MACHAKOS UNIVERSITY

University Examinations for 2022/2023

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF MECHANICAL AND MANUFACTURING ENGINEERING
SECOND YEAR ……… SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (MECHANICAL 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 (COMPULSORY) (30 MARKS)

a) Differentiate between an isolated, a closed and an open thermodynamic system providing real-life examples for each case (3 marks)

b) In the compression stroke of an internal combustion engine, the heat rejected to the cooling water is 45 kJ/kg and the work input is 90 kJ/kg. Calculate the change in specific internal energy of the working fluid stating whether it is a gain or a loss (2 marks)

c) Air is expanded reversibly behind a piston according to a law $pv = constant$. If the final volume is twice the initial volume and the work done on the fluid during the expansion is $34.7 \times 10^3\ Nm$, determine the initial pressure of the air if its final volume is $0.1\ m^3$

(7 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:

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

(5 marks)

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

g) 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. (3 marks)

QUESTION TWO (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 THREE (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 FOUR (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 mark)

(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)

QUESTION FIVE (20 MARKS)

(a) Show that the specific heats of at constant volume c_v and 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 $-15^{o}C$. The ambient air temperature is $30^{o}C$. 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)