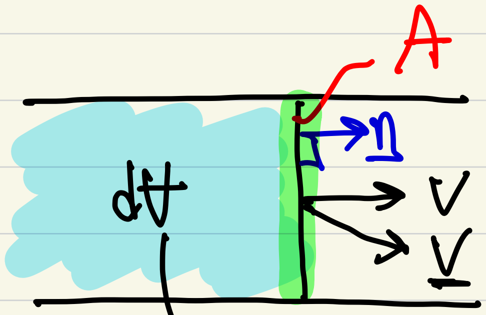
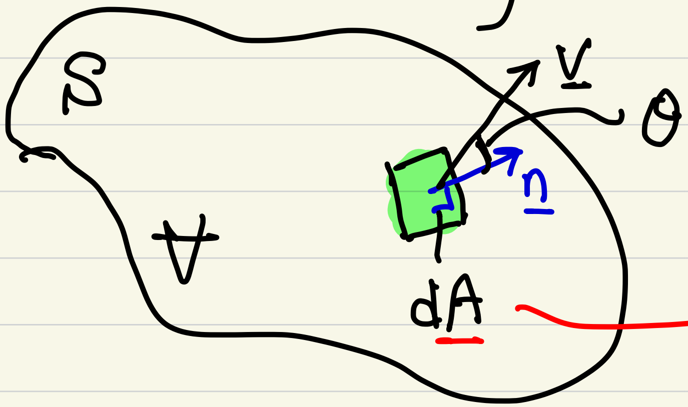
* Volume and mass flow rate.



$$d\forall = (\underline{V}\cdot\underline{n})\cdot A\cdot dt.$$

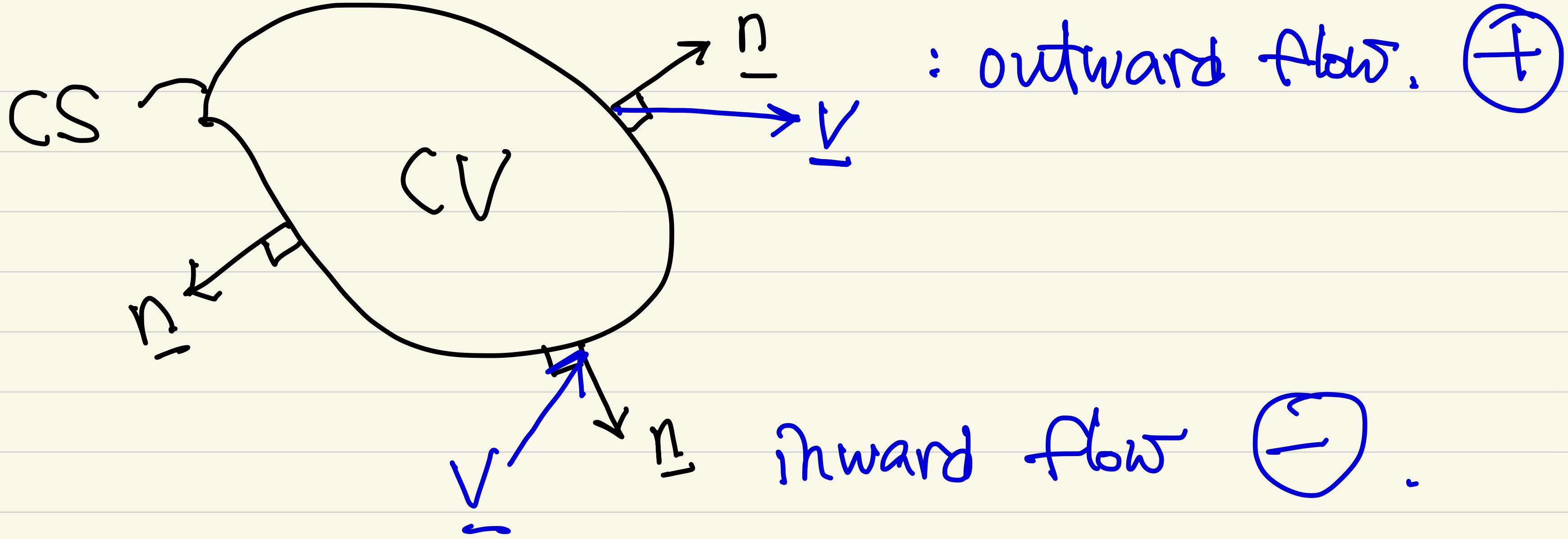
↓ arbitrary shape.



$$d\forall = (\underline{V}\cdot\underline{n})\, dA\cdot dt$$

$$\frac{d\forall}{dt} = dQ = (\underline{V}\cdot\underline{n})\, dA.$$

Volume flow rate : $Q = \int dQ = \int_S (\underline{V}\cdot\underline{n})\, dA = \int_S V_n\, dA.$



· mass flow rate : $d\dot{m} = \rho\, dQ = \rho(\underline{v}\cdot\underline{n})\,dA$.

$$\therefore\ \dot{m} = \frac{dm}{dt} = \int_S \rho(\underline{v}\cdot\underline{n})\,dA = \int_S \rho V_n\, dA.$$

if ρ = const (incompressible flow, 비압축성 유동)
(Ma < 0.2–0.3).

$$\dot{m} = \rho Q.$$

if ρ, V are constant, $\dot{m} = \rho V A$.

