9 Elasticity

QUICK LOOK

Inter-atomic Force

The forces between the atoms due to electrostatic interaction between the charges of the atoms are called inter-atomic 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*. 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) inter-atomic force working between them. 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 inter-atomic force is produced between two atoms.

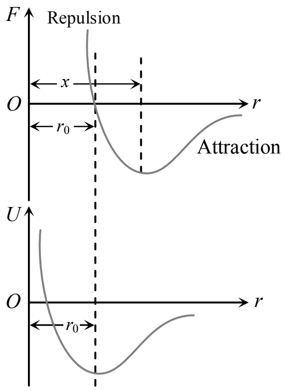


Figure: 9.1 Inter-atomic Forces and Potential Energy

The potential energy U is related with the inter-atomic force F by the following relation.

$$F = \frac{-dU}{dr}$$

- When two atoms are at very large distance, the potential energy is negative and becomes more negative as r is decreased.
- 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. ($U_0 = -7.2\times10^{-19}\,Joule$ for hydrogen).
- 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).

The force between two molecules is given by

$$F = F_{\text{att}} + F_{\text{rep}} = \frac{-a}{r^7} + \frac{b}{r^9}$$

The value of constants a and b depend upon the structure and nature of molecules.

The potential energy can be approximately expressed by the formula $U = \frac{A}{r^n} - \frac{B}{r^m}$

where constants A, B and numbers m and n are different for different molecules.

For majority of solids $n = 12$ and $m = 6$.

Elastic Property of Matter

- **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.
- **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.
- **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.
- **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.

Elastic the material will return to its original length (or shape) when any load is removed; rubber, steel, glass and wood are usefully elastic – they withstand everyday forces without permanent distortion.

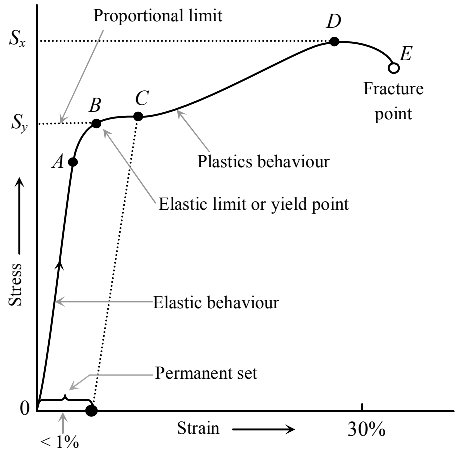
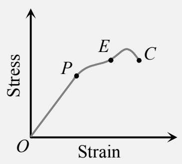
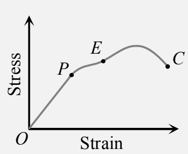
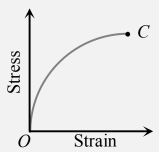


Figure: 9.2

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.

Table: 9.1 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

Solid: Solids have three types of expansion:

Liner expansion: $\alpha = \dfrac{\Delta L}{Lt},\ L_t = L_0(1+\alpha t)$

Superficial expansion: $\beta = \dfrac{\Delta A}{At},\ A_t = A_0(1+\beta t)$

Volume expansion: $\gamma = \dfrac{\Delta V}{At}, V_t = V_0(1+\gamma t)$

For isotropic objects: $\beta = 3\alpha, \gamma = 3\alpha$

$\alpha : \beta : \gamma = 1 : 2 : 3$

- For anisotropic objects: $\gamma = \alpha_1 + \alpha_2 + \alpha_3$
- Density decreases with increases of temperature $d_t = \dfrac{d_0}{1+\gamma t} = d_0(1-\gamma t)$

Liquids: Liquids posses only volume expansion. If γ_a and γ_r are apparent expansion and real expansion of liquid, while γ_g volume expansion of glass vessel, then $\gamma_r = \gamma_a + \gamma_g$

- Correction for Barometer height True barometer height, $H_0 = H\{1-(\gamma-\alpha)t\}$
- Correction for increase of length of pendulum with temperature $\dfrac{\Delta T}{T} = \dfrac{1}{2}\alpha\ \Delta t$
- Number of seconds lost per day $= \dfrac{1}{2}\alpha\ \Delta t \times 86400$ sec
- Volume coefficient of a gas (at constant pressure) $\gamma_v = \dfrac{\Delta B}{\Delta t} = \dfrac{1}{273}/°C$ for all gases
- Pressure coefficient of a gas (at constant volume) $\gamma_p = \dfrac{\Delta P}{\Delta t} = \dfrac{1}{273}/°C$ for all gases

Stress

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

Normal Stress: Here the force is applied normal to the surface. It is again of Two Types: Longitudinal and Bulk or volume stress

- **Longitudinal Stress:** 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. Deforming force is applied parallel to the length and causes increase in length. Area taken for calculation of stress is area of cross section. Longitudinal stress produced due to increase in length of a body under a deforming force is called tensile stress. Longitudinal stress produced due to decrease in length of a body under a deforming force is called compressional stress.
- **Bulk or Volume Stress:** It occurs in solids, liquids or gases. In case of fluids only bulk stress can be found. It produces change in volume and density, shape remaining same. Deforming force is applied normal to surface at all points. Area for calculation of stress is the complete surface area perpendicular to the applied forces. It is equal to change in pressure because change in pressure is responsible for change in volume.

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. Here deforming force is applied tangential to one of the faces. Area for calculation is the area of the face on which force is applied

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:

- **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.

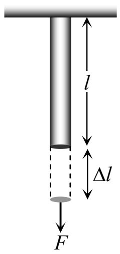


Figure: 9.3 Linear Strain

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

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

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

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

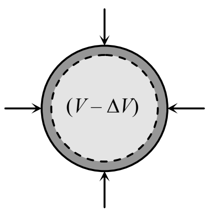


Figure: 9.4 Volumetric Strain

- **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.

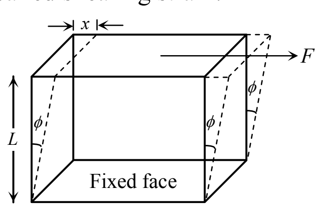


Figure: 9.5 Shearing Strain

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.

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

Hooke's Law and Modulus of Elasticity: According to this law, within the elastic limit, stress is proportional to the strain.

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

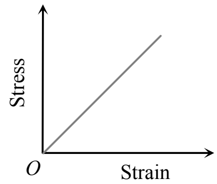


Figure: 9.6 Stress vs. Strain

The constant E is called modulus of elasticity.

$$\text{Coefficient of elasticity } E = \frac{\text{stess}}{\text{strain}}$$

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

$$\text{Strain} = \text{fractional change } = \frac{\Delta L}{L} \text{ or } = \frac{\Delta V}{L} \text{ or } \theta$$

Young's Modulus

$$Y = \frac{\text{longitudinal stree}}{\text{longitudinal strain}} = \frac{F/A}{\Delta L/L} = \frac{FL}{A\Delta L} = \frac{MgL}{\pi r^2 \Delta L}$$

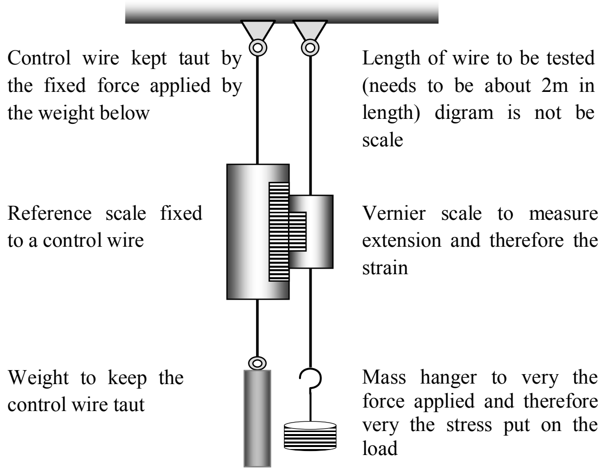


Figure: 9.7

Bulk Modulus: $B = \frac{\text{normal stress}}{\text{volume strain}} = \frac{F/A}{\Delta V/V}$ where $\Delta P = \frac{F}{A}$ change in pressure.

$$\text{Compressibility } C = \frac{1}{\text{Bulk modulus}} m^2 N$$

Relation between force constant K and intermolecular distance r_0 is $= Br_0$

Poisson's Ratio σ

$$\sigma = \frac{\text{lateral stress}}{\text{longitudinal strain}} = \frac{\Delta D / D}{\Delta L / L}$$

Theoretical value of σ lies between –1 and 0.5.

Fractional change in volume, $\frac{\Delta V}{V} = (1 - 2\sigma) \times \frac{\Delta L}{L}$

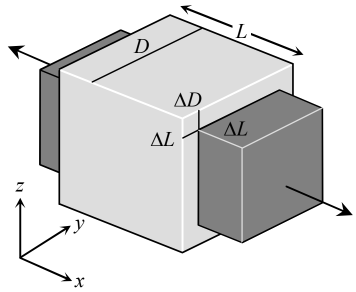


Figure: 9.8

Modulus of Rigidity: $\eta = \frac{\text{tangential stress}}{\text{sheer}} = \frac{F / A}{\theta}$

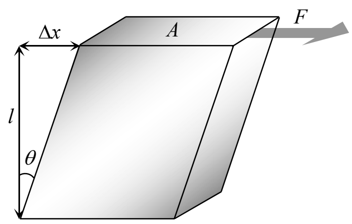


Figure: 9.9

Torsion of Cylinder: If θ is angle of shear and ϕ is angle of twist x = distance from axis of cylinder of length l.

Shearing strains at surface $\theta = \frac{r\phi}{l}$

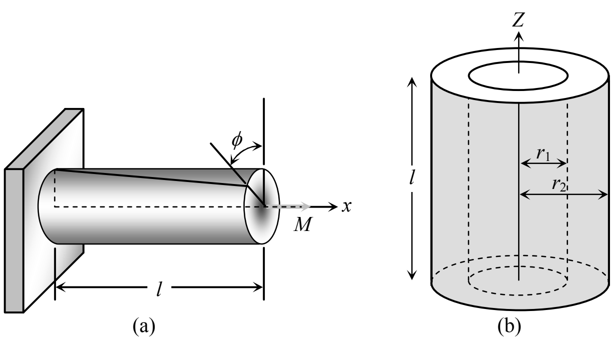


Figure: 9.10

Restoring couple $\tau = \frac{\pi \eta r^4 \phi}{2l}$ (solid cylinder figure 9.10 (a))

$\tau = \frac{\pi \eta \left(r_2^4 - r_1^4\right)}{2l}$ (hollow cylinder figure 9.10 (b))

Bending of Beam: Bending moment $\tau = \frac{YI\,g}{R}$

I_g = Geometrical moment of inertia $= \frac{\pi r^4}{4}$ for circular cross-section $= \frac{bd^3}{12}$ for rectangular cross-section

Depression of a beam loaded at both ends $\delta = \frac{Mgl^3}{48 YI_g}$

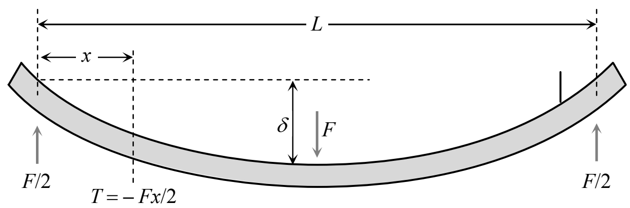


Figure: 9.11

Elastic Energy Stored

$U = \frac{1}{2} \times$ load $\times$ extension $= \frac{1}{2} Fx = \frac{1}{2} Kx^2$

$= \frac{1}{2} \times$ stress $\times$ strain $\times$ volume.

