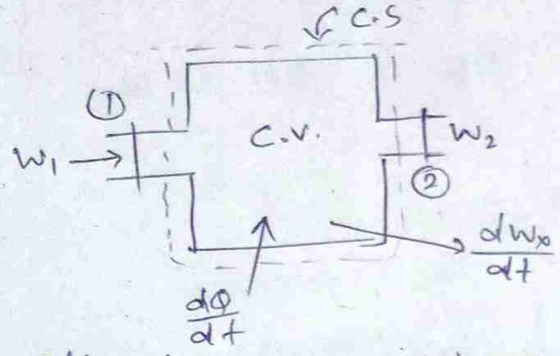
Variable flow processes :-

Many flow processes are not steady
e.g. filling up & evacuating gas cylinders.

non-steady state analysis.



mass accumulation in C.V. = Net mass in the Syst. (in-out),
if $m_v \rightarrow$ mass at time t is C.V.

$$\Rightarrow \quad \Delta m_v = \Delta m_1 - \Delta m_2$$

Similarly, Rate of energy accumulation = Rate of energy in - out

$$\frac{dE_v}{dt} = w_1\left(h_1 + \frac{V_1^2}{2} + Z_1 g\right) + \frac{dQ}{dt} - w_2\left(h_2 + \frac{V_2^2}{2} + Z_2 g\right) - \frac{dW_x}{dt}$$

where, $E_v = \left(U + \frac{mV^2}{2} + mgZ\right)_{C.V.}$

$$\Rightarrow \quad \frac{dE_v}{dt} = \frac{d}{dt}\left(U + \frac{mV^2}{2} + mgZ\right)_{C.V.}$$

$$= \frac{dm_1}{dt}\left(h_1 + \frac{V_1^2}{2} + Z_1 g\right) + \frac{dQ}{dt} - \frac{dm_2}{dt}\left(h_2 + \frac{V_2^2}{2} + Z_2 g\right) - \frac{dW_x}{dt}$$

$$w_1\left(h_1 + \frac{V_1^2}{2} + Z_1 g\right) \longrightarrow \boxed{\frac{d}{dt}\left(U + \frac{mV^2}{2} + mgZ\right)}_{C.V} \longrightarrow w_2\left(h_2 + \frac{V_2^2}{2} + Z_2 g\right)$$

$$\Delta E_v = Q - W_x + \int\left(h_1 + \frac{V_1^2}{2} + Z_1 g\right) dm_1 - \int\left(h_2 + \frac{V_2^2}{2} + Z_2 g\right) dm_2$$

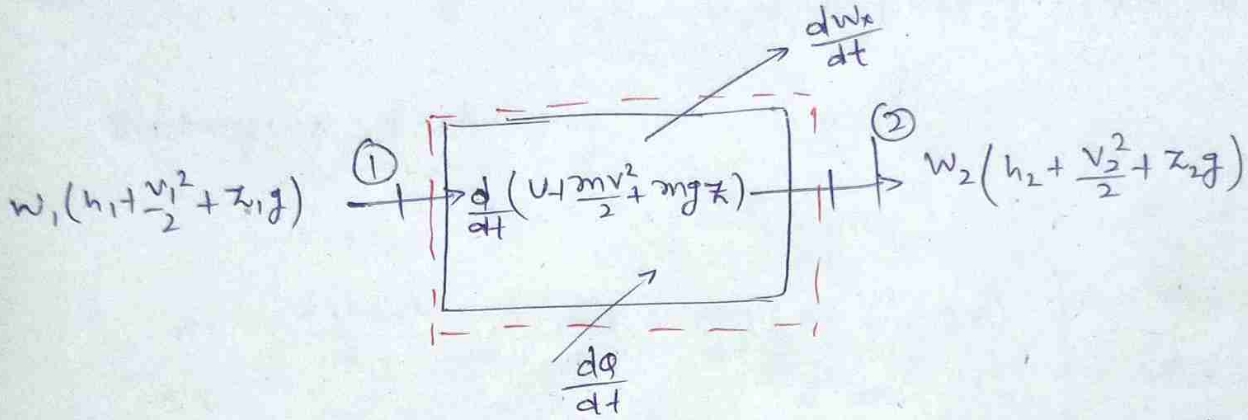
if $\frac{dE_v}{dt} = 0$

equation reduce to S.F.E.E.

i.f. $w_1 = 0$, $w_2 = 0 \Rightarrow$ closed system.

