MACHAKOS UNIVERSITY

University Examinations 2023/2024 Academic Year

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF MECHANICAL AND MANUFACTURING ENGINEERING

EMM 312: ENGINEERING THERMODYNAMICS III

Time: 2 Hours

Instructions:

- This paper consists of **FIVE** questions
- Attempt **Question 1** and any other **TWO** questions
- Maximum marks for each part of a question are as indicated.

Provided

- Molar (Universal) gas constant R_O = 8314.5 J/kmolK
- Thermodynamic and Transport Properties of Fluids, SI Units - by Rogers G.F.C and Mayhew Y.R
- Psychrometric chart

Question 1(30 marks)

a) With the aid of a schematic and a T-s diagram briefly describe the Carnot vapour cycle. [5 marks]

b) A Carnot cycle uses steam between the pressures of 40 and 0.08 bar. For the cycle determine the;

i. Heat supplied
ii. Turbine work output
iii. Cycle thermal efficiency. [5 marks]

c) Briefly explain the effects of the following attempts in the performance of a Rankine vapour cycle:

i. Increasing the boiler pressure for a constant condenser pressure
ii. Decreasing the condenser pressure for a constant boiler pressure. [5 marks]

d) i. State the Dalton's law of partial pressure for a non-reacting gas mixture.[2 marks]

ii. Obtain the following expression for the specific gas constant for a gaseous mixture;

$$R_m = \sum_{i=1}^{k} x_i R_i$$

Where; R_m – specific gas constant for the gaseous mixture
R_i – specific gas constant for each component gas i
x_i – mass fraction of each component gas I [3 marks]

e) Discuss the following types of regeneration in Rankine cycle.

i. Open feedwater regenerative system
ii. Closed feedwater regenerative system [5 marks]

f) For an air-vapour mixture, show that the specific humidity, w, is give by;

$$w = 0.622 \frac{p_v}{P - p_v}$$

Where p_v is partial vapour pressure and P is the mixture pressure [5 marks]

Question 2 (20 marks)

In a 80 MW steam power generating plant operating on the reheat Rankine cycle, steam enters the high-pressure turbine at 15 MPa and 500°C where it is expanded to an intermediate pressure of 15 bar. The steam is then reheated at constant pressure to a temperature of 450°C before being expanded in the low-pressure turbine to the condenser pressure of 0.075 bar. If the isentropic efficiencies of the high-pressure and low-pressure turbines are 0.88, determine the;

i. Mass flow rate of the steam
ii. rate at which heat is added
iii. cycle thermal efficiency
iv. specific steam consumption

Question 3 (20 marks)

Steam enters the HP turbine of an ideal regenerative-reheat Rankine cycle at 80 bar and 500°C and at a mass flow rate of 60 kg/s. The steam expands in the HP turbine to an intermediate pressure of 6 bar after which some of the steam then goes to an open feedwater heater and the balance is reheated to 400°C. Then, it is expanded in the LP turbine to a condenser pressure of 0.08 bar. Compute:

i. The steam quality at the end of expansion in the HP turbine
ii. The plant power output
iii. The cycle efficiency

Question 4 (20 marks)

a) A cylinder contains 0.09 m^3 of a gaseous mixture at 1 bar and 27 °C. The gaseous mixture contains 29.9% by mass nitrogen, 5.2% by mass hydrogen and 64.9% by mass carbon dioxide. For this gaseous mixture, calculate;
   i. Composition analysis on a mole basis
   ii. The molecular weight
   iii. The characteristic gas constant, R
   iv. The value of the isentropic index, γ

   Take c_p of nitrogen, hydrogen and carbon dioxide as 1.040, 14.31 and 0.846 kJ/kg K, respectively at 27 °C. [13 marks]

b) If the gaseous mixture undergoes a reversible non-flow process during which its volume is reduced to $1/4^{th}$ of its original volume, taking the law of compression as $pv^{1.25} = C$, estimate;
   i. The work transfer
   ii. The heat transfer
   iii. The change in entropy [7 marks]

Question 5 (20 marks)

a) For 70 m^3 of an air-water vapour mixture at 1.2 MPa, 32 °C and 65% relative humidity, determine the;
   i. Humidity ratio
   ii. Dew point
   iii. Mass aof air and mass of vapour
   iv. Amount of water vapour condensed if the mixture is cooled to 10 °C in a constant pressure process [12 marks]

b) A 100% outdoor summer air conditioning system has a room sensible heat load of 400 kW and a room latent load of 100 kW. The required inside conditions are 23 °C and 50% relative humidity, and the outdoor design conditions are 34 °C and 40% relative humidity. The air is supplied to the room at a dry bulb temperature of 15 °C. Find;
   i. The required mass flow rate of air

ii. The cooling coil capacity

Use the Psychrometric chart provided. [8 marks]