For twisting motion,

$U = \frac{1}{2} \times$ torque $\times$ angular twist $\frac{1}{2} \tau \theta = \frac{1}{2} C\theta^2$

Elastic energy density $u = \frac{1}{2} \times$ stress $\times$ strain ($Joule/m^3$)

$= \frac{1}{2} \times Y \times$ strain^2 ($Joule/m^3$)

- Maximum length of an elastic wire of density ρ which can support its own weight if its breaking strength is f

  $L_{\max} = \frac{f}{\rho g}$

  Extension of wires of length L due to its own weight is $\Delta L = \frac{L^2 \rho g}{2Y}$

  If two wires of same dimensions are subjected to same force, the wire showing less extension is more elastic. Breaking stress = constant for a given material

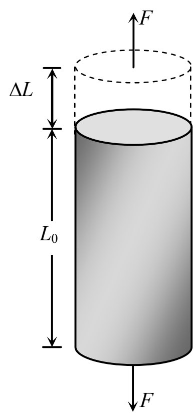


Figure: 9.12

- With rise of temperature elastic moduli decreases: Thermal energy density = Thermal energy per unit volume

$\frac{U}{V} = \frac{1}{2} X$ thermal stress X strain

$= \frac{F}{A}\frac{l}{L} = \frac{1}{2}(Y\alpha\Delta\theta)(\alpha\Delta\theta) = \frac{1}{2}Y\alpha^2(\Delta\theta)^2$

Thermal stress = $Y\alpha\Delta\theta$

Thermal strain $\alpha\Delta\theta$

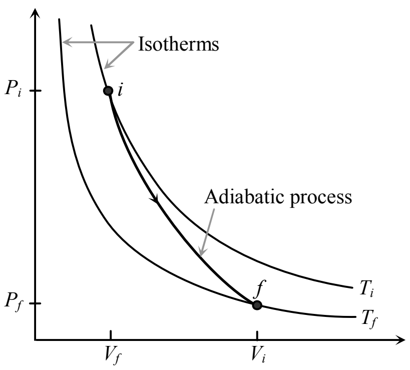
$\Delta\theta$ = Rise in temperature

α = Coefficient of linear expansion

Elasticity of Gas

Isothermal elasticity of a gas E_T = Pressure (P).

Adiabatic elasticity of a gas $E_s = \gamma P = \frac{C_P}{C_v} \cdot P$



The PV diagram for an adiabatic expansion here $T_f < T_i$

Figure: 9.13

Relations Among Elastic Constants: Module of elasticity are three, *viz*., Y, B and η while elastic constant are four, *viz*., Y, B, η and 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 following relations:

- $Y = 3B(1-2\sigma)$ $\quad$ $Y = 2\eta(1+\sigma)$
- $Y = \frac{9B\eta}{3B+\eta}$ $\quad$ $\sigma = \frac{3B-2\eta}{3B+2\eta}$

Factors Affecting Elasticity

- Hammering and Rolling: Crystal grains break up into smaller units by hammering and rolling. This result in increase in the elasticity of material.
- Annealing: The metals are annealed by heating and then cooling them slowly. Annealing results in decrease in the elasticity of material.
- Temperature: Intermolecular forces decreases with rise in temperature. Hence the elasticity decreases with rise in temperature but the elasticity of invar steel (alloy) does not change with change of temperature.
- Impurities: Due to impurities in a material elasticity can increase or decrease. The type of effect depends upon the nature of impurities present in the material.

Practical Applications of Elasticity

- The metallic parts of machinery are never subjected to a stress beyond elastic limit, otherwise they will get permanently deformed.
- The thickness of the metallic rope used in the crane in order to lift a given load is decided from the knowledge of elastic limit of the material of the rope and the factor of safety.
- The bridges are declared unsafe after long use because during its long use, a bridge under goes quick alternating strains continuously. It results in the loss of elastic strength.
- Maximum height of a mountain on earth can be estimated from the elastic behaviour of earth.

  At the base of the mountain, the pressure is given by $P = h\rho g$ and it must be less than elastic limit (K) of earth's supporting material.

  $K > P > h\rho g$

$\therefore$ $h < \frac{K}{\rho g}$ or $h_{\max} = \frac{K}{\rho g}$

- A hollow shaft is stronger than a solid shaft made of same mass, length and material.

  Torque required to produce a unit twist in a solid shaft

$$\tau_{\text{solid}} = \frac{\pi\eta r^4}{2l} \quad \text{. . . }(i)$$

and torque required to produce a unit twist in a hollow shaft

$$\tau_{\text{hollow}} = \frac{\pi\eta(r_2^4 - r_1^4)}{2l} \quad \text{. . . }(ii)$$

From (i) and (ii), $\frac{\tau_{\text{hollow}}}{\tau_{\text{solid}}} = \frac{r_2^4 - r_1^4}{r^4}$

$$= \frac{(r_2^2 + r_1^2)(r_2^2 - r_1^2)}{r^4} \quad \text{. . . }(iii)$$

Since two shafts are made from equal volume

$\therefore$ $\pi r^2 l = \pi(r_2^2 - r_1^2)l$

$\Rightarrow$ $r^2 = r_2^2 - r_1^2$

Substituting this value in equation (iii) we get, $\frac{\tau_{\text{hollow}}}{\tau_{\text{solid}}} = \frac{r_2^2 + r_1^2}{r^2} > 1$

$\therefore$ $\tau_{\text{hollow}} > \tau_{\text{solid}}$

i.e., the torque required to twist a hollow shaft is greater than the torque necessary to twist a solid shaft of the same mass, length and material through the same angle. Hence, a hollow shaft is stronger than a solid shaft.

MULTIPLE CHOICE QUESTIONS

Stress and Strain

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:

a. $\frac{W_1}{S}$ **b.** $\frac{W_1+(W/4)}{S}$

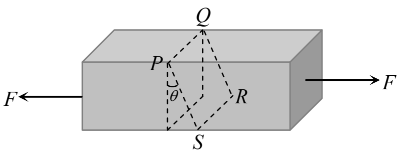
c. $\frac{W_1+(3W/4)}{S}$ **d.** $\frac{W_1+W}{S}$

2. On suspending a weight Mg, the length l of elastic wire and area of cross-section A its length becomes double the initial length. The instantaneous stress action on the wire is:

a. $\frac{Mg}{A}$ **b.** $\frac{Mg}{2A}$

c. $\frac{2Mg}{A}$ **d.** $\frac{4Mg}{A}$

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



a. $\frac{F}{A}$ **b.** $\frac{F\cos\theta}{A}$

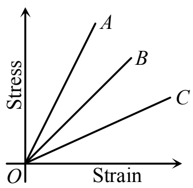
c. $\frac{F\cos^2\theta}{A}$ **d.** $\frac{F}{A\cos\theta}$

4. 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:

a. 0.02 **b.** 0.1

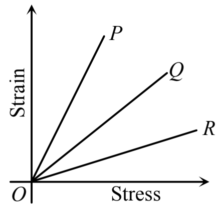
c. 0.005 **d.** 0.002

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



a. Rubber, brass and steel respectively
b. Brass, steel and rubber
c. Steel, brass and rubber respectively
d. Steel, rubber and brass

6. 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:



a. Elasticity of wire P is maximum
b. Elasticity of wire Q is maximum
c. Tensile strength of R is maximum
d. None of the above is true

Young's Modulus and Breaking Stress

7. A wire is loaded by 6 kg at its one end, the increase in length is 12 *mm*. If the radius of the wire is doubled and all other magnitudes are unchanged, then increase in length will be:

a. 6 *mm* **b.** 3 *mm*

c. 24 *mm* **d.** 48 *mm*

8. In CGS system, the Young's modulus of a steel wire is 2×10^{12}. To double the length of a wire of unit cross-section area, the force required is:

a. 4×10^6 dynes **b.** 2×10^{12} dynes

c. 2×10^{12} newtons **d.** 2×10^8 dynes

9. If x longitudinal strain is produced in a wire of Young's modulus y, then energy stored in the material of the wire per unit volume is:

a. yx^2 **b.** $2yx^2$

c. $\frac{1}{2}y^2x$ **d.** $\frac{1}{2}yx^2$

10. To double the length of a iron wire having 0.5 cm^2 area of cross-section, the required force will be: ($Y = 10^{12}$ dyne / cm^2)

a. $1.0\times10^{-7}\,N$ **b.** $1.0\times10^{7}\,N$

c. $0.5\times10^{-7}\,N$ **d.** $0.5\times10^{12}\,dyne$

11. An area of cross-section of rubber string is 2 cm^2. Its length is doubled when stretched with a linear force of 2×10^5 *dynes*. The Young's modulus of the rubber in *dyne* / *cm*^{2} will be:

a. 4×10^5 **b.** 1×10^5
c. 2×10^5 **d.** 1×10^4

12. An aluminum rod (Young's modulus $= 7\times10^9\ N/m^2$) has a breaking strain of 0.2%. The minimum cross-sectional area of the rod in order to support a load of 10^4 Newton's is:
a. $1\times10^{-2}\ m^2$ **b.** $1.4\times10^{-3}\ m^2$
c. $3.5\times10^{-3}\ m^2$ **d.** $7.1\times10^{-4}\ m^2$

13. If the density of the material increases, the value of Young's modulus:
a. Increases
b. Decreases
c. First increases then decreases
d. First decreases then increases

14. A steel ring of radius r and cross-section area 'A' is fitted on to a wooden disc of radius $R(R>r)$. If Young's modulus be E, then the force with which the steel ring is expanded is:
a. $AE\frac{R}{r}$ **b.** $AE\left(\frac{R-r}{r}\right)$
c. $\frac{E}{A}\left(\frac{R-r}{A}\right)$ **d.** $\frac{Er}{AR}$

15. When a weight of 10 kg is suspended from a copper wire of length 3 *metres* and diameter 0.4 mm, its length increases by 2.4 cm. If the diameter of the wire is doubled, then the extension in its length will be:
a. 9.6 cm **b.** 4.8 cm
c. 1.2 cm **d.** 0.6 cm

16. The extension of a wire by the application of load is 3 mm. The extension in a wire of the same material and length but half the radius by the same load is:
a. 12 mm **b.** 0.75 mm
c. 15 mm **d.** 6 mm

