# Solution for Q2

Solid steel bar, dia = 50 mm

Polar moment of inertia, $J_B = \frac{\pi \times 50^4}{32}$ mm$^4$ → 2

Hollow steel tube, $J_T = \frac{\pi \times (75^4 - 60^4)}{32}$ mm$^4$ → 2 } ... (1)

$J_B = 6.14 \times 10^5$ mm$^4$

$J_T = 1.83 \times 10^6$ mm$^4$

Torque $M_t = 2$ kN·m

Compatibility, $\phi_B = \phi_T$ ... (a) → 1

Equilibrium, $M_B + M_T = M_t$ ... (b) → 1

Eqn. (a) gives

$$\frac{M_B L}{G J_B} = \frac{M_T L}{G J_T}$$ → 2

or $M_B = M_T \cdot \frac{J_B}{J_T} = \frac{(50)^4}{(75^4 - 60^4)} M_T = 0.33 M_T$

Therefore from eqn. (b) $1.33 M_T = 2$

$\therefore M_T = 1.5$ kN-m → 2

$M_B = 0.5$ kN-m → 2 } ... (2)

Stresses: in bar

$$\tau_{\theta z} = \frac{0.5 \times \frac{25}{1000}}{J_B} \times (10^3)^4 = 2.037 \times 10^4 \text{ kN/m}^2$$ → 2

In tube, $\tau_{\theta z} = \frac{1.5 \times \frac{37.5}{1000}}{J_T} \times (10^3)^4 = 3.067 \times 10^4 \text{ kN/m}^2$ → 2

Angle of rotation of plate

$$\phi = \frac{0.5 \times 10^3 \times 0.65}{80 \times 10^9 \times 6.14 \times 10^{-7}} = 6.616 \times 10^{-3} \text{ rad}$$ → 2

Torsional stiffness

$$K_\theta = \frac{M_t}{\phi} = \frac{2 \times 10^3}{6.616 \times 10^{-3}} = 3.02 \times 10^5 \text{ N-m/rad}$$ → 2