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CLASS 11 PHYSICS NCERT SOLUTIONS

NCERT Solutions for Class 11 Physics Chapter 8: Mechanical Properties of Solids – Free PDF Download

Question: A steel wire of length 4.7 m and cross-sectional area 3.0 × 10-5 m2 stretches by the same amount as a copper wire of length 3.5 m and cross-sectional area 4.0 × 10-5 m2 under a given load. What is the ratio of the Young's modulus of steel to that of copper?

Contents

Class 11 Physics Chapter 8, “Mechanical Properties of Solids,” is the opening chapter of NCERT Physics Part II and introduces stress, strain, Hooke’s law, and the elastic moduli (Young’s, shear, and bulk) that describe how solids deform under load. The solutions below correspond to the genuine, current (2023 rationalised, 2026-27 reprint) NCERT in-text exercise questions 8.1 to 8.16 as they appear in the official textbook, with every numerical answer worked out independently from first principles.

NCERT Exercise Solutions: Mechanical Properties of Solids

8.1 Young’s modulus ratio of steel to copper wires

Question: A steel wire of length 4.7 m and cross-sectional area 3.0×10^{-5} m^2 stretches by the same amount as a copper wire of length 3.5 m and cross-sectional area 4.0×10^{-5} m^2 under a given load. What is the ratio of the Young’s modulus of steel to that of copper?

Solution: Since both wires carry the same load F and undergo the same elongation ΔL, using $Y = FL/(A \cdot \Delta L)$:

$Y_{steel}/Y_{copper} = (L_1/A_1) \div (L_2/A_2) = (L_1 \times A_2)/(L_2 \times A_1) = (4.7 \times 4.0 \times 10^{-5})/(3.5 \times 3.0 \times 10^{-5}) = 18.8/10.5 \approx$ **1.79**

So the Young’s modulus of steel is about 1.79 times that of copper.

8.2 Young’s modulus and yield strength from a stress-strain graph

Question: Read the following data off the given strain-stress graph for a given material: (a) What is the Young’s modulus? (b) What is the approximate yield strength for this material?

Solution (a): From the linear (elastic) portion of the graph, a stress of 150×10^6 Pa corresponds to a strain of 0.002. Since Y = stress/strain:

$Y = (150 \times 10^6)/0.002 =$ **7.5×10^{10} Pa** (75 GPa)

Solution (b): The graph departs from linearity (the “knee” of the curve, beyond which permanent deformation begins) at a stress of about **3×10^8 Pa**, which is the approximate yield strength.

8.3 Comparing two stress-strain graphs (materials A and B)

Question: The stress-strain graphs for materials A and B are shown schematically. (a) Which material has greater Young’s modulus? (b) Which material is stronger?

Solution (a): Young’s modulus is the slope of the initial linear (elastic) part of the stress-strain curve. The material whose elastic region is steeper has the greater Young’s modulus — that is **material A**.

Solution (b): Strength is judged by the stress the material can withstand before it fractures (the ultimate tensile stress at the end of the curve). The material that sustains the higher stress before breaking is the stronger one — again **material A**, since it reaches a higher breaking stress than B, even though B may be more ductile (stretches further before fracture).

8.4 True or false: rubber vs steel, and shear in a spring

Question: (a) The Young’s modulus of rubber is greater than that of steel. (b) The stretching of a coil is determined by its shear modulus. State whether these statements are true or false.

Solution (a): False. For the same tensile stress, rubber stretches (strains) far more than steel, which means rubber's Young's modulus is much smaller than steel's, not greater.

Solution (b): True. When a helical spring/coil is stretched, the wire of the coil is twisted rather than uniformly elongated along its own length, so the restoring force and the extension are governed mainly by the shear modulus of the wire material.

8.5 Elongation of steel and brass wires

Question: Two wires of diameter 0.25 cm, one made of steel and the other of brass, are loaded as shown (joined end to end and hung vertically): a 4.0 kg mass hangs at the joint between the steel wire above and the brass wire below, and a further 6.0 kg mass hangs at the bottom of the brass wire. The unloaded length of the steel wire is 1.5 m and of the brass wire is 1.0 m. Compute the elongations of the steel and brass wires. ($Y_{steel} = 2.0 \times 10^{11}$ Pa, $Y_{brass} = 0.91 \times 10^{11}$ Pa)

Solution: Radius r = 0.125 cm = 1.25×10^{-3} m, so cross-sectional area $A = \pi r^2 = 4.91 \times 10^{-6}$ m^2 for both wires.

Tension in the steel wire supports both masses: $F_{steel} = (4.0 + 6.0) \times 9.8 = 98$ N. Tension in the brass wire supports only the lower mass: $F_{brass} = 6.0 \times 9.8 = 58.8$ N.

