MAAE 2300B-Fluids I

Conversions:

Density: $1\ lbm/ft^3 = 16.018\ kg/m^3$ **Specific Vol:** $1\ ft^3/lbm = 0.062428\ m^3/kg$

Volume:
$1\ ft^3 = 0.028317\ m^3$
$1\ in^3 = 16.387\ cm^3$
$1\ US\ gal = 231\ in^3 = 0.00379\ m^3$
$0.0353\ ft^3 = 1\ L = 0.001\ m^3$

Mass:
$1\ lbm = 0.454\ kg$
$1\ slug = 32.174$ $slug = 14.6\ kg$
$1\ ton = 2000\ lbm$ $1\ tonne = 1000\ kg$

Pressure:
$1\ psi = 6.895\ kPa$
$1\ bar = 100\ kPa$
$1\ atm = 101.325\ kPa$

Force:
$1\ lbf = 4.448\ N$

Energy:
$1\ btu = 778\ lbf\,ft = 1.055\ kJ$
$1\ lbf\,ft = 1.356\ J$

Velocity:
$1\ ft/s = 0.3048\ m/s$
$1\ mph = 1.467\ ft/s$

Temperature:
$T(°F) = \left(\frac{9}{5}\right)\cdot T(°C) + 32$ $T(K) = T(°C) + 273$
$T(°R) = T(°F) + 459.67$

Theory Pascal's Law: A pressure change occurring anywhere in a confined incompressible fluid is transmitted throughout the fluid such that the same changes occur everywhere.

Properties: Extensive: Depends on size. Intensive: Can exist at any point in space

State Relations for liquid: → Liquids are nearly incompressible and have a single reasonably constant heat. → The density of liquid usually decreases slightly with temperature and increases moderately with press.

Stress & Pressure: → A solid can resist a shear stress by static deformation; a fluid cannot. → Any shear stress applied to a fluid, no matter how small, will result in motion. → The fluid moves and deforms continously as long as the shear stress applied.

No-Slip Condition: → At solid bondaries, the solid and fluid molecules interlock, and there is no relative velocity between the two. Exceptions are for conditions at very low pressures, such as outer space.

Surface tension: → Molecules deep within the liquid repel eachother because of their close packing. → Molecules at the surface are less dense and attract eachother. Since half of their neighbours are missing, the mechanical effect is that the surface is in tension. → Acts in the plane of the liquid surface.

Flow near a bounding surface: → significant velocity gradient → significant shear stress. → Reffered as a boundary layer.

Flow far from a bounding surface: → Neglible velocity gradient → Neglible shear stress. → significant inertia effects. → Reffered as free stream or inviscid flow.

Laminar Flow & Turbulent Flow: → Very Low Re (Laminar Flow): → Indicates viscous creeping motion. → Inertia effects are negligible. Moderate Re (Transition Flow): → Implies a smoothly varying laminar flow. High Re (Turbulent Flow): → slowly varying in the time-mean but has superimposed strong random high-frequency fluctuations.

Streamlines: → Are everywhere tangent to the local velocity vector.

Streamtube: → Is formed by a closed collection of stream lines.

Effects of acceleration on pressure distribution: → The motion within the fluid would eventually cease. → Fluid particles would be in approximately rigid body acceleration.

Reynold's Transport Theorem: → To convert a system analysis to control volume analysis, we must convert our math to apply to a specific region rather than to individual masses.

Systems & Control Volume: → The system is a fixed quantity of mass. → If the surroundings exert a net force on a system, Newton's second law states that the mass will begin to accelerate. → If the surroundings exert a net moment about the centre of mass of a system, there will be a rotation effect. → If heat is added to a system, or work is done by a system, the system energy must change according to the energy relation.

Applicability of Bernoulli's Equation: → steady flow → Incompressible flow. → Frictionless flow. → Flow along a singular streamline. → No shaft work & heat transfer between 1 & 2.

Turbines: → Inflow is used for radial turbines. → Outflow is used for radial compressors. → Turbines want to extract as small angular momentum as possible. → Compressors do the opposite.

Boundary Layers: → present on all bodies, comprise only a small portion of the entire flow region affected by the presence of a body.

Flow Seperation: → Flow over streamlined bodies tend to follow the body contour but flow over bluff bodies seperates early from the contour.

Buoyancy: → A body immersed in a fluid experiences a vertical buoyant force equal to the weight of the fluid it moves.