※ average velocity (bulk velocity) passing through a surface.

$$: V_{avg} \equiv \frac{Q}{A} = \left(\int_S (\underline{V}\cdot\underline{n})\, dA\right) \Big/ \left(\int_S dA\right)$$

or, $Q = V_{avg} \cdot A$.

3.2. Reynolds Transport Theorem.

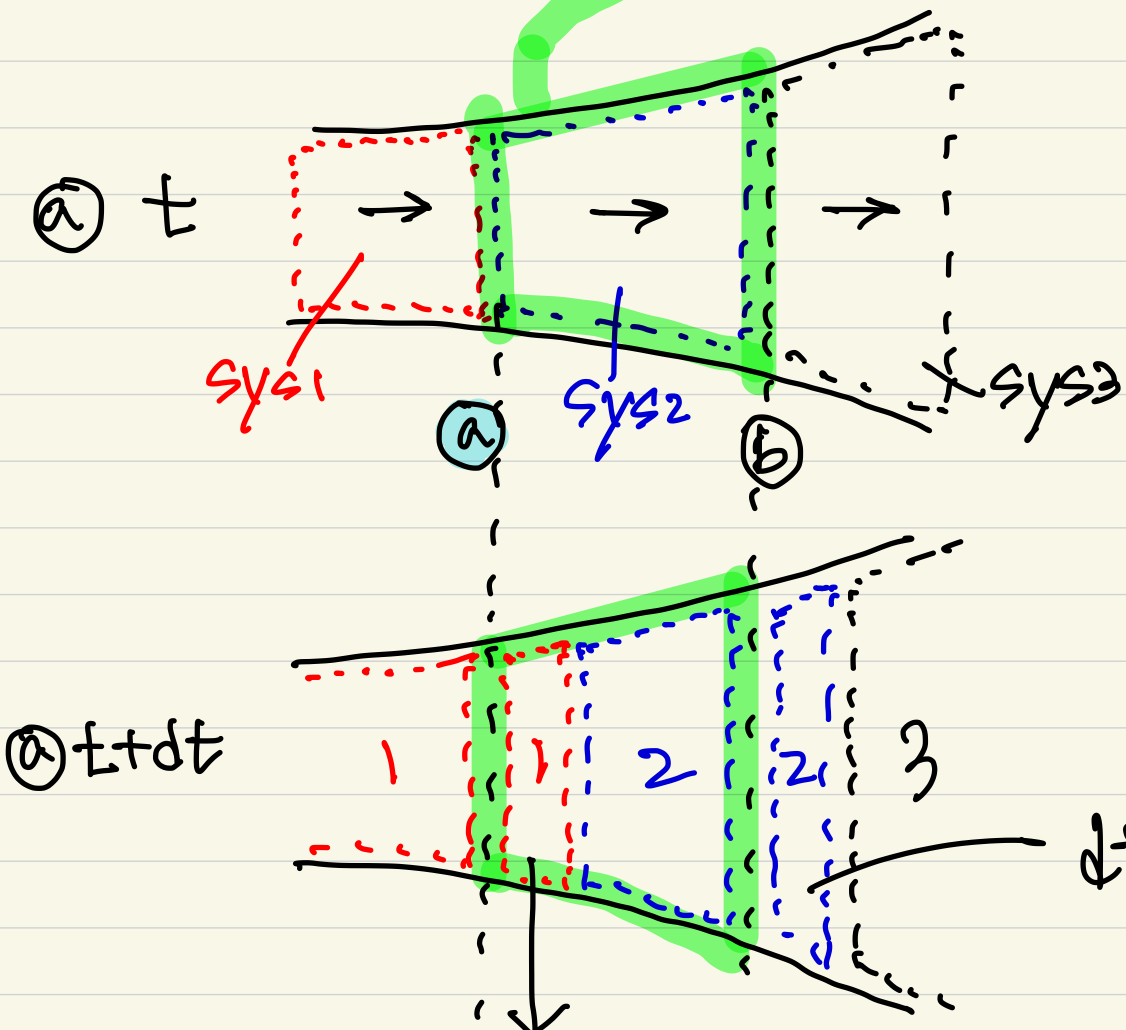
system analysis $\longleftrightarrow$ Control Volume analysis

(individual mass) (specific area, volume

C.V?.

- Lagrangian - Eulerian.
- moving coordinate. - fixed coordinate

· 1D fixed CV.



B : flow property.

$\beta \equiv \dfrac{dB}{dm}$ (intensive value).

$(dB = \beta \cdot dm)$.

$d\forall_{out} = V_b \cdot A_b \cdot dt$.

