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① a.

$$L = 1.5 \text{ m}$$

$$EI = 2.2 \times 10^6 \text{ N/m}^2$$

$$F = 3.5 \text{ kN} \rightarrow 3.5 \times 10^3$$

$$W = 1500 \text{ N/m}$$

$$y = ?$$

$$\frac{M}{I} = \frac{E}{R}$$

$$M = \frac{EI}{R}$$

$$MR = EI$$

$$\text{Slope} = \frac{dy}{dx} = \frac{WL^3}{6EI} = \frac{-1.500 \times 1.5^3}{6(2.2 \times 10^6)} = -383.522 \times 10^{-6}$$

$$\text{Deflection} = y = \frac{WL^3}{8EI} = \frac{-1.500 \times 1.5^3}{8(2.2 \times 10^6)} = -287.642 \times 10^{-6} \text{ mm}$$

Downwards

$$\text{Slope} = \frac{FL^2}{2EI} = \frac{-3.5 \times 10^3 \times 1.5^2}{2(2.2 \times 10^6)} = 1.789 \times 10^{-3}$$

$$\text{Deflection} = \frac{FL^3}{3EI} = \frac{-3.5 \times 10^3 \times 1.5^3}{3(2.2 \times 10^6)} = 1.789 \times 10^{-3} \text{ mm}$$

= 178.9 \times 10^{-3} \text{ mm}

$$\text{Deflection of } 40 \text{ mm} = 207.66 \times 10^{-3}$$

2 a.

$$D = 45 \text{ mm} \rightarrow 0.045 \text{ m} - r = 0.0225 \text{ m}$$

$$t = 10 \text{ mm} \rightarrow 0.01 \text{ m}$$

$$P_i = 115 \text{ bar} (1 \text{ bar} = 10^5) \rightarrow 115 \times 10^5 \text{ N/m}^2$$

$$P_o = 0$$

$$b. \quad \sigma_c = a + \frac{b}{r^2} \rightarrow \sigma_c = \frac{a}{r^2} + b$$

$$\sigma_c = \frac{a}{r^2} + b \quad r^2 \times a + b$$

$$r_i = 0.0175 \text{ m}$$

$$r_o = 0.0225 \text{ m}$$

Inside surface - $r = r_i = 0.0175 \text{ m}$

$$\sigma = -P = -115 \times 10^5 \text{ N/m}^2$$

Outside surface - $r = r_o = 0.0225 \text{ m}$

$$\sigma_r = 0$$

Inner Surface

Outer Surface

$$\sigma_r = a - \frac{b}{r^2}$$

$$\sigma_r = a - \frac{b}{r^2}$$

$$-115 \times 10^5 = \frac{a - b}{0.0175^2}$$

$$\sigma = \frac{a - b}{0.0225^2}$$

$$-115 \times 10^5 (0.0175^2) = a - b$$

$$\sigma = 0.0225^2 a - b$$

$$(x-1) \quad 115 \times 0.0175^2 = b - 0.0175^2 a$$

$$b = 0.0225^2 a$$

$$115 \times 10^5 \times 0.0175^2 = 0.0225^2 a - 0.0175^2 a$$

$$115 \times 10^5 \times 0.0175^2 = a(0.0225^2 - 0.0175^2)$$

$$a = \frac{115 \times 10^5 \times 0.0175^2}{0.0225^2 - 0.0175^2} = 17.609 \times 10^6$$

$$b = 0.0225^2 a = 0.0225^2 \times (17.609 \times 10^6) = 8.914 \times 10^3$$

$$\sigma_c = a + \frac{b}{r^2}$$

$$= 17.609 \times 10^6 + \frac{8.914 \times 10^3}{r^2}$$

$$\sigma_{ci} = 17.609 \times 10^6 + \frac{8.914 \times 10^3}{0.08175^2}$$

$$= 46.715 \times 10^6 \rightarrow 46.715 \text{ MPa}$$

$$\sigma_{co} = 17.609 \times 10^6 + \frac{8.914 \times 10^3}{0.0225^2}$$

$$= 35.216 \times 10^6 = 35.2 \text{ MPa}$$

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①
 $\sigma_x = 10 \times 10^6$
 $\sigma_y = 13 \times 10^6$
 $\nu = 0.2$
 $E = 165 \times 10^9$

a. $\frac{1}{1-\nu} (\sigma_x + \nu \sigma_y) = \frac{165 \times 10^9}{1+0.2} (10 \times 10^6 + 0.2(13 \times 10^6))$
 $\sigma_x = 1.27 \times 10^6 \text{ Pa}$
 $= 1.27 \text{ MPa}$ of compression

