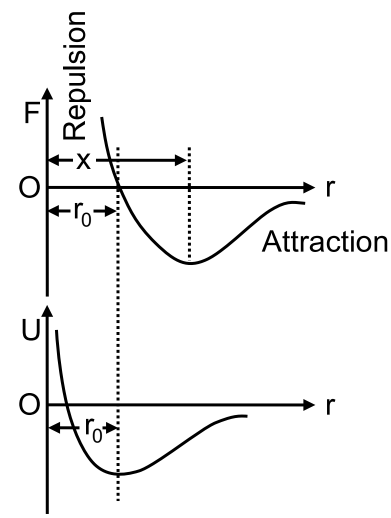
Elasticity

1. Interatomic Forces

The forces between the atoms due to electrostatic interaction between the charges of the atoms are called interatomic forces. These forces are electrical in nature and these are active if the distance between the two atoms is of the order of atomic size i.e. 10^{-10} metre.



(1) Every atom is electrically neutral, the number of electrons (negative charge) orbiting around the nucleus is equal to the number of proton (positive charge) in the nucleus. So if two atoms are placed at a very large distance from each other then there will be a very small (negligible) interatomic force working between them.

(2) When these two atoms are brought close to each other to a distance of the order of 10^{-10} m, the distances between their positive nuclei and negative electron clouds get disturbed, and due to this, attractive interatomic force is produced between two atoms.

(3) This attractive force increases continuously with decrease in r and becomes maximum for one value of r called critical distance, represented by x (as shown in the figure). Beyond this the attractive force starts decreasing rapidly with further decrease in the value of r.

(4) When the distance between the two atoms becomes r_0, the interatomic force will be zero. This distance r_0 is called normal or equilibrium distance. (r_0 = 0.74 Å for hydrogen).

(5) When the distance between the two atoms further decreased, the interatomic force becomes repulsive in nature and increases very rapidly with decrease in distance between two atoms.

(6) The potential energy U is related with the interatomic force F by the following relation.

(i) When two atoms are at very large distance, the potential energy is negative and becomes more negative as r is decreased.

(ii) When the distance between the two atoms becomes r_0, the potential energy of the system of two atoms becomes minimum (i.e. attains maximum negative value). As the state of minimum potential energy is the state of equilibrium, hence the two atoms at separation r_0 will be in a state of equilibrium.

($U_0 = -7.2 \times 10^{-19}$ Joule for hydrogen).

(iii) When the distance between the two atoms is further decreased (i.e. $r < r_0$) the negative value of potential energy of the system starts decreasing. It becomes zero and then attains positive value with further decrease in r (as shown in the figure).

2. Elastic Property of Matter

(1) Elasticity : The property of matter by virtue of which a body tends to regain its original shape and size after the removal of deforming force is called elasticity.

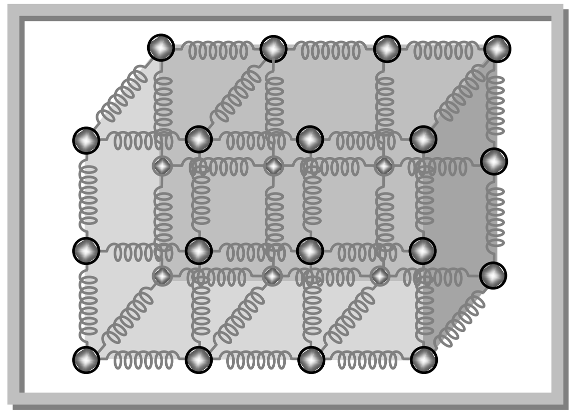
(2) Plasticity : The property of matter by virtue of which it does not regain its original shape and size after the removal of deforming force is called plasticity.

(3) Perfectly Elastic Body : If on the removal of deforming forces the body regain its original configuration completely it is said to be perfectly elastic.

A quartz fibre and phosphor bronze (an alloy of copper containing 4% to 10% tin, 0.05% to 1% phosphorus) is the nearest approach to the perfectly elastic body.

(4) Perfectly Plastic Body : If the body does not have any tendency to recover its original configuration, on the removal of deforming force, it is said to be perfectly plastic.
Paraffin wax, wet clay are the nearest approach to the perfectly plastic body.
Practically there is no material which is either perfectly elastic or perfectly plastic and the behaviour of actual bodies lies between the two extremes.

(5) Reason of Elasticity : In a solids, atoms and molecules are arranged in such a way that each molecule is acted upon by the forces due to neighbouring molecules. These forces are known as intermolecular forces.



For simplicity, the two molecules in their equilibrium positions (at inter-molecular distance $r = r_0$) (see graph in article 1) are shown by connecting them with a spring.
In fact, the spring connecting the two molecules represents the inter-molecular force between them. On applying the deforming forces, the molecules either come closer or go far apart from each other and restoring forces are developed. When the deforming force is removed, these restoring forces bring the molecules of the solid to their respective equilibrium position ($r = r_0$) and hence the body regains its original form.

(6) Elastic Limit : Elastic bodies show their property of elasticity upto a certain value of deforming force. If we go on increasing the deforming force then a stage is reached when on removing the force, the body will not return to its original state. The maximum deforming force upto which a body retains its property of elasticity is called elastic limit of the material of body.
Elastic limit is the property of a body whereas elasticity is the property of material of the body.

(7) Elastic Fatigue : The temporary loss of elastic properties because of the action of repeated alternating deforming force is called elastic fatigue.
It is due to this reason
(i) Bridges are declared unsafe after a long time of their use.
(ii) Spring balances show wrong readings after they have been used for a long time.
(iii) We are able to break the wire by repeated bending.

(8) Elastic After Effect : The time delay in which the substance regains its original condition after the removal of deforming force is called elastic after effect. It is the time for which restoring forces are present after the removal of the deforming force it is negligible for perfectly elastic substance, like quartz, phosphor bronze and large for glass fibre.

3. Stress

When a force is applied on a body there will be relative displacement of the particles and due to property of elasticity an internal restoring force is developed which tends to restore the body to its original state.
The internal restoring force acting per unit area of cross section of the deformed body is called stress.
At equilibrium, restoring force is equal in magnitude to external force, stress can therefore also be defined as external force per unit area on a body that tends to cause it to deform.
If external force F is applied on the area A of a body then,

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

Unit : N/m^2 (S.I.), $dyne/cm^2$ (C.G.S.)

Dimension : $[ML^{-1}T^{-2}]$

Stress developed in a body depends upon how the external forces are applied over it.

On this basis there are two types of stresses : Normal and Shear or tangential stress

(1) **Normal stress :** Here the force is applied normal to the surface.

It is again of two types : Longitudinal and Bulk or volume stress

(i) Longitudinal stress

(1) It occurs only in solids and comes in picture when one of the three dimensions viz. length, breadth, height is much greater than other two.
(2) Deforming force is applied parallel to the length and causes increase in length.
(3) Area taken for calculation of stress is area of cross section.
(4) Longitudinal stress produced due to increase in length of a body under a deforming force is called tensile stress.
(5) Longitudinal stress produced due to decrease in length of a body under a deforming force is called compressional stress.

(ii) Bulk or Volume stress

(1) It occurs in solids, liquids or gases.
(2) In case of fluids only bulk stress can be found.
(3) It produces change in volume and density, shape remaining same.
(4) Deforming force is applied normal to surface at all points.
(5) Area for calculation of stress is the complete surface area perpendicular to the applied forces.
(6) It is equal to change in pressure because change in pressure is responsible for change in volume.

(2) Shear or tangential stress : It comes in picture when successive layers of solid move on each other i.e. when there is a relative displacement between various layers of solid.

(i) Here deforming force is applied tangential to one of the faces.
(ii) Area for calculation is the area of the face on which force is applied.
(iii) It produces change in shape, volume remaining the same.

Difference Between Pressure and Stress

Pressure	Stress
Pressure is always normal to the area.	Stress can be normal or tangential.
Always compressive in nature.	May be compressive or tensile in nature.

