MULTIPLE CHOICE PROBLEMS (10 Points each)

1. In the hanger shown, the upper portion of link ABC is 3/8 in. thick and the lower portions are each 1/4 in. thick. Epoxy resin is used to bond the upper and lower portions together at B. The pin at A is of 3/8 in. diameter. The shearing stress in pin A is most nearly

(a) 6790 psi  
(b) 3400 psi  
(c) 2530 psi  
(d) 1260 psi  
(e) 1070 psi

\[ \sum M_p = 0 = (500 \text{lb})(15 \text{ in.}) - F_{AC}(10 \text{ in.}) \]

\[ F_{AC} = 750 \text{ lb} \]

\[ \tau_A = \frac{F_{AC}}{A_{pin}} \]

\[ = \frac{750 \text{ lb}}{\frac{\pi}{4} \left(\frac{3}{8} \text{ in.}\right)^2} \]

\[ = 6790 \text{ psi} \]

2. A couple \( \mathbf{M} \) of magnitude 1500 N\( \cdot \)m is applied to the crank of an engine. For the position shown, the average normal stress in connecting rod BC which has a 450-mm\(^2\) uniform cross section is most nearly

(a) -20.7 MPa  
(b) -41.4 MPa  
(c) -3.33 MPa  
(d) -6.66 MPa  
(e) -10.4 MPa

\[ \sum M_A = 0 = -M + F_{BC} \left(\frac{60}{208}\right) \left(0.08 \text{ m}\right) + F_{BC} \left(\frac{200}{208}\right) \left(0.01 \text{ m}\right) \]

\[ F_{BC} = 18.64 \text{ kN} \]

\[ \sigma_{BC} = -\frac{F_{BC}}{A_{BC}} \]

\[ = -\frac{18.64 \text{ kN}}{450 \text{ mm}^2} \]

\[ = -41.4 \text{ MPa} \]
3. The plastic block shown is bonded to a rigid support and to a vertical plate to which a 240-kN load $P$ is applied. If the plastic has a shear modulus of 1050 MPa, the deflection of the plate is most nearly

(a) $18.29 \text{ mm}$  
(b) $6.96 \text{ mm}$  
(c) $11.43 \text{ mm}$  
(d) $2.86 \text{ mm}$  
(e) $1.190 \text{ mm}$

$$\tau = \frac{P}{(80 \text{ mm})(120 \text{ mm})} = \frac{240 \times 10^3 \text{ N}}{9600 \text{ mm}^2} = 25 \text{ MPa}$$

$$\gamma = \frac{\tau}{G} = \frac{\Delta}{50 \text{ mm}}$$

$$\Delta = \frac{\tau}{G} (50 \text{ mm}) = \frac{25 \text{ MPa}}{1050 \text{ MPa}} (50 \text{ mm}) = 1.190 \text{ mm}$$

4. Knowing that $\sigma_{\text{ult}} = 240 \text{ MPa}$, and that a factor of safety of 2.0 is required, the maximum allowable value of the centric axial load $P$ is most nearly

(a) $54.3 \text{ kN}$  
(b) $41.7 \text{ kN}$  
(c) $143.9 \text{ kN}$  
(d) $90.0 \text{ kN}$  
(e) $35.3 \text{ kN}$

@ A 
\[ R = 10 \text{ mm} \] 
\[ \frac{r}{d} = 0.125 \] 

\[ K = 2.45 \] 

\[ P_{\text{all}} = \frac{(120 \text{ N/mm}^2)(15 \text{ mm})(80 \text{ mm})}{2.45} = 54.3 \text{ kN} \]

@ B 
\[ d = 50 \text{ mm} \] 
\[ r = 25 \text{ mm} \] 
\[ \frac{r}{d} = \frac{1}{2} \] 

\[ K = 2.16 \] 

\[ P_{\text{all}} = \frac{(120 \text{ N/mm}^2)(15 \text{ mm})(50 \text{ mm})}{2.16} = 41.7 \text{ kN} \]
5. An aluminum wire having a diameter \( d = 2 \text{ mm} \) and length \( L = 3.8 \text{ m} \) is subjected to a tensile load \( P \) (see figure). The aluminum has a modulus of elasticity \( E = 75 \text{ GPa} \). If the maximum permissible elongation of the wire is 3.0 mm and the allowable stress in tension is 60 MPa, the allowable load \( P_{\text{max}} \) is most nearly

