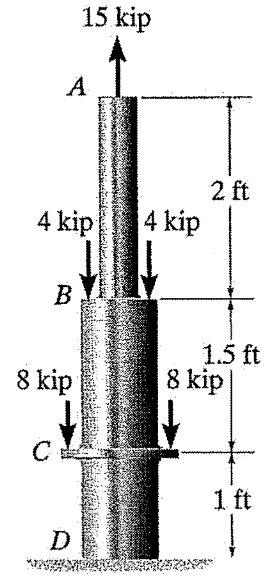
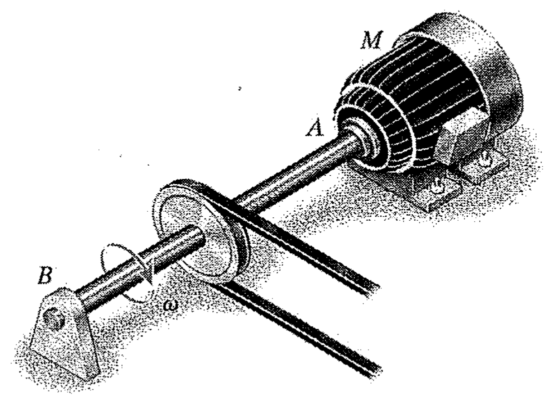
ENGR 350 – Mechanics of Materials,

Exam 2 – Nov 3, 2014

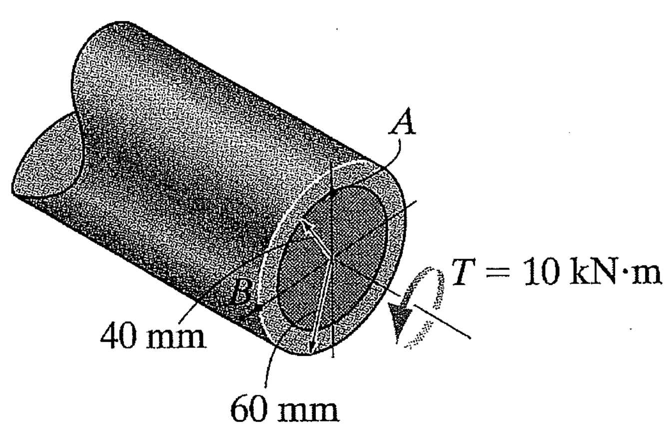
1) A steel bar is made from two segments having cross-sectional areas $A_{AB} = 1\ in^2$ and $A_{BD} = 2\ in^2$. Determine the vertical displacement of end A, and the displacements of points B and C. Determine the stresses in each segment AB, BC and CD. Use Young's modulus $E = 29*10^3$ ksi.



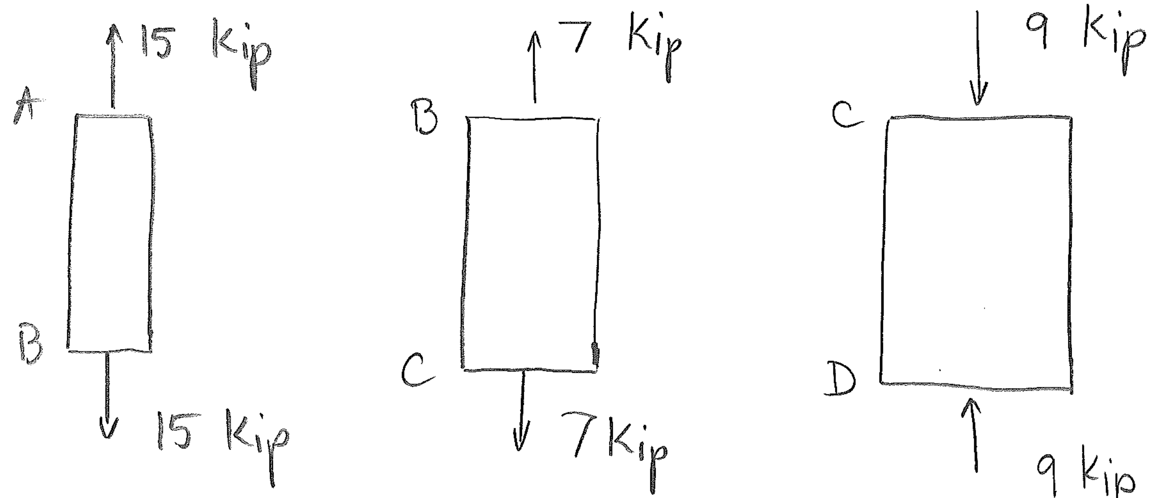
2) A solid shaft AB is used to transmit 5 hp from motor M to which it is attached. If the shaft rotates at $\omega = 175$ rpm and the steel has an allowable shear stress $\tau_{allow} = 14.5$ ksi, determine the required diameter of the shaft to the nearest 1/8 in.



