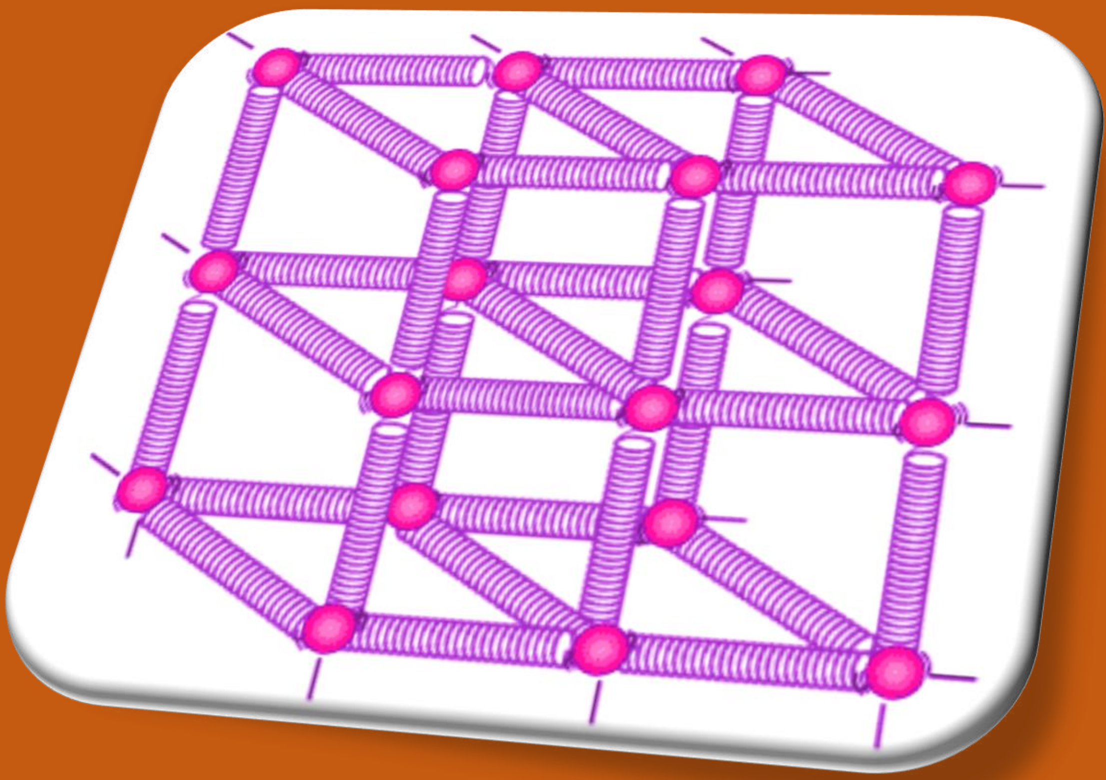
9. Mechanical Properties of Solids



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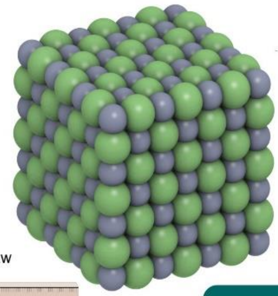
MECHANICAL PROPRTIES OF SOLIDS

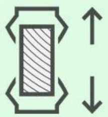


STRESS & ITS TYPES

(1) Stress is restoring force per unit area
(2) $\sigma = \frac{F}{A}$
(3) It is neither scalar nor vector.
(4) It's unit is N/m^2

NORMAL STRESS

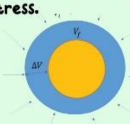
(1) Tensile stress is produced when axial force acts per unit Area.
(2) This stress results in Elongation:



(1) Compressive stress is produced when force compresses object per unit area.
(2) This stress results in Compression

VOLUMETRIC STRESS

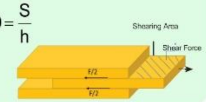
- When object is immersed inside the liquid. the hydrostatic pressure decreases the volume of an object. that results the volumetric stress.



SHEAR STRESS

(1) Shear stress is produced when force acts tangentially to a surface area.
(2) Deforming force acts tangentially to the surface

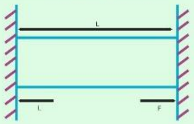
$\tan\theta = \frac{S}{h}$



THERMAL STRESS

(1) Difference in temperature of a rod results the change in configuration of it. This produces thermal stress.

$\frac{F}{A} = Y \propto \Delta T$

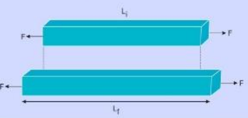


STRAIN & ITS TYPES

(1) Ratio of change in configuration to original configuration of body.
(2) It is a unit less quantity
(3) Strain = $\frac{\Delta \text{ configuration}}{\text{original configuration}}$

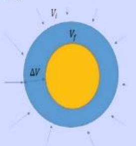
LINEAR STRAIN

(1) Linear strain is the ratio of change in length to original length.
(2) $\Sigma = \frac{\Delta\ell}{\ell}$



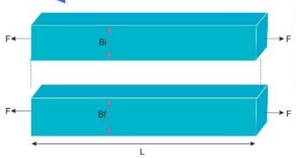
VOLUMETRIC STRAIN

(i) Ratio of change in volume to original volume.
(ii) $\Sigma = \frac{\Delta V}{V}$



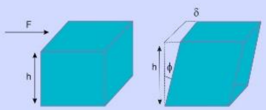
LATERAL STRAIN

(1) Lateral strain is ratio of change in breadth/ diameter to original breadth/ diameter.
(2) $\Sigma = \frac{\Delta(\text{Breadth / Diameter})}{\text{Breadth / Diameter}}$
(3) Change occurs in the direction perpendicular to the applied force.

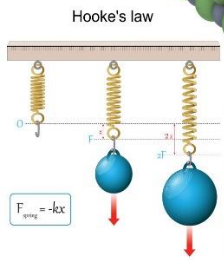


SHEAR STRAIN

(1) Angular deformation caused by shearing force is shearing strain.
(2) $\tan\theta = S/h$
(3) For small change $\theta = S/h$



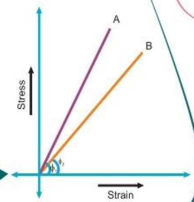
HOOKE'S LAW



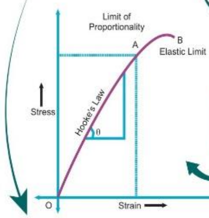
- When load is applied to bodies up to certain proportionality limit. stress is directly proportional to strain.
- $\sigma \propto \Sigma$
- $\sigma \propto Y\Sigma$
- $y = \frac{\sigma}{\Sigma}$, where Y is the proportionality constant named as Young's modules

STRESS-STRAIN GRAPH

Slope of stress strain curve will be Young's modulus

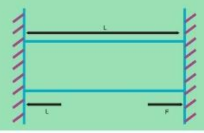


STRESS-STRAIN CURVE



THERMAL STRESS

(i) Energy stored due to elastic deformation.
(ii) Strain Energy density is energy per unit volume.
(iii) Strain Energy per unit volume = $\frac{1}{2} \times \sigma \times \Sigma$
(iv) Strain Energy per unit volume = $\frac{1}{2} \times \frac{(\sigma)^2}{y}$



POISSON'S RATIO

Ratio of lateral to longitudinal strain is Poisson's ratio

$\sigma = \frac{-\Sigma\text{lateral}}{\Sigma\text{longitudnal}} (-1 \le \sigma \le 0.5)$

Relation between Y, B, η and Σ
(1) Y = 3B (1 - 2σ).
(2) Y = 2N (1 + σ)
(3) $\sigma = \frac{3B - 2n}{2n + 6B}$

TYPES OF ELASTIC CONSTANTS

YOUNG'S MODULES = $\frac{\sigma}{\Sigma}$

- Property of material. that tells how easily it can be stretched.
- σ , E are normal stress and strains respectively

SHEAR MODULUS

- Ratio of shear stress by shear strain.
- Unit is pascal (Pa)

BULK MODULUS = $\frac{-\Delta P}{\Delta V / V}$

- Measure of ability of material to withstands the change in volume.
- Negative sign indicates decrease in volume

ISOTHERMAL BULK MODULUS
B = P

ADIABATIC BULK MODULUS
(1) B = YP.
(2) Y = Adiabatic constant

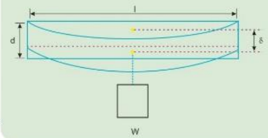
COMPRESSIBILITY = $1/B$

- Reciprocal of Bulk modulus
- Value depends on particle shape. density and chemical composition.

APPLICATIONS OF ELASTIC BEHAVIOUR OF SOLIDS

When weight is suspended in beam. it strouse buckling

$S = \frac{\omega\ell^3}{4bd^3y}$



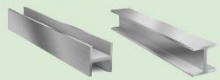
- Extension is measured in ropes of cranes while load is suspended on it

$\sigma = \frac{mg}{A}$

σ = stress produced in rope

I - SHAPED BEAMS

- I – Shape of beams makes them excellent for unidirectional bending.
- Use of rectangular shaped beams is not possible in railway tracks as of improper load distribution



Mechanical Properties of Solids

Elasticity is the property of the materials by virtue of which the bodies restore their natural shape and size on removal of the external (deforming) forces.

A perfect elastic body is one which completely regains its original form after the removal of the deforming forces e.g., a quartz fibre.

A perfect plastic body is one which does not regain its original form and remains in the deformed state. e.g., wet soil, wax, etc.

Stress

The restoring force developed per unit area of the body, when the body is subjected to a deforming force, is called stress.

Since the restoring force is equal and opposite to the external deforming force, the stress may be measured as the external force acting per unit area.

$$\therefore \text{Stress} = \frac{\text{external force applied}}{\text{area}} = \frac{F}{A}$$

Strain

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

There are three types of strain.

(a) longitudinal strain = $\dfrac{\text{change in length}}{\text{original length}} = \dfrac{\Delta l}{l}$

(b) volume strain = $\dfrac{\text{change in volume}}{\text{original volume}} = \dfrac{\Delta V}{V}$

(c) shearing strain is the ratio of the displacement of a layer in the direction of the tangential force and the distance of that layer from the fixed surface.

Hooke's law

Within elastic limit stress is directly proportional to strain.

i.e., stress $\propto$ strain or $\dfrac{\text{stress}}{\text{strain}}$ = constant

This constant is called modulus of elasticity.

Types of modulii of elasticity.

1. Young's Modulus of Elasticity 'Y'

Within elastic limit, the ratio of longitudinal stress to longitudinal strain is called Young's modulus of elasticity.

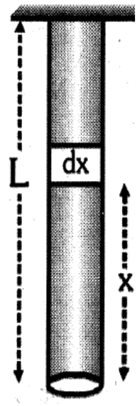
$$Y = \frac{\text{longitudinal stress}}{\text{longitudinal strain}} = \frac{F/A}{\ell/L} = \frac{FL}{\ell A}.$$

Within elastic limit, the normal force acting on a unit cross-sectional area of a wire due to which the length of the wire becomes double, is equivalent to the Young's modulus of elasticity of the material of the wire. If L is the original length of the wire, r is its radius and ℓ the increase in its length as a result of suspending a weight Mg at its lower end then Young's modulus of elasticity of the material of the wire is $Y = \dfrac{(Mg/\pi r^2)}{(\ell/L)} = \dfrac{MgL}{\pi r^2 \ell}$

Unit of Y : N/m^2 or pascal   Dimensions of Y : $[M^1L^{-1}T^{-2}]$

- **Increment of length due to own weight**

Consider a rope of mass M and length L hanging vertically. As the tension at different points on the rope is different, stress as well as strain will be different at different points.
(i) maximum stress will be at the point of suspension
(ii) minimum stress will be at the lower end.



Consider an element of rope of length dx at x distance from the lower end,

then tension there $T = \left(\frac{M}{L}\right) x\,g$

So stress $= \frac{T}{A} = \left(\frac{M}{L}\right)\frac{xg}{A}$

Let increase in length of this element be dy then strain $= \frac{dy}{dx}$

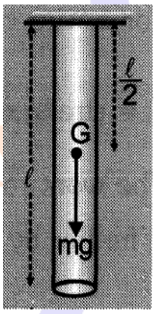
So, Young modulus of elasticity $Y = \frac{\text{stress}}{\text{strain}} = \frac{\frac{M}{L}\frac{xg}{A}}{dy/dx} \Rightarrow \left(\frac{M}{L}\right)\frac{xg}{A}\,dx = Ydy$

Summing up the expression for full length of the rope,

$$\frac{Mg}{LA}\int_0^L x dy = \int_0^{\Delta\ell} dy \Rightarrow \frac{Mg}{LA}\frac{L^2}{2} = Y\Delta\ell \Rightarrow \Delta\ell = \frac{MgL}{2AY}$$

[Since the stress is varying linearly we may apply the average method to evaluate strain.]

