MACHAKOS UNIVERSITY

University Examinations for 2022/2023

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF MECHANICAL AND MANUFACTURING ENGINEERING

SECOND YEAR FIRST SEMESTER EXAMINATIONS FOR

BACHELOR OF SCIENCE (ELECTRICAL AND ELECTRONICS ENGINEERING)

EEE 201: ENGINEERING THERMODYNAMICS I

DATE: **TIME:**

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 (COMPULSORY) (30 MARKS)

a) Define the term thermodynamics (1 mark)

b) State the second law of thermodynamics (1 mark)

c) Differentiate between forced convection and natural convection (2 marks)

d) Illustrate with an aid of a diagram a boundary and surrounding of an open and closed system. (3 marks)

e) Second year students of Machakos University design a steam plant operating in a closed cycle, its turbine develops 900 kW. The heat supplied to the steam in the boiler is 2800 kJ/kg, the heat rejected by the system to the cooling water in the condenser is 2100 kJ/kg and the feed pump work required to pump the condensate back into the boiler is 6 kW. Calculate the mass flow rate of steam round the cycle in kg/s. (5 marks)

f) A Carnot engine operates between a source temperature of 7000C and a sink temperature of 200C. 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)

g) In an experiment to find out the thermal conductivity of a material, an electric heater is sandwiched between two identical samples, each of size (10 cm by 10 cm) and thickness 0.5 cm, and all the four outer edges are well insulated. At steady state, it is observed that the electric heater draws 35 W of power and the temperature of each sample was 90°C on the inner surface and 82°C on the outer surface. Determine the thermal conductivity of the material at the average temperature. (5 marks)

h) One dimensional wall thickness of 100 mm experiences a heat flux of 1000 W/cubic metre is convective cooled at x = 50 mm by fluid at 20^{o}C. If steady state temperature distribution is $T(x)= a(L^{2} - x^{2})+b$. a= 10 ^{o} C/m , b=30 ^{o} C.

i. What is the thermal conductivity of the wall? (4 marks)

ii. What is the value of convection heat transfer coefficient? (3 marks)

QUESTION TWO (20 MARKS)

a) Using an equation, define Newtons Law of Cooling. (1 mark)

b) State the condition at which Reynolds analogy for forced convection is applicable. (1 mark)

c) List two assumptions made in the laminar sublayer film with regards to temperature and velocity. (2 marks)

d) Air flows through a 20 mm diameter tube 2 m long with a mean velocity of 40 m/s. The tube wall temperature is 150 ^{0}C and the air temperature increases from 15 to 100 ^{0}C. Using the Reynolds analogy with all properties at mean bulk temperature and taking the mean air pressure as 1 atm, determine

i. Thermodynamics and transport properties of air. (3 marks)

ii. Heat received by air. (2 marks)

iii. Coefficient of heat transfer. (3 marks)

iv. Pressure loss in millimeters of water in the tube due to friction. (6 marks)

v. Pumping power required. (2 marks)

QUESTION THREE (20 MARKS)

a) State the zeroth law of thermodynamics. (1 mark)

b) Define entropy, enthalpy and reversibility. (3 marks)

c) 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)

d) 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:

i. Carnot cycle using wet steam
ii. Rankine cycle with dry saturated steam at entry to the turbine
iii. Cycle performance when the steam is superheated to 500 ^{o}C. (Neglect pump work)

QUESTION FOUR (20 MARKS)

a) *Define absorptivity, reflectivity and transmissivity.* (3 marks)

b) Explain black and grey body. (2 marks)

c) A Second-year Electrical engineering student is working with a tea factory in developing a new dryer for drying green tea. The dryer uses steam which is conveyed through a steel pipe of 150 mm inside diameter, 10 mm wall thickness and 50 m long. The steam inside the pipe is a wet steam at a of pressure 165 bar. The design team proposes that the pipe should be insulated with 50 mm of a molded high temperature diatomaceous earth covering. They also proposed that this covering is in turn be insulated with 70 mm of asbestos felt. The heat transfer coefficients for the inside and outside surfaces are 500 and 25 W/m^{2}K, respectively, and the thermal conductivities of steel, diatomaceous earth and asbestos felt are 55, 0.085 and 0.065 W/mK respectively. The atmospheric temperature is 21°C.

i. Determine the amount of energy that is saved after insulation. (13 marks)
ii. The boiler that generates steam operates on biomass fuel with a calorific value of 21 kJ/kg. If the boiler runs for 4 hours a day and 292 days in a year, estimate the amount of fuel per year. (2 marks)

QUESTION FIVE (20 MARKS)

a) Using neat sketches, describe classification of the heat exchangers according to the flow directions of fluid. (5 marks)

b) A mechanical engineer is designing a cooling system for engine's exhaust gases. To achieve this purpose, the engineer proposes the use of a double-pipe heat exchanger which is either parallel or counterflow. The exhaust pipe has an outside diameter of 75 mm. The exhaust gas enters the exhaust pipe at 350 $^{\circ}$C, and the water enters from the mains at 10 ^{0}C. The heat transfer coefficients for the gases and water may be taken as 0.3 and 1.5 kW/m^{2}K, and the pipe thickness may be taken to be negligible. The gases are required to be cooled to 100 $^{\circ}$C and the mean specific heat capacity at constant pressure is 1.13 kJ/kgK. The gas flow rate is 0.0556 kg/s and the water flow rate is 0.389 kg/s. The specific heat capacity of water as 4.19 kJ/kgK. Using NTU method, evaluate each of the proposed design and select the best approach to achieve the intended purpose. (15 marks)