B.Sc. I, Paper-I Problem Set-3

Q.1 Young's modulus for brass is 8.96×10^{11} Pa. A 120N weight is attached to an 8m length of brass wire, find the increase in length. The diameter is 1.5mm

Solution:

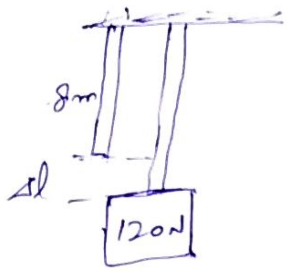
Young's modulus $Y = \frac{Fl}{A \Delta l}$

$\Delta l = \frac{Fl}{AY}$, Δl - increase in length

given quantities. $Y = 8.96 \times 10^{11}$ Pa

$l = 8m$

$F = 120N$, diameter of wire $r = 1.5mm$



area $A = \pi\left(\frac{r}{2}\right)^2 = \frac{\pi r^2}{4}$

$A = \frac{\pi \cdot (1.5 \times 10^{-3})^2}{4} = \frac{\pi \times 2.25 \times 10^{-6}}{4} m^2$

$A = 1.77 \times 10^{-6} m^2$

$\therefore \Delta l = \frac{120 \times 8}{1.77 \times 10^{-6} \times 8.96 \times 10^{11}}$ {all quantities in SI units}

$\Delta l = 60.5 \times 10^{-4} m$

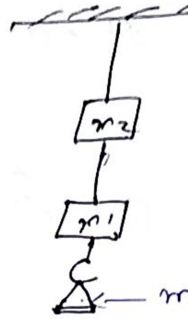
$\boxed{\Delta l = 0.605mm}$

(Q.2) The two wires shown in fig below are made of same material which has a breaking stress of 8×10^{8} N/m2

The area of cross-section of the upper wire is $0.006 cm^2$ and that of the lower wire is $0.003 cm^2$.

The ~~mass~~ mass $m_1 = 10kg$, $m_2 = 20kg$ and the hanger is light. Find the maximum load that can be put on the hanger without breaking a wire. Which wire will break first if the load is increased? ($g = 10 m/s^2$)

soln.



Breaking stress of both wires $= 8 \times 10^8 N/m^2$

$m_1 = 10 kg$, $m_2 = 20 kg$

Cross section area of lower wire $A_1 = 0.003 cm^2$

Cross-section area of upper wire $A_2 = 0.006 cm^2$

For lower wire

$$\text{stress}(P_1) = \frac{\text{Tension } (T_1)}{\text{Area of cross-section}(A_1)}$$

$$P_1 = \frac{T_1}{A_1}$$

$T_1 = m_1 g + m_0 g$, $m_0 \rightarrow$ maximum load that can be put on the hanger without breaking the wire.

Stress in the wire should not exceed the breaking stress in order to avoid the breaking of wire.

$$P_1 = \frac{m_1 g + m_0 g}{A_1}$$

$$8 \times 10^8 N/m^2 = \frac{10 kg\, g + m_0 g}{0.003 \times 10^{-4} m^2}$$

$$0.024 \times 10^4 N = 10 kg \cdot g + m_0 g$$

$$m_0 = \frac{2.4 \times 10^2 N}{g} - 10 kg = \frac{2.4 \times 10^2 N}{10 m/s^2} - 10 kg$$

$$m_0 = 24 kg - 10 kg = 14 kg$$

$\boxed{m_0 = 14 kg}$ for lower wire

For upper wire

Tension in wire $T_2 = m_1 g + m_2 g + m_0 g$

$$\text{Stress} = \frac{T_2}{A_2} = \frac{m_1 g + m_2 g + m_0 g}{A_2}$$

$$8 \times 10^8 = \frac{(10+20+m_0) g}{0.006 \times 10^{-4}} \quad \text{[in SI units]}$$

$$(30+m_0) g = 0.048 \times 10^4$$

$$m_0 = \frac{4.8 \times 10^2 - 30}{g} = \frac{4.8 \times 10^2}{10} - 30$$

$$m_0 = 48 - 30$$

$$\boxed{m_0 = 18 \text{ kg}}$$

Therefore, the maximum load that can be put on the hanger without breaking is 14 kg and if load increases ~~first~~ lower wire will break first.