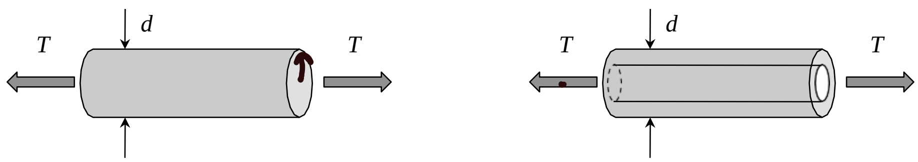
Conceptual question 8.1

Shaft (a) has a solid cross section with outer radius d. Shaft (b) has a tubular cross section with an outer radius of d. Each shaft has the same length and the same shear modulus G. Let $\tau_{a,max}$ and $\tau_{b,max}$ represent the maximum shear stress in shafts (a) and (b), respectively, due to the torque T applied at the shafts' ends. Circle the correct answer:

a) $|\tau_{a,max}| > |\tau_{b,max}|$

b) $|\tau_{a,max}| = |\tau_{b,max}|$

c) $|\tau_{a,max}| < |\tau_{b,max}|$



shaft (a) shaft (b)

$$\tau_{max} = \frac{TR}{I_p}$$

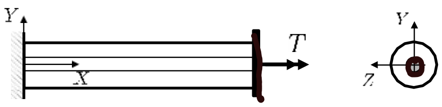
$$I_{p(a)} = \frac{\pi}{2}R^4$$

$$I_{p(b)} = \frac{\pi}{2}\left(R^4 - r_i^4\right) \leftarrow \text{smaller.}$$

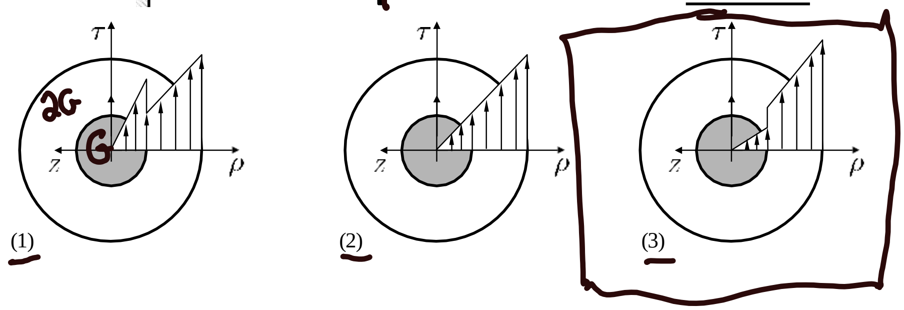
Conceptual question 8.2

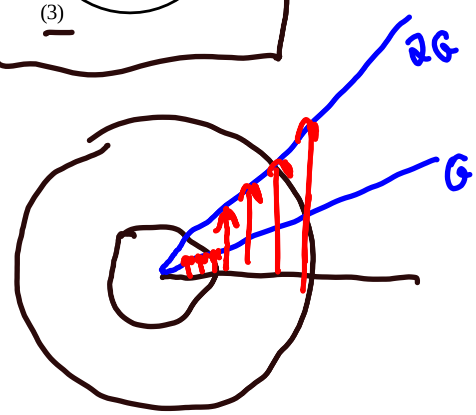
For each loading configuration shown below, indicate the correct stress distribution over a cross section perpendicular to the x-axis.

(a) A bimetallic bar with circular cross section comprised of two elastic materials is subjected to a torque *T*. Material A, depicted using white, is stiffer than material B, depicted using gray. Specifically, the Young's modulus of material A is two times larger than the Young's modulus of material B, and both materials have the same Poisson's ratio.