17. A force F is applied on the wire of radius r and length L and change in the length of wire is l. If the same force F is applied on the wire of the same material and radius $2r$ and length $2L$, Then the change in length of the other wire is:
a. l **b.** $2l$
c. $l/2$ **d.** $4l$

18. Two similar wires under the same load yield elongation of 0.1 mm and 0.05 mm respectively. If the area of cross-section of the first wire is $4mm^2$, then the area of cross section of the second wire is:
a. $6mm^2$ **b.** $8mm^2$
c. $10\ mm^2$ **d.** $12\ mm^2$

19. When a uniform wire of radius r is stretched by a $2kg$ weight, the increase in its length is 2.00 mm. If the radius of the wire is $r/2$ and other conditions remain the same, the increase in its length is:
a. 2.00 mm **b.** 4.00 mm
c. 6.00mm **d.** 8.00 mm

Hooke's Law and Modulus of Elasticity

20. 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:
a. l **b.** $2\ l$
c. $\frac{l}{2}$ **d.** $\frac{l}{4}$

21. 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:
a. 1 : 2 **b.** 1 : 1
c. 2 : 1 **d.** 8 : 1

22. 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:
a. $\frac{F}{AY}$ **b.** $\frac{2F}{AY}$
c. $\frac{1}{2}\left(\frac{F}{AY}\right)$ **d.** $\frac{3F}{AY}$

23. A 5 m long aluminum wire $(Y=7\times10^{10}N/m^2)$ of diameter 3 mm supports a 40 kg mass. In order to have the same elongation in a copper wire $(Y=12\times10^{10}N/m^2)$ of the same length under the same weight, the diameter should now be, in mm
a. 1.75 **b.** 2.0
c. 2.3 **d.** 5.0

24. 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:

a. Length 100 *cm*, diameter 1 *mm*
b. Length 200 *cm*, diameter 2 *mm*
c. Length 300 *cm*, diameter 3 *mm*
d. Length 50 *cm*, diameter 0.5 *mm*

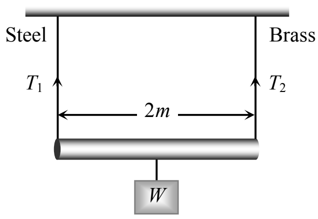
25. The coefficient of linear expansion of brass and steel are α_1 and α_2. If we take a brass rod of length L_1 and steel rod of length L_2 at $0°C$, their difference in length $(L_2 - L_1)$ will remain the same at any temperature if:

a. $\alpha_1 L_2 = \alpha_2 L_1$ **b.** $\alpha_1 L_2^2 = \alpha_2 L_1^2$
c. $\alpha_1^2 L_1 = \alpha_2^2 L_2$ **d.** $\alpha_1 L_1 = \alpha_2 L_2$

26. The force required to stretch a steel wire of $1 cm^2$ cross-section to 1.1 times its length would be: $(Y = 2\times10^{11}\ Nm^{-2})$

a. $2\times10^6\ N$ **b.** $2\times10^3\ N$
c. $2\times10^{-6}\ N$ **d.** $2\times10^{-7}\ N$

27. 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:

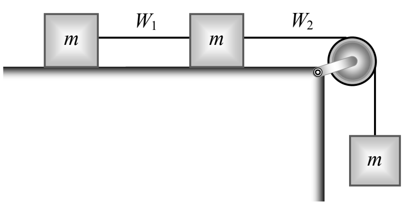


a. Will depend on the position of W

b. $\frac{T_1}{T_2} = 2$

c. $\frac{T_1}{T_2} = 1$ **d.** $\frac{T_1}{T_2} = 0.5$

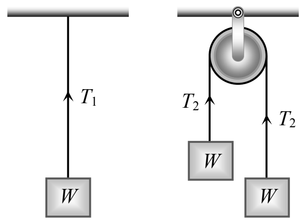
28. Three blocks, each of same mass m, are connected with wires W_1 and W_2 of same cross-sectional area a and Young's modulus Y. Neglecting friction the strain developed in wire W_2 is



a. $\frac{2}{3}\frac{mg}{aY}$ **b.** $\frac{3mg}{2aY}$

c. $\frac{1}{3}\frac{mg}{aY}$ **d.** $\frac{3mg}{aY}$

29. A wire elongates by 1.0 *mm* when a load W is hanged from it. If this wire goes over a pulley and two weights W each are hung at the two ends, the elongation of the wire will be:



a. 0.5 *m* **b.** 1.0 *mm*
c. 2.0 *mm* **d.** 4.0 *mm*

30. The Young's modulus of three materials are in the ratio 2 : 2 : 1. Three wires made of these materials have their cross-sectional areas in the ratio 1 : 2 : 3. For a given stretching force the elongation's in the three wires are in the ratio:

a. 1 : 2 : 3 **b.** 3 : 2 : 1
c. 5 : 4 : 3 **d.** 6 : 3 : 4

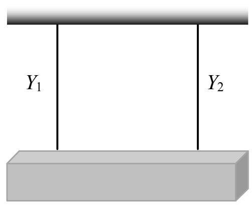
31. In the above problem, displacement of point C will be:

a. $24\times10^{-6} m$ **b.** $9\times10^{-6} m$
c. $4\times10^{-6} m$ **d.** $1\times10^{-6} m$

32. In the above problem, the displacement of point D will be:

a. $24\times10^{-6} m$ **b.** $9\times10^{-6} m$
c. $4\times10^{-6} m$ **d.** $1\times10^{-6} m$

33. Two wires of equal length and cross-section are suspended as shown. Their Young's modulii are Y_1 and Y_2 respectively. The equivalent Young's modulus will be:



a. $Y_1 + Y_2$ **b.** $\frac{Y_1 + Y_2}{2}$

c. $\frac{Y_1 Y_2}{Y_1 + Y_2}$ **d.** $\sqrt{Y_1 Y_2}$

34. If a load of 9*kg* is suspended on a wire, the increase in length is 4.5 *mm*. The force constant of the wire is:

a. $0.49\times10^4 N/m$ **b.** $1.96\times10^4 N/m$

c. $4.9\times10^4 N/m$ **d.** $0.196\times10^4 N/m$

35. Two wires *A* and *B* have the same length and area of cross section. But Young's modulus of *A* is two times the Young's modulus of *B*. Then the ratio of force constant of *A* to that of *B* is:

a. 1 **b.** 2

c. $\frac{1}{2}$ **d.** $\sqrt{2}$

Work Done in Stretching a Wire and Breaking of Wire

36. 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:

a. $\frac{V}{25}$ **b.** $5V$ **c.** $\frac{V}{5}$ **d.** $25V$

37. 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*

38. The Young's modulus of a wire is *Y*. If the energy per unit volume is *E*, then the strain will be:

a. $\sqrt{\frac{2E}{Y}}$ **b.** $\sqrt{2EY}$

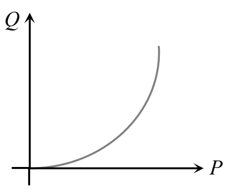
c. EY **d.** $\frac{E}{Y}$

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

a. $\frac{Fl}{2AL}$ **b.** $\frac{FA}{2L}$

c. $\frac{FL}{2A}$ **d.** $\frac{FL}{2}$

40. 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:



a. *P* = applied force, *Q* = extension

b. *P* = extension, *Q* = applied force

c. *P* = extension, *Q* = stored elastic energy

d. *P* = stored elastic energy, *Q* = extension

41. 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)

a. $F = 10\ N, A = 1\ cm^2, s = 10^{-3}$

b. $F = 15\ N, A = 2\ cm^2, s = 10^{-3}$

c. $F = 10\ N, A = 1/2\ cm^2, s = 10^{-4}$

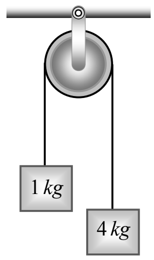
d. $F = 5\ N, A = 3\ cm^2, s = 10^{-3}$

42. To break a wire, a force of $10^6 N/m^2$ is required. If the density of the material is $3\times10^3 kg/m^3$, 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*

43. Two block of masses 1*kg* and 4*kg* are connected by a metal wire going over a smooth pulley as shown in the figure. The breaking stress of the metal is $3.18\times10^{10} N/m^2$. The minimum radius of the wire so it will not break is:



a. $1\times10^{-5} m$ **b.** $2\times10^{-5} m$

c. $3\times10^{-5} m$ **d.** $4\times10^{-5} m$

Bulk Modulus

44. If the volume of the given mass of a gas is increased four times, the temperature is raised from 27°*C* to 127°C. The elasticity will become:

a. 4 times **b.** $\frac{1}{4}$ times

c. 3 times **d.** $\frac{1}{3}$ times

45. 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?

a. $19.6\times10^8 N/m^2$ **b.** $19.6\times10^{-10} N/m^2$

c. $19.6\times10^{10} N/m^2$ **d.** $19.6\times10^{-8} N/m^2$

46. The ratio of the adiabatic to isothermal elasticities of a tri-atomic gas is:

a. $\frac{3}{4}$ **b.** $\frac{4}{3}$

c. 1 **d.** $\frac{5}{3}$

47. A gas undergoes a change according to the law $P = P_0 e^{\alpha V}$. The bulk modulus of the gas is:

a. P **b.** αPV

c. αP **d.** $\frac{PV}{\alpha}$

48. The ratio of two specific heats of gas C_p / C_v for argon is1.6 and for hydrogen is 1.4. Adiabatic elasticity of argon at pressure P is E. Adiabatic elasticity of hydrogen will also be equal to E at the pressure:

a. P **b.** $\frac{8}{7}P$

c. $\frac{7}{8}P$ **d.** 1.4 P

Modulus of Rigidity and Poisson's Ratio

49. If the Young's modulus of the material is 3 times its modulus of rigidity, then its volume elasticity will be:

a. Zero **b.** Infinity

c. $2\times10^{10}\ N/m^2$ **d.** $3\times10^{10}\ N/m^2$

50. Mark the wrong statement:

a. Sliding of molecular layer is much easier than compression or expansion

b. Reciprocal of bulk modulus of elasticity is called compressibility

c. It is difficult to twist a long rod as compared to small rod

d. Hollow shaft is much stronger than a solid rod of same length and same mass

51. The values of Young's and bulk modulus of elasticity of a material are $8\times10^{10}\ N/m^2$ and $10\times10^{10}\ N/m^2$ respectively. The value of Poisson's ratio for the material will be:

a. 0.25 **b.** – 0.25

c. 0.37 **d.** – 0.37

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

a. 0.125 **b.** 0.05

c. 0.215 **d.** 0.0125

Torsion of Cylinder and Inter-atomic Force Constant

53. Two wires A and B of same length and of the same material have the respective radii r_1 and r_2. Their one end is fixed with a rigid support, and at the other end equal twisting couple is applied. Then the ratio of the angle of twist at the end of A and the angle of twist at the end of B will be:

a. $\frac{r_1^2}{r_2^2}$ **b.** $\frac{r_2^2}{r_1^2}$

c. $\frac{r_2^4}{r_1^4}$ **d.** $\frac{r_1^4}{r_2^4}$

54. The work done in twisting a steel wire of length 25cm and radius 2mm through 45° will be: $(\eta = 8\times10^{10}\ N/m^2)$

a. 2.48 J **b.** 3.1 J

c. 15.47 J **d.** 18.79 J

55. The mean distance between the atoms of iron is $3\times10^{-10}\,m$ and inter-atomic force constant for iron is 7 N/m. The Young's modulus of elasticity for iron is:

a. $2.33\times10^5\ N/m^2$ **b.** $23.3\times10^{10}\ N/m^2$

c. $233\times10^{10}\ N/m^2$ **d.** $2.33\times10^{10}\ N/m^2$

56. The Young's modulus for steel is $Y = 2\times10^{11}\ N/m^2$. If the inter-atomic distance is 3.2$\mathring{A}$, the inter atomic force constant in $N/\mathring{A}$ will be:

a. 6.4×10^9 **b.** 6.4×10^{-9}

c. 3.2×10^9 **d.** 3.2×10^{-9}

57. The ratio of the lengths of two wires A and B of same material is 1 : 2 and the ratio of their diameter is 2 : 1. They are stretched by the same force, then the ratio of increase in length will be:

a. 2 : 1 **b.** 1 : 4

c. 1 : 8 **d.** 8 : 1

58. The Young's modulus of the material of a wire is $6\times10^{12}\ N/m^2$ and there is no transverse strain in it, then its modulus of rigidity will be:

a. $3\times10^{12}\ N/m^2$ **b.** $2\times10^{12}\ N/m^2$

c. $10^{12}\ N/m^2$ **d.** None of the above

59. A rod of length l and radius r is joined to a rod of length $l/2$ and radius $r/2$ of same material. The free end of small rod is fixed to a rigid base and the free end of larger rod is given a twist of $\theta°$, the twist angle at the joint will be:

a. $\frac{\theta}{4}$ b. $\frac{\theta}{2}$

c. $\frac{5\theta}{6}$ d. $\frac{8\theta}{9}$

60. The pressure of a medium is changed from 1.01×10^5 Pa to 1.165×10^5 Pa and change in volume is 10% keeping temperature constant. The Bulk modulus of the medium is:

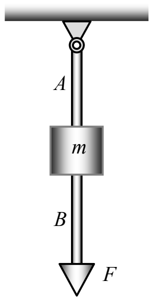
a. 204.8×10^5 Pa **b.** 102.4×10^5 Pa

c. 51.2×10^5 Pa **d.** 1.55×10^5 Pa

NCERT EXEMPLAR PROBLEMS

More than One Answer

61. The wire A and B shown in the figure are made of the same material and have radii r_A and r_B respectively. The block between them has a mass m. When the force F is $mg/3$, one of the wires breaks, then:



a. A will be break before B if $r_A = r_B$

b. A will break before B if $r_A < 2r_B$

c. A will break before B if $r_A = 2r_B$

d. the lengths of A and B must be known to predict which wire will break

62. A body of mass M is attached to the lower end of a metal wire, whose upper end is fixed. The elongation of the wire is l:

a. loss in gravitational potential energy of M is Mgl

b. the elastic potential energy stored in the wire is Mgl

c. the elastic potential energy stored in the wire is $\frac{1}{2}Mgl$

d. heat produced is $\frac{1}{2}Mgl$

63. A uniform plank is resting over a smooth horizontal floor and is pulled by applying a horizontal force at its one end which of the following statements is not correct?

a. Stress developed in plank material is maximum at the end at which force is applied and decrease linearly to zero at the other end

b. A uniform tensile stress is developed in the plank material

c. Since, plank is pulled at one end only, therefore, plank starts to accelerate along direction of the force. Hence, no stress is developed in the plank material

d. None of the above

64. Which of the following statements are correct?

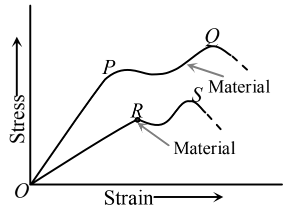
a. Poisson's ratio cannot be greater than 0.5

b. Basic reason of elasticity is inter-atomic force

c. Coefficient of restitution for collision of two bodies depends upon their Young's moduli of elasticity

d. None of these

65. The figure shows the stress-strain graphs for materials A and B. From the graph it follows that:



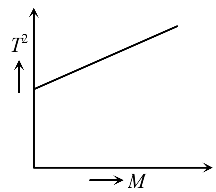
a. material A has a higher Young's modulus

b. material B is more ductile

c. material A is more brittle

d. material A can withstand greater stress

66. The graph shown was obtained from experimental measurements of the period of oscillations T for different masses M placed in the scale pan on the lower end of the spring balance. The most likely reason for the line not passing through the origin is that the:



a. Spring did not obey Hooke's Law

b. Amplitude of the oscillations was too large

c. Clock used needed regulating

d. Mass of the pan was neglected

67. A brass rod of cross-sectional area $1 cm^2$ and length 0.2 m is compressed lengthwise by a weight of 5kg. 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:

a. $10^{-5} J$ **b.** $2.5 \times 10^{-5} J$

c. $5 \times 10^{-5} J$ **d.** $2.5 \times 10^{-4} J$

68. A light rod of length 2 m is suspended from the ceiling horizontally by means of two vertical wires of equal length tied to its ends. One of the wires is made of steel and is of cross-section 0.1 cm^2. The other wire is of brass of cross-section 0.2 cm^2. A weight is suspended form a certain point of wires. Which of the following are correct?
a. The ratio of tensions in the steel and brass wires is 0.5
b. The load is suspended at a distance of 400/3 cm form the steel wire
c. Both (a) and (b)
d. Neither (a) nor (b)

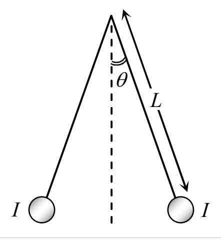
69. A copper wire and a steel wire of the same diameter and length are connected end to end and a force is applied, which stretches their combined length by 1 cm. The two wires will have:
a. Different stresses and strains
b. The same stress and strain
c. The same strain but different stresses
d. The same stress but different strains

70. A rubber cord catapult has cross-sectional area 25 mm^2 and initial length of rubber cord is $10cm.$ It is stretched to 5 cm. and then released to project a missile of mass 5 gm. Taking $Y_{rubber}=5\times10^8 N/m^2$ velocity of projected missile is:
a. $20ms^{-1}$ **b.** $100ms^{-1}$
c. $250ms^{-1}$ **d.** $200ms^{-1}$

71. If the tension on a wire is removed at once, then:
a. It will break
b. Its temperature will reduce
c. There will be no change in its temperature
d. Its temperature increases

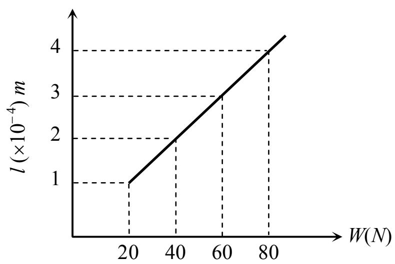
72. The extension in a string obeying Hooke's law is x. The speed of sound in the stretched string is v. If the extension in the string is increased to $1.5x$, the speed of sound will be:
a. 1.22 v **b.** 0.61 v
c. 1.50 v **d.** 0.75 v

73. Function $x=A\sin^2\omega t+B\cos^2\omega t+C\sin\omega t\cos\omega t$ represents SHM.



a. For any value of A, B and C (except $C=0$)
b. If $A=-B; C=2B$, amplitude $=|B\sqrt{2}|$
c. If $A=B; C=0$
d. If $A=B; C=2B$, amplitude $=|B|$

74. The adjacent graph shows the extension (Δl) of a wire of length $1m$ suspended from the top of a roof at one end with a load W connected to the other end. If the cross sectional area of the wire is $10^{-6}m^2$, calculate the young's modulus of the material of the wire:



a. $2\times10^{11}N/m^2$ **b.** $2\times10^{-11}N/m^2$
c. $3\times10^{-12}N/m^2$ **d.** $2\times10^{-13}N/m^2$

75. In a Young's double slit experiment, the separation between the two slits is d and the wavelength of the light is λ. The intensity of light falling on slit 1 is four times the intensity of light falling on slit 2. Choose the correct choice(s).
a. If $d=\lambda$, the screen will contain only one maximum
b. If $\lambda<d<2\lambda$, at least one more maximum (besides the central maximum) will be observed on the screen
c. If the intensity of light falling on slit 1 is reduced so that it becomes equal to that of slit 2, the intensities of the observed dark and bright fringes will increase
d. If the intensity of light falling on slit 2 is increased so that it becomes equal to that of slit 1, the intensities of the observed dark and bright fringes will increase

Assertion and Reason Problems

Note: Read the Assertion (A) and Reason (R) carefully to mark the correct option out of the options given below:
a. If both assertion and reason are true and the reason is the correct explanation of the assertion.
b. If both assertion and reason are true but reason is not the correct explanation of the assertion.
c. If assertion is true but reason is false.
d. If the assertion and reason both are false.
e. If assertion is false but reason is true.

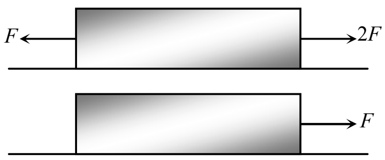
76. **Assertion:** Young's modulus for perfectly plastic body is zero.
Reason: For a perfectly plastic body, restoring force is zero

77. **Assertion:** Bulk modulus of elasticity (b) represents in compressibility of the material.
Reason: Bulk modulus of elasticity is proportional to change in pressure.

78. **Assertion:** Steel is more elastic than rubber.
Reason: Under given deforming force. Steel is deformed less than rubber.

79. **Assertion:** Two identical solid balls, one of ivory and the other of wet-clay are dropped from the same height on the floor. Both the balls will rise to same height after bouncing.
Reason: Ivory and wet-clay have same elasticity.

80. **Assertion:** Two identical uniform elastic rods are lying horizontally on smooth horizontal surface under the action of forces as shown in figure. The elongation in two rods will be same.



Reason: For a uniform elastic rod, the elongation is depending on a net force acting on the rod and is independent of point of application of force.

81. **Assertion:** The bridges are declared unsafe after a long use.
Reason: Elastic strength of bridges decreases with time.

82. **Assertion:** The stretching of a coil is determined by its shear modulus.
Reason: Shear modulus change only shape of a body keeping its dimensions unchanged.

83. **Assertion:** Spring balances show correct readings even after they had been used for a long time interval.
Reason: On using for long time, spring balances losses its elastic strength.

84. **Assertion:** Steel is more elastic than rubber.
Reason: Under given deforming force, steel is deformed less than rubber.