Alternate Method : Since the, weight acts at the centre of gravity, therefore



$\therefore$ The original length will be taken as $\frac{\ell}{2}$ $\therefore Y = \frac{Mg \times \frac{\ell}{2}}{A \times \Delta\ell} \Rightarrow \Delta\ell = \frac{Mg\ell}{2AY}$

But $M = (\ell A)\rho$ $\quad \therefore \Delta\ell = \frac{\ell A\rho g\ell}{2AY}$ or $\Delta\ell = \frac{\rho g\ell^2}{2Y}$

2. Bulk's modulus of elasticity 'K' or 'B'

Within elastic limit, the ratio of the volume stress (i.e., change in pressure) to the volume strain is called bulk's modulus of elasticity.

$$K \text{ or } B = \frac{\text{volume stress}}{\text{volume strain}} = \frac{F/A}{\frac{-\Delta V}{V}} = \frac{\Delta P}{\frac{-\Delta V}{V}}$$

The minus sign indicates a decrease in volume with an increase in stress and vice-versa.

Unit of K : M/m^2 or pascal

Compressibility 'C'

The reciprocal of bulk's modulus of elasticity is defined as compressibility.

$C = \frac{1}{K}$; SI unit of C : m^2/N or pascal^{-1}

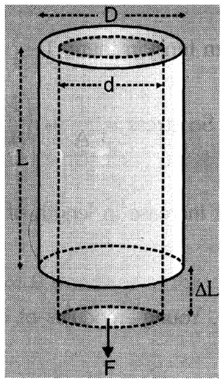
3. Modulus of Rigidity 'η'

Within elastic limit, the ration of shearing stress to shearing strain is called modulus of rigidity of a material

$$\eta = \frac{\text{shearing stress}}{\text{shearing strain}} = \left(\frac{\frac{F_{tangential}}{A}}{\phi}\right) = \frac{F_{tangential}}{A\phi}$$

Note : Angle of shear 'ϕ' is always taken in radians

4. Poisson's Ratio (σ)



Within elastic limit, the ratio of lateral strain to the longitudinal strain is called Poisson's ratio.

$$\sigma = \frac{\text{lateral strain}}{\text{longitudinal strain}} = \frac{\beta}{\alpha}$$

$$\beta = \frac{-\Delta D}{D} = \frac{d - D}{d} \text{ and } \alpha = \frac{\Delta L}{L}$$

$-1 \le \sigma \le 0.5$ (theoretical limit)

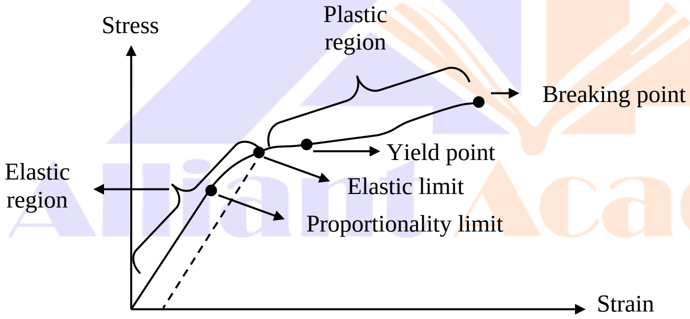
$\sigma \approx 0.2 - 0.4$ (experimental limit)

- **Relation between Y, K, η and σ :** (To be remembered)

$$Y = 3K(1 - 2\sigma), \qquad Y = 2\eta(1 + \sigma), \quad \frac{9}{Y} = \frac{3}{\eta} + \frac{1}{K}.$$

> ☞ Reciprocal of bulk modulus is called compressibility.

The stress v/s strain graph for a wire under the action of deforming forces is as shown below:



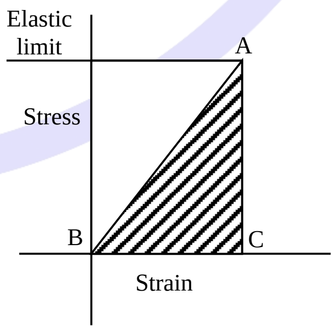
Elastic potential energy in a stretched wire

The elastic potential energy stored in a wire stretched by a length l is given by $U = \frac{AY}{2L} l^2$

where L is the original length of the wire

A is the cross-section of the wire

Y is the Young's modulus of the wire.



The above expression may be expressed as

$U = \frac{1}{2} \times$ maximum stretching force $\times$ extension

or $U = \frac{1}{2} \times \text{stress} \times \text{strain} \times \text{volume}$

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

The energy stored by a member within elastic limit is called elastic potential energy. The Area under the stress shown give within elastic limit will be elastic potential energy.

= Area of triangle ABC = $\frac{1}{2}$

Factor Affecting Elasticity

- **Effect of Temperature**

$T \uparrow \Rightarrow Y \downarrow$ Due to weakness of intermolecular force.

When temperature is increased, the elastic properties in general decreases i.e. elastic constants decrease. Plasticity increases with temperature.

For a special kind of steel, elastic constants do not vary appreciably with temperature. This steel is called INVAR steel.

- **Effect of Impurities**

  Y slightly increases with impurities. The inter molecular attraction strengthens impurities consequently, external deformation can be more effectively opposed.

- **Interatomic Force Constant :**

  k or $k_a = Y.\, r_0$

  Y = Young's modulus ; r_0 = interatomic distance under normal circumstances

Poisson's ratio

When a wire is stretched, its length increases, but at the same time its diameter also decreases. The ratio of change in diameter te the original diameter is called lateral strain within elastic limit. The ratio of change in length to original length is called longitudinal strain. The ratio of lateral strain to longitudinal strain is a constant, characteristic of the material and is called, Poisson's ratio (σ)

$$\therefore \text{Poisson's ratio}, \sigma = \frac{\text{lateral strain}}{\text{longitudin al strain}} = \frac{\Delta D / D}{\Delta L / L}$$

The value of σ is found to lie between 0 and 0.5

Application of Elastic Behaviour of Materials :

(1) Crane

Cross-sectional area $A \geq \frac{W}{S_y} = \frac{mg}{S_y}$

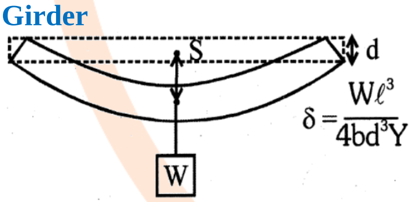
S_y = yield strength or breaking stress; W = weight of the object being lifted.

e.g. for 10 metric tone load

S_y for steel being 300×10^6 N/m^2

$A \geq 3.3 \times 10^{-4}$ m^2

(2) Girder



$$\delta = \frac{W\ell^3}{4bd^3Y}$$

Cross-section of different girders

(3) Max height of mountain

$H\rho g$ = breaking stress / tensile strength for a rock = 30×10^7 N/m^2

Illustrations

1. Consider an iron rod of length 1 m and a cross-section of 1 cm^2 with Young's modulus of 10^{12} dyne cm^{-2} The force with which the two ends must be pulled to produce an elongation of 1 mm is

   (A) 10^9 dyne (B) 10^8 dyne (C) 10^6 dyne (D) 10^{17} dyne

Ans (A)

$$F = YA\frac{\Delta l}{l} = 10^{12} \times 1 \times \frac{0.1}{100} = 10^{9} \text{ dyne}$$

2. A spherical ball contracts in volume by 0.01 % when subjected to a normal uniform pressure of 100 atmospheres. The bulk modulus of its material in dyne cm^{-2} is

(A) 10×10^{10} (B) 100×10^{2} (C) 1×10^{12} (D) 2×10^{11}

Ans (C)

$$\frac{\Delta V}{V} = \frac{0.01}{100}$$

$p = 100 \times 1.01 \times 10^{6}$ dyne cm^{-2}

$$K = \frac{p}{\frac{\Delta V}{V}} = \frac{100 \times 1.01 \times 10^{6}}{0.01/100} = 10^{12} \text{ dyne cm}^{-2}$$

3. A steel ring of radius r and cross-sectional area A is fitted to a wooden disc of radius R(R > r). If Young's modulus is Y, the force with which the steel ring is expanded is

(A) $AY\frac{R}{r}$ (B) $AY\left(\frac{R-r}{r}\right)$ (C) $\frac{Y}{A}\left(\frac{R-r}{r}\right)$ (D) $\frac{Yr}{AR}$

Ans (B) : Strain $= \frac{\Delta l}{l} = \frac{2\pi R - 2\pi r}{2\pi r} = \frac{R-r}{r}$

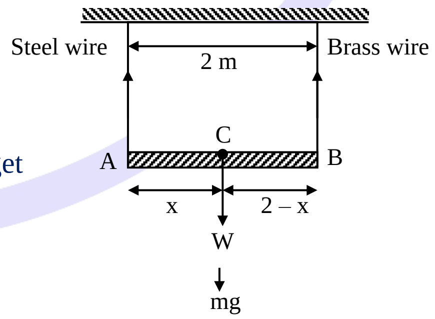
Stress $= Y \times$ strain $= \frac{F}{A}$

$\therefore F = YA \times \text{strain} = YA\left(\frac{R-r}{r}\right)$

4. A light rod of length 2 m is suspended horizontally from the ceiling of a stationary elevator by means of two vertical wires of equal lengths tied to its ends. One of the wires is made of steel ($Y = 2 \times 10^{11}$ N m^{-2}) and is of cross-section 10^{-3} m^2; and the other is of brass ($Y = 10^{11}$ N m^{-2}) of cross-section 2×10^{-3} m^2. Find the position along the rod at which a weight may be hung to produce equal stress in both the wires

(A) 1 m (B) 1.5 m (C) 1.33 m (D) 0.75 m

Ans (C)



If stresses in both wires are equal, then

$$\frac{T_1}{A_1} = \frac{T_2}{A_2} \quad \therefore \frac{T_1}{T_2} = \frac{A_1}{A_2} = \frac{10^{-3}}{2 \times 10^{-3}} = \frac{1}{2} \qquad \ldots (1)$$

Since the system is in equilibrium, taking moments about C, we get

$$T_1 x = T_2(2 - x) \text{ or } \frac{T_1}{T_2} = \frac{2-x}{x} \qquad \ldots (2)$$

From (1) and (2), $\frac{2-x}{x} = \frac{1}{2}$ or $x = 1.33$ m

5. In the above problem find the position along the rod at which a weight may be hung to produce equal strain in both the wires

(A) 1 m (B) 1.5 m (C) 1.33 m (D) 0.75 m

Ans (A) If the strains are equal,

$$\frac{T_1/A_1}{Y_1} = \frac{T_2/A_2}{Y_2} \qquad \left(\because \text{strain} = \frac{\text{stress}}{Y}\right)$$

$$\therefore \frac{T_1}{T_2} = \frac{A_1 Y_1}{A_2 Y_2} = \frac{1 \times 10^{-3} \times 2 \times 10^{11}}{2 \times 10^{-3} \times 10^{11}} = 1 \qquad \ldots (3)$$

Again, taking moments about C, we have

$T_1x = T_2(2 - x)$ or $\frac{T_1}{T_2} = \frac{2-x}{x}$ … (4)

i.e., $1 = \frac{2-x}{x} \Rightarrow x = 1$ m.

6. A thick rope of density 1.5×10^3 kg m^{-3} and Young's modulus 5×10^6 Nm^{-2}, 8 m in length is hung from the ceiling of a room. The increase in its length due to its own weight is

(A) 9.6×10^{-5} m (B) 19.2×10^{-7} m (C) 9.6×10^{-2} m (D) 9.6×10^{-3} m

Ans (D)

$$Y = \frac{W/A}{\Delta L/L} \Rightarrow \Delta L = \left(\frac{W}{A}\right)\left(\frac{L}{Y}\right) = \left(\frac{1.5\times10^3 \times A \times 8 \times 10}{A}\right)\left(\frac{4}{5\times10^6}\right) = 9.6\times10^{-3} \text{ m}$$

Observe that the weight is assumed to act at half the length of the hanging wire.

