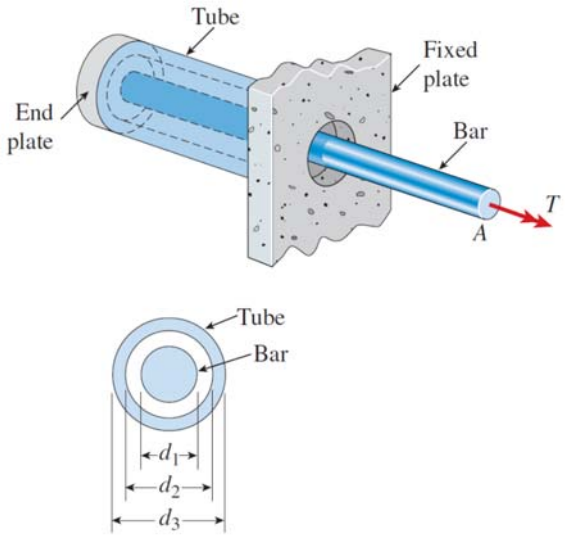
# Mechanics of Materials I
# Homework assignment # 4

**Problem 1.** A circular tube of outer diameter $d_3 = 70$ mm and inner diameter $d_2 = 60$ mm is welded at the right-hand end to a fixed plate and at the left-hand end to a rigid end plate (see figure). A solid circular bar of diameter $d_1 = 40$ mm is inside of, and concentric with, the tube. The bar passes through a hole in the fixed plate and is welded to the rigid end plate. The bar is 1.0 m long and the tube is half as long as the bar. A torque T=1000 N.m acts at end A of the bar. Also, both the bar and tube are made of an aluminum alloy with shear modulus of elasticity G=27 GPa.

(a) Determine the maximum shear stresses in both the bar and tube.

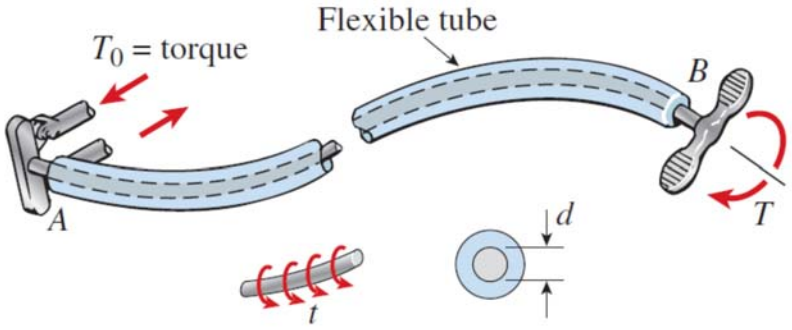
(b) Determine the angle of twist (in degrees) at end A of the bar.



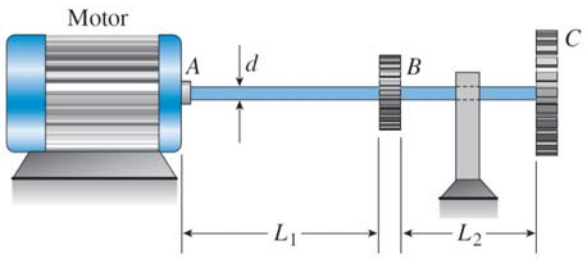

**Problem 2.** A magnesium-alloy wire of diameter d=4 mm and length L rotates inside a flexible tube in order to open or close a switch from a remote location (see figure). A torque T is applied manually (either clockwise or counterclockwise) at end B, thus twisting the wire inside the tube. At the other end A, the rotation of the wire operates a handle that opens or closes the switch. A torque $T_0 = 0.2\ N.m$ is required to operate the switch. The torsional stiffness of the tube, combined with friction between the tube and the wire, induces a distributed torque of constant intensity t=0.04 N.m/m (torque per unit distance) acting along the entire length of the wire.

(a) If the allowable shear stress in the wire is $\tau_{all} = 30\ MPa$, what is the longest permissible length $L_{max}$ of the wire?

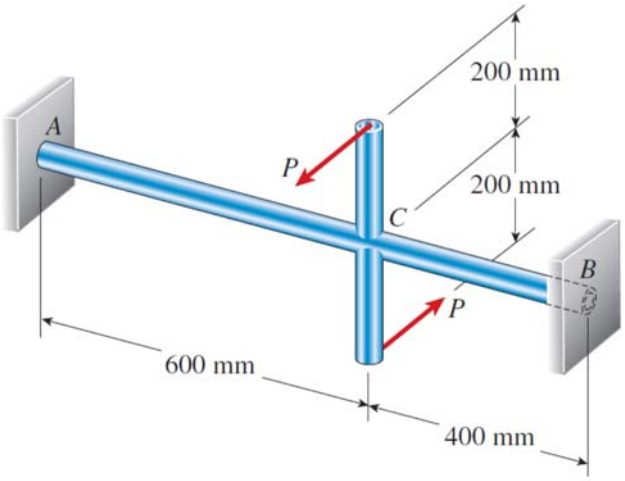
(b) If the wire has length L=4.0 m and the shear modulus of elasticity for the wire is G=15 GPa, what is the angle of twist $\varphi$ (in degrees) between the ends of the wire?



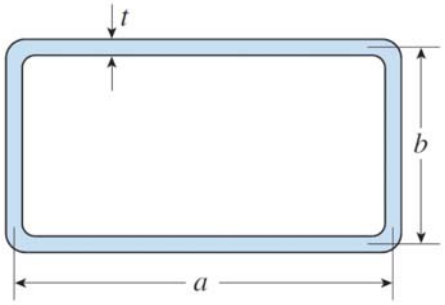
**Problem 3.** A motor delivers 275 hp at 1000 rpm to the end of a shaft (see figure). The gears at B and C take out 125 and 150 hp, respectively. Determine the required diameter d of the shaft if the allowable shear stress is 7500 psi and the angle of twist between the motor and gear C is limited to 1.5°. (Assume $G = 11.5 \times 10^6$ psi, $L_1 = 6$ ft, and $L_2 = 4$ ft.




**Problem 4.** A hollow steel shaft ACB of outside diameter 50 mm and inside diameter 40 mm is held against rotation at ends A and B (see figure). Horizontal forces P are applied at the ends of a vertical arm that is welded to the shaft at point C. Determine the allowable value of the forces P if the maximum permissible shear stress in the shaft is 45 MPa.




**Problem5.** A thin-walled rectangular tube has uniform thickness t and dimensions a × b to the median line of the cross section (see figure). How does the shear stress in the tube vary with the ratio $\beta = a/b$ if the total length $L_m$ of the median line of the cross section and the torque T remain constant? From your results, show that the shear stress is smallest when the tube is square ($\beta = 1$)




**Problem 6.** A stepped shaft with diameters $D_1 = 40$ mm and $D_2 = 60$ mm is loaded by torques T=1100 N.m (see figure).
If the allowable shear stress at the stress concentration is 120 MPa, what is the smallest radius $R_{min}$ that may be used for the fillet?