Example 1:

One end of a uniform wire of length L and of weight W is attached rigidly to a point in the roof and a weight W_1 is suspended from its lower end. If S is the area of cross-section of the wire, the stress in the wire at a height 3L/4 from its lower end is

(1) $\frac{W_1}{S}$ (2) $\frac{W_1 + (W/4)}{S}$ (3) $\frac{W_1 + (3W/4)}{S}$ (4) $\frac{W_1 + W}{S}$

Solution:

As the wire is uniform so the weight of wire below point P is $\frac{3W}{4}$

$\therefore$ Total force at point P = $W_1 + \frac{3W}{4}$

and area of cross-section = S

$\therefore$ Stress at point P = $\frac{\text{Force}}{\text{Area}} = \frac{W_1 + \frac{3W}{4}}{S}$

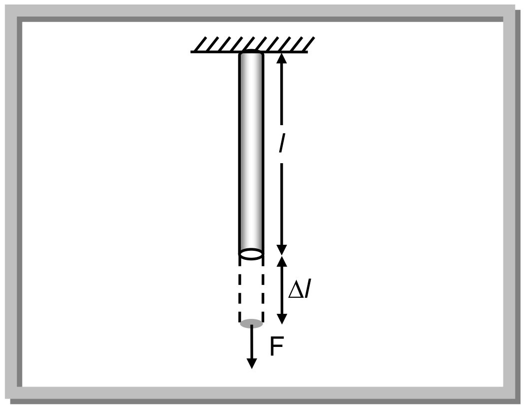
4. Strain

The ratio of change in configuration to the original configuration is called strain.
Being the ratio of two like quantities, it has no dimensions and units.

Strain are of Three Types

(1) Linear Strain : If the deforming force produces a change in length alone, the strain produced in the body is called linear strain or tensile strain.

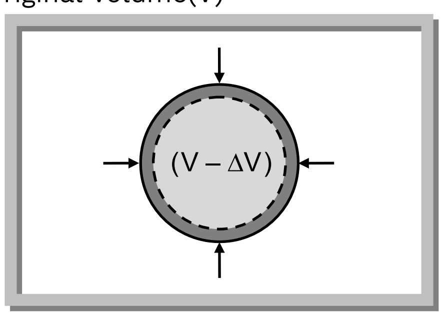
$$\text{Linear strain} = \frac{\text{Change in length}(\Delta\ell)}{\text{Original length}(\ell)}$$



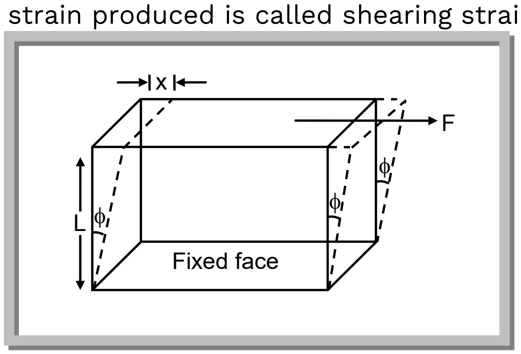
Linear strain in the direction of deforming force is called longitudinal strain and in a direction perpendicular to force is called lateral strain.

(2) Volumetric Strain : If the deforming force produces a change in volume alone the strain produced in the body is called volumetric strain.

$$\text{Volumetric strain} = \frac{\text{Change in volume}(\Delta V)}{\text{Original volume}(V)}$$



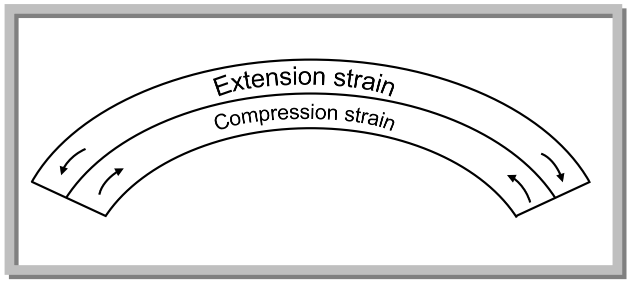
(3) Shearing Strain : If the deforming force produces a change in the shape of the body without changing its volume, strain produced is called shearing strain.



It is defined as angle in radians through which a plane perpendicular to the fixed surface of the cubical body gets turned under the effect of tangential force.

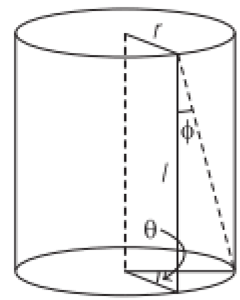
$$\phi = \frac{x}{L}$$

Note : " When a beam is bent both compression strain as well as an extension strain is produced.



5. Torsion of Cylinder

If the upper end of a cylinder is clamped and a torque is applied at the lower end the cylinder gets twisted by angle θ. Simultaneously shearing strain ϕ is produced in the cylinder.



(i) The angle of twist θ is directly proportional to the distance from the fixed end of the cylinder.
At fixed end $\theta = 0°$ and at free end θ = maximum.

(ii) The value of angle of shear ϕ is directly proportional to the radius of the cylindrical shell.
At the axis of cylinder $\phi = 0$ and at the outermost shell ϕ = maximum.

(iii) Relation between angle of twist (θ) and angle of shear (ϕ)

$AB = r\theta = \phi l$

$$\therefore \quad \varphi = \frac{r\theta}{l}$$

Example 2:

A cube of aluminium of sides 0.1 m is subjected to a shearing force of 100 N. The top face of the cube is displaced through 0.02 cm with respect to the bottom face. The shearing strain would be

(1) 0.02 (2) 0.1 (3) 0.005 (4) 0.002

Solution:

Shearing strain $\phi = \frac{x}{L} = \frac{0.02\text{cm}}{0.1\text{m}} = 0.002$

Example 3:

The length of a wire increases by 1% by a load of 2 kg-wt. The linear strain produced in the wire will be

(1) 0.02 (2) 0.001 (3) 0.01 (4) 0.002

Solution:

$$\text{Strain} = \frac{\text{Change in length}}{\text{Original length}} = \frac{1\%\text{ of L}}{L} = \frac{L/100}{L} = 0.01$$

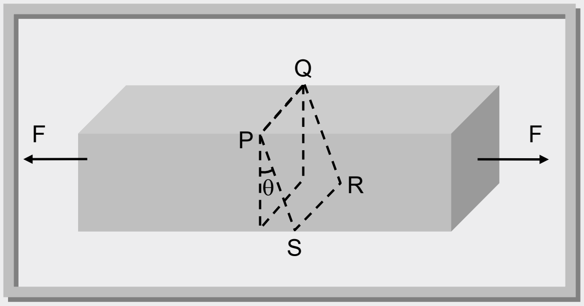
Concept Builder-1

Q.1 A and B are two wires. The radius of A is twice that of B. they are stretched by the same load. Then the stress on B is

(1) Equal to that on A (2) Four times that on A

(3) Two times that on A (4) Half that on A

Q.2 A bar is subjected to equal and opposite forces as shown in the figure. PQRS is a plane making angle with the cross-section of the bar. If the area of cross-section be 'A', then what is the tensile stress on PQRS



(1) F / A (2) F $\cos\theta$ / A (3) F $\cos^2\theta$ / A (4) F / A $\cos\theta$

Q.3 A wire is stretched to double its length. The strain is

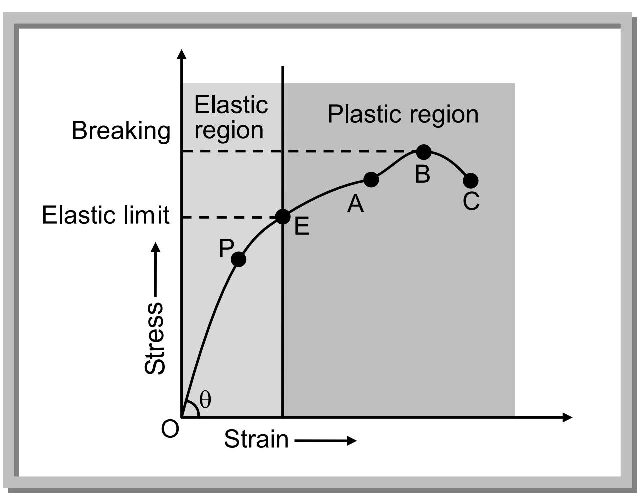
(1) 2 (2) 1 (3) Zero (4) 0.5

6. Stress-Strain Curve

If by gradually increasing the load on a vertically suspended metal wire, a graph is plotted between stress (or load) and longitudinal strain (or elongation) we get the curve as shown in figure. From this curve it is clear that :

(1) When the strain is small (< 2%) (i.e., in region OP) stress is proportional to strain. This is the region where the so called Hooke's law is obeyed. The point P is called **limit of proportionality** and slope of line OP gives the Young's modulus Y of the material of the wire. If θ is the angle of OP from strain axis then Y = $\tan\theta$.

