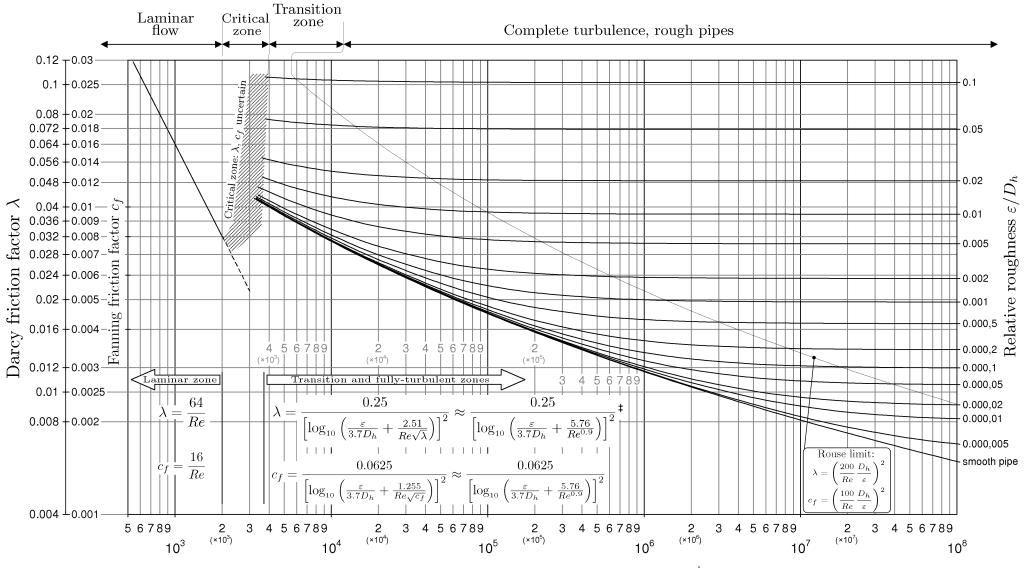# Moody chart for Darcy friction factor λ, used in $\Delta P = \frac{\lambda L}{D_h}\frac{1}{2}\rho U^2$

(also shows Fanning friction factor c_f, used in $\Delta P = \frac{4c_f L}{D_h}\frac{1}{2}\rho U^2$)

Laminar flow

Critical zone

Transition zone

Complete turbulence, rough pipes

Darcy friction factor λ

Fanning friction factor c_f

Critical zone: λ, c_f uncertain

Relative roughness ε/D_h

0.1
0.05
0.02
0.01
0.005
0.002
0.001
0.000,5
0.000,2
0.000,1
0.000,05
0.000,02
0.000,01
0.000,005
smooth pipe

Left axis λ: 0.12, 0.1, 0.08, 0.072, 0.064, 0.056, 0.048, 0.04, 0.036, 0.032, 0.028, 0.024, 0.02, 0.016, 0.012, 0.01, 0.008, 0.004

Left axis c_f: 0.03, 0.025, 0.02, 0.018, 0.016, 0.014, 0.012, 0.01, 0.009, 0.008, 0.007, 0.006, 0.005, 0.004, 0.003, 0.0025, 0.002, 0.001

Laminar zone

Transition and fully-turbulent zones

$$\lambda = \frac{64}{Re}$$

$$c_f = \frac{16}{Re}$$

$$\lambda = \frac{0.25}{\left[\log_{10}\left(\frac{\varepsilon}{3.7D_h} + \frac{2.51}{Re\sqrt{\lambda}}\right)\right]^2} \approx \frac{0.25}{\left[\log_{10}\left(\frac{\varepsilon}{3.7D_h} + \frac{5.76}{Re^{0.9}}\right)\right]^2}$$ ‡

$$c_f = \frac{0.0625}{\left[\log_{10}\left(\frac{\varepsilon}{3.7D_h} + \frac{1.255}{Re\sqrt{c_f}}\right)\right]^2} \approx \frac{0.0625}{\left[\log_{10}\left(\frac{\varepsilon}{3.7D_h} + \frac{5.76}{Re^{0.9}}\right)\right]^2}$$

Rouse limit:
$$\lambda = \left(\frac{200}{Re}\frac{D_h}{\varepsilon}\right)^2$$
$$c_f = \left(\frac{100}{Re}\frac{D_h}{\varepsilon}\right)^2$$

Reynolds number, $\frac{UD_h}{\nu}$ or $\frac{\rho U D_h}{\mu}$

X-axis: 10^3, 10^4, 10^5, 10^6, 10^7, 10^8

‡ This approximation to the Colebrook-White function is taken from equation 14 in: Colebrook, C F, "Turbulent Flow in Pipes, with particular reference to the Transition Region between the Smooth and Rough Pipe Laws," Paper 5204, *J. Instn. Civ. Engrs.* 1939, no. 4, vol 11, pp. 133–156.