Introduction and the First Law of Thermodynamics

1.5 A fluid at 0.7 bar occupying 0.09 m^3 is compressed reversibly to a pressure of 3.5 bar according to law pv^n = constant. The fluid is then heated reversible at constant volume until the pressure is 4 bar; the specific volume is then 0.5 m^3/kg. A reversible expansion according to a law pv^2 = constant restores the fluid to its initial state. Sketch the cycle on p-v diagram and calculate:

a) the mass of fluid present
b) the value of n in the first process
c) the net work of the cycle

1.10 The gases in the cylinder of an internal combustion engine have a specific internal energy of 800 kJ/kg and a specific volume of 0.06 m^3/kg at the beginning expansion. The expansion of the gases may be assumed to take place according to a reversible law, $pv^{1.5}$ = constant, from 55 bar to 1.4 bar. The specific internal energy after expansion is 230 kJ/kg. Calculate the heat rejected to the cylinder cooling water per kilogram of gases during the expansion stroke.

1.13 A turbine operating under steady-flow condition receives steam at the following state: pressure, 13.8 bar, specific volume 0.143 m^3/kg, specific internal energy 2590 kJ/kg, velocity 30 m/s. The state of the steam leaving the turbine is as follows: pressure 0.35 bar, specific volume 4.37 m^3/kg, specific internal energy 2360 kJ/kg, velocity 90 m/s. Heat is rejected to a surrounding at the rate of 0.25 kW and the rate of steam flow through the turbine is 0.38 kg/s. Calculate the power developed by the turbine?

1.14 A nozzle is a device for increasing the velocity of a steadily following fluid. At the inlet to a certain nozzle the specific enthalpy of the fluid is 3025 kJ/kg. The nozzle is horizontal and there is a negligible heat loss from it. Calculate:

a) the velocity of the fluid exit
b) the rate of flow when the inlet area is 0.1 m^2 and the specific volume at the inlet is 0.19 m^3/kg
c) the exit area of the nozzle when the specific volume at the nozzle is 0.5 m^3/kg

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1-5 Given ;

① $P_1 = 0.7$ bar.

$V_1 = 0.09\ m^3$

$P_2 = 3.5$ bar.

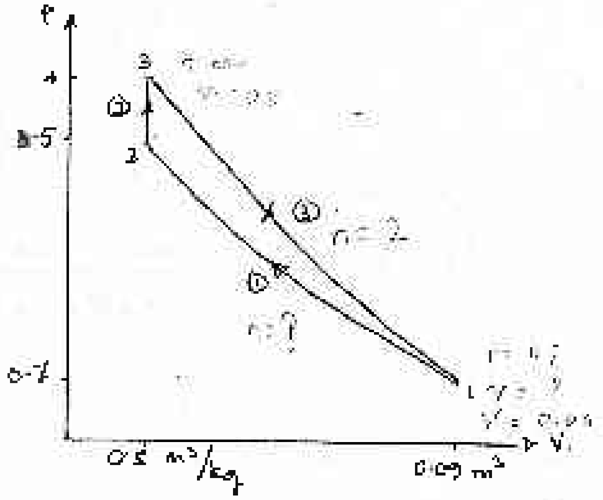
$pV^n = K$.

② Constant Volume

$P_3 = 4$ bar.

$v_3 = 0.5\ m^3/kg$.

③ $PV^2 =$ Constant.



a- the mass of fluid present.

$$P_1 v_1^2 = P_3 v_3^2$$

$$0.7 (v_1)^2 = 4 (0.5)^2 .$$

$$v_1^2 = 1.4285$$

$$v_1 = 1.1952\ m^3/kg.$$

$$V_1 = m v_1 .$$

$$m = \frac{V_1}{v_1} = \frac{0.09}{1.1952}$$

$$m = 0.0753\ kg$$

b- the value of n in the first process.

From :- $v_1 = 1.1952\ m^3/kg$. $P_1 = 0.7$ bar.

$v_2 = 0.5\ m^3/kg$ $P_2 = 3.5$ bar.

$$P_1 v_1^n = P_2 v_2^n$$

$$\frac{P_1}{P_2} = \left(\frac{v_2}{v_1}\right)^n$$

$$\frac{0.7}{3.5} = \left(\frac{0.5}{1.1952}\right)^n$$

$$0.2 = 0.4183^n$$

$$\log 0.2 = n \ln 0.4183$$

$$n = 1.847$$

c – the net work of the cycle.

process ①.

$$w = m\left(\frac{P_2V_2 - P_1V_1}{1-n}\right)$$

$$= 0.0753\left(\frac{3.5(0.5) - 0.7(1.1952)}{1-1.847}\right) \times 10^5$$

$$= -8119.7 \text{ Nm}$$

Process ②.

$$w = 0$$

process ③.

$$w = m\left(\frac{P_1V_1 - P_3V_3}{1-n}\right)$$

$$= 0.0753\left(\frac{0.7(1.1952) - 4(0.5)}{1-n}\right) \times 10^5$$

$$= 8759.9 \text{ Nm}.$$

Total Work = 8759.9 − 8119.7

= 640 Nm.