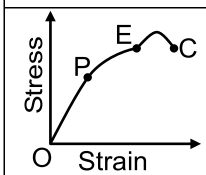
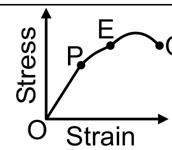
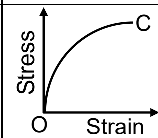
(2) If the strain is increased a little bit, i.e., in the region PE, the stress is not proportional to strain. However, the wire still regains its original length after the removal of stretching force. This behaviour is shown up to point E known as elastic limit or **yield-point.** The region OPE represents the **elastic behaviour** of the material of wire.



(3) If the wire is stretched beyond the elastic limit E, i.e., between EA, the strain increases much more rapidly and if the stretching force is removed the wire does not come back to its natural length. Some permanent increase in length takes place.

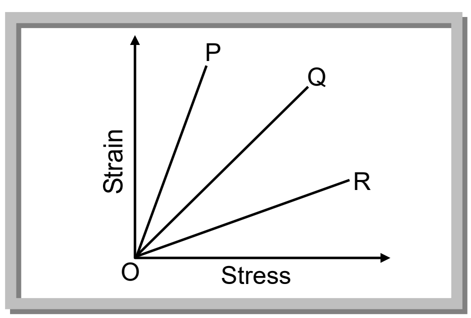
(4) If the stress is increased further, by a very small increase in it a very large increase in strain is produced (region AB) and after reaching point B, the strain increases even if the wire is unloaded and ruptures at C. In the region BC the wire literally flows. The maximum stress corresponding to B after which the wire begins to flow and breaks is called breaking or **tensile strength.** The region EABC represents the **plastic behaviour** of the material of wire.

(5) **Stress-strain curve for different materials.**

Brittle material	Ductile material	Elastomers
 The plastic region between E and C is small for brittle material and it will break soon after the elastic limit is crossed.	 The material of the wire have a good plastic range and such materials can be easily changed into different shapes and can be drawn into thin wires	 Stress strain curve is not a straight line within the elastic limit for elastomers and strain produced is much larger than the stress applied. Such materials have no plastic range and the breaking point lies very close to elastic limit. Example rubber

Example 4:

The strain stress curves of three wires of different materials are shown in the figure. P, Q and R are the elastic limits of the wires. The figure shows that



(1) Elasticity of wire P is maximum (2) Elasticity of wire Q is maximum0

(3) Tensile strength of R is maximum (4) None of the above is true

Solution:

On the graph stress is represented on X- axis and strain Y-axis

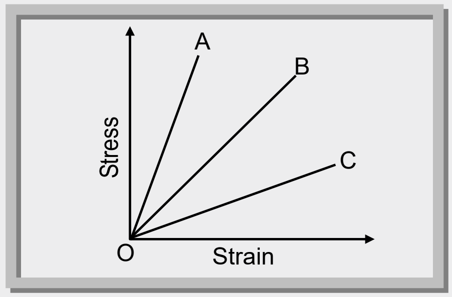
So from the graph Y = cotθ = $\dfrac{1}{\tan\theta} \propto \dfrac{1}{\theta}$ [where θ is the angle from stress axis]

$\therefore\ Y_P < Y_Q < Y_R$ [As $\theta_P > \theta_Q > \theta_R$]

We can say that elasticity of wire P is minimum and R is maximum.

Concept Builder-2

Q.1 The stress-strain curves for brass, steel and rubber are shown in the figure. The lines A, B and C are for



(1) Rubber, brass and steel respectively (2) Brass, steel and rubber
(3) Steel, brass and rubber respectively (4) Steel, rubber and brass

7. Hooke's Law and Modulus of Elasticity

According to this law, within the elastic limit, stress is proportional to the strain.

i.e. stress strain or $\frac{\text{stress}}{\text{strain}} = \text{constant} = E$

The constant E is called modulus of elasticity.

(1) It's value depends upon the nature of material of the body and the manner in which the body is deformed.
(2) It's value depends upon the temperature of the body.
(3) It's value is independent of the dimensions (length, volume etc.) of the body.
There are three moduli of elasticity namely Young's modulus (Y), Bulk modulus (K) and modulus of rigidity (η) corresponding to three types of the strain.

8. Young's Modulus (Y)

It is defined as the ratio of normal stress to longitudinal strain within limit of proportionality.

$$Y = \frac{\text{Normal stress}}{\text{longitudinal strain}} = \frac{F/A}{l/L} = \frac{FL}{Al}$$

If force is applied on a wire of radius r by hanging a weight of mass M, then

$$Y = \frac{MgL}{\pi r^2 \ell}$$

Important Points

(i) If the length of a wire is doubled,

Then longitudinal strain = $\frac{\text{change in length(l)}}{\text{initial length(L)}}$

$= \frac{\text{final length} - \text{initial length}}{\text{Initial length}} = \frac{2L - L}{L} = 1$

$\therefore$ Young's modulus = $\frac{\text{stress}}{\text{strain}} \Rightarrow Y = \text{stress}$

[As strain = 1]

So young's modulus is numerically equal to the stress which will double the length of a wire.

(ii) Increment in the length of wire

$$\ell = \frac{FL}{\pi r^2 Y} \qquad \left[\text{As } Y = \frac{FL}{Al}\right]$$

So if same stretching force is applied to different wires of same material, $\ell \propto \frac{L}{r^2}$

[As F and Y are constant]

i.e., greater the ratio $\frac{L}{r^2}$, greater will be the elongation in the wire.

(iii) Elongation in a wire by its own weight : The weight of the wire Mg act at the centre of gravity of the wire so that length of wire which is stretched will be L/2.

$$\therefore \text{ Elongation } = \ell = \frac{FL}{AY} = \frac{Mg(L/2)}{AY} = \frac{MgL}{2AY} = \frac{L^2 dg}{2Y}$$

[As mass (M) = volume (AL) × density (4)]

Example 5:

A wire of length 2m is made from 10 cm^3 of copper. A force F is applied so that its length increases by 2 mm. Another wire of length 8 m is made from the same volume of copper. If the force F is applied to it, its length will increase by

(1) 0.8 cm (2) 1.6 cm (3) 2.4 cm (4) 3.2 cm

Solution:

$$\ell = \frac{FL}{AY} = \frac{FL^2}{VY}$$

$$\therefore \ell \propto L^2 \qquad \text{[As V, Y and F are constant]}$$

$$\frac{\ell_2}{\ell_1} = \left[\frac{L_2}{L_1}\right]^2 = \left(\frac{8}{2}\right)^2 = 16$$

$$\Rightarrow \ell_2 = 16\,\ell_1 = 16 \times 2\text{mm} = 32 \text{ mm} = 3.2 \text{ cm}$$

Example 6:

Two wires A and B are of same materials. Their lengths are in the ratio 1 : 2 and diameters are in the ratio 2 : 1 when stretched by force F_A and F_B respectively they get equal increase in their lengths. Then the ratio F_A/F_B should be

(1) 1 : 2 (2) 1 : 1 (3) 2 : 1 (4) 8 : 1

Solution:

$$Y = \frac{FL}{\pi r^2 \ell}$$

$$\therefore F = Y\pi r^2 \frac{\ell}{L}$$

$$\frac{F_A}{F_B} = \frac{Y_A}{Y_B}\left(\frac{r_A}{r_B}\right)^2\left(\frac{l_A}{l_B}\right)\left(\frac{L_B}{L_A}\right)$$

$$= 1 \times \left(\frac{2}{1}\right)^2 \times (1) \times \left(\frac{2}{1}\right) = 8$$

Example 7:

A fixed volume of iron is drawn into a wire of length L. The extension x produced in this wire by a constant force F is proportional to

