Energy Balance for Closed System

$$\Delta E = E_2 - E_1 = Q - W$$

$$\Delta E = \Delta KE + \Delta PE + \Delta U$$

$$\boxed{\Delta KE + \Delta PE + \Delta U = Q - W}$$

$W > 0 \Rightarrow$ Work is done by the system

$Q > 0 \Rightarrow$ Energy is transferred by heat to the system

Could also use time rates

$$\frac{dE}{dt} = \dot{Q} - \dot{W}$$

Sometimes, the specific volume, energy is given => small case

$$u = 100 \text{ kJ/kg}$$
or Btu/lb

$$v = 0.5 \text{ m}^3\text{/kg}$$
$\text{ft}^3\text{/lb}$

If the mass is constant, can use either, but must be consistent.

Energy Balance => Must watch units

Look to the inside front cover

$$J = Kg\,\frac{m^2}{s^2} = N \cdot m$$

$$Pa = \frac{N}{m^2} = \left(Kg\,\frac{m}{s^2}\right)\frac{1}{m^2} = Kg\left(\frac{1}{m\,s^2}\right)$$

$$P\,V = \left(\frac{Kg}{m\,s^2}\right)(m^3) = Kg\,\frac{m^2}{s^2}$$

Pa

Example

Given => 5Kg mass closed system
=> 9 KJ of Wort done to the system
=> Elevation increases by 700 m
=> Specific internal energy decreases by 6 KJ/Kg
=> No change in Kinetic energy

$$\Rightarrow g = 9.6\ m/s^2$$

Determine: Heat Transfer

$$\cancel{\Delta KE}^{0} + \Delta PE + \Delta U = Q - W$$

$$\Delta PE = mg(z_2 - z_1) = (5\ kg)(9.6\ m/s^2)(700m)$$
$$= 33,600\ J = \underline{33.6\ kJ}$$

$$\Delta U = (\Delta u)(m) = (-6\ kJ/kg)(5\ kg) = \underline{-30\ kJ}$$

$$W = -9\ kJ$$

$$(33.6kJ) - 30kJ = Q - (-9kJ)$$

$$\boxed{Q = -5.4\ kJ}$$ Heat transfer from the system

Example

Given: => 2 lb mass in a closed system

Process 1-2: $V_1 = V_2 = 4.434\ ft^3/lb$

$P_1 = 100\ lb/in^2$, $u_1 = 1105.8\ Btu/lb$

$Q_{12} = -581.36\ Btu/lb$

Process 2-3: $P_2 = P_3 = 60\ lb/in^2$

$V_3 = 7.82\ ft^3/lb$

$u_3 = 1121.4\ Btu/lb$

Kinetic & Potential energy effects can be neglected for both processes

Determine: The work and heat transfer for process 2-3

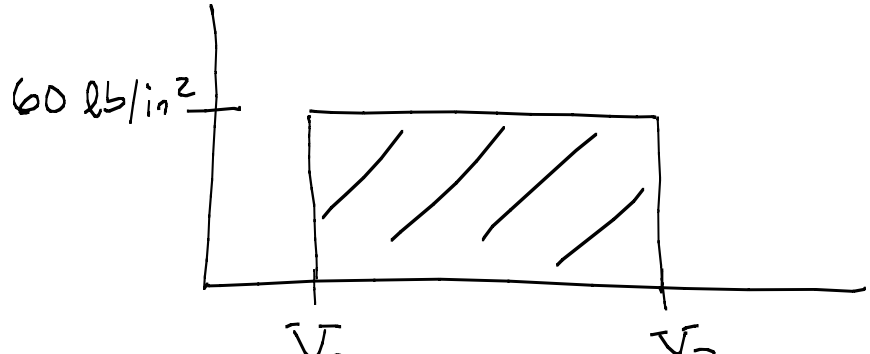
Process 2-3

$$\cancel{\Delta KE_{23}}^{\,0} + \cancel{\Delta PE_{23}}^{\,0} + \Delta U_{23} = Q_{23} - W_{23}$$

$$U_3 - U_2 = Q_{23} - W_{23}$$

$$U_3 = (1121.4\ \text{Btu/lb})(2\ \text{lb}) = \boxed{2242.8\ \text{Btu}}$$

$$W_{23} = \int_{V_2}^{V_3} p\,dV = \text{Area under } p\text{-}V \text{ diagram}$$



$$W_{23} = p(V_3 - V_2)$$

$$= \left(60\frac{\text{lb}}{\text{in}^2} \times \frac{144\,\text{in}^2}{\text{ft}^2}\right)\left((7.82\ \text{ft}^3/\text{lb})(2\ \text{lb}) - (4.434\ \text{ft}^3/\text{lb})(2\ \text{lb})\right)$$

$$W_{23} = 58{,}510\ \text{lb}\cdot\text{ft}\left(\frac{1\ \text{Btu}}{778.17\ \text{lb}\cdot\text{ft}}\right) = \boxed{75.2\ \text{Btu}}$$

Process 1-2

$$\cancel{\Delta KE_{12}}^{0} + \cancel{\Delta PE_{12}}^{0} + \Delta U_{12} = Q_{12} - \cancel{W_{12}}^{0} \quad (V_1 = V_2)$$

$$U_2 - U_1 = Q_{12}$$

$$U_1 = (1105.8\ \text{Btu/lb})(2\ \text{lb}) = \underline{2211.6\ \text{Btu}}$$

$$Q_{12} = -581.36\ \text{Btu}$$

$$U_2 - 2211.6\ \text{Btu} = -581.36\ \text{Btu}$$

$$\underline{U_2 = 1630.24\ \text{Btu}}$$

Process 2-3

$$U_3 - U_2 = Q_{23} - W_{23}$$

$$(2242.8\ \text{Btu}) - (1630.24\ \text{Btu}) = Q_{23} - (75.2\ \text{Btu})$$

$Q_{23} = 687.8 \text{ Btu}$