$\Delta L_{steel} = F_{steel}L_{steel}/(A \cdot Y_{steel}) = (98 \times 1.5)/(4.91 \times 10^{-6} \times 2.0 \times 10^{11}) \approx$ **1.49×10^{-4} m**

$\Delta L_{brass} = F_{brass}L_{brass}/(A \cdot Y_{brass}) = (58.8 \times 1.0)/(4.91 \times 10^{-6} \times 0.91 \times 10^{11}) \approx$ **1.30×10^{-4} m**

8.6 Shear deflection of an aluminium cube face

Question: The edge of an aluminium cube is 10 cm long. One face of the cube is firmly fixed to a vertical wall, and a mass of 100 kg is attached to the opposite face. Find the vertical deflection of this face. (Shear modulus of aluminium = 25 GPa)

Solution: Shearing force F = mg = 100 × 9.8 = 980 N. Area of the face $A = (0.1)^2 = 0.01$ m^2.

Using $\eta = (F/A)/(\Delta L/L)$, so $\Delta L = FL/(A\eta) = (980 \times 0.1)/(0.01 \times 25 \times 10^9) = 98/(2.5 \times 10^8) \approx$ **3.92×10^{-7} m**

8.7 Compressional strain in hollow steel columns

Question: Four identical hollow cylindrical steel columns support a big structure of mass 50,000 kg. The inner and outer radii of each column are 30 cm and 60 cm respectively. Assuming the load is distributed equally, calculate the compressional strain of each column. ($Y_{steel} = 2.0 \times 10^{11}$ Pa)

Solution: Cross-sectional area of one hollow column: $A = \pi(R^2 - r^2) = \pi(0.6^2 - 0.3^2) = \pi(0.27) \approx 0.848$ m^2.

Total weight = 50,000 × 9.8 = 4.9×10^5 N, shared equally by 4 columns: $F = 1.225 \times 10^5$ N per column.

Strain = stress/Y = $(F/A)/Y = (1.225 \times 10^5/0.848)/(2.0 \times 10^{11}) \approx$ **7.22×10^{-7}** (no units, since strain is dimensionless)

8.8 Strain in a copper piece under tension

Question: A piece of copper having a rectangular cross-section of 15.2 mm × 19.1 mm is pulled in tension with 44,500 N force, producing only elastic deformation. Calculate the resulting strain. ($Y_{copper} = 1.2 \times 10^{11}$ Pa)

Solution: Area $A = 15.2 \times 10^{-3} \times 19.1 \times 10^{-3} = 2.903 \times 10^{-4}$ m^2.

Stress = F/A = $44{,}500/(2.903 \times 10^{-4}) \approx 1.533 \times 10^8$ Pa. Strain = stress/Y = $(1.533 \times 10^8)/(1.2 \times 10^{11}) \approx$ **1.28×10^{-3}**

8.9 Maximum load on a steel cable

Question: A steel cable with a radius of 1.5 cm supports a chairlift at a ski area. If the maximum stress is not to exceed 10^8 N/m^2, what is the maximum load the cable can support?

Solution: Area $A = \pi r^2 = \pi(0.015)^2 \approx 7.07 \times 10^{-4}$ m^2.

Maximum load = maximum stress × A = $10^8 \times 7.07 \times 10^{-4} \approx$ **7.07×10^4 N** (about 7,210 kgf)

8.10 Diameter ratio of copper and iron wires under equal tension

Question: A rigid bar of mass 15 kg is supported symmetrically by three wires, each 2.0 m long. The two end wires are copper and the middle one is iron. Determine the ratio of their diameters if each wire is to have the same tension. ($Y_{iron} = 190 \times 10^9$ Pa, $Y_{copper} = 120 \times 10^9$ Pa)

Solution: Because the bar is rigid and symmetrically loaded, it stays horizontal, so all three wires (equal original length) stretch by the same ΔL. Tension $T = YA(\Delta L/L)$, and since ΔL/L and L are common to all three wires, equal tension requires:

$Y_{copper}A_{copper} = Y_{iron}A_{iron} \Rightarrow d_{copper}^2/d_{iron}^2 = Y_{iron}/Y_{copper} = 190/120$

$d_{copper}/d_{iron} = \sqrt{(190/120)} \approx$ **1.26**, i.e. $d_{copper} : d_{iron} \approx 1.26 : 1$ — the copper wires must be thicker than the iron wire, since copper is less stiff (lower Y) and needs a larger area to carry the same tension at the same strain.

8.11 Elongation of a whirling steel wire

Question: A 14.5 kg mass, fastened to the end of a steel wire of unstretched length 1.0 m, is whirled in a vertical circle with an angular velocity of 2 rev/s at the bottom of the circle. The cross-sectional area of the wire is 0.065 cm^2. Calculate the elongation of the wire when the mass is at the lowest point of its path. ($Y_{steel} = 2.0 \times 10^{11}$ Pa)

Solution: $\omega = 2$ rev/s $= 4\pi$ rad/s ≈ 12.57 rad/s. At the lowest point, tension must support the weight and provide the centripetal force:

$T = m(g + \omega^2 l) = 14.5 \times (9.8 + (12.57)^2 \times 1.0) = 14.5 \times (9.8 + 158.0) \approx 2432$ N

$A = 0.065 \times 10^{-4}$ m^2 $= 6.5 \times 10^{-6}$ m^2. $\Delta L = Tl/(AY) = 2432/(6.5 \times 10^{-6} \times 2.0 \times 10^{11}) \approx$ **1.87×10^{-3} m**

8.12 Bulk modulus of water

Question: Compute the bulk modulus of water from the following data: initial volume = 100.0 litre, pressure increase = 100.0 atm (1 atm = 1.013×10^5 Pa), final volume = 100.5 litre. Compare the bulk modulus of water with that of air (bulk modulus of air ≈ 1.0×10^5 Pa) and explain why the ratio is so large.

