Name: ---------- **Quiz: No. 9** **Time: 15 minutes**

ME:5160, Fall 2025

The exam is closed book and closed notes.

SAE 30W oil at 20°C (ρ=891 kg/m^3; μ=0.29 kg/m-s) flows through a straight horizontal pipe 25 m long, with diameter 4 cm. The average velocity is 2 m/s. (a) Is the flow laminar (Re<2300)? Calculate (b) the pressure drop Δp and (c) the power required P. (d) If the pipe diameter is halved, for the same flow rate, by what factor does the required power increase?

Hint: $Power = Q\Delta p$

Energy equation: $\left(\frac{p}{\rho g} + \frac{V^2}{2g} + z\right)_1 = \left(\frac{p}{\rho g} + \frac{V^2}{2g} + z\right)_2 + h_f$

Laminar pipe flow: $h_f = f\frac{L}{D}\frac{V^2}{2g}$; $f = \frac{64}{Re_D}$

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Solution:

KNOWN: D, L, ρ, μ, V

FIND: Flow regime, pressure drop, power, power if D -> $D/2$ (1)

ASSUMPTIONS: $\alpha \approx 1$, no minor losses

ANALYSIS:

(a)

$$Re_d = \frac{\rho V d}{\mu} = \frac{(891)(2.0)(0.04)}{0.29} \approx 246 < 2300 \quad (1)$$

Yes, laminar flow.

(b)

$$\left(\frac{p}{\rho g} + \frac{V^2}{2g} + z\right)_1 = \left(\frac{p}{\rho g} + \frac{V^2}{2g} + z\right)_2 + h_f \quad (1)$$

$$V_1 = V_2; z_1 = z_2$$

$$\frac{\Delta p}{\rho g} = h_f$$

$$\Delta p = \rho g h_f = \rho g \left(\frac{64}{Re_D}\frac{L}{D}\frac{V^2}{2g}\right) = \frac{32\mu LV}{D^2} \quad (2)$$

$$\Delta p = \frac{32(0.29)(25)(2.0)}{(0.04)^2} \approx 290{,}000\ Pa = 290kPa$$

(c)

$$Q = \frac{\pi}{4} d^2 V$$

$$Q = \frac{\pi}{4}(0.04)^2(2.0) \approx 0.00251 m^3/s \quad (1.5)$$

$$P = Q\Delta p = (0.00251)(290{,}000) \approx 728W$$

(d)

$$D = 2cm = 0.02m$$

$$Q = 0.00251 = \frac{\pi}{4}(0.02)^2 V$$

$$V = 8m/s \quad (1)$$

$$Re_d = \frac{\rho V d}{\mu} = \frac{(891)(8)(0.02)}{0.29} \approx 492 < 2300$$

Still laminar.

$$\Delta p = \frac{32\mu LV}{d^2} = \frac{32(0.29)(25)(8.0)}{(0.02)^2} \approx 4{,}640{,}000\ Pa$$

$$P = Q\Delta p = (0.00251)(4{,}640{,},000) \approx 11{,}646W \quad (0.5)$$

$$factor = \frac{11{,}646}{728} \approx 16$$