



GOVERNMENT OF KARNATAKA

DEPARTMENT OF SCHOOL EDUCATION (PRE-UNIVERSITY)

18TH CROSS, MALLESHWARAM, BENGALURU – 560 012

CHAPTER-WISE MULTIPLE-CHOICE QUESTIONS FOR COMPETITIVE EXAM

SUBJECT: I PUC - PHYSICS

NAME OF THE CHAPTER: 8. MECHANICAL PROPERTIES OF SOLIDS

SYNOPSIS

8.1. Elastic and Plastic materials:

- When a force is applied on a body, its shape or size or both may change. On the removal of that force, the body regains its original shape and size. Such bodies are called **elastic bodies** or elastic materials. Examples include ivory balls, rubber bands etc.
- When a force is applied on a body, its shape or size or both may change. However, on its removal, the body does not recover its original shape and size. Such bodies are called **plastic bodies**. Examples include a blob of wax, potter's clay etc.

8.2. Stress and Strain:

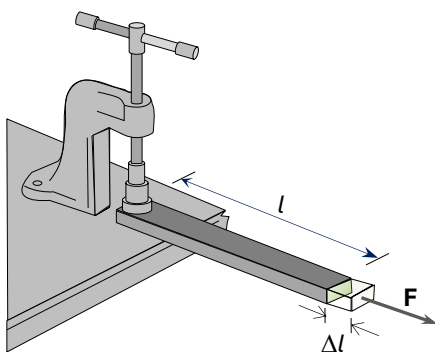


Fig (a)

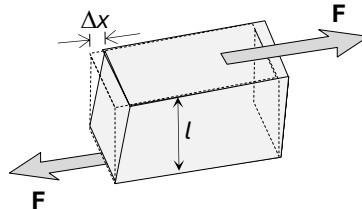
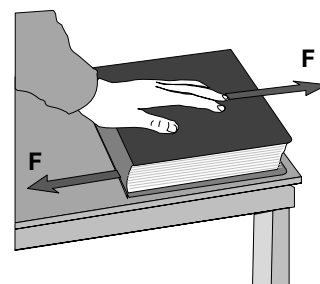


Fig (b)



- When a body such as a metallic rectangular strip as in Fig (a) is pulled along its length, restoring forces are developed in it to recover its original shape and size. The “restoring forces per unit area acting along the length of the object is called **longitudinal stress**”.

That is
$$\text{Longitudinal Stress} = \frac{F_{\text{perp}}}{A} \text{ (measured in Nm}^{-2}\text{)}$$

- When a body such as a block or a book as in Fig (b) is pushed along its surface/tangent, restoring forces are developed in it to recover its original shape and size. The “restoring forces per unit area acting tangentially to the surface of the object is called **shear stress**”.

That is
$$\text{Shear Stress} = \frac{F_{\text{tang}}}{A} \text{ (measured in Nm}^{-2}\text{)}$$

- When a body such as a cube as in Fig (c) is pressed in all the directions, restoring forces are developed in it to recover its original shape and size. The “restoring forces per unit area acting perpendicular to the surface at all points of the object is called **volume stress**”.

That is
$$\text{Volume Stress} = \frac{F_{\text{perp}}}{A} \text{ (measured in Nm}^{-2}\text{)}$$

➤ When a body such as a metallic rectangular strip as in Fig (a) is pulled along its length, its length changes by a certain amount Δl . *The ratio of change in the length of an object to its original length when subjected to longitudinal stress is called **longitudinal strain**.*

That is
$$\text{Longitudinal Strain} = \frac{\Delta l}{l} \text{ (No unit)}$$

➤ When a body such as a block or a book as in Fig (b) is pushed/pulled along its surface/tangent, its surface displaces parallel to the force by Δx . *The ratio of change in the length of an object parallel to the force to its original length perpendicular to the force when subjected to shear stress is called **shear strain**.*

That is
$$\text{Shear Strain} = \frac{\Delta x}{l} \text{ (No unit)}$$

➤ When a body such as a cube as in Fig (c) is pressed in all the directions, its volume changes by ΔV . The *"ratio of the change in volume to its original volume when subjected to volume stress is called **volume strain**".*

