NCERT solutions for class 11 physics chapter 9 mechanical properties of solids exercise

Q1 A steel wire of length 4.7 m and cross-sectional area $3.0 \times 10^{-5} m^2$ stretches by the same amount as a copper wire of length 3.5 m and cross-sectional area of $4.0 \times 10^{-5} m^2$ under a given load. What is the ratio of the Young's modulus of steel to that of copper?

Answer:

Let the Young's Modulus of steel and copper be Y_S and Y_C respectively.

Length of the steel wire l_S = 4.7 m

Length of the copper wire l_C = 4.7 m

The cross-sectional area of the steel wire $A_S = 3.0 \times 10^{-5} m^2$

The cross-sectional area of the Copper wire $A_C = 4.0 \times 10^{-5} m^2$

Let the load and the change in the length be F and Δl respectively

$$Y = \frac{Fl}{A\Delta l}$$
$$\frac{F}{\Delta l} = \frac{AY}{l}$$

Since F and Δl is the same for both wires we have

The ratio of Young's modulus of steel to that of copper is 1.79.

Q2 (a) Figure 9.11 shows the strain-stress curve for a given material. What are (a) Young's modulus

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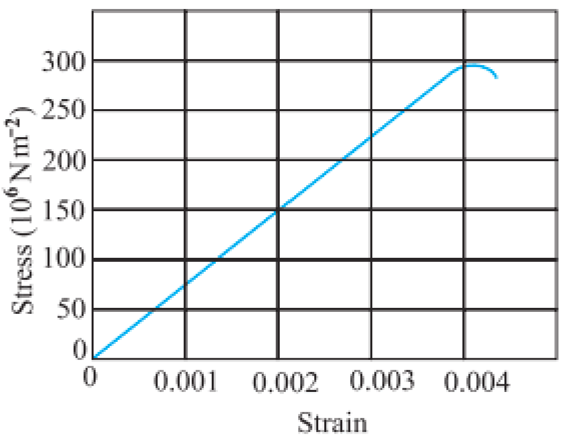

Fig. 9.11

Answer:

Young's modulus is given as the ratio of stress to strain when the body is behaving elastically.

For the given material

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

$$Y = \frac{150 \times 10^6}{0.002}$$

$$Y = 7.5 \times 10^2 Nm^{-2}$$

Q2 (b) Figure 9.11 shows the strain-stress curve for a given material. What are approximate yield strength for this material?

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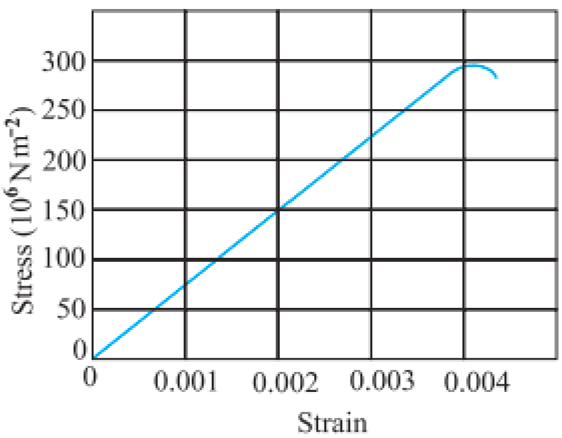

Fig. 9.11

Answer:

The Yield Strength is approxmiately $3 \times 10^8 Nm^{-2}$ for the given material. We can see above this value of strain, the body stops behaving elastically.

Q3 (a) The stress-strain graphs for materials A and B are shown in Fig. 9.12. The graphs are drawn to the same scale. Which of the materials has the greater Young's modulus?

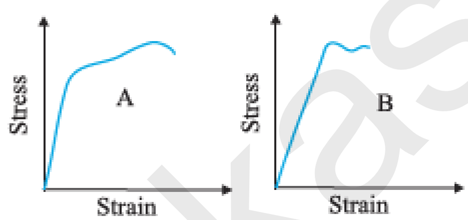

Fig. 9.12

Answer:

As we can see in the given Stress-Strain graphs that the slope is more in the graph corresponding to material A. We conclude that A has a greater Young's Modulus.