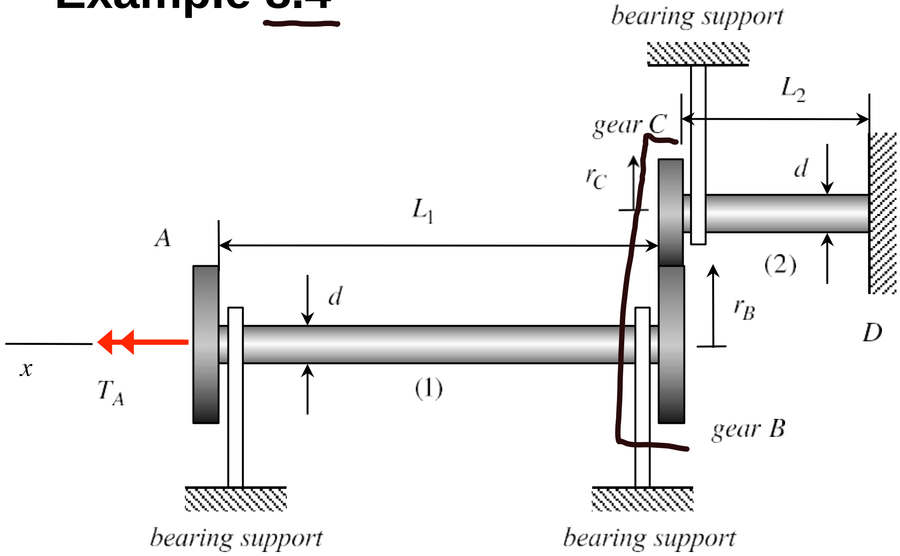
(a) 