That is
$$\text{Volume Strain} = \frac{\Delta V}{V} \text{ (no unit)}$$

EXAMPLE 8.1:

A cylindrical rod is fixed to a vertical support and a weight of 10 kg is suspended from the free end. The density of the material of the rod is 8 g.cm^{-3} . If the length of the rod is 0.5 m and its radius is $\frac{5}{\sqrt{\pi}} \text{ cm}$, the stress on the rod at a distance 30 cm below its clamped end is

- (A) 16 kPa (B) 56 kPa (C) 40 kPa (D) 56 Pa

Ans (B)

Example Solved:

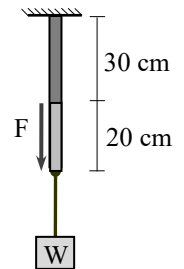
The weight of the part of the rod 30 cm below

$$W' = \rho \pi r^2 L g = 8000 \times \pi \times \left(\frac{5}{\sqrt{\pi}} \times 10^{-2}\right)^2 \times 0.2 \times 10 = 40 \text{ N}$$

Total force across the Surface

$$F = W + W' = 10 \times 10 + 40 = 140 \text{ N}$$

$$\text{Longitudinal stress} = \frac{F}{A} = \frac{F}{\pi r^2} = \frac{140}{\pi \left(\frac{5}{\sqrt{\pi}} \times 10^{-2}\right)^2} = 56 \text{ kPa}.$$



8.3. Hooke's Law – Relationship between Stress and Strain:

➤ *"Under the elastic limit, the stress on a body is directly proportional to its strain"* This is called Hooke's law.

➤ That is
$$\text{Stress} \propto \text{Strain} \text{ OR } \frac{\text{Stress}}{\text{Strain}} = \text{Constant} = \text{Elastic Modulus}$$

➤ There are three type of elastic moduli:

❶ Young's modulus:
$$\text{Young's modulus} = E = \frac{\text{Longitudinal Stress}}{\text{Longitudinal Strain}}$$

❷ Rigidity / torsional modulus:
$$\text{Rigidity/torsional modulus} = \eta = \frac{\text{Shear Stress}}{\text{Shear Strain}}$$

❸ Bulk modulus:
$$\text{Bulk modulus} = B = \frac{\text{Volume Stress}}{\text{Volume Strain}}$$

EXAMPLE 8.2:

Within the elastic limit, which among the graphs represents the variation of stress on a body with the strain caused in it?

(A) *a*(B) *b*(C) *c*(D) *d*

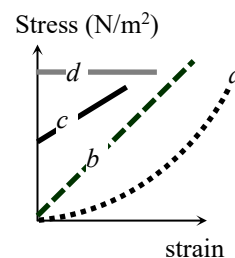
Ans (B)

Example Solved:

According to Hooke's law : stress $\propto$ strain

That is : stress = $E \times$ strain $\Leftrightarrow y = mx$

The graph of stress vs strain : a straight line starting from the origin as in choice (2)

**8.4. Poisson's Ratio and Energy Stored in a Stretched wire/rod:**

➤ The ratio of lateral to longitudinal strain is called **Poisson's ratio**.

That is **Poisson's Ratio** = $\frac{\text{Lateral strain}}{\text{Longitudinal Strain}}$

➤ When a wire/rod of length l is stretched by a force F , the stress and strain in it are F/A and $\Delta l/l$ respectively.

Then the energy stored in the wire/rod in expanding it is

Energy Stored = Work done to stretch

OR

$$U = \frac{1}{2} \times F \times \Delta l = \frac{1}{2} \times \frac{F}{A} \times \frac{\Delta l}{l} \times Al \Rightarrow U = \frac{\text{stress} \times \text{strain} \times \text{volume}}{2}$$

➤ The following table gives the Young's, rigidity and bulk moduli of some materials.

