Module 1- Thermal Engineering

Nov 20

1. (b) One kg of an ideal gas is heated at constant pressure from 25^0C to 200^0 C. The values of specific heats at constant volume and constant pressure are 0.73kJ/kg K and 0.98 kJ/kg K respectively. Find the following:

   (i) value of characteristic gas constant (ii) the heat added
   (iii) ideal work done (iv) change in internal energy (7)

2. **IV** (a) 0.0001 m^3 of air at 1000kN/m^2 expands isothermally to a volume of 0.001m^3. The initial temperature is 25^0C. Assume, R=0.297 kJ/kg K.

   Find the following:

   (i) the mass of the air (ii)final pressure
   (iii) Work transferred (iv) heat transferred (8)

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3 (b) A certain volume of gas at NTP is hated until its pressure becomes 2 bar and its volume is doubled. Find the final temperature of gas. (8)

APR 19

4 (b) A gas having initial pressure, volume, temperature as 275kN/m^2, 0.09m^3, and 185°C respectively, is compressed at constant pressure until its temperature is 15°C. Calculate the amount of heat transferred and work done during the process. Take R = 290 J/kgK and Cp = 1.005kJ/kgK. 8

5 (b) A quantity of gas has a pressure of 350kPa when its volume is 0.03 m^3 and temperature is 35°C. If R = 0.29kJ/kgK for this gas, determine the mass of the gas present. If the pressure is increased to 1MPa while volume remains constant, find out new temperature. 8

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6. III (a) A gas having an initial pressure, volume, temperature as 1 bar, 2m^3 and 100° C respectively is compressed at constant pressure until its temperature is 150° C. Calculate the amount of heat transferred and work done during the process. Assume Cp = 1·005KJ/Kg K and R = 0.297 KJ/Kg K 8

7 IV (a) Certain mass of air has an initial volume of $0.028 m^3$, pressure 1.25 bar and temperature 25° C which is compressed to a volume of $0.0042 m^3$ according to the law $PV^{1.3}$ = constant. Find the Final pressure and Work done during compression. Also find the Reduction in pressure at a constant volume required to bring the air back to its original temperature. 8

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8 (b) Air at a pressure of 1.5 bar and a volume of $0.1 m^3$ is expanded isothermally to a volume of $0.5 m^3$. Calculate the Final pressure of the gas, Heat supplied and work done during the process. 7

9. IV (a) A mass of air has an initial pressure of $2 MN/m^2$, volume $0.1 m^3$ and temperature 200°C. It is expanded to its final pressure of $0.3 MN/m^2$ and its volume become $0.5 m^3$. Determine,

(i) Mass of air (ii) Final temperature of air (assume R = 0.287 KJ/Kg K) 8

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10 (b) Some amount of gas is compressed according to the law $PV^{1.37} = C$. Before compression, the pressure and temperature are 1 bar and 316 k respectively. The compression ratio is 13.5.

Find (i) Pressure at the end of compression.

(ii) Temperature at the end of compression.

(iii) Work done/kg during compression.

Take R = 289 J/Kgk. 8

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11 (b) A quantity of air has a volume of $0.4 m^3$ at a pressure of 5 bar and a temperature of 80°C. It is expanded in a cylinder to a pressure of 1 bar. Determine the amount of work done by the air during expansion. 8

12 IV (a) A closed vessel contains 2kg of CO_2 at a temp. 20°C and pressure 0.7 bar. Heat is supplied to the vessel till the pressure become 1.4 bar. Find (i) final temperature (ii) work done (iii) heat added (C_v = 0.657kJ/kgK) 7

13 (b) A $5 m^3$ tank of compressed air at a pressure of 3 bar and 25°C develops a small leak such that the pressure falls to 2.8 bar in 24 hours. How much air has leaked off the tank ? 8

Module 1 - Thermal Engineering.

