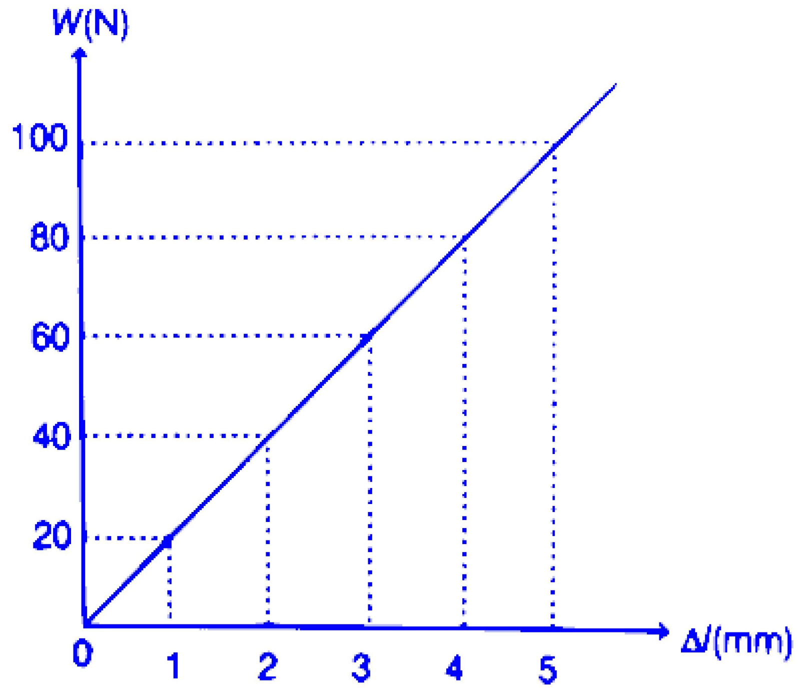
Elasticity

Question1

If the given graph shows the load (W) attached to and the elongation (Δl)produced in a wire of length one metre and area of cross-section $1 \mathrm{~mm}^2$, then the Young's modulus of the material of the wire is



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Options:

A.

$20 \times 10^{10} \mathrm{Nm}^{-2}$

B.

$2 \times 10^{10} \mathrm{Nm}^{-2}$

C.

$10 \times 10^{10} \mathrm{Nm}^{-2}$

D.

$4 \times 10^{10} \mathrm{Nm}^{-2}$

Answer: B

Solution:

$$
\begin{aligned}
Y & =\frac{W l}{A \Delta l}=\left(\frac{W}{\Delta l}\right) \frac{l}{A} \\
& =\frac{(20-0)}{(1-0) \times 10^{-3}} \times \frac{1}{1 \times 10^{-6}} \\
& =2 \times 10^{10} \mathrm{~N} / \mathrm{m}^2
\end{aligned}
$$

Question2

The elastic potential energy stored in a copper rod of length one metre and area of cross-section $1 \mathrm{~mm}^2$ when stretched by 1 mm is

(Young's modulus of copper $=1.2 \times 10^{11} \mathrm{Nm}^{-2}$)

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Options:

A.

$6 \times 10^{-2} \mathrm{~J}$

B.

$3 \times 10^{-2} \mathrm{~J}$

C.

60 J

D.

3 J

Answer: A

Solution:

$$
\begin{aligned}
U &= \frac{1}{2} \times \text{ stress } \times \text{ strain } \times \text{ volume} \\
&= \frac{1}{2} \times \left(Y \times \frac{\Delta l}{l}\right) \times \left(\frac{\Delta l}{l}\right) \times (A \times l) \\
&= \frac{1}{2} \times Y \times A \times \frac{\Delta l^2}{l} \\
&= \frac{1}{2} \times 1.2 \times 10^{11} \times \frac{1 \times 10^{-6} \times 1 \times 10^{-6}}{1} \\
&= 6 \times 10^{-2} \text{ J}
\end{aligned}
$$

Question3

A wire of length 0.5 m and area of cross-section $4 \times 10^{-6}\ \mathrm{m}^2$ at a temperature of $100^{\circ}\mathrm{C}$ is suspended vertically by fixing its upper end to the ceiling. The wire is then cooled to $0^{\circ}\mathrm{C}$, but is prevented from contracting by attaching a mass at the lower end. If the mass of the wire is negligible, then the value of the mass attached to the wire is

[Young's modulus of material of the wire $= 10^{11}\mathrm{Nm}^{-2}$, coefficient of linear expansion of the material of the wire $= 10^{-5}\ \mathrm{K}^{-1}$ and acceleration due to gravity $= 10\ \mathrm{ms}^{-2}$]

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Options:

A.

10 kg

B.

20 kg

C.

30 kg

D.