Material	Density (kg/m ³)	Young's Modulus (10 ⁹ N/m ²)	Ultimate Strength (10 ⁶ N/m ²)	Rigidity Modulus (10 ⁹ N/m ²)	Bulk Modulus (10 ⁹ N/m ²)	Poisson's Ratio
Steel	7860	200	400	84	60	0.29
Aluminum	2710	70	110	25	70	0.1
Glass	2190	65	50	28	53	0.05
Concrete	2320	30	40			
Wood	525	13	50	10		
Bone	1900	9	170			

EXAMPLE 8.3:

A rod of density ρ , length L and square cross section of side a is stretched by a constant force P . The energy stored in the rod is (E is the Young's modulus)

(A) $\frac{E^2 a L}{2P}$

(B) $\frac{P^2 L}{2a^2 E}$

(C) $\frac{P^2 a}{2L^2 E}$

(D) $\frac{P^3 L}{3a^3 E^2}$

Ans (B)

Example Solved:

According to Hooke's law : $U = \frac{\text{stress} \times \text{strain} \times \text{volume}}{2} = \frac{\text{stress}^2 \times \text{volume}}{2 \times \text{elastic modulus}} \because \text{strain} = \frac{\text{stress}}{E}$

That is : $U = \frac{\left(\frac{P}{a^2}\right)^2 \times a^2 L}{2 \times E} = \frac{P^2 L}{2a^2 E}$

8.5. Stress – Strain Curve, Yield Strength and Compressive Strengths:

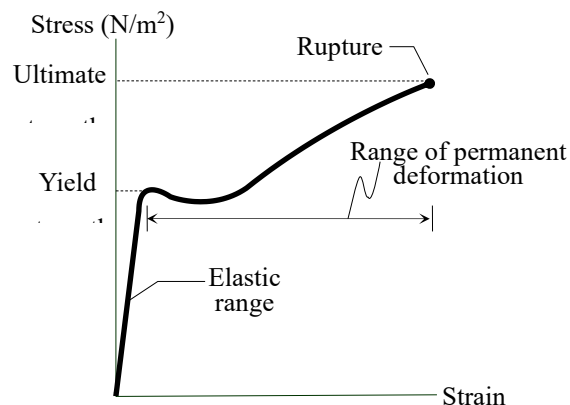
➤ A stress – strain graph of a typical solid is as shown in the figure below.

➤ For a substantial range of applied stresses, the stress–strain relation is **linear**, and the specimen recovers its original dimensions when the stress is removed.

➤ It is here in the linear region, that Hooke’s law applies.

➤ If the stress is increased beyond the **yield strength** S_y of the specimen, the specimen becomes permanently deformed.

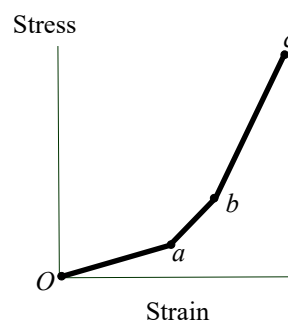
➤ If the stress continues to increase, the specimen eventually ruptures, at a stress called the **ultimate strength** S_u .



EXAMPLE 8.4:

A stress – strain graph of a spider web thread is given in the figure. From the figure, it can be concluded that

- (A) Hooke’s law is NOT valid in the region bc .
- (B) Hooke’s law is valid over the regions oa , ab and bc .
- (C) the stress produced in the thread reaches yield strength at c .
- (D) the modulus of elasticity of the thread has a fixed value.



Ans (B)

8.6. Experimental Determination of Young’s Modulus of a Wire:

➤ A typical experimental arrangement to determine the Young’s modulus of a material of wire under tension is shown in the figure

➤ It consists of two long straight wires of same length and equal radius suspended side by side from a fixed rigid support. The *reference wire* carries a millimetre main scale and a pan to place a weight.

➤ The *experimental wire* of uniform area of cross section also carries a pan in which known weights can be placed.

➤ A Vernier scale is attached to a pointer at the bottom of the experimental wire, and the main scale is fixed to the reference wire.

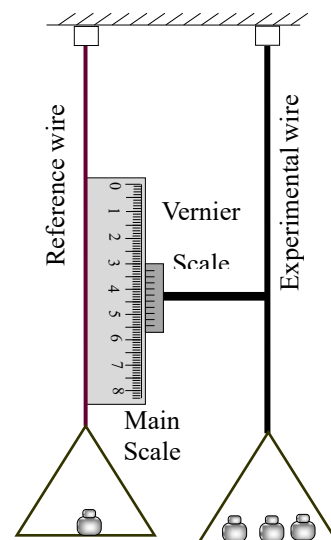
➤ The weights placed in the pan exert a downward force and stretch the experimental wire under a tensile stress. The elongation of the wire (increase in length) is

measured by the vernier arrangement.

