Machakos University

(University Examinations 2021/2022)

SCHOOL OF ENGINEERING

DEPARTMENT OF MECHANICAL AND MANUFACTURING ENGINEERING

EEE 201: THERMODYNAMICS

Time: 2 Hours

Instructions:

- This paper consists of FIVE questions
- Atempt Question One 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

Question 1(30 marks)

a) Briefly define the following terms as used in thermodynamics:
   - System
   - Surrounding
   - Universe
   - Heat engine
   - Cycle [5 marks]

b) oxygen has a molecular weight of 32 and a specific heat at constant volume = 650 J/kg K. Determine:
   - the ratio of the specific heats
   - the change in internal energy and enthalpy if 2.2 kg of the Oxygen gas is heated from 25 °C to 135 °C.

   Take universal gas constant to be R_o = 8314.3 kJ/kol K [5 marks]

c) A boiler is supplied with feed water at 12 kPa as saturated liquid and delivers steam at 3 bar and 400 °C. If the furnace of this boiler is oil fired, the calorific value of the oil being 44 MJ/kg; determine the efficiency of the combustion when 38000 kg of oil is supplied to generate 27000 kg of steam. [5 marks]

d) With the aid of a T-s diagram, describe the processes involved in the thermodynamic Carnot cycle. [5 marks]

e) A power utility company desires to use the hot ground water from a hot spring to power a heat engine. If the ground water is at 95 °C, estimate the maximum power output if a mass flow rate of 0.25 kg/s is possible. The atmosphere is at 20 °C. [5 marks]

f) Briefly explain the following terms as applied in heat transfer applications:
   - Conduction
   - Forced convection
   - Black body
   - Reflectivity
   - Absorptivity [5 marks]

Question 2 (20 marks)

a) Define the following thermodynamic processes:

- Isobaric process
- Adiabatic process
- Isothermal process [3 marks]

b) Show that the heat transferred, Q, during a polytropic process is given by;

$$Q = \left(\frac{n - \gamma}{\gamma - 1} \right) W_{poly}$$

Where, W_{poly} – work done during a polytropic process, pv^n = constant

n – polytropics exponent

ɤ - adiabatic index [8 marks]

c) A mass 3 kg of air is compressed through a polytropic process from an initial state of pressure 101 kPa and temperature 27 °C to a final state of pressure and temperature of 350 kPa and 325 °C, respectively. Determine the polytropic exponent and the heat transferred during the compression process. Take R = 0.287 kJ/kg K and ɤ = 1.4.

[9 marks]

Question 3 (20 marks)

a) Give a brief description to the following types of thermodynamic systems:

- Open system
- Closed system
- Isolated system [3 marks]

b) Show that the change of entropy during a constant pressure process can be obtained using the expression;

$$S_2 - S_1 = mc_p \ln \frac{v_2}{v_1}$$

Where; m – mass of the gas

v_1 – Initial specific volume of the gas

T_1 – Initial temperature of the gas

v_2, T_2 – corresponding values for the final condition [7 marks]

c) 1.5 kg of air is heated at constant pressure of 4 bar to 450 °C. if the initial volume is 0.8 m^3, determine;

- The initial temperature
- The final volume
- The heat exchanged
- The change in entropy

Take R = 287 J/kg K and γ = 1.4. [10 marks]

Question 4 (20 marks)

a) Differentiate between extensive and intensive thermodynamic properties. [2 marks]

b) Explain the following terms as used in steam utilizing systems;

- Wet steam
- Dryness fraction
- Degree of superheat [3 marks]

c) Steam enters the turbine in a power plant at 40 bar and 400 °C and is condensed at a pressure of 1 bar till it exits the condenser as saturated liquid.

i. Assuming the plant can be treated as an ideal Rankine cycle; determine the power produced per kg of steam and the efficiency of the cycle.

ii. Determine the efficiency of a Carnot cycle operated between these two temperatures. [15 marks]

Question 5 (20 marks)

a) Show that the critical radius of insulation of a cylindrical pipe is given by the expression:

$$r_{cr} = \frac{k}{h}$$

Where; k – thermal conductivity of insulation material

h – convection heat transfer coefficient [5 marks]

b) A 4-mm-diameter and 8-m-long electric wire is tightly wrapped with a 3-mm-thick plastic cover whose thermal conductivity is k = 0.15 W/m.K. Electrical measurements indicate that a current of 10 A passes through the wire and there is a voltage drop of 6 V along the wire. If the insulated wire is exposed to the ambient which is at 28 °C with a heat transfer coefficient of h = 12 $W/m^2.K$, determine under steady operating conditions:

i. The interface temperature of the wire and the plastic cover

ii. What will be the interface temperature of the wire and the plastic cover if the critical radius of insulation is used? [7 marks]

c) Stating the assumptions made, show that the overall heat transfer in a parallel-flow heat exchanger is given by the expression;

$$q = U A \Delta T_{lm}$$

Where; U = overall heat transfer coefficient

A = surface area across which heat transfer takes place

ΔT_{lm} = Logarithmic mean temperature difference. [8 marks]