40 kg

Answer: D

Solution:

As contraction in wire is prevented by extending it with a load,

Thermal contraction = Extension due to load

$$\Rightarrow \quad \alpha l \Delta T=\frac{F l}{Y A} \Rightarrow \alpha l \Delta T=\frac{m g l}{Y A}$$
$$\Rightarrow \quad m=\frac{\alpha \Delta T \cdot Y A}{g}=\frac{\alpha \Delta T Y A}{g}$$

Substituting given values,

$$m=\frac{10^{-5} \times 100 \times 10^{11} \times 4 \times 10^{-6}}{10}$$
$$=4 \times 10=40 \text{ kg}$$

Question4

A wire is stretched 1 mm by a force F. If a second wire of same material, same length and 4 times the diameter of the first wire is stretched by the same force F, then the elongation of the second wire is

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Options:

A.

$\frac{1}{8}$ mm

B.

8 mm

C.

16 mm

D.

$\frac{1}{16}$ mm

Answer: D

Solution:

Step 1: Formula for Elongation

The amount a wire stretches depends on Young's modulus formula:

$Y = \frac{Fl}{\Delta lA} = \frac{4Fl}{\Delta l\pi d^2}$

Step 2: What stays the same?

Both wires are made of the same material, have the same length, and the same stretching force. This means their Young's modulus (Y), original length (l), and force (F) are the same.

Step 3: Setting up the equation for both wires

Since Young's modulus is the same for both wires, we set the formulas equal for each wire:

$$Y_1 = Y_2$$
$$\frac{4Fl}{\Delta l_1 \pi d_1^2} = \frac{4Fl}{\Delta l_2 \pi d_2^2}$$

Step 4: Rearranging to compare elongations

We can simplify to find how the elongation (Δl) relates to diameter (d):

$\Delta l_1 \cdot d_1^2 = \Delta l_2 \cdot d_2^2$

So,

$\Delta l_2 = \Delta l_1 \cdot \left(\frac{d_1}{d_2}\right)^2$

Step 5: Substitute values

We are told $\Delta l_1 = 1$ mm (the first wire stretches 1 mm) and $d_2 = 4d_1$ (the second wire's diameter is 4 times bigger).

$\Delta l_2 = 1 \cdot \left(\frac{d_1}{4d_1}\right)^2 = 1 \cdot \left(\frac{1}{4}\right)^2 = \frac{1}{16}$ mm

Final Answer

The second, thicker wire stretches only $\frac{1}{16}$ mm when the same force is applied.

Question5

If the longitudinal strain of a stretched wire is 0.2% and the Poisson's ratio of the material of the wire is 0.3 , then the volume strain of the wire is

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Options:

A.

0.12%

B.

0.08%

C.

0.14%

D.

0.26%

Answer: B

Solution:

- **Longitudinal strain**, $\varepsilon_L = 0.2\% = 0.002$
- **Poisson's ratio**, $\mu = 0.3$

We are asked to find the **volume strain** (ε_V).

Step 1: Recall the formula for volume strain

For small deformations,

Volume strain $= \varepsilon_V = \varepsilon_L(1 - 2\mu)$

However, to be more precise, the change in volume $\Delta V / V = \varepsilon_L + 2\varepsilon_t$,

where $\varepsilon_t = -\mu\varepsilon_L$ (lateral strain is negative if the material stretches longitudinally).

So,

$\frac{\Delta V}{V} = \varepsilon_L + 2(-\mu\varepsilon_L)$

$\Rightarrow \varepsilon_V = \varepsilon_L(1 - 2\mu)$

Step 2: Substitute the values

$\varepsilon_V = 0.002(1 - 2 \times 0.3)$

$\varepsilon_V = 0.002(1 - 0.6)$

$\varepsilon_V = 0.002 \times 0.4 = 0.0008$

Step 3: Convert to percentage

$\varepsilon_V = 0.0008 \times 100 = 0.08\%$

✅ **Final Answer:**

$\boxed{0.08\%}$

Correct Option: (B) 0.08%

Question6

If the pressure on a body is increased from 200 kPa to 250 kPa , the volume of the body decreases by 0.25%. The compressibility of the material of the body is (in $\mathrm{m}^2\ \mathrm{N}^{-1}$)

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Options:

A.

2×10^7

B.

2×10^{-7}

C.

5×10^8

D.

5×10^{-8}

Answer: D

Solution:

$$\text{Compressibility } = \frac{1}{\text{Bulk modulus } (B)}$$

$$= \frac{-\frac{1}{\Delta P}}{\frac{\Delta V}{V}} = -\frac{\frac{\Delta V}{V}}{\Delta P}$$

$$= \frac{-(-0.0025)}{(250-200)\times 10^3} = 5\times 10^{-8}$$

Question7

When a wire made of material with Young's modulus γ is subjected to a stress S, the elastic potential energy per unit volume stored in the wire is

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Options:

A.

$\frac{YS}{2}$

B.

$\frac{S^2Y}{2}$

C.

$\frac{S^2}{2Y}$

D.