➤ The reference wire is used to compensate for any change in length that may occur due to change in room temperature, since any change in length

of the reference wire due to temperature change will be accompanied by an equal change in experimental wire.

➤ Both the reference and experimental wires are given an initial small load to keep the wires straight and the Vernier reading is noted.



- Now the experimental wire is gradually loaded with more weights to bring it under a tensile stress and the Vernier reading is noted again.
- The difference between two Vernier readings gives the elongation produced in the wire. Let r and l be the initial radius and length of the experimental wire, respectively.
- The Young's modulus of the material of the experimental wire is given by

$$E = \frac{Mg}{\pi r^2} \times \frac{\Delta l}{l}$$

EXAMPLE 8.5

In the apparatus of experimental determination of Young's modulus, a reference wire accompanies an experimental wire. This is to

- (A) compensate for any change of Young's modulus due to increased weights.
- (B) compensate for any change of Young's modulus due to increase of temperature.
- (C) compensate for any change in length of the experimental wire due to increase of temperature.
- (D) (B) and (C) are correct

Ans (C)

8.7. Applications of Elastic Behavior of Solids:

- Crane's lift ropes often come with two cables instead of one. This is to prevent the load from falling if one of the cable snaps when the load exceeds the ultimate strength of the rope.
- Thick ropes of cranes often come braided than in a single piece. Again, this is to prevent the entire cable from snapping at a time.
- If a rectangular beam [as in Fig (a)] is used as a bridge between two piers, which has a length l , thickness d and width b , due to its own weight and the weight of the bodies above it W , it undergoes a bending given by

$$\delta = \frac{Wl^3}{4bd^3E}$$

where E is the Young's modulus of the material of the beam.

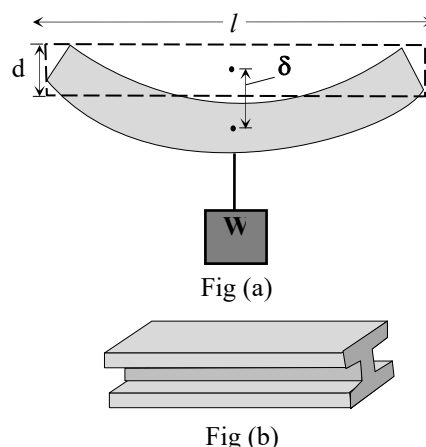
- In order to reduce this bending, usually, l is reduced and by cutting out its mass between the ends and making it in the shape of an I. These are called I-shaped girders.

EXAMPLE 8.6:

Mountain climbers use nylon rope for safety. This is because

- (A) nylon fibre has large Young's modulus.
- (B) nylon fibre has small Young's modulus.
- (C) nylon fibre has large ultimate strength.
- (D) (B) and (C) are correct

Ans (D)



PRACTICE QUESTIONS - Mechanical Properties of Solids

1. Restoring force in a body;

- (A) always exists inside the body.
- (B) appears inside the body when an external force is applied to it.
- (C) never exists inside the body.
- (D) always exists outside the body.

2. Match Column I with Column II

Column I	Column II
(a) A body which regains its original shape after the removal of external forces.	(1) Elasticity
(b) A body which does not regain its original shape after the removal of external forces.	(2) Elastic body
(c) A body which does not show any deformation on applying external forces.	(3) Plastic body
(d) The property of the body to regain its original configuration when the deforming forces are removed.	(4) Rigid body

- (A) (a) – (3), (b) – (1), (c) – (4), (d) – (2) (B) (a) – (4), (b) – (2), (c) – (3), (d) – (1)
(C) (a) – (2), (b) – (3), (c) – (4), (d) – (1) (D) (a) – (2), (b) – (3), (c) – (1), (d) – (4)

3. Fluids can develop

- (A) longitudinal strain only (B) longitudinal and shearing strain
- (C) longitudinal, shearing & volumetric strain (D) volumetric strain only

4. According to Hooke's law of elasticity, if stress is increased, the ratio of stress to strain

- (A) decreases (B) increases (C) becomes zero (D) remains constant

5. Modulus of elasticity is defined as ratio of

- (A) longitudinal stress to the original length
- (B) longitudinal stress to the decrease in area.
- (C) applied stress to the resulting strain, within elastic limit
- (D) applied weight to the resulting change in volume.

