

continuity $\dot{m} = \int_A \rho \vec{V} \cdot \vec{n}\, dA = \rho\vec{V}A$ steady, 1-d flow

fluid shear $\tau = \mu \frac{du}{dy}$ wall shear, $\tau_w = \mu\left(\frac{du}{dy}\right)_{y=0}$

x-momentum $\sum F_x = \int_A \vec{V}_x \rho \vec{V} \cdot \vec{n}\, dA$ steady flow

Bernoulli $\frac{P}{\rho} + \frac{u^2}{2} + gZ = \text{constant}$ steady, incompressible, frictionless, work = 0

Reynolds number, $Re_L = \frac{\rho\, u\, L}{\mu}$

Pipe flow $\frac{P_1}{\rho g} + \frac{{u_1}^2}{2g} + Z_1 = \frac{P_2}{\rho g} + \frac{{u_2}^2}{2g} + Z_2 + h_f + h_m$

$h_f = \frac{fL}{D}\frac{\bar{u}^2}{2g}$ $f = \frac{64}{Re_D}$ laminar flow $h_m = K\frac{\bar{u}^2}{2g}$

Drag coefficient, $C_D = \frac{Drag}{\frac{1}{2}\rho u_\infty^2 A}$ Mach number, $M = \frac{u_\infty}{c}$ c = speed of sound $= \sqrt{kRT}$

$PV = mRT = n\bar{R}T$ Ideal gas ($T > 2^*T_{crit}$, $P < 10$ MPa) $u \approx u_f$ @ T; $v \approx v_f$ @ T Subcooled liquid

$\dot{Q} + \sum \dot{m}_i(h + \frac{\vec{V}^2}{2} + gZ)_i = \dot{W} + \sum \dot{m}_e(h + \frac{\vec{V}^2}{2} + gZ)_e + \frac{dE}{dt}$ First law for control volume

$q + h_1 + ½\vec{V}_1^{\,2} + gZ_1 = w + h_2 + ½\vec{V}_2^{\,2} + gZ_2$ Single-inlet, single-exit, steady flow

$w = -\int v\, dP - ½(\vec{V}_2^{\,2} - \vec{V}_1^{\,2}) - g(Z_2 - Z_1)$ Reversible, steady flow