ROHINI COLLEGE OF ENGINEERING AND TECHNOLOGY

ME 3391 EMGINEERING THERMODYNAMICS

DIGITAL NOTES

An engine is tested by means of a water brake at 1000 rpm. The measured torque of the engine is 10000 mN and the water consumption of the brake is 0.5 m³/s, its inlet temperature being 20°C. Calculate the water temperature at exit, assuming that the whole of the engine power is ultimately transformed into heat which is absorbed by the cooling water.

(**Ans.** 20.5°C)

Solution: Power = $T.\omega$

$$= 10000 \times \left(\frac{2\pi \times 1000}{60}\right)$$

$$= 1.0472 \times 10^6 \text{ W}$$

$$= 1.0472 \text{MW}$$

Let final temperature = t°C

$\therefore$ Heat absorb by cooling water / unit = $\dot{m}\, s\, \Delta t$

$$= \dot{v}\rho s\, \Delta t$$

$$= 0.5 \times 1000 \times 4.2 \times (t - 20)$$

$\therefore \quad 0.5 \times 1000 \times 4.2 \times (t - 20) = 1.0472 \times 10^6$

$\therefore \quad t - 20 = 0.4986 \approx 0.5$

$\therefore \quad t = 20.5°C$

$\therefore \quad$ $$U_2 - U_1 = -21.85 \text{ kJ}$$

The internal energy of the gas decreases by 21.85 kJ in the process.

In a cyclic process, heat transfers are + 14.7 kJ, – 25.2 kJ, – 3.56 kJ and + 31.5 kJ. What is the net work for this cyclic process?

(**Ans.** 17.34 kJ)

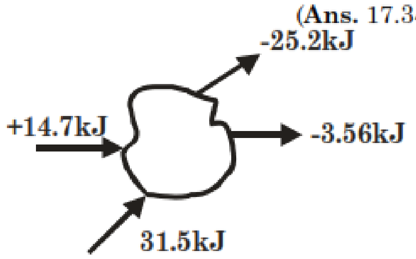
Solution : $\sum Q = (14.7 + 31.5 - 25.2 - 3.56)$ kJ

$= 17.44$ kJ

From first law of thermodynamics (for a cyclic process)

$$\sum Q = \sum W$$

$\therefore \sum W = 17.44$ kJ



During one cycle the working fluid in an engine engages in two work interactions: 15 kJ to the fluid and 44 kJ from the fluid, and three heat interactions, two of which are known: 75 kJ to the fluid and 40 kJ from the fluid. Evaluate the magnitude and direction of the third heat transfer.

(**Ans.** – 6 kJ)

Solution: From first law of thermodynamics

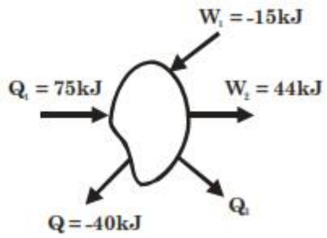
$$\sum đQ = \sum đW$$

$\therefore \quad Q_1 + Q_2 + Q_3 = W_1 + W_2$

or $\quad 75 - 40 + Q_3 = -15 + 44$

$Q_3 = -6$kJ

i.e. 6kJ from the system



A domestic refrigerator is loaded with food and the door closed. During a certain period the machine consumes 1 kWh of energy and the internal energy of the system drops by 5000 kJ. Find the net heat transfer for the system.

(**Ans.** – 8.6 MJ)

Solution: $Q = \Delta E + W$

$$Q_{2\text{-}1} = (E_2 - E_1) + W_{2\text{-}1}$$
$$= -5000\text{kJ} + \frac{-1000 \times 3600}{1000}\text{kJ}$$
$$= -8.6\text{MJ}$$

1.5 kg of liquid having a constant specific heat of 2.5 kJ/kg K is stirred in a well-insulated chamber causing the temperature to rise by 15°C. Find ΔE **and** W **for the process.**

(**Ans.** ΔE = 56.25 kJ, W = – 56.25 kJ)

Solution: Heat added to the system = 1.5 × 2.5 × 15kJ = 56.25 kJ

∴ ΔE rise = 56.25kJ

As it is insulated then ~~d~~Q = 0

∴ $\Delta Q = \Delta E + W$

or $0 = 56.25 + W$

or $W = -56.25$ kJ

A system composed of 2 kg of the above fluid expands in a frictionless piston and cylinder machine from an initial state of 1 MPa, 100°C to a final temperature of 30°C. If there is no heat transfer, find the net work for the process.