$\frac{S}{2Y}$

Answer: C

Solution:

Elastic potential energy per unit volume

$$\begin{aligned} U &= \frac{W}{V} = \frac{\frac{1}{2} F \Delta l}{A \cdot l} \\ &= \frac{1}{2} \cdot \frac{F}{A} \cdot \frac{\Delta l}{l} \\ &= \frac{1}{2} \times \text{ Stress } \times \text{ Strain} \\ &= \frac{1}{2} \times \text{ Stress } \times \frac{\text{Stress}}{Y} \\ &= \frac{1}{2} \times S \times \frac{S}{Y} = \frac{S^2}{2Y} \end{aligned}$$

Question8

The force required to stretch a steel wire of area of cross-section $1 \mathrm{~mm}^2$ to double its length is

(Young's modulus of steel $= 2 \times 10^{11} \mathrm{~N}-\mathrm{m}^{-2}$)

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Options:

A.

$2 \times 10^3 \mathrm{~N}$

B.

$2 \times 10^5 \mathrm{~N}$

C.

$2 \times 10^2 \mathrm{~N}$

D.

$2 \times 10^4 \mathrm{~N}$

Answer: B

Solution:

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

$$F = \frac{YA\Delta l}{l} = \frac{YA(2l - l)}{l}$$

$$= AY = 1 \times 10^{-6} \times 2 \times 10^{11}$$

$$= 2 \times 10^{5} \text{ N}$$

Question9

When a wire of length ' L ' clamped at one end is pulled by a force ' F ' from the other end, its length increases by ' L '. If the radius of the wire and the applied force were halved, then the increase in its length is

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Options:

A.

$3L$

B.

$4L$

C.

1.5 L

D.

$2L$

Answer: D

Solution:

We know that,

$$Y=\frac{FL}{\pi r^2 \Delta L}$$

$$\Rightarrow \Delta L=\frac{FL}{\pi r^2 Y}$$

$$\Rightarrow \Delta L \propto \frac{FL}{r^2}$$

$$\Rightarrow \quad \frac{\Delta L_2}{\Delta L_1}=\frac{F_2}{F_1} \times \frac{L_2}{L_1} \times\left(\frac{r_1}{r_2}\right)^2$$

$$=\left(\frac{F_{1/2}}{F_1}\right) \times\left(\frac{L_1}{L}\right)\left(\frac{r_1}{r_{1/2}}\right)^2$$

$$\Rightarrow \quad \frac{\Delta L_2}{\Delta L_1}=\frac{1}{2} \times 1 \times 2^2$$

$$\Delta L_2=2 \Delta L_1 \qquad [\because \Delta L_1=L]$$

$$=2 L$$

Question10

When a sphere is taken to the bottom of a sea of depth 1 km , it contracts in volume by 0.01%, then the Bulk modulus of the material of the sphere is

(Acceleration due to gravity $=10 \mathrm{~ms}^{-2}$)

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Options:

A.

$10 \times 10^6 \mathrm{~N}-\mathrm{m}^{-2}$

B.

$1.2 \times 10^{10} \mathrm{~N}-\mathrm{m}^{-2}$

C.

$10 \times 10^{10} \mathrm{~N}-\mathrm{m}^{-2}$

D.

$10 \times 10^{11}\ \mathrm{N-m^{-2}}$

Answer: C

Solution:

- Depth of sea, $h = 1\,\mathrm{km} = 1000\,\mathrm{m}$
- Relative decrease in volume, $\frac{\Delta V}{V} = 0.01\% = 0.0001 = 10^{-4}$
- Acceleration due to gravity, $g = 10\,\mathrm{m/s^2}$
- Density of sea water, $\rho \approx 10^3\,\mathrm{kg/m^3}$

Step 1. Calculate the pressure at that depth

$P = \rho g h = 1000 \times 10 \times 1000 = 10^7\,\mathrm{N/m^2}$

Step 2. Use the definition of Bulk modulus K

$K = -\frac{\Delta P}{\Delta V / V}$

Here, $\Delta P = P = 10^7\,\mathrm{N/m^2}$, and $\frac{\Delta V}{V} = -10^{-4}$

$K = \frac{10^7}{10^{-4}} = 10^{11}\,\mathrm{N/m^2}$

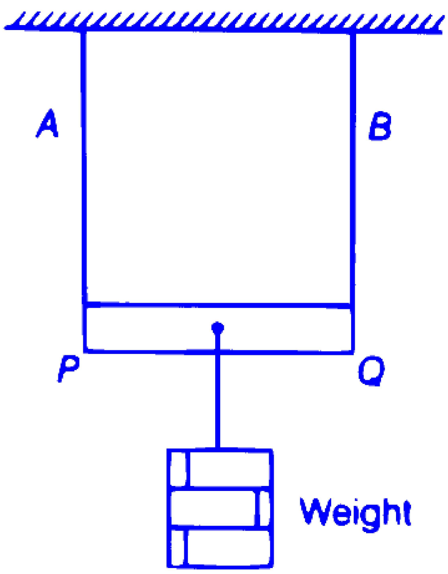
✅ **Final Answer:**

$\boxed{K = 10^{11}\,\mathrm{N/m^2}}$

Correct Option: D) $10 \times 10^{10}\,\mathrm{N/m^2}$

Question11

As shown in the figure, a light uniform rod PQ of length 150 cm is suspended from the ceiling horizontally using two metal wires A and B tied to the ends of the rod. The ratios of the radii and the Young's moduli of the materials of the two wires A and B are respectively $2:3$ and $3:2$. The position at which a weight should be suspended from the rod such that the elongations of the two wires become equal is



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Options:

A.

