MEN 102
Exam 1
Fall 2005

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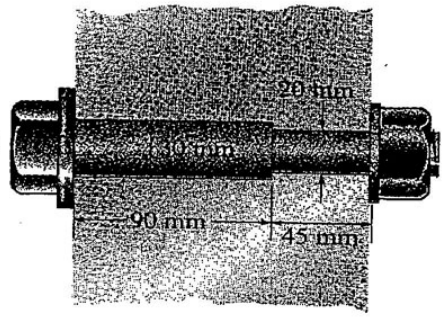
1) (20 pts) The bolt is made of steel for which $E = 200\,000 MPa$ and the single threaded screw on the bolt has a lead of $0.1\,mm$. Determine the maximum normal stress in the bolt if the nut is given one full turn after it first fits snug against the rigid plate. Assume that the washer, the bolt head and the nut are rigid. *Note*: The lead represents the distance the screw advances along its axis for one complete turn of the screw.

bolt head →



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$F_{BIG} - F_{small} = 0 \Rightarrow F_{BIG} = F_{small} = F$ ✓

$\delta_{BIG/small} = 0.0001\ m$ ✓

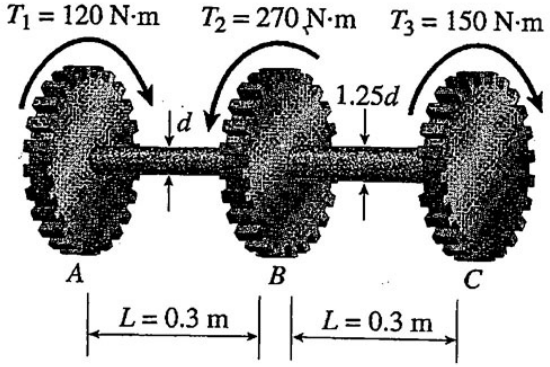
$\delta_{BIG} - \delta_{small} = 0.0001\ m$

$$\frac{F_{BIG} \times 0.09}{\pi(0.015)^2 \times 200000(10^6)} - \frac{F_{small} \times 0.045}{\pi(0.02)^2 \times 200000(10^6)} = 0.01$$

$\Rightarrow 6.36 \times 10^{-10} F_E - 1.79 \times 10^{-10} F = 0.01$

$\Rightarrow$ **F = 21884199.41 N** X

2) (15 pts) A shaft ABC consists of a solid bar of diameter d from A to B and a hollow bar of outside diameter $1.25\,d$ and inside diameter d from B to C. Torques are applied to the shafts through gears as shown. If the shaft has a shear modulus of elasticity $G = 80\,GPa$, calculate the required diameter d if the angle of twist between any two gears is limited to 1°.



$\pi \rightarrow 180°$

$\theta_x \leftarrow 1°$

$\Rightarrow \phi_{B/A} = 0.017$ rad. ✓ 10

$$\phi_{B/A} = \frac{270(0.3)}{80(10^9) \times \frac{\pi}{2}\left(\frac{d}{2}\right)^4} = 0.017$$

$\Leftrightarrow$ ~~$d_1 = 6 \times 10^{-4}$ m~~ $d_1 = 6 \times 10^{-7}$ m ✗

$$\phi_{C/B} = \frac{150(0.3)}{80(10^9) \times \frac{\pi}{2}\left[(1.5d)^4 - d^4\right]} = 0.017 \quad \checkmark$$

$$\Leftrightarrow \frac{45}{80(10^9)\frac{\pi}{2}(2.44d^4 - d^4)} = 0.017$$

$$(1.44d^4)$$

$$\Leftrightarrow \frac{2.48 \times 10^{-7}}{d^4} = 0.017$$

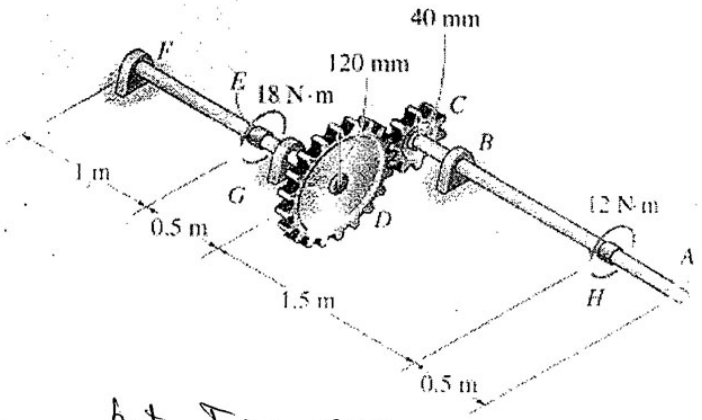
$d_2 = 1.46 \times 10^{-8}$ m ✗

$d_2 = 0.0618$ m

$d_1 > d_2$

$\theta_2 > \theta_1 \Rightarrow$ the diameter is ~~$d = 0.0618$ m~~ $d = 6 \times 10^{-7}$ m ✗

3) (15 pts) The two A-36 steel shafts AC and FD ($G = 75\,GPa$) are coupled together using the meshed-gear arrangement shown. If A is a fixed support, determine the angle of twist at end F due to the applied torsional loading. Each shaft has a diameter of 30 mm, and the bearings at F, B, and G allow free rotation.



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$P_D = \frac{T_D}{r_D}$ but $T_D = 18\ N.m$

$r_D = 0.12\,m$

$\Leftrightarrow P_D = \frac{18}{0.12} = 150N$ ✓ $\boxed{P_D = 150N}$ ⊖

$150 = \frac{T_C}{0.04} \Rightarrow \boxed{T_C = 6\ N.m}$ ✓

$6 + 12 - T_A = 0 \Rightarrow \boxed{T_A = -18\ N.m}$ ✗ ⊖

$\phi_{A/H} = \frac{18 \times 0.5}{75(10^9) \times \left[\frac{\pi}{2}(0.03)^4\right]} = 9.43 \times 10^{-5}\ rd$ ✗

$\boxed{\phi_{A/H} = 9.43 \times 10^{-5}\ rd}$

$\phi_{C/A} = \frac{6 \times 2}{75 \times 10^9 \times \frac{\pi}{2}(0.03)^4} = 1.25 \times 10^{-4}$

$\boxed{\phi_{C/A} = 1.25 \times 10^{-4}\ rd.}$ ✗

$S_D = S_C \Leftrightarrow \phi_C \times r_{C/A} = \phi_{D/O} \times r_D$ ✓

$\Leftrightarrow 1.25 \times 10^{-4} \times 0.04 = \phi_D \times 0.12$

$\Leftrightarrow \boxed{\phi_{D/O} = 4.17 \times 10^{-5}\ rd}$ OK