**Course: ME 5160, Fall 2024**

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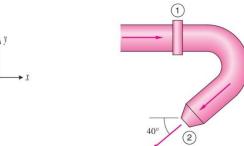**The exam is closed book and closed notes.**

Water at 20°C ($\rho$=998 kg/m$^3$) flows through the elbow and waterjet exits to the atmosphere. The pipe diameter is $D_1 = 10cm$, while $D_2 = 3cm$. At a flow rate of 0.0153 m$^3$/s, the pressure $p_1 = 2.3$ atm (gage). Neglecting the weight of water and elbow, estimate $x$ component of the force on the flange bolts at section 1.

{2.3atm = 233kPa}



**Continuity Equation:**

$$-\frac{d}{dt}\int_{CV}\rho d\forall = \int_{CS}\rho \underline{V}_R \cdot \underline{n}\, dA$$

**Momentum Equation:**

$$\sum \underline{F} = \frac{d}{dt}\int_{CV}\underline{V}\rho d\forall + \int_{CS}\underline{V}\rho \underline{V}_R \cdot \underline{n}\, dA$$

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**Solution:**

Format (+3)

a) Continuity:

$$Q = V_1 A_1 = V_2 A_2 \qquad \textbf{(+2)}$$

$$V_1 = \frac{Q}{A_1} = \frac{0.0153}{\left(\frac{\pi}{4}\right)(0.1)^2} = 1.95 \; m/s \quad \textbf{(+1)}$$

$$V_2 = \frac{Q}{A_2} = \frac{0.0153}{\left(\frac{\pi}{4}\right)(0.03)^2} = 21.64 \; m/s \quad \textbf{(+1)}$$

$x$ – momentum:

$$\sum F_x = \dot{m}u_2 - \dot{m}u_1$$

$$-F_{x,bolts} + p_1 A_1 = \rho Q(-V_2 \cos 40° - V_1) \; \textbf{(+2)}$$

$$F_{x,bolts} = (233 \times 10^3)\frac{\pi}{4}(0.1)^2 + (998)(0.0153)(21.64 \cos 40° + 1.95) = 2113 \; N \quad \textbf{(+1)}$$