Ministry of Higher Education & Scientific Research
University of Technology
Laser&Optoelectronic Eng. Department
Branch: Laser Eng.
Class: 2nd Year:
Subject: Thermodynamics &Fluid Mechanics

Final Examination
Time: 3 hr
Date 5/6/ 2016
Examiner: Prof. Khalid Salem
Code: LE 2310
Academic Year 2015-2016

Attempt only (5) questions

Q1) A) In a steady flow system, air flows at a rate of 2 kg/sec. It enters at a pressure of 390 KN/m^2, velocity of 240 m/sec, internal energy 1500 kJ/kg and specific volume of 0.3 m^3/kg. It leaves the system at a pressure of 130 KN/m^2, velocity of 120 m/sec, internal energy 1200 kJ/kg and specific volume 1.5 m^3/kg. If the power developed by the system is 2000 KW .Neglect potential energy; determine the heat transfer (in Watt) in the system (is it gain or loss). (8 marks)

Q1)B) derive the characteristic equation of a perfect gas. (i.e. PV=m R T) (4 marks)

Q2)A) 1.5 kg of air at a temperature of 30 °C occupies 0.2 m^3, is compressed till its temperature becomes 100 °C according to the law $PV^{5/4}$= Const, take Cp=1.1 kJ/kg.K, Cv=0.72 kJ/kg.K ,

1) draw P-V diagram and determine initial & final pressure.(3 marks)
2) determine the difference in internal energy. (1 marks)
3) what is the value of specific work done and specific heat rejected .(2 marks)

Q2) B) What is the volume of 3 kg of CO_2, H_2 and O_2 in standard atmosphere (i.e. Temperature =15 °C, Pressure =101325N/m^2). (3 marks)

Q2)C) Prove that the characteristic gas constant is equal to the difference of specific heats.(3 marks)

Q3) A quantity of gas occupies a volume of 0.3 m^3 at a pressure of 100KN/m^2 and a temperature of 20 °C .The gas is compressed isothermally to a pressure of 500KN/m^2 and then expand adiabatically to its initial pressure .If the cycle is complete by returning to the initial state by constant pressure process (take γ=1.4, Cp=1 kJ/kg.K)

1) determine the mass of the gas and draw P-V diagram for the cycle.(2 marks)
2) verify the 1st law of thermodynamics (i.e. $\sum Q = \sum W$).(10 marks)

Q4) The volumetric analysis of a gas is as follows: CO 30% ,O_2 60%, H_2 10%.This gas is mixed with air in proportions 2 volume of gas to 1 volume of air. Take the molar specific heat capacity at constant volume for diatomic gas =20 kJ/kg mol K . Air contains 21% oxygen by volume and the remainder is N_2 .If the air-gas mixture is kept at 30 °C and 2 bar for temperature and pressure respectively. Determine for the air-gas mixture:

a) The mean relative molecular mass of the mixture(M_{av}) (2 marks)
b) The value of the adiabatic index of the mixture (γ). (2 marks)
c) The characteristic gas constant for the mixture(R). (2 marks)
d) The density of air-gas mixture. (2 marks)
e) The partial pressure and mass fraction of N_2 in the mixture. (4 marks)

Q5) For the velocity meter shown in fig1,derive an equation that relate the distance R and the velocity at point1 If the velocity of water in point 1 is 3 m/s , find the value ofdistance Rin mm.Assume the pipe diameter is20 cm, find volume and mass flow rate of water.(12 marks)

Q6)A) For a large tank shown in fig2 , what is the value of R. (6 marks)

Q6) B) If gauge pressure reads 200 KPa. What is the absolute pressure assume the atmospheric pressure is 1 Bar . Determine the absolute pressure in KPa, Bar and mm Hg. (6 marks)

Fig 1

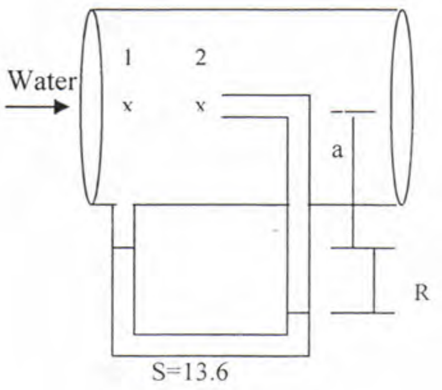
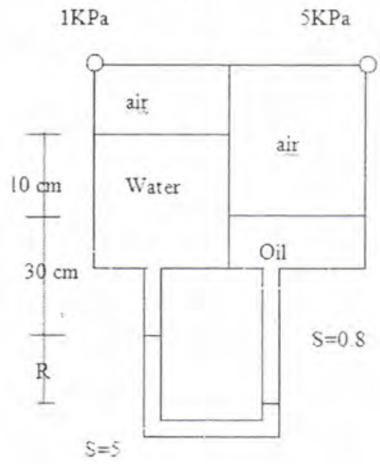


Fig 2



Q6)

A)

$$10^3 + 0.5\gamma_w + 5R\gamma_w - 0.8(R+0.3)\gamma_w = 5\times10^3$$

$$5R\gamma_w - 0.8R\gamma_w = \frac{5\times10^3 - 10^3}{\gamma_w} - 0.5\gamma_w + 0.8\times0.3\gamma_w$$

$$4.2R = \frac{4000}{\gamma_w} - 0.5 + 0.24$$

$$4.2R = 0.4 - 0.5 + 0.24$$

$$R = \frac{0.14}{4.2} = 0.0334\,m$$

B)

$$P_{abs} = P_{atm} + P_{gauge}$$

$$= 1\times10^5 \frac{N}{m^2} + 200000 \frac{N}{m^2}$$

$$P_{ab} = 3\times10^5 \frac{N}{m^2}$$

$$= 3\times10^5\ Pa$$

$$= 3\times10^2\ kPa$$

$$= 3\ bar$$

$$P_{ab} = 3\times10^5 \frac{N}{m^2}$$ [illegible] $$\frac{760\ mm\ Hg}{101325\ N/m^2}$$

$$= 2250.18\ mm\ Hg$$

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Q5

$$\frac{P_1}{\gamma_w} + \frac{V_1^2}{2g} + \cancel{z_1} = \frac{P_2}{\gamma_w} + \cancel{\frac{V_2^2}{2g}} + \cancel{z_2}$$

$$\frac{P_2 - P_1}{\gamma_w} = \frac{V_1^2}{2g} \quad \text{— (1)}$$

$$P_1 + a\gamma_w + SR\gamma_w - (R+a)\gamma_w = P_2$$

$$\frac{P_2 - P_1}{\gamma_w} = a + SR - (R+a)$$

$$= \cancel{a} + SR - R - \cancel{a}$$

$$\frac{P_2 - P_1}{\gamma_w} = R(S-1) \quad \text{— (2)}$$

$$\frac{V_1^2}{2g} = R(S-1)$$

$$\therefore V_1 = \sqrt{2gR(S-1)}$$

$$3 = \sqrt{2(9.8)R(13.6-1)}$$

$$\therefore R = 0.0364\ m$$

$$= 36.4\ mm$$

$$\dot{m} = \rho VA = 10^3(3)\pi(0.1)^2$$

$$= 94.246\ kg/s$$

$$Q = VA = 3\pi(0.1)^2 = 0.094\ m^3/s$$

(Q4)

$$M_{av} = \frac{2(\overset{8.4}{0.3\times 28} + \overset{19.2}{0.6\times 32} + \overset{0.2}{0.1\times 2}) + 1(\overbrace{\overset{22.12}{0.79\times 28} + \overset{6.72}{0.21\times 32}}^{28.84}}{3}$$

$= 28.146$

$\bar{C}_{p_{av}} = \bar{C}_{v_{av}} + 8.3143$

$= 20 + 8.3143 = 28.3143$

$\gamma = \frac{\bar{C}_{p_{av}}}{\bar{C}_{v_{av}}} = \frac{28.3143}{20} = 1.4157$

$R = \frac{R_m}{M_{av}} = \frac{8.314}{28.146} = 0.2953 \frac{KJ}{Kg\,K}$

$V = \frac{8.3143 \times 303 \times 10^3}{2\times 10^5} = 12.56\ m^3$

$\rho = \frac{M_{av}}{V} = 2.234\ Kg/m^3$

$P_{N_2} = \frac{P_T}{3} \times 0.79 = 0.52\ bar = 52666\ N/m^2$

$m_T = 3 \times M_{av} = 84.438\ Kg$

$m_{N_2} = 0.79 \times 28 = 22.12\ Kg$

$\% M_{N_2} = \frac{22.12}{84.43} = 26.2\%$

$Q_{31} = m\,C_p(T_1 - T_3)$

$T_3 = ?$

$P_3 V_3 = mRT_3$

$$T_3 = \frac{100\times10^3(0.1894)}{0.358(0.285)\times10^3} = 185.63^\circ K$$

$\therefore Q_{31} = m\,C_p(T_1 - T_3)$

$= 0.358(1)\times10^3(303 - 185.63)$

$= 38437.8\,J$

$W_{31} = P(V_1 - V_3) = 100\times10^3(0.3 - 0.1894)$

$= 111000\,J$

1st law

$\Sigma Q = \Sigma W$

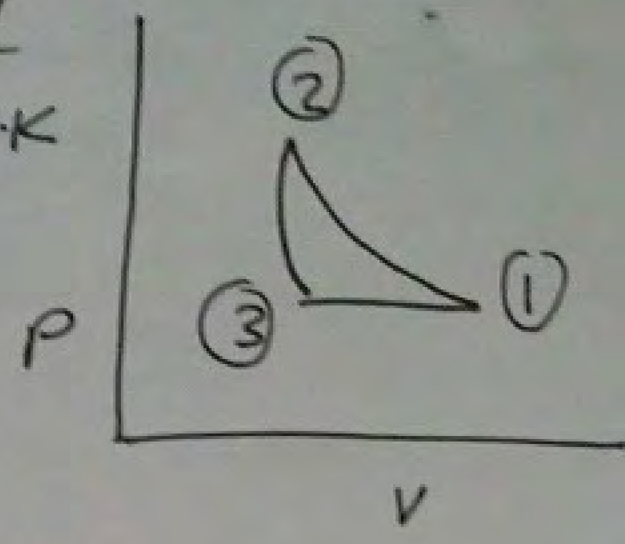
$Q_{12} + Q_{23} + Q_{31} \overset{?}{=} W_{12} + W_{23} + W_{31}$

$-48283 + 0 + 38437.8 = -48283 + 27647 + 11100$

$\therefore$ 1st law is verified.

Q3

$\gamma = \frac{C_p}{C_v}$, $\Rightarrow C_v = 0.714 \frac{kJ}{kg \cdot K}$



$P_1 V_1 = mRT_1$

$m = \frac{(100 \times 10^3)(0.3)}{R(293)} = 0.358\ kg$

1-2 isothermal process

$Q - W = \Delta U^{\,\nearrow 0}$

$Q_{12} = W_{12} = P_1 V_1 \ln \frac{P_1}{P_2} = 100 \times 10^3 \times 0.3 \ln \frac{100}{500}$

$= -48283.14\ J$

$P_1 V_1 = P_2 V_2 \Rightarrow V_2 = \frac{P_1}{P_2} V_1 = 0.06\ m^3$

2-3 adiabatic

$P_3 V_3^{\gamma} = P_2 V_2^{\gamma}$

$V_3^{\gamma} = \frac{P_2 V_2^{\gamma}}{P_2} = \frac{500 \times 10^3 (0.06)^{1.4}}{100 \times 10^3} = 0.0973$

$V_3 = 0.0973^{\frac{1}{\gamma}} = 0.1894\ m^3$

$Q^{\nearrow 0} - W = \Delta U$

$W_{23} = -\Delta U = -\frac{(P_2 V_2 - P_3 V_3)}{\gamma - 1}$

$= \frac{-(500 \times 0.06 \times 10^3 - 100 \times 10^3 \times 0.1894)}{1.4 - 1}$

$= \frac{30 - 18.937}{0.4} = -27647\ J$

Q2 B)