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1. Given Data $T_1 = 25°C$ $T_2 = 200°C$ $C_v = 0.73$ kJ/kg.K
$C_p = 0.98$ kJ/kg.K , Isobaric process
$m = 1$ kg

Find $R, Q, W, \Delta U$

(i) $R = C_p - C_v = 0.98 - 0.73 = 0.25$ kJ/kgK

(ii) $Q = m C_p (T_2 - T_1) = 1 \times 0.98 \times (200 - 25) = 171.5$ kJ

(iii) $W = m R (T_2 - T_1) = 1 \times 0.25 \times (200 - 25) = 43.75$ kJ

(iv) $\Delta U = Q - W = 171.5 - 43.75 = 127.75$ kJ

2. Given Data $V_1 = 0.0001\ m^3$ $P_1 = 1000\ kN/m^2$
$V_2 = 0.001\ m^3$ $T_1 = 25°C$
$R = 0.297$ kJ/kg.K , Isothermal Expansion

(i) $$m = \frac{P_1 V_1}{R T_1} = \frac{1000 \times 0.0001}{0.297 \times (25 + 273)} = 1.13 \times 10^{-3}\ kg$$

(ii) $$P_1 V_1 = P_2 V_2 \Rightarrow P_2 = \frac{P_1 V_1}{V_2} = \frac{1000 \times 0.0001}{0.001} = 100\ kN/m^2$$

(iii) $$W = P_1 V_1 \ln \frac{V_2}{V_1} = 1000 \times 0.0001 \times \ln\left(\frac{0.001}{0.0001}\right)$$
$$= 0.2303\ kJ$$

(iv) $Q = \Delta U + W = 0 + W = 0.2303$ kJ

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3. Given Data $T_1 = 20°C = 293.15\ K$ } NTP
$P_1 = 101325\ Pa$
$P_2 = 2$ bar
$\frac{V_2}{V_1} = 2$
$T_2 = ?$

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$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \Rightarrow T_2 = \frac{P_2}{P_1} \times \frac{V_2}{V_1} \times T_1$$

$$= \frac{2\times10^5}{101325} \times 2 \times 293.15$$

$$= 1157.27\text{K}$$

$$= 884.12^\circ\text{C}$$

APR 19

4. Given Data $P_1 = 275 \text{ kN/m}^2$ $V_1 = 0.09 \text{ m}^3$ $T_1 = 185^\circ\text{C}$

$T_2 = 15^\circ\text{C}$ $R = 290 \text{ J/kg K}$ $C_p = 1.005 \text{ kJ/kg.k}$

Isobaric process

$$m = \frac{P_1 V_1}{R T_1} = \frac{275\times10^3 \times 0.09}{290 \times 458} = 0.186 \text{ kg}$$

$$Q_{1-2} = m C_p (T_2 - T_1) = 0.186 \times 1.005 \times (288 - 458)$$

$$= -31.78 \text{ kJ}$$

-ve sign indicate that heat is extracted from the gas during the process

$$W_{1-2} = mR(T_2 - T_1) = 0.186 \times 290 \times (288 - 458)$$

$$= -9.17 \text{ kJ}$$

-ve sign indicate that work is done on the gas during the process.

5. Given Data $P_1 = 350$ kPa $V_1 = 0.03\ m^3$

$T_1 = 35°C$ $R = 0.29$ kJ/kg.K

$P_2 = 1$ MPa $V_2 = V_1$

$m = ?$ $T_2 = ?$

$$m = \frac{P_1 V_1}{R T_1} = \frac{350 \times 0.03}{0.29 \times 308} = 0.1175 \text{ kg}$$

$$\frac{P_1}{T_1} = \frac{P_2}{T_2} \Rightarrow T_2 = \frac{T_1 \times P_2}{P_1} = \frac{308 \times 1\times10^6}{350\times10^3} = 880\text{ K}$$

ie $T_2 = 880 - 273 = \underline{\underline{607°c}}$

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6. Given Data $P_1 = 1$ bar $V_1 = 2m^3$ $T_1 = 100°c$

$P_2 = P_1$ $T_2 = 150°c$

$C_p = 1.005$ kJ/kg.K $R = 0.297$ kJ/kg.K

$Q = ?$ $W = ?$

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$$m = \frac{P_1 V_1}{R T_1} = \frac{1\times10^5 \times 2}{297 \times 373} = 1.805 \text{ kg}$$

$$Q = m C_p (T_2 - T_1) = 1.805 \times 1.005 (423 - 373)$$

$$= 90.7 \text{ kJ}$$

$$W = mR(T_2 - T_1) = 1.805 \times 0.297 \times (423 - 373)$$

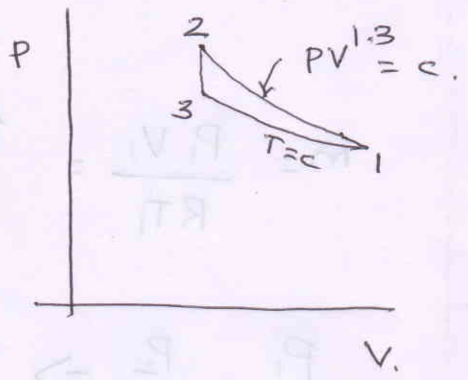
$$= 26.8 \text{ kJ}$$

7 Given Data $V_1 = 0.028\ m^3$ $P_1 = 1.25$ bar

$T_1 = 25^\circ C$ $V_2 = 0.0042\ m^3$

$n = 1.3$

Find P_2, W, P_3



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

$$\Rightarrow T_2 = T_1 \times \left(\frac{V_1}{V_2}\right)^{n-1} = 298 \times \left(\frac{0.028}{0.0042}\right)^{1.3-1}$$

$$= 526.49\ K$$

$$\frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^{n} \Rightarrow P_2 = P_1 \times \left(\frac{V_1}{V_2}\right)^{n}$$

$$= 1.25 \times 10^5 \times \left(\frac{0.028}{0.0042}\right)^{1.3} = 14.723 \times 10^5\ Pa$$

$$W_{1-2} = \frac{P_2 V_2 - P_1 V_1}{n-1} = \frac{(14.723 \times 10^5 \times 0.0042) - (1.25 \times 10^5 \times 0.028)}{(1.3 - 1)}$$

$$= \cancel{8958\ J}\ 8945\ J = \cancel{8.958\ kJ}\ 8.945\ kJ$$

$$\frac{P_2}{T_2} = \frac{P_3}{T_3} \Rightarrow P_3 = \frac{P_2}{T_2} \times T_3 = \frac{14.723 \times 298}{526.49}$$

$$= \underline{8.33\ \text{bar}}$$

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8 Given Data $P_1 = 1.5$ bar $V_1 = 0.1\ m^3$ $T_1 = T_2$

$V_2 = 0.5\ m^3$ Find P_2, Q, W.

$$P_1V_1 = P_2V_2 \Rightarrow P_2 = \frac{P_1V_1}{V_2} = \frac{1.5 \times 0.1}{0.5} = \underline{\underline{0.3 \text{ bar}}}$$

$$W = P_1V_1 \ln\frac{V_2}{V_1} = 1.5\times10^5 \times 0.1 \times \ln\left(\frac{0.5}{0.1}\right)$$

$$= 24141.57\ J \simeq 24.14\ kJ$$

$\Delta U = 0$ [$\because$ isothermal process]

$$Q = \Delta U + W = 0 + W = W = \underline{\underline{24.14\ kJ}}$$

9. Given Data $P_1 = 2\ MN/m^2$ $V_1 = 0.1\ m^3$

$T_1 = 200°C$ $P_2 = 0.3\ MN/m^2$

$V_2 = 0.5\ m^3$ $R = 0.287\ kJ/kg.K$

$$\text{(i)}\ m = \frac{P_1V_1}{RT_1} = \frac{2\times10^3 \times 0.1}{0.287\times473} = 1.473\ kg$$

$$\text{(ii)}\ \frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \Rightarrow T_2 = \frac{P_2V_2}{P_1V_1} \times T_1$$

$$= \frac{0.3\times0.5}{2\times0.1} \times 473$$

$$= 354.75\ K$$

$$= \underline{\underline{81.75\ °C}}$$

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10 Given Data $n = 1.37$ $P_1 = 1$ bar $T_1 = 316\,K$