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Q3 (b) The stress-strain graphs for materials A and B are shown in Fig. 9.12. The graphs are drawn to the same scale. Which of the two is the stronger material?

Fig. 9.12

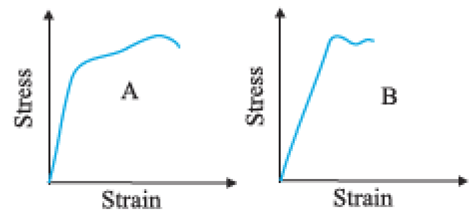

Fig. 9.12

Answer:

The material which fractures at higher stress is said to be stronger. As we can see in the given Stress-Strain graphs the stress at which the material fractures is higher in A than that in B we conclude that A is the stronger material.

Q4 (a) Read the following two statements below carefully and state, with reasons, if it is true or false.

The Young's modulus of rubber is greater than that of steel;

Answer:

False: Young's Modulus is defined as the ratio of the stress applied on a material and the corresponding strain that occurs. As for the same amount of pressure applied on a piece of rubber and steel, the elongation will be much lesser in case of steel than that in the case of rubber and therefore the Young's Modulus of rubber is lesser than that of steel.

Q4 (b) Read the following two statements below carefully and state, with reasons, if it is true or false. The stretching of a coil is determined by its shear modulus.

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Answer:

True: As the force acts Normal to the parallel planes in which helical parts of the wire lie, the actual length of the wire would not change but it's shape would. Therefore the amount of elongation of the coil taking place for corresponding stress depends upon the Shear Modulus of elasticity.

Q5 Two wires of diameter 0.25 cm, one made of steel and the other made of brass are loaded as shown in Fig. 9.13. The unloaded length of steel wire is 1.5 m and that of brass wire is 1.0 m. Compute the elongations of the steel and the brass wires.

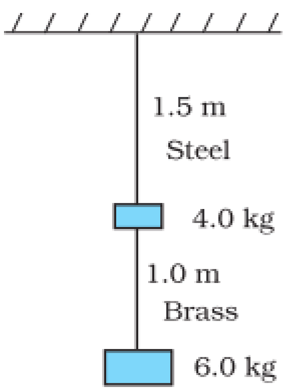

Fig. 9.13

Answer:

Tension in the steel wire is F_1

$$F_1 = (4+6) \times 9.8$$
$$F_1 = 98N$$

Length of steel wire $l_1 = 1.5$ m

The diameter of the steel wire, d = 0.25 cm

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Area od the steel wire, $A = 4.9 \times 10^{-6}\ m^2$

Let the elongation in the steel wire be Δl_1

Young's Modulus of steel, Y $_1$ = $2 \times 10^{11} Nm^{-2}$

Tension in the Brass wire is F $_2$

$$F_2 = (6) \times 9.8$$
$$F_2 = 58.8N$$

Length of Brass wire l $_2$ = 1.5 m

Area od the brass wire, $A = 4.9 \times 10^{-6}\ m^2$

Let the elongation in the steel wire be Δl_2

Young's Modulus of steel, Y $_2$ = $0.91 \times 10^{11} Nm^{-2}$

Q6 The edge of an aluminium cube is 10 cm long. One face of the cube is firmly fixed to a vertical wall. A mass of 100 kg is then attached to the opposite face of the cube. The shear modulus of aluminium is 25 GPa. What is the vertical deflection of this face?