7. A steel wire of length 20 cm and uniform cross section 1 mm^2 is tied rigidly at both the ends. The temperature of the wire is altered from 40°C to 20°C. The coefficient of linear expansion for steel is 1.1×10^{-5} K^{-1} and the Young's modulus of steel is 2.0×10^{11} Nm^{-2}. The change in tension of the wire is

(A) 22 N (B) 44 N (C) 16 N (D) 8 N

Ans (B)

Thermal tension, $F = YA\,\alpha\,\Delta\theta = 2 \times 10^{11} \times 10^{-6} \times 1.1. \times 10^{-5} \times 20 = 44$ N

8. Two wires A and B are made of same material. Their lengths are in the ratio 1 : 2 and their diameters are in the ratio 2 : 1. If they are pulled by the same force, their increase in length will be in the ratio

(A) 2 : 1 (B) 8 : 1 (C) 1 : 8 (D) 1 : 4

Ans (C)

$$\Delta L = \left(\frac{F}{A}\right)\left(\frac{L}{Y}\right) = \left(\frac{4F}{\pi d^2}\right)\left(\frac{L}{Y}\right) \propto \frac{L}{d^2}$$

$$\frac{\Delta L_A}{\Delta L_B} = \frac{L_A}{L_B}\left(\frac{d_B}{d_A}\right)^2 = \left(\frac{1}{2}\right)\left(\frac{1}{2}\right)^2 = \frac{1}{8}$$

9. A load of 4 kg is suspended from a ceiling through a steel wire of length 20 m and radius 2 mm. It is found that the length of the wire increases by 0.031 mm, as equilibrium is achieved. If $g = 3.1 \times \pi$ ms^{-2}, the value of Young's modulus is

(A) 2×10^{12} N m^{-2} (B) 4×10^{11} N m^{-2} (C) 2×10^{11} N m^{-2} (D) 0.02×10^9 N m^{-2}

Ans (A)

Length of the wire is $l = 20$ m

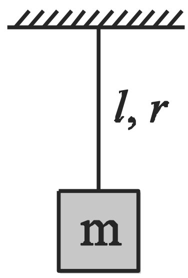
Radius of wire is $r = 2 \times 10^{-3}$ m

Increase in length is

$\Delta l = 0.031 \times 10^{-3}$ m

$g = 3.1 \times \pi$ ms^{-2}

Load is $F = mg = 4 \times 3.1 \times \pi$ N



Young's modulus of material of wire is

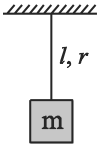
$$Y = \frac{Fl}{A\Delta l} = \frac{Fl}{\pi r^2 \Delta l}$$

$$\therefore Y = \frac{4 \times 3.1 \times \pi \times 20}{\pi(2\times10^{-3})^2 \times 0.031 \times 10^{-3}} = 2\times10^{12} \text{ Nm}^{-2}$$

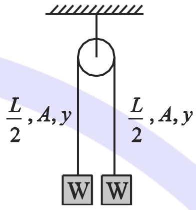
10. A wire elongates by l mm when a load W is suspended from it. If the wire gets over a pulley (equally on both the sides) and two weights W each are hung at the two ends, the elongation of the wire will be

(A) zero (B) $\frac{l}{2}$ (C) l (D) 2l

Ans (C)



Extension in the first case is $l = \frac{FL}{AY}$



Extension in the second case is

$$l' = \frac{\frac{FL}{2}}{AY} + \frac{\frac{FL}{2}}{AY} = \frac{FL}{AY}$$

It is clear that $l' = l$

11. If stress is numerically equal to Young's modulus, the elongation will be

(A) 1/4 the original length (B) 1/2 the original length

(C) equal to the original length (D) twice the original length

Ans (C)

$$Y = \frac{\text{stress}}{\text{strain}},$$

If Y = stress, strain = 1 or $\frac{\Delta l}{l} = 1 \Rightarrow \Delta l = l$

12. On taking a solid rubber ball from the surface to the bottom of a lake 200 m deep, the reduction in volume is found to be 0.5%. If the density of water is 1000 kg m^{-3} and $g = 10 \text{ ms}^{-2}$, the bulk modulus of rubber is

(A) 2×10^8 Pa (B) 4×10^8 Pa (C) 6×10^8 Pa (D) 8×10^8 Pa

Ans (B)

$$\frac{\Delta V}{V} \times 100 = -0.5 \text{ (given)}$$

Increase in pressure,

$P = \rho gh = 1000 \times 10 \times 200 = 2 \times 10^6$ Pa

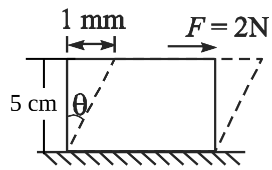
$$B = -\frac{P}{\frac{\Delta V}{V}} = \frac{-2 \times 10^6}{-0.5 \times 10^{-2}} = 4 \times 10^8 \text{ Pa}$$

13. A cube of rubber with edge length 5 cm has a force of 2 N applied horizontally to the top face, parallel to an edge, while the bottom face is held fixed. If the top face is displaced horizontally through a distance of 1 mm, the shear modulus of the rubber is

(A) $3 \times 10^4 \text{ Nm}^{-2}$ (B) $2 \times 10^4 \text{ Nm}^{-2}$ (C) $6 \times 10^4 \text{ Nm}^{-2}$ (D) $4 \times 10^4 \text{ Nm}^{-2}$

Ans (D)

Shear modulus, $N \text{ or } G = \frac{F/A}{\tan\theta}$



$$\tan\theta = \frac{10^{-3}}{5 \times 10^{-2}} = 0.02 \text{ rad} \qquad N \text{ or } G = \frac{\frac{2}{25 \times 10^{-4}}}{0.02} = 4 \times 10^4 \text{ Nm}^{-2}$$

14. A bar of cross-section A is subjected to equal and opposite tensile forces at its ends. Consider a plane section of the bar, whose normal makes an angle ϕ with the axis (along with the length) of the bar. The shearing stress on this plane is

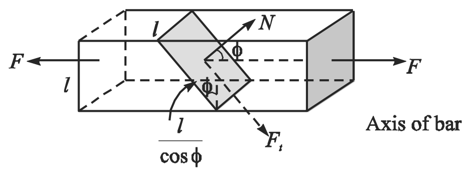
(A) $\frac{F}{A}\cos^2\phi$ (B) $\frac{F}{A}\sin^2\phi$ (C) $\frac{F}{A}\tan\phi$ (D) $\frac{F}{A}\sin\phi\cos\phi$

Ans (D)

Tangential force is $F_t = F\sin\phi$

Area of section considered is $A' = l\cdot\dfrac{l}{\cos\phi} = \dfrac{l^2}{\cos\phi} = \dfrac{A}{\cos\phi}$

$\therefore$ Shearing stress $= \dfrac{F_t}{A'} = \dfrac{F\sin\phi}{\dfrac{A}{\cos\phi}} = \dfrac{F}{A}\sin\phi\cos\phi$



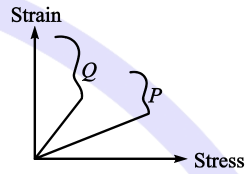
15. Figure shows the stress-strain curves of two metals P and Q. From the graph it can be concluded that

(A) Q has greater Young's modulus and lesser ductility

(B) P has greater Young's modulus and lesser ductility

(C) P has greater Young's modulus and greater ductility

(D) Q has greater Young's modulus and greater ductility



Ans (B)

Stress and strain are plotted against X and Y axes. So, the Young's modulus of the substance, within the proportionality limit is given by the reciprocal of the slope of stress-strain curve.

The measure of ductility is obtained as the length of the stress-strain curve between the yield point and ultimate load.

16. Which of the following is/are true?

(i) in the language of physics steel is more elastic than rubber

(ii) in the language of physics water is more elastic than air.

(A) (i) (B) (ii) (C) (i) and (ii) (D) neither (i) nor (ii)

Ans (C)

A smaller change in shape or size under the action of same force corresponds to higher elasticity.

For identical steel and rubber bars, under the action of same force, rubber stretches more. So rubber is less elastic than steel. For equal volumes of water and air, under the action of same pressure, water gets compressed less. So water is more elastic than air.

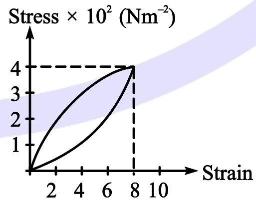
17. A rubber material of volume 2000 cc, is alternately subjected to tension and released. The figure shows the stress-strain curve of rubber. Each curve is a quadrant of an ellipse. The amount of energy lost as heat per cycle is

(A) 1.83 J

(B) 1.37 J

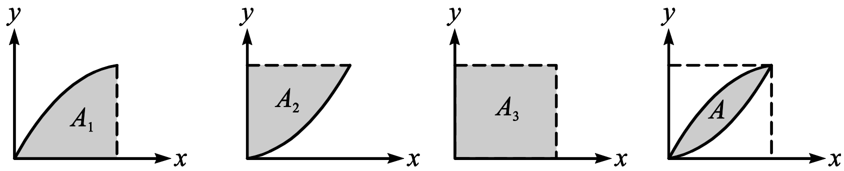
(C) 3.65 J

(D) 5.03 J



Ans (C)

Hysterisis loss corresponding to elasticity per unit volume of a substance is given by the area of the hysterisis loop i.e. stress-strain curve corresponding to one complete loading and deloading.



Area of an ellipse = π × semi major axis × semi minor axis.

$A_1 = \frac{1}{4}(\pi\times 8\times 4\times 10^2)$ and $A_2 = \frac{1}{4}(\pi\times 8\times 4\times 10^2)$

$A_3 = 8\times 4\times 10^2$

$\therefore$ Area of hysterisis loop is $A = A_1 + A_2 - A_3$

$$= 2\left[\frac{\pi}{4}\times 8\times 4\times 10^{2}\right] - 8\times 4\times 10^{2} = 1826.55\ \text{J m}^{-3}$$

Total hysterisis loss = 1826.55 × volume = 1826.55 × 2000 × 10^{-6} = 3.653 J

NCERT LINE BY LINE QUESTIONS

1. Which of the following materials is/are close to ideal plastics? [NCERT, XI Pg. 235]
   (1) Putty (2) Mud (3) Steel (4) Both(1)&(2)
2. The restoring mechanism in solids can be visualized by taking a model of [NCERT, XI Pg. 236]
   (1) Spring-ball system (2) Atwood machine
   (3) Plum - Pudding (4) Liquid - Drop
3. Bulk modulus is relevant for [NCERT. XI Pg.246)
   (1) Solids only (2) Solid (3) Fluids (4) Both (2) & (3)
4. The strain produced by a hydraulic pressure is called [NCERT, XI Pg. 238]
   (1) Longitudinal strain (2) Shearing strain
   (3) Volume strain (4) Both(1)&(2)
5. The ratio of stress and strain, within proportional limit is called [NCERT, XI Pg. 239]
   (1) Modulus of elasticity (2) Compressibility
   (3) Poisson's ratio (4) Both (2) & (3)

6. For most materials [NCERT, XI Pg. 242]

(1) $G \approx \frac{Y}{3}$ (2) $G \approx \frac{Y}{2}$ (3) $G \approx 3Y$ (4) $G \approx 2Y$

7. The strain perpendicular to the applied force is called [NCERT, XI Pg. 244]

(1) Longitudinal strain (2) Volume strain
(3) Lateral strain (4) Shear strain

8. For aluminium alloys Poisson's ratio is about [NCERT, XI Pg. 244]

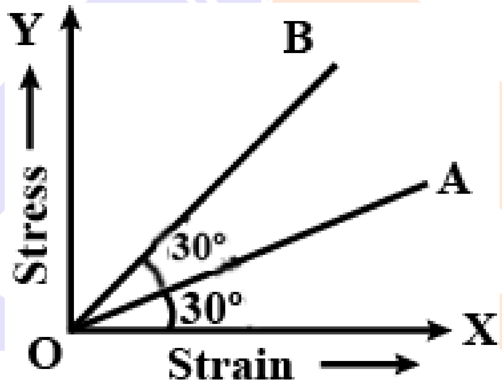
(1) 0.20 (2) 0.16 (3) 0.33 (4) 0.40

9. The average depth of Indian ocean is about 3000 m. The fractional compression, $\frac{\Delta V}{V}$ of water at the bottom of the ocean is $(B = 2\times10^9\,Nm^{-2}, g = 10\,ms^{-2})$

[NCERT, XI Pg. 243]

(1) 1.5% (2) 2.5% (3) 4% (4) 3%

10. In the graph shown, if the Young's Modulus of material *A* is V, then the Young's Modulus for material B is [NCERT, XI Pg. 238]

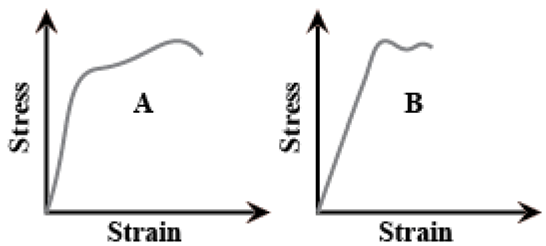


(1) $\sqrt{3}Y$ (2) V/3 (3) 3Y (4) 2Y

11. The volume contraction of a solid copper cube. 10 cm on an edge, when subjected to a hydraulic pressure of 10^7 Pa is (B» 14010^9 N m^{-2}) [NCERT. XI Pg. 248]

