UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2023/2024

COURSE NAME	:	THERMODYNAMICS
COURSE CODE	:	DAK 20703
PROGRAMME CODE	:	DAK
EXAMINATION DATE	:	JANUARY/FEBRUARY 2024
DURATION	:	3 HOURS
INSTRUCTIONS	:	1. ANSWER ALL QUESTIONS 2. THIS FINAL EXAMINATION IS CONDUCTED VIA ☐ Open book ☒ Closed book 3. STUDENTS ARE **PROHIBITED** TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RESOURCES DURING THE EXAMINATION CONDUCTED VIA CLOSED BOOK

THIS QUESTION PAPER CONSISTS OF **SIX (6)** PAGES.

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Q1 Thermodynamics is the science of energy, that concerned with the ways in which energy is stored within a body.

(a) System can be defined as a quantity of matter or a region in space chosen for study.

(i) List three (3) types of system in thermodynamic applications.

(3 marks)

(ii) Explain each thermodynamic system mentioned in **Q1 (a) (i)**.

(6 marks)

(b) An automobile tire with a volume of 0.4 m^3 is inflated to a gage pressure of 150 kPa. Calculate the mass of air in the tire if the temperature is 30 °C. Assume the atmospheric pressure is 100 kPa.

(4 marks)

(c) A piston-cylinder device contains 0.3 m^3 of liquid water and 0.7 m^3 of water vapor in equilibrium at 600 kPa. Heat is transferred at constant pressure until the temperature reaches 300 °C.

(i) Find the initial temperature of the water.

(1 mark)

(ii) Calculate the total mass of the water.

(8 marks)

(iii) Calculate the final volume of the water.

(3 marks)

Q2 The First Law is usually referred to as the Law of Conservation of Energy, where energy can neither be created nor destroyed, but rather transformed from one state to another.

(a) 0.087 kg of an air initially exists at 140 kPa and 130 °C. The gas is then expanded polytropically to a state of 110 kPa and 120 °C. It is then cooled reversibly at a constant pressure, then is cooled at constant volume until the pressure is 100 kPa and is then allowed to compress reversibly according to a law PV = constant back to the initial conditions. The work done in the constant pressure is 0.525 kJ.

(i) Sketch the P-V diagram for this process.

(3 marks)

(ii) Calculate the value of n.

(6 marks)

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(iii) Calculate the total boundary work done during this process.

(8 marks)

(b) Refrigerant-134a enters a diffuser steadily as saturated vapor at 700 kPa with a velocity of 100 m/s, and it leaves at 800 kPa and 40 °C. The refrigerant is gaining heat at a rate of 3 kJ/s as it passes through the diffuser. If the exit area is 75 percent greater than the inlet area, calculate the mass flow rate of the refrigerant.

(8 marks)

Q3 Understanding the principles of chemical reactions and phase equilibrium is essential in fields such as materials science, and process engineering. These principles form the foundation for designing and optimizing chemical processes, developing new materials with desired properties, and ensuring the safety and efficiency of industrial operations.

(a) Ethane is burned with 20 percent excess air during a combustion process. Assume the process takes place in a complete combustion and a total pressure of 100 kPa. [Mw: Air =29, C =12, H=1 kg/kmol]

(i) Determine all the coefficient values for this combustion equation.

(2 marks)

(ii) Calculate the air fuel ratio.

(3 marks)

(iii) Find the dew point temperature of the product.

(5 marks)

(b) A mixture of 1 kmol of H_2O and 2 kmol of O_2 is heated to 4000 K at a pressure of 1 atm. Assume that only H_2O, OH, O_2, H_2 are present.

(i) Construct the chemical reaction for the equilibrium composition.

(2 marks)

(ii) State the mass balance for the hydrogen and oxygen.

(2 marks)

(iii) Develop two (2) equations that show the dissociation of H_2O in the products.

