해군사관학교
REPUBLIC OF KOREA NAVAL ACADEMY

유 체 역 학

『17. 가속도장』

해군사관학교 공학처
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Division of Engineering

Nov. 09th, 2021

Review – Fluid Mechanics

❖ Velocity Field

$$\mathbf{V} = u(x, y, z, t)\hat{\mathbf{i}} + v(x, y, z, t)\hat{\mathbf{j}} + w(x, y, z, t)\hat{\mathbf{k}}$$

❖ Eulerian and Lagrangian

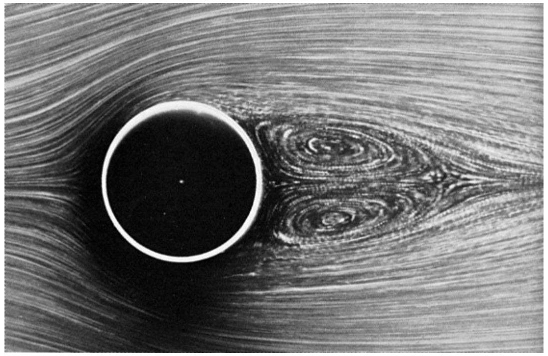
- Eulerian Method
- Lagrangian Method

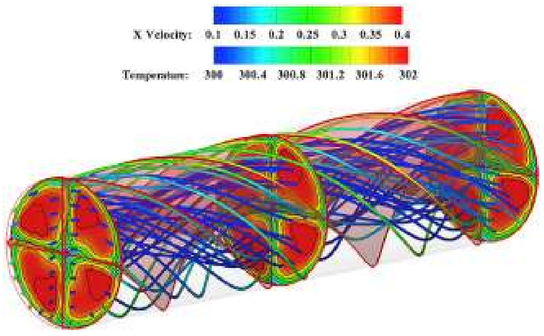
❖ One-, Two-, Three-Dimensional Flow

❖ Steady and Unsteady Flows

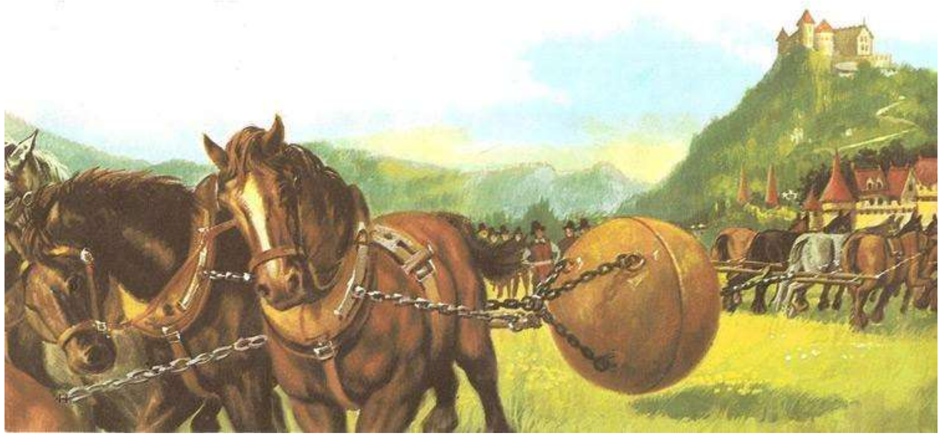
❖ Laminar and Turbulent Flows

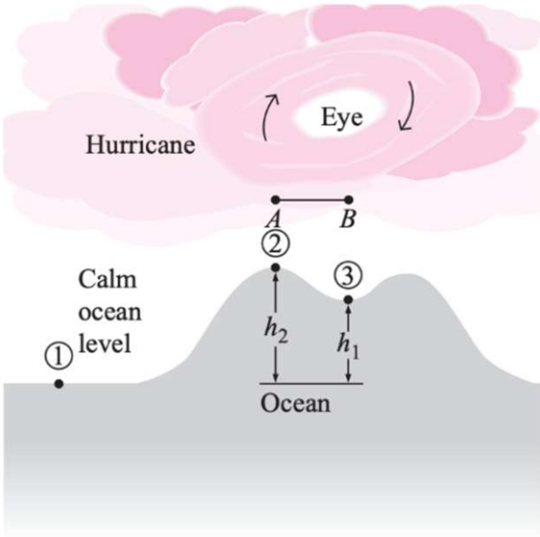
❖ Streamlines, Streaklines, and Pathline