$d\forall_{in} = V_a \cdot A_a \cdot dt$

· total amount of "B" in the CV.

$$: \underline{B_{CV}} = \int_{CV} dB = \int_{\underline{CV}} \beta \cdot dm = \int_{CV} \beta \rho \, d\forall$$

$$\frac{d}{dt} B_{CV} = \frac{B_{CV}(t+dt) - B_{CV}(t)}{dt}$$

$$= \frac{1}{dt}\left[B_2(t+dt) + \beta\rho \, d\forall_{in} - \beta\rho \, d\forall_{out} - B_2(t) \right]$$

$$= \frac{1}{dt}\left[B_2(t+dt) - B_2(t) \right] - (\beta\rho VA)_{out} + (\beta\rho VA)_{in}$$

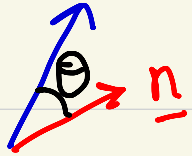
$$(d\forall = V \cdot A \cdot dt)$$

$$= \frac{d}{dt} B_{sys}$$

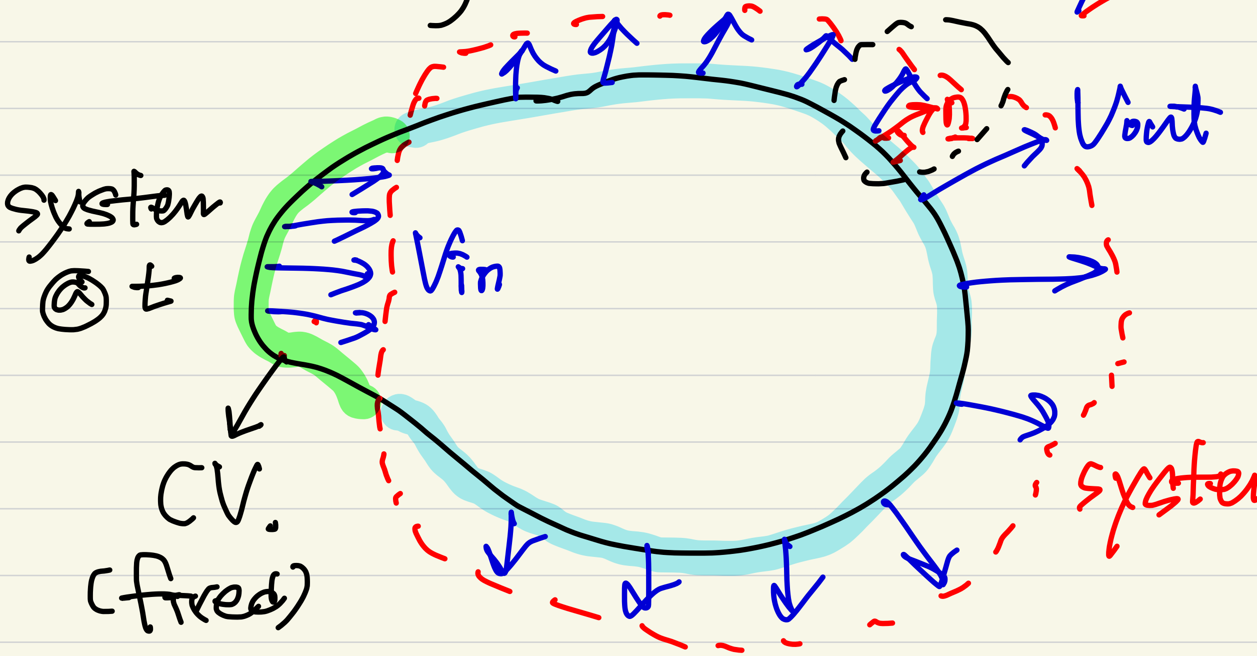
$$\boxed{\therefore \frac{d}{dt} B_{sys} = \frac{d}{dt}\int_V \beta\rho \, d\forall + (\beta\rho VA)_{out} - (\beta\rho VA)_{in}}$$

– 1D RTT.

· Arbitrary fixed CV.



$$dB = \beta \cdot dm = \beta \rho \, d\forall = \beta \rho (\underline{V} \cdot \underline{n}) \, dA.$$



$$\frac{d}{dt} B_{sys} = \frac{d}{dt}\int_{CV} \beta\rho \, d\forall + \underbrace{\int_{CS} \beta\rho V \cos\theta \cdot dA_{out} - \int_{CS} \beta\rho V \cos\theta \cdot dA_{in}}_{\text{flux terms.}}$$

Lagrangian

$$= \underbrace{\frac{d}{dt}\int_{CV} \beta\rho \, d\forall + \int_{CS} \beta\rho (\underline{V} \cdot \underline{n}) \, dA.}_{\text{Eulerian.}}$$

if CV is moving at V_s, relative velocity. $\underline{V}_r = \underline{V} - V_s$

$$\frac{d}{dt} B_{sys} = \frac{d}{dt} \int_{CV} \beta \rho \, d\forall + \int_{CS} \beta \rho (\underline{V}_r \cdot \underline{n}) \, dA$$

- mass : $B = m$, $\beta = \frac{dB}{dm} = 1$.
- momentum : $B = m\underline{V}$, $\beta = \frac{dB}{dm} = \underline{V}$.
- angular mtm : $B = (\underline{r} \times \underline{V}) m$, $\beta = \underline{r} \times \underline{V}$
- energy : $B = E$, $\beta = e$.