$\sigma_y = \frac{165 \times 10^9}{1-\nu} (\sigma_y + \nu \sigma_x)$
 $= \frac{165 \times 10^9}{1-0.2} (13 \times 10^6 + 0.2(10 \times 10^6))$
 $\sigma_y = 1.89 \times 10^6 \text{ Pa}$
 $= 1.89 \text{ MPa}$ tensile

b. $\sigma_x = 20 \times 10^6 \text{ N/m}^2$
 $\sigma_y = -15 \times 10^6 \text{ N/m}^2$

$\epsilon_x = \frac{1}{E} (\sigma_x - \nu \sigma_y)$
 $= \frac{1}{165 \times 10^9} (20 \times 10^6 - 0.2(-15 \times 10^6))$
 $\epsilon_x = 139.39 \times 10^{-6} \mu \epsilon$

$\epsilon_y = \frac{1}{E} (\sigma_y - \nu \sigma_x)$
 $= \frac{1}{165 \times 10^9} (-15 \times 10^6 - 0.2(20 \times 10^6))$
 $\epsilon_y = -115.15 \times 10^{-6} \mu \epsilon$

4.

$$D = 0.2 \text{ m}$$

$$L = 0.39 \text{ m}$$

$$t = 1.5 \times 10^{-3} \text{ m}$$

$$\sigma = 100 \times 10^6 \text{ N/m}^2$$

$$n_c = 0.9$$

$$n_L = 0.6$$

$$\sigma_c = \frac{PD}{2t n_c} \rightarrow P = \frac{2t n_c \sigma_c}{D}$$

$$\sigma_L = \frac{PD}{4t n_L} \rightarrow P = \frac{4t n_L \sigma_L}{D}$$

$$P_{\max c} = \frac{2(1.5 \times 10^{-3})(0.9)(100 \times 10^6)}{0.2} = 1.35 \times 10^6 \text{ N/m}^2 = 13.5 \text{ Bar}$$

$$P_{\max L} = \frac{4(1.5 \times 10^{-3})(0.6)(100 \times 10^6)}{0.2} = 1.8 \times 10^6 \text{ N/m}^2 = 18 \text{ Bar}$$

$$\therefore P_{\max} = 13.4 \text{ Bar}$$

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⑤ $L = 0.35 \text{ m}$ $K = ?$
 $P = 50 \times 10^6 \text{ Pa}$
 $\nu = 0.3$
 $E = 165 \times 10^9 \text{ Pa}$
 $V = L^3 = 0.35^3 = 42.875 \times 10^{-3}$

a. $K = \frac{E}{-3(1-2\nu)} = \frac{165 \times 10^9}{3(1-2(0.3))}$
 $K = 137.5 \times 10^9 \text{ Nm}^{-2}$

$$K = \frac{\sigma}{\epsilon_v} = \frac{-P}{\epsilon_v} \rightarrow \epsilon_v = \frac{-P}{K}$$

$$= \frac{-50 \times 10^6}{137.5 \times 10^9} = -363.64 \times 10^{-6}$$

$$\epsilon_v = \frac{\Delta V}{V} \quad \Delta V = \epsilon_v V = -363.64 \times 10^{-6} (0.35)$$
$$\Delta V = -15.59 \times 10^{-6} \text{ m}^3$$

b. An orthotropic material ~~is~~ has different elastic properties in different directions. Some materials will ~~have more~~ be more orthotropic than others and each axis will have different strengths and directional forces.