Example (2): In an internal combustion engine, during the compression stroke the heat rejected to the cooling water is (50 kJ/kg) and the work input is (100 kJ/kg). Calculate the change in internal energy of the working fluid stating whether it is a gain or loss.

Solution:

$q - w = \Delta u$

Since heat is rejected, then it will have a negative sign. Also work input will have a negative sign. Hence:

$-50 - (-100) = \Delta u$

$\Delta u = 50\ KJ/kg$

Example (3): (0.3 kg) of nitrogen gas at (40 °C) is contained in a cylinder. The piston is moved to compress nitrogen until the temperature becomes (160 °C). The work done during the process is (30 kJ). Calculate the heat transferred from the nitrogen to the surroundings. Take (C_v for nitrogen = 0.75 kJ/kg.K).

Solution:

The absolute temperatures: $T_1 = 40 + 273 = 313\ K$

$T_2 = 160 + 273 = 433\ K$

Applying the first law of thermodynamics:

$Q - W = \Delta U$

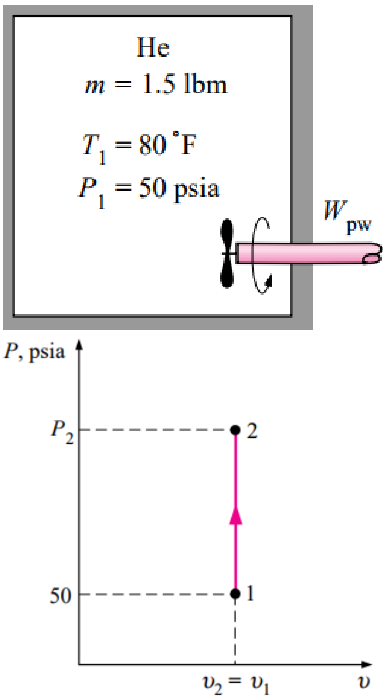
$\Delta U = mC_v\Delta T = mC_v(T_2 - T_1)$

$Q - W = mC_v(T_2 - T_1)$

$Q - (-30) = 0.3 * 0.75(433 - 313)$

$Q = -3\ KJ$

Example (4): An insulated rigid tank initially contains (1.5 lbm) of helium at (80 °F) and (50 psia). A paddlewheel with a work of (25.45 Btu). Determine (a) the final temperature and (b) the final pressure of the helium gas. Take (C_v = 0.753 Btu/lbm · °F)



Solution:

$$Q - W = \Delta U$$

For insulated $Q = 0$

$$W = \Delta U = m(u_2 - u_1) = mC_v(T_2 - T_1)$$

$$25.45 = 1.5 * 0.753(T_2 - 80)$$

$$T_2 = 102.5\ °F$$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$for\ rigid\ tank\ V_1 = V_2$$

$$\frac{50}{(80 + 460)} = \frac{P_2}{(102.5 + 460)}$$

$$P_2 = 52.1\ psai$$

5. THE FIRST LAW OF THERMODYNAMICS FOR NON-FLOW PROCESSES

The energy equation for non-flow processes is written as:

$$Q - W = \Delta U$$

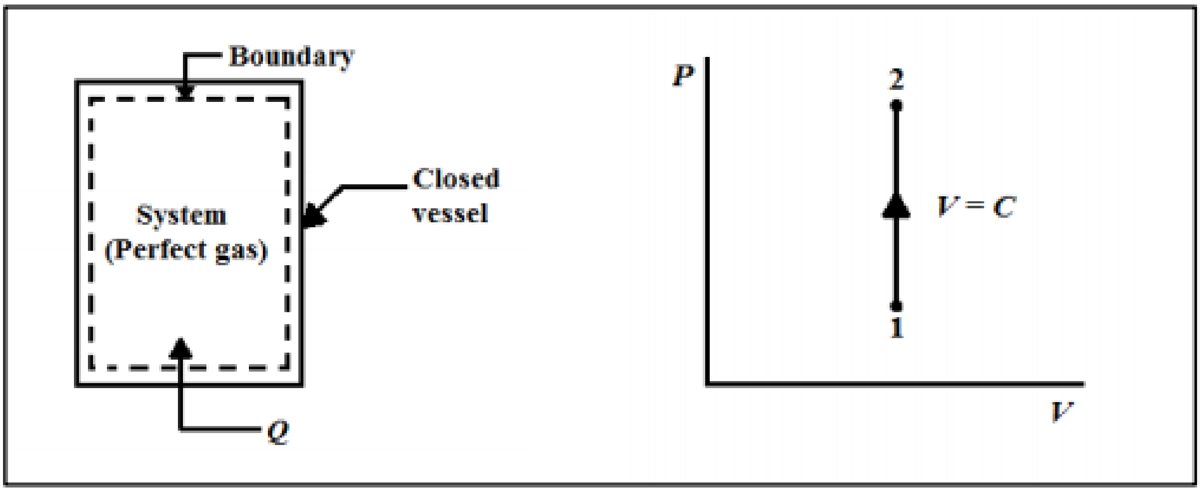
$$q - w = \Delta u \qquad (per\ unit\ mass)$$

