

Module 5: Friction Losses (CIVL 318)

Reynolds Number:	$N_R = \frac{vD\rho}{\eta}$
	$N_R < 2000 \Rightarrow$ laminar
	$2000 < N_R < 4000 \Rightarrow$ critical flow
	$N_R > 4000 \Rightarrow$ turbulent flow
Laminar flow:	$f = \frac{64}{N_R}$
Turbulent flow::	$f = \frac{0.25}{\left[\log \left(\frac{1}{3.7(D/\epsilon)} + \frac{5.74}{N_R^{0.9}} \right) \right]^2}$
Darcy's Equation:	$h_L = f \times \frac{L}{D} \times \frac{v^2}{2g}$

Roughness, ϵ :

Material (new, clean)	ϵ (m)
Glass	Smooth
Plastic	3.0×10^{-7}
Copper, brass, lead (tubing)	1.5×10^{-6}
Commercial steel, welded steel	4.6×10^{-5}
Wrought iron	4.6×10^{-5}
Ductile Iron - coated	1.2×10^{-4}
Ductile Iron - uncoated	2.4×10^{-4}
Concrete	1.2×10^{-4}
Riveted steel	1.8×10^{-3}

Example 1: Flow is said to be in the **critical region**, with neither fully laminar or fully turbulent flow, if the Reynolds number for the flow is between 2000 and 4000.

Determine the range of velocities and volume flow rates for which flow is in the critical region for:

- (1) water at 5°C flowing in 1/2-in copper tubing
- (2) water at 95°C flowing in 1/2-in copper tubing
- (3) fuel oil at 10°C ($sg = 0.94$, $\eta = 2.4 \text{ Pa} \cdot \text{s}$),
flowing in 12-in Schedule 40 steel pipe

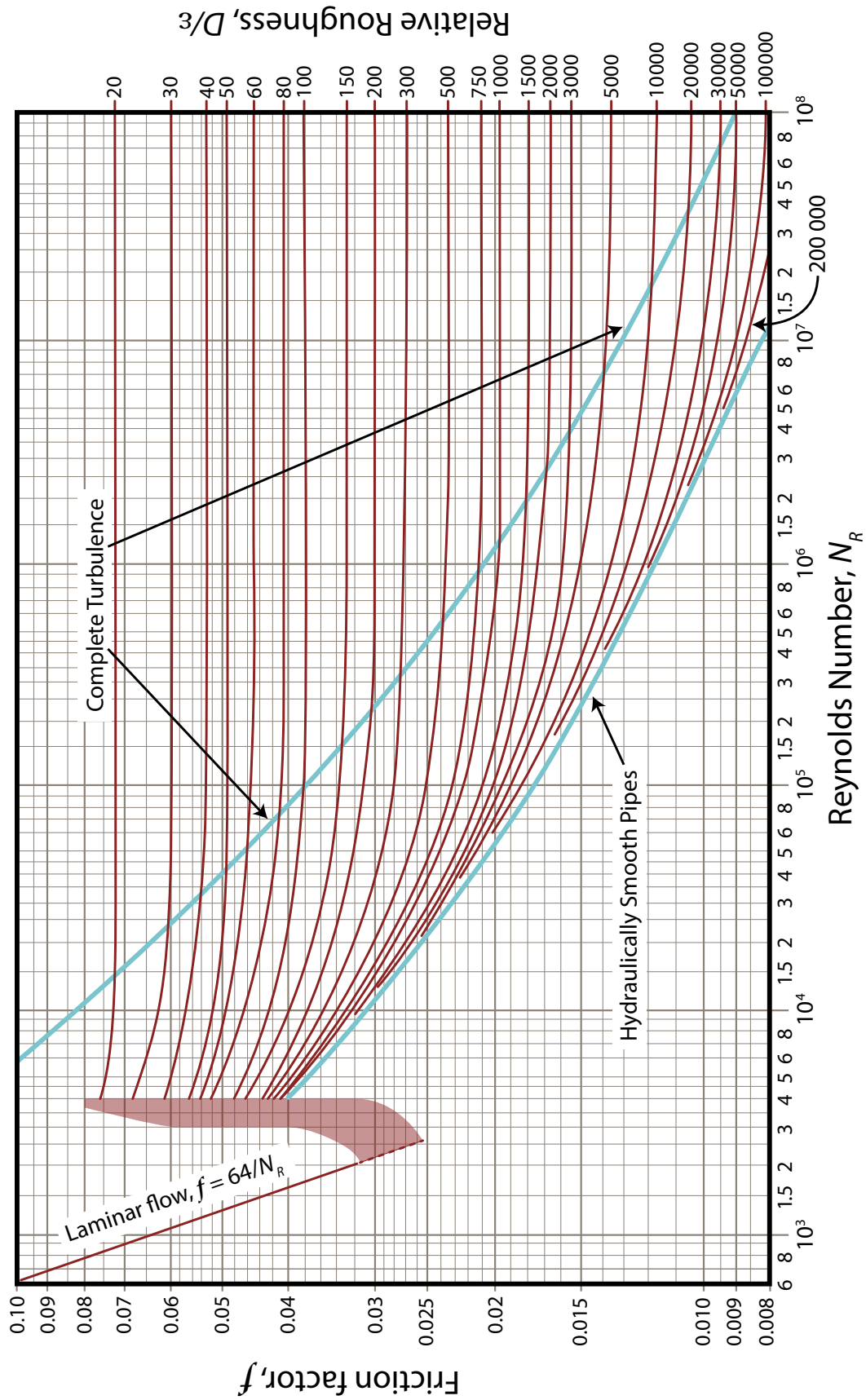
Example 2:

Determine the headloss due to friction in fuel oil at 10°C flowing through 125 m of 12-in Schedule 40 steel pipe with an average flow velocity of 4.5 m/s.