85. **Assertion:** Glassy solids have sharp melting point.
Reason: The bonds between the atoms of glassy solids get broken at the same temperature.

86. **Assertion:** Sterss is the internal force per unit area of a body.
Reason: Rubber is less elastic than steel.

87. **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.

Comprehension Based

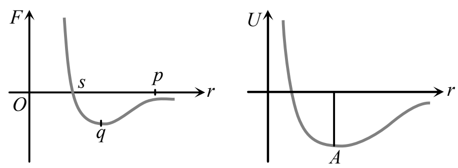
Paragraph–I

States of mater can be explained with the help of intermolecular forces. The molecules are bound together by these forces. These force are attractive in the range $r > r_0$ where nuclei of one atom pulls electrons of other to keep the atoms bonded. When $r < r_0$ the nuclei of two atoms exert forces of repulsion. This maintains the size of matter as solid. Thus it is equilibrium between these electrical forces of attraction and repulsion which maintain equilibrium with certain atoms or molecules in a solid in the state of minimum potential energy.

88. The expression of minimum potential energy is given by $E = -\frac{A}{r^n} + \frac{B}{r^m}$, where A, B, m and n are some constants. Here:

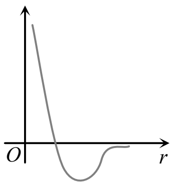
a. $m = n$
b. $m > n$
c. $m < n$
d. $m >< n$

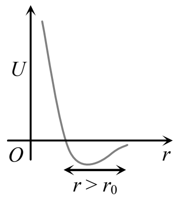
89. The lattice or binding energy curves of solids and inter atomic forces are shown by two similar curves. For solids point A shows state of minimum potential energy of molecules or atoms. It corresponds to which point in the $F vs r$ graph.

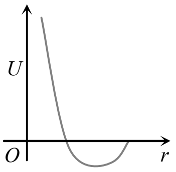


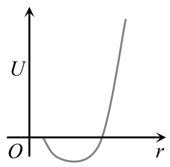
a. p
b. q
c. s
d. no relation between tow graphs

90. The shape of potential energy *vs* inter molecular distance curve, which can explain perfect elastic behaviour of solids is:

a. 

b. 

c. 

d. 

Match the Column

91. Column I defines the type of modulus or coefficient of elasticity. Column II gives the type of corresponding modulus. Match the definition with proper type of elasticity.

Column I	Column II
(A) Ratio of longitudinal or tensile stress to longitudinal strain	**1.** Modulus of Rigidly
(B) Ratio of normal or hydrostatic stress to volumetric strain	**2.** Poisson's ratio
(C) Ratio of lateral strain to longitudinal strain	**3.** Bulk modulus
(D) Ratio of tangential stress to shear strain	**4.** Young's modulus

a. A → 1, B → 2, C → 3, D → 4
b. A → 4, B → 3, C → 2, D → 1
c. A → 3, B → 2, C → 1, D → 4
d. A → 2, B → 1, C → 4, D → 3

92. Match Elasticity is material property but materials can have different types of elasticity depending on the type of stress and strain applied. Type of elasticity also depends on the forms of matter. Column I give the conditions of bodies under different usage. Column II gives type of elasticity. Match the correct option of elasticity with the use of body under specific situations.

Column I	Column II
(A) Derive shaft of a truck	**1.** Bulk modulus
(B) Suspension bridge	**2.** Shear modulus
(C) Water lift pump	**3.** Young's modulus
(D) Change in cross-section of wire with stretching of wire is studied as	**4.** Poisson's ratio

a. A → 2, B → 3, C → 1, D → 4
b. A → 1, B → 3, C → 4, D → 2
c. A → 3, B → 2, C → 1, D → 4
d. A → 2, B → 3, C → 4, D → 1

Integer

93. The length of a wire increases by 8 mm, when a weight of 5 kg is hung. If the conditions are the same, but the radius of the wire is doubles, what will be the increase in length in mm.

94. A lift is tied with thick iron wires and its mass is 1000 kg. If the maximum acceleration of lift is 1.2 ms^{-2} and maximum safe stress is $1.4\times10^{8}\,Nm^{-2}$, find the minimum diameter of the wire in cm, $g = 9.8 m/s^2$.

95. When equal volume of two metal are mixed together, the specific gravity of alloy is 4. When equal masses of the same two metals are mixed together, the specific gravity of the alloy is 3. Calculate the specific gravity of each metal.

96. A wire is loaded by 6 kg at its one end, the increase in length is 12 *mm*. If the radius of the wire is doubled and all other magnitudes are unchanged, then increase in length will be

97. A wire extends by 1 *mm* when a force is applied. Double the force is applied to another wire of same material and length but half the radius of cross-section. The elongation of the wire in *mm* will be

98. One end of a horizontal thick copper wire of length 2*L* and radius 2*R* is welded to an end of another horizontal thin copper wire of length *L* and radius *R*. When the arrangement is stretched by applying forces at two ends, the ratio of the elongation in the thin wire to that in the thick wire is:

99. When a certain weight is suspended from a long uniform wire, its length increases by one cm. If the same weight is suspended from another wire of the same material and length but having a diameter half of the first one then the increase in length will be:

100. Young's modulus of rubber is $10^4\ N/m^2$ and area of cross-section is 2 cm^2. If force of 2×10^5 dynes is applied along its length, then its initial length *l* becomes:

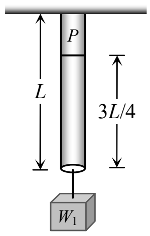
ANSWER

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
c	c	c	d	c	d	b	b	d	d
11.	**12.**	**13.**	**14.**	**15.**	**16.**	**17.**	**18.**	**19.**	**20.**
b	d	a	b	d	a	c	b	d	a
21.	**22.**	**23.**	**24.**	**25.**	**26.**	**27.**	**28.**	**29.**	**30.**
d	a	c	d	d	a	d	a	b	d
31.	**32.**	**33.**	**34.**	**35.**	**36.**	**37.**	**38.**	**39.**	**40.**
b	a	b	b	b	d	b	a	a	c
41.	**42.**	**43.**	**44.**	**45.**	**46.**	**47.**	**48.**	**49.**	**50.**
b	a	d	d	a	b	b	b	b	c
51.	**52.**	**53.**	**54.**	**55.**	**56.**	**57.**	**58.**	**59.**	**60.**
c	b	c	a	d	b	c	a	d	d
61.	**62.**	**63.**	**64.**	**65.**	**66.**	**67.**	**68.**	**69.**	**70.**
a	b	c	c	b	d	b	a	d	c
71.	**72.**	**73.**	**74.**	**75.**	**76.**	**77.**	**78.**	**79.**	**80.**
d	a	a,b,c	a	a,b	a	a	a	d	c
81.	**82.**	**83.**	**84.**	**85.**	**86.**	**87.**	**88.**	**89.**	**90.**
a	a	e	a	d	b	a	b	c	a
91.	**92.**	**93.**	**94.**	**95.**	**96.**	**97.**	**98.**	**99.**	**100.**
b	a	2	1	2,6	3	8	2	4	2

SOLUTION

Multiple Choice Questions

1. **(c)** 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 $P = \frac{\text{Force}}{\text{Area}} = \frac{W_1 + \frac{3W}{4}}{S}$

2. **(c)** When the length of wire becomes double, its area of cross section will become half because volume of wire is constant $(V = AL)$.

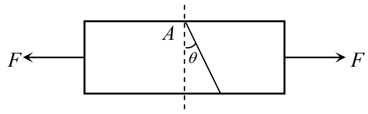
So, the instantaneous stress $= \frac{\text{Force}}{\text{Area}} = \frac{Mg}{A/2} = \frac{2Mg}{A}$.

3. **(c)** As tensile stress $= \frac{\text{Normal force}}{\text{Area}} = \frac{F_N}{A_N}$

and here $A_N = \frac{A}{\cos\theta}$,

F_N = Normal force $= F\cos\theta$

So, Tensile stress $= \frac{F\cos\theta}{A/\cos\theta} = \frac{F\cos^2\theta}{A}$



4. **(d)** Shearing strain $\phi = \frac{x}{L} = \frac{0.02cm}{0.1m} = 0.002$

5. **(c)** From the graph $\tan\theta_C < \tan\theta_B < \tan\theta_A$

$\Rightarrow$ $Y_C < Y_B < Y_A$

$\therefore$ $Y_{\text{Rubber}} < Y_{\text{Brass}} < Y_{\text{Steel}}$

6. **(d)** On the graph stress is represented on X- axis and strain Y-axis

So, from the graph $Y = \cot\theta$

$= \frac{1}{\tan\theta} \propto \frac{1}{\theta}$ [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.

7. **(b)** $l \propto \frac{1}{r^2}$.

If radius of the wire is doubled then increment in length will become $\frac{1}{4}$ times *i.e.* $\frac{12}{4} = 3mm$

8. **(b)** To double the length of wire, Stress = Young's modulus

$\therefore$ $\frac{F}{A} = 2\times10^{12}\,\frac{dyne}{cm^2}$.

If $A = 1$ then $F = 2\times10^{12}$ dyne

9. **(d)** Energy stored per unit volume $= \frac{1}{2}\times\text{Stress}\times\text{Strain}$

$= \frac{1}{2}\times\text{Young's modulus}\times(\text{Strain})^2 = \frac{1}{2}\times Y\times x^2$

10. **(d)** If length of wire doubled then strain = 1

Y = stress

$\Rightarrow$ $F = Y\times A = 10^{12}\times0.5 = 0.5\times10^{12}$ dyne

11. **(b)** If length of the wire is doubled then strain = 1

$\therefore$ Y = Stress $= \frac{\text{Force}}{\text{Area}} = \frac{2\times10^5}{2} = 10^5\,\frac{\text{dyne}}{\text{cm}^2}$

12. **(d)** $Y = \frac{F/A}{\text{strain}}$

$\Rightarrow$ $A = \frac{F}{Y\times\text{strain}} = \frac{10^4}{7\times10^9\times0.002}$

$= \frac{1}{14}\times10^{-2} = 7.1\times10^{-4}\,m^2$

13. **(a)** If density of the material increases then more force (stress) is required for same deformation *i.e.* the value of young's modulus increases.