$$since\ U = mC_vT$$

$$Q - W = mC_v\Delta T$$

$$q - w = C_v\Delta T \qquad (per\ unit\ mass)$$

5.1 Constant Volume (Isochoric) Process: consider a completely closed vessel filled with a perfect gas as shown in the figure below. Let Q units of heat be supplied to the system. This increases the pressure and temperature of the system at constant volume as presented by process 1-2 on the (P-V) diagram shown below. Since there is no change in volume, therefore:



Applying the first law of thermodynamics:

$Q - W = \Delta U = mC_v(T_2 - T_1)$

For a constant volume process, no work is done on the system. Hence:

$W = \int PdV = 0$

Then: $Q = mC_v(T_2 - T_1)$

For a unit mass, we get:

$q = C_v(T_2 - T_1)$

Example (5): (1 kg) of air enclosed in a rigid container, is initially at (4.8 bar) and (150 °C). The container is heated until the temperature becomes (200 °C). Calculate the final pressure of the air and the heat supplied during the process. Take ($C_v = 0.718\ KJ/kg.K$)

Solution:

The absolute temperatures: $T_1 = 150 + 273 = 423\ K$

$$T_2 = 200 + 273 = 473\ K$$

Since we have a rigid container, then the volume is constant. (W = 0).

For a constant volume process:

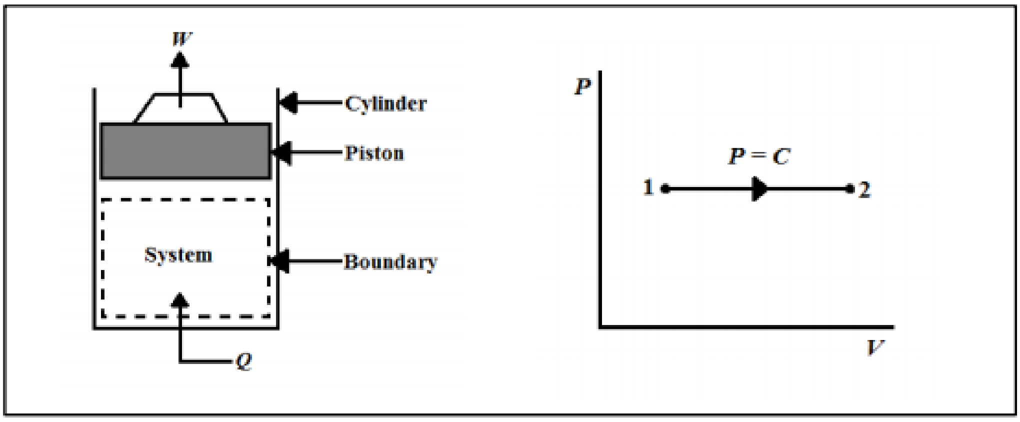
$$\frac{P_1}{T_1} = \frac{P_2}{T_2} \rightarrow \frac{4.8}{423} = \frac{P_2}{473}$$

$P_2 = 5.37\ bar$

$Q = mC_v(T_2 - T_1) = 1 * 0.718 * (473 - 423)$

$Q = 35.9\ KJ$

5.2 Constant Pressure (Isobaric) Process: consider a cylinder with a piston carrying perfect gases as shown in the figure below. When heat (Q) is supplied to the system, its temperature will rise and it will expand, forcing the piston to move upward. Thus a displacement work is done by the system against a constant force. The (P-V) diagram of the process is shown in the figure below.



Work done by the system:

$$W = \int PdV = P(V_2 - V_1)$$

Applying the first law of thermodynamics:

$$Q - W = \Delta U$$

then, $(U_2 + PV_2) - (U_1 + PV_1) = Q$

since $H = U + PV$

then: $Q = H_2 - H_1$

$$Q = mC_p(T_2 - T_1)$$

For a unit mass, we get:

$$q = C_p(T_2 - T_1)$$

It can be seen that during an isobaric process, the heat transfer is equal to the change in enthalpy.

Example (6): When a stationary mass of gas was compressed without friction at constant pressure, its initial state of (0.4 m^3) and (0.105 MPa) was found to change to a final state of (0.2 m^3) and (0.105 MPa). There was a transfer of (42.5 kJ) of heat from the gas during the process. How much did the internal energy of the gas change?

Solution:

Since we have a constant pressure process, then work done by the gas is:

$$W = P(V_2 - V_1) = 0.105 \times 10^6(0.2 - 0.4) = -21\ KJ$$

$$Q - W = \Delta U$$

$$-42.5 - (-21) = \Delta U$$

$$\Delta U = -21.5\ KJ$$