Unit Conversions:

1 slug = 14.594 kg
1 ft = 0.305 m
1 K = 1.8 °R
°C + 273 = K
1 lbf = 1 sl · ft/s² = 4.448 N
1 Pa = 1 N/m²
1 N = 1 kg · m/s²

Spec. Grav.:

$SG_{gas} = \frac{\rho_{gas}}{\rho_{air}}$

$SG_{liq} = \frac{\rho_{liq}}{\rho_{H_2O}}$

Reynolds no.:

$Re = \frac{\rho V L}{\mu} = \frac{VL}{\nu}$

↳ V, velocity
L, length, i.e. width
μ, viscosity

Long. shear:

$\tau = \mu \frac{V}{h}$

↳ h, H, length
Ω, angular velocity
r, radius

Rot. shear:

$\tau = \mu \frac{\Omega r}{H}$

← flow between plates

Hydrostatic pressure:

liquid: $P_2 - P_1 = \underbrace{-\rho g(z_2 - z_1)}_{\text{linear}}$

gas: $P(z) = P_a\left(1 - \frac{B \cdot z}{T_0}\right)^{5.26}$

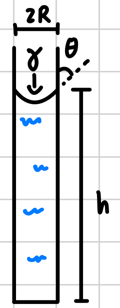
↳ P_a, atm. pressure
T_0, 288.16 K
B, 0.0065 K

Meniscus and capillary tube (< 1mm):

$\rho g \pi R^2 \cdot h = 2\pi R \gamma \cdot \cos\theta$

$h = \frac{2\gamma\cos\theta}{\rho g R}$

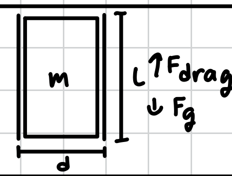
↳ γ, surface tension
θ, meniscus angle
r, radius
g, gravity
ρ, density



Force Balance:

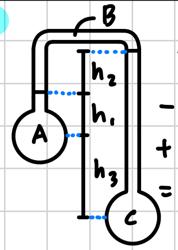
$F_{drag} = \tau_{wall} A_{wall} = F_g$
$= \mu \frac{V}{C_r} \cdot \pi D L$

↳ C_r, radius clearance



Barometer Qs:

$P_{Tot} = P_a + P_1 + P_2 + P_3 + P_4 + P_5$



$P_A - P_A(h_1) - P_B(h_2) + P_C(h_1 + h_2 + h_3) = P_C$

Note: $P = \rho g h$ Pa $\qquad \gamma = \rho g$ N/m³

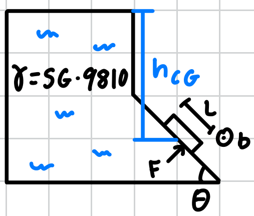
Force on surface:

$F = P_{CG} A = \gamma h_{CG} A$

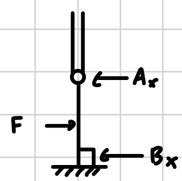
$Y_{CP} = -\frac{I_{xx}\sin\theta}{h_{cg} A}$

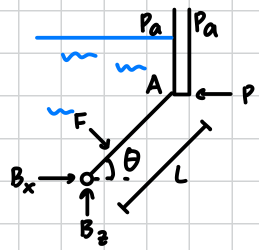
$I_{xx} = \frac{bL^3}{12}$

$X = \frac{1}{2}L - Y_{CP}$



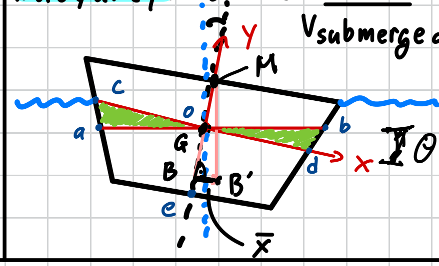
Reactions:





Buoyancy:

$\theta, \overline{MG} = \frac{I_0}{V_{submerged}} - \overline{GB}$



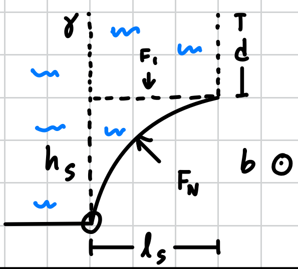
Force on curved surface:

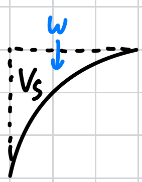
$F_N = \sqrt{F_x^2 + F_y^2}$

$F_x = \gamma h_c A = \gamma(d + \frac{1}{2}h_s)(b \cdot h_s)$

$F_y = F_1 + W = \gamma(d b l_s) + \gamma(V_s)$

$\theta = \tan^{-1}\left(\frac{F_y}{F_x}\right)$





Solid mechanics:

Thin-wall cyl: $\frac{Pr}{t}$

Longitudinal: $\frac{Pr}{2t}$

Shear: $\tau = \frac{F}{A}$

Torque: $T = F \cdot r$

Reynold's TT:

General:

$\frac{dB}{dt} = \frac{d}{dt}\int_{CV} b\rho \, d\hat{v} + \int_{CS} \rho b(\vec{V} \cdot \cancel{\vec{n}}) \, dA = 0$

Cons. of mass (B = m, b = 1):

Incompressible:

$\Sigma Q_{in} = \Sigma Q_{out}$

$\Sigma(A_i V_i)_{in} = \Sigma(A_i V_i)_{out}$

Fixed, steady:

$\Sigma(\dot{m}_i)_{in} = \Sigma(\dot{m}_i)_{out}$

$\Sigma(\rho_i A_i V_i)_{in} = \Sigma(\rho_i A_i V_i)_{out}$

Cons. of lin. mom. ($B = m\vec{V}$, $b = \vec{V}$)

1D in/out-lets:

$\Sigma F = -F + \Sigma(\dot{m}_i V_i)_{out} - \Sigma(\dot{m}_i V_i)_{in}$

↳ $\dot{m} = \rho A V = \frac{\dot{w}}{g}$, $Q = AV = \frac{\dot{w}}{\rho g}$

usually gauge

↳ $\Sigma F = -F + P_1 A_1 + P_2 A_2 = \dot{m}_2 V_2 - \dot{m}_1 V_1$

Bernoulli eqn:

$\frac{P_1}{\rho} + \frac{1}{2}V_1^2 + g z_1 = \frac{P_2}{\rho} + \frac{1}{2}V_2^2 + g z_2$

Cons. of ang. mom. ($B = H = \int \vec{r} \times \vec{v} \, dm$, $b = \vec{r} \times \vec{v}$):

General:

$\Sigma M_0 = \frac{d}{dt}\left[\int_{CV} (\vec{r} \times \vec{v}) \rho \, dV\right] + \int_{CS} (\vec{r} \times \vec{v}) \rho (\vec{V} \cdot n) \, dA$

1D in/out-lets:

$\int_{CS} (\vec{r} \times \vec{v})(\vec{v} \cdot n) \, dA = \Sigma(\vec{r} \times \vec{v})_{out} \dot{m}_{out} - \Sigma(\vec{r} \times \vec{v})_{in} \dot{m}_{in}$

Energy eqn ($B = E$, $b = e = \frac{dE}{dM}$):

General:

$\dot{Q} - \dot{W}_s - \dot{W}_v = \frac{d}{dt}\left[\int_{CV} (\hat{u} + \frac{1}{2}\vec{v}^2 + gz) \rho \, dv\right] + \int_{CS} (\hat{h} + \frac{1}{2}\vec{V}^2 + gz) \rho (\vec{V} \cdot n) \, dA$

Steady flow:

$\left(\frac{P}{\gamma} + \frac{V^2}{2g} + z\right)_{in} = \left(\frac{P}{\gamma} + \frac{V^2}{2g} + z\right)_{out} + \underbrace{h_{fric} - h_{pump} + h_{turbine}}_{\text{head (length, m)}}$

Buckingham π thm.:

Step 1: List the parameters in the problem and count their total number *n*.

Step 2: List the primary dimensions of each of the *n* parameters.

Step 3: Set the *reduction j* as the number of primary dimensions. Calculate *k*, the expected number of Π's,
$k = n - j$

Step 4: Choose *j repeating parameters.*

Step 5: Construct the *k* Π's, and manipulate as necessary.

Step 6: Write the final functional relationship and check your algebra.

Ex π-theorem

Want $\tau = f(U, \delta, u', \rho, dp/dx)$
$\quad$ 1 $\quad$ 2 3 4 5 6 $\rightarrow n = 6$

Setup MTL:

τ	U	δ	u'	ρ	dp/dx
$ML^{-1}T^{-2}$	LT^{-1}	L	LT^{-1}	ML^{-3}	$ML^{-2}T^{-2}$

$\leftarrow \frac{p}{L} = \frac{ML^{-1}T^{-2}}{L}$

$\rightarrow M, L, T \rightarrow j = 3$

Now find $k = n - j = 6 - 3$ possible π_k's given (ρ, U, δ) as rep. var. If not given, choose a length, velocity, and a mass/density. Remember our fxn will be $\pi_1 = f(\pi_2, \pi_3)$

$\pi_1 = \rho^a U^b \delta^c \tau = M^0 L^0 T^0 == (ML^{-3})^a (LT^{-1})^b (L)^c (ML^{-1}T^{-2})$

$M: 0 = a + 1$

$L: 0 = -3a + b + c - 1$

$T: 0 = -b - 2$

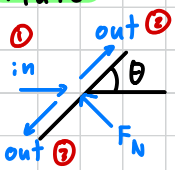
$a = -1,\; c = 0,\; b = -2$

$\pi_1 = \rho^{-1} U^{-2} \delta^0 \tau = \frac{\tau}{\rho U^2}$

Repeat for $\pi_2 = \rho^a U^b \delta^c u'$ and $\pi_3 = \rho^a U^b \delta^c \frac{dp}{dx}$ to write final answer: $\boxed{\frac{\tau}{\rho U^2} = f\left(\frac{u'}{U}, \frac{\delta\, dp}{\rho U^2 dx}\right)}$

Ex Cons. of lin. mom.

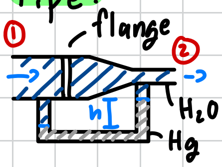
Plate:



$\Sigma F = -F + \dot{m}_2 V_2 + \dot{m}_3(-V_3) - \dot{m}_1 V_1$

$F_N = \dot{m}_2 V_2 + \dot{m}_3(-V_3) - \dot{m}_1 V_1 \cos\theta$

Pipe:



$P_1 - P_2 = \Delta\gamma h = (\gamma_{Hg} - \gamma_{H_2O})h = P_{gage}$ or P_1

$Q_1 = Q_2 = A_1 V_1 = A_2 V_2$ since $\dot{m}_1 = \dot{m}_2$

$\Sigma F = -F_{flange} + P_1 A_1 = \dot{m} V_{out} - \dot{m} V_{in}$
$= \dot{m}(V_{out} - V_{in})$

Cart: