DPP – Elasticity

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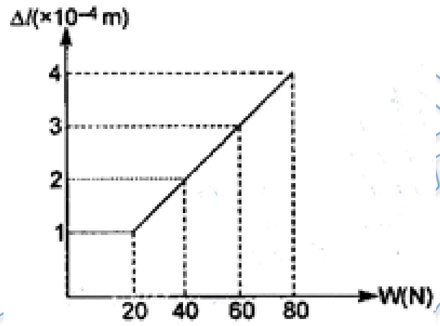
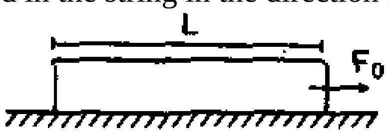
Q 1. The adjacent graph shows the extension (Δl) of a wire of length 1 m suspended from the top of a roof at one end and with a load W connected to the other end. If the cross-sectional area of the wire is 10^{-6} m^2, calculate the Young's modulus of the material of the wire:



(a) 2×10^{11} N/m^2
(b) 2×10^{-11} N/m^2
(c) 3×10^{12} N/m
(d) 2×10^{13} N/m^2

Q 2. A constant force F_0 is applied on a string placed over a smooth horizontal uniform elastic string surface as shown in figure. Young's modulus of string is Y and area of cross-section is S. The strain produced in the string in the direction of force is:



(a) $\frac{F_0 Y}{S}$
(b) $\frac{F_0}{SY}$
(c) $\frac{F_0}{2SY}$
(d) $\frac{F_0 Y}{2S}$

Q 3. A uniform rod of mass m and length L has area of cross-section A and young modulus γ. This rod is rotating about its one end with angular velocity ω. Elongation in length of rod is (Gravity is absent)

(a) $\frac{ml^2\omega^2}{3A\gamma}$
(b) $\frac{ml^2\omega^2}{2A\gamma}$
(c) $\frac{ml^2\omega^2}{6A\gamma}$
(d) $\frac{ml^2\omega^2}{4A\gamma}$

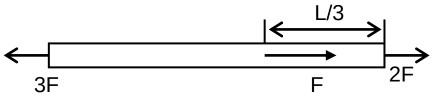
Q 4. If ρ is the density of the material of a wire and σ is breaking stress. The greatest length of the wire that can hang freely without breaking is:

(a) $\frac{2\sigma}{\rho g}$
(b) $\frac{\rho}{\sigma g}$
(c) $\frac{\rho g}{2\sigma}$
(d) $\frac{\sigma}{\rho g}$

Q 5. A uniform rod of length L has a mass per unit length λ and area of cross-section A. The elongation in the rod is l due to its own weight if it is suspended from the ceiling of a room. The Young's modulus of the rod is:

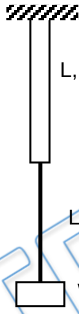
(a) $\frac{2\pi g L^2}{Al}$ (b) $\frac{\lambda g L^2}{2Al}$ (c) $\frac{2\lambda g L}{Al}$ (d) $\frac{\lambda g l^2}{AL}$

Q 6. A uniform slender rod of length L, cross-sectional area A and Young's modulus Y is acted upon by the forces shown in the figure. The elongation of the rod is



(a) 3FL/5AY (b) 2FL/5AY
(c) 3FL/8AY (d) 8FL/3AY

Q 7. Two wires of the same material (Young's modulus Y) and same length L but radii R and 2R respectively are joined end to end and a weight W is suspended from the combination as shown in the figure. The elastic potential energy in the system is

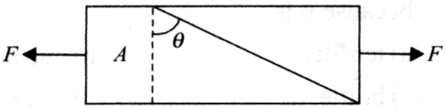


(a) $\frac{3W^2L}{4\pi R^2 Y}$ (b) $\frac{3W^2L}{8\pi R^2 Y}$
(c) $\frac{5W^2L}{8\pi R^2 Y}$ (d) $\frac{W^2L}{\pi R^2 Y}$

Q 8. A copper wire of cross – section A is under a tension T. Find the decrease in the cross – section area. Young's modulus is Y and Poisson's ratio is σ.

(a) $\frac{\sigma T}{2AY}$ (b) $\frac{\sigma T}{AY}$ (c) $\frac{2\sigma T}{AY}$ (d) $\frac{4\sigma T}{AY}$

Q 9. A bar of cross – section A is subjected to equal and opposite tensile forces F at its ends. Consider a plane through the bar making an angle θ with a plane at right angle to the bar. Then shearing stress will be maximum if θ



(a) 0° (b) 30° (c) 45° (d) 60°

Q 10. A steel plate has face area 4 cm^2 and thickness 0.5 cm is fixed rigidly at the lower surface. A tangential force of 10 N is applied on the upper surface. Find the lateral displacement of the upper surface with respect to the lower surface. Rigidity modulus of steel = 8.4×10^{10} Nm^{-2}

(a) 1.5 μm (b) 1.5 A° (c) 1.5 nm (d) 1.5 pm

Q 11. A stone of mass m tied to one end of a thread of length *l*. The diameter of the thread is d and it is suspended vertically. The stone is now rotated in a horizontal plane and makes an angle θ with the vertical. Find the increase in length of the wire. Youngs modulus of the wire is Y