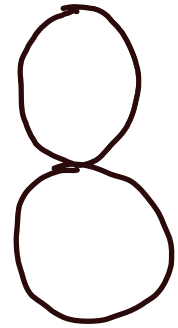
Answer: ______





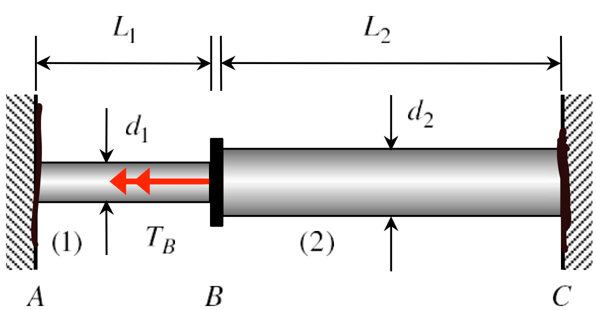
Example 8.4





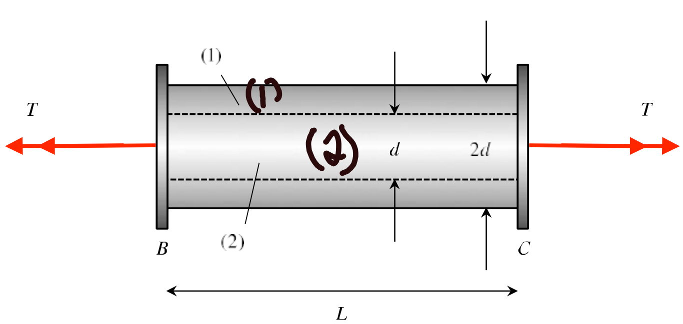
$$-\frac{r_C}{r_B}\phi_C = \phi_B$$

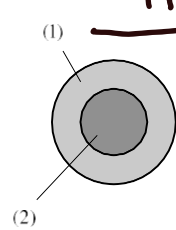
Example 8.5



$$\Delta\phi_1 + \Delta\phi_2 = 0$$

Example 8.7





$$\Delta\phi_1 = \Delta\phi_2.$$

$$\Delta\phi_1 = \frac{T_1 L_1}{G_1 I_{p1}}$$

Additional Example: Complex assembly

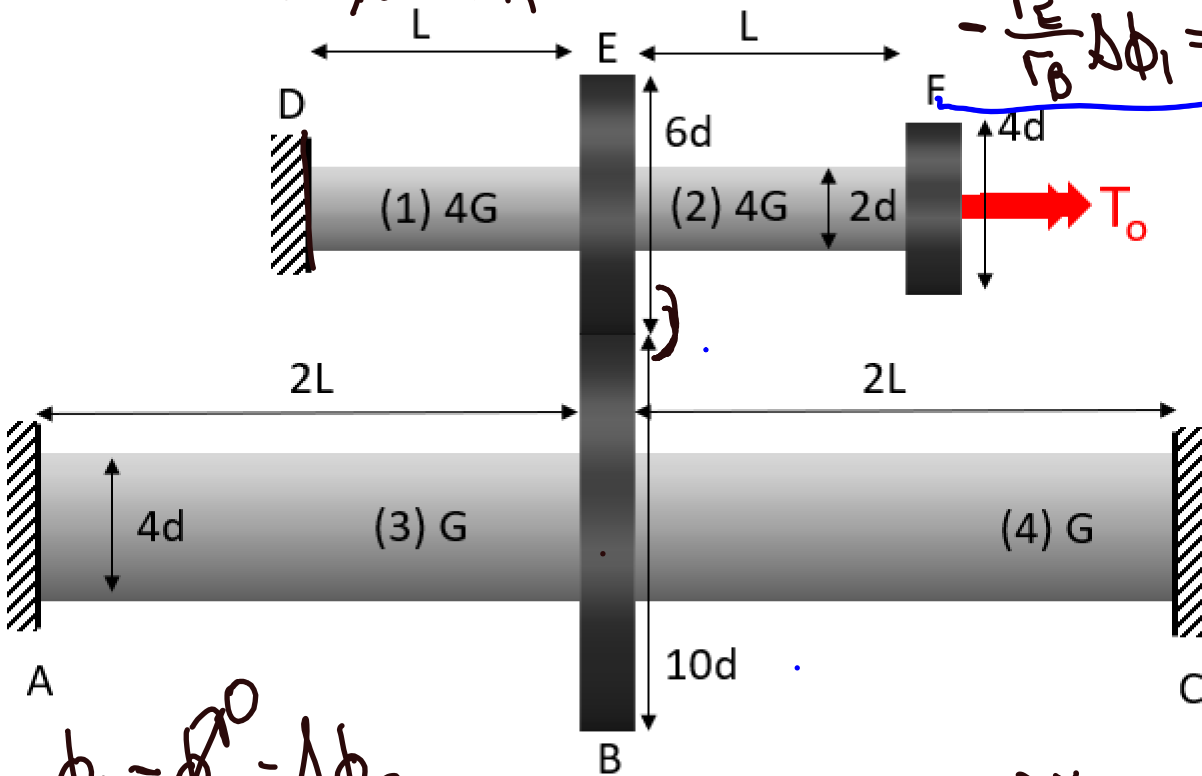
$\Delta\phi_3 + \Delta\phi_4 = 0$

(a) Set up the equilibrium equations.
(b) Identify the key compatibility equations.