(1) $\frac{1}{L^2}$ (2) $\frac{1}{L}$ (3) L^2 (4) L

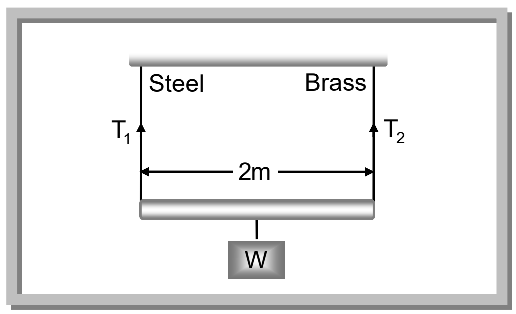
Solution:

$\ell = \frac{FL}{AY} = \frac{FL^2}{ALY} = \frac{FL^2}{VY}$

for a fixed volume $\ell \propto L^2$

Example 8:

A two metre long rod is suspended with the help of two wires of equal length. One wire is of steel and its cross-sectional area is 0.1 cm^2 and another wire is of brass and its cross-sectional area is 0.2 cm^2. If a load W is suspended from the rod and stress produced in both the wires is same then the ratio of tensions in them will be



(1) Will depend on the position of W (2) $\frac{T_1}{T_2} = 2$

(3) $\frac{T_1}{T_2} = 1$ (4) $\frac{T_1}{T_2} = 0.1$

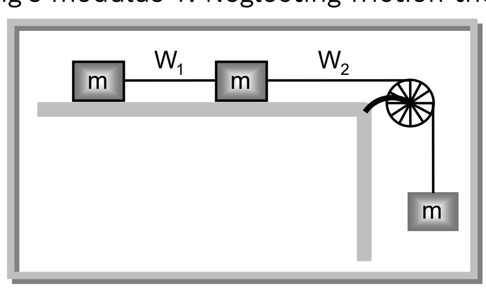
Solution:

$$\text{Stress} = \frac{\text{Tension}}{\text{Area of cross section}} = \text{constant}$$

$$\therefore \frac{T_1}{A_1} = \frac{T_2}{A_2} \Rightarrow \frac{T_1}{T_2} = \frac{A_1}{A_2} = \frac{0.1}{0.2} = \frac{1}{2} = 0.5$$

Example 9:

Three blocks, each of same mass m, are connected with wires W_1 and W_2 of same cross-sectional area a and Young's modulus Y. Neglecting friction the strain developed in wire W_2 is



(1) $\frac{2}{3}\frac{mg}{aY}$ (2) $\frac{3mg}{2aY}$ (3) $\frac{1}{3}\frac{mg}{aY}$ (4) $\frac{3mg}{aY}$

Solution:

If the system moves with acceleration a and T is the tension in the string W_2 then by comparing this condition from standard case $T = \frac{m_1 m_2}{m_1 + m_2} g$

In the given problem $m_1 = (m + m) = 2m$ and $m_2 = m$

$\therefore$ Tension $= \frac{m.2m.g}{m+2m} = mg$

$\therefore$ Stress $= \frac{T}{a} = \frac{2}{3a} mg$ and

Strain $= \frac{\text{Stress}}{\text{Young's modulus}} = \frac{2}{3}\frac{mg}{aY}$

Concept Builder-3

Q.1 The diameter of a brass rod is 4 mm and Young's modulus of brass is 9×10^{10} N/m^2. The force required to stretch by 0.1% of its length is

(1) 360π N (2) 36 N (3) $144\pi \times 10^3$ N (4) $36\pi \times 10^5$ N

Q.2 A wire of length L and radius r is rigidly fixed at one end. On stretching the other end of the wire with a force F, the increase in its length is l. If another wire of same material but of length 2L and radius 2r is stretched with a force of 2F, the increase in its length will be

(1) ℓ (2) 2ℓ (3) $\frac{\ell}{2}$ (4) $\frac{\ell}{4}$

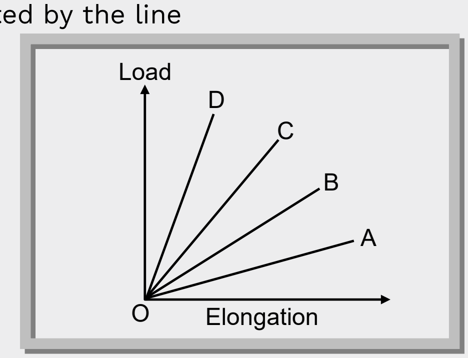
Q.3 A uniform plank of Young's modulus Y is moved over a smooth horizontal surface by a constant horizontal force F. The area of cross-section of the plank is A. the compressive strain on the plank in the direction of the force is

(1) $\frac{F}{AY}$ (2) $\frac{2F}{AY}$ (3) $\frac{1}{2}\left(\frac{F}{AY}\right)$ (4) $\frac{3F}{AY}$

Q.4 A wire is stretched by 0.01 m by a certain force F. Another wire of same material whose diameter and length are double to the original wire is stretched by the same force. Then its elongation will be

(1) 0.005 m (2) 0.01 m (3) 0.02 m (4) 0.002 m

Q.5 The load versus elongation graph for four wires of the same material is shown in the figure. The thickest wire is represented by the line



(1) OD (2) OC (3) OB (4) OA

Q.6 The dimensions of four wires of the same material are given below. In which wire the increase in length will be maximum when the same tension is applied

(1) Length 100 cm, diameter 1 mm
(2) Length 200 cm, diameter 2 mm
(3) Length 300 cm, diameter 3 mm
(4) Length 50 cm, diameter 0.5 mm

Q.7 The Young's modulus of a wire of length L and radius r is Y N/m^2. If the length and radius are reduced to L / 2 and r / 2, then its Young's modulus will be

(1) Y/2 (2) Y (3) 2Y (4) 4Y

9. Work Done in Stretching a Wire

In stretching a wire work is done against internal restoring forces. This work is stored in the wire as elastic potential energy or strain energy.

If a force F acts along the length L of the wire of cross-section A and stretches it by x then

$$Y = \frac{\text{stress}}{\text{strain}} = \frac{F/A}{x/L} = \frac{FL}{Ax} \Rightarrow F = x$$

So the work done for an additional small increase dx in length, $dw = Fdx = \frac{YA}{L}x.dx$

Hence the total work done in increasing the length by ℓ,

$$W = \int_0^{\ell} dW = \int_0^{\ell} Fdx = \int_0^{\ell} \frac{YA}{L}.x\,dx = \frac{1}{2}\frac{YA}{L}\ell^2$$

This work done is stored in the wire.

$\therefore$ Energy stored in wire $U = \frac{1}{2}\frac{YAl^2}{L} = \frac{1}{2}Fl$ $\left[\text{As } F = \frac{YAl}{L}\right]$

Dividing both sides by volume of the wire we get energy stored in per unit volume of wire.

$$U_V = \frac{1}{2}\times\frac{F}{A}\times\frac{l}{L} = \frac{1}{2} \times \text{stress} \times \text{strain}$$

$$= \frac{1}{2} \times Y \times (\text{strain})^2 = \frac{1}{2} \times Y \times (\text{strain})^2$$

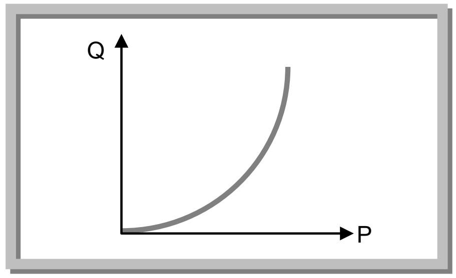
$$= \frac{1}{2Y}(\text{stress})^2 \quad [\text{As AL = volume of wire}]$$

Total energy stored in wire (U)	**Energy stored in per unit volume of wire (U_V)**
$\frac{1}{2}F\ell$	$\frac{1}{2}F\ell$ / Volume
$\frac{1}{2}$ × stress × strain × volume	$\frac{1}{2}$ × stress × strain
$\frac{1}{2}$ × Y × (strain)^2 × volume	$\frac{1}{2}$ × Y × (strain)^2
$\frac{1}{2Y}$ × (stress)^2 × volume	$\frac{1}{2Y}$ × (stress)^2

Note : If the force on the wire is increased from F_1 to F_2 and the elongation in wire is ℓ then energy stored in the wire $U = \frac{1}{2}\frac{(F_1 + F_2)}{2}\ell$

Example 10:

The graph shows the behaviour of a length of wire in the region for which the substance obeys Hooke's law. P and Q represent



(1) P = applied force, Q = extension
(2) P = extension, Q = applied force
(3) P = extension, Q = stored elastic energy
(4) P = stored elastic energy, Q = extension

Solution:

The graph between applied force and extension will be straight line because in elastic range applied force $\propto$ extension, but the graph between extension and stored elastic energy will be parabolic in nature.

As $U = \frac{1}{2}kx^2$ or $U \propto x^2$

Concept Builder-4

Q.1 A wire suspended vertically from one of its ends is stretched by attaching a weight of 200 N to the lower end. The weight stretches the wire by 1 mm, then the elastic energy stored in the wire is

(1) 0.1 J (2) 0.2 J (3) 10 J (4) 20 J

Q.2 When a 4 kg mass is hung vertically on a light spring that obeys Hooke's law, the spring stretches by 2 cms. The work required to be done by an external agent in the stretching this spring by 5 cms will be ($g = 9.8\ m/s^2$)

(1) 4.900 J (2) 2.450 J (3) 0.495 J (4) 0.245 J

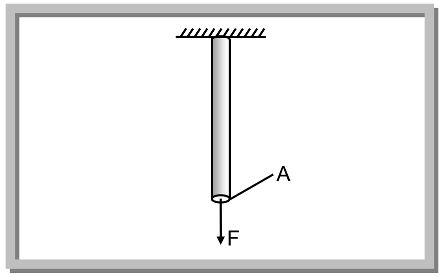
Q.3 Which of the following cases will have the greatest strain energy (F is the stretching force, A is the area of cross section and s is the strain)

(1) $F = 10\ N,\ A = 1\ cm^2,\ s = 10^{-3}$
(2) $F = 15\ N,\ A = 2\ cm^2,\ s = 10^{-3}$
(3) $F = 10\ N,\ A = \frac{1}{2}\ cm^2,\ s = 10^{-4}$
(4) $F = 5\ N,\ A = 3\ cm^2,\ s = 10^{-3}$

10. Breaking of Wire

When the wire is loaded beyond the elastic limit, then strain increases much more rapidly. The maximum stress corresponding to B (see stress-strain curve) after which the wire begin to flow and breaks, is called breaking stress or tensile strength and the force by application of which the wire breaks is called the breaking force.

(i) Breaking force depends upon the area of cross-section of the wire i.e., Breaking force A
Breaking force = P × A



Here P is a constant of proportionality and known as breaking stress.

(ii) Breaking stress is a constant for a given material and it does not depends upon the dimension (length or thickness) of wire.

(iii) If a wire of length L is cut into two or more parts, then again it's each part can hold the same weight. Since breaking force is independent of the length of wire.

(iv) If a wire can bear maximum force F, then wire of same material but double thickness can bear maximum force 4F because Breaking force $\propto \pi r^2$.

(v) The working stress is always kept lower than that of a breaking stress.

So that safety factor = $\dfrac{\text{breaking stress}}{\text{working stress}}$ may have large value.

(vi) Breaking of wire under its own weight.

Breaking force = Breaking stress Area of cross section

Weight of wire = Mg = ALdg = PA

[As mass = volume density = ALd]

$\Rightarrow$ Ldg = P $\qquad \therefore \quad L = \dfrac{P}{dg}$

This is the length of wire if it breaks by its own weight.

Example 11:

A body of mass 10 kg is attached to a wire 0.3 m long. Its breaking stress is 4.8×10^7 N/m^2. The area of cross-section of the wire is 10^{-6} m^2. What is the maximum angular velocity with which it can be rotated in the horizontal circle

(1) 1 rad/sec (2) 2 rad/sec (3) 4 rad/sec (4) 8 rad/sec

Solution:

Breaking force = centrifugal force

Breaking stress × area of cross-section = $m\omega^2 l$

$$4.8 \times 10^7 \times 10^{-6} = 10 \times \omega^2 \times 0.3$$

$$\Rightarrow \omega^2 = 16 \Rightarrow \omega = 4 \text{rad / sec}$$

Concept Builder-5

Q.1 A wire of diameter 1 mm breaks under a tension of 1000 N. Another wire of same material as that of the first one, but of diameter 2 mm breaks under a tension of

(1) 500 N (2) 1000 N (3) 10000 N (4) 4000 N

Q.2 In steel, the Young's modulus and the strain at the breaking point are 2×10^{11} N/m^2 and 0.04 respectively. The stress at the breaking point for steel is therefore

(1) 2×10^{11} Nm^{-2} (2) 4×10^{13} Nm^{-2} (3) 8×10^{-13} Nm^{-2} (4) 8×10^{9} Nm^{-2}

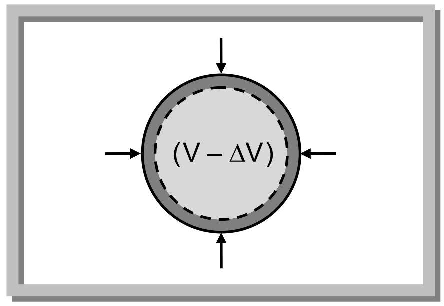
Q.3 To break a wire, a stress of 10^6 N/m^2 is required. If the density of the material is 3×10^3 kg/m^3, then the length of the wire which will break by its own weight will be

(1) 34 m (2) 30 m (3) 300 m (4) 3 m

11. Bulk Modulus

When a solid or fluid (liquid or gas) is subjected to a uniform pressure all over the surface, such that the shape remains the same, then there is a change in volume.

Then the ratio of normal stress to the volumetric strain within the elastic limits is called as Bulk modulus. This is denoted by K.



$$K = \frac{\text{Normal stress}}{\text{volumetric strain}}$$

$$K = \frac{F/A}{-\Delta V/V} = \frac{-pV}{\Delta V}$$

where p = increase in pressure; V = original volume; V = change in volume

The negative sign shows that with increase in pressure p, the volume decreases by V i.e. if p is positive, V is negative. The reciprocal of bulk modulus is called compressibility.

$$C = \text{compressibility} = \frac{1}{K} = \frac{\Delta V}{pV}$$

S.I. unit of compressibility is $N^{-1}m^2$ and C.G.S. unit is $dyne^{-1}\ cm^2$.

Gases have two bulk moduli, namely isothermal elasticity K_θ and adiabatic elasticity K_ϕ.

Example 12:

When a pressure of 100 atmosphere is applied on a spherical ball of rubber, then its volume reduces to 0.01%. The bulk modulus of the material of the rubber in dyne/cm^2 is

(1) 10×10^{12} (2) 100×10^{12} (3) 1×10^{12} (4) 20×10^{12}

Solution:

1 atm = $10^5 N/m^2$ $\therefore$ 100 atm = 10^7 N/m

and a $\therefore \frac{\Delta V}{V} = 0.0001 \Rightarrow K = \frac{P}{\Delta V/V} = \frac{10^7}{0.0001} = 1\times10^{11} N/m^2 = 1\times10^{12}\frac{\text{Dyne}}{\text{cm}^2}$

Concept Builder-6

Q.1 A uniform cube is subjected to volume compression. If each side is decreased by 1%, then bulk strain is

(1) 0.01 (2) 0.06 (3) 0.02 (4) 0.03

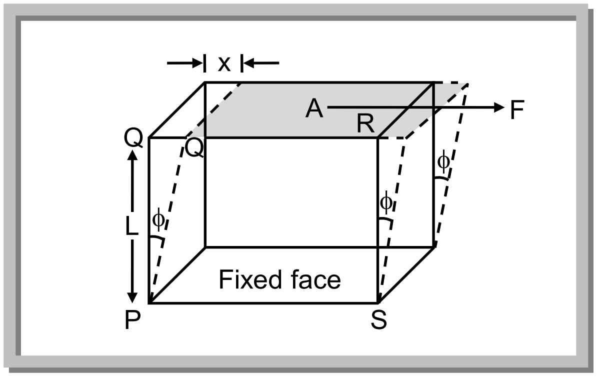
Q.2 A ball falling in a lake of depth 200 m shows 0.1% decrease in its volume at the bottom. What is the bulk modulus of the material of the ball

(1) 19.6×10^{8} N/m^2 (2) 19.6×10^{-10} N/m^2 (3) 19.6×10^{10} N/m^2 (4) 19.6×10^{-8} N/m^2

12. Modulus of Rigidity

Within limits of proportionality, the ratio of tangential stress to the shearing strain is called modulus of rigidity of the material of the body and is denoted by η, i.e.

$$\eta = \frac{\text{Shearing stress}}{\text{Shearing strain}}$$



In this case the shape of a body changes but its volume remains unchanged.
Consider a cube of material fixed at its lower face and acted upon by a tangential force F at its upper surface having area A. The shearing stress, then, will be

$$\text{Shearing stress} = \frac{F_{\parallel}}{A} = \frac{F}{A}$$

This shearing force causes the consecutive horizontal layers of the cube to be slightly displaced or sheared relative to one another, each line such as PQ or RS in the cube is rotated through an angle by this shear. The shearing strain is defined as the angle ϕ in radians through which a line normal to a fixed surface has turned. For small values of angle,

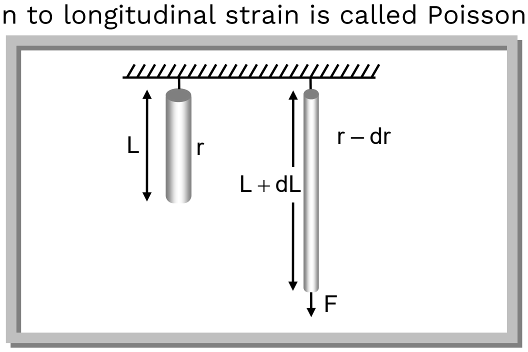
$$\text{Shearing strain} = \varphi = \frac{QQ'}{PQ} = \frac{x}{L}$$

$$\text{So, } \eta = \frac{\text{shear stress}}{\text{shear strain}} = \frac{F/A}{\varphi} = \frac{F}{A\varphi}$$

Only solids can exhibit a shearing as these have definite shape.

13. Poisson's Ratio

When a long bar is stretched by a force along its length then its length increases and the radius decreases as shown in the figure.
Lateral strain : The ratio of change in radius to the original radius is called lateral strain.
Longitudinal strain : The ratio of change in length to the original length is called longitudinal strain.
The ratio of lateral strain to longitudinal strain is called Poisson's ratio (σ).



i.e. $\sigma = \dfrac{\text{Lateral strain}}{\text{Longitudinal strain}}$

$$\sigma = \frac{-dr/r}{dL/L}$$

Negative sign indicates that the radius of the bar decreases when it is stretched.
Poisson's ratio is a dimensionless and a unitless quantity.

14. Relation Among Volumetric Strain, Lateral Strain and Poisson's Ratio

If a long bar have a length L and radius r then volume V = $\pi r^2 L$
Differentiating both the sides

Dividing both the sides by volume of bar $\dfrac{dV}{V} = \dfrac{\pi r^2 dL}{\pi r^2 L} + \dfrac{\pi 2rL\,dr}{\pi r^2 L}$

$\Rightarrow$ Volumetric strain = longitudinal strain + 2(lateral strain)

$$\Rightarrow \frac{dV}{V} = \frac{dL}{L} - 2\sigma\frac{dL}{L} = (1-2\sigma)\frac{dL}{L}$$

$$\left[\text{As } \sigma = \frac{-dr/r}{dL/L} \;\Rightarrow\; \frac{dr}{r} = -\sigma\frac{dL}{L}\right]$$

Important Points

(i) If a material having

$\sigma = 0.5$ then $\dfrac{dV}{V} = [1-2\sigma]\dfrac{dL}{L} = 0$

Volume = constant or K = ∞ i.e., the material is incompressible.

(ii) If a material having $\sigma = 0$, then lateral strain is zero i.e. when a substance is stretched its length increases without any decrease in diameter e.g. cork. In this case change in volume is maximum.

(iii) Theoretical value of Poisson's ratio lies between –1 to 0.5.

(iv) Practical value of Poisson's ratio for most materials lies between 0.2 to 0.5.

15. Relation Among Y, K, σ & η

Moduli of elasticity are three, viz. Y, K & η while elastic constants are four, viz, Y, K, η and σ. Poisson's ratio σ is not modulus of elasticity as it is the ratio of two strains and not of stress to strain. Elastic constants are found to depend on each other through the relations:

$Y = 3K(1 - 2\sigma)$

$Y = 2\eta(1 + \sigma)$

$$\frac{9}{Y} = \frac{3}{\eta} + \frac{1}{K}$$

Example 14:

There is no change in the volume of a wire due to change in its length on stretching. The Poisson's ratio of the material of the wire is

(1) + 0.50 (2) – 0.50 (3) + 0.25 (4) – 0.25

Solution:

$$\frac{dV}{V} = \frac{dL}{L} - 2\sigma\frac{dL}{L} = (1-2\sigma)\frac{dL}{L}$$

[As there is no change in the volume of the wire]

$\therefore 1 - 2\sigma = 0 \Rightarrow \sigma = \dfrac{1}{2}$

Example 15:

The values of Young's and bulk modulus of elasticity of a material are 8×10^{10} N/m^2 and 10×10^{10} N/m^2 respectively. The value of Poisson's ratio for the material will be

(1) 0.25 (2) – 0.25 (3) 0.37 (4) – 0.37

Solution:

$Y = 3K(1 - 2\sigma)$ $\Rightarrow \sigma = 0.37$

Example 16:

The of a material is 0.20. If a longitudinal strain of 4.0×10^{-3} is caused, by what percentage will the volume change

(1) 0.48% (2) 0.32% (3) 0.24% (4) 0.50%

Solution:

Longitudinal strain = $\times 10^{-3}$ or 0.4%

Lateral strain = $\sigma \times 0.4\% = 0.2 \times 0.4\% = 0.08\%$

$\therefore$ Volumetric strain = longitudinal strain - 2 lateral strain

$= 0.4 - 2 \times (0.08) = 0.24\%$

$\therefore$ Volume will change by 0.24%.

Concept Builder-7

Q.1 Minimum and maximum values of Poisson's ratio for a metal lies between

(1) –1 to + 1 (2) 0 to 1 (3) –0.5 to 1 (4) 0 to 0.5

Q.2 For a given material, the Young's modulus is 2.4 times that of rigidity modulus. Its Poisson's ratio is

(1) 2.4 (2) 1.2 (3) 0.4 (4) 0.2

Q.3 The Poisson's ratio for a metal is 0.25. If lateral strain is 0.0125, the longitudinal strain will be

(1) 0.125 (2) 0.05 (3) 0.215 (4) 0.0125

ANSWER KEY FOR CONCEPT BUILDERS

CONCEPT BUILDER-1

1.	(2)	**2.**	(3)
4.	(2)		

CONCEPT BUILDER-2

1.	(3)

CONCEPT BUILDER-3

1.	(1)	**2.**	(1)
3.	(1)	**4.**	(1)
5.	(1)	**6.**	(4)
7.	(2)		

CONCEPT BUILDER-4

1.	(1)	**2.**	(2)
3.	(2)		

CONCEPT BUILDER-5

1.	(4)	**2.**	(4)
3.	(1)		

CONCEPT BUILDER-6

1.	(4)	**2.**	(1)

CONCEPT BUILDER-7

1.	(4)	**2.**	(4)
3.	(2)		

Exercise - I

Elastic Behaviour Longitudinal Stress, Young Modulus

1. A force F is needed to break a copper wire having radius R. The force needed to break a copper wire of radius 2 R will be :

(1) F/2 (2) 2 F

(3) 4 F (4) F/4

2. The lower surface of a cube is fixed. On its upper surface, force is applied at an angle of 30° from its surface. The change will be in its :–

(1) Shape

(2) Size

(3) Volume

(4) Both shape and size.

3. Which one of the following substances possesses the highest elasticity :–

(1) Rubber (2) Glass

(3) Steel (4) Copper

4. A 2m long rod of radius 1 cm which is fixed from one end is given a twist of 0.8 radians. The shear strain developed will be:–

(1) 0.002 (2) 0.004

(3) 0.008 (4) 0.016

5. The maximum stress that can be applied to the material of a wire used to suspend an elevator is $\frac{3}{\pi} \times 10^8$ N/m^2. If the mass of elevator is 900 kg and it move up with an acceleration 2.2 m/s^2 then calculate the minimum radius of the wire.