(a) $\frac{4mgl}{\pi d^2 Y \cos\theta}$ (b) $\frac{4mgl}{\pi d^2 Y \sin\theta}$
(c) $\frac{4mgl}{\pi d^2 Y}$ (d) $\frac{4mgl}{\pi d^2 Y \sec\theta}$

Q 12. The modulus of elasticity of a gas at constant temperature is
(Symbols have their usual meanings)

(a) γP (b) P/γ (c) P (d) P/V

Q 13. A solid sphere of radius R and bulk modulus of elasticity K is kept in a liquid inside a cylindrical container. A massless piston of cross-sectional area A floats on liquid surface. A mass M is put on the piston in order to compress the liquid. The fractional change in the radius of the sphere will be

(a) $\frac{3Mg}{KA}$ (b) $\frac{3Mg}{2KA}$ (c) $\frac{Mg}{KA}$ (d) $\frac{Mg}{3KA}$

Q 14. A cable that can support a load W is cut into two equal parts. The maximum load that can be supported by either part is–

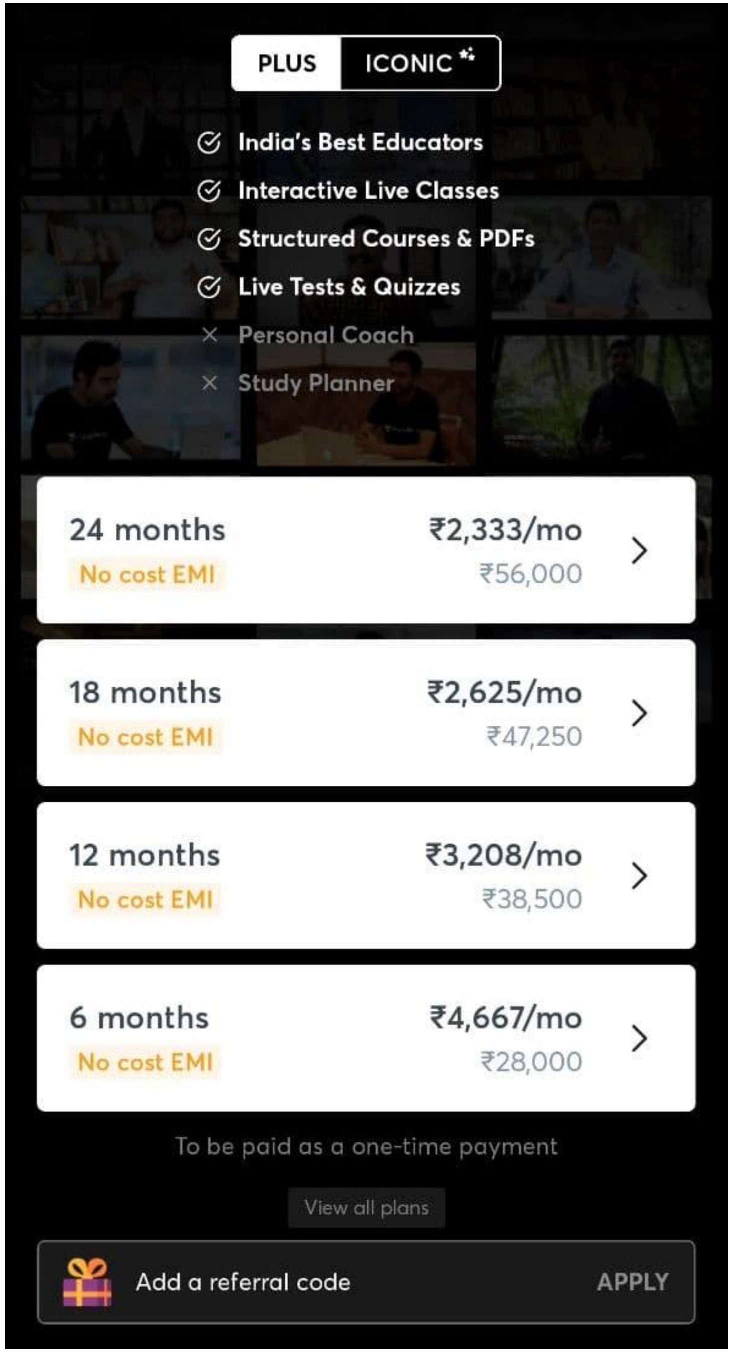
(a) W/4 (b) W/2 (c) W (d) 2 W

Q 15. A uniform rod of mass m and length L has area of cross-section A and young modulus γ. Elastic potential energy of rod if it is suspended from the ceiling of a room, is

(a) $\frac{Lg^2m^2}{6A\gamma}$ (b) $\frac{Lg^2m^2}{3A\gamma}$
(c) $\frac{Lg^2m^2}{2A\gamma}$ (d) $\frac{Lg^2m^2}{A\gamma}$

Answer Key

Q.1 a	**Q.2 c**	**Q.3 a**	**Q.4 d**	**Q.5 b**
Q.6 d	**Q.7 c**	**Q.8 c**	**Q.9 c**	**Q.10 c**
Q.11 a	**Q.12 c**	**Q.13 d**	**Q.14 c**	**Q.15 a**