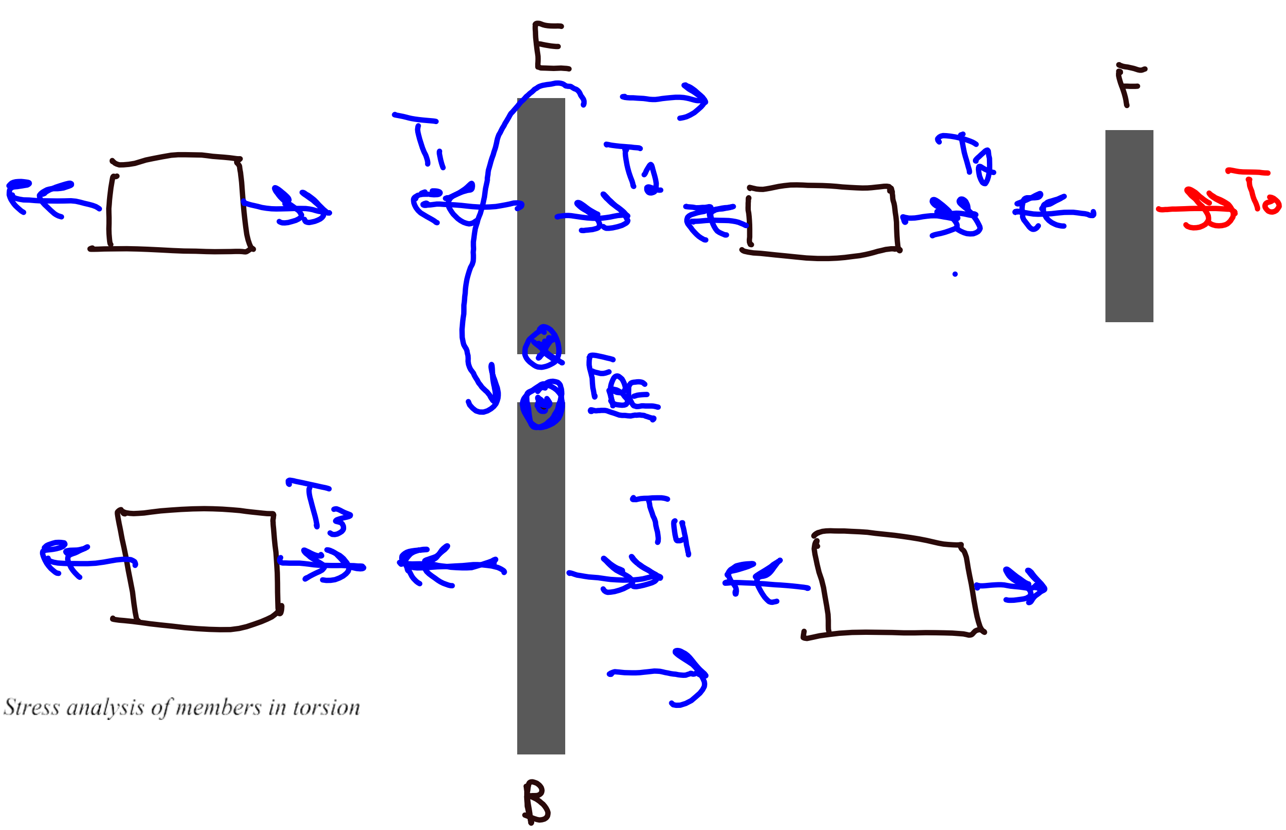
$-\frac{r_E}{r_B}\phi_E = \phi_B$

$-\frac{r_E}{r_B}\Delta\phi_1 = \Delta\phi_3$

$\phi_E - \phi_D^{0} = \Delta\phi_1$



$\phi_B - \phi_A^{0} = \Delta\phi_3$



Stress analysis of members in torsion

1.) Equilibrium

$$(\Sigma M)_F = T_0 - T_2 = 0$$

$$(\Sigma M)_E = T_2 - T_1 + F_{BE}(3d) = 0$$

$$(\Sigma M)_B = T_4 - T_3 + F_{BE}(5d) = 0$$

5 unknowns
3 equations.

2 compatibility.

3.) Compatibility

$$\Delta\phi_3 + \Delta\phi_4 = 0$$

$$-\frac{r_E}{r_C}\Delta\phi_1 = \Delta\phi_3$$

2.) Torque-Twist.

$$\Delta\phi_1 = \frac{T_1 L_1}{G_1 I_{p1}}$$

$\Delta\phi_2$

$\Delta\phi_3$

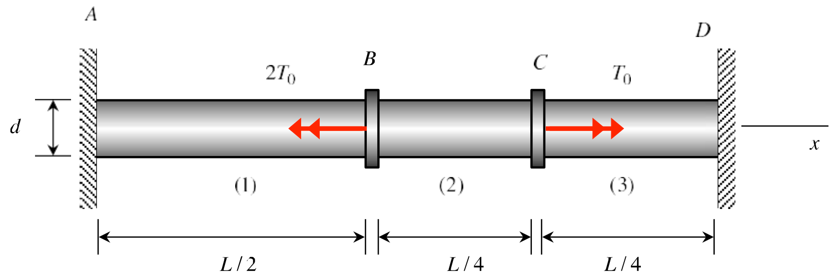
$\Delta\phi_4$

Example 8.6

A uniform shaft with fixed ends at A and D is subjected to external torques of magnitudes T_0 and $2T_0$ as shown in the figure below. The material of the shaft has a shear modulus of G.

a) Determine expressions for the maximum shear stress in each of the three segments of the shaft.

b) Determine an expression for the angle of rotation of the shaft at joint B.

