EQUATION SHEET

Tuesday, October 18, 2022 1:01 AM

- $\mu_{AIR} = 1.81 \times 10^{-5}$ [Pa·s] @ 15°C | $\rho_{AIR} = 1.2$ [kg/m³] @ 20°C
- $\mu_{WATER} = 1.00 \times 10^{-3}$ [Pa·s] @ 20°C | $\rho_{WATER} = 1000$ [kg/m³]
- $\tau_{SHEAR\ STRESS} = \mu\left(\frac{du}{dy}\right)$
- SUTHERLAND'S LAW

$$\frac{\mu_?}{\mu_{REF}} = \left(\frac{T_?}{T_{REF}}\right)^{3/2} \cdot \left(\frac{T_{REF} + S}{T_? + S}\right)$$

  - $\mu_{REF} = 1.716 \times 10^{-5}$ [Pa·s] @ $T_{REF} = 273.15$ [K]
  - $S = 110.4$ [K]
- SPECIFIC HEAT CAPACITIES

  $C_{P_{AIR}} = 1005$ [J/kg/K] | $C_{P_{STEAM}} = 1.87$ [kJ/kg/K]

  $C_{V_{AIR}} = 718$ [J/kg/K] | $C_{V_{STEAM}} = 1.41$ [kJ/kg/K]

  $C_{P_{WATER}} = 4.18$ [J/kg/K]
- INCOMPRESSIBLE FLOW : $\frac{\rho}{\rho_{REF}} < 4\% - 5\%$ → $C_p = 1$ FOR INCOMP. @ STAGNATION POINT
- GIBB'S PHASE RULE : $F = C + 2 - \Pi$
  - F: # OF INDEPENDENT STATE VARIABLES
  - P: # OF PHASES PRESENT (SOLID/LIQUID/GAS)
  - C: # OF COMPONENTS (DIFFERENT FLUIDS) → AIR HAS 2 PRIMARY COMPONENTS
- STATE EQUATIONS (ONLY APPLICABLE @ STATES)
  - IDEAL GAS
    - → $P\forall = nRT$, n = # OF MOLES, $R_{GAS} = 8.314$ (J/MOLE/K)
    - → $P\forall = mRT$, m = MASS, $R = 287$ (kJ/kg/K)
  - $P = \rho RT$
    - → $R = \frac{R_{GAS}}{(\text{MOLAR WEIGHT})}$
      - MOLAR WEIGHT = $\sum$ [(% MAKE UP) × (INDIVIDUAL MOLAR WEIGHT)]
- SPECIFIC HEAT CAPACITIES
  - RATIOS $\gamma = \frac{C_P}{C_V}$
    - → MONOTOMIC GAS : $\gamma = \frac{5}{3} = 1.67$
    - → DIATOMIC GAS : $\gamma = \frac{7}{5} = 1.4$
    - → TRIATOMIC GAS : $\gamma \approx 1.3$
- ENTHALPY : $h = u + P\forall$
  - $h = C_p T$, $u = C_v T$, $P\forall = R_{GAS} T$
  - $C_p - C_v = R_{GAS}$ (ONLY FOR IDEAL GAS)
- DIMENSIONLESS NUMBERS
  - MACH NUMBER : $M = \frac{u}{c}$
    - → u : LOCAL FLOW VELOCITY
    - → C : SPEED OF SOUND IN MEDIUM = a

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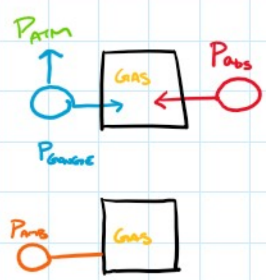
→ C: SPEED OF SOUND IN MEDIUM $= a$