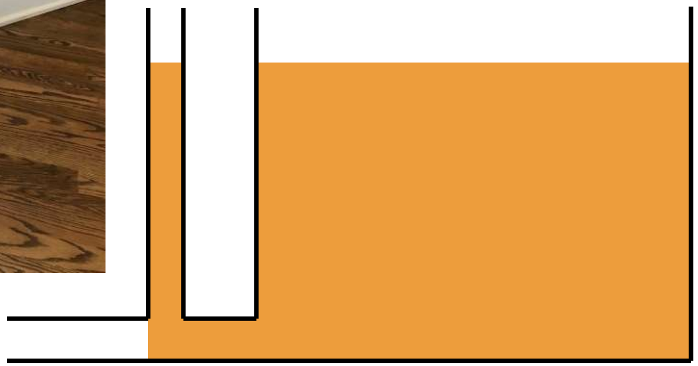




Review – Fluid Mechanics







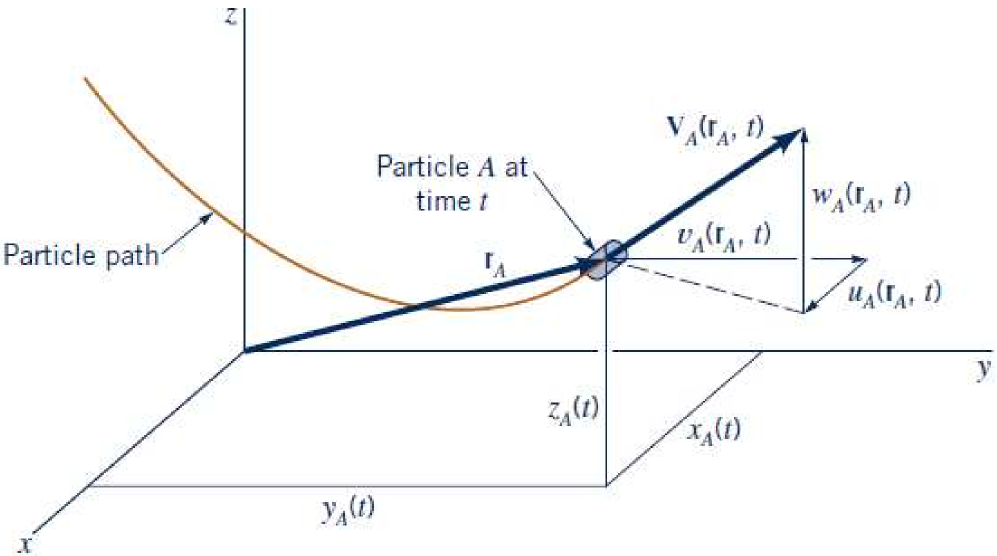
The Acceleration Field

❖ **Eulerian Description**

❖ **The Material Derivative**

$$\mathbf{V}_A = \mathbf{V}_A(\mathbf{r}_A, t) = \mathbf{V}_A[x_A(t), y_A(t), z_A(t), t]$$

$$\mathbf{a}_A(t) = \frac{d\mathbf{V}_A}{dt} = \frac{\partial \mathbf{V}_A}{\partial t} + \frac{\partial \mathbf{V}_A}{\partial x}\frac{dx_A}{dt} + \frac{\partial \mathbf{V}_A}{\partial y}\frac{dy_A}{dt} + \frac{\partial \mathbf{V}_A}{\partial z}\frac{dz_A}{dt}$$



$$\mathbf{a}_A = \frac{\partial \mathbf{V}_A}{\partial t} + u_A\frac{\partial \mathbf{V}_A}{\partial x} + v_A\frac{\partial \mathbf{V}_A}{\partial y} + w_A\frac{\partial \mathbf{V}_A}{\partial z}$$

$$\frac{D(\ )}{Dt} \equiv \frac{\partial(\ )}{\partial t} + u\frac{\partial(\ )}{\partial x} + v\frac{\partial(\ )}{\partial y} + w\frac{\partial(\ )}{\partial z}$$

