ES 202 Fluid and Thermal Systems
Exam 1 Review Session (1/11/03)

- Conservation and accounting principles:
    - mass (mass transfer; without generation)
    - momentum (mass transfer, force transfer; without generation)
        - classification of force:
            - body force
            - surface force
        - classification of surface force
            - normal force
            - shear force
    - energy (mass transfer, heat transfer, work transfer; without generation)
    - entropy (mass transfer, heat transfer; with generation)

- Objectives, design and modeling assumptions of steady state devices:
    - nozzle, diffuser
    - compressor, turbine
    - valve
    - heat exchanger

- Concept of pressure:
    - surface (normal) force
    - the only surface force when a fluid is at rest
    - same magnitude in all directions at a point

- Hydrostatic distribution of pressure:
    - does not vary in horizontal direction
    - increases linearly with depth (proportional to fluid density)

$$\frac{dP}{dy} = -\rho g$$

- Applications:
    - manometer
    - Pitot-static tube (flow speed measurement device)
    - multiple layer of fluids

- Force and moment calculations:
    - by first principles (direction integration on arbitrary shape)
    - by formula (for common surface shapes)

- Force analysis:
    - concept of centroid

$$F = P_c A$$

where P_c is the pressure at the geometric center (centroid) of submerged surface

- Moment analysis:
    - concept of line of action of resultant force, center of pressure
    - center of pressure always lies below the centroid

$$y_p = y_c + \underbrace{\frac{I_{xx,c}}{y_c A}}_{\text{offset}}$$

- Applications:
  - plane surfaces (vertical, horizontal and inclined)
  - curved surfaces
    - horizontal force component is the same regardless of shape as long as vertical projection of submerged surface is the same
    - vertical force component depends on the amount of fluid above/below the surface

- Origin of buoyancy force

- Quantification of buoyancy force (Archimedes' principle):
  - magnitude equals the weight of fluid displaced by submerged body
  - direction is always upward through the centroid of displaced volume

- Classification of fluid energy
  - mechanical energy
  - thermal energy

- Fundamental difference between them

- Components of mechanical energy
  - flow work (pressure energy)
  - kinetic energy
  - potential energy

- Mechanical energy balance
  - derived from general energy balance and extract out the mechanical energy term

$$\left(\frac{P}{\rho}+\frac{V^2}{2}+gz\right)_{\text{in}}+w_{\text{in}}=\left(\frac{P}{\rho}+\frac{V^2}{2}+gz\right)_{\text{out}}+w_{\text{out}}+\text{losses}$$

- Conservation of mechanical energy leads to Bernoulli's equation

$$P+\frac{\rho V^2}{2}+\rho gz=\text{constant}$$

  - interpreted as interchange of mechanical energy among its various components while keeping their sum to be constant

- Assumptions of Bernoulli's equation

- Strategy in problem solving
  - apply conservation of mass to relate unknown velocities
  - apply Bernoulli's equation to relate unknown pressures

- "Modified" Bernoulli's equation as a correction for viscous losses

$$\left(P+\frac{\rho V^2}{2}+\rho gz\right)_{\text{up}}=\left(P+\frac{\rho V^2}{2}+\rho gz\right)_{\text{down}}+\rho gh_L$$

- Concept of stagnation pressure
  - as a measure of total loss in a system

- Concept of viscosity as fluid friction

- Distinction between laminar and turbulent flow

- Estimation of total loss in system
    - major loss (due to friction on single straight pipe surface)

$$\Delta P = f \frac{L}{D} \frac{\rho V^2}{2}$$

        - introduction of friction factor as a non-dimensional group
        - functional dependency of friction factor
        - Moody diagram, Haaland formula, Colebrook formula
        - types of design problem
            - specify mass flow rate, determine pressure drop
            - specify pressure drop, determine mass flow rate (more difficult)
                - requires iterative solution

    - minor loss (due to friction in flow direction changes)
        - exit
        - entrance
        - connection
        - turn

$$\Delta P = K_L \frac{\rho V^2}{2}$$

        - introduction of loss coefficient, K_L, as a non-dimensional group
        - tabulation of empirically determined values of K_L

- Strategy to estimation of total loss
    - follow a "divide and conquer" approach
    - identify sources of loss
    - express individual major and/or minor loss
    - sum up <u>pressure difference</u> to get total loss (pressure differences are additive – telescoping effect)

- Pipe system
    - series configuration
        - same mass flow rate throughout
    - parallel configuration
        - same pressure drop across each pipe section

- Dimensional analysis
    - Buckingham Pi Theorem
    - representation of functional relationship in non-dimensional space