3) The hollow circular shaft is subjected to an internal torque of T = 10 kN*m. Determine the shear stress developed at points A and B. Represent each state of stress on a volume element.



① Free-body diagrams :



$$\delta_{CD} = \delta_C = -\frac{FL}{EA_{CD}} = -\frac{9 \cdot 10^3\,lb \cdot 1 \cdot 12\,in}{29 \cdot 10^6\,\frac{lb}{in^2} \cdot 2\,in^2} = -0.0021\,in$$ (C is moving down toward D)

$$\delta_{BC} = \frac{FL}{EA_{BC}} = \frac{7 \cdot 10^3 \cdot 1.5 \cdot 12}{29 \cdot 10^6 \cdot 2} = 0.001862\,in$$

$$\delta_B = \delta_{CD} + \delta_{BC} = -0.0021 + 0.001862 = -0.00031\,in$$

$$\delta_{AB} = \frac{FL}{EA_{AB}} = \frac{15 \cdot 10^3 \cdot 2 \cdot 12}{29 \cdot 10^6 \cdot 1} = 0.01241\,in$$

$$\delta_A = \delta_{CD} + \delta_{BC} + \delta_{AB} = -0.00031 + 0.01241 = 0.01211\,in$$

$$\sigma_{AB} = \frac{F}{A_A} = \frac{15 \cdot 10^3\,lb}{1\,in} = 15{,}000\,psi = 15\,Ksi$$

$$\sigma_{BC} = \frac{F}{A_{BC}} = \frac{7 \cdot 10^3}{2} = 3.5 \cdot 10^3\,psi = 3.5\,Ksi$$

$$\sigma_{CD} = \frac{F}{A_{CD}} = -\frac{9 \cdot 10^3}{2} = -4.5 \cdot 10^3\,psi = -4.5\,Ksi$$

(2) $P = 5\ hp \cdot 550\ \frac{ft \cdot lb}{s} = 2750\ \frac{ft \cdot lb}{s}$

$\omega = 175\ rpm = 175 \cdot 2\pi \cdot \frac{1}{60} = 18.33\ \frac{rad}{s}$

$T = \frac{P}{\omega} = \frac{2750}{18.33} = 150.1\ ft \cdot lb$

$$\tau = \frac{Tc}{J} = \frac{T \cdot \frac{d}{2}}{\frac{\pi d^4}{32}} = \frac{16T}{\pi d^3} = \tau_{allow} \Rightarrow$$

$$\Rightarrow d = \sqrt[3]{\frac{16T}{\pi \tau_{allow}}} = \sqrt{\frac{16 \cdot 150.1 \cdot 12\ lb \cdot in}{\pi \cdot 14500\ \frac{lb}{in^2}}} =$$

$= 0.8586\ in$

Choose the next available diameter $\left(\frac{1}{8}'' = 0.125''\right)$

$$\boxed{d = 0.875\ in}$$

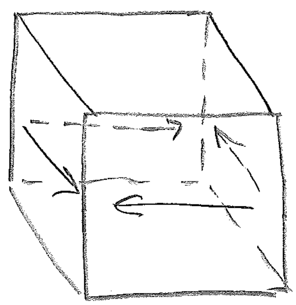
(3) $\tau = \dfrac{Tc}{J}$

$$J = \frac{\pi}{32}\left(d_o^4 - d_i^4\right) = \frac{\pi}{32}\left(120^4 - 80^4\right) = 1.633 \cdot 10^7 \text{ mm}^4$$

$$\tau_A = \frac{T r_A}{J} = \frac{(10 \cdot 10^6 \text{ N} \cdot \text{mm}) \cdot (40 \text{ mm})}{1.633 \cdot 10^7 \text{ mm}^4} = 24.5 \text{ MPa}$$

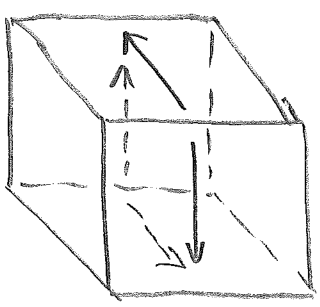
$$\tau_B = \frac{T r_B}{J} = \frac{10 \cdot 10^6 \cdot 60}{1.633 \cdot 10^7} = 36.7 \text{ MPa}$$

(A)



$\tau_A = 24.5$ MPa

(B)



$\tau_B = 36.7$ MPa