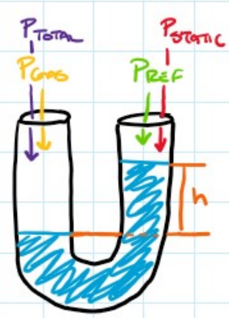
- REYNOLDS NUMBER: $R_e = \frac{\rho U L}{\mu}$
  → ρ: DENSITY OF THE FLUID
  → L: CHARACTERISTIC LINEAR DIMENSION
  → μ: VISCOSITY
- SPEED OF SOUND: $a = \sqrt{\gamma R T} = 340\ m/s$
  → $\gamma = \frac{C_p}{C_v}$
  → $C_p - C_v = R_{GAS}$
  · $C_p = \frac{(P_0 - P_\infty)}{\frac{1}{2}\rho U^2}$
- KNUDSEN NUMBER: $K_n = \frac{\lambda}{L}$
  → MEAN FREE PATH LENGTH: $\lambda = \frac{\mu\sqrt{\pi}}{\rho\sqrt{2RT}}$
  → RELATES MEAN DISTANCE TRAVELED BY MOLECULES TO AIRCRAFT LENGTH
- FROUDE NUMBER: $\frac{U}{\sqrt{gH}}$ → KINETIC E / → POTENTIAL E

· MOMENTUM
- FINAL MOMENTUM: $-mU$
- CHANGE IN MOMENTUM: $2mU$
- TIME BETWEEN COLLISIONS: $\frac{2L}{U}$
- $F = \frac{2mU}{\frac{2L}{U}} = \frac{mU^2}{L}$
  ↳ $P = \frac{F}{L^2} = \frac{mU^2}{L^3}$
- $E_{TRANS} = m\, C_{v_{TRA}} \Delta T$
  ↳ $C_{v_{TRA}} = 3/2\, R$

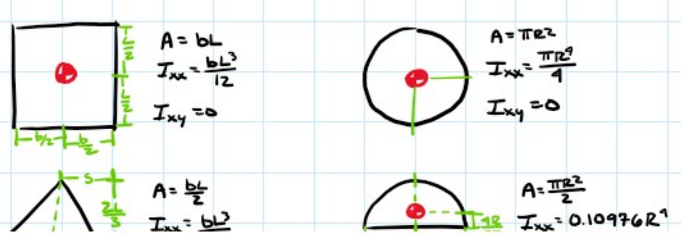
· PRESSURE: $P\forall = RT$



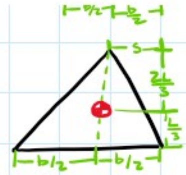
- ATMOSPHERIC PRESSURE: $dP = -\rho g\, dz$
  → $P = \int_{z_1}^{z_2} -\rho g\, dz$
  → $P = \rho R T$
- PRESSURE READINGS
  → ABSOLUTE (P_{ABS}): $P_{ABS} = \rho g h$
  → GAUGE (P_{GAUGE}): $P_{GAUGE} = P_{GAS} - P_{ATM}$
  → VACUUM (P_{VAC}): $P_{VAC} = P_{AMB} - P_{GAS}$
  → U-TUBE:
  · $h = \frac{P}{\rho g}$
  · $P_{GAS} = \rho g h + P_{REF}$
  · $P_{TOTAL} - P_{STATIC} = \frac{1}{2}\rho U^2 = \rho g h$



- PRESSURE FORCES: $F = P \cdot A$
- HYDROSTATIC PRESSURE: $\rho g h$
  → $y_{cp} = -\gamma \sin\theta \frac{I_{xx}}{P_{cg} A}$
  → $X_{cp} = -\gamma \sin\theta \frac{I_{xy}}{P_{cg} A}$



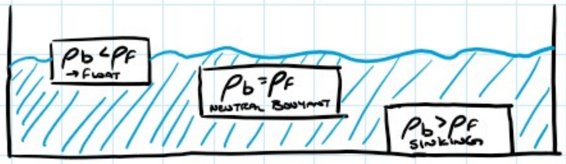
- → $y_{cp} = -\gamma \sin\theta \frac{I_{xx}}{p_{cg} A}$
- → $x_{cp} = -\gamma \sin\theta \frac{I_{xy}}{p_{cg} A}$
- → $\Sigma F = \int \rho g h \, dh$
- → $\Sigma M = 0$



$A = \frac{bL}{2}$, $I_{xx} = \frac{bL^3}{36}$, $I_{xy} = \frac{b(b-2s)L^2}{72}$

$A = \frac{\pi R^2}{2}$, $I_{xx} = 0.10976R^4$, $I_{xy} = 0$

- BOUYANCY: $F_B = \rho_F \, g \, \forall_{submerged}$
  - → $\rho_F g \forall_{sub} = \rho_b g \forall$
    - ↳ $\frac{\forall_{sub}}{\forall} = \frac{\rho_b}{\rho_F}$