14. **(b)** Initial length (circumference) of the ring = $2\pi r$

Final length (circumference) of the ring = $2\pi R$

Change in length = $2\pi R - 2\pi r$.

$$\text{Strain} = \frac{\text{Change in length}}{\text{Original length}} = \frac{2\pi(R-r)}{2\pi r} = \frac{R-r}{r}$$

Now Young's modulus $E = \dfrac{F/A}{l/L} = \dfrac{F/A}{(R-r)/r}$

$\therefore \quad F = AE\left(\dfrac{R-r}{r}\right)$

15. **(d)** $l \propto \dfrac{1}{r^2}$ (F, L and Y are constant) $\dfrac{l_2}{l_1} = \left(\dfrac{r_1}{r_2}\right)^2 = \left(\dfrac{1}{2}\right)^2$

$\Rightarrow \quad l_2 = \dfrac{l_1}{4} = \dfrac{2.4}{4} \Rightarrow l_2 = 0.6\,cm$

16. **(a)** $\dfrac{l_2}{l_1} = \left(\dfrac{r_1}{r_2}\right)^2 = (2)^2$

$\Rightarrow \quad l_2 = 4l_1 = 4\times 3 = 12mm$

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

$\Rightarrow \quad l \propto \dfrac{1}{r^2}$ (F and Y are constant)

$\Rightarrow \quad \dfrac{l_2}{l_1} = \dfrac{L_2}{L_1} \times \left(\dfrac{r_1}{r_2}\right)^2 = 2\times\left(\dfrac{1}{2}\right)^2 = \dfrac{1}{2}$

$\therefore \quad l_2 = \dfrac{l_1}{2}$

i.e. the change in the length of other wire is $\dfrac{l}{2}$

18. **(b)** $l = \dfrac{FL}{AY}$

$\therefore \quad l \propto \dfrac{1}{A}$ (F, L and Y are constant)

$\Rightarrow \quad \dfrac{A_2}{A_1} = \dfrac{l_1}{l_2}$

$\Rightarrow \quad A_2 = A_1\left(\dfrac{0.1}{0.05}\right) = 2A_1 = 2\times 4 = 8mm^2$

19. **(d)** $l = \dfrac{FL}{\pi r^2 Y}$

$\therefore \quad l \propto \dfrac{1}{r^2}$ (F, L and Y are constant)

$\Rightarrow \quad \dfrac{l_2}{l_1} = \left(\dfrac{r_1}{r_2}\right)^2 = (2)^2 \Rightarrow l_2 = 4l_1 = 4\times 2 = 8\,mm.$

20. **(a)** $l = \dfrac{FL}{\pi r^2 Y}$

$\Rightarrow \quad \dfrac{l_2}{l_1} = \dfrac{F_2}{F_1}\dfrac{L_2}{L_1}\left(\dfrac{r_1}{r_2}\right)^2 = 2\times 2\times\left(\dfrac{1}{2}\right)^2 = 1$

$\therefore \quad l_2 = l_1$

i.e. the increment in length will be same.

21. **(d)** $Y = \dfrac{FL}{\pi r^2 l}$

$\therefore \quad F = Y\pi r^2 \dfrac{l}{L}$

$\Rightarrow \quad \dfrac{F_A}{F_B} = \dfrac{Y_A}{Y_B}\left(\dfrac{r_A}{r_B}\right)^2\left(\dfrac{l_A}{l_B}\right)\left(\dfrac{L_B}{L_A}\right) = 1\times\left(\dfrac{2}{1}\right)^2\times(1)\times\left(\dfrac{2}{1}\right) = 8$

22. **(a)** Compressive strain

$$= \frac{\text{Stress}}{\text{Young's modulus}} = \frac{F/A}{Y} = \frac{F}{AY}$$

23. **(c)** $l = \dfrac{FL}{\pi r^2 Y} = \dfrac{4FL}{\pi d^2 Y}$ [As $r = \dfrac{d}{2}$]

If the elongation in both wires (of same length) are same under the same weight then $d^2 Y = \text{constant}$ $\left(\dfrac{d_{Cu}}{d_{Al}}\right)^2 = \dfrac{Y_{Al}}{Y_{Cu}}$

$\Rightarrow \quad d_{Cu} = d_{Al} \times \sqrt{\dfrac{Y_{Al}}{Y_{Cu}}} = 3\times\sqrt{\dfrac{7\times 10^{10}}{12\times 10^{10}}} = 2.29\,mm$

24. **(d)** If same force is applied on four wires of same material then elongation in each wire depends on the length and diameter of the wire and given by $l \propto \dfrac{L}{d^2}$ and the ratio of $\dfrac{L}{d^2}$ is maximum for (d) option.

25. **(d)** Difference in lengths of rods will remain same if expansion is same in both the rods.

If expansion in first rod is $l_1 = L_1\alpha_1\Delta\theta$ and expansion in second rod is $l_2 = L_2\alpha_2\Delta\theta$ then $L_1\alpha_1\Delta\theta = L_2\alpha_2\Delta\theta$

$\therefore \quad L_1\alpha_1 = L_2\alpha_2$

26. **(a)** $L_2 = 1.1\,L_1$

$\therefore \quad \text{Strain} = \dfrac{l}{L_1} = \dfrac{L_2 - L_1}{L_1} = \dfrac{1.1L_1 - L_1}{L_1} = 0.1$

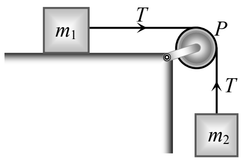
$\Rightarrow \quad F = YA\dfrac{l}{L} = 2\times 10^{11}\times 1\times 10^{-4}\times 0.1 = 2\times 10^6\,N.$

27. **(d)** Stress $= \dfrac{\text{Tension}}{\text{Area of cross-section}} = \text{constant}$

$\therefore \quad \dfrac{T_1}{A_1} = \dfrac{T_2}{A_2}$

$\Rightarrow \quad \dfrac{T_1}{T_2} = \dfrac{A_1}{A_2} = \dfrac{0.1}{0.2} = \dfrac{1}{2} = 0.5.$

28. **(a)** 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



$\Rightarrow \quad T = \dfrac{m_1 m_2}{m_1 + m_2} g$

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

$\therefore$ Tension $= \dfrac{m.2m.g}{m+2m} = \dfrac{2}{3} mg$

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

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

29. **(b)** Elongation in the wire $\propto$ Tension in the wire

In first case $T_1 = W$ and second case $T_2 = \dfrac{2W \times W}{W+W} = W$

As $\dfrac{T_1}{T_2} = 1$

$\therefore \quad \dfrac{l_1}{l_2} = 1 \Rightarrow l_2 = l_1 = 1.0mm$

30. **(d)** $l = \dfrac{FL}{AY}$ and for a given stretching force $l \propto \dfrac{1}{AY}$

Let three wires have young's modulus $2Y$, $2Y$ and Y and their cross sectional areas are A, $2A$ and $3A$ respectively.

$l_1 : l_2 : l_3 = \dfrac{1}{A_1 Y_1} : \dfrac{1}{A_2 Y_2} : \dfrac{1}{A_3 Y_3}$

$= \dfrac{1}{A \times 2Y} : \dfrac{1}{2A \times 2Y} : \dfrac{1}{3A \times Y} = \dfrac{1}{2} : \dfrac{1}{4} : \dfrac{1}{3} = 6:3:4.$

31. **(b)** Increment in the length BC

$= \dfrac{MgL}{AY} = \dfrac{10 \times 10 \times 0.2}{10^{-4} \times 4 \times 10^{10}} = 5 \times 10^{-6} m$

$\therefore$ Displacement of point $C = 4 \times 10^{-6} + 5 \times 10^{-6}$

$= 9 \times 10^{-6} m$

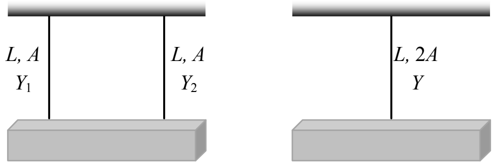
32. **(a)** Increment in the length CD

$= \dfrac{MgL}{AY} = \dfrac{10 \times 10 \times 0.15}{10^{-4} \times 1 \times 10^{10}} = 15 \times 10^{-6} m$

$\therefore$ Displacement of point $D = 4 \times 10^{-6} + 5 \times 10^{-6} m + 15 \times 10^{-6}$

$= 24 \times 10^{-6} m.$

33. **(b)** Let the equivalent young's modulus of given combination is Y and the area of cross section is $2A$.



For parallel combination $k_1 + k_2 = k_{eq}$.

$\Rightarrow \quad \dfrac{Y_1 A}{L} + \dfrac{Y_2 A}{L} = \dfrac{Y 2A}{L} \Rightarrow Y_1 + Y_2 = 2Y$

$\therefore \quad Y = \dfrac{Y_1 + Y_2}{2}$

34. **(b)** Force constant $k = \dfrac{F}{l} = \dfrac{mg}{l} = \dfrac{9 \times 9.8}{4.5 \times 10^{-3}}$

$\Rightarrow \quad k = 1.96 \times 10^4 N/m$

35. **(b)** Force constant of wire $k = \dfrac{YA}{L}$

$\Rightarrow \quad \dfrac{k_A}{k_B} = \dfrac{Y_A}{Y_B} = 2$ [As L and A are same]

36. **(d)** $U = \dfrac{1}{2}\left(\dfrac{YA}{L}\right) l^2$

$\therefore \quad U \propto l^2 \Rightarrow \dfrac{U_2}{U_1} = \left(\dfrac{l_2}{l_1}\right)^2 = \left(\dfrac{10}{2}\right)^2 = 25 \Rightarrow U_2 = 25U_1$

37. **(b)** $W = \dfrac{1}{2} \times F \times l = \dfrac{1}{2} mgl = \dfrac{1}{2} \times 10 \times 10 \times 1 \times 10^{-1} = 0.05\ J$

38. **(a)** Energy per unit volume $= \dfrac{1}{2} \times \text{Y} \times (\text{strain})^2$

$\therefore \quad$ Strain $= \sqrt{\dfrac{2E}{Y}}$

39. **(a)** Energy stored per unit volume $= \dfrac{1}{2}\left(\dfrac{F}{A}\right)\left(\dfrac{l}{L}\right) = \dfrac{Fl}{2AL}$

40. **(c)** 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 $U = \dfrac{1}{2} kx^2$ or $U \propto x^2$

41. **(b)** Strain energy $=\frac{1}{2}\times$ stress $\times$ strain $\times$ volume

$=\frac{1}{2}\times\frac{F}{A}\times$ strain $\times AL$ $=\frac{1}{2}\times F\times$ strain $\times L$

For wire (a) $U=\frac{1}{2}\times 10\times 10^{-3}\times L=5\times 10^{-3}L$

For wire (b) $U=\frac{1}{2}\times 15\times 10^{-3}\times L=7.5\times 10^{-3}L$

For wire (c) $U=\frac{1}{2}\times 10\times 10^{-4}\times L=0.5\times 10^{-3}L$

For wire (d) $U=\frac{1}{2}\times 5\times 10^{-3}=2.5\times 10^{-3}L$

For a given length wire (b) will have greatest strain energy.