90 cm from P

B.

100 cm from P

C.

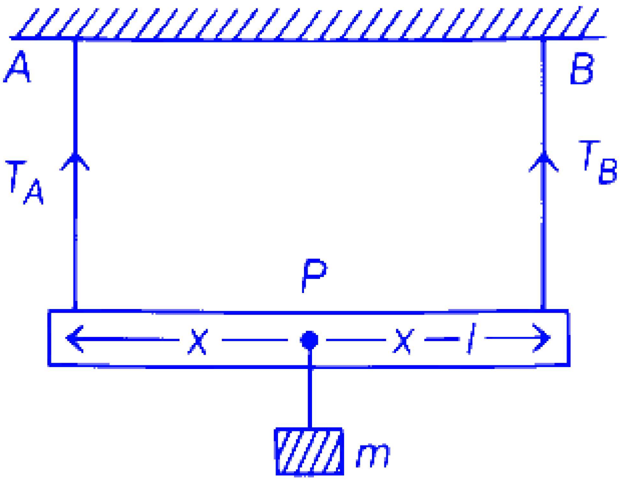
40 cm from Q

D.

45 cm from Q

Answer: A

Solution:



Elongations in A and B are same $\Rightarrow$

$$\Delta l_A = \Delta l_B$$
$$\frac{T_A l_A}{A_A \cdot Y_A} = \frac{T_B l_B}{A_B \cdot Y_B}$$
$$\Rightarrow \quad \frac{T_A}{r_A^2 Y_A} = \frac{T_B}{r_B^2 Y_B}$$
$$\Rightarrow \quad \frac{T_A}{T_B} = \left(\frac{r_A}{r_B}\right)^2 - \left(\frac{Y_A}{Y_B}\right)$$

Given, $\frac{r_A}{r_B} = \frac{2}{3}$ and $\frac{Y_A}{Y_B} = \frac{3}{2}$

$\therefore \quad \frac{T_A}{T_B} = \left(\frac{2}{3}\right)^2 \left(\frac{3}{2}\right) = \frac{2}{3} \qquad \ldots (i)$

For rotational equilibrium of bar; taking moments about point of suspension ' P ',

$$T_A \cdot x = T_B(l - x)$$
$$\Rightarrow \quad \frac{l - x}{x} = \frac{T_A}{T_B} = \frac{2}{3} \quad [form Eq. (i)]$$
$$\Rightarrow \quad \frac{150 - x}{x} = \frac{2}{3}$$
$$150 \times 3 = 5x \quad [\because l = 150 \text{ cm}]$$

or

$x = 90 \text{ cm}(\text{ from } P)$

Question12

The work done on a wire of volume of 2 cm^3 is 16×10^2 J. If the Young's modulus of the material of the wire is $4 \times 10^{12} \text{Nm}^{-2}$. Then the strain produced in the wire is

Options:

A. 0.03 m

B. 0.04 m

C. 0.01 m

D. 0.02 m

Answer: D

Solution:

To find the strain produced in the wire, follow these calculations:

Volume Conversion:

Given volume $V = 2\,\text{cm}^3$.

Convert this to cubic meters:

$V = 2 \times 10^{-6}\,\text{m}^3$

Energy Density Calculation:

The work done on the wire is given as $W = 16 \times 10^2$ J.

Calculate the energy density u:

$u = \frac{W}{V} = \frac{16\times10^2}{2\times10^{-6}} = 8 \times 10^8\ \text{J/m}^3$

Strain Calculation:

Using the formula for energy density:

$u = \frac{1}{2} \times Y \times (\text{strain})^2$

where $Y = 4 \times 10^{12}\,\text{N/m}^2$ is Young's modulus.

Rearrange to solve for strain:

$\text{strain} = \sqrt{\frac{2u}{Y}} = \sqrt{\frac{2\times8\times10^8}{4\times10^{12}}}$

Simplify the expression:

$\text{strain} = 2 \times 10^{-2} = 0.02$

Therefore, the strain produced in the wire is 0.02.

Question13

A wire of length 100 cm and area of cross-section $2\ \mathrm{mm}^2$ is stretched by two forces of each 440 N applied at the ends of the wire in opposite directions along the length of the wire. If the elongation of the wire is 2 mm , the Young's modulus of the material of the wire is

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Options:

A. $2.1 \times 10^{11} \mathrm{Nm}^{-2}$

B. $2.4 \times 10^{11} \mathrm{Nm}^{-2}$

C. $4.4 \times 10^{11} \mathrm{Nm}^{-2}$

D. $1.1 \times 10^{11} \mathrm{Nm}^{-2}$

Answer: D

Solution:

Given:

Length of the wire (L): 100 cm = 1 m

Cross-sectional area (A):

