretched *i.e.* the distance between molecules increases, the point P shifts to P_1. Similarly when the body is compressed, the point P shifts to P_2. In both cases, potential energy is more than the minimum value. As every system tends to have minimum potential energy, so the molecule at states P_1 and P_2 tends to come back at P. This gives rise to the property of elasticity.

2. Define the terms stress, strain, elastic limit.

s. ***Stress*** **:** When a deforming force is applied on a body, internal restoring force comes into play which tends to bring the body back to its original configurations. This internal restoring force developed per unit area is called stress. If F is the restoring force acting on area A, then

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

The unit of stress in C.G.S system is dyne/cm^2 and in S.I. system is Nm^{-2}. The dimensional formula of stess is $[M^1L^{-1}T^{-2}]$.

Strain **:** When a deforming force is applied on a body, there is change in the configuration of the body. This change in configuration per unit original configuration is called strain.

Elastic limit **:** The limit upto which a body remains elastic is called elastic limit. It is measured by that value of the load which gives maximum recoverable extension.

Q.3. What are different kinds of strains ?

Ans. Depending upon the deformation, there are different types of strains.

(*i*) ***Longitudinal or Tensile srain*** **:** When the deformation is in length, the strain is called longitudinal or Tensile strain

It is defined as,

$$\text{longitudinal strain} = \frac{\text{Charge in length}}{\text{Original length}}$$

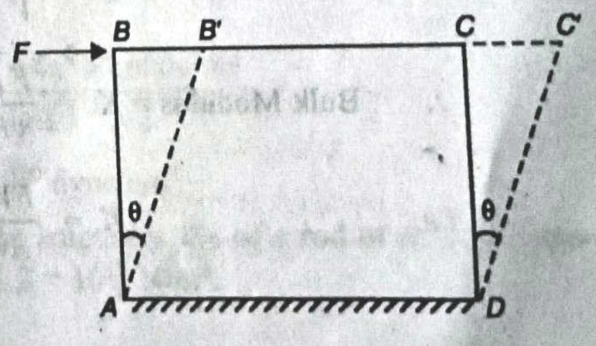
(*ii*) ***Volume strain*** **:** When the deformation is in volume, the strain produced is called valume strain.

It is defined as

$$\text{Volume strain} = \frac{\text{Charge in volume}}{\text{Original volume}}$$

(*iii*) ***Shearing strain*** **:** When the deformation is in shape only, the strain produced is called shearing strain.

It is defined as the angle in radian through which a plane perpendicular to a fixed surface gets turned.



In the figure, AD is a fixed surface and a force F is applied tangentially along the face BC. The plane AB is rotated through an angle θ to AB'. Then

$$\text{Shearing strain} = \theta = \tan\theta = \frac{BB'}{AB}$$

Q.4. State Hooke's law. Hence define different types of modulii of elasticity. What is poison's ratio ?

Ans. ***Hooke's law*** : The law states that, within elastic limit, stress is proportional to strain, *i.e.*

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

$$\therefore \quad \frac{\text{Stress}}{\text{Strain}} = \text{Constant}$$

This constant is called modulus of elasticity.

Depending on the different types of strains, there are three types of modulus of elasticity.

(*i*) ***Young's modulus*** : It is defined as the ratio of longitudinal stress and longitudinal strain.

Let us consider a wire of length L and area of cross-section A. If the wire is elongated by l due to the application of a force F, then

$$\text{Longitudinal stress} = \frac{F}{A}$$

$$\text{Longitudinal strain} = \frac{l}{L}$$

$$\therefore \quad \text{Young's modulus} = Y = \frac{F/A}{l/L} = \frac{FL}{Al}$$

The unit of Young's modulus in c.g.s. system is to dyne/cm^2 and in S.I system is Nm^{-2}.

Bulk modulus : It is defined as the ratio of volume stress and volume strain.

Let us consider a sphere of volume V surface area A. If a compressive force F decreases the volume by v, then,

$$\text{Volume stress} = \frac{F}{A}$$

$$\text{Volume strain} = \frac{v}{V}$$

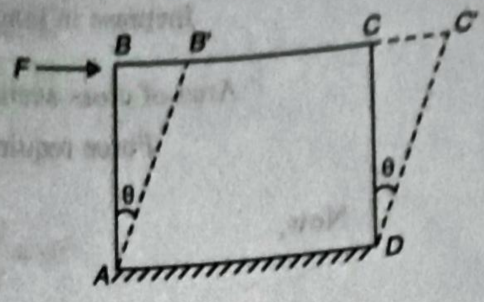
$$\therefore \quad \text{Bulk Modulus} = K = \frac{F/A}{v/V}$$

$$\textit{i.e.} \quad K = \frac{FV}{Av}$$

***Rigidity modulus* : It is defined as the ratio of shearing stress and shearing strain.**

Let the plane AB of a cube $ABCD$ be turned through an angle θ due to the action of a tangential force F on the face BC.