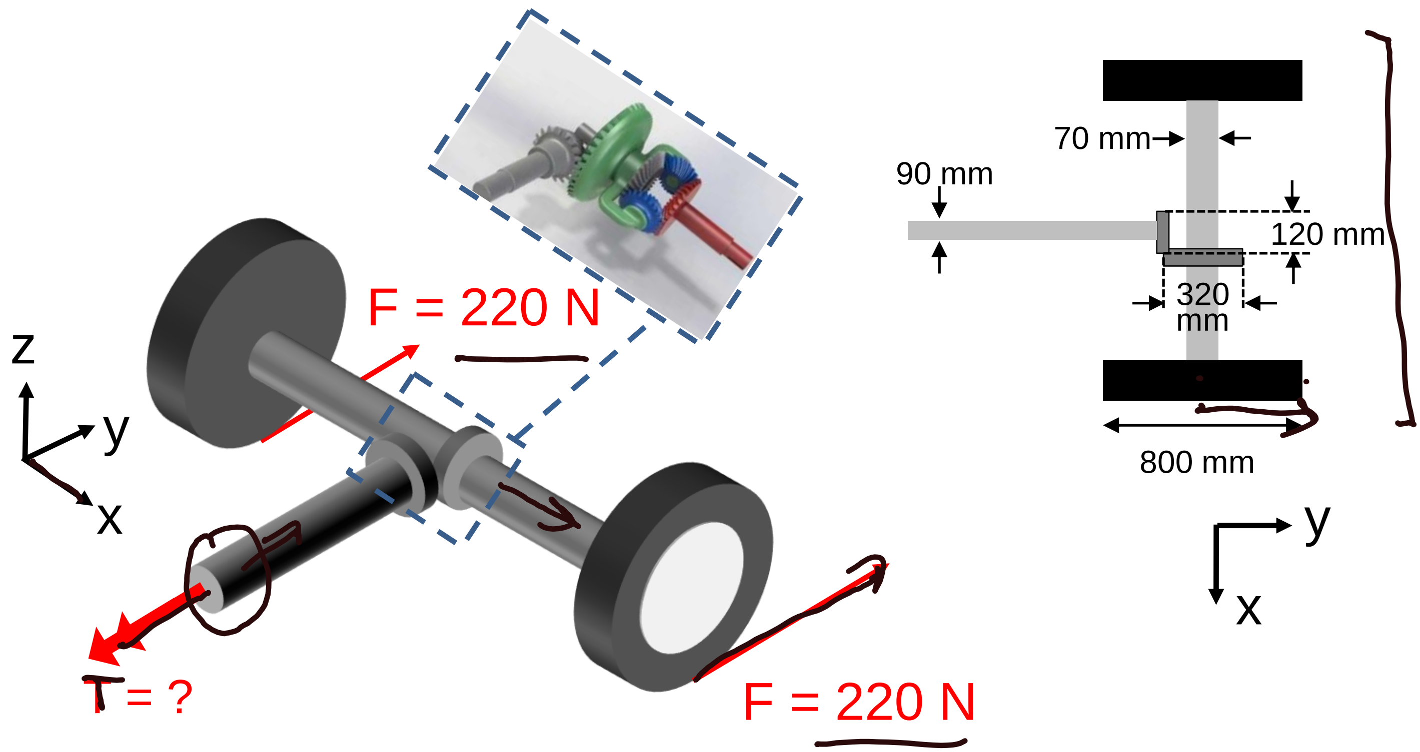


Motivation for Quiz Format

- Students requested more low-stakes assignments instead of high-stakes ones
- Students learn more from doing things than from watching someone else doing them
- Students want to see the relationship to the applications they are interested in

Stress analysis of members in torsion

Lecture 12 Quiz



(a) What torque needs to be applied to the drive shaft for each wheel to output a force of 220 N?

(b) (completely separate from part a) A drive shaft must be designed to operate at a torque of 3200 N*m with an outer diameter of 90 mm and a length of 1320 mm. Using a hollow aluminum tube, what inner diameter is required? The shear modulus of aluminum is 27 GPa. The allowable shear stress in the aluminum is 60 MPa.