$A = 2\,\mathrm{mm}^2 = 2 \times 10^{-6}\,\mathrm{m}^2$

Force (F): 440 N

Elongation of the wire (ΔL):

$\Delta L = 2\,\mathrm{mm} = 2 \times 10^{-3}\,\mathrm{m}$

Calculation of Young's Modulus:

Young's modulus Y is given by the formula:

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

Substitute the given values:

$Y = \frac{F \cdot L}{A \cdot \Delta L} = \frac{440 \times 1}{2 \times 10^{-6} \times 2 \times 10^{-3}}$

Simplify:

$Y = \frac{440}{4} \times 10^9 = 110 \times 10^9$

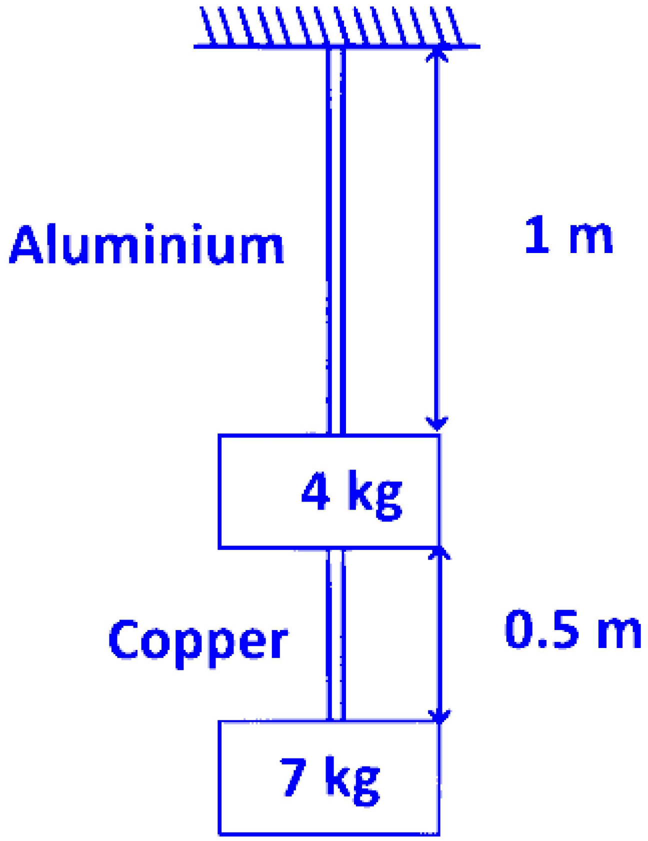
Hence, the Young's modulus Y is:

$Y = 1.1 \times 10^{11}\ \text{N/m}^2$

Question14

The elongation of copper wire of cross-sectional area $3.5\ \text{mm}^2$, in the figure shown, is

$\left(Y_{\text{Copper}} = 10 \times 10^{10}\text{Nm}^{-2} \text{ and } g = 10\ \text{ms}^{-2}\right)$



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Options:

A. 10^{-4} m

B. 10^{-3} m

C. 10^{-6} m

D. 10^{-2} m

Answer: A

Solution:

Given the problem, we are to determine the elongation of a copper wire with the following specifications:

Cross-sectional area: $3.5\,\mathrm{mm}^2$

Mass of block A (m_A): $4\,\mathrm{kg}$

Mass of block C (m_C): $7\,\mathrm{kg}$

Young's Modulus for Copper, Y: $10 \times 10^{10}\,\mathrm{N/m}^2$

Acceleration due to gravity, g: $10\,\mathrm{m/s}^2$

To calculate the elongation (ΔL) of the copper wire, use the formula for linear elongation induced by a force:

$\Delta L = \frac{F \cdot L}{Y \cdot A}$

Here, the force F is due to the weight of block C, which is calculated as $F = m_C \cdot g$. The length L is given as $0.5\,\mathrm{m}$.

Substituting the given values:

$\Delta L = \frac{7 \cdot 9.8 \cdot 0.5}{10^{11} \cdot 3.5 \times 10^{-6}}$

Calculate the result:

$\Delta L = 10^{-4}\,\mathrm{m}$

Thus, the elongation of the copper wire is 10^{-4} m.

Question15

A 4 kg stone attached at the end of a steel wire is being whirled at a constant speed $12\ \mathrm{ms}^{-1}$ in a horizontal circle. The wire is 4 m long with a diameter 2.0 mm and Young's modulus of the steel is $2 \times 10^{11}\mathrm{Nm}^{-2}$. The strain in the wire is.

Options:

A. 2.4×10^{-4}

B. 2.3×10^{-5}

C. 4.6×10^{-4}

D. 6.9×10^{-4}

Answer: A

Solution:

To calculate the strain in the wire, let's begin with the given data:

Mass, $m = 4\,\text{kg}$

Velocity, $v = 12\,\text{m/s}$

Length of wire = 4 m

Diameter = 2.0 mm or radius = 1.0×10^{-3} m

Young's modulus of steel = 2×10^{11} N/m^2

Step-by-Step Calculation:

Calculate the Cross-Sectional Area of the Wire:

Area $= \pi r^2 = \pi \times (1.0 \times 10^{-3})^2 = \pi \times 10^{-6}\,\text{m}^2$

Calculate the Centripetal Force required to revolve the stone in a horizontal circle:

$F_c = \frac{mv^2}{r} = \frac{4 \times 12^2}{4} = 144\,\text{N}$

(Note: The original calculation contained an error with the radius used in centripetal force.)

