Mechanical properties of Solids

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NCERT Exercise Solution — Ch. 8 (old 9)

9.1 / 8.1 Given,

$L_s = 4.7\ m \quad A_s = 3\times10^{-5}\ m^2$

$L_{cu} = 3.5\ m \quad A_{cu} = 4\times10^{-5}\ m^2$

here ΔL and F is same for both wires.

By $Y = \frac{FL}{A\Delta L}$

$$\frac{Y_s}{Y_{cu}} = \frac{L_s}{L_{cu}} \cdot \frac{A_{cu}}{A_s}$$

$$= \frac{4.7 \times 4\times10^{-5}}{3.5 \times 3\times10^{-5}}$$

$$= \frac{188}{105} = 1.79$$

$$\frac{Y_s}{Y_{cu}} = 1.8 \quad \text{Ans}$$

9.2 From given graph

(a) stress $= 150\times10^{6}\ N/m^2$

strain $= 0.002$

By $Y = \frac{\text{stress}}{\text{strain}} = \frac{150\times10^6}{0.002}$

$= 75\times10^{9}$

$Y = 7.5\times10^{10}\ N/m^2$

(b) Yield strength $= 300\times10^{6}\ N/m^2$

$= 3\times10^{8}\ N/m^2$

Ans

9.3 (a) Slope of the stress-strain graph is more for material A. Therefore material A has the greater Young's modulus as $Y = \frac{stress}{strain}$

(b) From graph it is clear that material A can withstand more strain than B. Therefore material A is stronger.

9.4 (a) False.

By $Y = \frac{stress}{strain}$, for a force F, $(Strain)_R > (Strain)_S$

$\therefore Y_S > Y_R$

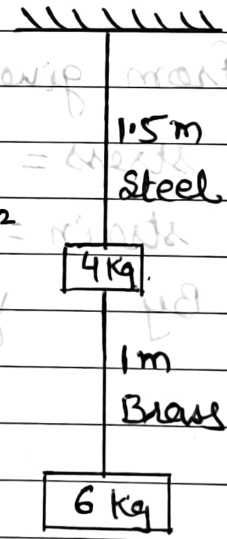
(b) ~~Stree~~ True

Because on stretching a coil, its helical shape changes not its length.

9.5 Given,

Diameter $d_{steel} = d_{brass} = 0.25$ cm

$= 0.25 \times 10^{-2}$ m



For steel wire, $Y_S = 2\times10^{11}$ Nm^{-2}

$\Delta L_S = \frac{FL}{AY} = \frac{mgL}{\pi r^2 Y}$

$= \frac{(4+6)\times10\times1.5}{3.14\times\left(\frac{0.25}{2}\times10^{-2}\right)^2\times2\times10^{11}}$

$= \frac{10\times10\times1.5\times4}{3.14\times0.25\times0.25\times10^{-4}\times2\times10^{11}}$

$$\Delta L_s = \frac{100 \times 1.5 \times 4 \times \cancel{16}^{8} \times 10^{-7}}{3.14 \times \cancel{2}}$$

$$= \frac{3200 \times 1.5 \times 10^{-7}}{3.14}$$

$$= \frac{480 \times 10^{-4}}{314}$$

$$\Delta L_s = 1.5 \times 10^{-4}\ m$$

Ans

For Brass wire, $Y_B = 0.91 \times 10^{11}\ N m^{-2}$

$$\Delta L_B = \frac{mgL}{\pi r^2 Y}$$

$$= \frac{6 \times 10 \times 1}{3.14 \times \left(\frac{0.25}{2} \times 10^{-2}\right)^2 \times 0.91 \times 10^{11}}$$