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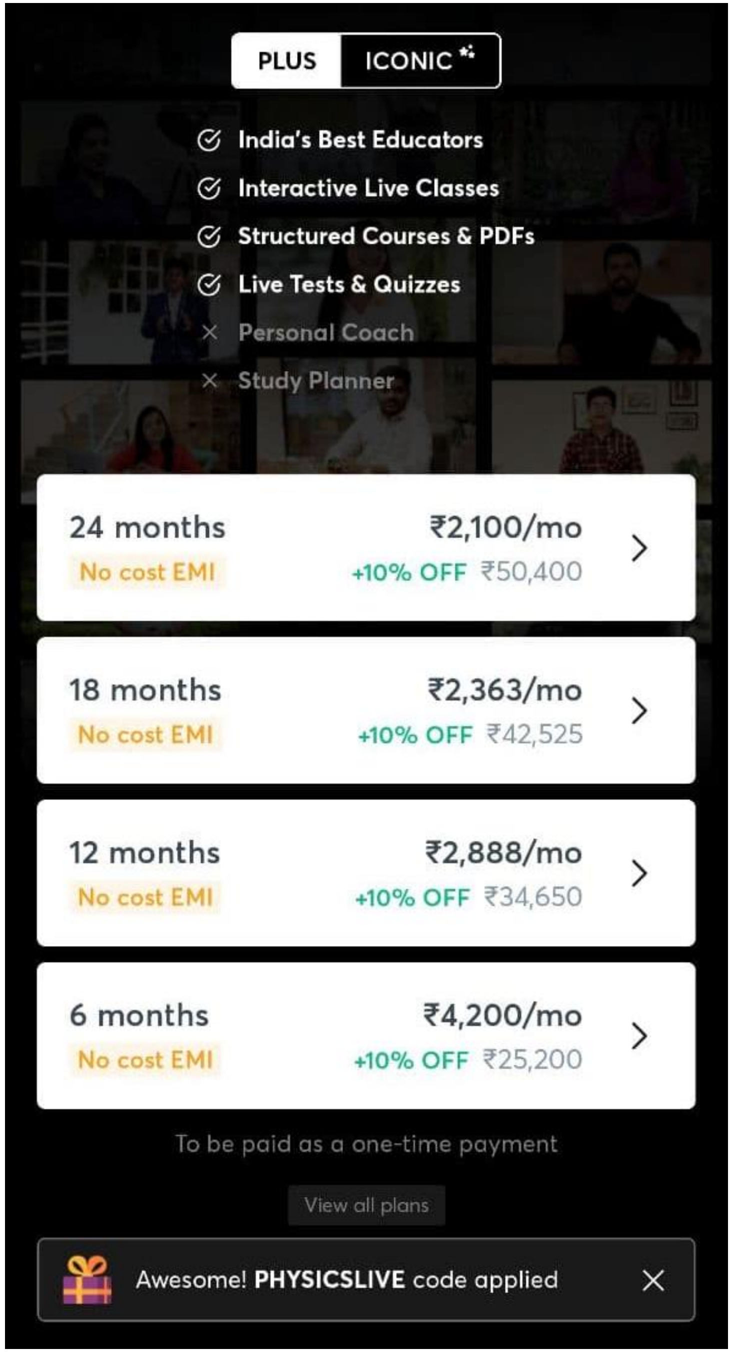
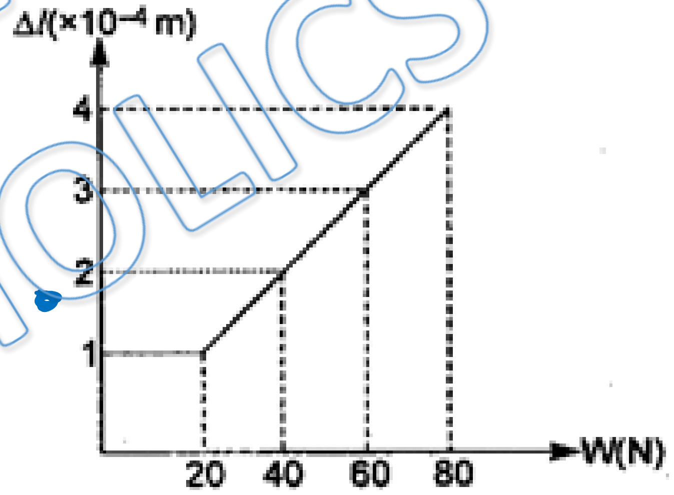


JEE Main & Advanced, NSEP, INPhO, IPhO
Physics DPP - Solution

DPP – Elasticity

By Physicsaholics Team

Q1) The adjacent graph shows the extension (Δl) of a wire of length 1 m suspended from the top of a roof at one end and with a load W connected to the other end. If the cross-sectional area of the wire is 10^{-6} m^2, calculate the Young's modulus of the material of the wire :