Calculate the Stress on the Wire:

Stress $= \frac{\text{Force}}{\text{Area}} = \frac{144}{\pi \times 10^{-6}} = \frac{144}{3.14159 \times 10^{-6}}\,\text{Nm}^{-2}$

Simplifying:

Stress $\approx 4.59 \times 10^{7}\,\text{Nm}^{-2}$

Calculate the Strain using Young's Modulus:

Strain $= \frac{\text{Stress}}{\text{Young's modulus}} = \frac{4.59 \times 10^{7}}{2 \times 10^{11}}$

Solving for strain:

$\text{Strain} = 2.295 \times 10^{-4}$

Rounding off to one decimal place gives:

$\text{Strain} \approx 2.4 \times 10^{-4}$

The strain in the wire is approximately 2.4×10^{-4}.

Question16

The elastic energy stored per unit volume in terms of longitudinal strain ε and Young's modulus Y is

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Options:

A. $\frac{\gamma\varepsilon^2}{2}$

B. $\frac{1}{2}Y_\varepsilon$

C. $2\gamma\varepsilon^2$

D. $2Y_\varepsilon$

Answer: A

Solution:

Given the following:

Longitudinal strain ε

Young's modulus Y

The relationship between stress and Young's modulus is given by:

$\text{Young's modulus} = \frac{\text{stress}}{\text{strain}}$

From this, we can express stress as:

$\text{Stress} = Y \cdot \varepsilon$

The formula for elastic energy stored per unit volume is:

$U = \frac{1}{2} \times \text{stress} \times \text{strain}$

Substituting in the expression for stress, we get:

$U = \frac{1}{2} \times Y \cdot \varepsilon \times \varepsilon = \frac{Y\varepsilon^2}{2}$

Question17

When the load applied to a wire is increased from 5 kg wt to 8 kg wt . The elongation of the wire increases from 1 mm to 1.8 mm . The work done during the elongation of the wire is (acceleration due to gravity $= 10 \text{ ms}^{-2}$)

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Options:

A.

47×10^{-3} J

B.

72×10^{-3}j

C.

25×10^{-3} J

D.

97×10^{-3} J

Answer: A

Solution:

When the load on a wire is increased from 5 kg to 8 kg, the elongation of the wire changes from 1 mm to 1.8 mm. To find the work done during this elongation, we use the acceleration due to gravity as $10\,\text{ms}^{-2}$.

First, calculate the work done for the initial elongation:

The force due to a 5 kg load is:

$5\,\text{kg} \times 9.8\,\text{N/kg} = 49\,\text{N}$

Work done for an elongation of 1 mm (0.001 m) under this force is:

$W_1 = \frac{1}{2} \times 49 \times 0.001 = 0.0245\,\text{J} = 24.5 \times 10^{-3}\,\text{J}$

Now, calculate the work done for the increased elongation:

The force due to an 8 kg load is:

$8\,\text{kg} \times 9.8\,\text{N/kg} = 78.4\,\text{N}$

Work done for an elongation of 1.8 mm (0.0018 m) under this force is:

$W_2 = \frac{1}{2} \times 78.4 \times 0.0018 = 0.07056\,\text{J} = 70.56 \times 10^{-3}\,\text{J}$

The work done during the additional elongation (from 1 mm to 1.8 mm) is the difference between these two energies:

$\Delta W = W_2 - W_1 = 70.56 \times 10^{-3} - 24.5 \times 10^{-3} = 46.06 \times 10^{-3}\,\text{J}$

This value rounds to $47 \times 10^{-3}\,\text{J}$.

Question18

If the work done in stretching a wire by 1 min is 2 J . The work necessary for stretching another wire of satrs material but with double radius of cross-section and half the length by 1 mm is

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Options:

A. 16 J

B. 8 J

C. 4 J

D. $\frac{1}{4} J$

Answer: A

Solution:

The work done in stretching a wire can be calculated by considering the relation:

$W = \frac{1}{2}\left(\frac{F}{A}\right)$ (strain) (volume)

Breaking it down further:

$W = \frac{1}{2}\left(\frac{F}{A}\right)\left(\frac{e}{l}\right) \times A \times l$

This simplifies to:

$W = \frac{1}{2} Fe$

We deduce that:

$W \propto F \propto \frac{VAe}{l}$

Since:

$W \propto \frac{r^2}{l}$

Let's compare the initial and new wire conditions:

For the first wire, we have the following proportion:

$\frac{2}{W_2} = \frac{r_1^2}{r_2^2} \times \frac{l_2}{l_1}$

Plugging in the values given:

$= \frac{r^2}{4r^2} \times \frac{l}{2l} = \frac{1}{8}$

Solving for W_2:

$W_2 = 8 \times 2 = 16\,\mathrm{J}$

Hence, the work necessary to stretch the second wire is 16 Joules.