Answer:

Edge of the aluminium cube, l = 10 cm = 0.1 m

Area of a face of the Aluminium cube, A = l ^{2} = 0.01 m ^{2}

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Tangential Force is F

$$F = 100 \times 9.8$$
$$F = 980\ N$$

Tangential Stress is F/A

$$\frac{F}{A} = \frac{980}{0.01}$$
$$\frac{F}{A} = 98000N$$

Shear modulus of aluminium $\eta = 2.5 \times 10^{10} Nm^{-2}$

$$Tangential\ Strain = \frac{\frac{F}{A}}{\eta}$$
$$= \frac{98000}{2.5 \times 10^{10}}$$
$$= 3.92 \times 10^{-6}$$

Let the Vertical deflection be Δl

$$\Delta l = Tangential\ Stress \times Side$$
$$\Delta l = 3.92 \times 10^{-6} \times 0.1$$
$$\Delta l = 3.92 \times 10^{-7} m$$

Q7 Four identical hollow cylindrical columns of mild steel support a big structure of mass 50,000 kg. The inner and outer radii of each column are 30 and 60 cm respectively. Assuming the load distribution to be uniform, calculate the compressional strain of each column.

Answer:

Inner radii of each column, r_1 = 30 cm = 0.3 m

Outer radii of each colum, r_2 = 60 cm = 0.6 m

Mass of the structure, m = 50000 kg

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Stress on each column is P

$$P = \frac{50000 \times 9.8}{4 \times \pi \times (0.6^2 - 0.3^2)}$$
$$P = 1.444 \times 10^5 Nm^{-2}$$

Youngs Modulus of steel is $Y = 2 \times 10^{11} Nm^{-2}$

$$Compressional\ strain = \frac{P}{Y}$$
$$= \frac{1.444 \times 10^5}{2 \times 10^{11}}$$
$$= 7.22 \times 10^{-7}$$

Q8 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?

Answer:

Length of the copper piece, l = 19.1 mm

The breadth of the copper piece, b = 15.2 mm

Force acting, F = 44500 N

Modulus of Elasticity of copper, $\eta = 42 \times 10^9 Nm^{-2}$

Q9 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 $10^8 Nm^{-2}$, what is the maximum load the cable can support?

Answer:

Let the maximum Load the Cable Can support be T

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Maximum Stress Allowed, P = 10 ^{8} N m $^{-2}$

Radius of Cable, r = 1.5 cm

$$T = P\pi r^2$$
$$T = 10^8 \times \pi \times (1.5 \times 10^{-2})^2$$
$$T = 7.068 \times 10^4 N$$

Q10 A rigid bar of mass 15 kg is supported symmetrically by three wires each 2.0 m long. Those at each end are of copper and the middle one is of iron. Determine the ratios of their diameters if each is to have the same tension.

Answer:

Each wire must support the same load and are of the same length and therefore should undergo the same extension. This, in turn, means they should undergo the same strain.

$$Y = \frac{Fl}{\Delta l A}$$
$$Y = \frac{4Fl}{\Delta l \pi d^2}$$
$Yd^2 = k$ As F, l and Δl are equal for all wires

$$Y_{iron} = 1.9 \times 10^{11} Nm^{-2}$$

$$Y_{copper} = 1.1 \times 10^{11} Nm^{-2}$$

Q11 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.

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Answer:

Mass of the body = 14.5 kg

Angular velocity, ω = 2 rev/s

$\omega = 4\pi \ rad/s$

The radius of the circle, r = 1.0 m

Tension in the wire when the body is at the lowest point is T

$$T = mg + m\omega^2 r$$
$$T = 14.5 \times 9.8 + 14.5 \times (4\pi)^2$$
$$T = 2431.84N$$

Cross-Sectional Area of wire, A = 0.065 cm ^{2}

Young's Modulus of steel, $Y = 2 \times 10^{11} Nm^{-2}$

$$\Delta l = \frac{Fl}{AY}$$
$$\Delta l = \frac{2431.84 \times 1}{0.065 \times 10^{-4} \times 2 \times 10^{11}}$$
$$\Delta l = 1.87mm$$

Q12 Compute the bulk modulus of water from the following data: Initial volume = 100.0 litre, Pressure increase = 100.0 atm ($1atm = 1.013 \times 10^5 Pa$), Final volume = 100.5 litre. Compare the bulk modulus of water with that of air (at constant temperature). Explain in simple terms why the ratio is so large.