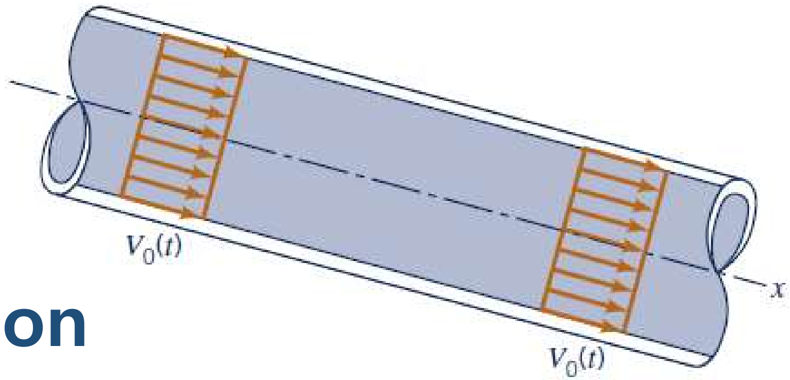
$$\frac{D(\ )}{Dt} = \frac{\partial(\ )}{\partial t} + (\mathbf{V}\cdot\nabla)(\ )$$

Material Derivative – Temperature

Unsteady Effects / Convective Effects

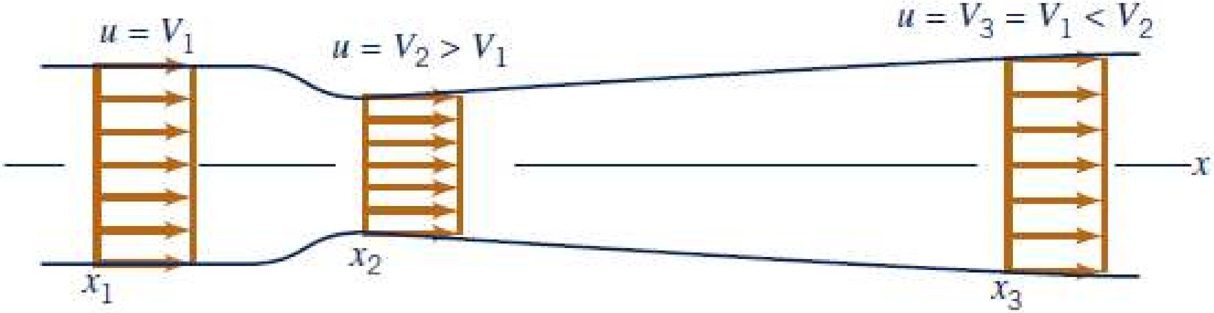
❖ Unsteady Effects

- ❖ $[\partial(\ )/\partial t]$ represents the effects of the unsteadiness
- ❖ $\partial \mathbf{V}/\partial t$: Local Acceleration
- ❖ Uniform flow in a constant diameter pipe



❖ Convective Effects

- ❖ $(\mathbf{V} \cdot \nabla)\mathbf{V}$: Convective Acceleration
- ❖ Uniform, Steady flow in a variable area pipe