(1) 6 mm (2) 7 mm

(3) 8 mm (4) 5 mm

6. The breaking stress of a wire depends upon

(1) Length of the wire

(2) Radius of the wire

(3) Material of the wire

(4) Shape of the cross section

7. The upper end of a wire of radius 4 mm and length 100 cm is clamped and its other end is twisted through an angle of 30°. Then angle of shear is

(1) 12° (2) 0.12°

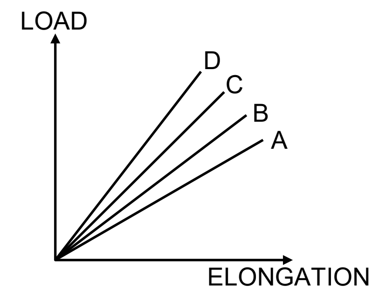
(3) 1.2° (4) 0.012°

8. The diameter of a brass rod is 4 mm and Young's modulus of brass is 9×10^{10} N/m^2. The force required to stretch by 0.1% of its length is :

(1) 360 π N (2) 36 N

(3) 144 $\pi \times 10^3$ N (4) 36 $\pi \times 10^5$ N

9. The load versus elongation graph for four wires of the same materials is shown in the figure. The thinnest wire is represented by the line



(1) OC (2) OD

(3) OA (4) OB

10. The following four wires are made of the same material. Which of these will have the largest extension when the same tension is applied–

(1) Length 50 cm and diameter 0.5 mm

(2) Length 100 cm and diameter 1 mm

(3) Length 200 cm and diameter 2 mm

(4) Length 300 cm and diameter 3 mm

11. If the density of the material increase, the value of Young's modulus :–

(1) increases

(2) decreases

(3) first increases, then decreases

(4) first decreases, then increases

12. Two wires of the same material have lengths in the ratio 1 : 2 and their radii are in the ratio $1:\sqrt{2}$. If they are stretched by applying equal forces, the increase in their lengths will be in the ratio :–

(1) 2 (2) $\sqrt{2}:2$

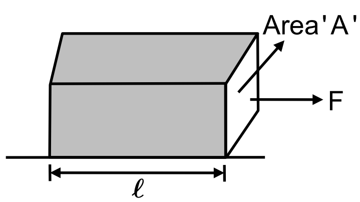
(3) 1 : 1 (4) 1 : 2

13. The Young's modulus of a rubber string 8 cm long and density 1.5 kg/m^3 is 5×10^8 N/m^2, is suspended on the ceiling in a room. The increase in length due to its own weight will be :–

(1) 9.6×10^{-5} m (2) 9.6×10^{-11} m

(3) 9.6×10^{-3} m (4) 9.6 m

14. A block of mass 'M' area of cross–section 'A' & length 'ℓ' is placed on smooth horizontal floor. A force 'F' is applied on the block as shown. If Y is young modulus of material, then total extension in the block will be:



(1) $\frac{Fl}{AY}$ (2) $\frac{Fl}{2AY}$

(3) $\frac{Fl}{3AY}$ (4) cannot extend

Tangential Stress and Strain, Shear Modulus

15. A square brass plate of side 1.0 m and thickness 0.005 m is subjected to a force F on its smaller opposite edges, causing a displacement of 0.02 cm. If the shear modulus of brass is 0.4×10^{11} N/m^2, the value of the force F is

(1) 4×10^3 N

(2) 400 N

(3) 4×10^4 N

(4) 1000 N

Pressure and Volumetric Strain, Bulk Modulus of Elasticity

16. A metal block is experiencing an atmospheric pressure of 1×10^5 N/m^2, when the same block is placed in a vacuum chamber, the fractional change in its volume is (the bulk modulus of metal is 1.25×10^{11} N/m^2)

(1) 4×10^{-7} (2) 2×10^{-7}

(3) 8×10^{-7} (4) 1×10^{-7}

17. An increase in pressure required to decrease the 200 litres volume of a liquid by 0.004% in container is : (Bulk modulus of the liquid = 2100 MPa) :–

(1) 188 kPa (2) 8.4 kPa

(3) 18.8 kPa (4) 84 kPa

18. Two wires of the same material and length but diameter in the ratio 1 : 2 are stretched by the same force. The ratio of potential energy per unit volume for the two wires when stretched will be :

(1) 1 : 1 (2) 2 : 1

(3) 4 : 1 (4) 16 : 1

19. A fixed volume of iron is drawn into a wire of length ℓ. The extension produced in this wire by a constant force F is proportional to :–

(1) $\frac{1}{\ell^2}$ (2) $\frac{1}{\ell}$

(3) ℓ^2 (4) ℓ

Elastic Potential Energy

20. If the potential energy of a spring is V on stretching it by 2 cm, then its potential energy when it is stretched by 10 cm will be :

(1) V/25 (2) 5 V

(3) V/5 (4) 25 V

21. If work done in stretching a wire by 1mm is 2J, the work necessary for stretching another wire of same material, but with double the radius and half the length by 1mm in joule is -

(1) 1/4 (2) 4

(3) 8 (4) 16

22. A wire of length 50 cm and cross sectional area of 1 sq. mm is extended by 1 mm. The required work will be ($Y = 2 \times 10^{10}\ Nm^{-2}$)

(1) 6×10^{-2} J (2) 4×10^{-2} J

(3) 2×10^{-2} J (4) 1×10^{-2} J

23. The elastic energy stored in a wire of Young's modulus Y is

(1) $Y \times \frac{\text{Strain}^2}{\text{Volume}}$

(2) Stress × Strain × Volume

(3) $\frac{\text{Stress}^2 \times \text{Volume}}{2Y}$

(4) $\frac{1}{2}$ Y × stress × Strain × Volume

24. A wire of length 50 cm and cross sectional area of 1 sq. mm is extended by 1 mm. The required work will be ($Y = 2 \times 10^{10}\ Nm^{-2}$)

(1) 6×10^{-2} J (2) 4×10^{-2} J

(3) 2×10^{-2} J (4) 1×10^{-2} J

25. On stretching a wire, the elastic energy stored per unit volume is

(1) $F\ell/2AL$ (2) FA/2L

(3) FL/2A (4) FL/2

26. Two wires of same diameter of the same material having the length ℓ and 2ℓ. If the force F is applied on each, the ratio of the work done in the two wires will be :–

(1) 1 : 2 (2) 1 : 4

(3) 2 : 1 (4) 1 : 1

27. A liquid has only

(1) shear modulus

(2) Young’s modulus

(3) bulk modulus

(4) All of the above

28. The relation between γ, η and K for a elastic material is

(1) $\frac{1}{\eta} = \frac{1}{3\gamma} + \frac{1}{9K}$ (2) $\frac{1}{K} = \frac{1}{3\gamma} + \frac{1}{9\eta}$

(3) $\frac{1}{\gamma} = \frac{1}{3K} + \frac{1}{9\eta}$ (4) $\frac{1}{\gamma} = \frac{1}{3\eta} + \frac{1}{9K}$

ANSWER KEY

Que.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Ans.	3	4	3	2	1	3	2	1	3	1	1	3	2	2	3	3	4	4	3	4	4	3	3	3	1
Que.	26	27	28																						
Ans.	1	3	4																						

Exercise - II

1. A uniform wire (Young's modulus 2×10^{11} Nm^{-2}) is subjected to longitudinal tensile stress of 5×10^{7} Nm^{-2}. If the overall volume change in the wire is 0.02%, the fractional decrease in the radius of the wire is close ot :

(1) 1.5×10^{-4} (2) 0.25×10^{-4}

(3) 5×10^{-4} (4) 1.0×10^{-4}

2. A brass rod of length 2 m and cross-sectional area 2.0 cm^2 is attached end to end to a steel rod of length L and cross-sectional area 1.0 cm^2. The compound rod is subjected to equal and opposite pulls of magnitude 5×10^4 N at its ends. If the elongations of the two rods are equal, then length of the steel rod (L) is

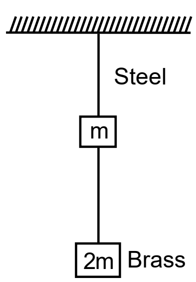
($Y_{Brass} = 1.0 \times 10^{11}$ N/m^2 and