(1) 0.07 cm^3 (2) 0.03 cm^3 (3) 0.02 cm^3 (4) 0.01 cm^3

12. The stress-strain graphs for materials A and B are as shown in figure



The correct Statement is [NCERT, XI Pg_ 247]

(1) A is having greater Young's modulus ard B is stronger
(2) B is having greater Young's modulus ard A is stronger
(3) B is having greater Young's modulus ard it is stronger as well
(4) A is having greater Young's modulus ard it is stronger as well

13. The edge of an aluminum cube is 10 cm. One face of the cube is firmly fixed to a vertical wall. A mass of 100 kg is attached to the opposite face of the cube. The vertical deflection of this face is $(G = 25\times10^9$ Pa) [NCERT, XI Pg. 248]

(1) 4×10^{-7}m (2) 3×10^{-6} m (3) 2×10^{-6} m (4) 1×10^{-6}m

14. A rigid bar of mass 15 kg is supported symmetrically by three wires each 2.0 m long. Those at each end are of Copper and the middle one is of iron. If tension in each rod is same, the ratio of diameters is nearly [NCERT, XI Pg. 248]

(1) 6 (2) 0.8 (3) 4.2 (4) 2.0

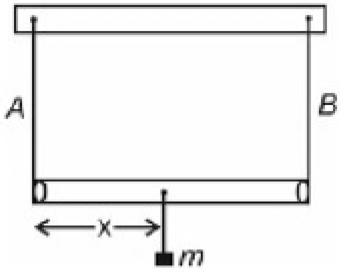
15. The density of water at a depth where pressure is 80.0 atm (Given density at the surface is 1.03 x 10^3 kg m^{-3}, $B = 2.2\times10^9$ N nr^2) [NCERT, XI Pg. 248]

(1) $1.034\times$ 10kg m^{-3} (2) 1.34×10^3 kg m^{-3}

(3) 1.64×10^3kg m^{-3} (4) 2.084×10^3kg m^{-3}

16. A rod of length 1.05 m having negligible mass is supported at its ends by two wires of steel (wire A) and aluminum (wire B) of equal lengths as shown in figure. The cross-sectional areas of wire ***A*** and ***B*** are 2.0 mm^2 and 4.0 mm^2, respectively. The distance x from left end, where a mass m is suspended in order to produce equal stresses, is

$(Y_{steel} = 2\times10^{11}\,Nm^{-2}, Y_{Al} = 7\times10^{10}\,Nm^{-2})$ [NCERT. XI Pg 249]



(1) 70 cm (2) 35 cm (2) 43.2 cm (4) 40 cm

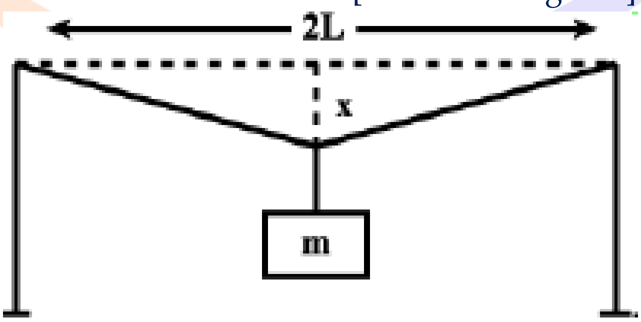
17. In Q16, the distance x from left end to produce equal strains is [NCERT. XI Pg 249.)

(1) 70 cm (2) 43.2 cm (3) 65 cm (4) 35 cm

18. A 15 kg mass, fastened to the end of a steel wire of unstretched length 1.0 m, is whirled in a vertical circle with an angular velocity of 4TT radian's at the bottom of the circle. The cross-sectional area of the wire is 0.065 cm^2. The elongation of the wire when the mass is at the lowest point is (g = 10 m/s^2) [NCERT, XI Pg. 248]

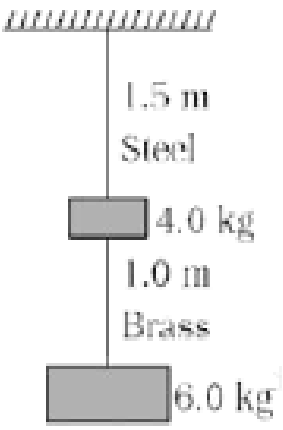
(1) 1.93 mm (2) 2.05 mm (3) 1.65 mm (4) 3.05 mm

19. A mild steel wire of length 2L and cross-sectional area ***A*** is stretched, within elastic limit, horizontally between two pillars as shown in the figure. A mass m is suspended from the mid-point of the wire. Strain in the wire is [NCERT. XI Pg. 249]



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

20. Two wires of diameter 0.25 cm, one made of steel and the other made of brass are loaded as shown in the figure. The unloaded length of steel wire is 1.5 m and that of brass wire is 1.0 m. The ratio of tensile stress in steel to brass wire is (g = 10 m/s^2) [NCERT, XI Pg. 248]



1) $\frac{5}{9}$ 2) $\frac{5}{2}$ 3) $\frac{3}{2}$ 4) $\frac{4}{3}$

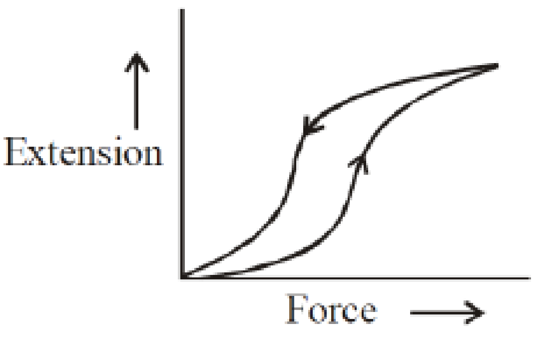
NCERT BASED PRACTICE QUESTIONS

1. If the length of a wire is reduced to half, then it can hold the
(a) half load (b) same load
(c) double load (d) one fourth load

2. The Young's modulus of a perfectly rigid body is
(a) unity (b) zero (c) infinity (d) some finite non-zero constant

3. According to Hooke's law of elasticity, if stress is increased, then the ratio of stress to strain
(a) becomes zero (b) remains constant
(c) decreases (d) increases

4. The diagram shows a force - extension graph for a rubber band. Consider the following statements :
I. It will be easier to compress this rubber than expand it
II. Rubber does not return to its original length after it is stretched
III. The rubber band will get heated if it is stretched and released



Which of these can be deduced from the graph?
(a) III only (b) II and III (c) I and III (d) I only

5. A 2 m long rod of radius 1 cm which is fixed from one end is given a force of 8 N. The longitudinal strain developed will be [take g = 2.5×10^{11} N/m2]
(a) 10^{-8} (b) 10^{-6} (c) 10^{-5} (d) 10^{-4}

6. The restoring force per unit area is known as
(a) strain (b) elasticity (c) stress (d) plasticity

7. In magnitude hydraulic stress is equal to

(a) hydraulic force (b) hydraulic pressure
(c) restoring force (d) hydraulic strain

8. Substances which can be stretched to cause large strains are called
(a) brittle (b) ductile (c) plastic (d) elastomer

9. The reason for the change in shape of a regular body is
(a) volume stress (b) shearing strain (c) longitudinal strain (d) metallic strain

10. Longidudinal stress depends on
(a) area (b) length (c) volume (d) mass

11. If h = s hear mokulus and g = young's modulus, then in general
(a) $g > h$ (b) $g = h$ (c) $g < h$ (d) none of these

12. Which of the following affects the elasticity of a substance?
(a) Hammering and annealing (b) Change in temperature
(c) Impurity in substance (d) All of the above

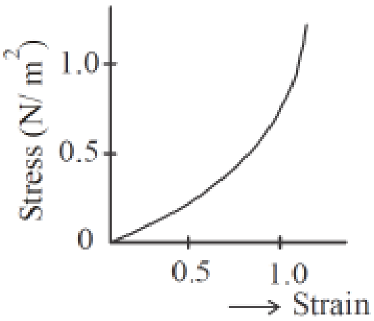
13. If the load is increased beyond the _______ point, the strain increases rapidly for even a small change in the stress.
(a) elastic point (b) yield point (c) plastic point (d) fracture point

14. What is the phenomenon of temporary delay in regaining the original configuration by an elastic body, after the removal of a deforming force?
(a) Elastic fatigue (b) Elasticity
(c) Plasticity (d) Elastic after effect

15. Which of the following types of stress causes no change in shape?
(a) compressive stress (b) hydraulic stress
(c) oblique stress (d) none of these

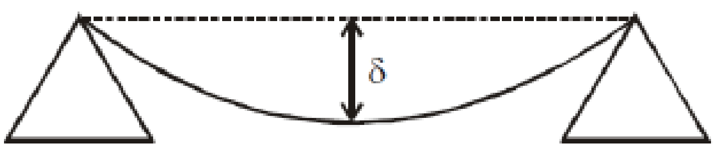
16. A vertical metal cylinder of radius 2 cm and length 2 m is fixed at the lower end and a load of 100 kg is put on it. Find the strain. [Youn's modulus of the metal = $2 \times 10^{11} N/m^2$]
(a) 4×10^{-6} (b) 3×10^{-8} (c) 2×10^{-9} (d) 6×10^{-8}

17. The graph given is a stress-strain curve for



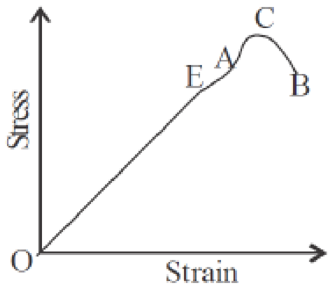
(a) elastic objects (b) plastics (c) elastomers (d) None of these

18. A beam of metal supported at the two edges is loaded at the centre. The depression at the centre is proportional to



(a) Y^2 (b) Y (c) $1/Y$ (d) $1/Y^2$

19. For the given graph, Hooke's law is obeyed in the region



(a) OA (b) C (c) OE (d) OB

20. If the ratio of radii of two wires of same material is 3 : 1 and ratio of their lengths is 5 : 1, then the ratio of the normal forces that will produce the same extension in the length of two wires is

(a) 2 : 1 (b) 4 : 1 (c) 1 : 4 (d) 1 : 1

21. An iron bar of length l cm and cross section A cm2 is pulled by a force of F dynes from ends so as to produce an elongation Dl cm. Which of the following statement is correct?

(a) Elongation is inversely proportional to length

(b) Elongation is directly proportional to cross section A

(c) Elongation is inversely proportional to crosssection

(d) Elongation is directly proportional to Young's modulus

22. Two wires of equal lengths are made of the same material. Wire A has a diameter that is twice as that of wire B. If identical weights are suspended from the ends of these wires, the increase in length is

(a) four times for wire A as for wire B

(b) twice for wire A as for wire B

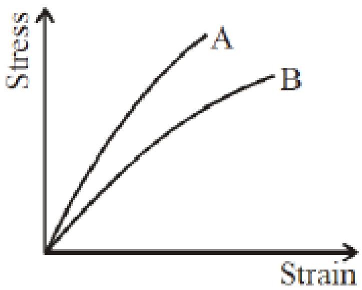
(c) half for wire A as for wire B

(d) one-fourth for wire A as for wire B

23. Two persons pull a rope towards themselves. Each person exerts a force of 100 N on the rope. Find the Young's modulus of the material of the rope if it extends in length by 1 cm. Original length of the rope = 2 m and the aea of cross-section = 2 cm2.

(a) 10^8 N/m^2 (b) 10^7 N/m^2 (c) 10^6 N/m^2 (d) 10^5 N/m^2

24. **Assertion :** The stress-strain graphs are shown in the figure for two materials A and B are shown in figure. Young's modulus of A is greater than that of B.



Reason : The Young's modules for small strain is, y=stress/strain= slope of linear portion, of graph; and slope of A is more than slope that of B.

(a) Assertion is correct, reason is correct; reason is a correct explanation for assertion.

(b) Assertion is correct, reason is correct; reason is not a correct explanation for assertion

(c) Assertion is correct, reason is incorrect

(d) Assertion is incorrect, reason is correct

25. When forces are applied on a body such that it is still in static equilibrium, then the extent to which the body gets deformed, depends on

(a) nature of the material (b) magnitude of deforming force

(c) Both (a) & (b) (d) None of these

26. A steel wire of length l and cross section area A is stretched by 1 cm under a given load. When the same load is applied to another steel wire of double its length and half of its cross section area, the amount of stretching (extension) is

(a) 0.5 cm (b) 2 cm (c) 4 cm (d) 1.5 cm

27. Two wires are made of the same material and have the same volume. However wire 1 has cross-sectional area A and wire 2 has cross-sectional area $9A$. If the length of wire 1 increases by Δx on applying force F, how much force is needed to stretch wire 2 by the same amount?