(a) 189 N  
(b) 186 N  
(c) 183 N  
(d) 180 N  
(e) 177 N

\[
\sigma = \frac{P}{A} = \frac{P}{\pi d^2 / 4} = \frac{P}{\pi (0.002 \text{ m})^2} = \frac{P}{3.8 \text{ m}}
\]

\[
P_{\text{max}} = \sigma_{\text{all}} A = \left(60 \times 10^6 \text{ N/m}^2\right) \left(\frac{\pi}{4}\right) (0.002 \text{ m})^2 = 188.6 \text{ N}
\]

6. A line of slope 4:10 has been scribed on a cold-rolled yellow-brass plate, 6 in. wide and 0.25 in. thick. For this material, \( E = 15 \times 10^6 \text{ psi} \) and \( v = 0.34 \). The slope of the line when a 45-kip compressive centric axial load is applied is most nearly

(a) 3.99728:10.02 (0.39893)  
(b) 6.8 (0.75)  
(c) 4.99592:8.016 (0.62324)  
(d) 4.00272:10.02 (0.39947)  
(e) 4.00272:9.98 (0.40107)

\[
\sigma_x = \frac{P}{A} = \frac{45 \text{ kips}}{(6 \text{ in})(0.25 \text{ in})} = -30 \text{ ksi}
\]

\[
\varepsilon_x = \frac{1}{E} \sigma_x = -\frac{30 \times 10^3 \text{ psi}}{15 \times 10^6 \text{ psi}} = -0.002
\]

\[
\varepsilon_y = -\frac{v}{E} \sigma_x = -\frac{0.34}{15 \times 10^6 \text{ psi}} (30 \times 10^3 \text{ psi}) = +6.8 \times 10^{-4}
\]

\[
L_x' = L_x (1 + \varepsilon_x) = 10 (1 - 0.002) = 9.98
\]

\[
L_y' = L_y (1 + \varepsilon_y) = 4 (1 + 6.8 \times 10^{-4}) = 4.00272
\]
WORK OUT PROBLEM (40 Points)

7. The concrete post \((E_c = 25 \text{ GPa} \text{ and } a_c = 9.9 \times 10^{-6} \, /\text{°C})\) is reinforced with six steel bars, each of 22-mm diameter \((E_s = 200 \text{ GPa} \text{ and } a_s = 11.7 \times 10^{-6} \, /\text{°C})\). If the temperature increases 35°C, determine

(a) the normal stresses induced in the steel,
(b) the normal stresses induced in the concrete.

**Equilibrium**

\[ P_c + 6P_s = 0 \]

**Load - Temperature - Deformation**

\[ S_c = \frac{P_c L}{A_c E_c} + \alpha_c \Delta T L \]

\[ S_s = \frac{P_s L}{A_s E_s} + \alpha_s \Delta T L \]

**Kinematics**

\[ S_c = S_s \]

\[-6P_s \]

\[ \frac{P_c}{A_c E_c} \alpha_c \Delta T + \frac{P_s}{A_s E_s} \alpha_s \Delta T = \frac{P_s}{A_s E_s} \]

\[ (\alpha_c - \alpha_s) \Delta T = \frac{P_s}{A_s E_s} + \frac{6P_s}{A_c E_c} = P_s \left( \frac{1}{A_s E_s} + \frac{6}{A_c E_c} \right) \]

\[ P_s = \frac{(\alpha_c - \alpha_s) \Delta T}{\frac{1}{A_s E_s} + \frac{6}{A_c E_c}} \]

\[ = \frac{(9.9 \times 10^{-6} /\text{°C} - 11.7 \times 10^{-6} /\text{°C})(35^\circ C)}{\frac{\pi}{4} (22 \text{mm})^2 (200 \times 10^3 \text{N/mm}^2)} + \frac{6}{(240 \text{mm})^2 - 6 \times \frac{\pi}{4} (22 \text{mm})^2} \]

\[ = -3600 \text{N} \]