6. The dimensional formula for modulus of elasticity is

- (A) $[ML^{-2}T^{-3}]$ (B) $[ML^{-1}T^{-1}]$ (C) $[MLT^{-2}]$ (D) $[ML^{-1}T^{-2}]$

7. Which of the following statements is incorrect?

- (A) Young's modulus and shear modulus are relevant only for solids.
- (B) Bulk modulus is relevant for solids, liquids and gases.
- (C) Metals have larger values of Young's modulus than elastomers.
- (D) Alloys have larger values of Young's modulus than metals

8. Elastomers are the materials which can be

- (A) easily broken
- (B) drawn into thin wires without breaking
- (C) stretched to a large value of strain without breaking
- (D) pressed into thin sheets without breaking

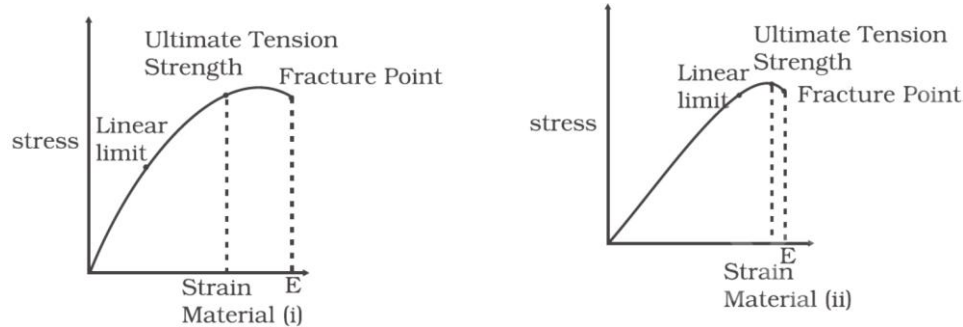
9. The change in shape of a regular body is due to

- (A) longitudinal strain
- (B) shearing strain
- (C) metallic strain
- (D) bulk strain

10. Which of the following have linear relationship?

- (A) applied stress and resulting strain for all values of stress
- (B) applied stress and resulting strain within elastic limit
- (C) longitudinal stress and original length
- (D) longitudinal stress and decrease in area

11. The stress-strain graphs for two materials are shown in figure (assume same scale).



- (A) Material (ii) is more elastic than material (i) and hence material (ii) is more brittle.
- (B) Material (i) and (ii) have the same elasticity and the same brittleness.
- (C) Material (i) is elastic over a larger region of strain as compared to (ii).
- (D) Material (ii) is more brittle than material (i).

12. For an ideal liquid

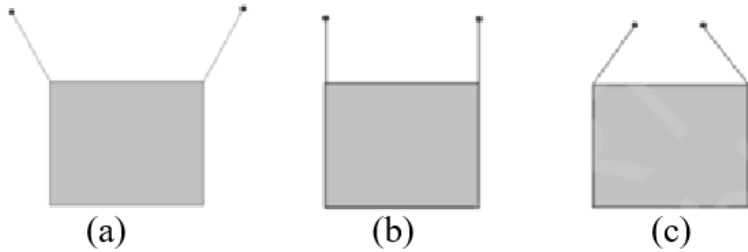
- (A) bulk modulus is infinite and shear modulus is zero.
- (B) bulk modulus is zero and shear modulus is infinite.
- (C) bulk modulus is infinite and shear modulus is also infinite
- (D) bulk modulus is zero and shear modulus is also zero.

13. Which of the following statements is incorrect?

- (A) The bulk modulus for solids is much larger than for liquids.
- (B) Gases are least compressible.
- (C) For a system in equilibrium, the value of bulk modulus is always positive.
- (D) The SI unit of bulk modulus is same as that of pressure.

14. The maximum load a wire can withstand without breaking, when its length is reduced to half of its original length, will

- (A) be double.
- (B) be half.
- (C) be four times.
- (D) remain same.