42. **(a)** Length of the wire which will break by its own weight

$$L=\frac{P}{dg}=\frac{10^6}{3\times 10^3\times 10}=\frac{100}{3}=33.3m\simeq 34m$$

43. **(d)** Tension in the wire $T=\frac{2m_1m_2}{m_1+m_2}g$

$\Rightarrow$ $T=\frac{2\times 1\times 4}{1+4}\times 10$

$\Rightarrow$ $T=16N$

Breaking force = Breaking stress × Area of cross-section

Tension in the wire = $3.18\times 10^{10}\times \pi r^2$

$16=3.18\times 10^{10}\times \pi r^2$

$\Rightarrow$ $r=\sqrt{\frac{16}{3.18\times 10^{10}\times 3.14}}=4\times 10^{-5}m.$

44. **(d)** From the ideal gas equation $\frac{P_1V_1}{T_1}=\frac{P_2V_2}{T_2}$

$\Rightarrow$ $\frac{E_2}{E_1}=\frac{P_2}{P_1}=\frac{V_1}{V_2}\times\frac{T_2}{T_1}=\left(\frac{1}{4}\right)\times\left(\frac{400}{300}\right)=\frac{1}{3}$

$\Rightarrow$ $E_2=\frac{E_1}{3}$

i.e. elasticity will become $\frac{1}{3}$ times.

45. **(a)** $K=\frac{P}{\Delta V/V}=\frac{hdg}{\Delta V/V}$

$=\frac{200\times 10^3\times 9.8}{0.001}=19.6\times 10^8 N/m^2$

46. **(b)** For tri-atomic gas $\gamma=4/3$

$\therefore$ Ratio of adiabatic to isothermal elasticity $\gamma=\frac{4}{3}$.

47. **(b)** $P=P_oe^{\alpha V}$

$\Rightarrow$ $\frac{dP}{dV}=P_oe^{\alpha V}\alpha=P\alpha$ [As $P=P_oe^{\alpha V}$]

$\Rightarrow$ $\frac{dP}{dV}V=P\alpha V$ $\Rightarrow\frac{dP}{(dV/V)}=P\alpha V$

$\therefore$ $K=P\alpha V$

48. **(b)** Adiabatic elasticity = γ(pressure)

For Argon $(E_\phi)_{Ar}=1.6P$ and for Hydrogen $(E_\phi)_{H_2}=1.4P'$

According to problem $(E_\phi)_{H_2}=(E_\phi)_{Ar}$

$\Rightarrow$ $1.4P'=1.6P$

$\Rightarrow$ $P'=\frac{16}{14}P=\frac{8}{7}P.$

49. **(b)** $Y=2\eta(1+\sigma)$

$\Rightarrow$ $3\eta=2\eta(1+\sigma)$

$\Rightarrow$ $\sigma=\frac{3}{2}-1=\frac{1}{2}$

Now substituting the value of σ in the following expression.

$\Rightarrow$ $Y=3K(1-2\sigma)\Rightarrow K=\frac{Y}{3(1-2\sigma)}=\infty$

50. **(c)** For twisting, Angle of shear $\phi\propto\frac{1}{L}$

i.e. if L is more then ϕ will be small.

51. **(c)** $Y=3K(1-2\sigma)$

$\Rightarrow$ $8\times 10^{10}=3\times 10\times 10^{10}(1-2\sigma)\Rightarrow\sigma=0.37$

52. **(b)** $\sigma=\frac{\text{Lateral strain}}{\text{Longitudinal strain}}$

$\therefore$ Longitudinal strain $=\frac{\text{Lateral strain}}{\sigma}=\frac{0.0125}{0.25}=0.05$

53. **(c)** $\tau_1=\tau_2$

$\Rightarrow$ $\frac{\pi\eta r_1^4\theta_1}{2l_1}=\frac{\pi\eta r_2^4\theta_2}{2l_2}\Rightarrow\frac{\theta_1}{\theta_2}=\left(\frac{r_2}{r_1}\right)^4$

54. **(a)** $W=\frac{1}{2}C\theta^2=\frac{\pi\eta r^4\theta^2}{4l}$

$=\frac{3.14\times 8\times 10^{10}\times(2\times 10^{-3})^4\times(\pi/4)^2}{4\times 25\times 10^{-2}}=2.48J$

55. **(d)** $Y=\frac{k}{r_o}=\frac{7}{3\times 10^{-10}}=2.33\times 10^{10}N/m^2.$

56. **(b)** $k = Y \times r_0 = 2\times10^{11}\times3.2\times10^{-10}$

$= 6.4\times10^{1}\, N/m = 6.4\times10^{-9}\, N/Å$

57. **(c)** $l = \dfrac{FL}{AY} \Rightarrow l \propto \dfrac{L}{d^2}$

$\Rightarrow \quad \dfrac{l_1}{l_2} = \dfrac{L_1}{L_2}\times\left(\dfrac{d_2}{d_1}\right)^2 = \dfrac{1}{2}\times\left(\dfrac{1}{2}\right)^2 = \dfrac{1}{8}$

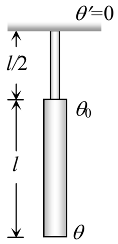
58. **(a)** $Y = 2\eta(1+\sigma)$

For no transverse strain ($\sigma = 0$)

$\Rightarrow \quad Y = 2\eta$

$\Rightarrow \quad \eta = \dfrac{Y}{2} = 3\times10^{12}\, N/m^2$

59. **(d)** $\tau = C.\theta = \dfrac{\pi\eta r^4\theta}{2L} =$ Constant



$$\Rightarrow \quad \frac{\pi\eta r^4(\theta-\theta_0)}{2l} = \frac{\pi\eta(r/2)^4(\theta_0-\theta')}{2(l/2)}$$

$$\Rightarrow \quad \frac{(\theta-\theta_0)}{2} = \frac{\theta_0}{16} \Rightarrow \theta_0 = \frac{8}{9}\theta$$

60. **(d)** $K = \dfrac{\Delta p}{\Delta V/V}$

$$= \frac{(1.165-1.01)\times10^5}{10/100} = \frac{0.155\times10^5}{1/10} = 1.55\times10^5\, pa$$

NCERT Exemplar Problems

More than One Answer

61. **(a)** Tension in $B = T_B = \dfrac{mg}{3}$

Tension in $A = T_A = T_B + mg = \dfrac{4mg}{3}$

$\therefore \quad T_A = 4T_B$

Stress $\dfrac{T}{\pi r^2} = S$

Wire breaks when S is equal to breaking stress for

$r_A = r_B,\ S_A = 4S_B$

$\therefore \quad A$ breaks before B For $r_A = 2r_B,\ S_B = \dfrac{T_B}{\pi r_B^2}$

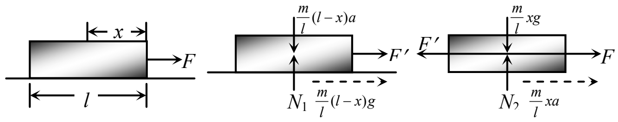
$$S_A = \frac{T_A}{\pi r_A^2} = \frac{4T_B}{\pi(2r_B)^2} = \frac{T_B}{\pi r_B^2} = S_B$$

As the stresses are equal, either may break.

62. **(b)**

63. **(c)** Since force is applied at one end only, therefore, the plank starts to accelerate along the direction of this force and a stress is developed in its material. Hence, (c) is wrong.

To calculate stress in the material of the plank, at a distance x from the end of which force is applied, free-body diagrams are considered as shown in the figure.



$\Rightarrow \quad F' = \dfrac{m}{l}(l-x)a \quad \Rightarrow F - F' = \dfrac{m}{l}xa$

From these two equations $F' = \dfrac{F(l-x)}{l}$

$\therefore \quad$ Stress $= \dfrac{F'}{A} = \dfrac{F(l-x)}{Al}$ where A is cross-sectional area of the plank. It shows that stress varies linearly with x. It is maximum at $x = 0$ and zero $x = l$.

64. **(c)** Suppose a uniform rod is pulled by a tension due to which a longitudinal stress is developed in its material. Then tensile strain in the material of the rod $\varepsilon_1 = \dfrac{\sigma}{Y}$

Where Y is Young's modulus of elasticity. If its Poisson's ratio is μ then lateral strain will be equal to $\mu\varepsilon_1$. Lateral strain has opposite nature to that of the longitudinal strain. We also know volumetric strain $\varepsilon_V = \varepsilon_x + \varepsilon_y + \varepsilon_Z$

Hence, $\varepsilon_V = \varepsilon_1 + 2(-\mu\varepsilon_1) = (1-2\mu)\varepsilon_1$

Since, tension is applied on the material, therefore, its volume cannot decrease. Hence, ε_V cannot be negative. Therefore, $(1-2\mu)$ cannot be less than zero or μ cannot be greater than 0.5. Hence, option (a) is correct. It can be easily understood that option (b) and (c) are correct. So, option (d) is obviously wrong.

65. **(b)** The slope of the linear portion of the curve gives Young's modulus of the material. The slope of the linear portion OP for material A is greater than that of the linear portion OR for material B. Hence, statement (a) is correct. The plastic region for material A (from P to Q) is greater than that (from R to S) for material B, which indicates that material A is more ductile. Hence, statement (*b*) is correct.

The breaking stress for material B (*i.e.,* stress corresponding to point S) is less than that for material A (i.e., stress corresponding to point Q), which implies that material B can break more easily than material A. Thus, material B is more brittle. Hence, choice (c) is also incorrect. Material A is stronger than material B because it can withstand a greater stress before it breaks. The breaking stress is the stress corresponding to point Q for material A and to point S for material B. Hence, the correct choices are (a) and (d).

66. **(d)** $T = 2\pi\sqrt{\frac{M}{K}}$

$\Rightarrow \quad T^2 \propto M$

If we draw a graph between T^2 and M then it will be straight line. and for $M = 0$, $T^2 = 0$

i.e. the graph should pass through the origin.

but from the it is not reflected it means the mass of pan was neglected.

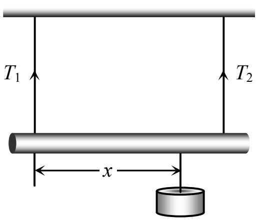
67. **(b)** $U = \frac{1}{2}\times\frac{(\text{stress})^2}{Y}\times\text{volume} = \frac{1}{2}\times\frac{F^2\times A\times L}{A^2\times Y}$

$= \frac{1}{2}\times\frac{F^2L}{AY} = \frac{1}{2}\times\frac{(50)^2\times 0.2}{1\times10^{-4}\times1\times10^{11}} = 2.5\times10^{-5}\,J$

68. **(a)** $\frac{T_1}{0.1} = \frac{T_2}{0.2}$ or $\frac{T_1}{T_2} = \frac{1}{2} = 0.5$

Further, $T_1x = T_2(2-x)$ or, $\frac{T_1}{T_2} = \frac{2-x}{x}$

Hence, $\frac{2-x}{x} = 0.5\frac{1}{2}$



Or, $4 - 2x = x$ or, $x = \frac{4}{3}m = \frac{400}{3}$ cm.

69. **(d)** Stress $= \frac{\text{Force}}{\text{area}}$.

In the present case, force applied and area of cross-section of wires are same, therefore stress has to be the same.

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

Since the Young's modulus of steel wire is greater than the copper wire, therefore, strain in case of steel wire is less than that in case of copper wire.

70. **(c)** Potential energy stored in the rubber cord catapult will be converted into kinetic energy of mass.