$Y_{Steel} = 2.0 \times 10^{11}$ N/m^2)

(1) 1.5 m (2) 1.8 m

(3) 1 m (4) 2 m

3. If the ratio of lengths, radii and Young's modulus of steel and brass wires in the figure are a, b, c respectively. Then the corresponding ratio of increase in their lengths would be :



(1) $\frac{2ac}{b^2}$ (2) $\frac{3a}{2b^2c}$

(3) $\frac{3c}{2ab^2}$ (4) $\frac{2a^2c}{b}$

4. One end of uniform wire of length L and of weight W is attached rigidly to a point in the roof and a weight W_1 is suspended from its lower end. If s is the area of cross–section of the wire, the stress in the wire at a height $\frac{L}{4}$ from its lower end is :–

(1) $\frac{W_1}{s}$ (2) $\frac{\left[W_1 + \frac{W}{4}\right]}{s}$

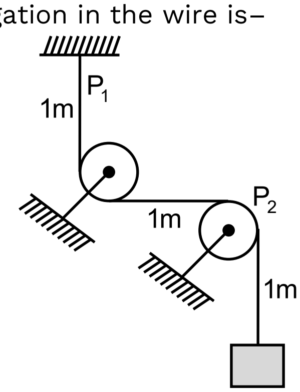
(3) $\frac{\left[W_1 + \frac{3W}{4}\right]}{s}$ (4) $\frac{W_1 + W}{4}$

5. A steel wire 1.5 m long and of radius 1 mm is attached with a load 3 kg at one end the other end of the wire is fixed it is whirled in a vertical circle with a frequency 2Hz. Find the elongation of the wire when the weight is at the lowest position–
($Y = 2 \times 10^{11}$ N/m² and g = 10 m/s²)

(1) 1.77×10^{-3} m (2) 7.17×10^{-3} m

(3) 3.17×10^{-7} m (4) 1.37×10^{-7} m

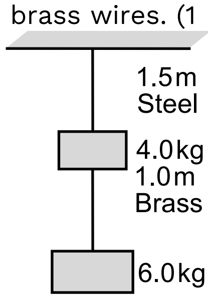
6. A copper wire of length 3m and area of cross–section 1 mm^2, passes through an arrangement of two frictionless pulleys, P_1 and P_2. One end of the wire is rigidly clamped and a mass of 1 kg is hanged from the other end. If the Young's modulus for copper is 10×10^{10} N/m^2, then the elongation in the wire is–



(1) 0.05 mm (2) 0.1 mm

(3) 0.2 mm (4) 0.3 mm

7. Two wires of diameter 0.25 cm, one made of steel and other made of brass are loaded as shown in figure. The unloaded length of steel wire is 1.5 m and that of brass wire is 1.0 m. Young's modulus of steel is 2.0×10^{11} Pa and that of brass is 0.91×10^{11} Pa. Calculate the elongation of steel and brass wires. (1 Pa = 1 Nm^{-2})



(1) Steel wire : 1.49×10^{-4} m, Brass wire : 1.31×10^{-4} m
(2) Steel wire : 1.60×10^{-3} m, Brass wire : 1.31×10^{-5} m
(3) Steel wire : 1.30×10^{-5} m, Brass wire : 1.31×10^{-5} m
(4) Steel wire : 1.22×10^{-2} m, Brass wire : 1.44×10^{-4} m

8. A 5m aluminium wire ($Y = 7 \times 10^{10}$ N/m^2) of diameter 3 mm supports a 40 kg mass. In order to have the same elongation in a copper wire ($Y = 12 \times 10^{10}$ N/m^2) of the same length under the same weight, the diameter should be in mm
(1) 1.75
(2) 2.0
(3) 2.3
(4) 5.0

9. When a force is applied on a wire of uniform cross-sectional area 3×10^{-6} m^2 and length 4m, the increase in length is 1 mm. Energy stored in it will be ($Y = 2 \times 10^{11}$ N / m^2)
(1) 6250 J
(2) 0.177 J
(3) 0.075 J
(4) 0.150 J

10. A brass rod of cross–sectional area 1 cm^2 and length 0.2 m is compressed lengthwise by a weight of 5 kg. If Young's modulus of elasticity of brass is 1×10^{11} N/m^2 and g = 10 m/sec^2, then increase in the energy of the rod will be :–
(1) 10^{-5} joule
(2) 2.5×10^{-5} joule
(3) 5×10^{-5} joule
(4) 2.5×10^{-4} joule

11. A weight is suspended from a long metal wire. If the wire suddenly breaks, its temperature :–
(1) Rises
(2) Falls
(3) Remains unchanged
(4) Attains a value 0 K

ANSWER KEY

Que.	1	2	3	4	5	6	7	8	9	10	11
Ans.	2	4	2	2	1	4	1	3	3	2	1

Exercise – III (Previous Year Question)

1. The following four wires are made of the same material. Which of these will have the largest extension when the same tension is applied ? **[NEET_2013]**

(1) length = 100 cm, diameter = 1 mm

(2) length = 200 cm, diameter = 2 mm

(3) length = 300 cm, diameter = 3 mm

(4) length = 50 cm, diameter = 0.5 mm

2. Copper of fixed volume 'V' is drawn into wire of length ℓ. When this wire is subjected to a constant force 'F', the extension produced in the wire is $\Delta\ell$. Which of the following graphs is a straight line ? **[NEET - 2014]**

(1) $\Delta\ell$ versus $1/\ell$ (2) $\Delta\ell$ versus ℓ^2

(3) $\Delta\ell$ versus $1/\ell^2$ (4) $\Delta\ell$ versus ℓ

3. The approximate depth of an ocean is 2700 m. The compressibility of water is 45.4×10^{-11} Pa^{-1} and density of water is 10^3 kg/m^3.What fractional compression of water will be obtained at the bottom of the ocean ? **[AIPMT-2015]**

(1) 1.0×10^{-2} (2) 1.2×10^{-2}

(3) 1.4×10^{-2} (4) 0.8×10^{-2}

4. The Young's modulus of steel is twice that of brass. Two wires of same length and of same area of cross section, one of steel and another of brass are suspended from the same roof. If we want the lower ends of the wires to be at the same level, then the weights added to the steel and brass wires must be in the ratio of: **[AIPMT-2015]**

(1) 1 : 1 (2) 1 : 2

(3) 2 : 1 (4) 4 : 1

5. The bulk modulus of a spherical object is 'B'. If it is subject to uniform pressure 'p', the fractional decrease in radius is : **[NEET-2017]**

(1) $\frac{p}{B}$ (2) $\frac{B}{3p}$

(3) $\frac{3p}{B}$ (4) $\frac{p}{3B}$

6. Two wires are made of the same material and have the same volume. The first wire has cross-sectional area A and the second wire has cross-sectional area 3A. If the length of the first wire is increased by $\Delta\ell$ on applying a force F, how much force is needed to stretch the second wire by the same amount ? **[NEET 2018]**

(1) 9 F (2) 6 F

(3) 4 F (4) F

7. When a block of mass M is suspended by a long wire of length L, the length of the wire becomes $(L + \ell)$. The elastic potential energy stored in the extended wire is : **[NEET-2019]**

(1) $\frac{1}{2}Mg\ell$ (2) $\frac{1}{2}MgL$

(3) $Mg\ell$ (4) MgL

8. The stress-strain curves are drawn from the different materials X and Y. It is observed that the ultimate strength point and the fracture point are close to each other for material X but are far apart for material Y. We can say that materials X and Y are likely to be (respectively) **[NEET (Osisha)-2019]**

(1) ductile and brittle

(2) brittle and ductile

(3) brittle and plastic

(4) plastic and ductile

9. A wire of length L, area of cross section A is hanging from a fixed support. The length of the wire changes to L_1 when mass M is suspended from its free end. The expression for Young's modulus is : **[NEET-2020]**

(1) $\frac{MgL}{AL_1}$ (2) $\frac{MgL}{A\left(L_1 - L\right)}$

(3) $\frac{MgL_1}{AL}$ (4) $\frac{Mg(L_1 - L)}{AL}$

ANSWER KEY									
Que.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Ans.	4	2	2	3	4	1	1	2	2