Mansoura University

(BME) Program - Level 100

Full Semester 2014 / 2015

Course Title: Thermodynamics

Faculty of Engineering

Final Exam.

Time: 2 hours

Date: June, 2015

Solve the Following Problems:

1- (a) Prove that for perfect gase , $C_p = C_v + R$, Where C_p , C_v are the specific heat at constant pressure and constant volume respectively, and R is the gas constant.

(4 marks)

(b) A cylinder contains $0.45\ m^3$ of a gas at $1\ bar$ and $80°C$. The gas is compressed to a volume of $0.13\ m^3$, the final pressure being $5\ bar$. Determine : (i) The mass of gas ; (ii) The value of index 'n' for compression ; (iii) The heat received or rejected by the gas during compression. (iv) The change of entropy during the process. Take $\gamma = 1.4$, $R = 294\ J/kg°C$.

(9 marks)

2- A turbine, operating under steady-flow conditions, receives $4500\ kg$ of steam per hour. The steam enters the turbine at a velocity of $50\ m/s$, an elevation of $5.5\ m$ and a specific enthalpy of $2800\ kJ/kg$. It leaves the turbine at a velocity of $95\ m/s$, an elevation of $1.5\ m$ and a specific enthalpy of $2300\ kJ/kg$. Heat losses from the turbine to the surroundings amount to $16000\ kJ/h$. Determine the power output of the turbine.

(12 marks)

3- (a) Prove that the Carnot cycle efficiency depends only on the temperature limits of heat source and heat sink only. Drew the cycle on T-S diagram.

(5 marks)

(b) A Carnot cycle operates between source and sink temperatures of $250°C$ and $-15°C$. If the system receives $90\ kJ$ from the source, find : (i)Efficiency of the system ; (ii) The net work transfer ; (iii) Heat rejected to sink.

(7 marks)

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1)

Model Answer of Thermodynamic Exam.. BME level 100 program Faculty of Engineering - Mansoura University.

1- (a) for perfect gas in closed system:

$$\delta Q = dU + \delta W \quad (a)$$

for constant pressure process

$$\delta Q = m c_p dT \quad (1) \text{ (assume } c_p \text{ is constant)}$$

$$dU = m c_v dT \quad (2)$$

$$\delta W = p dV \quad , \because pV = mRT$$

$$pdV + Vdp = mRdT$$

$$\because p = \text{const.} \rightarrow \therefore dp = 0 \rightarrow \therefore pdV = mRdT \quad (3)$$

$\boxed{4}$

from equation a, 1, 2, 3

$$\therefore \cancel{m} c_p \cancel{dT} = \cancel{m} c_v \cancel{dT} + \cancel{m} R \cancel{dT} \text{ , so}$$

$$\boxed{c_p = c_v + R}$$

(b) $P_1 V_1 = mRT_1 \quad \therefore 10^5 \times 0.45 = m \times 294 \times (80+273)$

353

(i) $\boxed{m = 0.4336 \text{ Kg}}$ # $\boxed{2}$

(ii) $\because \frac{T_2}{T_1} = \left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}} = \left(\frac{V_1}{V_2}\right)^{n-1} \quad , \quad \frac{p_2}{p_1} = \left(\frac{V_1}{V_2}\right)^{n}$

$$\therefore \frac{5}{1} = \left(\frac{0.45}{0.13}\right)^{n} \Longrightarrow \ln 5 = n \ln\left(\frac{0.45}{0.13}\right) \Rightarrow n = 1.296 \#$$

(ii) $\boxed{n = 1.296 \#}$ $\boxed{2}$

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Q1 (b) contin..

(iii) $Q = mC_n \Delta T = m C_n (T_2 - T_1)$ $\boxed{3}$

$$\frac{T_2}{T_1} = \left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}} \quad \therefore \frac{T_2}{353} = \left(\frac{5}{1}\right)^{\frac{0.296}{1.296}} \Rightarrow T_2 = 509.8\,K$$

$$C_n = C_v \frac{n-\gamma}{n-1} \Rightarrow \because \gamma \quad \because C_v = \frac{R}{\gamma - 1} = \frac{294}{0.4} = 735 \frac{J}{kg \cdot K}$$

$$\therefore C_n = (735)\frac{1.296 - 1.4}{0.296} = -258.24 \; J/kg.K \; \#$$

$$\therefore Q = 0.4336(-258.24)(509.8 - 353) = -17558 \; J$$

$\boxed{Q = -17.558 \; kJ}$ heat rejected.

(iv) $\Delta S = m C_n \ln \frac{T_2}{T_1} = 0.4 \times (-258.24) \ln \frac{509.8}{353}$

$\boxed{\Delta S = -37.8 \simeq -38 \; J/K \; \#}$ $\boxed{2}$

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Q2

$P = \dot{W}$ KW, or W.

From the 1st law for open system:

$$\dot{Q} + \dot{m}\left(h + \frac{C^2}{2} + gz\right)_i = \dot{m}\left(h + \frac{C^2}{2} + gz\right)_o + P$$

2 mark

$$-\frac{16000}{3600} + \frac{4500}{3600}\left(2800 + \frac{(50)^2}{2000} + \frac{9.81 \times 5.5}{1000}\right)$$

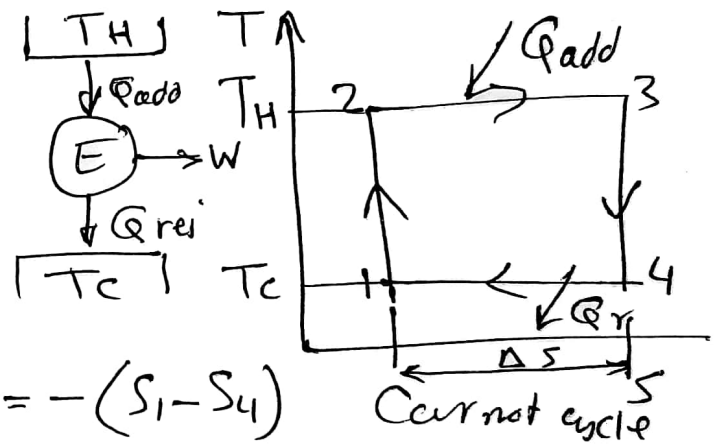
$$= \frac{4500}{3600}\left(2300 + \frac{(95)^2}{2000} + \frac{9.81 \times 1.5}{1000}\right) + P$$

10 mark

$$\therefore P = 616.5 \ \frac{KJ}{s} = 616.5 \ KW \ \#$$

Q3: (a) $Q_{add} = T_H (S_3 - S_2)$

$Q_{rej} = T_C (S_1 - S_4)$



$\Sigma W = \Sigma Q$

but $(S_3 - S_2) = (S_4 - S_1) = -(S_1 - S_4)$

$$\therefore W_{net} = T_H (S_3 - S_2) - T_C (S_4 - S_1)$$

$$\eta_{Carnot} = \frac{W_{net}}{Q_{add}} = \frac{T_H \cancel{(S_3 - S_2)} - T_C \cancel{(S_4 - S_1)}}{T_H \cancel{(S_3 - S_2)}}$$

$$= 1 - \frac{T_C}{T_H}$$

, so it depends only on the temp. limits of heat source and heat sink.

5 marks

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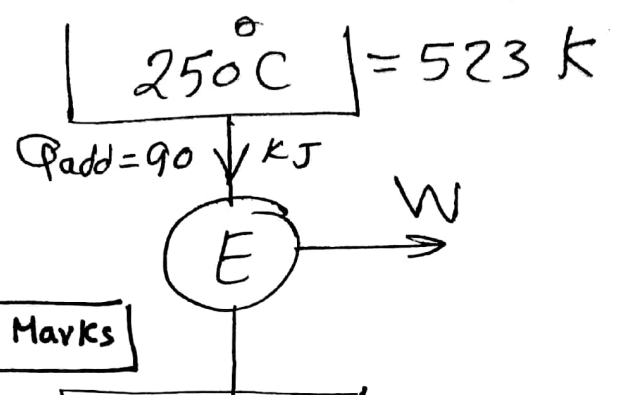
Q3 Continuous:



$$\eta_{carnot} = 1 - \frac{T_C}{T_H}$$ 3 Marks

$$= 1 - \frac{258}{523} \approx 0.507 \#$$

$\because \eta_{carnot} = \frac{W}{Q_{add}}$ $\therefore 0.507 = \frac{W}{90} \Rightarrow W = 45.6$ KJ (2 marks) #

$\because Q_{add} = W + Q_{rej}$ $\therefore 90 = 45.6 + Q_{rej}$

$\therefore Q_{rej} = 44.4$ KJ # 2 marks

Q4 # from steam tables

$h_1 = h_f + x_1 h_{fg}$ at 10 bar

$= 762.6 + 0.95(2013.6) = 2675.5$ KJ/kg #

$v_1 = v_f + x_1(v_g - v_f)$ at 10 bar

$= 0.001127 + 0.95(0.1943 - 0.001127) = 0.1846$ m³/kg

(i) $m_1 = \frac{V}{v_1} = \frac{0.8}{0.1846} = 4.33$ kg # 3

$\because h_1 = h_2 = h_f + x_2 h_{fg}$ at 5 bar

$\therefore 2675.5 = 640.1 + x_2(2107.4) \Rightarrow x_2 = 0.966$ #

$v_2 = v_f + x_2(v_g - v_f)$ at 5 bar 2

$= 0.001 + 0.966(0.3737) = 0.362$ m³/kg

$m_2 = \frac{V}{v_2} = \frac{0.8}{0.362} = 2.21$ kg 2

$\therefore \Delta m = m_1 - m_2 = 4.33 - 2.21 = 2.12$ kg blown off #

the final cooling process with constant volume

$u_2 = u_f + x_2 u_{fg}$ at 5 bar $\therefore u_2 = 639.6 + 0.966(1920.6)$

$= 2495$ KJ/kg 2

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$v = \text{const} \quad \therefore v_2 = v_3 = 0.362 \ m^3/kg$

$\therefore v_3 = v_f + x_3 (v_g - v_f)$ at 4 bar.

$0.362 = 0.001 + x_3 (0.4622 - 0.001) =$

$x_3 = 0.782$ $\boxed{2}$

$\therefore u_3 = u_f + x_3 u_{fg}$ at 4 bar

$= 604.3 + 0.782 (1948.5) = 2128 \ KJ/Kg.$

$\therefore Q = m_2 (u_3 - u_2) = 2.21 (2128 - 2495)$

$= -811$ KJ heat rejected. $\boxed{2}$

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