MACHAKOS UNIVERSITY

University Examinations for 2022/2023 Academic Year

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF MECHANICAL AND MANUFACTURING ENGINEERING

SECOND YEAR SECOND SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (MECHANICAL ENGINEERING)

EMM 222: ENGINEERING THERMODYNAMICS II

DATE: 21/4/2023 **TIME: 8:30 – 10:30 AM**

INSTRUCTIONS

- This paper contains **FIVE (5)** questions.
- You are required to answer **THREE (3)** questions only.
- Question **one** is compulsory.
- Attempt any other two questions.
- Question one carries 30 marks and the others carry 20 marks each.

QUESTION ONE (30 MARKS)

a) Explain the essence of second law of thermodynamics (4 marks)

b) Define entropy and show that it is a property of system. (5 marks)

c) Explain Clausius inequality (5 marks)

d) A Carnot engine operates between a source temperature of 700^0C and a sink temperature of 20^0C. Assuming that the engine will have a net output of 65 hp, determine the thermal efficiency of the engine, the heat supplied and the heat rejected. (6 marks)

e) A rigid cylinder of volume 0.025 m^3 contains steam at 80 bar and 350°C. the cylinder is cooled until the pressure is 50 bar. Calculate the state of the steam after cooling and the amount of heat rejected by the steam. Sketch the process on a T-s diagram indicating the area which represents the heat flow. (5 marks)

f) Two identical bodies of constant heat capacity are at the same initial temperature T_1. A refrigerator operates between these two bodies until one body is cooled to temperature T_2. If the bodies remain at constant pressure and undergo no change of phase, find the minimum amount of work needed to do is, in terms of T_1, T_2 and heat capacity. (5 marks)

QUESTION TWO (20 MARKS)

a) Define the following terms and write down the expression for thermal efficiency (4.5 marks)

i. Thermal reservoir,

ii. Heat engine,

iii. Heat pump

b) Differentiate between Kelvin Planck and Clausius statement (4 marks)

c) State and prove the Carnot theorem (5 marks)

d) Heat pump is used for heating the premises in winter and cooling the same during summer such that temperature inside remains 25ºC. Heat transfer across the walls and roof is found 2MJ per hour per degree temperature difference between interior and exterior. Determine the minimum power required for operating the pump in winter when outside temperature is 1ºC and also give the maximum temperature in summer for which the device shall be capable of maintaining the premises at desired temperature for same power input.

(4 marks)

e) A cold storage of 100Tonnes of refrigeration capacity runs at 1/4th of its carnot COP. Inside temperature is – 150C and atmospheric temperature is 350C. Determine the power required to run the plant. Take one tonnes of refrigeration as 3.52KW. (2.5 marks)

QUESTION THREE (20 MARKS)

a) Define entropy, enthalpy and adiabatic. (3 marks)

b) Cledius a student at Machakos University heated reversibly one kilogram of steam at constant pressure of 7 bar, entropy 6.5 kJ/kgK until the temperature is 250 decree Celsius. Calculate heat supplied and show in a T-s diagram the area which represent the heat flow.

(5 marks)

c) Ann and Faith design a steam power plant which operates between a boiler pressure of 42 bar and a condenser pressure of 0.035 bar. Calculate for these limits the cycle efficiency and work ratio for Carnot cycle using wet steam. (4 marks)

d) A reversible heat engine operates between temperature 8000C and 500^0C of thermal reservoir. Engine drives a generator and a reversed carnot engine using the work output from the heat engine for each unit equality. Reversed Carnot engine abstracts heat from 500^0C reservoir and rejected that to a thermal reservoir at 715^0C. Determine the heat rejected to the reservoir by the reversed engine as a fraction of heat supplied from 800^0C reservoir to the heat engine. Also determine the heat rejected per hour for the generator output of 300KW. **(8 marks)**

QUESTION FOUR (20 MARKS)

a) Differentiate between reversible and irreversible process using a diagram (3 marks)

b) 1 kg of steam at 7 bar, entropy 6.5kJ/kgK, is heated reversibly at constant pressure until the temperature is 250^0C. calculate the heat supplied, and shown on a T-s diagram the area which represents the heat flow. (6 marks)

c) Dry saturated steam at 100 bar expands isothermally and reversibly to a pressure of 10 bar. Calculate the heat supplied and the work done per kg of steam during the process.

(5 marks)

d) Steam enters a turbine with a pressure of 30 bar, a temperature of 400 ^oC, and a velocity of 160 m/s. Saturated vapor at 100 ^oC exits with a velocity of 100 m /s. At steady state, the turbine develops work equal to 540 kJ per kg of steam flowing through the turbine. Heat transfer between the turbine and its surroundings occurs at an average outer surface temperature of 350 K. Determine the rate at which entropy is produced within the turbine per kg of steam flowing, in Neglect the change in potential energy between inlet and exit.

(6 marks)

QUESTION FIVE (20 MARKS)

a) A 0.3 kg metal bar initially at 1200K is removed from an oven and quenched by immersing it in a closed tank containing 9 kg of water initially at 300K. Each substance can be modeled as incompressible. An appropriate constant specific heat value for the water is c_w 4.2 kJ/kgK, and an appropriate value for the metal is c_m 0.42 kJ/kg K. Heat transfer from the tank contents can be neglected. Determine

i. the final equilibrium temperature of the metal bar and the water, in K, (3 marks)

ii. the amount of entropy produced, in kJ/K (3 marks)

b) Machakos second-year students generate steam at 7 bar, with a dryness fraction of 0.96. they designed a throttling device that throttled down to 3.5 bar. Calculate the change of entropy per unit mass of steam from their proposed design. (4 marks)

c) In an air turbine, the air expands from 6.8 bar and 430 ^oC to 1.013 bar and 150^oC. The heat loss from the turbine can be assumed to be negligible. Show that the process is irreversible, and calculate the change of entropy per kilogram of air. (5 marks)

d) Refrigerant 134a is compressed adiabatically in a piston–cylinder assembly from saturated vapor at 0^oC to a final pressure of 0.7 MPa. Determine the minimum theoretical work input required per unit mass of refrigerant, in kJ/kg. (5 marks)