$PV = MRT$

$R = \frac{R_m}{m.m}$

$V_{CO_2} = \frac{3 \times \frac{8314.3}{44} \times (273+15)}{101325} = 1.6 m^3$

$V_{H_2} = \frac{3 \times \frac{8314.3}{2} (273+15)}{101325} = 35.4 m$

$V_{O_2} = \frac{3 \times \frac{8314.3}{32} (273+15)}{101325} = 2.155 m^3$

Q2 ©

$q = C_p dT$

$q - w = \Delta u$

$q = w + \Delta u$

$C_p dT = p dv + C_v dT$

$p dv = R dT$

$C_p dT = R dT + C_v dT$

$C_p = R + C_v$

$R = C_p - C_v$

Q2) A) $R = C_p - C_v$ ✓

$R = 1.1 - 0.72 = 0.38 \ \frac{KJ}{Kg.K}$

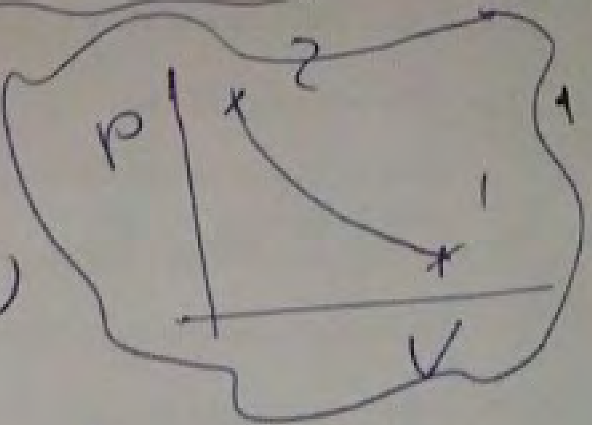
$P_1 V_1 = mRT_1$

$P_1 = \frac{1.5(0.38)\times10^3(273+30)}{0.2} = 863550 \ N/m^2$ 1

$\frac{T_1}{T_2} = \left(\frac{P_1}{P_2}\right)^{\frac{n-1}{n}} \Rightarrow T_2 = \frac{T_1}{\left(\frac{P_1}{P_2}\right)^{\frac{n-1}{n}}}$ or

$\left(\frac{T_1}{T_2}\right)^{\frac{n}{n-1}} = \frac{P_1}{P_2} \Rightarrow P_2 = \frac{P_1}{\left(\frac{T_1}{T_2}\right)^{\frac{n}{n-1}}}$

$\therefore P_2 = \frac{863550}{\left(\frac{303}{373}\right)^{\frac{1.25}{0.25}}} = 2441285.12 \ N/m^2$ 1



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

$= 1.5(0.72)\times10^3(100-30)$

1 $= 75600 \ J$

$W = \frac{mR(T_2-T_1)}{n-1} = \frac{1.5(0.38)\times10^3(-70)}{0.25} = -159600 \ J$

$w = -106400 \ J/kg$ 1

$Q - W = \Delta U$

$Q = W + \Delta U = -159600 + 75600 = -84000 \ J$

$q = -56000 \ J/kg$ 1

Q1 A)

$$q + u_1 + p_1 v_1 + \frac{V_1^2}{2} + z_1 = W + u_2 + p_2 v_2 + \frac{V_2^2}{2} + z_2$$

$P = \dot{m} w$

$2 \times 10^3 = 2(w)$

$w = 1000 \frac{J}{kg}$

$$q + 1500 + 390 \times 0.3 + \frac{240^2}{2(1000)} = 1 + 130.0(1.5) + 1200 + \frac{120^2}{2000}$$

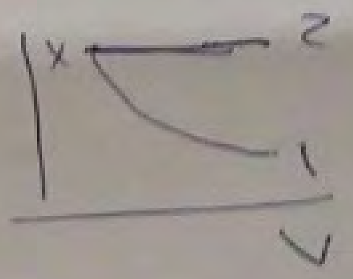
$q = 1 + 195 + 1200 + 7.2 - 1500 - 117 - 28.8$

$q = -244.6 \frac{kJ}{kg} (2) \frac{kg}{s}$

$q = -489.2\ kW = -489200\ W$ ✓

B)

From $1 \rightarrow x$ Boyl's low



$P_1 V_1 = P_x V_x$ — (1)

from $x \rightarrow 2$ charl's law

$\frac{V_x}{T_x} = \frac{V_2}{T_2} = const$ — (2)

from 1 $V_x = \frac{P_1 V_1}{P_x}$ into 2 $\frac{P_1 V_1}{P_x T_x} = \frac{V_2}{T_2}$

But $P_x = P_2$, $T_x = T_1$ then

$\frac{P_1 V_1}{P_2} = \frac{V_2 T_1}{T_2} = const \Rightarrow \frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} = \frac{PV}{T} = const$

$\frac{Pv}{T} = const = R$ characteristic gas const

for m kg of gas $\frac{P m v}{T} = mR \Rightarrow \frac{PV}{T} = mR$

$\therefore PV = mRT$ ✓