$$\delta W_b = F ds = PA ds = P dV$$

$$W_b = \int_1^2 P dV = P(V_2 - V_1) \quad \text{only if } f(v) = P$$

$$W_b = m P (v_2 - v_1)$$

specific volume

car engine

$$W_b = W_{friction} + W_{atm} + W_{crank} = \int_1^2 (F_{friction} + PA_{atm} + F_{crank}) dx$$

$$PV = mRT \Leftrightarrow PV = C \Rightarrow W_b = PV \ln\left(\frac{V_2}{V_1}\right)$$

$$PV^n = C$$

$$W_b = \int_1^2 P dV = \int_1^2 C V^{-n} dV = C \frac{V_2^{-n+1} - V_1^{-n+1}}{-n+1} = \frac{P_2 V_2 - P_1 V_1}{1-n}$$

$$= \frac{mR(T_2 - T_1)}{1-n} \quad \text{only if } n \neq 1$$

$F = kx$ { $P = \frac{F}{A}$ } $W_{spring} = \frac{1}{2}k(x_2^2 - x_1^2)$

$$E_{in} - E_{out} = \Delta E_{system} \quad (kJ)$$

$$\dot{E}_{in} - \dot{E}_{out} = dE/dt \quad (kW)$$

$Q = \dot{Q}\Delta t$ $W = \dot{W}\Delta t$ $\Delta E = (dE/dt)\Delta t$

$$e_{in} - e_{out} = \Delta e_{system} \quad (kJ/kg)$$

$$\delta E_{in} - \delta E_{out} = dE_{system}$$

$$\delta e_{in} - \delta e_{out} = de_{system}$$

$W_{net,out} = Q_{net,in}$ or $\dot{W}_{net,out} = \dot{Q}_{net,in}$

for a cycle

$$(Q_{in} - Q_{out}) - (W_{out} - W_{in}) = \Delta E_{system} \quad \text{(general)}$$

$$\text{〃} \quad \text{〃} \quad \text{〃} \quad \text{〃} \quad \text{〃} = \Delta U \quad \text{(Stationary)}$$

$$\Delta U + W_b = \Delta H$$

$$h = u + Pv$$

$$h = u + RT$$

$$x = \frac{m_{vapor}}{m_{total}}$$

$$v_{avg} = v_f + x v_{fg}$$

$$u_{avg} = u_f + x u_{fg}$$

$$h_{avg} = h_f + x h_{fg}$$

$$c_v \, dT = du$$

$$c_v = \left(\frac{\partial u}{\partial T}\right)_v$$

$$c_p \, dT = dh$$

$$c_p = \left(\frac{\partial h}{\partial T}\right)_p$$

$$\Delta u = u_2 - u_1 = \int_1^2 c_v(T) \, dT$$

$$\Delta h = h_2 - h_1 = \int_1^2 c_p(T) \, dT$$

$$u_2 - u_1 = C_{v,avg}(T_2 - T_1)$$

$$C_p = C_v + R$$

$$h_2 - h_1 = C_{p,avg}(T_2 - T_1)$$

$$\bar{C}_p = \bar{C}_v + R_u$$

$$k = \frac{C_p}{C_v}$$

# Chapter 5

- $m_{in} - m_{out} = \Delta m_{cv}$
- $\sum_{in} \dot{m} = \sum_{out} \dot{m}$
- $\sum_{in} \dot{V} = \sum_{out} \dot{V}$
- $\dot{m} = \rho V_{avg} A_c$
- $\dot{V} = VA$
- $\dot{m} = \rho \dot{V} = \frac{\dot{V}}{v}$
- $e = u + \frac{V^2}{2} + gz$
- $E_{mass} = m\theta = m\left(h + \frac{V^2}{2} + gz\right)$
- $\dot{E}_{mass} = \dot{m}\theta = \dot{m}\left(h + \frac{V^2}{2} + gz\right)$
- $\theta = h + \frac{V^2}{2} + gz$
- $\dot{E}_{in} = \dot{E}_{out}$

$$\dot{Q}_{in} + \dot{W}_{in} + \sum_{in} \dot{m}\left(h + \frac{V^2}{2} + gz\right) = \dot{Q}_{out} + \dot{W}_{out} + \sum_{out} \dot{m}\left(h + \frac{V^2}{2} + gz\right)$$

- $\sum_{in} \dot{m} = \sum_{out} \dot{m}$

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

- $\dot{Q} - \dot{W} = \dot{m}\left[h_2 - h_1 + \frac{V_2^2 - V_1^2}{2} + g(z_2 - z_1)\right)$
- $\left(\dot{Q}_{in} + W_{in} + \sum_{in} m\theta\right) - \left(Q_{out} + W_{out} + \sum_{out} m\theta\right) = (m_2 e_2 - m_1 e_2)_{system}$
- $Q - W = \sum_{out} mh - \sum_{in} mh + (m_2 u_2 - m_1 u_1)_{system}$