Solution: $\Delta P = 100 \times 1.013 \times 10^5 = 1.013 \times 10^7$ Pa, $\Delta V/V = 0.5/100.0 = 5.0 \times 10^{-3}$.

$B = \Delta P/(\Delta V/V) = (1.013 \times 10^7)/(5.0 \times 10^{-3}) \approx$ **2.03×10^9 Pa**

Ratio $B_{water}/B_{air} \approx (2.03 \times 10^9)/(1.0 \times 10^5) \approx$ **2.03×10^4**. This huge ratio reflects the fact that a gas like air is highly compressible (molecules are far apart and easily pushed closer), while liquid water molecules are already packed close together and strongly resist further compression.

8.13 Density of water at depth

Question: What is the density of water at a depth where the pressure is 80.0 atm, given that its density at the surface is 1.03×10^3 kg/m^3? ($B_{water} = 2.2 \times 10^9$ Pa)

Solution: $\Delta P = 80 \times 1.013 \times 10^5 \approx 8.10 \times 10^6$ Pa. Fractional volume change $\Delta V/V = \Delta P/B = (8.10 \times 10^6)/(2.2 \times 10^9) \approx 3.69 \times 10^{-3}$.

Since mass is conserved while volume shrinks slightly, density increases: $\rho_2 \approx \rho_1(1 + \Delta V/V) = 1.03 \times 10^3 \times 1.00369 \approx$ **1.034×10^3 kg/m^3**

8.14 Fractional volume change of a glass slab

Question: Compute the fractional change in volume of a glass slab when subjected to a hydraulic pressure of 10 atm. ($B_{glass} = 37 \times 10^9$ Pa)

Solution: $\Delta P = 10 \times 1.013 \times 10^5 = 1.013 \times 10^6$ Pa.

$\Delta V/V = \Delta P/B = (1.013 \times 10^6)/(37 \times 10^9) \approx$ **2.74×10^{-5}**

8.15 Volume contraction of a copper cube

Question: Determine the volume contraction of a solid copper cube, 10 cm on an edge, when subjected to a hydraulic pressure of 7.0×10^6 Pa. ($B_{copper} = 140 \times 10^9$ Pa)

Solution: $V = (0.1)^3 = 1.0 \times 10^{-3}$ m^3.

$\Delta V = V \times \Delta P/B = (1.0 \times 10^{-3}) \times (7.0 \times 10^6)/(140 \times 10^9) \approx$ **5.0×10^{-8} m^3** (equal to 0.05 cm^3)

8.16 Pressure needed to compress water by 0.10%

Question: How much should the pressure on a litre of water be changed to compress it by 0.10%? ($B_{water} = 2.2 \times 10^9$ Pa)

Solution: $\Delta V/V = 0.10\% = 1.0 \times 10^{-3}$.

$\Delta P = B \times (\Delta V/V) = 2.2 \times 10^9 \times 1.0 \times 10^{-3} \approx$ **2.2×10^6 Pa** (about 21.7 atm)

Notes and Extra Questions

Elasticity questions in this chapter almost always reduce to three formulas: Young's modulus $Y = (F/A)/(\Delta L/L)$ for stretching/compressing along a length, shear modulus $\eta = (F/A)/(\Delta x/L)$ for a sideways (tangential) deformation, and bulk modulus $B = \Delta P/(\Delta V/V)$ for a uniform pressure squeezing a volume. Always identify which of these three applies before substituting numbers.

Keep a mental table of typical values: $Y_{steel} \approx 2.0 \times 10^{11}$ Pa, $Y_{copper} \approx 1.1\text{-}1.2 \times 10^{11}$ Pa, $Y_{iron} \approx 1.9 \times 10^{11}$ Pa, $Y_{aluminium} \approx 0.7 \times 10^{11}$ Pa, and $B_{water} \approx 2.1\text{-}2.2 \times 10^9$ Pa. Metals have Y of order 10^{11} Pa while rubber-like materials are 10^3-10^4 times smaller.

For circular-motion tension problems (like 8.11), always add the centripetal-force term to the weight when the mass is at the lowest point of a vertical circle, and subtract it ($T = m\omega^2 l - mg$) if it were at the top — a very common source of sign mistakes.

When two wires are joined in series and share a common load path, remember that the wire nearer the ground carries only the mass below it, while a wire higher up carries the combined weight of everything hanging beneath it (as in question 8.5).