

**TECHNICAL UNIVERSITY OF MOMBASA**

**Faculty of Engineering and Technology**

**DEPARTMENT OF MECHANICAL AND AUTOMOTIVE ENGINEERING**

**UNIVERSITY EXAMINATIONS FOR:**

**THE DEGREE IN BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING**

**(BSME)**

**EMG 2302: ENGINEERING THERMODYNAMICS II**

**END OF SEMESTER EXAMINATION**

**SERIES: MAY 2016 (SUPPLEMENTARY)**

**TIME: 2 HOURS**

**INSTRUCTIONS TO CANDIDATES**

1. You should have the following for this examination:
    - **Answer Booklet**
    - **A Non-Programmable Scientific Calculator**
    - **Thermodynamic and Transport Properties of Fluids (SI Edition) by Y.R Mayhew and G.F.C Rogers**
    - **P-h diagram for R-134a**
    - **Psychrometric Chart**
  2. This paper consists of **FIVE** Questions.
  3. Answer **ANY THREE** Questions.
  4. All questions carry equal marks.
  5. **This paper consists of SIX printed pages.**
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### Question 1

a) A refrigeration system operates on the basic reversed Carnot Cycle using a condensable working fluid.

i. Show the cycle on T – s and p – h diagrams on which the exit from the evaporator is State 1.

(7 Marks)

ii. Show that the  $COP_{REF} = \frac{T_1}{T_2 - T_1}$  (14 Marks)

iii. Show that the  $COP_{HP} = \frac{T_2}{T_2 - T_1}$  (5 Marks)

iv. Show that the  $COP_{HP} - COP_{REF} = 1.0$  (3 Marks)

b) A refrigerator operating on the basic reversed Carnot Cycle has working temperatures in the evaporator and condenser of  $-30^\circ\text{C}$  and  $32^\circ\text{C}$ , respectively.

What are the maximum  $COP_{REF}$  and  $COP_{HP}$ ?

If the actual refrigerator has a  $COP_{REF}$  of 0.75 of the maximum  $COP_{REF}$ , calculate the refrigeration effect in kW per kW power input.

(11 Marks)

## **Question 2**

Steam leaves a boiler at 2.5 MPa and 300°C and is expanded in the HP Turbine to 0.10MPa at which pressure the liquid and vapour phases are completely separated. The vapour phase is reheated at constant pressure to 250°C and then expanded in the LP Turbine to 4.0kPa after which the LP Turbine exhaust is completely condensed and under cooled by 3.0°C and discharged into a hot well using a condensate pump. The separated liquid phase from the HP Turbine is used in a heat exchanger to heat process water from 40°C to 65°C. This stream is then discharged into the hot well.

A feed pump then transfers water from the hot well to the boiler.

- a) Show the layout of the plant on a labelled diagram. (8 Marks)
- b) Show the processes on a T – s diagram. Show the layout of the plant on a labelled diagram. (8 Marks)
- c) Calculate the boiler steam output (kg/sec) required for a total turbine work output of 2MW.

All assumptions made must be stated.

(24 Marks)

### Question 3

a) State Avogadro's Law and use it to show that the product of molecular mass and gas constant for all gases is a constant.

(8 Marks)

b) State Dalton's Law and use it to show the following:

i.  $V_i = (P_i/P)V$

ii.  $C_p = \sum x_i \cdot C_{pi}$

Where subscript  $i$  denotes property of individual gas in a mixture and  $x$  is the mass fraction

(15 Marks)

a) Stating from the definition of  $C_p$  and  $C_v$ , show that:

$$C_p - C_v = R \text{ where } R \text{ is the gas constant}$$

(5 Marks)

b) A vessel of volume  $0.4 \text{ m}^3$  contains  $0.45 \text{ kg}$  of Carbon Monoxide (molecular weight 28) and  $1.0 \text{ kg}$  of air at  $15^\circ\text{C}$ . The gravimetric analysis of air is 23.3% oxygen and 76.7% nitrogen. The molecular weights of oxygen and nitrogen are 32 and 28 respectively.

Calculate the partial pressure of each gas and the total pressure inside the vessel.

(12 Marks)

#### **Question 4**

- a) Give concise definitions of the following terms used in psychrometry and the symbol for each definition.
- i. Saturated vapour
  - ii. Superheated vapour
  - iii. Specific humidity
  - iv. Relative humidity
  - v. Dew point temperature
  - vi. Percentage saturation

(20 Marks)

- b) Show that the specific humidity ( $\omega$ ) is given by:

$$\omega = (0.622) (P_s) / (P - P_s)$$

Where  $P_s$  is the partial pressure of the vapour in the mixture,  $P$  is the total pressure and 0.622 is a constant derived from the properties of air and vapour.

(7 Marks)

- c) Air at a barometric pressure of 1.01325 bar and temperature of 17°C has a relative humidity of 60%. Calculate the specific humidity and dew point temperature.

(13 Marks)

### Question 5

a) Give concise definitions/meaning of the following terms as used in psychrometry:

- i. Adiabatic mixing process
- ii. Sensible heating process
- iii. Sensible cooling process
- iv. Dehumidification
- v. Humidification

(10 Marks)

b) A mixture of vapour and air at State 1 ( $\omega_1, m_{a1}, t_1, h_1$ ) is adiabatically mixed with a mixture of vapour and air at State 2 ( $\omega_2, m_{a2}, t_2, h_2$ ) to form a mixture at State 3 ( $\omega_3, m_{a3}, t_3, h_3$ ).

- i. Show that  $(h_1 - h_3) / (h_3 - h_2) = m_{a2} / m_{a1}$
- ii. Show that  $(h_1 - h_3) / (h_3 - h_2) = (\omega_1 - \omega_3) / (\omega_3 - \omega_2)$

(16 Marks)

c) Show the above processes on a labelled hand-drawn psychrometric chart.

d) Given that  $t_1 = 40^\circ\text{C}$ ,  $\omega_1 = 0.020$  kg/kg air, and that  $t_2 = 25^\circ\text{C}$ ,  $\omega_2 = 0.01$  kg/kg air, and  $m_{a2} / m_{a1} = 0.05$ .

Show the processes and final state 3 on the psychrometric chart provided and hence obtain the final specific humidity, relative humidity and enthalpy.

(12 Marks)