1-10 Given;

$u_1 = 800 \text{ KJ/kg}$

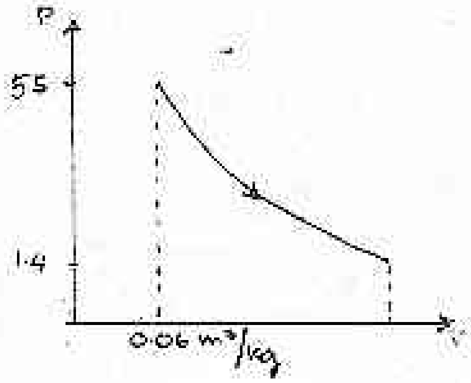
$V_1 = 0.06 \text{ m}^3/\text{kg}$

$pV^{1.5} = K$

$P_2 = 1.4 \text{ bar}$

$U_2 = 230 \text{ KJ/kg}$

$P_1 = 55 \text{ bar}$



$$Q - W = U_2 - U_1$$

$$P_1 V_1^{1.5} = P_2 V_2^{1.5}$$

$$(55)(0.06)^{1.5} = (1.4)(V_2)^{1.5}$$

$$V_2^{1.5} = 0.5774$$

$$1.5 \ln V_2 = \ln 0.5774$$

$$V_2 = 0.693 \text{ m}^3/\text{kg}$$

$$W = \frac{P_2 V_2 - P_1 V_1}{1 - n}$$

$$= \frac{1.4(0.693) - 55(0.06)}{1 - 1.5} \times 10^5$$

$$= 465960 \text{ Nm} \times$$

$$Q - W = U_2 - U_1$$

$$Q - 465960 = 230000 - 800000$$

$$Q = -104040 \text{ J/kg}$$

$$= -104 \text{ KJ/kg} \times$$

1.13 Given ;

$P_1 = 13.8$ bar.

$V_1 = 0.143\ m^3/kg$

$u_1 = 2590$ KJ/kg.

$C_1 = 30$ m/s.

$P_2 = 0.35$ bar.

$V_2 = 4.37\ m^3/kg.$

$u_2 = 2360$ KJ/kg.

$C_2 = 90$ m/s.

$Q = -0.25$ Kw. $= -0.25/0.38 = -0.657$ KJ/kg.

$\dot{m} = 0.38$ kg/s.

We know ;

$h = u + pv.$

$$Q - W = \left(h_2 + \frac{C_2^2}{2}\cdot\frac{1}{10^3}\right) - \left(h_1 + \frac{C_1^2}{2}\cdot\frac{1}{10^3}\right)$$

$$= \left(u_2 + p_2 v_2 + \frac{C_2^2}{2}\cdot\frac{1}{10^3}\right) - \left(u_1 + p_1 v_1 + \frac{C_1^2}{2}\cdot\frac{1}{10^3}\right)$$

$$= \left(2360 + 0.35\times10^5(4.37) + \frac{90^2}{2}\cdot\frac{1}{10^3}\right) - \left(2590 + 13.8\times10^5(0.143) + \frac{30^2}{2}\cdot\frac{1}{10^3}\right)$$

$$= \left(2360 + \frac{152950}{1000} + 4.05\right) - \left(2590 + \frac{197340}{1000} + 0.45\right)$$

$= 2517 - 2787.8$

$= -270.8$

$-0.657 - W = -270.8$

$W = 270.143$ KJ/kg.

so ;

Power, $P = W \cdot \dot{m}$

$= 270.143$ KJ/kg $\times$ 0.38 kg/s

$= 102.7$ Kw.

1-14 Given ;

$h_1 = 3025$ KJ/kg.

$C_1 = 60$ m/s.

$h_2 = 2700$ KJ/kg.

$Z_1 = Z_2$.

$Q = 0$

$W = 0$.

a- the velocity of the fluid exit.

$$\cancel{Q} - \cancel{W} = \left(h_2 + \frac{C_2^2}{2} \cdot \frac{1}{10^3}\right) - \left(h_1 + \frac{C_1^2}{2} \cdot \frac{1}{10^3}\right)$$

$$0 = \left(h_2 - h_1\right) + \left(\frac{C_2^2}{2} - \frac{C_1^2}{2}\right)\frac{1}{10^3}$$

$$= (2790 - 3025) + \left(\frac{C_2^2}{2} - \frac{60^2}{2}\right)\frac{1}{10^3}$$

$$235 = \left(\frac{C_2^2}{2} - 1800\right)\frac{1}{10^3}$$

$$C_2 = 688 \text{ m/s.}$$

b- $$\dot{m} = \frac{C_1 A_1}{V_1}$$

$$\dot{m} = \frac{60 \times 0.1}{0.19} = 31.6 \text{ kg/s.}$$

c- $$\dot{m} = \frac{C_2 A_2}{V_2}$$

$$31.6 = \frac{688 \times A_2}{0.5}$$

$$A = 0.0229 \text{ m}^2$$ //