Then



$$\text{shearing stress} = \frac{F}{A}$$

$$\text{shearing strain} = \theta$$

$$\therefore \quad \text{Modulus of rigidity} = \eta = \frac{F/A}{\theta} = \frac{F}{A\theta}$$

***Poisson's ratio* : It is defined as the ratio of lateral strain and longitudinal strain.** If β is the lateral strain and α is the longitudinal strain, the

$$\text{Poisson's ratio} = \sigma = \frac{\beta}{\alpha}$$

NUMERICAL PROBLEMS

Q.1. A mass of 100 gram is attached to the end of a rubber string 49 cm long and having an area of cross-section 20 sq. mm. The string is whirled round horizontally at a constant speed of 40 r.p.s. in a circle of radius 51 cm. Find the Young's modulus of rubber.

Ans. Here,

$$\text{Mass} = m = 100 \text{ g}$$

$$\text{Area of cross-section} = A = 20 \text{ sq. mm} = 20 \times 10^{-2} \text{ sq. cm.}$$

$$\text{Original length} = L = 49 \text{ cm.}$$

$$\text{Increase in length} = l = (51 - 49) = 2 \text{ cm}$$

$$\text{Angular velocity, } w = 40 \text{ r.p.s.}$$

$$= 40 \times 2\pi \text{ radian/sec}$$

Let $\quad$ Young's modulus $= Y = ?$

Here, Restoring force is equal to the centripetal force *i.e.*

$$F = m\,r\,w^2 = 100 \times 51 \times (2\pi \times 40)^2$$

Now,

$$Y = \frac{FL}{Al}$$

$$= \frac{100 \times 51 \times 4\pi^2 \times 1600 \times 49}{20 \times 10^{-2} \times 2}$$

$$= 3.95 \times 10^{10} \text{ dyne/cm}^2$$

Q.2. Calculate the force required to increase the length by 1% of a rod of area of cross-section 10^{-3} m^2. Modulus of elasticity is 1.2×10^{12} N/m^2.

Ans. Let Original length of the rod $= L$

$$\text{Increase in length} = l = \frac{1}{100} \times L$$

$$\text{Area of cross-section} = A = 10^{-3}\ m^2$$

$$\text{Force required} = F$$

Now, $$F = \frac{Y A l}{L}$$

$$= \frac{1.2 \times 10^{12} \times 10^{-3} \times L}{100 \times 2}$$

$$= 1.2 \times 10^7\ N.$$

Q.3. A stress of 1 Kg/sq. mm is applied to a wire of Young's modulus 10^{11} N/m². Find percentage increase in length.

Ans. Let Original length $= L$

Increase in length $= l$

$$\text{Strain} = \frac{l}{L}$$

$$\text{Stress} = 1\ \text{Kg/sq. mm}$$

$$= 9.8 \times 10^6\ N/m^2$$

$$Y = 10^{11}\ N/m^2$$

Now, $$Y = \frac{\text{Stress}}{\text{Strain}}$$

$$\Rightarrow \quad \text{Strain} = \frac{\text{Stress}}{Y}$$

$$\Rightarrow \quad \frac{l}{L} = \frac{9.8 \times 10^6}{10^{11}} = 9.8 \times 10^{-5}$$

$\therefore$ percentage increase in length $= \frac{l}{L} \times 100\%$

$$= 9.8 \times 10^{-5} \times 100\%$$

$$= 0.0098\%$$

Q.4. Find the greatest length of a wire that can hang vertically without breaking. Giv[en] breaking stress of steel to be 7.9×10^9 dyne/cm² and density of steel is 7.9 g cm⁻³

Ans. Let Length of the wire $= L = ?$

Area of cross-section $= A$

density of wire $= \rho = 7.9\ g\ cm^{-3}$

weight of the wire = $A L \rho g$ dyne

Now, breaking stress = $\dfrac{\text{Weight of the wire}}{\text{Area of cross-section}}$

$$\Rightarrow \quad 7.9 \times 10^9 = \frac{AL \times 7.9 \times 980}{A}$$

$$\Rightarrow \quad L = \frac{7.9 \times 10^9}{7.9 \times 980} = \frac{1000}{980} \times 10^6$$

$$\therefore \quad L = 1.02 \times 10^6 \text{ cm.}$$

Q.5. If the normal density of sea water is 1 g cm^{-3}, what will be its density at a depth of 3 Km ? Given compressibility of water = 0.000048 per atmosphere.
1 atmosphere = 1.01×10^6 dyne/cm^2