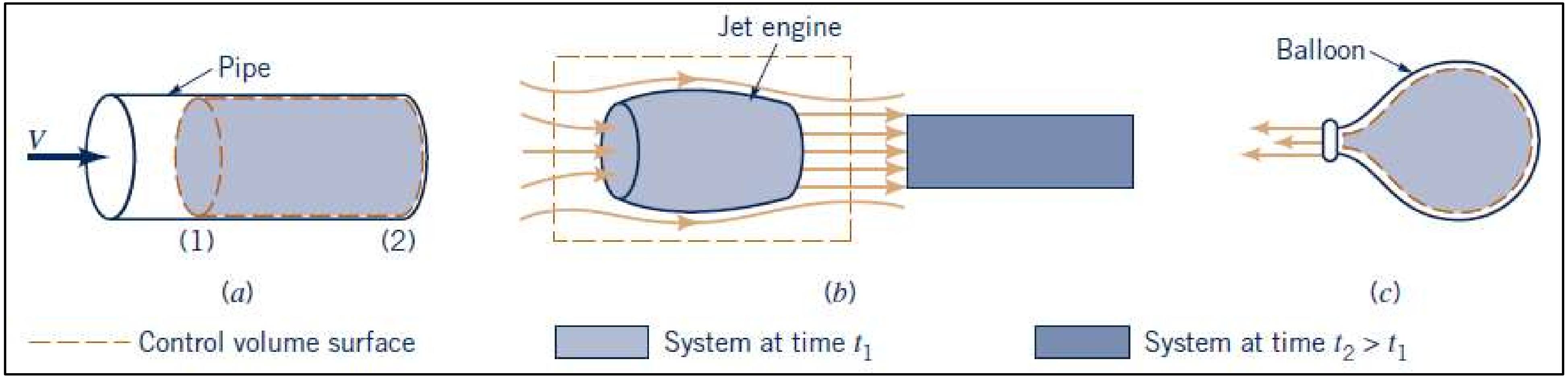
System & Control Volume

❖ System

- Collection of matter of fixed identity
  - Always the same atoms or fluid particles

❖ Control Volume

- Volume in space through which fluid may flow
  - Independent of mass



The Reynolds Transport Theorem

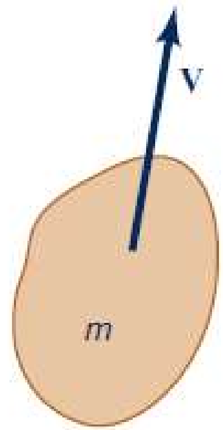
❖ **An analytical tool to shift from one representation to the other**

- **B : Any Fluid Parameter**
- **b : amount of that parameter per unit ma**

$$B_{\text{sys}} = \lim_{\delta V \to 0} \sum_i b_i (\rho_i \, \delta V_i) = \int_{\text{sys}} \rho b \, dV$$

$$\frac{dB_{\text{sys}}}{dt} = \frac{d\left(\int_{\text{sys}} \rho b \, dV\right)}{dt}$$

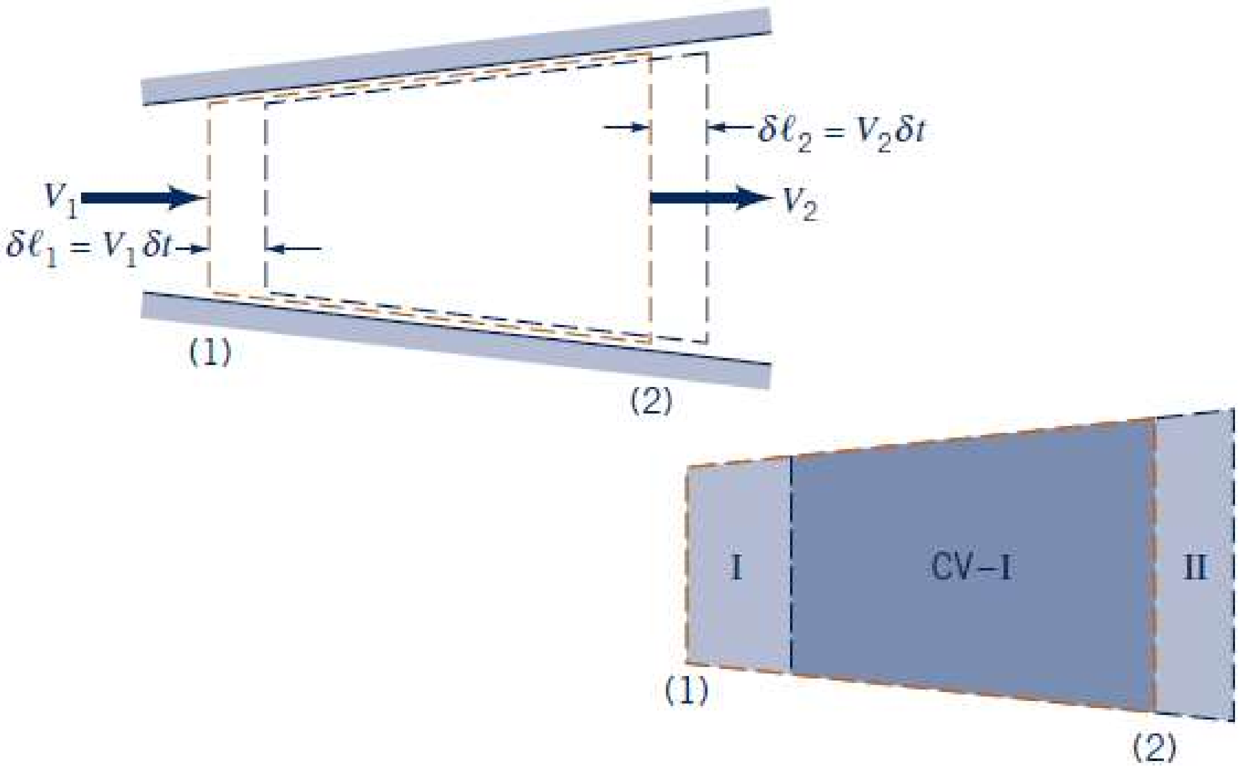
$$\frac{dB_{\text{cv}}}{dt} = \frac{d\left(\int_{\text{cv}} \rho b \, dV\right)}{dt}$$

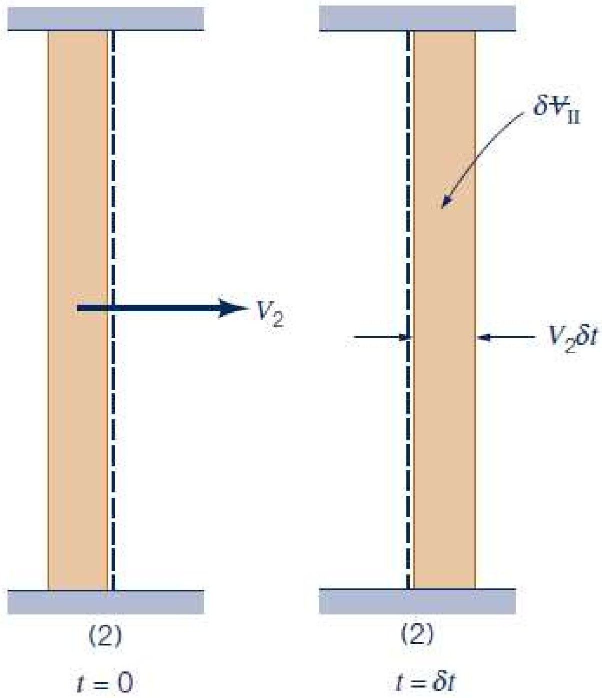


B	$b = B/m$
m	1
$m\mathbf{V}$	$\mathbf{V}$
$\frac{1}{2}mV^2$	$\frac{1}{2}V^2$

Derivation of the Theorem

❖ At One Dimensional Flow





$$\frac{DB_{sys}}{Dt} = \frac{\partial B_{cv}}{\delta t} + \dot{B}_{out} - \dot{B}_{in}$$

$$\frac{DB_{sys}}{Dt} = \frac{\partial B_{cv}}{\partial t} + \rho_2 A_2 V_2 b_2 - \rho_1 A_1 V_1 b_1$$

