Elasticity

Question1

Two wires A and B made of same material and areas of cross-section in the ratio $1 : 2$ are stretched by same force. If the masses of the wires A and B are in the ratio $2 : 3$, then the ratio of the elongations of the wires A and B is

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Options:

A.

1 : 2

B.

8 : 3

C.

1 : 3

D.

4 : 3

Answer: B

Solution:

The mass of a wire is $m = \rho AL$

Since, the material is the same, the density ρ is constant for both wires.

$$\frac{m_A}{m_B}=\frac{\rho A_A L_A}{\rho A_B L_B} \Rightarrow \frac{m_A}{m_B}=\frac{A_A L_A}{A_B L_B}$$

$$\frac{2}{3}=\frac{1}{2} \times \frac{L_A}{L_B}$$

$$\frac{L_A}{L_B}=\frac{2}{3} \times 2=\frac{4}{3}$$

The ratio of elongations is

$$\frac{\Delta L_A}{\Delta L_B}=\frac{\frac{F L_A}{A_A Y}}{\frac{F L_B}{A_B Y}}=\frac{L_A}{A_A} \times \frac{A_B}{L_B}$$

Substitute $\frac{L_A}{L_B}=\frac{4}{3}$ and $\frac{A_B}{A_A}=\frac{2}{1}$

$$\frac{\Delta L_A}{\Delta L_B}=\frac{4}{3} \times \frac{2}{1}=\frac{8}{3}$$

The ratio of the elongations of the wires A and B is $\frac{8}{3}$.

Question2

If a brass sphere of radius 36 cm is submerged in a lake at a depth where the pressure is 10^7 Pa, then the change in the radius of the sphere is

(Bulk modulus of brass $= 60 \mathrm{GPa}$)

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Options:

A.

4×10^{-2} cm

B.

2×10^{-3} cm

C.

4×10^{-3} cm

D.

2×10^{-2} cm

Answer: B

Solution:

$$B=\frac{F}{A}\times\frac{V}{\Delta V}$$
$$B=\frac{PV}{\Delta V}$$

$$Here,\ V=\frac{4}{3}\pi R^3$$
$$\Delta V=4\pi R^2\Delta R$$

$$\therefore\quad B=P\times\frac{4}{3}\pi R^3\times\frac{1}{4\pi R^2\Delta R}$$
$$B=\frac{PR}{3\Delta R}$$
$$\Delta R=\frac{PR}{3B}=\frac{10^7\times 36\times 10^{-2}}{3\times 60\times 10^9}$$
$$\Delta R=2\times 10^{-5}\ \mathrm{m}$$
$$=2\times 10^{-3}\ \mathrm{cm}$$

Question3

A simple pendulum is made of a metal wire of length L, area of cross-section A, material of Young's modulus Y and a bob of mass m. This pendulum is hung in abus moving with a uniform speed v on a horizontal circular road of radius R. The elongation in the wire is

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Options:

A. $\frac{mL}{RAY}\sqrt{g^2R^2+v^4}$

B. $\frac{mgL}{AY}$

C. $\frac{mLv^2}{RAY}$

D. $\frac{L}{AY}\sqrt{mg+\frac{mv^2}{R}}$

Answer: A

Solution:

Gravitational force acting on the pendulum,

$F_g = mg$

where, $m =$ mass of bob

Centripetal force acting on the pendulum,

$F_c = \frac{mv^2}{R}$

where, $v =$ speed of bus and $R =$ radius of circular path

The net force experienced by the wire is the resultant of the gravitational force and the centripetal force. It can be determined by vector addition.

$$F_{\text{net}} = \sqrt{F_g^2 + F_c^2}$$

$$= \sqrt{(mg)^2 + \left(\frac{mv^2}{R}\right)^2} = m\sqrt{g^2 + \left(\frac{v^2}{R}\right)^2}$$

$$= \frac{m}{R}\sqrt{g^2R^2 + v^4}$$

The elongation (ΔL) in the wire,

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

where, $F =$ net force, $L =$ original length of wire, $A =$ area of cross-section of the wire and $Y =$ Young's modulus.