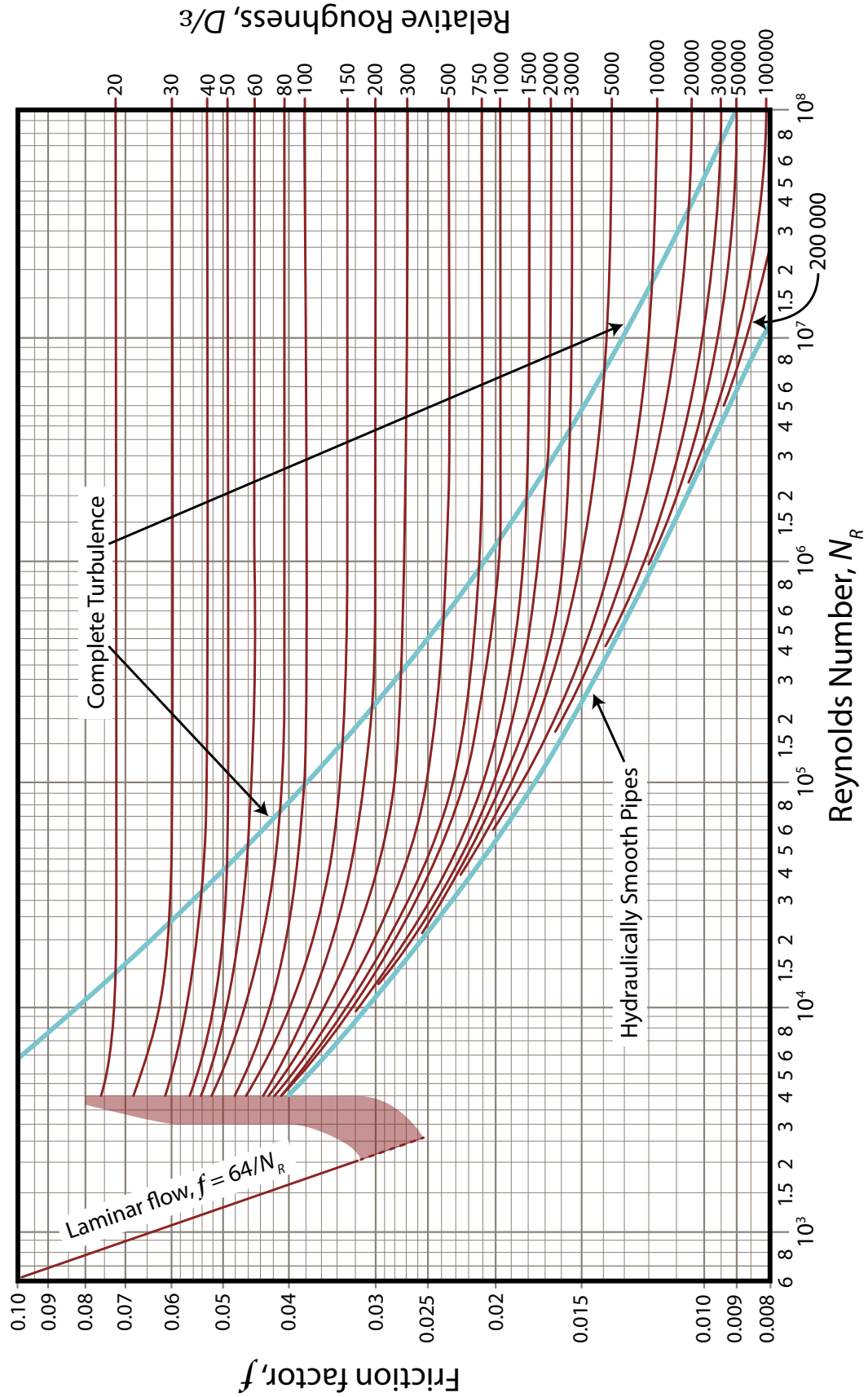
Then determine the headloss if the average flow velocity is reduced to 2.25 m/s.

($sg = 0.94$, $\eta = 2.4 \text{ Pa} \cdot \text{s}$).