(a) 16 F (b) 25 F (c) 81 F (d) 64 F

28. A wire elongates by l mm when a load W is hanged from it. If the wire goes over a pulley and two weights W each are hung at the two ends, the elongation of the wire will be (in mm)

(a) l (b) $2l$ (c) zero (d) $l/2$

29. A thick rope of density ρ and length L is hung from a rigid support. The Young's modulus of the material of rope is Y. The increase in length of the rope due to its own weight is

(a) $(1/4)\ \rho g L^2/Y$ (b) $(1/2)\ \rho g L^2/Y$

(c) $\rho g L^2/Y$ (d) $\rho g L/Y$

30. Which of the following elastic moduli is used to describe the elastic behaviour of object as they respond to the deforming forces acting on them?

(a) Young's modulus (b) Shear modulus

(c) Bulk modulus (d) All of these

31. Which of the following is the correct relation? Y =Young's modulus & G = modulus of rigidity?

(a) $Y < G$ (b) $Y > G$ (c) $Y = G$ (d) None of these

32. The isothermal bulk modulus of a gas at atmospheric pressure is

(a) 1 mm of Hg (b) 13.6 mm of Hg

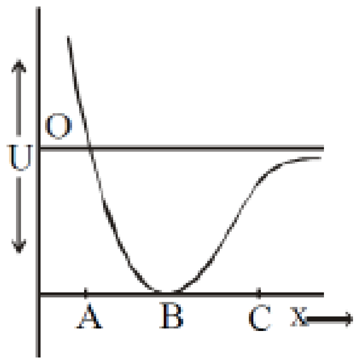
(c) 1.013×10^5 N/m2 (d) 2.026×10^5 N/m2

33. The ratio of shearing stress to the corresponding shearing strain is called

(a) bulk modulus (b) Young's modulus

(c) modulus of rigidity (d) None of these

34. The potential energy U between two atoms in a diatomic molecules as a function of the distance x between atoms has been shown in the figure. The atoms are



(a) attracted when x lies between A and B and are repelled when x lies between B and C

(b) attracted when x lies between B and C and are repelled when x lies between A and B

(c) are attracted when they reach B from C

(d) are repelled when they reach B from A

35. Select the correct statement(s) from the following.

I. Modulus of rigidity for a liquid is not zero

II. Young's modulus of a material decreases with rise in temperature

III. Poisson's ratio is unitless

(a) I only (b) II only (c) I and II (d) II and III

36. A metallic wire of length 2.0 m is elongated by 2.0 mm. Area of cross-section of the wire is 4.0 mm2. The elastic potential energy stored in the wire in elongated condition is [young's modulus of the metallic wire is = 2×10^{11} N/m2]

(a) 8.23 (b) 0.83 (c) 6.23 (d) 0.63

37. **Assertion :** Bulk modulus of elasticity (k) represents incompressibility of the material.

Reason : Bulk modulus of elasticity is proportional to change in pressure.

(a) Assertion is correct, reason is correct; reason is a correct explanation for assertion.

(b) Assertion is correct, reason is correct; reason is not a correct explanation for assertion

(c) Assertion is correct, reason is incorrect

(d) Assertion is incorrect, reason is correct.

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

(a) 0.01 (b) 0.06 (c) 0.02 (d) 0.03

39. **Assertion :** Identical springs of steel and copper are equally stretched. More work will be done on the steel spring

Reason : Steel is more elastic than copper.

(a) Assertion is correct, reason is correct; reason is a correct explanation for assertion.

(b) Assertion is correct, reason is correct; reason is not a correct explanation for assertion

(c) Assertion is correct, reason is incorrect

(d) Assertion is incorrect, reason is correct.

40. The Poisson's ratio of a material is 0.5. If a force is applied to a wire of this material, there is a decrease in the crosssectional area by 4%. The percentage increase in the length is :

(a) 1% (b) 2% (c) 2.5% (d) 4%

41. A 5 metre long wire is fixed to the ceiling. A weight of 10 kg is hung at the lower end and is 1 metre above the floor. The wire was elongated by 1 mm. The energy stored in the wire due to stretching is

(a) zero (b) 0.05 joule (c) 100 joule (d) 500 joule

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

(a) 0.2 J (b) 10 J (c) 20 J (d) 0.1 J

43. A spherical ball contracts in volume by 0.02% when subjected to a pressure of 100 atmosphere. Assuming one atmosphere = 105 N m^{-2}, the bulk modulus of the material of the ball is

(a) 0.02×10^5 N/m^2 (b) 0.02×10^7 N/m^2

(c) 50×10^7 N/m^2 (d) 50×10^9 N/m^2

44. The bulk moduli of ethanol, mercury and water are given as 0.9, 25 and 2.2 respectively in units of 109 Nm–2. For a given value of pressure, the fractional compression in volume is $\frac{\Delta V}{V}$. Which of the following statements about $\frac{\Delta V}{V}$ for these three liquids is correct?

(a) Ethanol > Water > Mercury

(b) Water > Ethanol > Mercury

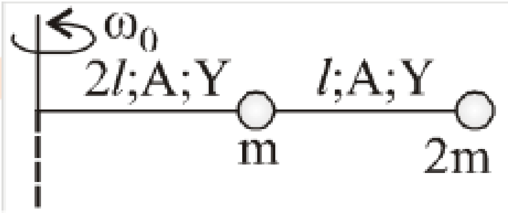
(c) Mercury > Ethanol > Water

(d) Ethanol > Mercury > Water

45. A material has poisson's ratio 0.50. If a uniform rod of it suffers a longitudinal strain of 2×10^{-3}, then the percentage change in volume is

(a) 0.6 (b) 0.4 (c) 0.2 (d) Zero

46. The system is rotated with angular speed w0 (see figure). What is the ratio of energy stored in each wire?



(a) 31:9 (b) 50:9 (c) 47:9 (d) 8:9

47. When a force is applied on a wire of uniform cross-section area 3 × 10–6 m2 and length 4m, the increase in length is 1 mm. Energy stored in it will be (Y = 2 × 1011 N/m2)

(a) 6250 J (b) 0.177 J (c) 0.075 J (d) 0.150 J

48. A metal rod of Young's modulus 2 × 1010 N m^{-2} undergoes an elastic strain of 0.06%. The energy per unit volume stored in J m^{-3} is

(a) 3600 (b) 7200 (c) 10800 (d) 14400

49. Steel ruptures when a shear of 3.5×10^8 N m^{-2} is applied. The force needed to punch a 1 cm diameter hole in a steel sheet 0.3 cm thick is nearly:

(a) 1.4×10^4 N (b) 2.7×10^4 N (c) 3.3×10^4 N (d) 1.1×10^4 N

50. When the load on a wire is increasing slowly from 2 kg to 4 kg, the elongation increases from 0.6 mm to 1 mm. The work done during this extension of the wire is (g=10 m/s^2)

(a) 9×10^{-3} J (b) 12×10^{-3} J (c) 14×10^{-3} J (d) 16×10^{-3} J

TOPIC WISE PRACTICE QUESTIONS

Topic 1: Hooke's Law and Young's Modulus

1. A steel ring of radius r and cross sectional area A is fitted onto a wooden disc of radius R (R > r). If the Young's modulus of steel is Y, then the force with which the steel ring is expanded is

(a) A Y (R/r) (b) A Y (R – r)/r (c) (Y/A)[(R – r)/r] (d) Y r/A R

2. Strain is expressed by

(a) $\Delta\theta/\theta$ (b) $\Delta v/v$ (c) $\Delta l/l$ (d) all of the above

3. The longitudinal extension of any elastic material is very small. In order to have an appreciable change, the material must be in the form of

(a) thin block of any cross section (b) thick block of any cross section

(c) long thin wire (d) short thin wire

4. The length of an elastic string obeying Hooke's law is a metre when the longitudinal tension is 4 N and b metre when the longitudinal tension is 5 N. The length of the string in metre when the longitudinal tension is 9 N is

(a) $a - b$ (b) $5b - 4a$ (c) $2b - \frac{1}{4}a$ (d) $4a - 3b$

5. Which of the following affects the elasticity of a substance?

(a) Hammering and annealing (b) Change in temperature
(c) Impurity in substance (d) All of the above

6. A thick rope of density r and length L is hung from a rigid support. The Young's modulus of the material of rope is Y. The increase in length of the rope due to its own weight is
(a) $(1/4)\rho g L^2/Y$ (b) $(1/2)\rho g L^2/Y$ (c) $\rho g L^2/Y$ (d) $\rho g L/Y$

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
(a) Y/2 (b) Y (c) 2Y (d) 4Y

8. A steel wire of length *l* and cross section area A is stretched by 1 cm under a given load. When the same load is applied to another steel wire of double its length and half of its cross section area, the amount of stretching (extension) is
(a) 0.5 cm (b) 2 cm (c) 4 cm (d) 1.5 cm

9. Hooke's law states that
(a) stress is directly proportional to the strain (b) stress is inversely proportional to the strain
(c) stress is proportional to Young's modulus (d) stress and strain are independent of each other

10. A force of 6×10^6 Nm^{-2} is required for breaking a material. Then density r of the material is 3×10^3 kg m^{-3}. If the wire is to break under its own weight, the length of the wire made of that material should be (take $g = 10$ ms^{-2})
(a) 20 m (b) 200 m (c) 100 m (d) 2000 m

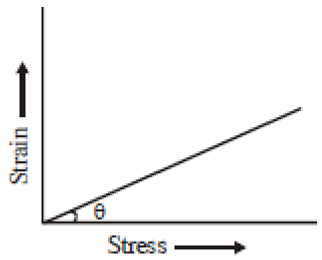
11. The length of a metal is ℓ_1 when the tension in it is T_1 and is ℓ_2 when the tension is T_2. The original length of the wire is
(a) $\frac{\ell_1 + \ell_2}{2}$ (b) $\frac{\ell_1 T_2 + \ell_2 T_1}{T_1 + T_2}$ (c) $\frac{\ell_1 T_2 - \ell_2 T_1}{T_2 - T_1}$ (d) $\sqrt{T_1 T_2 \ell_1 \ell_2}$

12. Which of the following substance has the highest elasticity?
(a) Steel (b) Copper (c) Rubber (d) Sponge

13. A wire breaks when subjected to a stress S. If ρ is the density of the material of the wire, then the length of the wire so that it breaks by its own weight is
(a) $\rho g S$ (b) $\frac{\rho g}{S}$ (c) $\frac{gS}{\rho}$ (d) $\frac{S}{\rho g}$

14. The breaking stress for a wire of unit cross section is called its
(a) yield point (b) tensile strength (c) elastic fatigue (d) young's modulus

15. The value of tan $(90° - \theta)$ in the graph gives



(a) Young's modulus of elasticity (b) compressibility (c) strain (d) tensile strength

16. The pressure that has to be applied to the ends of a steel wire of length 30 cm to keep its length constant when its temperature is raised by 150°C is: (For steel Young's modulus is $2 \times 10^{11} Nm^{-2}$ and coefficient of thermal expansion is $1.1 \times 10^{-5} K^{-1}$)
(a) 3.3×10^8 Pa (b) 3.3×10^6 Pa (c) 3.3×10^4 Pa (d) 3.3×10^5 Pa

17. The force exerted by a special compression device is given as function of compression x as $F_x(x) = kx(x-\ell)$ for $0 \le x \le \ell$, where ℓ is maximum possible compression and k is a constant. The force exerted by the device under compression is maximum when compression is –

(a) 0 (b) $\ell/4$ (c) $\ell/2$ (d) $\ell/2$

18. What per cent of length of wire increases by applying a stress of 1 kg weight/mm^2 on it?
(Y = 1 × 10^{11} N/m^2 and 1 kg weight = 9.8 newton)

(a) 0.0067% (b) 0.0098% (c) 0.0088% (d) 0.0078%

19. There are two wire of same material and same length while the diameter of second wire is two times the diameter of first wire, then the ratio of extension produced in the wires by applying same load will be

(a) 1 : 1 (b) 2 : 1 (c) 1 : 2 (d) 4 : 1

20. A metallic rod breaks when strain produced is 0.2%. The Young's modulus of the material of the rod is 7 × 10^9 N/m^2. What should be its area of cross-section to support a load of 10^4N?

(a) 7.1 × 10^{-8} m^2 (b) 7.1 × 10^{-6} m^2 (c) 7.1 × 10^{-4} m^2 (d) 7.1 × 10^{-2} m^2

21. To break a wire, a force 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

(a) 34 m (b) 30 m (c) 300 m (d) 3 m

22. Two wires are made of the same material and have the same volume. However wire 1 has cross-sectional area A and wire 2 has cross-sectional area 3A. If the length of wire 1 increases by Δx on applying force F, how much force is needed to stretch wire 2 by the same amount?

