(University of Choice)

MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY (MMUST)

MAIN CAMPUS

UNIVERSITY EXAMINATIONS

2021/2022 ACADEMIC YEAR

THIRD YEAR SECOND SEMESTER EXAMINATIONS

FOR THE DEGREE

OF

BACHELOR OF SCIENCE IN EDUCATION TECHNOLOGY

COURSE CODE: TEM 371

COURSE TITLE: THERMODYNAMICS I

DATE: 22.04.2022 **TIME:** 1200-1400 HRS

INSTRUCTIONS TO CANDIDATES

1. This paper consists of **FOUR** questions
2. Answer Question **ONE (Compulsory)** and any other **TWO** Questions
3. All symbols have their usual meaning

TIME: 2 Hours

MMUST observes ZERO tolerance to examination cheating

This Paper Consists of 4 Printed Pages. Please Turn Over

QUESTION ONE [30 marks]

a) State the "Zeroth law" (1 Mark)

b) A steam turbine producing 55 MW power is fed with steam at 70 bar and 500°C. Steam leaves the turbine at 0.08 bar with a dryness fraction of 0.90. Determine the mass flow rate of steam through the adiabatic turbine. (5 Marks)

c) Determine the volume for carbon dioxide contained inside a cylinder at 0.2Mpa, 27°C:
   i. Assuming it behaves as an ideal gas (2 Marks)
   ii. Taking into account the pressure and volume associated with its molecules (4 Marks)

d) Derive the formula for change of entropy for a perfect gas undergoing a process (5 Marks)

e) Outline implications of the second law of thermodynamics (5 Marks)

f) A heat engine operates between the maximum and minimum temperatures of 671°C and 60°C respectively, with an efficiency of 50% of the appropriate Carnot efficiency. It drives a heat pump which uses river water at 4.4°C to heat a block of flats in which the temperature is to be maintained at 21.1°C. Assuming that a temperature difference of 11.1°C exists between the working fluid and the river water, on the one hand, and the required room temperature on the other, and assuming the heat pump to operate on the reversed Carnot cycle, but with a COP of 50% of the ideal COP, find the heat input to the engine per unit heat output from the heat pump. Why is direct heating thermodynamically more wasteful? (8 Marks)

QUESTION TWO [20 marks]

a) A 10 kg mass of lead heated to 200 °C is dropped into a lake at a temperature of 18°C. Find the change in entropy of the lake? (4 Marks)

b) A thermal power plant generates 300 MW of electricity with an efficiency of 35%. What is the rate of heat rejection? (4 Marks)

c) A cylinder fitted with a frictionless piston with 0.5 m^2 cross-sectional area contains 0.10 m^3 of air. The piston is in contact with an uncompressed spring with a spring constant

of 800 kN / m. The air is heated so that the piston rises and pushes against the spring until the air volume increases to 0.15 m^3. Find the work done in compressing the spring and the final air pressure. (5 Marks)

d) An ideal gas with c_p = 1.044 kJ / kgK and c_v = 0.745 kJ / kgK contained in a cylinder–piston assembly initially has a pressure of 150 kPa, a temperature of 30 °C, and a volume of 0.22 m^3. It is heated slowly at constant volume (process 1–2) until the pressure is doubled. It is then expanded slowly at constant pressure (process 2–3) until the volume is doubled. Determine the work done and heat added in the combined process (7 Marks).

QUESTION THREE **[20 marks]**

a) A gas initially at a pressure of 40 kPa and a volume of 0.1 m^3 is compressed until the pressure doubles and its volume is 0.04 m^3. The internal energy of the gas increases by 2.1 kJ. During compression gas pressure varies linearly with volume so that $P = a + bV$. What is the heat transfer during this process? (6 Marks)

b) Show that the specific energy of a system is given by $e = gz + \frac{V^2}{2} + u$ (5 Marks)

c) A mass of 1.5 kg of air is compressed in a quasi-static process from 0.1MPa to 0.7 MPa for which pv = constant. The initial density of air is 1.16 kg/m^3. Find the work done by the piston to compress the air. (4 Marks)

d) A rigid container contains 0.5 kg of air at 20 °C and a volume of 0.3 m^3. The air is heated until its temperature reaches 150 °C. What is the work done by the air on the surroundings? (2 Marks)

e) 5 kg of liquid having a constant specific heat of 2.5 kJ/kg K is stirred in a well-insulated chamber causing the temperature to rise by 15°C. Find internal energy (ΔU) and work (*W*) for the process. (3 Marks)

QUESTION FOUR **[20 marks]**

a) Gas in a cylinder is expanded by a piston in a process for which $PV^n = C$, where C and n are constants. The initial pressure and volume are 3 bar and 0.2 m^3 respectively and the final volume is 0.6 m^3. Determine the work done by the gas if (a) $n = 1.4$ and (b) $n = 1.0$. (6 Marks)

b) Oxygen enters a compressor at a pressure of 100 kPa, temperature of 300 K and a velocity of 5 m / s with a mass flow rate of 0.5 kg / s. The compressor is cooled at a rate of 1 kW. The gas exits at 500 kPa and 400 K with a velocity of 3 m / s. Find the work input to the compressor. (6 Marks)

c) A piston driven by compressed air at 200 kPa in a cylinder is required to do 500 J of work while moving through a distance of 0.25 m. What should the diameter of the cylinder be? (6 Marks)

d) The piston of an oil engine, of area 0.0045 m^2, moves downwards 75 mm, drawing in 0.00028 m^3 of fresh air from the atmosphere. The pressure in the cylinder is uniform during the process at 80 kPa, while the atmospheric pressure is 101.325 kPa, the difference being due to the flow resistance in the induction pipe and the inlet valve. Estimate the displacement work done by the air finally in the cylinder. (2 marks)