Question19

Two copper wires A and B of lengths in the ratio $1:2$ and diameters in the ratio $3:2$ are stretched by foren in the ratio $3:1$. The ratio of the clastic potential energies stored per unit volume in the wires A and B is.

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Options:

A. $2:1$

B. $4:9$

C. $16:9$

D. $4:3$

Answer: C

Solution:

To solve this problem, we start by examining the given relationships for the two copper wires, A and B.

Given Ratios:

Lengths: $\frac{l_A}{l_B} = \frac{1}{2}$

Diameters: $\frac{d_A}{d_B} = \frac{3}{2}$ implies $\frac{r_A}{r_B} = \frac{3}{2}$. Thus, $\frac{r_A^2}{r_B^2} = \frac{9}{4}$.

Forces: $\frac{F_A}{F_B} = \frac{3}{1}$

Elastic Potential Energy Per Unit Volume:

The elastic potential energy per unit volume in the wire is given by:

$$U = \frac{1}{2} \frac{F \cdot \Delta L}{V}$$

Young's Modulus Definition:

From Young's modulus Y, we have:

$$Y = \frac{F \cdot L}{A \cdot \Delta L} \implies \Delta L = \frac{F \cdot L}{A \cdot Y}$$

Volume:

$$V = A \cdot L$$

Substituting ΔL and V into the expression for U:

$$U = \frac{1}{2} \cdot \frac{F \cdot F \cdot L}{A \cdot L \cdot A \cdot Y} = \frac{1}{2} \frac{F^2}{A^2 Y}$$

Ratio of Elastic Potential Energies U_A and U_B:

$$\frac{U_A}{U_B} = \frac{\frac{1}{2} \frac{F_A^2}{(\pi r_A^2)^2 Y}}{\frac{1}{2} \frac{F_B^2}{(\pi r_B^2)^2 Y}} = \frac{F_A^2 (r_B^2)^2}{F_B^2 (r_A^2)^2}$$

Now plug in the ratios:

$$\frac{U_A}{U_B} = \left(\frac{3}{1}\right)^2 \cdot \left(\frac{4}{9}\right)^2$$

Calculate the final ratio:

$$\frac{U_A}{U_B} = \frac{9}{1} \cdot \frac{16}{81}$$

$$\frac{U_A}{U_B} = \frac{144}{81}$$

$$\frac{U_A}{U_B} = \frac{16}{9}$$

Thus, the ratio of elastic potential energies stored per unit volume in wires A and B is 16 : 9.

Question20

Two wires A and B of same cross-section are connected end to end. When same tension is created in both wires, the elongation in B wire is twice the elongation in A wire. If L_A and L_B are the initial lengths of the wires A and B respectively, then (Young's modulus of material of wire $A = 2 \times 10^{11}\ \mathrm{Nm}^{-2}$ and Young's modulus of material of wire $B = 1.1 \times 10^{11}\ \mathrm{Nm}^{-2}$).

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Options:

A. $\frac{L_A}{L_B} = \frac{10}{11}$

B. $\frac{L_A}{L_B} = \frac{4}{5}$

C. $\frac{L_A}{L_B} = \frac{9}{11}$

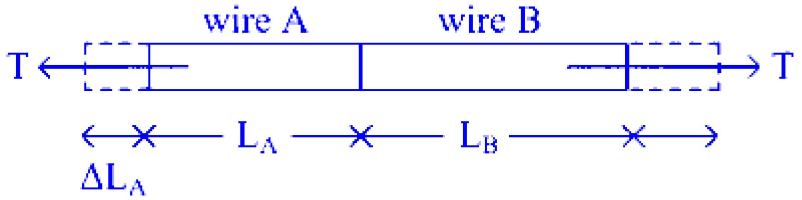
D. $\frac{L_A}{L_B} = \frac{3}{7}$

Answer: A

Solution:

Two wires, A and B, with the same cross-sectional area, are connected end-to-end. When the same tension is applied to both wires, wire B elongates twice as much as wire A. Let the initial lengths of wires A and B be L_A and L_B respectively. The Young's modulus for wire A is $2 \times 10^{11}\ \mathrm{N/m^2}$ and for wire B is $1.1 \times 10^{11}\ \mathrm{N/m^2}$.

Let's illustrate this situation with the following image:



We are given that the elongation in wire B is twice that of wire A when the same tension T is applied. This can be expressed mathematically as:

$\Delta L_B = 2\Delta L_A$

The Young's modulus formulas for wires A and B are as follows:

$Y_A = \frac{TL_A}{A \cdot \Delta L_A}$ and $Y_B = \frac{TL_B}{A \cdot \Delta L_B}$

By taking the ratio of these two equations, we obtain:

$\frac{Y_A}{Y_B} = \frac{L_A}{L_B} \times \frac{\Delta L_B}{\Delta L_A}$

Substitute the given values:

$\frac{2 \times 10^{11}}{1.1 \times 10^{11}} = \frac{L_A}{L_B} \times \frac{2\Delta L_A}{\Delta L_A}$

This simplifies to:

$\frac{2}{1.1} = \frac{L_A}{L_B} \times 2$

Therefore:

$\frac{L_A}{L_B} = \frac{2}{1.1 \times 2} = \frac{1}{1.1} \approx \frac{10}{11}$

Thus, the ratio of the initial lengths of wires A and B is approximately $\frac{L_A}{L_B} = \frac{10}{11}$.

