Problem 1: There is a hollow circular tube denoted as $T$ whose total length ($L$) is 15 in; the tube takes load $P$ delivered by a plate. The outer diameter of the tube is 3.0 in while the inner diameter is 2.75 in. Inside the tube is a solid circular bar denoted as $B$; the diameter of rod $B$ is 1.5 in. The length of the inner rod is 14.99 in. The outer tube and inner rod are both made of steel whose modulus is $E = 29 \times 10^3$ ksi and yield stress, $\sigma_y = 36$ ksi.

a) Determine the load $P_y$ that induces yielding for the first time and the corresponding shortening, $\delta_y$, of the tube.

b) Determine the load $P_p$ that induces total yielding (referred to as the plastic load) and the corresponding shortening, $\delta_p$, of the tube.

c) Plot the load-displacement diagram for the structural system.

Problem 2: An aluminum rod that is hollow takes a torque load $T$. The rod has an outer diameter of radius $r_2$ which is two times the inner radius $r_1$.

a) If the maximum shear strain in the tube is $400 \times 10^{-6}$ rad, what is the shear strain on the inner surface, $\gamma_1$?

b) If the maximum allowable rate of twist is 0.15 degrees per foot and the maximum shear strain is to be kept at $400 \times 10^{-6}$ rad by adjusting $T$, what is the minimum required outer radius ($r_2)_{\text{min}}$?

Problem 3: A car requires its tire to be replaced. To replace, the mechanic applies a force of $P = 25$ lb on two ends of the lug wrench. The wrench is made of steel whose shear modulus is $G = 11.4 \times 10^6$ psi. Each arm of the luge wrench is 9.0 in long and has a diameter of $d = 0.5$ in. What is the maximum shear stress in the arm that is turning the lug nut (arm $A$)? For this arm, determine the angle of twist (in degrees) as well.
**Problem 4:** A steel shaft denoted as $ABCD$ is constructed from solid circular elements of varying diameters (3.0, 2.5 and 2.0 in); each segment is 24 in. Torque is applied at the end of each segment of 12.0, 9.0 and 9.0 k-in at point $B$, $C$, and $D$, respectively. The steel used to construct the rod has a shear modulus of $G = 11.6 \times 10^3$ ksi.

a) Determine the maximum shear stress $\tau_{\text{max}}$ in the shaft.

b) What is the angle of twist (in degrees) at the shaft end $D$.

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**Problem 5:** A rod, $AB$, of length $L$ is prismatic with constant diameter $d$. A distributed torque, $t(x)$ is distributed along the length of the rod. The torque is maximum at the fixed support at $T_A$ and linearly reduces to zero at tip $B$. The shear modulus is $G$. Determine the maximum shear stress, $\tau_{\text{max}}$, in the bar and the angle of twist at $B$.

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**Problem 6:** A circular rod 50 in long is fixed at both ends ($A$ and $B$) and has an applied torque, $T_0$, at $x$. A unique facet of the rod is that it is hollow for half its lengths. The outer diameter of the rod is 3.0 in while the inner radius for the hollow portion is 2.4 in. What is $x$ (relative to $A$) such that the torques at the two ends (i.e., at $A$ and $B$)?

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**Problem 7:** A rod consisting of two sections with diameters $D_2 = 1.0$ in and $D_1$ (not defined) are combined via a filleted connection (with radius $R$). A torque of 500 lb-in is applied to the rod. What is the maximum shear stress, $\tau_{\text{max}}$, at the stress concentration when $D_1$ is 0.9, 0.8 and 0.7 in?