15. The temperature of a wire is doubled. The Young's modulus of elasticity
- (A) will also double. (B) will become four times.
(C) will remain same. (D) will decrease.
16. Which of the following statement is correct of
- (A) Iron is more elastic than rubber (B) Rubber is more elastic than hard glass
(C) Air is more elastic than water (D) water is more elastic than castor oil
17. Bulk modulus is defined as the ratio of
- (A) bulk stress and longitudinal strain (B) shearing stress and shearing strain
(C) tensile stress and longitudinal strain (D) hydraulic stress and hydraulic strain
18. Which of the following statements is correct regarding Poisson's ratio?
- (A) It is the ratio of the longitudinal strain to the lateral strain.
(B) Its value is independent of the nature of the material.
(C) It is a unit less and dimensionless quantity.
(D) The practical value of Poisson's ratio lies between 0 and 1.
19. If stress-strain relation for volumetric change is in the form $\frac{\Delta V}{V} = KP$ where P is applied uniform pressure, then K stands for
- (A) shear modulus (B) compressibility (C) Young's modulus (D) bulk modulus
20. A rectangular frame is to be suspended symmetrically by two strings of equal length on two supports as shown in the figure. It can be done in one of the following three ways; The tension in the strings will be
- 
- (a) (b) (c)
- (A) the same in all cases (B) least in (a) (C) least in (b) (D) least in (c)
21. A uniform wire of cross-sectional area A , length L and Young's modulus Y is fixed at one end. If the free end of wire is pulled by a constant force F , then the strain produced in the wire is
- (A) F/AY (B) YF/AL (C) YA/FL (D) YAF/L
22. A steel wire of cross-sectional area $3 \times 10^{-6} \text{ m}^2$ can withstand maximum strain of 10^{-3} . Young's modulus of steel is $2 \times 10^{11} \text{ Nm}^{-2}$. The maximum mass the wire can hold is (take $g = 10 \text{ m s}^{-2}$)
- (A) 40 kg (B) 60 kg (C) 80 kg (D) 100 kg
23. Assertion: The compressibility of solids is less than that of gases and liquids.
Reason: There is tight coupling between the neighbouring atoms in solids
- (A) Both assertion and reason are true and reason is the correct explanation of assertion.
(B) Both assertion and reason are true but reason is not the correct explanation of assertion.
(C) Assertion is true but reason is false.
(D) Both assertion and reason are false.

- 24. Assertion:** For small deformations, the stress and strain are proportional to each other.
Reason: A class of solids called elastomers does not obey Hooke's law.
- (A) Both assertion and reason are true and reason is the correct explanation of assertion.
 (B) Both assertion and reason are true but reason is not the correct explanation of assertion.
 (C) Assertion is true but reason is false.
 (D) Both assertion and reason are false.
- 25.** The force required to stretch a wire of area of cross section $2 \times 10^{-4} \text{ m}^2$ so that its length becomes 1.5 times original length is (Young's modulus = $3.6 \times 10^{11} \text{ N m}^{-2}$)
 (A) $3.6 \times 10^{-7} \text{ N}$ (B) $1.8 \times 10^7 \text{ N}$ (C) $3.6 \times 10^7 \text{ N}$ (D) $1.8 \times 10^{-7} \text{ N}$
- 26.** A steel rod of radius 10 mm and length 2 m is stretched by a force of 100 kN along its length. The elongation in the wire is 3.2 mm. The stress produced in the material of the rod is
 (A) $3.18 \times 10^{-8} \text{ N m}^{-2}$ (B) $3.18 \times 10^8 \text{ N m}^{-2}$ (C) $3.14 \times 10^{-4} \text{ N m}^{-2}$ (D) $1.00 \times 10^5 \text{ N m}^{-2}$
- 27.** The upper face of a cube of edge 1 m moves through a distance of 1 mm relative to the lower fixed surface under action of a tangential force $1.5 \times 10^8 \text{ N}$. The tangential strain produced is
 (A) 10^{-3} (B) 1.5×10^{11} (C) 1.5×10^8 (D) 10^3
- 28.** When a rubber ball is taken in deep of 100 m in sea its volume is decrease by 0.1% due to hydraulic stress. If the density of sea water is 1000 kg m^{-3} , the compressibility of the rubber is (take $g = 10 \text{ m s}^{-2}$)
 (A) $10^9 \text{ m}^2 \text{ N}^{-1}$ (B) $10^6 \text{ m}^2 \text{ N}^{-1}$ (C) $10^{-6} \text{ m}^2 \text{ N}^{-1}$ (D) $10^{-9} \text{ m}^2 \text{ N}^{-1}$
- 29.** A steel wire of length l_s and cross section A_s stretched by the same amount as copper wire of length l_c and cross section A_c under given load. The ratio of Young's modulus of steel to that of copper is
 (A) $\frac{l_s A_s}{l_c A_c}$ (B) $\frac{l_s A_c}{l_c A_s}$ (C) $\frac{l_c A_c}{l_s A_s}$ (D) $\frac{l_c A_s}{l_s A_c}$
- 30.** A glass slab is subjected to a pressure of 10 atm. The fractional change in its volume is (Bulk modulus of glass = $37 \times 10^9 \text{ N m}^{-2}$, $1 \text{ atm} = 1 \times 10^5 \text{ Nm}^{-2}$)
 (A) 2.7×10^{-2} (B) 2.7×10^{-3} (C) 2.7×10^{-4} (D) 2.7×10^{-5}
- 31.** The elastic energy stored per unit volume in a stretched wire is
 (A) $\frac{1}{2} \frac{\text{stress}}{Y}$ (B) $\frac{1}{2} \frac{(\text{stress})^2}{Y}$ (C) $\frac{1}{2} \frac{(\text{stress})^2}{Y^2}$ (D) $\frac{1}{2} \frac{\text{stress}}{Y^2}$
- 32.** A beam of metal supported at the two ends is loaded at the centre. The depression at the centre is proportional to
 (A) Y^2 (B) Y (C) $\frac{1}{Y}$ (D) $\frac{1}{Y^2}$

