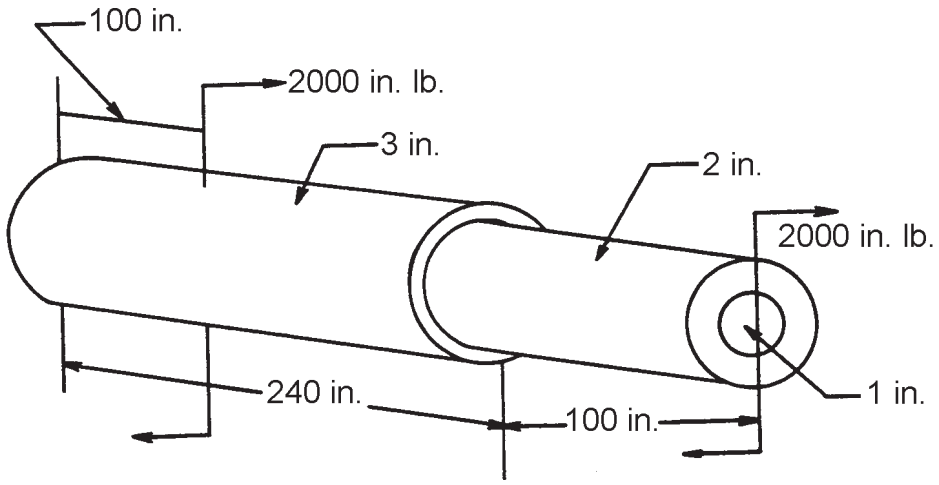
**Problem Statement**

12. For the steel torsion member shown, only the smaller portion (2 inch diameter section) is hollow. The member experiences two 2000 in-lb torsional loads as shown. Find the torsional deflection (angle of twist) developed in the 340 inch long member. (Modulus of Elasticity = 30,000,000 psi, Shear Modulus of Elasticity = 12,000,000 psi).

A. 0.0163 Rad
**B. 0.0184 Rad**
C. 0.0214 Rad
D. 0.0298 Rad




**Given**

Two 2000 in-lb torsional loads
The 2 inch diameter section is hollow
Section one is 240 inches long and section two is 100 inches long
G = 12,000,000 psi

**Find**

Torsional deflection

**Definitions**

$\theta$ = angle of twist in radians
T = internal resisting torque
L = length
G = shear modulus
J = polar moment of inertia

**Formulas**

$$\theta = \frac{TL}{JG}$$

$$J_{solid\ shaft} = \frac{\pi d^4}{32}$$

$$J_{hollow\ shaft} = \frac{\pi(d_o{}^4 - d_i{}^4)}{32}$$

**Steps**

1. Cut the shaft where there is a change in load or geometry
2. Draw free body diagrams of each cut.
3. Calculate the internal resisting torque (T) for each free body diagram.
4. Calculate the angle of twist for each section.
5. Sum the angles for the total deflection.

**Solution**

$T_1$ = 4000 in-lb

$T_2$ = 2000 in-lb

$T_3$ = 2000 in-lb

$$\theta_1 = \frac{T\,L}{J\,G} = \frac{4000\,\text{lb}\,(100\,\text{in})}{[\pi(3\,\text{in}^4)/32][12\,\text{x}\,10^6\,\text{psi}]} = 0.00419\,\text{rad}$$

$$\theta_2 = \frac{T\,L}{J\,G} = \frac{2000\,\text{lb}\,(140\,\text{in})}{[\pi(3\,\text{in}^4)/32][12\,\text{x}\,10^6\,\text{psi}]} = 0.00293\,\text{rad}$$

$$\theta_3 = \frac{T\,L}{J\,G} = \frac{2000\,\text{lb}\,(100\,\text{in})}{[\pi(2\,\text{in}^4 - 1\text{in}^4)/32][12\,\text{x}\,10^6\,\text{psi}]} = 0.01132\,\text{rad}$$

$$\theta_T = \theta_1 + \theta_2 + \theta_3 = 0.0184\text{rad}$$

**Answer is (B) 0.0184 Rad**