  - → GASES LIGHTER THAN AIR: HYDROGEN, HELIUM, AIR
- DYNAMIC PRESSURE $= \frac{1}{2}\rho u^2$
- TOTAL PRESSURE OF FLOW: $P_0 = P + \frac{1}{2}\rho u^2 + \rho g z$
  - → $P_0 = P_{TOT}$: TOTAL PRESSURE
  - → P: STATIC PRESSURE, HAS TO BE MEASURED

- THEMODYNAMIC PROCESS: $dU = \int Q - \int W$
  - dU: INTERNAL ENERGY OF THE FLUID (TEMP.)
  - $\int Q$: HEAT ADDITION/REMOVAL
  - $\int W$: WORK ADDITION/REMOVAL
  - WORK FLOW: $W = \int_{\forall_1}^{\forall_2} P \, d\forall = \int_{P_1}^{P_2} \forall \, dP = d(P\forall) = P \, d\forall + \forall \, dP$
    - → $W = F \cdot \Delta x$
- NOZZEL FLOW: $F = \underbrace{(\rho_2 A_2 u_2^2 - \rho_1 A_1 u_1^2)}_{\text{FLOW ACCELERATION}} + \underbrace{(P_1 A_1 - P_2 A_2)}_{\text{PRESSURE ACCELERATION}}$
  - $\Sigma F = 0 = \dot{m}\forall + (P_1 A_1 - P_2 A_2)$
    - → $\Sigma F = (\rho_1 A_1 u_1) u_1 - (\rho_2 A_2 u_2) u_2 + (P_1 A_1 - P_2 A_2)$
- ENTHALPY
  - $H = U + P\forall$ [kJ]
    - → U: INTERNAL ENERGY
    - → $P\forall$: FLOW WORK
  - $h = u + P\forall = C_p T$ [kJ/kg]
- TOTAL ENERGY
  - KINETIC ENERGY: $\frac{1}{2}u^2$ [kJ/kg]
  - POTENTIAL ENERGY: gh [kJ/kg]
  - INTERNAL ENERGY: $h = u + P\forall$ [kJ/kg]
  - FLOW WORK:
    - → $h_0 = h + \frac{1}{2}u^2 + gz$
    - → $C_p T_0 = C_p T + \frac{1}{2}u^2 + gz$
  - TRANSLATIONAL KINETIC ENERGY $\propto \frac{P}{\rho} = \frac{1}{3}(u^2 + v^2 + w^2) = C^2$: MEAN SQUARED SPEED
- ISENTROPIC PROCESS
  - 1^{ST} LAW:
    - → CLOSED SYSTEM: $du = \int q - \int w$
    - → OPEN SYSTEM: $dh_0 = \int q - \int w_{shaft}$

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- $\frac{T_0}{T} = 1 + \frac{(\gamma-1)^2}{2} M^2$ (M = MACH NUMBER)

- ADIABATIC: $\int q = 0$ (ENSURED)

→ CONSTANT PRESSURE, EXPANSION/COMPRESSION

• Pv^{γ} = CONSTANT

- COMPRESSIBLE ($\frac{\rho}{\rho_{REC}}$ = 4%-5%) (CONSEQUENCE)

- REVERSIBLE ($\Delta s = 0$) (MEASURED)

→ CHANGE IN ENTROPY: $S = \frac{q}{T}$ [J/kgK]

→ $Tds = dh - vdP$

→ $\Delta s = C_p \ln\left(\frac{T_2}{T_1}\right) - R\ln\left(\frac{P_2}{P_1}\right)$

• ICE → STEAM

- PHASE CHANGE: $q = mH$ [J]

→ ENTHALPY FUSION: $H_{fus} = 333$ ENTHALPY VAPORIZATION: $H_{vap} = 2257$ [J/g]

- TEMP. CHANGE: $q = mC(T_2 - T_1)$ [J]

- OPEN SYSTEM (CONSTANT PRESSURE)

→ $C_{P_{WAT}} = 4.18$, $C_{P_{STEAM}} = 1.87$ [J/g]

- CLOSED SYSTEM (CONSTANT VOLUME)

→ $C_{V_{WAT}} = 4.18$, $C_{V_{STEAM}} = 1.41$ [J/g]