Answer:

Pressure Increase, P = 100.0 atm

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Initial Volume = 100.0 l

Final volume = 100.5 l

Change in Volume = 0.5 l

Let the Bulk Modulus of water be B

The bulk modulus of air is $B_a = 1.0 \times 10^5 Nm^{-2}$

The Ratio of the Bulk Modulus of water to that of air is

$$\frac{B}{B_a} = \frac{2.026 \times 10^9}{1.0 \times 10^5}$$
$$\frac{B}{B_a} = 20260$$

This ratio is large as for the same pressure difference the strain will be much larger in the air than that in water.

Q13 What is the density of water at a depth where pressure is 80.0 atm, given that its density at the surface is $1.03 \times 103 Kg$?

Answer:

Water at the surface is under 1 atm pressure.

At the depth, the pressure is 80 atm.

Change in pressure is $\Delta P = 79\ atm$

Bulk Modulus of water is $B = 2.2 \times 10^9 Nm^{-2}$

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The negative sign signifies that for the same given mass the Volume has decreased

The density of water at the surface $\rho = 1.03 \times 10^3 \ kg \ m^{-3}$

Let the density at the given depth be $\rho^{'}$

Let a certain mass occupy V volume at the surface

$$\rho = \frac{m}{V}$$

$$\rho^{'} = \frac{m}{V + \Delta V}$$

Dividing the numerator and denominator of RHS by V we get

The density of water at a depth where pressure is 80.0 atm is $1.034 \times 10^3 \ kg \ m^{-3}$.

Q14 Compute the fractional change in volume of a glass slab when subjected to a hydraulic pressure of 10 atm.

Answer:

Bulk's Modulus of Glass is $B_G = 3.7 \times 10^{10} Nm^{-2}$

Pressure is P = 10 atm.

The fractional change in Volume would be given as

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The fractional change in Volume is 2.737×10^{-5}

Q15 Determine the volume contraction of a solid copper cube, 10 cm on an edge, when subjected to a hydraulic pressure of $7.0 \times 10^{6} Pa$

Answer:

The bulk modulus of copper is $B_C = 140 GPa = 1.4 \times 10^{11} Nm^{-2}$

Edge of copper cube is s = 10 cm = 0.1 m

Volume Of copper cube is $V = s^3$

$V = (0.1)^3$

$V = 0.001\ m^3$

Hydraulic Pressure applies is $P = 7.0 \times 10^{6} Pa$

From the definition of bulk modulus

The volumetric strain is 5×10^{-5}

Volume contraction will be

The volume contraction has such a small value even under high pressure because of the extremely large value of bulk modulus of copper.

Q16 How much should the pressure on a litre of water be changed to compress it by 0.10%?

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Answer:

Change in volume is $\Delta V = 0.10\%$

$$Volumetric\ Strain = \frac{0.1}{100}$$
$$\frac{\Delta V}{V} = 0.001$$

Bulk modulus of water is $B_w = 2.2 \times 10^9\ Nm^{-2}$

A pressure of $2.2 \times 10^6 Pa$ is to be applied so that a litre of water compresses by 0.1%.

Note: The answer is independent of the volume of water taken into consideration. It only depends upon the percentage change.

Q17 Anvils made of single crystals of diamond, with the shape as shown in Fig. 9.14, are used to investigate behaviour of materials under very high pressures. Flat faces at the narrow end of the anvil have a diameter of 0.50 mm, and the wide ends are subjected to a compressional force of 50,000 N. What is the pressure at the tip of the anvil?

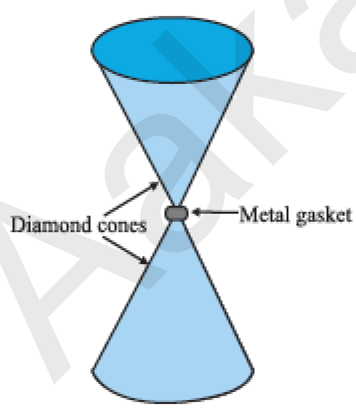

Fig. 9.14

Answer:

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The diameter of at the end of the anvil, d = 0.50 mm

Cross-sectional area at the end of the anvil is A

Compressional Force applied, F = 50000N

The pressure at the tip of the anvil is P

$$P = \frac{F}{A}$$
$$P = \frac{50000}{1.96 \times 10^{-7}}$$
$$P = 2.55 \times 10^{11} Nm^{-2}$$

The pressure at the tip of the anvil is $2.55 \times 10^{11} Nm^{-2}$.