$$= \frac{60 \times 4 \times 16 \times 10^{-7}}{3.14 \times 0.91}$$

$$= \frac{384 \times 10^{-4}}{2.86} = 1.3 \times 10^{-4}\ m$$

$$\Delta L_B = 1.3 \times 10^{-4}\ m$$

Ans

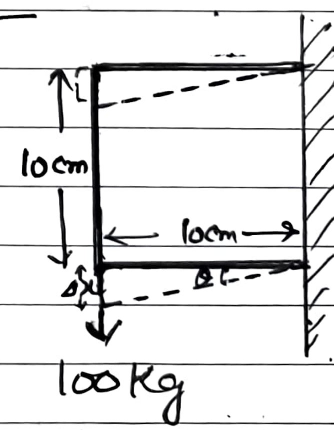
9.6 Given,

side of cube $= 10\ cm = 0.10\ m$

$m = 100\ kg$

Shear modulus $G = 25\ GPa$

$= 25 \times 10^{9}\ Pa$



$$G = \frac{FL}{A\Delta x}$$

$$\Delta x = \frac{FL}{AG} = \frac{mgL}{AG}$$

$$= \frac{100 \times 10 \times 0.10}{0.10 \times 0.10 \times 25 \times 10^9}$$

$$\Delta x = 4 \times 10^{-7}\ m$$

Ans

9.7 Mass supported by one coloumn $= \frac{50,000}{4}$

$= 12500$ kg

Area $A = \pi(r_1^2 - r_2^2)$ [$r_1 = 60$ cm $= 0.6$ m, $r_2 = 30$ cm $= 0.3$ m

$= \pi(0.6^2 - 0.3^2)$

$= 3.14 \times (0.36 - 0.9)$

$= 3.14 \times 0.27\ m^2$

$A = 85.05\ m^2$

Δl -

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9.7 Mass supported by one caloumn = $\frac{50,000}{4}$

$m = 12500$ Kg

$r_1 = 60$ cm $= 0.6$ m

$r_2 = 30$ cm $= 0.3$ m

$Y_s = 2 \times 10^{11}$ Nm^{-2}

$$A = \pi (r_1^2 - r_2^2)$$
$$= 3.14 \times (0.6^2 - 0.3^2)$$
$$= 3.14 \times (0.36 - 0.09)$$
$$= 3.14 \times 0.27$$
$$A = 0.8505 \ m^2$$

Now $Y = \frac{FL}{A\Delta L}$

$$\frac{\Delta L}{L} = \frac{F}{AY} = \frac{mg}{AY}$$

$$= \frac{12500 \times 10^5}{0.8505 \times 2 \times 10^{11}}$$

$$= \frac{62500 \times 10^{-11}}{0.8505}$$

$$\frac{\Delta L}{L} = 7.34 \times 10^{-7}$$

Ans

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9.8 Given,

$l = 19.1\ mm = 19.1 \times 10^{-3}\ m$

$b = 15.2\ mm = 15.2 \times 10^{-3}\ m$

$F = 44,500\ N$

and $Y_{Cu} = 1.2 \times 10^{11}\ Nm^{-2}$

strain = ?

$$Y = \frac{\text{stress}}{\text{strain}} = \frac{F/A}{\text{strain}}$$

$$\text{strain} = \frac{F}{AY}$$

$$= \frac{44500}{19.1 \times 10^{-3} \times 15.2 \times 10^{-3} \times 1.2 \times 10^{11}}$$

$$= \frac{44500 \times 10^{-5}}{290 \times 1.2}$$

$$= \frac{445}{348} \times 10^{-3}$$

$$\text{strain} = 1.27 \times 10^{-3}$$

$$= 0.127\ \%$$ Ans

9.9. Given,

$l = 1.5\ cm = 1.5 \times 10^{-2}\ m$

Max. stress $= 10^{8}\ Nm^{-2}$

$F = ?$

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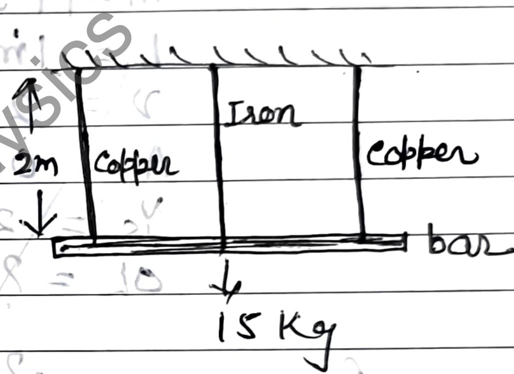
$$Stress = \frac{F}{A}$$

$$F = stress \times A$$
$$= 10^8 \times 3.14 \times (1.5 \times 10^{-2})^2 \quad [\because A = \pi r^2]$$
$$= 10^4 \times 3.14 \times 2.25$$
$$F = 7.06 \times 10^4 \text{ N}$$

9.10 Here,
$Y_{cu} = 1.2 \times 10^{11} \text{ Nm}^{-2}$
$Y_{Iron} = 1.9 \times 10^{11} \text{ Nm}^{-2}$



Given F, L and ΔL are same here.

$$Y = \frac{FL}{A\Delta L} = \frac{mgL}{\pi\left(\frac{d}{2}\right)^2 \Delta L}$$

$$\frac{Y_{cu}}{Y_{Iron}} = \frac{d_{iron}^2}{d_{cu}^2}$$

or $\frac{d_{iron}}{d_{cu}} = \sqrt{\frac{Y_{cu}}{Y_{iron}}} \Rightarrow \frac{d_{cu}}{d_{iron}} = \sqrt{\frac{Y_{iron}}{Y_{cu}}}$

$$\frac{d_{cu}}{d_{iron}} = \sqrt{\frac{1.9 \times 10^{11}}{1.2 \times 10^{11}}} = \sqrt{\frac{19}{12}}$$

$$= \sqrt{1.73}$$

$$\frac{d_{cu}}{d_{iron}} = 1.31 \Rightarrow d_{cu} = 1.31\, d_{iron}$$

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$$\frac{d_{cu}}{d_{iron}} = \sqrt{\frac{19}{12}} = \sqrt{1.58}$$

$$\frac{d_{cu}}{d_{iron}} = 1.25$$

	1.25
1	1.58
	1
22	58
	44
245	1400

Ans

9.11 Given,

$m = 14.5$ kg

$L = 1$ m

$\nu = 2$ rev/s

$A = 0.065\ cm^2 = 0.065 \times 10^{-4}\ m^2$

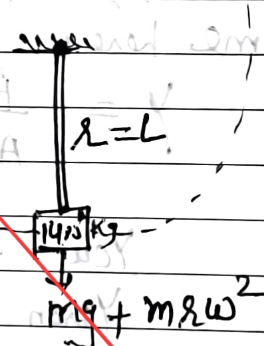
$Y_s = 2 \times 10^{11}\ Nm^{-2}$

$\Delta L = ?$

$F = mg + mr\omega^2$

$= mg + mr(2\pi\nu)^2$

$= mg + mr \times 4\pi^2\nu^2$



$F = 14.5 \times 10 + 14.5 \times 1 \times 39.44 \times 2^2$

$= 145 + 14.5 \times 39.44 \times 4$

$= 145 + 14$[illegible]

$= 145$[illegible]

$F =$

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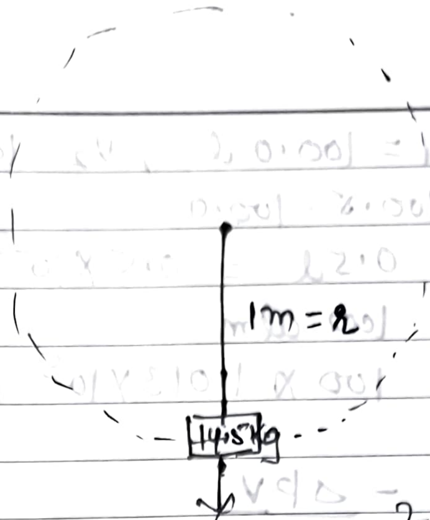
9.11



$$F = mg + mr\omega^2$$

Given,

$m = 14.5\ kg$, $L = 1\ m = r$

$\nu = 2\ rev/s$, $A = 0.065\ cm^2 = 0.065 \times 10^{-4}\ m^2$

$Y_s = 2 \times 10^{11}\ Nm^{-2}$

$\Delta L = ?$

$$F = mg + mr\omega^2$$
$$= 14.5 \times 10 + 14.5 \times 1 \times 4\pi^2\nu^2 \quad [\omega = 2\pi\nu]$$
$$= 145 + 14.5 \times 39.44 \times 4 \quad [\nu = 2\ rev/s]$$
$$= 145 + 14.5 \times 157.76$$
$$= 145 + 2287.52$$
$$F = 2432.52\ N$$

Now $$\Delta L = \frac{FL}{AY}$$
$$= \frac{2432.52 \times 1000}{0.065 \times 10^{-4} \times 2 \times 10^{11}}$$
$$= \frac{2432.52}{130} \times 10^{-4}$$
$$= 18.712 \times 10^{-4}$$
$$\Delta L = 1.87 \times 10^{-3}\ m$$
$$= 1.87\ mm$$

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9.12 Given, $V_1 = 100.0\ l$, $V_2 = 100.5\ l$

$$\Delta V = 100.5 - 100.0$$
$$= 0.5\ l = 0.5 \times 10^{-3}\ m^3$$
$$\Delta P = 100\ atm$$
$$= 100 \times 1.013 \times 10^5\ Nm^{-2}/Pa$$

$$B = -\frac{\Delta P V}{\Delta V}$$

$$|B|_w = \frac{100 \times 1.013 \times 10^5 \times 100 \times 10^{-3}}{0.5 \times 10^{-3}}$$

$$= 2 \times 1.013 \times 10^9$$
$$B_w = 2.026 \times 10^9\ Pa$$

Ratio

$$\frac{B_w}{B_{air}} = \frac{2.026 \times 10^9}{1 \times 10^5\ Pa}$$

$$= 2.026 \times 10^4$$

Ratio is large because intermolecular force are stronger in liquids than gases.

9.13 Given,

$\rho_s = 1.03 \times 10^3\ kg/m^3$, $\rho_d = ?$

$$\Delta P = 80\ atm - 1\ atm$$
$$= 79\ atm$$
$$\Delta P = 79 \times 1.013 \times 10^5\ Pa$$
$$B_w = 2.2 \times 10^9\ Pa$$

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$$\frac{\Delta V}{V} = \frac{V_s - V_d}{V_s} = \frac{\frac{m}{\rho_s} - \frac{m}{\rho_d}}{\frac{m}{\rho_s}}$$

$$= \left(\frac{1}{\rho_s} - \frac{1}{\rho_d}\right)\rho_s$$

$$\frac{\Delta V}{V} = \left(1 - \frac{\rho_s}{\rho_d}\right)$$

$$B = \left|\frac{\Delta P}{\Delta V/V}\right|$$

$$\frac{\Delta V}{V} = \frac{\Delta P}{B}$$

$$1 - \frac{\rho_s}{\rho_d} = \frac{79 \times 1.013 \times 10^5}{2.2 \times 10^9}$$

$$= \frac{80.027 \times 10^{-4}}{2.2}$$

$$1 - \frac{\rho_s}{\rho_d} = 36.37 \times 10^{-4}$$

$$\frac{\rho_s}{\rho_d} = 1 - 36.37 \times 10^{-4}$$

$$= 1 - 0.003637$$

$$\frac{\rho_s}{\rho_d} = 0.9963$$

$$\begin{array}{r} 1.000000 \\ 0.003637 \\ \hline 0.996363 \end{array}$$

$$\rho_d = \frac{\rho_s}{0.9963} = \frac{1.03 \times 10^3}{0.9963}$$

$$= 1.0337 \times 10^3$$

$$\rho_d \simeq 1.034 \times 10^3 \ kg/m^3$$

14.

$P = 10$ atm

$= 10 \times 1.013 \times 10^5$ Pa

$B_{glass} = 37 \times 10^9$ Pa

$\frac{\Delta V}{V} = \frac{P}{B}$ $\left[B = \frac{P}{\Delta V / V} \right]$

$= \frac{10 \times 1.013 \times 10^5}{37 \times 10^9}$

$= \frac{10.13}{37} \times 10^{-4}$

$\frac{\Delta V}{V} = 0.274 \times 10^{-4}$

$\frac{\Delta V}{V} \times 100 = 0.274 \times 10^{-4} \times 100$ %

$= 0.274 \times 10^{-2}$ %

$= 0.00274$ %

ie the fractional change $= 0.0027$ %

15.

$V = 10^3 cm^3$

$V = 10^3 \times 10^{-6} m^3$ $[1 cm = 10^{-2} m]$

$V = 10^{-3} m^3$

$P = 7 \times 10^6$ Pa

$B_{cu} = 140 \times 10^9$ Pa

$\Delta V = ?$

$B = \frac{pV}{\Delta V}$

$\Delta V = \frac{pV}{B} = \frac{7 \times 10^6 \times 10^{-3}}{140 \times 10^9}$

$= \frac{7}{140} \times 10^{-6} = 0.05 \times 10^{-6} m^3$

$\Delta V = 0.05 cm^3$

18

$V = 1\,l$

$V = 1 \times 10^{-3}\ m^3$

$\Delta V = 0.10\%$ of V

$= \frac{0.10}{100} \times 10^{-3}$

$\Delta V = 0.10 \times 10^{-5}$

$\Delta V = 1 \times 10^{-6}\ m^3$

$B_w = 2.2 \times 10^9\ Pa$

$$B = \frac{pV}{\Delta V}$$

$$p = \frac{B \Delta V}{V}$$

$$= \frac{2.2 \times 10^9 \times 1 \times 10^{-6}}{1 \times 10^{-3}}$$

$P = 2.2 \times 10^6\ Nm^{-2}$