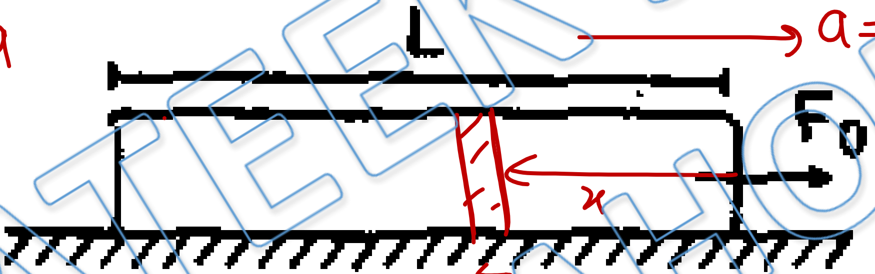
$$Y = \frac{F/A}{\Delta l / l} = \frac{W l}{A \Delta l}$$

$$= \frac{20 \times 1}{10^{-6} \times 1 \times 10^{-4}}$$

$$= 20 \times 10^{10} = 2 \times 10^{11}$$

(a) 2×10^{11} N/m^2
(b) 2×10^{-11} N/m^2
(c) 3×10^{12} N/m
(d) 2×10^{13} N/m^2

Q2) A constant force F_0 is applied on a string placed over a smooth horizontal uniform elastic string surface as shown in figure. Young's modulus of string is Y and area of cross-section is S. The strain produced in the string in the direction of force is:



Tension at $x = x$

$T = \left[\frac{m}{L}(L-x)\right] a$

$a = \frac{F_0}{m}$

$T = \frac{m}{L}(L-x)\frac{F_0}{m}$

$= F_0\left(1-\frac{x}{L}\right)$

dx → natural length.

dl → elongation in length dx

for length dx

strain = (stress)/Y

$\frac{dl}{dx} = \frac{F_0}{YS}\left(1-\frac{x}{L}\right)$

$dl = \frac{F_0}{YS}\left(1-\frac{x}{L}\right)dx$

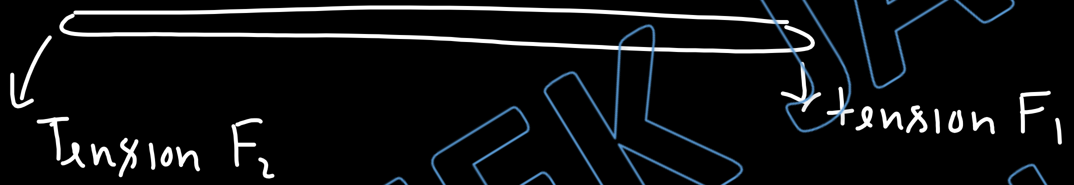
(a) $\frac{F_0 Y}{S}$ (b) $\frac{F_0}{SY}$ (c) $\frac{F_0}{2SY}$ ✓ (d) $\frac{F_0 Y}{2S}$

$\Delta l = \frac{F_0}{SY}\int_0^L \left(1-\frac{x}{L}\right)dx$

$= \frac{F_0}{2SY}$

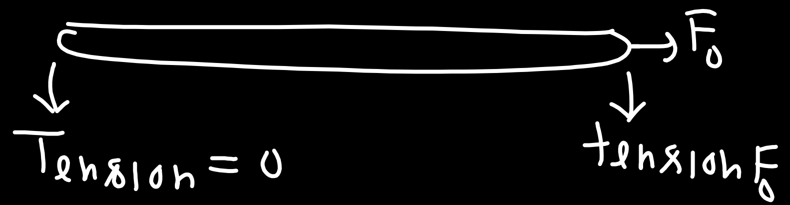
Ans. c

If tension is linearly changing with position



$$\text{Av. tension} = \frac{F_1 + F_2}{2}$$

$$Y = \frac{F_{av}/A}{\Delta l/l}$$

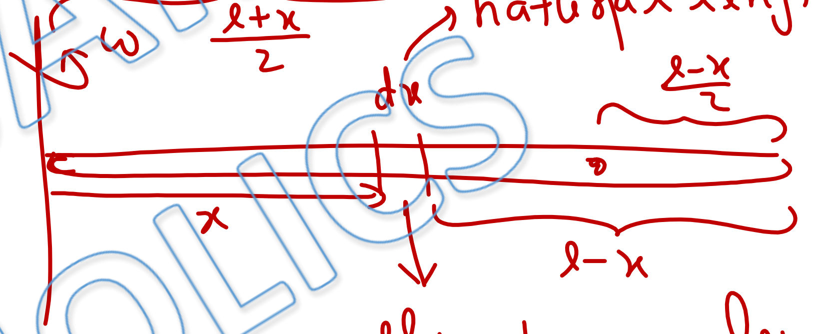


$$F_{av} = \frac{F_0 + 0}{2}$$

$$\text{Strain} = \frac{F_0/2}{SY} = \frac{F_0}{2SY}$$

Q3) A uniform rod of mass m and length L has area of cross-section A and young modulus γ. This rod is rotating about its one end with angular velocity ω. Elongation in length of rod is (Gravity is absent)