Derivation of the Theorem

❖ General Form for Fixed, Nondeforming Control Volume

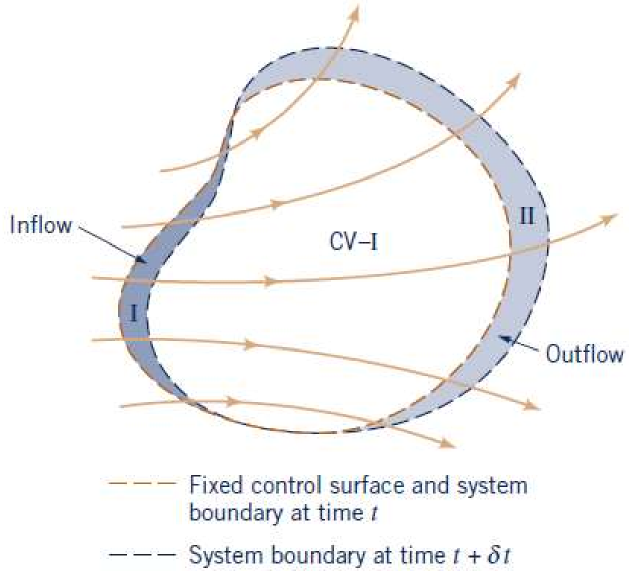
$$\delta \dot{B}_{out} = \lim_{\delta t \to 0} \frac{\rho b\, \delta \forall}{\delta t} = \lim_{\delta t \to 0} \frac{(\rho b V \cos\theta\, \delta t)\, \delta A}{\delta t} = \rho b V \cos\theta\, \delta A$$

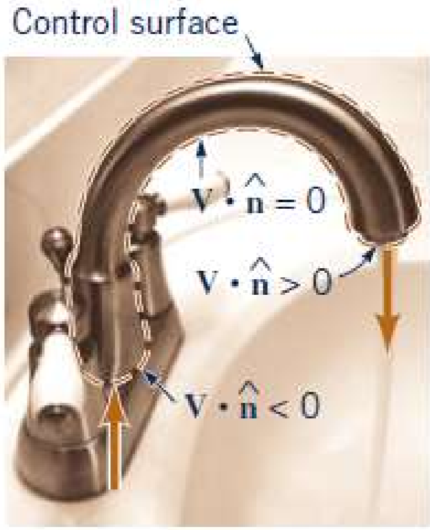
$$\dot{B}_{in} = -\int_{cs_{in}} \rho b V \cos\theta\, dA = -\int_{cs_{in}} \rho b \mathbf{V} \cdot \hat{\mathbf{n}}\, dA$$

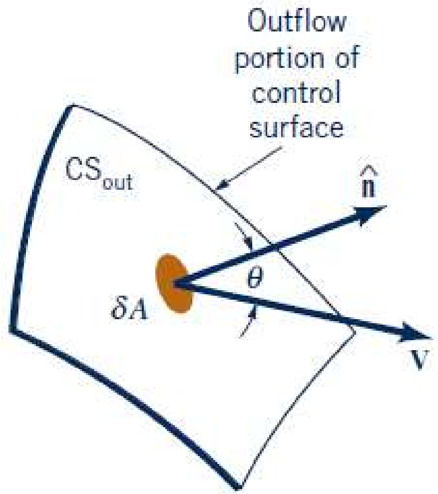
$$\dot{B}_{out} - \dot{B}_{in} = \int_{cs_{out}} \rho b \mathbf{V} \cdot \hat{\mathbf{n}}\, dA - \left(-\int_{cs_{in}} \rho b \mathbf{V} \cdot \hat{\mathbf{n}}\, dA\right)$$

$$= \int_{cs} \rho b \mathbf{V} \cdot \hat{\mathbf{n}}\, dA$$

$$\frac{DB_{sys}}{Dt} = \frac{\partial}{\partial t}\int_{cv} \rho b\, d\forall + \int_{cs} \rho b\, \mathbf{V} \cdot \hat{\mathbf{n}}\, dA$$







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