(**Ans.** 100.52 kJ)

Heat transfer is not there so

$$Q = \Delta E + W$$
$$W = -\Delta E$$
$$= -\Delta U$$
$$= -\int_1^2 C_v dT$$
$$= -0.718(T_2 - T_1)$$
$$= -0.718(100 - 30)$$
$$= -50.26 \text{ kJ/kg}$$

∴ Total work (W) = 2 × (-50.26) = -100.52 kJ

A mass of 8 kg gas expands within a flexible container so that the *p–v* relationship is of the from $pv^{1.2}$ = constant. The initial pressure is 1000 kPa and the initial volume is 1 m³. The final pressure is 5 kPa. If specific internal energy of the gas decreases by 40 kJ/kg, find the heat transfer in magnitude and direction.

(**Ans.** + 2615 kJ)

Solution: $\frac{T_2}{T_1} = \left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}} = \left(\frac{V_1}{V_2}\right)^{n-1}$

$$\therefore \quad \frac{p_2}{p_1} = \left(\frac{V_1}{V_2}\right)^n$$

$$\text{or} \quad \frac{V_2}{V_1} = \left(\frac{p_1}{p_2}\right)^{\frac{1}{n}}$$

$$\text{or} \quad V_2 = V_1 \times \left(\frac{p_1}{p_2}\right)^{\frac{1}{n}}$$

$$= 1 \times \left(\frac{1000}{5}\right)^{\frac{1}{1.2}} = 82.7\,m^3$$

$$\therefore \quad W = \frac{p_1V_1 - p_2V_2}{n-1}$$

$$= \frac{1000 \times 1 - 5 \times 82.7}{1.2 - 1} = 2932.5\,kJ$$

$$\Delta E = -8 \times 40 = -320\ kJ$$

$$\therefore \quad Q = \Delta E + W = -320 + 2932.5 = 2612.5\,kJ$$

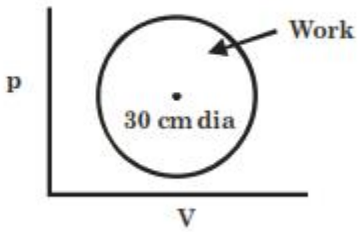
An imaginary engine receives heat and does work on a slowly moving piston at such rates that the cycle of operation of 1 kg of working fluid can be represented as a circle 10 cm in diameter on a *p–v* diagram on which 1 cm = 300 kPa and 1 cm = 0.1 m³/kg.

(a) How much work is done by each kg of working fluid for each cycle of operation?

(b) The thermal efficiency of an engine is defined as the ratio of work done and heat input in a cycle. If the heat rejected by the engine in a cycle is 1000 kJ per kg of working fluid, what would be its thermal efficiency?

(**Ans.** (a) 2356.19 kJ/kg, (b) 0.702)

Solution: Given Diameter = 10 cm



$$\therefore \text{ Area} = \frac{\pi \times 10^2}{4}\,cm^2 = 78.54\ cm^2$$

$$1\ cm^2 = 300\,kPa \times 0.1\,m^3/kg$$

$$= 30\,kJ$$

$$\therefore \text{ Total work done} = 78.54 \times 30\,kJ/kg$$

$$= 2356.2\,kJ/kg$$

$$\text{Heat rejected} = 1000\,kJ$$

$$\text{Therefore, } \eta = \frac{2356.2}{2356.2 + 1000} \times 100\%$$

$$= 70.204\%$$