KEY ANSWERS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
B	C	D	D	C	D	D	C	B	B	D	A	B	D	D	A
17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
D	C	B	C	A	B	A	B	C	B	A	D	B	D	B	C

PREVIOUS YEAR QUESTIONS (2020) ONWARDS

1. Young's modulus of a perfect rigid body is (2020)
(A) unity (B) between zero and unity (C) zero (D) infinity
2. A metallic rod breaks when strain produced is 0.2%. The Young's modulus of the material of the rod is $7 \times 10^9 \text{ N/m}^2$. The area of cross section to support a load of 10^4 N is (2022)
(A) $7.1 \times 10^{-4} \text{ m}^2$ (B) $7.1 \times 10^{-8} \text{ m}^2$ (C) $7.1 \times 10^{-2} \text{ m}^2$ (D) $7.1 \times 10^{-6} \text{ m}^2$
3. A stretched wire of a material whose Young's modulus $Y = 2 \times 10^{11} \text{ Nm}^{-2}$ has Poisson's ratio 0.25. Its lateral strain $\epsilon_l = 10^{-3}$. The elastic energy density of the wire is (2023)
(A) $1 \times 10^5 \text{ Jm}^{-3}$ (B) $4 \times 10^5 \text{ Jm}^{-3}$ (C) $8 \times 10^5 \text{ Jm}^{-3}$ (D) $16 \times 10^5 \text{ Jm}^{-3}$
4. A thick metal wire of density ρ and length ' L ' is hung from a rigid support. The increase in length of the wire due to its own weight is (Y = Young's modulus of the material of the wire). (2024)
(A) $\rho g L / Y$ (B) $\rho g L^2 / 2Y$ (C) $\rho g L^2 / Y$ (D) $\rho g L^2 / 4Y$
5. Two wires A and B are made of same material. Their diameters are in the ratio of 1: 2 and lengths are in the ratio of 1: 3. If they are stretched by the same force, then increase in their lengths will be in the ratio of (2025)
(A) 4: 3 (B) 3: 4 (C) 2: 3 (D) 3: 2
6. There are two wires of same material and same length while the diameter of the second wire is two times the diameter of the first wire. Then the ratio of the extensions produced in the wires by applying same load will be (2026)
(A) 1: 1 (B) 1: 2 (C) 2: 1 (D) 4: 1

KEY ANSWERS

1	2	3	4	5	6
D	A	D	B	A	D