(a) 4 F (b) 6 F (c) 9 F (d) F

23. The Young's modulus of a perfectly rigid body is

(a) unity (b) zero (c) infinity (d) some finite non-zero constant

24. An iron rod of length 2m and cross-sectional area of 50 mm^2 stretched by 0.5 mm, when a mass of 250 kg is hung from its lower end. Young's modulus of iron rod is

(a) 19.6×10^{20} N/m^2 (b) 19.6×10^{18} N/m^2 (c) 19.6×10^{10} N/m^2 (d) 19.6×10^{15} N/m^2

25. A force of 10^3 newton, stretches the length of a hanging wire by 1 millimetre. The force required to stretch a wire of same material and length but having four times the diameter by 1 millimetre is

(a) 4 × 10^3 N (b) 16 × 10^3 N (c) $\frac{1}{4}\times10^3$ N (d) $\frac{1}{16}\times10^3$ N

26. An elevator cable is to have a maximum stress of 7×10^7 N/m^2 to allow for appropriate safety factors. Its maximum upward acceleration is 1.5 m/s^2. If the cable has to support the total weight of 2000 kg of a loaded elevator, the area of cross–section of the cable should be :

(a) 3.28 cm^2 (b) 2.38 cm^2 (c) 0.328 cm^2 (d) 8.23 cm^2

27. A uniform heavy rod of mass 0.2 kg, cross-sectional area 'a' and length l is hanging from a fixed support. Young's modulus of the material of the rod is Y. Find the elongation of the rod. [Neglect lateral contraction]

(a) $\frac{\ell}{5aY}$ (b) $\frac{5\ell}{aY}$ (c) $\frac{\ell}{aY}$ (d) $\frac{3\ell}{8aY}$

28. 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 to :

(a) 1.0 × 10^{-4} (b) 1.5 × 10^{-4} (c) 0.25 × 10^{-4} (d) 5 × 10^{-4}

29. A structural steel rod has a radius of 10 mm and length of 1.0 m. A 100 kN force stretches it along its length. Young's modulus of structural steel is 2 × 10^{11}Nm^{-2}. The percentage strain is about

(a) 0.16% (b) 0.32% (c) 0.08% (d) 0.24%

30. The effect of temperature on the value of Young's modulus of elasticity for various substances in general is

(a) it increases with increase in temperature (b) it remains constant
(c) it decreases with rise in temperature
(d) it sometimes increases and sometimes decreases with temperature

Topic 2: Bulk & Rigidity Modulus and Work done in Stretching a Wire

31. If in a wire of Young's modulus Y, longitudinal strain X is produced, then the value of potential energy stored in its unit volume will be
(a) $Y X^2$ (b) $2 Y X^2$ (c) $Y^2 X/2$ (d) $Y X^2/2$

32. A beam of metal supported at the two edges is loaded at the centre. The depression at the centre is proportional to
(a) Y^2 (b) Y (c) 1/Y (d) $1/Y^2$

33. The only elastic modulus that applies to fluids is
(a) Young's modulus (b) shear modulus (c) modulus of rigidity (d) bulk modulus

34. When a pressure of 100 atmosphere is applied on a spherical ball, then its volume reduces to 0.01%. The bulk modulus of the material of the rubber in dyne/cm2 is
(a) 10×10^{12} (b) 100×10^{12} (c) 1×10^{12} (d) 10×10^{12}

35. If a rubber ball is taken at the depth of 200 m in a pool, its volume decreases by 0.1%. If the density of the water is 1×10^3 kg/m^3 and g = 10m/s^2, then the volume elasticity in N/m^2 will be
(a) 10^8 (b) 2×10^8 (c) 10^9 (d) 2×10^9

36. 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
(a) + 0.50 (b) – 0.50 (c) + 0.25 (d) – 0.25

37. The amount of work done in increasing the length of a wire through 1 cm will be
(a) $\frac{YA}{2L}$ (b) $\frac{YL}{2A}$ (c) $\frac{YL^2}{2A}$ (d) None of these

38. The Young's modulus of the material of a wire is 2×10^{10} Nm^{-2}. If the elongation strain is 1%, then the energy stored in the wire per unit volume in Jm^{-3} is
(a) 10^6 (b) 10^8 (c) 2×10^6 (d) 2×10^8

39. A 5 metre long wire is fixed to the ceiling. A weight of 10 kg is hung at the lower end and is 1 metre above the floor. The wire was elongated by 1 mm. The energy stored in the wire due to stretching is
(a) zero (b) 0.05 joule (c) 100 joule (d) 500 joule

40. 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
(a) 1 : 2 (b) 1 : 4 (c) 2 : 1 (d) 1 : 1

41. Identical springs of steel and copper ($Y_s > Y_{cu}$) are equally stretched. Then
(a) less work is done on steel spring (b) less work is done on copper spring
(c) equal work is done on both the springs (d) data not complete

42. An elastic string of unstretched length L and force constant k is stretched by a small length x. It is further stretched by another small length y. The work done in the second stretching is :
(a) $\frac{1}{2}ky^2$ (b) $\frac{1}{2}k\left(x^2+y^2\right)$ (c) $\frac{1}{2}k\left(x+y\right)^2$ (d) $\frac{1}{2}ky\left(2x+y\right)$

43. If a spring extends by x on loading, then the energy stored by the spring is (if T is tension in the spring and k is spring constant)
(a) $\frac{T^2}{2x}$ (b) $\frac{T^2}{2k}$ (c) $\frac{2x}{T^2}$ (d) $\frac{2T^2}{k}$

44. A spring of force constant 800 N/m has an extension of 5 cm. The work done in extending it from 5 cm to 15 cm is

(a) 16 J (b) 8 J (c) 32 J (d) 24 J

45. Energy per unit volume in a stretched wire is equal to

(a) half of load × strain (b) load × strain (c) stress × strain (d) half of stress × strain

46. Young's modulus of the material of a wire is Y. On pulling the wire by a force F, the increase in its length is x. The potential energy of the stretched wire is

(a) $\frac{1}{2}Fx$ (b) $\frac{1}{2}Yx$ (c) $\frac{1}{2}Fx^2$ (d) None of these

47. Consider four steel wires of dimensions given below (d = diameter and l = length) : Which will have minimum stored potential energy on pulling it by same force F?

(a) l = 1m, d = 1mm (b) l = 2m, d = 2 mm (c) l = 2m, d = 1mm (d) l = 1m, d = 2 mm

48. If in a wire of young's modulus Y, longitudinal strain z is produced, then potential energy stored in its unit volume varies directly as

(a) $u \propto z$ (b) $u \propto z^2$ (c) $u \propto z^3$ (d) $u \propto z^4$

49. A metal rod of Young's modulus 2×10^{10} Nm^{-2} undergoes an elastic strain of 0.06%. The energy per unit volume stored in Jm^{-3} is

(a) 3600 (b) 7200 (c) 10800 (d) 14400

50. Two similar cylinders having same torsional rigidity are twisted by an angle f and 2 f respectively. What is ratio of work done in twisting them?

(a) 1/2 (b) 1/4 (c) 3/2 (d) 2/3

51. Bulk modulus exists

(a) for solid only (b) liquid only (c) gases only (d) all the above

52. A metallic wire of length 2.0 m is elongated by 2.0 mm. Area of cross-section of the wire is 4.0 mm^2. The elastic potential energy stored in the wire in elongated condition is [young's modulus of the metallic wire is = 2×10^{11} N/m^2]

(a) 8.23 (b) 0.83 (c) 6.23 (d) 0.63

53. Which of the following is not correct for elastic potential energy of a strained body.

(a) $U = \frac{1}{2}\frac{AY^2}{L^2}\ell^2$ (b) $U = \frac{1}{2} \times \text{stress} \times \text{strain}$

(c) $U = \frac{1}{2} \times \text{stress} \times \text{strain} \times \text{volume}$ (d) $U = \frac{1}{2} \times \text{maximum stretching force} \times \text{extension}$

54. A metalic rod of length l and cross-sectional area A is made of a material of Young modulus Y. If the rod is elongated by an amount y, then the work done is proportional to

(a) y (b) $\frac{1}{y}$ (c) y^2 (d) $\frac{1}{y^2}$

55. The Poisson's ratio of a material is 0.5. If a force is applied to a wire of this material, there is a decrease in the cross-sectional area by 4%. The percentage increase in the length is :

(a) 1% (b) 2% (c) 2.5% (d) 4%

56. The bulk moduli of ethanol, mercury and water are given as 0.9, 25 and 2.2 respectively in units of 109 Nm–2. For a given value of pressure, the fractional compression in volume is $\frac{\Delta V}{V}$. Which of the following statements about $\frac{\Delta V}{V}$ for these three liquids is correct ?

(a) Ethanol > Water > Mercury (b) Water > Ethanol > Mercury

(c) Mercury > Ethanol > Water (d) Ethanol > Mercury > Water

57. A material has poisson's ratio 0.50. If a uniform rod of it suffers a longitudinal strain of 2×10^{-3}, then the percentage change in volume is

(a) 0.6 (b) 0.4 (c) 0.2 (d) Zero

58. For a given material, the Young's modulus is 2. 4 times that of rigidity modulus. Its Poisson's ratio is

(a) 2.4 (b) 1.2 (c) 0.4 (d) 0.2

59. The upper end of a wire of diameter 12mm and length 1m is clamped and its other end is twisted through an angle of 30°. The angle of shear is

(a) 18° (b) 0.18° (c) 36° (d) 0.36°

60. Steel ruptures when a shear of 3.5×10^8 Nm^{-2} is applied. The force needed to punch a 1 cm diameter hole in a steel sheet 0.3 cm thick is nearly:

(a) 1.4×10^4 N (b) 2.7×10^4 N (c) 3.3×10^4 N (d) 1.1×10^4 N

NEET PREVIOUS YEARS QUESTIONS

1. 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? **[2018]**

(a) 9 F (b) 6 F (c) F (d) 4 F

2. The bulk modulus of a spherical object is 'B'. If it is subjected to uniform pressure 'p', the fractional decrease in radius is **[2017]**

(a) $\frac{B}{3p}$ (b) $\frac{3p}{B}$ (c) $\frac{p}{3B}$ (d) $\frac{p}{B}$

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? **[2015]**

(a) 1.0×10^{-2} (b) 1.2×10^{-2} (c) 1.4×10^{-2} (d) 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 : **[2015]**

(a) 2 : 1 (b) 4 : 1 (c) 1 : 1 (d) 1 : 2

5. 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 ‘Dl’. Which of the following graphs is a straight line? **[2014]**

(a) Δl versus $\frac{1}{l}$ (b) Δl versus l^2 (c) Δl versus $\frac{1}{l^2}$ (d) Δl versus l

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

(1) Mgl (2) MgL (3) $\frac{1}{2}$ Mgl (4) $\frac{1}{2}$ MgL

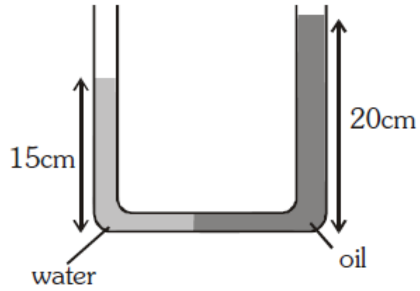
7. An object kept in a large room having air temperature of 25°C takes 12 minutes to cool from 80°C to 70°C. The time taken to cool for the same object from 70°C to 60°C would be nearly :- **[NEET – 2019 ODISSA]**

(1) 10 min (2) 12 min (3) 20 min (4) 15 min

8. Two small spherical metal balls, having equal masses, are made from materials of densities ρ_1 and ρ_2 $(\rho_1 = 8\rho_2)$ and have radii of 1mm and 2mm, respectively. They are made to fall vertically (from rest) in a viscous medium whose coefficient of viscosity equals η and whose density is 0.1 ρ_2. The ratio of their terminal velocities would be :- **[NEET – 2019 ODISSA]**

1) $\frac{79}{72}$ 2) $\frac{19}{36}$ 3) $\frac{39}{72}$ 4) $\frac{79}{36}$

9. In a U-tube as shown in figure, water and oil are in the left side and right side of the tube respectively. The heights from the bottom for water and oil columns are 15 cm and 20 cm respectively. The density of the oil is :- [take $\rho_{water} = 1000\ kg/m^3$] **[NEET – 2019 ODISSA]**



(1) 1200 kg/m^3 (2) 750 kg/m^3 (3) 1000 kg/m^3 (4) 1333 kg/m^3

10. A deep rectangular pond of surface area A, containing water (density= ρ, specific heat capacity=s), is located in a region where the outside air temperature is at a steady value of –26°C. The thickness of the frozen ice layer in this pond, at a certain instant is x.
Taking the thermal conductivity of ice as K, and its specific latent heat of fusion as L, the rate of increase of the thickness of ice layer, at this instant would be given by :- **[NEET – 2019 (ODISSA)]**

1) $26K/\rho r(L-4s)$ 2) $26K/(\rho x^2-L)$ 3) $26K/(\rho xL)$ 4) $26K/\rho r(L+4s)$

11. The stress-strain curves are drawn for two 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 – 2019 (ODISSA)]**

(1) ductile and brittle (2) brittle and ductile (3) brittle and plastic (4) plastic and ductile

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

1) $\frac{MgL}{A(L_1-L)}$ 2) $\frac{MgL}{AL}$ 3) $\frac{Mg(L_1-L)}{AL}$ 4) $\frac{MgL}{AL_1}$

13. Given below are two statements: One is labelled as Assertion (A) and the other is labelled as Reason (R). **[NEET-2022]**

Assertion (A):The stretching of a spring is determined by the shear modulus of the material of the spring

Reason (R):A coil spring of copper has more tensile strength than a steel spring of same dimensions.