After putting values,

$\Delta L = \frac{m \cdot L}{RAY}\sqrt{g^2R^2 + v^4}$

Question4

A wire of cross-sectional area 10^{-6} m^2 is elongated by 0.1% when the tension in it is 1000 N . The Young's modulus of the material of the wire is (assume radius of the wire is constant)

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Options:

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

B. $10^{12}\mathrm{Nm}^{-2}$

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

D. $10^{9}\mathrm{Nm}^{-2}$

Answer: B

Solution:

Given the following parameters:

Cross-sectional area: $A = 10^{-6}\ \mathrm{m}^2$

Elongation: $\frac{\Delta l}{l} = 0.1\% = \frac{0.1}{100}$

Tension: $T = 1000\ \mathrm{N}$

We need to find the Young's modulus Y of the material of the wire. The formula for Young's modulus is:

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

Where stress is defined as:

$\text{Stress} = \frac{\text{Tension}}{\text{Area}}$

And strain is the elongation:

$\text{Strain} = \frac{\Delta l}{l}$

Substituting the given values into the formulas:

$\text{Stress} = \frac{1000}{10^{-6}}$

$\text{Strain} = \frac{0.1}{100}$

Now, calculating Young's modulus:

$Y = \frac{1000}{10^{-6}} \times \frac{100}{0.1}$

Simplifying:

$Y = 10^{12}\ \mathrm{N/m}^2$

Therefore, the Young's modulus of the material of the wire is $10^{12}\ \mathrm{N/m}^2$.

Question5

A block of mass 2 kg is tied to one end of a 2 m long metal wire of $1.0\ \mathrm{mm}^2$ area of cross-section and rotated in a vertical circle such

that the tension in the wire is zero at the highest point. If the maximum elongation in the wire is 2 mm , the Young's modulus of the metal is

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

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Options:

A. $1.0 \times 10^{11} \mathrm{Nm}^{-2}$

B. $1.2 \times 10^{11} \mathrm{Nm}^{-2}$

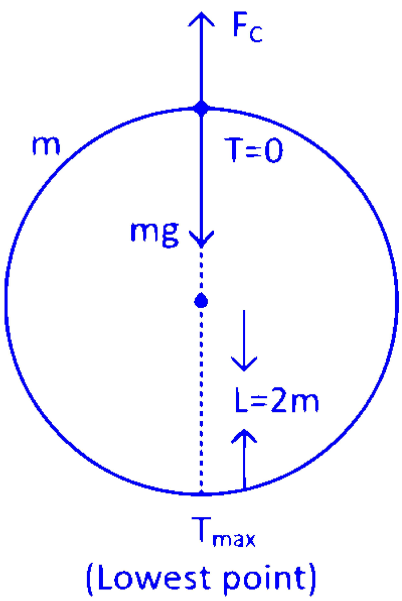
C. $2.0 \times 10^{11} \mathrm{Nm}^{-2}$

D. $0.2 \times 10^{11} \mathrm{Nm}^{-2}$

Answer: B

Solution:

Mass of block, $m = 2$ kg



Length of metal wire, $L = 2$ m At top (highest) point, tension $T = 0$ So, the velocity required (critical) at bottom point to complete the revolution

$v = \sqrt{5 g L}$

Tension at lowest point (where elongation is maximum)

$$T = mg + \frac{mv^2}{L}$$

$$= mg + \frac{m(5g)L}{L}$$

$$T = 6mg = 6 \times 2 \times 10$$

$$\text{Tension } = 120 \text{ N}$$

$$\text{Strain } = \frac{\Delta L}{L} = \frac{2 \times 10^{-3}}{2} = 10^{-3}$$

$$\text{Stress } = \frac{T}{A} = \frac{120}{1 \times 10^{-6}}$$

$$= 1.2 \times 10^8 \text{ N/m}^2$$

$$\text{Young's modulus } = \frac{\text{Stress}}{\text{Strain}} = \frac{1.2 \times 10^8}{10^{-3}}$$

$$= 1.2 \times 10^{11} \text{Nm}^{-2}$$

Question6

If the length of a string is P when the tension in it is 6 N and its length is Q when the original length of the string is

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Options:

A. $3P + 4Q$

B. $3P - 4Q$

C. $4P + 3Q$

D. $4P - 3Q$

Answer: D

Solution:

Let original length of the spring be l m and Young's modulus be

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

Now, when $F=6 \mathrm{~N}, \Delta l=(P-l)$, then

$Y=\frac{6 l}{A(P-I)} \quad \ldots$ (i)

and when, $F=10 \mathrm{~N}$ and $\Delta l=(Q-l)$, then

$Y=\frac{8 l}{A(Q-l)} \quad \ldots$ (ii)

From Eqs. (i) and (ii), we get

$$\begin{aligned} \frac{6 l}{A(P-l)} & =\frac{8 l}{A(Q-l)} \\ \Rightarrow \quad 6(Q-l) & =8(P-l) \\ 6 Q-6 l & =8 P-8 l \\ \Rightarrow \quad-6 l+8 l & =8 P-6 Q \\ \Rightarrow \quad 2 l & =8 P-6 Q \\ \Rightarrow \quad l & =4 P-3 Q \end{aligned}$$