Q18 (a) A rod of length 1.05 m having negligible mass is supported at its ends by two wires of steel (wire A) and aluminium (wire B) of equal lengths as shown in Fig. 9.15. The cross-sectional areas of wires A and B are 1.0 mm2 and 2.0 mm2, respectively. At what point along the rod should a mass m be suspended in order to produce equal stresses

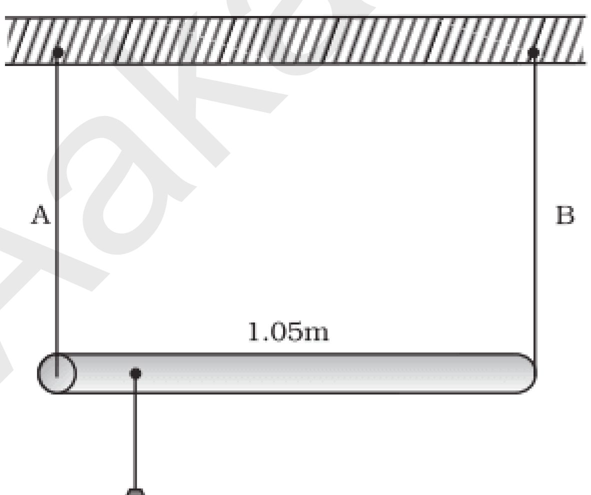

Fig. 9.15

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Answer:

Cross-Sectional Area of wire A is $A_A = 1\ mm^2$

Cross-Sectional Area of wire B is $A_B = 2\ mm^2$

Let the Mass m be suspended at x distance From the wire A

Let the Tension in the two wires A and B be F_A and F_B respectively

Since the Stress in the wires is equal

$$\frac{F_A}{A_A} = \frac{F_B}{A_B}$$
$$\frac{F_A}{1} = \frac{F_B}{2}$$
$$2F_A = F_B$$

Equating moments of the Tension in the wires about the point where mass m is suspended we have

$$xF_A = (1.05 - x)F_B$$
$$xF_A = (1.05 - x) \times 2F_A$$
$$x = 2.1 - 2x$$
$$x = 0.7m$$

The Load should be suspended at a point 70 cm from a wire A such that there are equal stresses in the two wires.

Q18 (b) A rod of length 1.05 m having negligible mass is supported at its ends by two wires of steel (wire A) and aluminium (wire B) of equal lengths as shown in Fig. 9.15. The cross-sectional areas of wires A and B are $1.0mm^2\ \ and\ \ 2.0mm^2$ respectively. At what point along the rod should a mass m be suspended in order to produce equal strains in both steel and aluminium wires.

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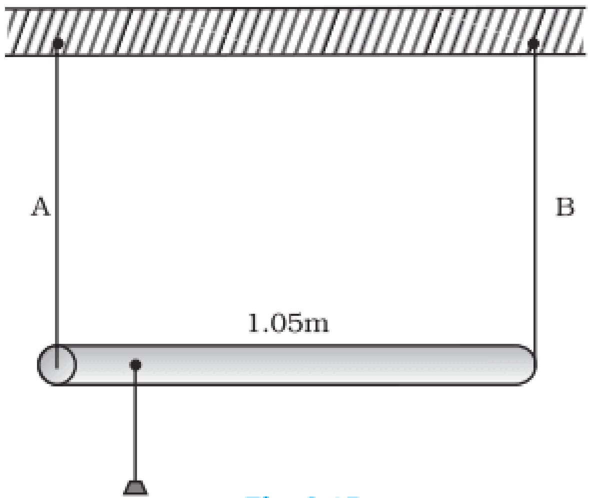

