MACHAKOS UNIVERSITY

University Examinations for 2020/2021 Academic Year

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF MECHANICAL AND MANUFACTURING ENGINEERING

SECOND YEAR FIRST SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (MECHANICAL ENGINEERING)

EMM 203: ENGINEERING THERMODYNAMICS 1

DATE: 11/8/2021 **TIME: 2:00 – 4:00 PM**

INSTRUCTIONS

Answer question ONE and any other two questions.

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) i Explain the **THREE** conditions that must be met for a thermodynamics process to be said to be reversible (3 marks)

ii 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 expansion is $34.7 \times 10^3\ Nm$, determine the initial volume and pressure. Take the final volume as $0.1\ m^3$. (6 marks)

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

d) If the enthalpy of steam at $50\ bar$ is $2720\ kJ/kg$, Calculate:

i. Its dryness fraction (2 marks)

ii. Its specific volume (2 marks)

iii. Its internal energy (2 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 mass of gas flows through a gas turbine unit at a constant rate of $18\ kg/s$ and develops $15000\ kW$. The enthalpies of the gasses at inlet and outlet are $1250\ kJ/kg$ and $400\ kJ/kg$ respectively, and the velocities of the gases at inlet and outlet are $60\ m/s$ and $150\ m/s$ respectively

i. Calculate the rate at which heat is rejected from the turbine (8 marks)

ii. Find the area of the inlet pipe (2 marks)

iii. Find the area of the outlet pipe (2 marks)

Take the specific volumes of the gases at the inlet and outlet as $0.5\ m^3/kg$ and $0.1\ m^3/kg$ respectively and the universal gas constant $R_o = 8314\ Nm/mole.K$

b) A particular perfect gas occupies a volume of $0.003\ m^3$ at a pressure of $7 \times 10^5\ N/m^2$ and a temperature of 131^oC.

(i) If the mass of the gas is $0.01\ kg$, calculate the molar mass of the gas (5 marks)

(ii) If the gas is allowed to expand until it attains a pressure of $1 \times 10^5\ N/m^2$ and a final volume of $0.02\ m^3$, calculate the final temperature of the gas (3 marks)

QUESTION THREE (20 MARKS)

a) Steam at a pressure of $7\ bar$ and 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 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^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 mark)

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