Question7

A steel wire of length 3 m and a copper wire of length 2.2 m are connected end to end. When the combination is stretched by a force, the net elongation is 1.05 mm . If the area of cross-section of each wire is $6 \mathrm{~mm}^2$, then the load applied is (Young's moduli of steel and copper are respectively $2 \times 10^{11} \mathrm{Nm}^{-2}$ and $1.1 \times 10^{11} \mathrm{Nm}^{-2}$)

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Options:

A. 180 N

B. 90 N

C. 135 N

D. 120 N

Answer: A

Solution:

Using Hooke's law,

$F = kx$

The spring constant (k) for material is given by

$k = \frac{YA}{L}$

Let denote the extension as x_s and x_C

$x_S + x_C = 1.05 \text{ mm}$

$= 1.05 \times 10^{-3} \text{ m}$

Forces in both wires,

$F = k_S x_S = k_C x_C$

Here, $\frac{Y_s A}{L_S} x_s = \frac{Y_c A}{L_C} x_C$

Let x_s to x_c,

$\frac{x_s}{x_c} = \frac{Y_c L_s}{Y_s L_c}$

$\frac{x_S}{x_C} = \frac{1.1 \times 10^{11} \times 3}{2 \times 10^{11} \times 2.2} = \frac{3}{4}$

Thus,

$$\frac{3}{4} x_C + x_C = 1.05 \times 10^{-3}$$

$$\frac{7}{4} x_C = 1.05 \times 10^{-3}$$

$$x_C = 0.6 \times 10^{-3} \text{ m}$$

For x_S,

$$x_s = \frac{3}{4} \times 0.6 \times 10^{-3}$$

$$x_s = 0.45 \times 10^{-3} \text{ m}$$

Therefore, using the spring constant for steel,

$$F=\frac{Y_S A}{L_S} x_S$$

$$F=\frac{2 \times 10^{11} \times 6 \times 0.45}{3 \times 10^9}$$

$$F=\frac{2 \times 6 \times 0.45}{3} \times 10^2$$

$$F=180 \mathrm{~N}$$

Therefore, the load applied is 180 N .

Question8

Two wires A and B of same length, same radius and same Young's modulus are heated to same range of temperatures. If the coefficient of linear expansion of A is $\frac{3}{2}$ times that of B, then the ratio of the thermal stresses produced in the two wires A and B is

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Options:

A. 2 : 3

B. 9 : 4

C. 4 : 9

D. 3 : 2

Answer: D

Solution:

The ratio of the linear expansion coefficients of A to B is $\frac{3}{2}$.

The Young's modulus Y is the same for both wires.

For a wire, the thermal expansion formula is:

$$\Delta l=l \alpha \Delta T$$

where Δl is the change in length, l is the original length, α is the coefficient of linear expansion, and ΔT is the change in temperature.

We use Young's modulus Y:

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

Stress is given by:

$\text{Stress}_A = Y \times \alpha_A \Delta T$

For wire A, using the formula for Young's modulus:

$Y = \frac{(\text{Stress}\quad)_A}{l \times \alpha_A \times \Delta T}$

Similarly, for wire B:

$Y = \frac{(\text{Stress}\quad)_B}{l \times \alpha_B \times \Delta T}$

Given that Y is the same for both A and B:

$\frac{\text{Stress}\quad_A}{\alpha_A \Delta T} = \frac{\text{Stress}\quad_B}{\alpha_B \Delta T}$

Therefore, the ratio of the thermal stresses is determined by the ratio of their coefficients of linear expansion:

$\frac{\text{Stress}\quad_A}{\text{Stress}\quad_B} = \frac{\alpha_A}{\alpha_B} = \frac{3}{2}$

Thus, the ratio of the thermal stresses produced in wires A and B is 3 : 2.

Question9

A wire of length 40 cm is stretched by 0.1 cm . The strain on the wire is

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Options:

A. 25×10^{-4}

B. 40×10^{-4}

C. 10×10^{-4}

D. 12.5×10^{-4}

Answer: A

Solution:

To determine the strain on the wire, consider the following:

Original length of the wire: 40 cm

Amount it is stretched (elongation): 0.1 cm

The formula to calculate strain is:

$$\text{Strain} = \frac{\text{Elongation}}{\text{Original Length}}$$

Substituting the given values:

$$\text{Strain} = \frac{0.1}{40} = 0.0025$$

To express this in scientific notation:

$$0.0025 = 25 \times 10^{-4}$$

Thus, the strain on the wire is 25×10^{-4}.
