Fluid Mechanics Exam 1 Review

Units, etc

- Make sure units cancel out properly, don't just add them at the end
- Avoid making calculations with inches, gallons, minutes etc

Know about fluid properties, where to find them (ρ, γ, SG, $\mu(T)$, σ)

$$\gamma = \rho g \qquad \rho = \frac{p}{RT} \qquad \tau = \mu \frac{dv}{dy} \qquad \nu = \frac{\mu}{\rho} \qquad h = \frac{4\sigma}{\gamma d}$$

Calculate shear stress and shear force

Pressure & Pressure Head

Differential Equation of Hydrostatics: $\frac{dp}{dz} = -\rho g = -\gamma \qquad \frac{dp}{dx} = 0$

For incompressible fluids (liquids), γ is a constant, so can directly integrate:

$\Delta p = \gamma \, \Delta z$ (no sign here, so remember that p always increases downward)

For compressible fluids (air), can *not* directly integrate since $\rho = f(p,T)$

$$p(z) = p_o \left(\frac{T_o - \alpha(z - z_o)}{T_o} \right)^{\frac{g}{\alpha R}}$$ α = ~ 5.9 ºC/km = 5.9 K/km = -0.0059 K/m

Manometers: use $\Delta p = \gamma \, \Delta z$, start at location of known p, work along a path towards unknown p, adding $\gamma\Delta z$ downward, subtracting $\gamma\Delta z$ upward.

Gage vs. Absolute Pressure:

$p_{abs} = p_g + p_{atm}$ $\qquad$ p_{atm} ~ 14.7 psi or 101.3 kPa

p_{abs} is always > 0, p_g can be + or - $\qquad$ Negative p_g is also termed a “vacuum”

Pressures sometimes expressed as “pressure head” e.g., 29.9” of Hg = p/γ_{Hg}

Hydrostatic forces on planar (flat) surfaces

Pressure forces are always *perpendicular* to a surface submerged in a static fluid

- Calculate $F = \gamma h_c A$, where h_c is the vertical depth to the centroid of the area of interest (*don't* use 1/3 and 2/3 when calculating magnitude!)

- Determine the location (y_{cp}) of F, using $y_{cp} = I_c/(y_c A) + y_c$,

- y is the distance along slope ($h_c = y_c \sin\alpha$)

Hydrostatic forces on curved surfaces

Project the curved surface onto the vertical and horizontal planes, and draw the pressure forces acting on the projected surfaces. Include weight of the CV in vertical force. Then calc the horizontal and vertical reaction forces using same methods as for planar surfaces.

Resultant force on a curved surface always acts through the center of curvature

Can also use buoyancy to determine the vertical component of force if object is displacing fluid.

Buoyancy = upward force on submerged object due to pressure increase with depth

F_b = W of displaced fluid = γ_{fl} * Vol of displaced fluid

Don't forget to include both W and F_b when calculating forces on immersed objects

Flow and Average Velocity

$$V = \frac{1}{A}\int_A v\,dA \qquad Q = \int_A v\,dA = V A$$

Determine V, Q based on a given velocity profile using integration

Continuity Equation (Conservation of Mass)

$$\frac{d(\rho V)_{CV}}{dt} = (\rho Q)_{in} - (\rho Q)_{out}$$

Steady flow: $mass\ flow = const. = (\rho Q)_{in} = (\rho Q)_{out}$

For liquids, ρ is constant so $(VA)_{in} = (VA)_{out} = Q$

Unsteady, incompressible flow (e.g. draining tank):

$$\frac{dV_{CV}}{dt} = (Q)_{in} - (Q)_{out}$$

express both sides of the equation as function of *h*:

$$A\frac{dh}{dt} = (Q)_{in} - (Q(h))_{out}$$

solve by separating *h* and *t* and integrating