Question21

Same tension is applied to the following four wires made of same material. The elongation is longest in

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Options:

A. wire of length 200 cm and diameter 2 mm

B. wire of length 300 cm and diameter 3 mm

C. wire of length 50 cm and diameter 0.5 mm

D. wire of length 100 cm and diameter 1 mm

Answer: A

Solution:

We know that, young's modulus,

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

Where, $A=$ Area of cross-section, $l=$ length of wire and $\Delta l=$ elongation in the longest wire.

Here, $A=\pi r^2$

$=\pi\left(\frac{d}{2}\right)^2=\pi\frac{d^2}{4} \quad (\because d=2r)$

$$\therefore \quad Y=\frac{Fl}{\frac{\pi d^2}{4}\Delta l}$$

$$\Rightarrow \Delta l=\frac{4Fl}{\pi d^2 Y}=\left(4\frac{F}{\pi Y}\right)\frac{l}{d^2}\Rightarrow \Delta l=k\frac{l}{d^2}$$

where, $k=\frac{4F}{\pi y}=$ constant

For wire given in option (a)

$(\Delta)_1=k\cdot\frac{50}{(0.05)^2}=20000\mathrm{k}$

similarly,

For wire given in option (b)

$(\Delta)_2=k\times\frac{200}{(0.2)^2}=5000\mathrm{k}$

For wire given in option (c)

$\Delta l_3=k\cdot\frac{300}{(0.3)^2}=3333.33\ \mathrm{k}$

For wire given in option (d)

$\Delta l_4=\frac{100}{(0.1)^2}=10000\ \mathrm{k}$

Hence, we see that wire given in option (a) has maximum elongation.

Question22

Young's modulus of a wire is $2\times10^{11}\mathrm{Nm}^{-2}$. If an external stretching force of 2×10^{11} N is applied to a wire of length L. The final length of the wire is (cross-section = unity)

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Options:

A. 2 L

B. 1.5 L

C. 3 L

D. 1.25 L

Answer: A

Solution:

Given, Young's modulus, $Y = 2 \times 10^{11}\ \mathrm{N/m^2}$

Applied force, $F = 2 \times 10^{11}\ \mathrm{N}$

Cross-sectional area, $A = 1\ \mathrm{m^2}$

Let initial and final length be $L_1 = L$ and $L_2 = ?$

$$\begin{aligned}
\text{Since, } Y &= \frac{FL_1}{A(L_2 - L_1)} \\
\therefore \quad & \frac{L_2 - L_1}{L_1} = \frac{2 \times 10^{11}}{2 \times 10^{11}} = 1 \\
\Rightarrow \quad & \frac{L_2}{L_1} - 1 = 1 \Rightarrow \frac{L_2}{L_1} = 2 \\
\Rightarrow \quad & L_2 = 2L_1 \\
\therefore \quad & L_2 = 2L
\end{aligned}$$

Question23

The Young's modulus of a rubber string of length $12\ \mathrm{cm}$ and density $1.5\ \mathrm{kgm^{-3}}$ is $5 \times 10^8\ \mathrm{Nm^{-2}}$. When this string is suspended vertically, the increase in its length due to its own weight is (Take, $g = 10\ \mathrm{ms^{-2}}$)

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Options:

A. $2.16 \times 10^{-10}\ \mathrm{m}$

B. $9.6 \times 10^{-11}\ \mathrm{m}$

C. $9.6 \times 10^{-3}\ \mathrm{m}$

D. $2.16 \times 10^{-3}\ \mathrm{m}$

Answer: A

Solution:

Given, length of rubber,

$$l = 12 \text{ cm}$$
$$= 12 \times 10^{-2} \text{ m}$$

Density of rubber, $\rho = 1.5 \text{ kg m}^{-3}$

Young's modulus, $Y = 5 \times 10^8 \text{ N/m}^2$

As we know that,

$$Y = \frac{mgl}{A\Delta l} \times \frac{1}{2}$$

Centre of mass of rod is at the centre of rod

$$\therefore \quad Y = \frac{\rho(A \cdot l) \cdot g \cdot l}{2A \cdot \Delta l}$$

where, A is area of cross-section and g is acceleration due to gravity.

$$\therefore \quad Y = \frac{\rho l^2 g}{2\Delta l} \Rightarrow \Delta l = \frac{\rho l^2 g}{2Y}$$
$$= \frac{1.5 \times (12 \times 10^{-2})^2 \times 10}{2 \times 5 \times 10^8} = 2.16 \times 10^{-10} \text{ m}$$
