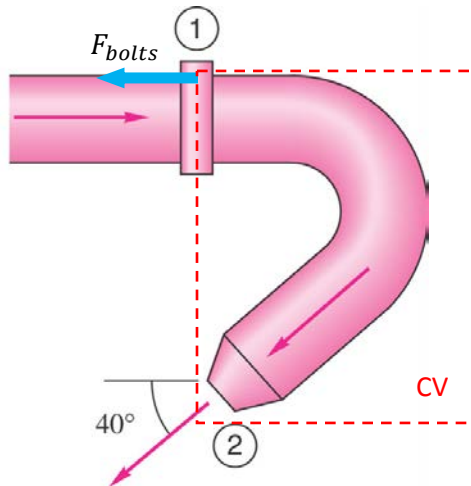


NAME

Fluids-ID

Quiz 7. Water at 20°C flows through an elbow and exits to the atmosphere ($p_2 = 0$ gage). The pipe diameter is $D_1 = 10$ cm, while $D_2 = 3$ cm. At a mass flow rate \dot{m} of 15.3 kg/s, the pressure $p_1 = 2.3$ atm (gage). Neglecting the weight of water and elbow, estimate the horizontal force on the flange bolts F_{bolts} at section 1. (Hint: $\rho_{water} = 998$ kg/m³, 1 atm = 101,350 N/m²)



For steady incompressible flow (uniform flow over CS),

Continuity equation:

$$\dot{m} = \rho Q = \text{constant}$$

Momentum equation:

$$\sum \underline{F} = \sum_{CS} \rho \underline{V} \underline{V} \cdot \underline{A}$$

Note: Attendance (+2 points), format (+1 point)

Solution:

From the x-direction force balance,

$$\sum F_x = -F_{bolts} + p_1 A_1 = \dot{m} u_2 - \dot{m} u_1 \quad (\because p_2 = 0 \text{ gage})$$

(+4 point)

where,

$$u_1 = \frac{Q}{A_1} = \frac{\dot{m}/\rho}{\pi D_1^2/4} = \frac{15.3 \text{ kg/s}}{998 \text{ kg/m}^3} \times \frac{4}{\pi (0.1 \text{ m})^2} = 1.95 \text{ m/s}$$

(+1 point)

$$u_2 = -\frac{Q}{A_2} \cos 40^\circ = -\frac{\dot{m}/\rho}{\pi D_2^2/4} \cos 40^\circ = -\frac{15.3 \text{ kg/s}}{998 \text{ kg/m}^3} \times \frac{4}{\pi (0.03 \text{ m})^2} \times \cos 40^\circ = -16.6 \text{ m/s}$$

(+1 point)

Thus,

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$$\begin{aligned}F_{bolts} &= p_1 A_1 + \dot{m}(u_1 - u_2) \\ &= (2.3 \times 10^5 \text{ N/m}^2) \times \frac{\pi(0.1 \text{ m})^2}{4} + 15.3 \text{ kg/s} \times (16.6 + 1.95) \text{ m/s} = 2115 \text{ N}\end{aligned}$$

$$\mathbf{F_{bolts} = 2115 \text{ N}}$$

(+1 point)