$\Rightarrow \quad \frac{1}{2}mv^2 = \frac{1}{2}\frac{YAl^2}{L}$

$\Rightarrow \quad v = \sqrt{\frac{YAl^2}{mL}}$

$= \sqrt{\frac{5\times10^8\times25\times10^{-6}\times(5\times10^{-2})^2}{5\times10^{-3}\times10\times10^{-2}}} = 250\ m/s$

71. **(d)** Due to tension, intermolecular distance between atoms is increased and therefore potential energy of the wire is increased and with the removal of force interatomic distance is reduced and so is the potential energy. This change in potential energy appears as heat in the wire and thereby increases the temperature.

72. **(a)** Speed of sound in a stretched string

$v = \sqrt{\frac{T}{\mu}}$ ...(*i*)

Where T is the tension in the string and μ is mass per unit length.

According to Hooke's law, $F \propto x$

$\therefore \quad T \propto x$ ...(*ii*)

From (*i*) and (*ii*) $v \propto \sqrt{x}$

$\therefore \quad v' = \sqrt{1.5}\ v = 1.22\ v$

73. **(a, b, c)** $x = \frac{A}{2}(1-\cos 2\omega t) + \frac{B}{2}(1+\cos 2\omega t) + \frac{C}{2}\sin 2\omega t$

For $A = 0$, $B = 0$ $\quad x = \frac{C}{2}\sin 2\omega t$

For $A = -B$ and $C = 2B$ $\quad x = B\cos 2\omega t + B\sin 2\omega t$

Amplitude $= |B\sqrt{2}|$

For $A = B$; $C = 0$; $x = A$

Hence, this is not correct option

For $A = B, C = 2B$, $x = B + B\sin 2\omega t$

It is also represents SHM.

74. **(a)** From the graph $l = 10^{-4}m$, $F = 20N$

$A = 10^{-6}m^2$, $L = 1m$

$\therefore \quad Y = \frac{FL}{Al} = \frac{20\times1}{10^{-6}\times10^{-4}} = 20\times10^{10} = 2\times10^{11}\,N/m^2$

75. **(a, b)** For at least one maxima, $\sin\theta = \frac{\lambda}{d}$

If $\lambda = d$, $\sin\theta = 1$ and $y \to \infty$

If $\lambda < d < 2d$, $\sin\theta$ exists and y is finite

Assertion and Reason

76. **(a)** Young's modulus of a material, $Y = \frac{\text{Stress}}{\text{Strain}}$

Here, $\text{Stress} = \frac{\text{restoring force}}{\text{area}}$

As restoring force is zero, for a perfectly plastic body hence $Y = 0$.

77. **(a)** Bulk modulus of elasticity measures how good the body is to regain its original volume on being compressed. Therefore, it represents incompressibility of the material.

$B = -\frac{PV}{dV}$

Where P is increase in pressure, and dV is change in volume.

78. **(a)** Elasticity is a measure of tendency of the body to regain its original configuration. As steel is deformed less than rubber, therefore steel is more elastic than rubber.

79. **(d)** Ivory is more elastic than wet-clay. Hence the ball of ivory will rise to a greater height. In fact the ball of wet-clay will not rise at all, it will be somewhat flattened permanently.

80. **(c)** In assertion, tension at any point (distance x from right end) in both the rods is same and hence elongation is same. Reason is wrong through it seems to be correct for situation given in assertion.

81. **(a)** A bridge during its use undergoes alternating strains for a large number of times each day, depending upon the movement of vehicles on it. When a bridge is used for long time, it losses it elastic strength. Due to which the amount of strain in the bridge for a given stress will become large and ultimately, the bridge may collapse. This may not happen, if the bridge is declared unsafe after long use.

82. **(a)** Because, the stretching of coil simply changes its shape without any change in the length of the wire used in coil. Due to which shear modulus of elasticity is involved.

83. **(e)** When a spring balance has been used for a long time, the spring in the balance fatigued and there is loss of strength of the spring. In such a case, the extension in the spring is more for a given load and hence the balance gives wrong readings.

84. **(a)** Elasticity is a measure of tendency of the body to regain its original configuration. As steel is deformed less than rubber therefore steel is more elastic than rubber.

85. **(d)** In a glassy solid (*i.e.*, amorphous solid) the various bonds between the atoms or ions or molecules of a solid are not equally strong. Different bonds are broken at different temperatures. Hence there is no sharp melting point for a glassy solid.

86. **(b)** Stress is defined as internal force (restoring force) per unit area of a body. Also, rubber is less elastic than steel, because restoring force is less for rubber than steel.

87. **(a)** Work done $= \frac{1}{2} \times \text{Stress} \times \text{Strain} = \frac{1}{2} \times Y \times (\text{Strain})^2$.

Since, elasticity of steel is more than copper, hence more work has to be done in order to stretch the steel.

Comprehension Based

88. **(b)** To maintain energy minimum for solids $m > n$ because for smaller $r < r_0$, the energy must be + *ve*. To maintain the shape and size of solid and for $r = r_0$ $\frac{dU}{dr} = 0$ so that U is minimum.

For $r = r_0$, $\frac{dU}{dr} = 0$ or $F = -\frac{dU}{dr} = 0$

89. **(c)** At point, S, $F = 0$, *i.e.,* atom or molecules are in equilibrium when $r = r_0$. If $r > r_0$ force is attractive and when $r < r_0$ force is repulsive. This makes the solids to show elastic behaviour as shown in figure

Also $F = -\frac{dU}{dr} = 0$, U is minimum for solids at point S.

90. **(a)** Symmetric parabolic curve will show that during compression $r_1 < r_0$ at A or expansion $r_2 < r_0$ at B. The potential energy $U > U_{\min}$ are equal at A and B so that mean distance $\frac{r_1 + r_2}{2} = r_0$ to show elastic behaviour

Match the Column

91. **(b)** $Y = \frac{F}{A} \times \frac{l}{\Delta l} = \frac{\text{Longitudinal stress}}{\text{Longitudinal strain}} = \text{Young's modulus}$

$K = \frac{F}{A} \times \frac{V}{\Delta V} = \frac{\text{Normal stress}}{\text{Volumetric strain}} = \text{Bulk modulus}$

= Volume elasticity

$\text{Poisson's ratio} = \frac{\text{Lateral strain}}{\text{Longitudinal strain}}$

$$\Rightarrow \quad \sigma = \frac{\frac{\Delta D}{D}}{\frac{\Delta l}{l}} = \frac{\Delta D}{D} \times \frac{l}{\Delta l}$$

92. **(a)** Drive shaft is driven by force acting tangentially to the surface to rotate it.

Suspension bridge is made by pulling cable which involve longitudinal or tensile stress. Thus it is related to Young's modulus. In water lift-pump, water is compressed by hydrostatic or normal stress to compress its volume. This is related to Bulk modulus. Decrease in cross-section with increase in length (for volume of solid to be conserved). Poisson's ratio is defined as

$$\sigma = \frac{\text{Lateral strain}}{\text{Longitudinal strain}} = \frac{\Delta D / D}{\Delta l / l}$$

Integer

93. **(2)** $Y = \frac{Fl}{A\Delta l}$ or $\Delta l = \frac{Fl}{AY} = \frac{Fl}{\pi r^2 Y}$

So $\Delta l \propto \frac{1}{r^2} \therefore \frac{\Delta l_3}{\Delta l} = \frac{r^2}{r_1^2}$

Or $\Delta l_1 = \Delta t \frac{r^2}{r_1^2} = 8 \times \frac{r^2}{(2r)^2} = 2$ mm,

94. **(1)** The maximum tension in the rope is

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

Stress, $S = \frac{F}{A} = \frac{F}{(\pi D^2/4)}$

or $D^2 = \frac{4F}{rS} = \frac{4 \times 11000 \times 7}{22 \times 1.4 \times 10^8} = \frac{1}{10^4}$

$\therefore\ D = \frac{1}{10^2} m = 1\text{cm}.$

95. **(2, 6)** Let $m_1, m_2 =$ masses of two metals,

$V_1, V_2 =$ volumes of two metals.

If ρ is the density of mixture of two metals, then

$\rho = (m_1 + m_2)/(V_1 + V_2)$

When equal volumes of two metals of density ρ_1 and ρ_2 are mixed, then $V_2 = V_2 = V$ and $m_1 = \rho_1 V$ and $m_2 = \rho_2 V$.

If ρ is the density of mixture of two metals, then

$$\rho = \frac{(\rho_1 V + \rho_2 V)}{V + V} = \frac{\rho_1 + \rho_2}{2}$$

or $\rho_1 + \rho_2 = 2\rho = 2 \times 4 = 8$ . . .(*i*)

When equal masses are mixed, then

$m_1 = m_2 = m$ and $V_1 = m/\rho_1$ and $V_2 = m/\rho_2$

So, $\rho = \frac{m + m}{(m/\rho_1) + (m/\rho_2)} = \frac{2\rho_1\rho_2}{\rho_1 + \rho_2} = 3$

or $\rho_1\rho_2 = \frac{3}{2}(\rho_1 + \rho_2) = \frac{3}{2} \times 8 = 12$ . . . (*iii*)

Solving (*i*) and (*ii*), we get, $\rho_1 = 2$ and $\rho_2 = 6$.

96. **(3)** $l \propto \frac{1}{r^2}$. If radius of the wire is doubled then increment in length will become $\frac{1}{4}$ times *i.e.* $\frac{12}{4} = 3mm$

97. **(8)** $l = \frac{FL}{\pi r^2 r}$

$\Rightarrow\ l \propto \frac{F}{r^2}$ (Y and L are constant)

$\frac{l_2}{l_1} = \frac{F_2}{F_1} \times \left(\frac{r_1}{r_2}\right)^2 = 2 \times (2)^2 = 8$

$\therefore\ l_2 = 8l_1 = 8 \times 1 = 8mm$

98. **(2)** $\Delta l = \frac{FL}{AY} = \frac{FL}{(\pi r^2)Y}$

$\therefore\ \Delta l \propto \frac{L}{r^2}$

$\therefore\ \frac{\Delta l_1}{\Delta l_2} = \frac{L/R^2}{2L/(2R)^2} = 2$

99. **(4)** $l = \frac{FL}{AY}$

$\Rightarrow\ l \propto \frac{1}{r^2}$ (F, L and Y are constant)

$\Rightarrow\ \frac{l_2}{l_1} = \left(\frac{r_1}{r_2}\right)^2 = (2)^2 = 4 \Rightarrow l_2 = 4l_1 = 4cm$

100. **(2)** $Y = 10^4\,N/m^2$

$A = 2 \times 10^{-4}\,m^2$

$F = 2 \times 10^5\,dyne = 2N$

$\Rightarrow\ l = \frac{FL}{AY} = \frac{2 \times L}{2 \times 10^{-4} \times 10^4} = L$

$\therefore$ Final length = initial length + increment = $2L$

* * *