Broad categories of fluid flow and canonical geometries

Category	Canonical geometry
Internal Flows	Circular pipe
exact laminar, D_h turbulent: noncircular ducts	
h_m: transitions: contraction or diffuser	
h_m: fittings	
h_p, h_t: pumps/turbines	$\frac{p_1}{\gamma}+z_1+\alpha_1\frac{V_1^2}{2g}+h_p=\frac{p_2}{\gamma}+z_2+\alpha_2\frac{V_2^2}{2g}+h_t+h_L+\Sigma h_m$
External Flows	
BL theory: Slender bodies	flat plate BL
C_D: bluff body	sphere: Stokes flow $\frac{F}{\mu UR}=6\pi$, $C_D=24/Re$, $2/3\ C_f$ & $1/3\ C_p$
appendages	
Free Shear flows	
mixing layers	2D
jets	2D and axi
wakes	2D and axi

circular pipe

laminar flow $Re = \frac{U_m D}{\nu} < 2000$

$u(r) = u_{max}(1 - r^2/R^2)$ $u_{max} = \frac{R^2}{4\mu}\left(-\frac{d\hat{p}}{dx}\right)$ $\hat{p} = p + \gamma z$

$\tau_w = \frac{8\mu U_m}{D}$ $\Delta h = h_1 - h_2 = h_L = f \frac{L}{D}\frac{V^2}{2g}$

$f = 64/Re$ $C_f = 16/Re$ $Po = C_f Re = 16$

Re only determines transition; since, creeping flow and no inertia forces and shear[illegible] absent

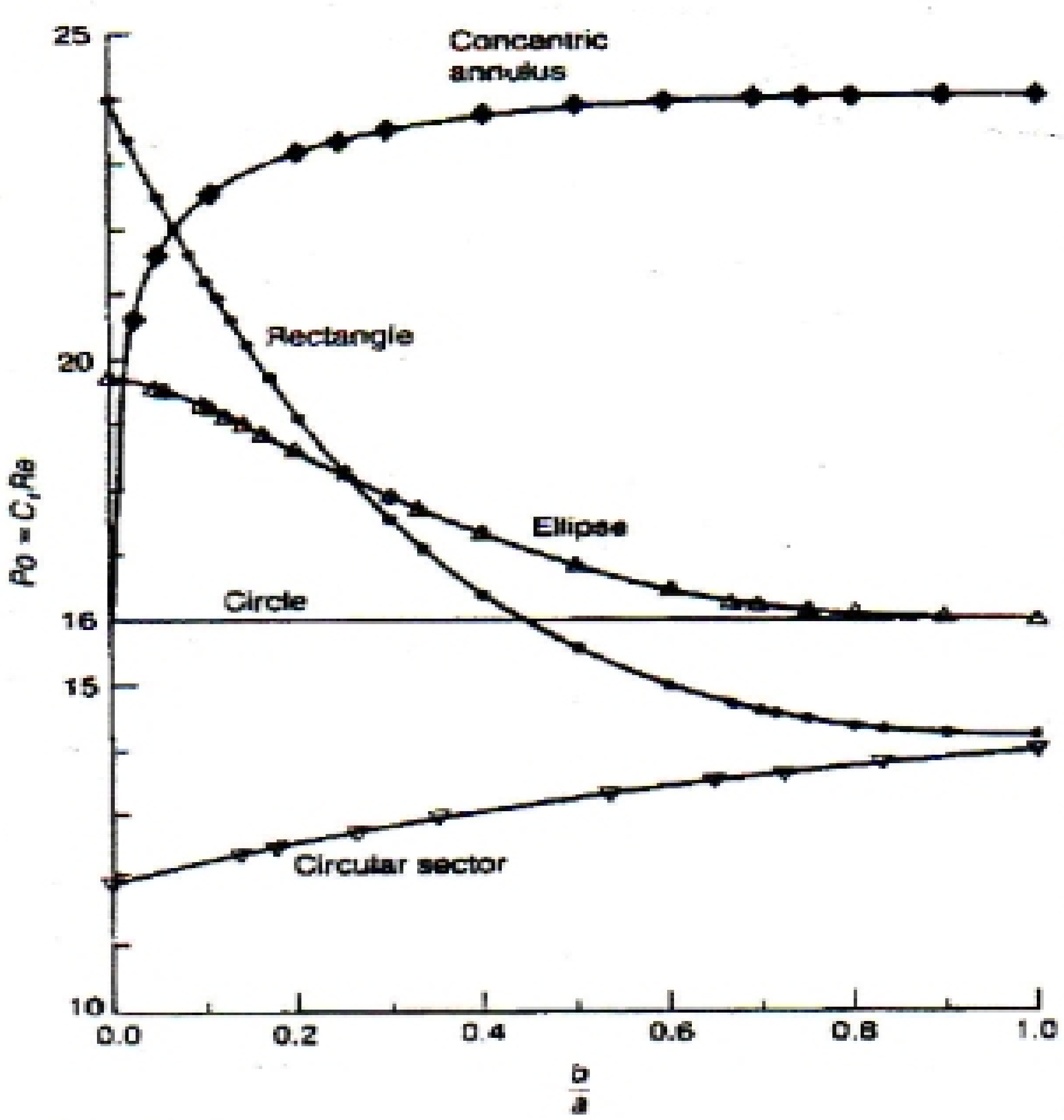

FIGURE 3-13
Comparison of Poiseuille numbers for various duct cross sections when Reynolds number is scaled by the hydraulic diameter. [*Numerical data taken from Shah and London (1978).*]

turbulent flow

Kolmogorov scales:

$$\varepsilon = \frac{u_0^2}{\tau_0} = \frac{u_0^3}{l_0}$$

$u_0^2 = k$ = kinetic energy

$l_0 = L_\delta$ = width of flow

ie size of largest eddy

dissipation = $\frac{d}{dt}$(KE) where $\frac{d(KE)}{dt}$ is from largest scales

ε occurs at smallest scales (energy cascade) at which turbulence is isotropic and has universal form

$\eta = (\nu^3/\varepsilon)^{1/4}$ length $\eta / l_0 = Re^{-3/4}$

$u_\eta = (\varepsilon \nu)^{1/4}$ velocity $u_\eta / u_0 = Re^{-1/4}$

$\tau_\eta = (\nu/\varepsilon)^{1/2}$ time $\tau_\eta / \tau_0 = Re^{-1/2}$

micro scale << large scale and range of scales increase Re power law