Tension at $x = x$, $T =$ Centrifugal force from $x = x$ to $x = l$



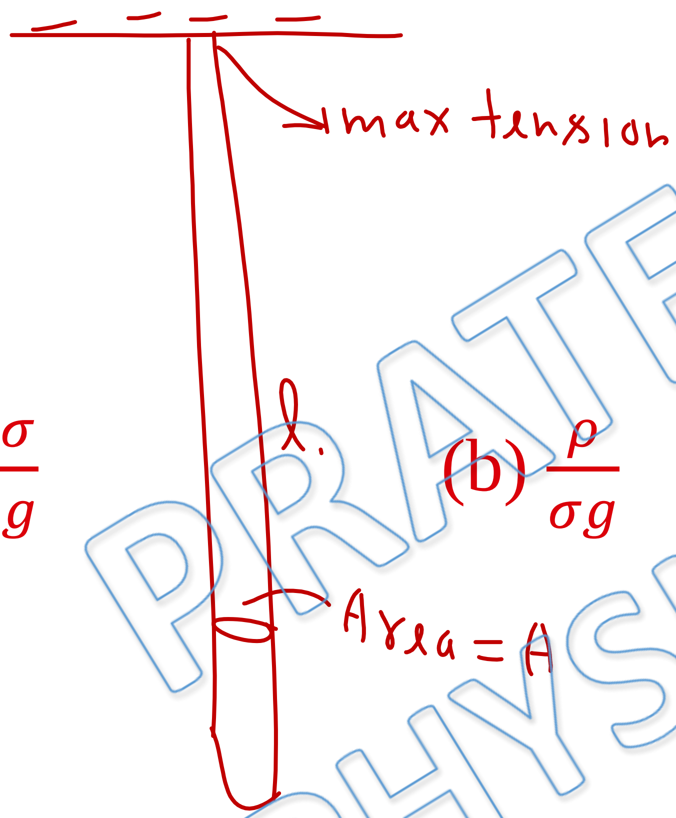
$$\text{stress} = \frac{T}{A} = \frac{m r_{cm}\omega^2}{A} = \frac{\frac{m}{Al}(l-x)\frac{(l+x)}{2}\omega^2}{} = \frac{m\omega^2}{2lA}(l^2 - x^2)$$

(a) $\frac{ml^2\omega^2}{3A\gamma}$ (b) $\frac{ml^2\omega^2}{2A\gamma}$ (c) $\frac{ml^2\omega^2}{6A\gamma}$ (d) $\frac{ml^2\omega^2}{4A\gamma}$

$$\text{strain} = \frac{dy}{dx} = \frac{\text{stress}}{\gamma} = \frac{m\omega^2}{2lA\gamma}(l^2 - x^2)$$

$$\Delta l = \int dy = \int_0^l \frac{m\omega^2}{2A\gamma l}(l^2 - x^2)dx = \frac{m\omega^2}{2A\gamma l}\left[l^2 x - \frac{x^3}{3}\right]_0^l = \frac{m\omega^2}{2A\gamma l} \times \frac{2l^3}{3}$$

Q4) If ρ is the density of the material of a wire and σ is breaking stress. The greatest length of the wire that can hang freely without breaking is:



Tension at top = $(\rho A l)g$

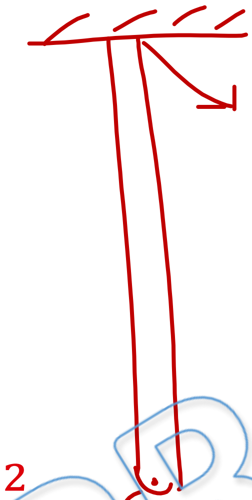
Stress at top = $\rho l g$

for breaking $\sigma = \rho l g$

(a) $\frac{2\sigma}{\rho g}$ (b) $\frac{\rho}{\sigma g}$ (c) $\frac{\rho g}{2\sigma}$ ✓(d) $\frac{\sigma}{\rho g}$

$$l = \frac{\sigma}{\rho g}$$

Q5) A uniform rod of length L has a mass per unit length λ and area of cross-section A. The elongation in the rod is l due to its own weight if it is suspended from the ceiling of a room. The Young's modulus of the rod is:



weight of rod = $\lambda L g$

tension = $\lambda L g$

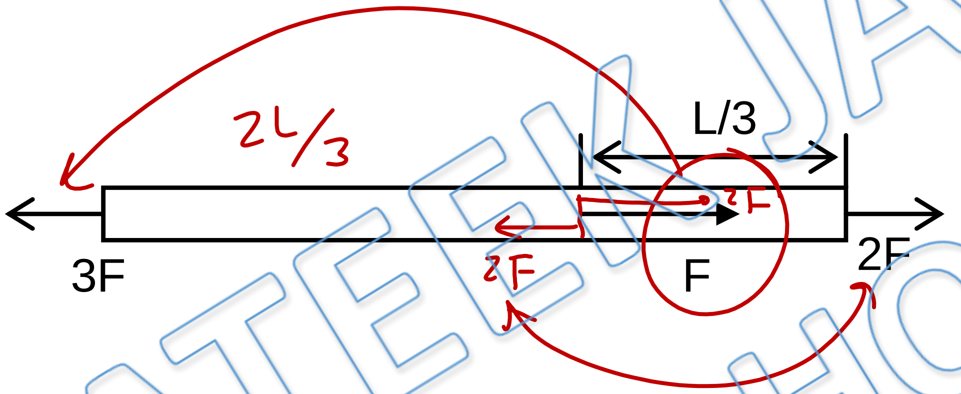
av. tension = $\frac{\lambda L g}{2}$

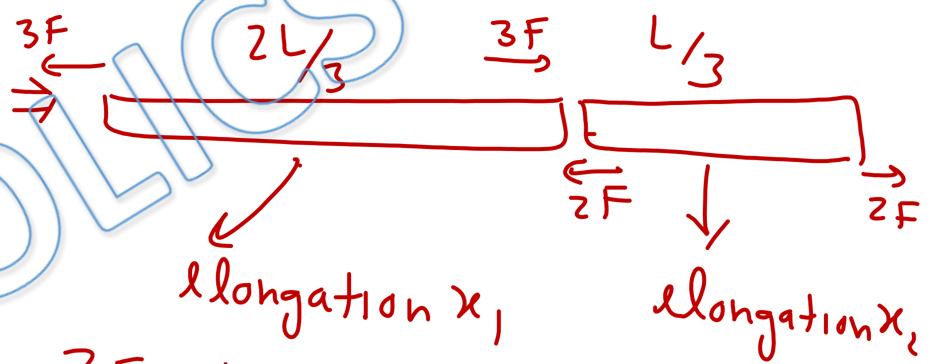
tension = 0

$$Y = \frac{\lambda L g / 2A}{l / L} = \frac{\lambda L^2 g}{2 A l}$$

(a) $\frac{2\pi g L^2}{Al}$ (b) $\frac{\lambda g L^2}{2Al}$ (c) $\frac{2\lambda g L}{Al}$ (d) $\frac{\lambda g l^2}{AL}$

Q6) A uniform slender rod of length L, cross-sectional area A and Young's modulus Y is acted upon by the forces shown in the figure. The elongation of the rod is





(a) 3FL/5AY (b) 2FL/5AY

(c) 3FL/8AY (d) 8FL/3AY

$$x_1 = \frac{3F}{YA}\frac{2L}{3} = \frac{2FL}{YA}$$

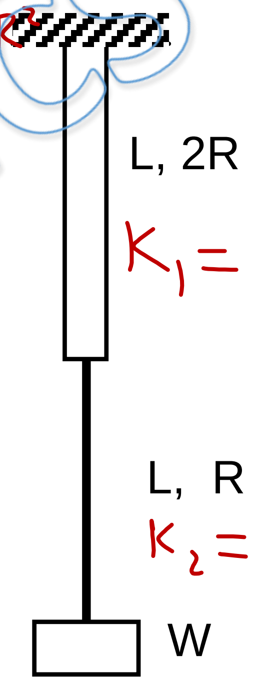
$$x_2 = \frac{2FL}{YA\,3} = \frac{2}{3}\frac{FL}{YA}$$

$$\text{net elongation} = \frac{FL}{YA}\left[2+\frac{2}{3}\right] = \frac{8}{3}\frac{FL}{YA}$$

Q7) Two wires of the same material (Young's modulus Y) and same length L but radii R and 2R respectively are joined end to end and a weight W is suspended from the combination as shown in the figure. The elastic potential energy in the system is

$$\frac{1}{K_{eff}} = \frac{1}{K_1} + \frac{1}{K_2} = \frac{L}{4\pi Y R^2} + \frac{L}{\pi Y R^2} = \frac{5}{4}\frac{L}{\pi Y R^2}$$

$$K_{eff} = \frac{4\pi Y R^2}{5L}$$



$$K_1 = \frac{Y 4\pi R^2}{L}$$

$$K_2 = \frac{Y \pi R^2}{L}$$

$$U = \frac{F^2}{2K_{eff}} = \frac{W^2 \times 5L}{2 \times 4\pi Y R^2}$$

(a) $\frac{3W^2L}{4\pi R^2Y}$

(b) $\frac{3W^2L}{8\pi R^2Y}$

(c) $\frac{5W^2L}{8\pi R^2Y}$ ✓

(d) $\frac{W^2L}{\pi R^2Y}$

Q8) A copper wire of cross – section A is under a tension T. Find the decrease in the cross – section area. Young's modulus is Y and Poisson's ratio is σ. $= \frac{-\text{Lateral strain}}{\text{Lo strain}}$

$A = \pi r^2$

$dA = 2\pi r\,dr$

$\frac{dA}{A} = 2\frac{dr}{r}$

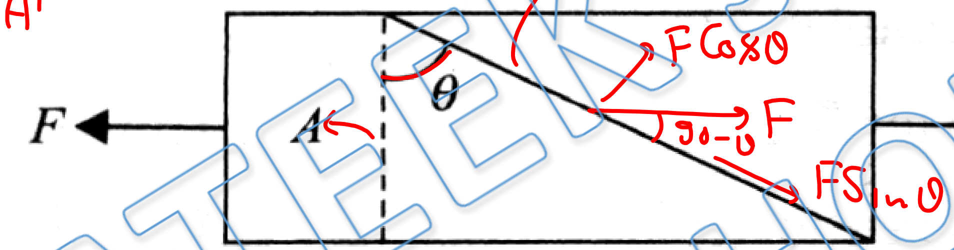
$\frac{\Delta A}{A} = 2\frac{\Delta r}{r} = 2\sigma\,|\text{Longitudinal strain}| = \frac{2\sigma \times \text{stress}}{Y}$

