Oil with an absolute viscosity of 0.16 N·s/m² and a density of 925 kg/m³ is flowing in a 200-mm-diameter pipe at 0.50 L/s. How much power is lost per meter of pipe length?

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Eq. 4.7: \( V = \frac{0.00050}{\pi 0.200^2} = 0.01592 \text{ m/s} \)

Eq. 8.1: \( R = \frac{0.20(0.01592)925}{0.16} = 18.40 \), flow is laminar. Eq. 8.29: \( f = 64/18.40 \)

Eq. 8.14: \( \frac{h_p}{L} = \frac{64/18.40(1/0.20)0.01592^2/[2(9.81)]} = 0.0001796 \text{ meter per meter} \)

Eq. 5.41: Power loss = \( (925 \times 9.81)(\pi 0.100^2)0.01592(0.0001796) = 0.000815 \text{ watts per meter} \)
8.14 Water at 50°F enters a pipe with a uniform velocity of \( U = 14 \) fps. (a) What is the distance at which the transition occurs from a laminar to a turbulent boundary layer? (b) If the thickness of this initial laminar boundary layer is given by \( 4.91\sqrt{\nu x/U} \) (from Eq. 9.10), what is its thickness at the point of transition?

Table A.1 for water at 50°F: \( \nu = 1.410 \times 10^{-5} \) ft\(^2\)/sec

(a) Sec. 8.10: At transition point (turbulent boundary layer begins): For \( \Re_x = 500,000 = Ux/\nu \)

\[
x = 500,000 \nu / U = 500,000(0.000 \ 0141)/14 = 0.504 \text{ ft} = 6.04 \text{ inches}
\]

(b) Given: \( \delta = 4.91\sqrt{\nu x/U} = 4.91\sqrt{0.000 \ 0141 \times 0.504/14} = 0.0035 \) feet or 0.0420 inches
In a 36-in-diameter pipe velocities are measured as 18.5 fps at \( r = 0 \) and 18.0 fps at \( r = 4.0 \) in. Approximately what is the flow rate?

Eq. 8.40: \[ 18.0 = 18.5 - 5.76u_\ast \log[18/(18 - 4.0)] \] from which \( u_\ast = 0.795 \) fps

Eq. 8.37: \[ 0.795 = u_\ast = V\sqrt{f/8} \]. Thus \( f^{1/2} = 2.25/V \) \hspace{1cm} (1)

Eq. 8.43: \[ V/18.5 = 1/(1 + 1.326f^{1/2}) \] \hspace{1cm} (2)

Eliminating \( f \) between (1) and (2): \[ \frac{18.5}{V} = 1 + 1.326 \frac{2.25}{V} \], from which \( V = 15.52 \) fps (so \( f = 0.0579 \))

Eq. 4.7: \[ Q = AV = (\pi/4)(36/12)^215.52 = 109.7 \text{ cfs} \]
Water at 60°C flows in a 15-mm-diameter copper tube \((e = 0.0015 \text{ mm})\) at 0.06 L/s. Find the head loss per 10 m, using Eq. (8.29) or (8.52) to find \(f\). What is the centerline velocity, and what is the value of \(\delta\)?

**Table A.1:** At 60°C, \(v = 0.474 \times 10^{-6} \text{ m}^2/\text{s}\)

Eq. 4.7: \(V = Q/A = \frac{4Q}{\pi D^2} = \frac{4(0.06 \times 10^{-3})}{\pi(0.015)^2} = 0.340 \text{ m/s}\)

Eq. 8.1: \(R = \frac{DV}{\nu} = \frac{0.015(0.340)}{0.474 \times 10^{-6}} = 10740\) (flow is turbulent); \(\frac{e}{D} = \frac{0.0015}{0.015} = 0.000100\)

Eq. 8.52: \(f = 0.0304\); Eq. 8.13: \(h_f = 0.031 \frac{10 \times 0.340^2}{(0.015)^2(9.81)} = 0.1191 \text{ m}\)

Eq. 8.43: \(0.340/\mu_{\text{max}} = 1/[1 + 1.326(0.0304)^{1/2}]; \mu_{\text{max}} = 0.418 \text{ m/s}\)

Eq. 8.38: \(\delta = \frac{14.14(0.474 \times 10^{-6})}{0.340(0.0304)^{1/2}} = 0.0001132 \text{ m}\)