$$\frac{dE_v}{dt} = \frac{dQ}{dt} - \frac{dW_x}{dt}$$

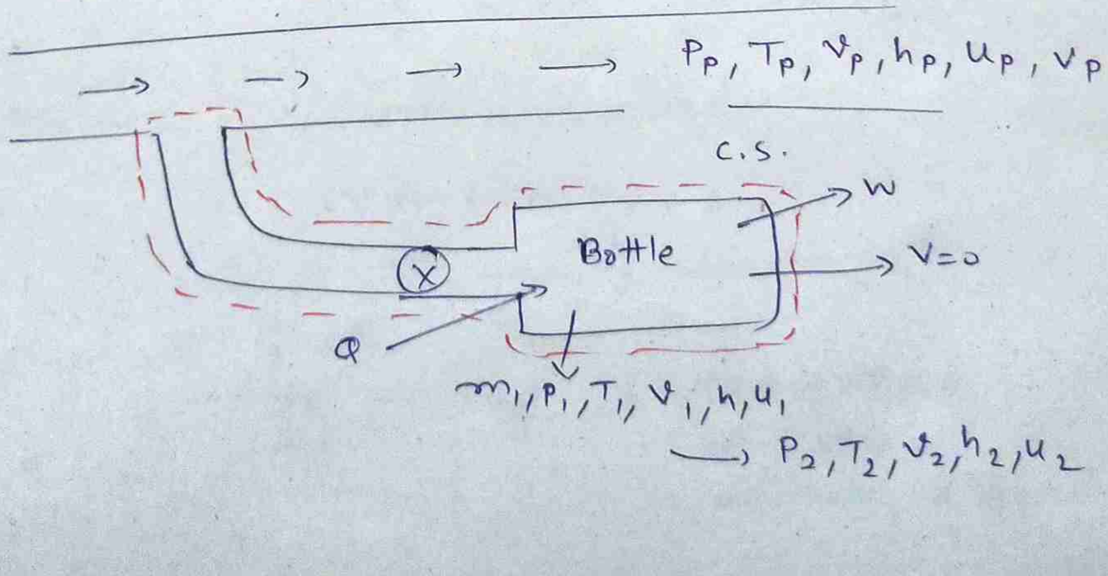
$$\Rightarrow dE_v = dQ - dW_x$$



$$\Rightarrow \frac{d}{dt}\left(U + \frac{mV^2}{2} + mgz\right) = w_1\left(h_1 + \frac{V_1^2}{2} + z_1 g\right) + \frac{dQ}{dt} - w_2\left(h_2 + \frac{V_2^2}{2} + z_2 g\right) - \frac{dW_x}{dt}$$

$$\Rightarrow \Delta E_{cv} = Q - W_x + \int\left(h_1 + \frac{V_1^2}{2} + z_1 g\right) - \int\left(h_2 + \frac{V_2^2}{2} + z_2 g\right) dm_2$$

Ex.



Control volume technique

$$\frac{dE_v}{dt} = \frac{dQ}{dt} - \frac{dW_x}{dt} + \frac{dm}{dt}\left(h_p + \frac{V_p^2}{2}\right)$$

$$\Rightarrow \Delta E_{c.v.} = Q + (m_2 - m_1)\left(h_p + \frac{V_p^2}{2}\right)$$

No macros. velocity in bottle & negligible P.E.

$$\Rightarrow m_2 u_2 - m_1 u_1 = Q + (m_2 - m_1)\left(h_p + \frac{V_p^2}{2}\right)$$

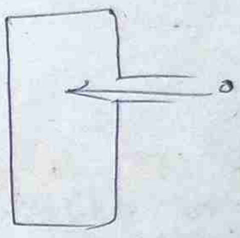
$$\Rightarrow Q = m_2 u_2 - m_1 u_1 - \left(h_p + \frac{V_p^2}{2}\right)(m_2 - m_1)$$

Discharging & charging a tank.

$$W_x = 0, \quad dQ$$

$$\Rightarrow \frac{d(U_{cv})}{dt} = \frac{dQ}{dt} - \frac{dm}{dt}\left(h + \frac{V^2}{2} + gz\right)$$

$$\& \; dm = -dm)$$



Assuming KE & P.E small $dQ = 0$

$$\Rightarrow d(mu) = +dm(u + pv)$$

$$\Rightarrow m\,du + u\,dm = +dm(u + pv)$$

$$\Rightarrow m\,du = pv\,dm$$

$$\frac{dm}{m} = \frac{du}{pv} \quad \text{——— (1)}$$

$$V = vm = \text{Constant.}$$

$$\Rightarrow v\,dm + m\,dv = 0$$

$$\Rightarrow \frac{dm}{m} = -\frac{dv}{v} \quad \text{——— (2)}$$

from eqn (1) & (2) —

$$\frac{du}{pv} = -\frac{dv}{v} \Rightarrow du + p\,dv = 0$$

$$\Rightarrow dQ = 0$$

adiabatic & quasi static