(a) $\frac{\sigma T}{2AY}$ (b) $\frac{\sigma T}{AY}$ (c) $\frac{2\sigma T}{Y}$ (d) $\frac{4\sigma T}{AY}$

$\frac{\Delta A}{A} = \frac{2\sigma T}{Y A}$

Q9) A bar of cross – section A is subjected to equal and opposite tensile forces F at its ends. Consider a plane through the bar making an angle θ with a plane at right angle to the bar. Then shearing stress will be maximum if θ

$\cos\theta = \frac{A}{A'}$ → $A' = A/\cos\theta$



Shearing stress

$= \frac{F\sin\theta}{A/\cos\theta}$

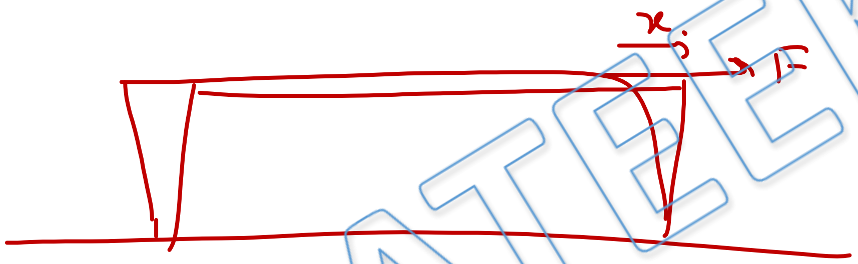
$= \frac{F}{A} \times \sin\theta\cos\theta$

(a) 0º (b) 30º (c) 45º (d) 60º

$= \frac{F}{2A}\sin 2\theta$

max at $\theta = 45°$

Q10) A steel plate has face area 4 cm^2 and thickness 0.5 cm is fixed rigidly at the lower surface. A tangential force of 10 N is applied on the upper surface. Find the lateral displacement of the upper surface with respect to the lower surface. Rigidity modulus of steel = 8.4×10^{10} Nm^{-2}



$$\eta = \frac{F/A}{x/l}$$

$$x = \frac{Fl}{A\eta} = \frac{10 \times .5 \times 10^{-2}}{4 \times 10^{-4} \times 8.4 \times 10^{10}}$$

(a) 1.5 μm (b) 1.5 A° (c) 1.5 nm (d) 1.5 pm

$$x = \frac{5 \times 10^{4}}{33.6} \times 10^{-12}\ m$$

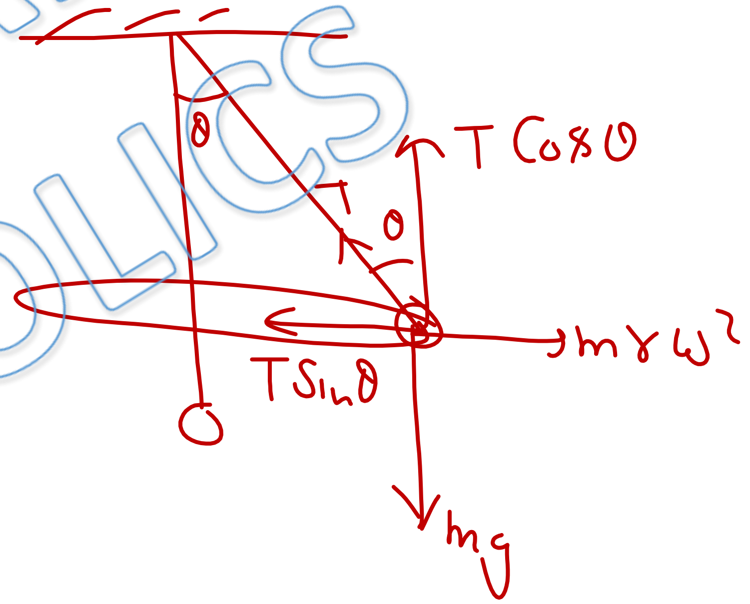
$$= \frac{500}{33.6} \times A^{\circ}$$

$$= 15\ A^{\circ}$$

Q11) A stone of mass m tied to one end of a thread of length l. The diameter of the thread is d and it is suspended vertically. The stone is now rotated in a horizontal plane and makes an angle θ with the vertical. Find the increase in length of the wire. Youngs modulus of the wire is Y