Ans. Let us consider a mass of m gram of volume V. Then

normal density = $\rho = \dfrac{m}{V}$

Now bulk modulus of water

$$= K = \frac{1}{\text{Compressibility}}$$

$$\Rightarrow \quad K = \frac{1}{0.000048/1.01 \times 10^6}$$

$$= \frac{1.01 \times 10^6}{0.000048}$$

$$= \frac{1.01}{48} \times 10^{12} \text{ dynes/cm}^2$$

Pressure at a depth of 3 Km = P

$$P = h \rho g = 3 \times 10^5 \times 1 \times 980 \text{ dynes/cm}^2$$

Let decrease of volume = v

Now, $K = \dfrac{PV}{v}$

$$\Rightarrow \quad v = \frac{PV}{K} = \frac{3 \times 10^5 \times 980 \times V \times 48}{1.01 \times 10^{12}}$$

$$= \frac{3 \times 98 \times 48 \times V}{1.01} \times 10^{-6}$$

$$= 0.013 \text{ V}$$

Volume of water at a depth of 3 Km

$$= V_1 = V - v$$
$$= V - 0.013\text{ V}$$
$$V_1 = 0.987\text{ V}.$$

As mass remains the same, so density at the depth is,

$$\rho_1 = \frac{m}{V_1}$$

Now,
$$\frac{\rho_1}{\rho} = \frac{m}{V_1} \times \frac{V}{m}$$

$$\Rightarrow \quad \frac{\rho_1}{1} = \frac{V}{V_1} = \frac{V}{0.987\text{ V}} = 1.013$$

$$\therefore \quad \rho_1 = 1.013 \text{ g cm}^{-3}.$$

Q.6. Two exactly similar wires, one of steel and other of copper are stretched by equal forces. If the total elongation is 2 cm, find how much each wire is elongated. Young's modulus of steel is 2×10^{12} dyne/cm^2 and that for copper is 12×10^{11} dyne/cm^2.

Ans. Let length of each wire $= L$

Area of cross-section of each wire $= A$

Stretching force on each wire $= F$

Elongation of steel wire $= l_1$

Elongation of copper wire $= l_2$

Young's modulus of steel $= Y_1 = 2 \times 10^{12}$ dyne/cm^2

Young's modulus of copper $= Y_2 = 12 \times 10^{11}$ dyne/cm^2

Now,
$$Y_1 = \frac{FL}{Al_1}, \quad Y_2 = \frac{FL}{Al_2}$$

$$\Rightarrow \quad \frac{Y_1}{Y_2} = \frac{l_2}{l_1}$$

$$\Rightarrow \quad \frac{l_1}{l_2} = \frac{Y_2}{Y_1} = \frac{12 \times 10^{11}}{2 \times 10^{12}} = \frac{12}{20} = \frac{3}{5}$$

$$\Rightarrow \quad \frac{l_1}{l_1 + l_2} = \frac{3}{3+5} \qquad [l_1 + l_2 = 2 \text{ cm}]$$

$$\Rightarrow \quad \frac{l_1}{2} = \frac{3}{8} \quad \therefore \quad l_1 = \frac{3}{4} \text{ cm}.$$

Hence, $l_2 = 2 - \frac{3}{4} = \frac{5}{4}$ cm.

Q.7. A lift is tied with thick iron wires and its mass is 1000 Kg. If the maximum acceleration of the lift is 1.2 ms^{-2} and the maximum safe stress is 1.4×10^8 N/m^2, find the minimum diameter of the wire.

Ans. Tension in the wire = F

$$F = m(g + a)$$
$$= 1000\,(9.8 \times 1.2)$$
$$= 11000 \text{ N}$$

Let D be the minimum diameter of the wire.

Area of cross-section $= \dfrac{\pi D^2}{4}$

Now, stress $= \dfrac{F}{A}$

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

$$\Rightarrow \quad \frac{\pi D^2}{4} = \frac{11000}{1.4\times10^8}$$

$$\Rightarrow \quad D^2 = \frac{4\times11000}{1.4\times10^8}\times4 = \frac{4\times11\times7}{14\times22}\times10^{-4}$$

$$\Rightarrow \quad D^2 = 10^{-4} \quad \therefore \quad D = 10^{-2}\text{ m} = 0.01 \text{ m}.$$

Q.8. A steel wire of length 4 m is stretched through 2 mm. The area of cross-section of the wire is 2 mm^2. If Young's modulus of steel is 2×10^{11} Nm^{-2}, find

(*i*) the energy density of the wire and

(*ii*) elastic potential energy stored in the wire.

Ans. (*i*) Energy density $= u = \dfrac{1}{2}\times\text{stress}\times\text{strain}$

$$\Rightarrow \quad u = \frac{1}{2}\times Y\times(\text{Strain})^2$$
$$= \frac{1}{2}\times Y\times\left(\frac{l}{L}\right)^2$$
$$= \frac{1}{2}\times2\times10^{11}\times\left(\frac{2\times10^{-3}}{4}\right)^2$$

$$\therefore \quad u = 2.5 \times 10^4 \text{ Jm}^{-3}.$$

(*ii*) Elastic potential energy = U

$$U = \text{energy density} \times \text{volume}$$
$$= u\,AL$$
$$= 2.5 \times 10^4 \times 2 \times 10^{-6} \times 4$$

$$\therefore \quad U = 0.2 \text{ J}.$$