ME 326 - Intermediate Fluid Mechanics

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REVIEW OF FLUID MECHANICS (ES 330)

Goodarz Ahmadi

Department of Mechanical and Aeronautical Engineering
Clarkson University
Potsdam, NY 13699-5725

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REVIEW OF FLUID MECHANICS (ES 330)

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Outline

- Fluid Kinematics
  - Velocity
  - Acceleration
- Balance Laws
  - Mass
  - Momentum
  - Energy
- Bernoulli's Equation

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Fluid Kinematics

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Fluid Kinematics

Velocity (Vector)

$$\mathbf{V} = \frac{d\mathbf{x}(t)}{dt}$$

Components

$$u = \frac{dx(t)}{dt}$$

$$v = \frac{dy(t)}{dt}$$

$$w = \frac{dz(t)}{dt}$$

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Fluid Kinematics

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Acceleration

$$\mathbf{a} = \frac{d\mathbf{V}(x,y,z,t)}{dt} = \frac{\partial \mathbf{V}}{\partial t} + \frac{\partial \mathbf{V}}{\partial x}\frac{dx}{dt} + \frac{\partial \mathbf{V}}{\partial y}\frac{dy}{dt} + \frac{\partial \mathbf{V}}{\partial z}\frac{dz}{dt}$$

$$\mathbf{a} = \underbrace{\frac{d\mathbf{V}}{dt}}_{\text{Total Derivative}} = \underbrace{\frac{\partial \mathbf{V}}{\partial t}}_{\text{Transient Acceleration}} + \underbrace{u\frac{\partial \mathbf{V}}{\partial x} + v\frac{\partial \mathbf{V}}{\partial y} + w\frac{\partial \mathbf{V}}{\partial z}}_{\text{Convective Acceleration}}$$

$$\mathbf{a} = \frac{d\mathbf{V}}{dt} = \underbrace{\frac{\partial \mathbf{V}}{\partial t}}_{\text{Transient}} + \underbrace{\mathbf{V}\cdot\nabla\mathbf{V}}_{\text{Convective}}$$

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CONSERVATION LAWS (Steady Flows)

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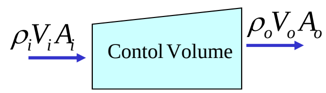
Mass



$$\sum_{\text{Outlets}} \dot{m}_o - \sum_{\text{Inlets}} \dot{m}_i = 0$$

$$\sum \text{Mass Out} = \sum \text{Mass In}$$

$$\sum_{\text{Outlets}} \rho_o V_o A_o - \sum_{\text{Inlets}} \rho_i V_i A_i = 0$$

$$\rho_1 V_1 A_1 = \rho_2 V_2 A_2$$

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CONSERVATION LAWS

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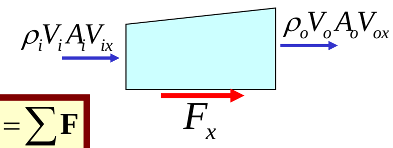
Momentum



$$\sum_{\text{Outlets}} \underbrace{\dot{m}_o \mathbf{V_o}}_{\text{Flux of momentum out of CV}} - \sum_{\text{Inlets}} \underbrace{\dot{m}_i \mathbf{V}_i}_{\text{Flux of momentum into CV}} = \sum \mathbf{F}$$

x-direction

$$\sum_{\text{Outlets}} \rho_o V_o A_o V_{ox} - \sum_{\text{Inlets}} \rho_i V_i A_i V_{ix} = \sum F_x$$

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CONSERVATION LAWS

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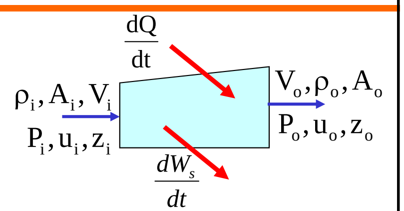
Energy



$$\sum \text{Energy Out} = \sum \text{Energy In}$$

$$\frac{dQ}{dt} + \sum_i \dot{m}_i \left(\frac{P_i}{\rho_i} + u_i + \frac{V_i^2}{2} + gz_i\right) = \frac{dW_s}{dt} + \sum_o \dot{m}_o \left(\frac{P_o}{\rho_o} + u_o + \frac{V_o^2}{2} + gz_o\right)$$

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Bernoulli's Equation

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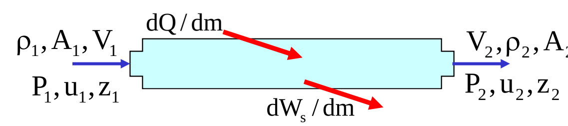

$$\frac{dQ}{dm} + \left(\frac{P_1}{\rho} + u_1 + \frac{V_1^2}{2} + gz_1\right) = \frac{dW_s}{dm} + \left(\frac{P_2}{\rho} + u_2 + \frac{V_2^2}{2} + gz_2\right) + \sum h_\ell + \sum h_m$$

$$h_\ell = f \frac{L}{D} \frac{V^2}{2} \qquad h_m = K \frac{V^2}{2}$$

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