Fig. 9.15

Answer:

Cross-Sectional Area of wire A is $A_A = 1\ mm^2$

Cross-Sectional Area of wire B is $A_B = 2\ mm^2$

Let the Mass m be suspended at y distance From the wire A

Let the Tension in the two wires A and B be F_A and F_B respectively

Since the Strain in the wires is equal

Equating moments of the Tension in the wires about the point where mass m is suspended we have

$$yF_A = (1.05 - y)F_B$$
$$yF_A = (1.05 - y) \times \frac{7}{10}F_A$$
$$10y = 7.35 - 7y$$
$$y = 0.432m$$

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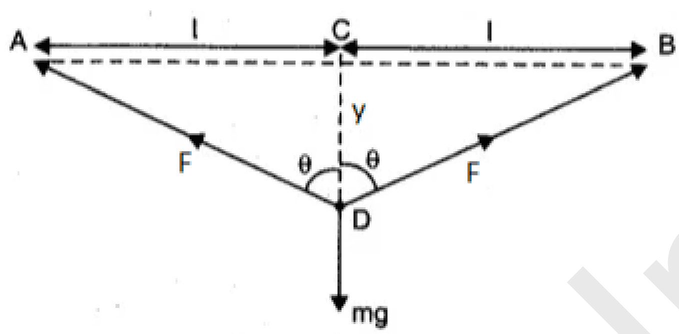
The Load should be suspended at a point 43.2 cm from the wire A such that there is an equal strain in the two wires.

Q19 A mild steel wire of length 1.0 m and cross-sectional area $0.50 \times 10^{-2} cm^2$ is stretched, well within its elastic limit, horizontally between two pillars. A mass of 100 g is suspended from the mid-point of the wire. Calculate the depression at the midpoint.

Answer:



Let the ends of the steel wire be called A and B.

length of the wire is 2l = 1 m.

The cross-sectional area of the wire is $A = 0.50 \times 10^{-2} cm^2$

Let the depression at the midpoint due to the suspended 100 g be y.

Change in the length of the wire is Δl

The strain is $\frac{\Delta l}{2l} = \frac{y^2}{2l^2}$

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The vertical components of the tension in the arms balance the weight of the suspended mass, we have

The stress in the wire will be

$$\frac{F}{A} = \frac{mgl}{2Ay}$$

The Young's Modulus of steel is $Y = 2 \times 10^{11} Nm^{-2}$

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

$$Y = \frac{\frac{mgl}{2Ay}}{\frac{y^2}{2l^2}}$$

$$Y = \frac{mgl^3}{Ay^3}$$

The depression at the mid-point of the steel wire will be 1.074 cm.

Q20 Two strips of metal are riveted together at their ends by four rivets, each of diameter 6.0 mm. What is the maximum tension that can be exerted by the riveted strip if the shearing stress on the rivet is not to exceed $6.9 \times 10^7 Pa$? Assume that each rivet is to carry one quarter of the load.

Answer:

Diameter of each rivet, d = 6.0 mm

Maximum Stress $P = 6.9 \times 10^7 Nm^{-2}$

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The number of rivets, n = 4.

The maximum tension that can be exerted is T

Q21 The Marina trench is located in the Pacific Ocean, and at one place it is nearly eleven km beneath the surface of water. The water pressure at the bottom of the trench is about $1.1 \times 10^8 Pa$ A steel ball of initial volume $0.32 m^3$ is dropped into the ocean and falls to the bottom of the trench. What is the change in the volume of the ball when it reaches to the bottom?

Answer:

The pressure at the bottom of the trench, $P = 1.1 \times 10^8 Pa$

The initial volume of the steel ball, V = 0.32 m^3

Bulk Modulus of steel, $B = 1.6 \times 10^{11} Nm^{-2}$

The change in the volume of the ball when it reaches the bottom of the trench is $2.2 \times 10^{-4} m^3$.

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