$r = 13.5$ $R = 289$ J/kg.K.

(i)

$$P_1 V_1^n = P_2 V_2^n \Rightarrow P_2 = P_1 \left(\frac{V_1}{V_2}\right)^n = P_1 \cdot r^n$$

$$= 1 \times (13.5)^{1.37} = 35.36 \text{ bar}$$

(ii)

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{n-1} \Rightarrow T_2 = T_1 \left(\frac{V_1}{V_2}\right)^{n-1} = T_1 \cdot r^{n-1}$$

$$= 316 \times (13.5)^{1.37-1} = 827.77\,K$$

$$= 554.77\,^\circ C$$

(iii)

$$W = \frac{\cancel{m}R(T_2 - T_1)}{n-1} = \frac{289(827.77 - 316)}{\cancel{289}(1.37-1)}$$

$$\cancel{m = \frac{P_1 V_1}{R T_1}} = \cancel{389} = 399.73 \text{ kJ/kg}$$

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11. Given Data $V_1 = 0.4\,m^3$ $P_1 = 5$ bar $T_1 = 80^\circ C$

$P_2 = \cancel{\#}$ bar $\cancel{T_2 = 80^\circ c}$ $W = ?$

Assume isentropic expansion

$$P_1 V_1^{\gamma} = P_2 V_2^{\gamma} \Rightarrow V_2 = \left(\frac{P_1}{P_2}\right)^{1/\gamma} \times V_1$$

$$= \left(\frac{5}{1}\right)^{\frac{1}{1.4}} \times 0.4 = 1.26\,m^3$$

$$W = \frac{P_1 V_1 - P_2 V_2}{\gamma - 1} = \frac{(5\times10^5 \times 0.4) - (1\times10^5\times1.26)}{1.4 - 1} = 185 \text{ kJ}$$

12 Given Data $m = 2\,kg$ $T_1 = 20^\circ C$ $P_1 = 0.7$ bar

$P_2 = 1.4$ bar $C_v = 0.657$ kJ/kg.K

Find T_2, W, Q

$$\frac{P_1}{T_1} = \frac{P_2}{T_2} \Rightarrow T_2 = \frac{P_2}{P_1} \times T_1 = \frac{1.4}{0.7} \times 293$$

(i) $$= 586\ K$$

ie $T_2 = \underline{\underline{313\ ^\circ C}}$

(ii) $W = 0$ ($\because$ isochoric process)

(iii) $Q - W = \Delta U$

$$\therefore Q - 0 = \Delta U \Rightarrow Q = \Delta U = m\,C_v\,(T_2 - T_1)$$

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$$= 2 \times 0.657 \times (313 - 20)$$

$$= 385\ kJ$$

13. Given Data $V_1 = 5\,m^3 = V_2$ $P_2 = 2.8$ bar

$P_1 = 3$ bar $T_1 = 25^\circ C = T_2$

$$m_1 = \frac{P_1 V_1}{R T_1} = \frac{3 \times 10^5 \times 5}{287 \times 298} = 17.538\ kg$$

$$m_2 = \frac{P_2 V_2}{R T_2} = \frac{2.8 \times 10^5 \times 5}{287 \times 298} = 16.369\ kg$$

$m_1 - m_2 = 17.538 - 16.369 = \underline{1.169\ kg}$ of air has leaked off.