MACHAKOS UNIVERSITY

University Examinations for 2021/2022 Academic Year

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF MECHANICAL AND MANUFACTURING ENGINEERING

SECOND YEAR SECOND SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (ELECTRICAL AND ELECTRONICS ENGINEERING)

EMM 203: ENGINEERING THERMODYNAMICS 1

DATE: **TIME:**

INSTRUCTIONS

1. ***This paper contains FIVE questions.***
2. ***Question ONE is compulsory and carries 30 marks.***
3. ***Four remaining questions carry 20 marks each.***
4. ***Attempt Question ONE and any other TWO.***

QUESTION ONE (30 MARKS)

a) Define the following terms as used in thermodynamics

(i) Thermodynamic system (1 mark)

(ii) Working fluid (1 mark)

(iii) Heat engine (1 mark)

(iv) Entropy (1 mark)

(v) Coefficient of performance (COP) (1 mark)

b) A certain fluid at 10 bar is contained in a cylinder behind a piston, the initial volume being $0.005\ m^3$. Calculate the work done by the fluid when it expands reversibly according to a law, $p = \frac{A}{V^2} - \frac{B}{V}$, to a final volume of $0.1\ m^3$ and a final pressure of 1 bar. Where **A** and **B** are constants (8 marks)

c) Distinguish between the Clausius' and Kevin-Planck's statements of the Second Law of thermodynamics (2 marks)

d) Find the temperature, specific volume, internal energy and enthalpy of dry saturated steam at 9.8 bar. **(8 Marks)**

e) Show that the work done by a perfect gas undergoing a reversible adiabatic process is given by:

$$W = \frac{p_1 v_1 - p_2 v_2}{\gamma - 1}$$

(4 marks)

f) In a coal-fired steam power plant, the temperature of high-pressure steam is $540°C$ and the temperature of the cooling tower water is $20°C$. Calculate the Carnot efficiency of the power plant. (2 marks)

QUESTION TWO (20 MARKS)

a) A turbine operating under steady flow conditions receives steam at the following state: pressure $13.8\ bar$; specific volume, $0.143\ m^3/kg$; specific internal energy, $2590\ kJ/kg$; velocity, $30\ m/s$. The state of the steam leaving the turbine is as follows: pressure, $0.35\ bar$; specific volume, $4.37\ m^3/kg$; specific internal energy, $2360\ kJ/kg$; velocity, 90 m/s. Heat is rejected to the surroundings at the rate of $0.25\ kW$ and the rate of steam flow through the turbine is $0.38\ kg/s$. Calculate the power developed by the turbine (10 marks)

b) A perfect gas has a molar mass of $26\ kg/mol$ and a value of $\gamma = 1.26$. Calculate the heat rejected:

(i) When a unit mass of the gas is contained in a rigid vessel at $3\ bar$ and $315°C$, and is then cooled until the pressure falls to $1.5\ bar$ (5 marks)

(ii) When a unit mass flow rate of the gas enters a pipeline at $280°C$, and flows steadily to the end of the pipeline where the temperature is $20°C$. Neglect the changes in velocities of the gas in the pipeline. Take $R_o = 8314.15\ Nm/mole.K$ (5 marks)

QUESTION THREE (20 MARKS)

a) Steam at $7\ bar$, dryness fraction 0.9, expands reversibly at constant pressure until the temperature is 200^oC. Calculate:

(i) Work done by the system (7 marks)

(ii) Heat supplied into the system (6 marks)

b) $0.9\ kg$ of nitrogen gas (molar mass $28\ kg/kmol$) is compressed reversibly and isothermally from a pressure of $1.01\ bar$ and temperature 20^oC to a pressure of $4.2\ bar$. Calculate:

(i) The work done by nitrogen (5 marks)

(ii) The heat flow during the process (2 marks)

QUESTION FOUR (20 MARKS)

a) Show that the specific heats at constant volume c_v and at constant pressure c_p can be related using the following equation:

$c_v + R = c_p$ (9 marks)

b) A cyclic heat engine operates between a source temperature of 800^oC and a sink temperature of 30^oC. If the work done is $1\ kW$, calculate the rate of heat rejection by the heat engine (6 marks)

c) A domestic freezer maintains a temperature of -15^oC. The ambient air temperature is 30^oC. If heat leaks into the freezer at the continuous rate of $1.75\ kJ/s$. What is the least power necessary to pump this heat out continuously? (5 marks)

QUESTION FIVE (20 MARKS)

a) $0.03\ m^3$ of oxygen (molar mass $32\ kg/kmol$) contained in a cylinder behind a piston is initially at $1.05\ bar$ and 15^oC. The gas is compressed isothermally and reversibly until the pressure is $4.2\ bar$. Calculate:

(i) Change of entropy (7 marks)

(ii) Heat flow away from the system (2 marks)

(iii) Work done by the system (1 mark)

(iv) Sketch the process on a temperature-entropy (T-s) diagram (1 marks)

b) Steam at $100\ bar$ and 375^oC expands isentropically in a cylinder behind a piston to a pressure of $10\ bar$. Calculate the work done per kilogram of steam (9 marks)