Equations

Volumetric Flow Rate:
$Q = VA$

Mass flow rate
$\dot{m} = \rho VA$

Thermo Prop.
$P = \rho RT$
$R = C_p - C_v$
$C_v = R/k-1$
$C_p = kR/k-1$
$k = C_p/C_v$

State Relations for liquids:
$\frac{P}{P_a} = (B+1)\left(\frac{\rho}{\rho_a}\right)^n - B$

Specific Weight
$\gamma = \rho g$

Specific gravity
$SG = \rho/\rho_{ref}$

Pressure: $p = \rho g h$

Kinematic Visc.
$\nu = \mu/\rho$

Newtonian Fluid
$\tau = \mu(du/dy)$

Reynolds Number
$Re = \rho VL/\mu$

Pressure Gradient
$\nabla p = \rho(\vec{g} - \vec{a}) + \mu\nabla^2\vec{V}$

Hydrostatic Pressure distribution ($\rho = C$)
$p_2 - p_1 = -\rho g(z_2 - z_1)$

Hydrostatic Pressure distribution ($\rho \neq C$)
$p = C(T_0 - \lambda)^{g/R\lambda}$

Barometer
$h = P_a/\gamma_m$
$P_{abs} = P_g + P_{atm}$
$P_A - P_B = (P_A - P_1) + (P_1 - P_2) + (P_2 - P_B)$

Acc. Pressure distribution

Case A
$\Sigma F = ma_x$
$pdA - \left(p + \frac{\partial p}{\partial x}dx\right)dA = (\rho dA dx)a_x$
$\frac{\partial P}{\partial x} = -\rho a_x$ $\frac{\partial P}{\partial y} = \rho a_y$
$\frac{\partial P}{\partial z} = -\rho(a_z + g)$

Case B
$\frac{\partial P}{\partial r} = \rho\omega^2 r$

Reynolds Transport Theorem
$B_{sys} = \int \beta\rho\, dVol$

Conservation of mass
$\Sigma\dot{m}_e = \Sigma\dot{m}_i$

Linear Momentum
$P_{sys} = mv$
$\Sigma F = P_2 - P_1$

Stag. Pressure
$P_0 = p + \frac{1}{2}\rho V^2$

Energy Grade line:
$h_0 = z + p/\gamma + V^2/2g$

Hydraulic Grade line
$(z + p/\gamma)$

Bernoulli's
$P_1 + \frac{1}{2}\rho V_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho V_2^2 + \rho g y_2$

Bell mouth Intake
$P_{atm} = P_b + \frac{1}{2}\rho V_B^2$
$V_B = \sqrt{2(P_{atm} - P_B)/\rho}$

Orifice
$C_c = A_v/A_o$
$C_v = V/V_i$
$C_D = Q/Q_i$
$V = \sqrt{2gh}$

Venturi
$Q = C_v A_2\left(\frac{2(p_1 - p_2)}{\rho\left(1 - \frac{A_2^2}{A_1^2}\right)}\right)^{1/2}$

Thin Plate Orifice
$Q = C_D A_o\left(\frac{2(P_1 - P_2)}{\rho\left(1 - \frac{C_c^2 A_o^2}{A_i^2}\right)}\right)^{1/2}$

Angular Momentum
$\Sigma M = \dot{m}_2 r_2 V_2 - \dot{m}_1 r_1 V_1$

Torque
$T_{shaft} = \dot{m}(r_2 V_2 - r_1 V_1)$

Steady-Flow Energy
$\dot{m}\left(\frac{P_1}{\rho} + \frac{V_1^2}{2} + gy_1\right) + \frac{dW}{dt} = \dot{m}\left(\frac{P_2}{\rho} + \frac{V_2^2}{2} + gy_2\right)$

Head Friction
$h_u = z_1 + \frac{V_1^2}{2g} + \frac{P_1}{\rho g}$
$h_d = z_2 + \frac{V_2^2}{2g} + \frac{P_2}{\rho g}$
$h_f = h_u - h_d$

Pump Work
$\dot{W}_f = \dot{m}gh_p$
$\dot{W}_p = \frac{\dot{W}_f}{\eta_p}$

Hydrostatic Forces

Plane Surface
$F = PA = \rho g h A$

Curved Surface
$F_h = F_H$ $F_v = W_{air} + W_1 + W_2$

Buoyancy

Submerged
$F_B = F_{v2} - F_{v1}$
$F_B = \int(p_2 - p_1)dA = -\gamma\int(z_2 - z_1)dA$

Floating
$F_B = \gamma \cdot$ displaced volume

Stresses in Pipes & Vessels
$\sigma_T = PD/2t$ $\sigma_x = PD/4t$