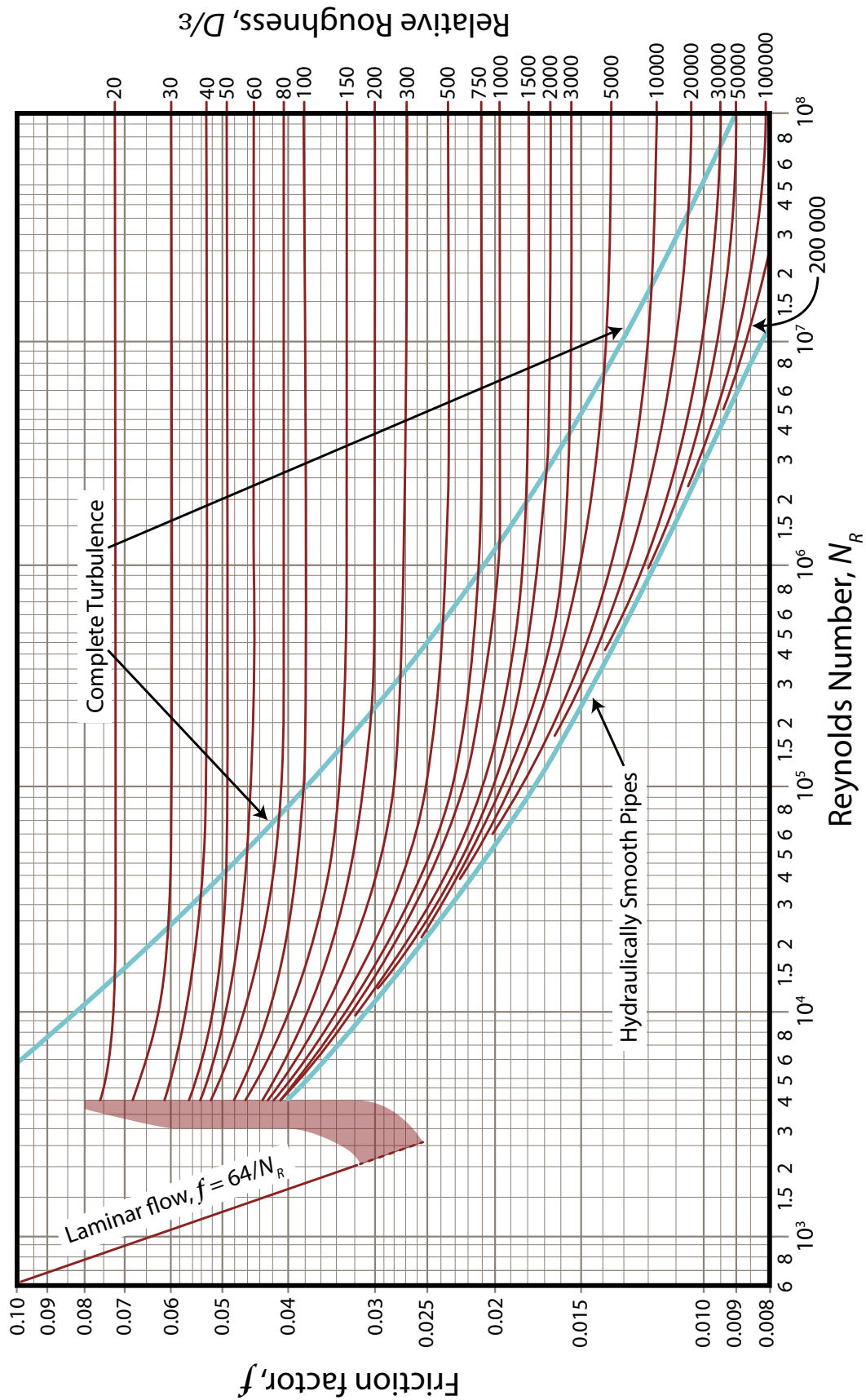
Example 3 Use the Moody diagram to determine the friction factor for flow with $N_R = 2 \times 10^6$ and a relative roughness of 1428.



Example 4 Use the Moody diagram to determine the friction factor for flow with $N_R = 1.6 \times 10^5$ and in new clean 1/2-in copper tubing.



Example 5 A 75 m section of wooden flume is replaced with 54-in high density polyethylene (HDPE) pipe with inside diameter of 1.37 m. The pipe is smooth and transports $190 \times 10^3 \text{ m}^3/\text{day}$. Determine the headloss due to friction in the pipe, assuming an average temperature of 10°C .



Example 6:

Ethyl alcohol at 25°C flows through $1\frac{1}{2}$ -in Schedule 80 steel pipe at 5 L/s. Determine the pressure drop, due to friction losses, in a 125 m section of pipe.

Example 7:

Ethyl alcohol at 25°C flows through 3-in Schedule 80 steel pipe at 5 L/s. Determine the pressure drop, due to friction losses, in a 125 m section of pipe.

Example 8:

A horizontal 12-in Schedule 80 steel pipe transports oil ($sg = 0.85$, $\eta = 3.0 \times 10^{-3} \text{ Pa} \cdot \text{s}$) at 185 L/s. The pipe has pumping stations spaced at 6.0 km intervals. Determine the power required by each pump to maintain the same pressure at each pump outlet if all losses are due to friction.