In the light of the above statements, choose the most appropriate answer from the options given below

(1) Both (A) and (R) are true and (R) is the correct explanation of (A)

(2) Both (A) and (R) are true and (R) is the not correct explanation of (A)

(3) (A) is true but (R) is false

(4) (A) is false but (R) is true

NCERT LINE BY LINE QUESTIONS – ANSWERS

1. (d)	2. (a)	3. (d)	4. (c)	5. (a)	6. (a)	7. (c)	8. (c)	9. (a)	10. (c)
11. (a)	12. (c)	13. (a)	14. (b)	15. (a)	16. (a)	17. (b)	18. (a)	19. (b)	20. (b)

NCERT BASED QUESTONS-ANSWERS

1)	b	2)	c	3)	b	4)	c	5)	b
6)	c	7)	b	8)	d	9)	b	10)	a
11)	a	12)	d	13)	b	14)	d	15)	b
16)	a	17)	c	18)	c	19)	c	20)	d
21)	c	22)	d	23)	a	24)	d	25)	c
26)	c	27)	c	28)	a	29)	b	30)	d
31)	b	32)	c	33)	c	34)	b	35)	d
36)	b	37)	a	38)	d	39)	a	40)	d
41)	b	42)	d	43)	d	44)	a	45)	b
46)	b	47)	c	48)	a	49)	c	50)	c

TOPIC WISE PRACTICE QUESTIONS - ANSWERS

1)	2	2)	4	3)	3	4)	2	5)	4	6)	2	7)	2	8)	3	9)	1	10)	2
11)	3	12)	1	13)	4	14)	2	15)	1	16)	1	17)	4	18)	2	19)	4	20)	3
21)	1	22)	3	23)	3	24)	3	25)	2	26)	1	27)	3	28)	3	29)	1	30)	3
31)	4	32)	3	33)	4	34)	3	35)	4	36)	2	37)	1	38)	1	39)	2	40)	1
41)	2	42)	4	43)	2	44)	2	45)	4	46)	1	47)	3	48)	2	49)	1	50)	2
51)	1	52)	2	53)	2	54)	3	55)	4	56)	1	57)	4	58)	4	59)	2	60)	1

NEET PREVIOUS YEARS QUESTIONS-ANSWERS

1)	1	2)	3	3)	2	4)	1	5)	2	6)	3	7)	4	8)	4	9)	2	10)	3
11)	2	12)	1	13)	3														

TOPIC WISE PRACTICE QUESTIONS - SOLUTIONS

1. **(b)** Let T be the tension in the ring, then

$$Y=\frac{T.2\pi r}{A.2\pi(R-r)}=\frac{Tr}{A(R-r)}\quad \therefore T=\frac{YA(R-r)}{r}$$

2. **(d)** Concept based

3. **(c)** $\Delta l=\dfrac{FL}{AY}$

Thus, extension is directly proportional to length and inversely to area. Thus for appreciable extension, length must be long and area less, or long and thin wire

4. **(b)** Using Hooke's law, $F = kx$ we can write

$4 = k(a-\ell_0)$ … (i) and $5 = k(b-\ell_0)$ … (ii)

If ℓ be the length under tension 9N, then $9 = k(\ell-\ell_0)$ … (iii)

After solving above equations, we get $\ell = (5b-4a)$.

5. **(d)** Due to the all following operations, the elasticity of the substance is changed. The hammering increases elasticity while annealing decreases it. The increase in temperature increases the elasticity while decrease in temperature decreases it. The impurity in the substance increases the elasticity.

6. (b) Take a small section δy at distance y from top as shown in figure. Let area of rope be A

Stress due to this section = ρAgδy/A=ρdδy

Strain on section y = δl/y

Using Stress = Y \times Strain

$$\Rightarrow \rho g\delta y = Y\times\frac{\delta l}{y} \Rightarrow \Delta l = \frac{\rho g}{y}\int_0^L y\delta y \quad \Rightarrow \Delta l = \frac{\rho g L^2}{2Y}$$

7. **(b)** Young's modulus of wire does not vary with dimension of wire.

8. **(c)** Young’s modulus of elasticity is

$$Y = \frac{F/A}{\Delta L/L} \quad \therefore \Delta L = \frac{FL}{AY}$$

So, $\Delta L \propto \frac{L}{A} \quad \therefore \frac{\Delta L_2}{\Delta L_1} = \frac{L_2}{L_1}\times\frac{A_1}{A_2} = \frac{2}{1}\times\frac{2}{1} = 4$

$\Delta L_2 = 4\times\Delta L_1 = 4\times 1 = 4\,\text{cm}$

9. **(a)** According to Hooke’s Law “ for metals within the limit of proportionality, stress applied to the body is proportional to resultant strain i.e., stress $\propto$ strain $\Rightarrow$ stress/strain = E=const. Where the proportionality constant E, is called modulus of elasticity or simply elasticity.

10. **(b)** Breaking stress $= \frac{\text{Force}}{\text{area}}$

The breaking force will be its own weight.

F = mg = V ρ g = area × ℓρ g

Breaking stress $= 6\times10^6 = \frac{\text{area}\times\ell\times\rho g}{\text{area}}$ or $\ell = \frac{6\times10^6}{3\times10^3\times10} = 200\,\text{m}$

11. **(c)** If ℓ is the original length of wire, then change in length of first wire, $\Delta\ell_1 = (\ell_1 - \ell)$ change in length of second wire, $\Delta\ell_2 = (\ell_2 - \ell)$

Now, $Y = \frac{T_1}{A}\times\frac{\ell}{\Delta\ell_1} = \frac{T_2}{A}\times\frac{\ell}{\Delta\ell_2}$ or $\frac{T_1}{\Delta\ell_1} = \frac{T_2}{\Delta\ell_2}$ or $\frac{T_1}{\ell_1-\ell} = \frac{T_2}{\ell_2-\ell}$

$T_1\ell_2 - T_1\ell = T_2\ell_1 - T_2\ell$ or $\ell = \frac{T_2\ell_1 - T_1\ell_2}{T_2 - T_1}$

12. (a) Modulus of elasticity gives the idea of elasticity. For above materials, values of E are:
Glass: 50−90GPa

Rubber:0.01−0.1GPa

Steel:200GPa

Copper: 117GPa

13. **(d)** The stress due to this weight is $S = L\rho g$; $\therefore L = \frac{S}{\rho g}$

14. **(b)** Tensile strength = breaking stress × area of cross section

15. **(a)** $\tan(90^0 - \theta) = \frac{\text{stress}}{\text{strain}}$

16. **(a)** Young's modulus $Y = \frac{\text{stress}}{\text{strain}}$

stress = Y × strain

Stress in steel wire = Applied pressure

Pressure = stress = Y × strain

Strain $= \frac{\Delta L}{L} = \alpha\Delta T$ (As length is constant)= $2\times10^{11}\times1.1\times10^{-5}\times150 = 3.3\times10^8$ Pa

17. (d) For W to be maximum ; $\frac{dW}{dx} = 0$;

i.e. F(x)=0 ⇒ x=l, x=0 ; clearly for d=l, the work done is maximum.

18. **(b)** Stress = 1 kg wt/mm^2 = 9.8 N/mm^2 = 9.8×10^6 N/m^2.

19. **(d)** ∵ Both wires are same materials so both will have same Young's modulus, and let it be Y.

$$Y = \frac{\text{stress}}{\text{strain}} = \frac{F}{A(\Delta L/L)}, F = \text{applied force}$$

A = area of cross-section of wire

Now, $Y_1 = Y_2 \Rightarrow \frac{FL}{(A_1)(\Delta L_1)} = \frac{FL}{(A_2)(\Delta L_2)}$

Since load and length are same for both $\Rightarrow r_1^2 \Delta L_1 = r_2^2 \Delta L_2$, $\left(\frac{\Delta L_1}{\Delta L_2}\right) = \left(\frac{r_2}{r_1}\right)^2 = 4$

$\Delta L_1 : \Delta L_2 = 4:1$

20. **(c)** Maximum possible strain = 0.2/100

$$\therefore A = \frac{F}{Y \times \text{strain}} = \frac{10^4 \times 100}{(7\times10^9)\times 0.2} = 7.1\times10^{-4}\,\text{m}^2$$

21. (a) $L = \frac{S}{dg} = \frac{10^6}{3\times10^3\times10} = \frac{100}{3} = 34\text{m}$

22. (c) As shown in the figure, the wires will have the same Young's modulus (same material) an the length of the wire of area of cross-section 3A will be *l*/3 (same volume as wire 1).

For wire 1, $Y = \frac{F/A}{\Delta x/l}$ --------(i) ; For wire 2, $Y = \frac{F^{|}/3A}{\Delta x/(l/3)}$ -------(ii)

From (i) and (ii), $\frac{F}{A} \times \frac{l}{\Delta x} = \frac{F}{3A} \times \frac{l}{3\Delta x} \Rightarrow F = 9F$

23. **(c)** For a perfectly rigid body strain produced is zero for the given force applied, so Y = stress/strain = ∞

24. **(c)** $Y = \frac{F/A}{\Delta\ell/\ell} = \frac{\frac{250\times9.8}{50\times10^{-6}}}{\frac{0.5\times10^{-3}}{2}} \Rightarrow 19.6\times10^{10}\,\text{N/m}^2$

25. **(b)** $F = Y \times A \times \frac{l}{L} \to F \propto r^2$ (*Y*, *l* and *L* are constant)

If diameter is made four times then force required will be 16 times, i.e., 16 × 10^3 N

26. **(a)** Given, the breaking strength of cable $f_u = 7 \times 10^7\ \text{N/m}^2$

The force carried by the cable,

$F = m(g + a) = 2000\,(9.8 + 1.5) = 22600$ N

The area of cross-section, $A = \frac{F}{f_u} = \frac{22600}{7\times10^7} = 3.28\times10^{-4}\,m^2$

27. (c) $T = (L-x)\frac{W}{L}$; elongation $= \frac{Tdx}{AY} = \frac{(L-x)Wdx}{LAY}$; Total elongation= $\frac{W}{LAY}\int_0^L (L-x)dx = \frac{WL}{2AY}$

28. **(c)** Given , $y = 2\times10^{11}\,\text{Nm}^{-2}$; Stress$\left(\frac{F}{A}\right) = 5\times10^7\,\text{Nm}^{-2}$

$\Delta V = 0.02\% = 2\times10^{-4}\,\text{m}^3$

$\gamma = \frac{\text{stress}}{\text{strain}} \Rightarrow \text{strain}\left(\frac{\Delta\ell}{\ell_0}\right) = \frac{\gamma}{\text{stress}}$ ---------(i)

$\Delta V = 2\pi r\ell_0\Delta r - \pi r^2\Delta\ell$ ----------(ii)

From eqns (i) and (ii) putting the value of $\Delta\ell, \ell_0$ and ΔV and solving we get $\frac{\Delta r}{r} = 0.25\times10^{-4}$

29. **(a)** Given: *F* = 100 kN = 10^5 N

$Y = 2\times10^{11}\ Nm^{-2}$; $\ell_0 = 1.0$ m

radius r = 10 mm = 10^{-2} m

$$\Rightarrow \text{Strain} = \frac{\text{Stress}}{Y} = \frac{F}{AY} = \frac{10^5}{\pi r^2 Y} = \frac{10^5}{3.14\times10^{-4}\times2\times10^{11}} = \frac{1}{628}$$

30. **(c)** We know that interatomic binding energy decreases with temperature. So, more strain is produced at higher temperature. As a result, Y decreases.