$T\cos\theta = mg$

$T = \frac{mg}{\cos\theta}$



(a) $\frac{4mgl}{\pi d^2 Y \cos\theta}$ (b) $\frac{4mgl}{\pi d^2 Y \sin\theta}$

(c) $\frac{4mgl}{\pi d^2 Y}$ (d) $\frac{4mgl}{\pi d^2 Y \sec\theta}$

$\frac{\Delta l}{l} = \frac{mg}{YA\cos\theta}$

$\Delta l = \frac{mgl}{YA\cos\theta} = \frac{4mgl}{Y\pi d^2\cos\theta}$

Q12) The modulus of elasticity of a gas at constant temperature is (Symbols have their usual meanings)

$$B = -\frac{dP}{dV/V}$$

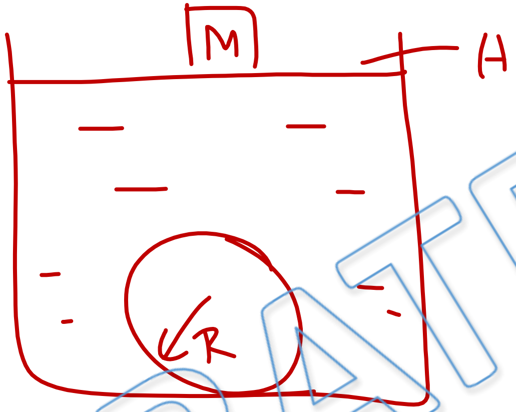
$$PV = nRT$$

$$P\,dV + V\,dP = 0$$

$$-\frac{dP}{dV/V} = P$$

(a) γP (b) P/γ (c) P ✓ (d) P/V

Q13) A solid sphere of radius R and bulk modulus of elasticity K is kept in a liquid inside a cylindrical container. A massless piston of cross-sectional area A floats on liquid surface. A mass M is put on the piston in order to compress the liquid. The fractional change in the radius of the sphere will be



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

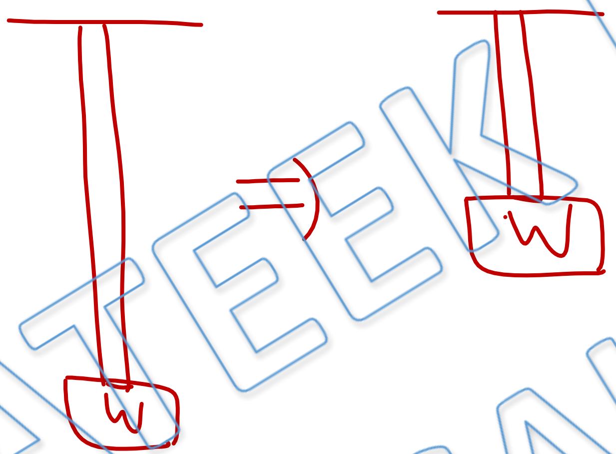
$$\frac{\Delta V}{V} = -\frac{\Delta P}{K} = \frac{Mg}{AK}$$

(a) $\frac{3Mg}{KA}$ (b) $\frac{3Mg}{2KA}$ (c) $\frac{Mg}{KA}$ (d) $\frac{Mg}{3KA}$ ✓

$$V = \frac{4}{3}\pi R^3$$

$$\frac{\Delta V}{V} = 3\frac{\Delta R}{R} = \frac{Mg}{AK}$$

Q14) A cable that can support a load W is cut into two equal parts. The maximum load that can be supported by either part is–



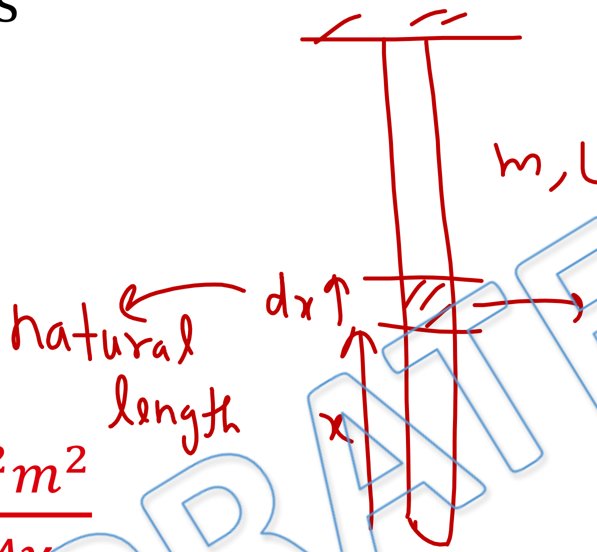
Breaking tension

= Breaking stress × A

↓ Constant

(a) W/4 (b) W/2 (c) W (d) 2 W

Q15) A uniform rod of mass m and length L has area of cross-section A and young modulus γ. Elastic potential energy of rod if it is suspended from the ceiling of a room , is



tension $= \frac{m x g}{L}$

Stress $= \frac{m x g}{A L}$

(a) $\frac{Lg^2m^2}{6A\gamma}$ ✓

(b) $\frac{Lg^2m^2}{3A\gamma}$

(c) $\frac{Lg^2m^2}{2A\gamma}$

(d) $\frac{Lg^2m^2}{A\gamma}$

Energy per unit volume

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

Energy stored in length dx

$$dU = \frac{\left(\frac{m x g}{A L}\right)^2 A\,dx}{2Y}$$

$$= \frac{m^2 g^2}{2AYL^2} x^2\,dx$$

$$U = \frac{m^2 g^2}{2AYL^2} \int_0^L x^2\,dx$$

$$= \frac{m^2 g^2 L}{6AY}$$

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