31. **(d)** $\text{P.E.} = \frac{1}{2}\times\text{stress}\times\text{strain}\times\text{volume}$ or (P.E./volume) $= \frac{1}{2}\times(\text{Y}\times\text{strain})$ (strain)

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

32. (c) Potential energy stored per unit volume of a wire $= \frac{1}{2}\times\text{stress}\times\text{strain}$

$$\text{Y} = \frac{\text{stress}}{\text{strain}} \Rightarrow \text{stress} = \text{Y}\times\text{strain}\ ;\ \ \text{U} = \frac{1}{2}\times\text{YX}\times\text{X} = \frac{1}{2}\text{YX}^2$$

33. **(d)** The depression at the centre is $\delta = \frac{Mgl^3}{4bd^3Y}$ or $\delta \propto \frac{1}{Y}$

34. **(c)** $K = \frac{100}{0.01/100} = 10^6\,\text{atm} = 10^{11}\,\text{N/m}^2 = 10^{12}\,\text{dyne/cm}^2$

35. **(d)** $K = \frac{\Delta P}{\Delta V/V} = \frac{h\rho g}{\Delta V/V} = \frac{200\times10^3\times10}{0.1/100} = 2\times10^9$

36. **(b)**

37. **(a)** $W = \frac{1}{2}\times(\text{Y}\times\text{strain})\times\text{strain}\times\text{volume} = \frac{1}{2}(\text{YA/L})\ell^2 = \frac{1}{2}(\text{YA/L})(\ell)^2 = \frac{\text{YA}}{2\text{L}}$

38. **(a)** $Y = 2\times10^{10}\,\text{Nm}^{-2}; \frac{\Delta\ell}{\ell} = 0.01$

Work done per unit volume $= \frac{1}{2}\times\text{stress}\times\text{strain} = \frac{1}{2}\times\text{Y}\times\text{strain}^2 = \frac{1}{2}\text{Y}\left(\frac{\Delta\ell}{\ell}\right)^2$

$$\therefore U = \frac{1}{2}\times2\times10^{10}\times\left(\frac{1}{100}\right)^2 = U = 10^6\,\text{Jm}^{-3}$$

39. **(b)** $W = \frac{1}{2}\times F\times l = \frac{1}{2}mgl = \frac{1}{2}\times10\times10\times1\times10^{-3} = 0.05J$

40. **(a)** $W = \frac{1}{2}\frac{(Stress)^2}{Y}\times Volume$

As F, A and Y are same $\Rightarrow W_\propto$ Volume (area is same)

$W \propto l \qquad (V = Al)$

$$\frac{W_1}{W_2} = \frac{l_1}{l_2} = \frac{l}{2l} = \frac{1}{2}$$

41. **(b)** Young's modulus of steel is greater than that of copper. Hence, in order to produce same extension, large force will have to be applied on the steel spring that the copper spring.
Obviously, more work will be done on the steel spring.

42. **(d)** $W_1 = \frac{1}{2}kx^2$ and $W_2 = \frac{1}{2}k(x+y)^2$

$$\therefore W = W_2 - W_1 = \frac{1}{2}k(x+y)^2 - \frac{1}{2}kx^2 = \frac{1}{2}ky(2x+y)$$

43. **(b)** $U = \frac{F^2}{2k} = \frac{T^2}{2k}$

44. **(b)** Small amount of work done in extending the spring by dx is

$dW = k\,x\,dx$

$$\therefore W = k\int_{0.05}^{0.15} x dx = \frac{800}{2}\left[(0.15)^2 - (0.05)^2\right] = 8J$$

45. **(d)** Factual question, $u = \frac{1}{2}\text{stress} \times \text{strain}$

46. **(a)** When a wire is stretched through a length, then work has to be done, this work is stored in the wire in the form of elastic potential energy.

Potential energy of stretched wire is

$$U = \frac{1}{2} \times stress \times strain \;\; \therefore U = \frac{1}{2} \times F \times s \Rightarrow U = \frac{1}{2}Fx$$

47. **(c)** We have, $U = \frac{F^2}{2k}$; where $k = \frac{Yl}{A} = \frac{Yl}{\frac{1}{4}\pi d^2} \Rightarrow U \propto \frac{d^2}{l}$

48. **(b)** Concept based

49. **(a)** U / volume = $= \frac{1}{2} \mathrm{Y} \times \text{strain}^2 = 3600 \text{ J m}^{-3}$

[Strain = 0.06×10^{-2}]

50. **(b)** Concept based

51. **(d)** Concept based

52. **(b)** Conceptual

53. **(b)** Concept based

54. **(c)** Volume V = cross sectional A × length l or $V = Al$

$$Strain = \frac{Elongation}{Original\ length} = \frac{Y}{l}$$

Young's modulus $Y = \frac{Stress}{Strain}$; Work done, $W = \frac{1}{2} \times stress \times strain \times volume$

$$W = \frac{1}{2} \times Y \times (strain)^2 \times Al = \frac{1}{2} \times Y \times \left(\frac{y}{l}\right)^2 \times Al = \frac{1}{2}\left(\frac{YA}{l}\right) y^2 \Rightarrow W \propto y^2$$

55. **(d)** $\frac{\Delta r / r}{\Delta l / l} = 0.5 = \frac{1}{2}, \frac{\Delta r}{r} = \frac{1}{2}\frac{\Delta l}{l}$

56. **(a)** $\text{Compressibility} = \frac{1}{\text{Bulk modulus}}$

As bulk modulus is least for ethanol (0.9) and maximum for mercury (25) among ehtanol, mercury and water. Hence compression in volume Ethanol > Water > Mercury

57. **(d)** We know

$(dv / v) = (1 - 2\sigma)\,(dL / L)$

Given : $\sigma = 0.5$

Strain = $(dL / L) = (2 \times 10^{-3})$

$\therefore (dv / v) = \{1 - (2 \times 0.5)\}\,(dL / L)$

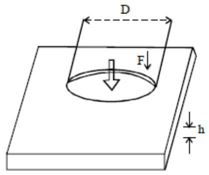
$(dv / v) = 0$

58. **(d)** $Y = 2\eta(1+\sigma)$

$$2.4\eta = 2\eta(1+\sigma) \Rightarrow 1.2 = 1+\sigma \Rightarrow \sigma = 0.2$$

59. **(b)** $r\theta = \ell\phi \Rightarrow \phi = \frac{r\theta}{\ell} = \frac{6\text{mm} \times 30^0}{1\text{m}} = 0.18^0$

60. **(c)**



Shearing strain is created along the side surface of the punched disk. Note that the forces exerted on the disk are exerted along the circumference of the disk, and the total force exerted on its center only.
Let us assume that the shearing stress along the side surface of the disk is uniform, then

$$F = \int_{\text{surface}} dF_{max} = \int_{\text{surface}} \sigma_{max} dA = \sigma_{max} \int_{\text{surface}} dA$$

$$= \int \sigma_{max} A = \sigma_{max} \cdot 2\pi\left(\frac{D}{2}\right)h$$

$$= 3.5 \times 10^8 \times \left(\frac{1}{2} \times 10^{-2}\right) \times 0.3 \times 10^{-2} \times 2\pi$$

$$= 3.297 \times 10^4 \simeq 3.3 \times 10^4 \text{ N}$$

NEET PREVIOUS YEARS QUESTIONS-EXPLANATIONS

1. **(a)** Wire 1:

$$\Delta\ell = \left(\frac{F}{AY}\right)3\ell \text{ ---------------(i)}$$

Wire 2 :

$$\Delta\ell = \left(\frac{F^{|}}{3AY}\right)\ell \text{ --------------(ii)}$$

From equation (i) & (ii),

$$\Delta\ell = \left(\frac{F}{AY}\right)3\ell = \left(\frac{F^{|}}{3AY}\right)\ell \text{ or } F^{|} = 9F$$

2. **(c)** Bulk modulus is given by

$$B = \frac{P}{\left(\frac{\Delta V}{V}\right)} \text{ or } \frac{\Delta V}{V} = \frac{P}{B}$$

$$3\frac{\Delta R}{R} = \frac{P}{B} \text{(here, } \frac{\Delta R}{R} = \text{fractional decreases in radius)} \Rightarrow \frac{\Delta R}{R} = \frac{P}{3B}$$

3. **(b)** Compressibility of water,
$K = 45.4 \times 10^{-11}$ Pa^{-1}
density of water P = 10^3 kg/m^3 ; depth of ocean, h = 2700 m

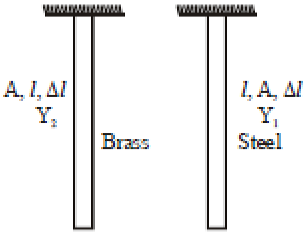
We have to find $\frac{\Delta V}{V} = ?$

As we know, compressibility, $K = \frac{1}{B} = \frac{(\Delta V / V)}{P} (P = \rho gh)$

So, $(\Delta V / V) = K\rho gh = 45.4 \times 10^{-11} \times 10^3 \times 10 \times 2700 = 1.2258 \times 10^{-2}$

4. **(a)** Young's modulus

$$\frac{W_1}{Y_1} = \frac{W_2}{Y_2} [\because A, l, \Delta l \text{ same for both brass and steel}]$$



$$\frac{W_1}{W_2} = \frac{Y_1}{Y_2} = 2\ \left[Y_{steel} / Y_{brass} = 2\,\text{given}\right]$$

5. **(b)** $Y = \dfrac{\frac{E}{A}}{\frac{\Delta l}{l}} \Rightarrow \Delta l = \dfrac{Fl}{AY}$ **;** But $V = Al$ so $A = \dfrac{V}{l}$

Therefore $\Delta l = \dfrac{Fl^2}{VY} \propto l^2$

Hence graph of Δl versus l^2 will give a straight line

6. U =1/2 (force)(elongation) $= \dfrac{1}{2}(Mg)\ell = \dfrac{1}{2}Mg\ell$

7. By Newton's law of cooling

$$\frac{T_1 - T_2}{\Delta t} = C\left[\frac{T_1 - T_2}{2} - T_0\right]$$

$$\frac{(80-70)}{12} = C(75-25)$$

$$10 = C \times 600\,\textbf{;}\ \therefore C = \frac{1}{60}\ \text{--------(i)}$$

$$\frac{(70-60)}{t^{|}} = C(65-25)$$

$$\therefore C = \frac{1}{t^{|}(4)}\ \text{------------(ii)}$$

From (i) and (ii), we get

$$\frac{1}{4t^{|}} = \frac{1}{60} \Rightarrow t^{|} = \frac{60}{4}$$

$$\therefore t^{|} = 15\,\text{minutes}$$

8. Terminal velocity $= \dfrac{2}{9}\dfrac{r^2}{\eta}(\rho - \sigma)g$

$$\therefore V_{T_1} = \frac{2 \times 1^2}{9\eta}(\rho_1 - 0.01\rho_2)g = \frac{2}{9\eta}(8\rho_2 - 0.1\rho_2)g$$

$$\therefore V_{T_2} = \frac{2}{9\eta}(7.9)g\ \text{-------------(i)}$$

$$\therefore V_{T_1} = \frac{2 \times 2^2}{9\eta}(\rho_2 - 0.1\rho_2)g$$

$$\therefore V_{T_2} = \frac{8}{9\eta}(0.9\rho)g\ \text{---------------(ii)}$$

$$\therefore \frac{V_{T_1}}{V_{T_2}} = \frac{7.9}{4(0.9)} = \frac{79}{36}$$

9. $Q = KA\left(\frac{\Delta T}{\Delta x}\right)dt$

Now, $Q = mL$

$\therefore\ mL = KA\left(\frac{\Delta T}{\Delta x}\right)dt$

$\therefore\ mL = \frac{KA[0-(-26)]dt}{x}$

$\therefore\ (\rho A\,dx)L = KA\,\frac{[0-(-26)]}{x}\,dt$

$\therefore\ \frac{dx}{dt} = \frac{26K}{x\rho L}$

10. $h_1 - h_2 = f_1 g h_1 + f_2 g h_2 \Rightarrow 20 - 15 = 10\left(f_1 20 - k_2 / cm^3 \times 15\right) \Rightarrow \frac{1}{2} = 20f_1 - 15 \Rightarrow 15.5 = 20f_1$

$\therefore f_1 = \frac{15.5\times10^{-2}}{20} = 75\,kg/cm^3 \quad = 750\,kg/m^3$

11. Ductile materials have a fracture strength lower than the ultimate Tensile strength (i.e., the points are far apart.) whereas in brittle materials, the fracture strength is equivalent to ultimate tensile strength (i.e., the points are close.)

$\therefore$ Material X is brittle and Y is ductile in nature.

12. $Y = \frac{FL}{Ae}$; Where $e = L_1 - L$

$F = mg$; $Y = \frac{MgL}{A(L_1 - L)}$

13 $F = kx$

$\eta = \frac{stress}{strain} = \frac{F/A}{\phi}$

Where ϕ is strain