(2 marks)

(iv) Based on the equations in **Q3 (b) (iii)**, find the equilibrium constants for these two reactions.

(4 marks)

(v) Determine the equilibrium composition of this mixture.

(5 marks)

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Q4 Understanding entropy and isentropic processes is crucial in the field of thermodynamics as they help us comprehend the behavior of systems during phase transitions. They provide valuable insights into the conservation of energy and the reversible nature of thermodynamic processes.

(a) Steam enters an adiabatic turbine steadily at 3 MPa and 400 °C and leaves at 50 kPa and 100 °C. The power output of the turbine is 2 MW.

(i) State the enthalpy for both input and outlet streams.

(2 marks)

(ii) Determine the quality and enthalpy at the isentropic state.

(8 marks)

(iii) Find the isentropic efficiency of the turbine.

(2 marks)

(b) Refrigerant-R134a flows into an adiabatic compressor as a saturated vapor at 120 kPa with a rate of 0.3 m^3/min, and it exits under a pressure of 1 MPa. The compressor exhibits an isentropic efficiency of 80 percent.

(i) Solve the mass flow rate into the compressor.

(3 marks)

(ii) Determine the actual compressor work.

(6 marks)

(iii) Calculate the temperature of the refrigerant at the exit of the compressor.

(4 marks)

- END OF QUESTIONS -

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APPENDIX A

FORMULA

$\left(\frac{Q_H}{Q_L}\right)_{rev} = \frac{T_H}{T_L}$

$\eta_{th\ rev} = 1 - \frac{T_H}{T_L}$

$\eta_{th} = \frac{W_{net,\ out}}{Q_{in}}$

$\left(\frac{T_2}{T_1}\right)_{s=const.} = \left(\frac{v_1}{v_2}\right)^{k-1}$

$\left(\frac{T_2}{T_1}\right)_{s=const.} = \left(\frac{P_2}{P_1}\right)^{(k-1)/k}$

$COP_R = \frac{Q_L}{W_{net,\ in}} = \frac{Q_L}{Q_H - Q_L}$

$\frac{P_1}{P_2} = \left(\frac{V_2}{V_1}\right)^n = \left(\frac{T_1}{T_2}\right)^{\frac{n}{n-1}}$

$P_1V_1 = P_2V_2$

$E_{in} - E_{out} = \Delta E_{system}$

$Q - W = \Delta U$

$\dot{m} = \frac{1}{v}(VA)$

$W = \dot{W}\Delta t$

$PV = mRT$

$COP_R = \frac{1}{(T_H/T_L) - 1}$

$COP_{HP} = \frac{Q_H}{W_{net.in}} = \frac{Q_H}{Q_H - Q_L}$

$W = VI\Delta t$

$W_{12} = \frac{P_2V_2 - P_1V_1}{1-n}$

$W_{12} = P(V_2 - V_1)$

$Q - W = \Delta U + \Delta KE + \Delta PE$

$W = P_1V_1 \ln\frac{V_2}{V_1}$

$\Delta U = U_2 - U_1 = C_v(T_2 - T_1)$

$\Delta H = H_2 - H_1 = C_P(T_2 - T_1)$

$\dot{W}_{in} = \dot{m}(h_2 - h_1)$

$\dot{W}_{out} = \dot{m}(h_1 - h_2)$

$q_{net} - w_{net} = \left(u_2 - u_1 + \frac{V_2^2 - V_1^2}{2} + \frac{g(z_2 - z_1)}{1}\right)$

$\left(h_1 + \frac{V_1^2}{2}\right) = \left(h_2 + \frac{V_2^2}{2}\right)$

$P_v = \frac{N_v}{N_{prod}}(P_{prod})$

$K_p = \frac{N_C^{v_C} N_D^{v_D}}{N_A^{v_A} N_B^{v_B}}\left(\frac{P}{N_{total}}\right)^{\Delta v}$

$\eta_T = \frac{w_a}{w_s} \cong \frac{h_1 - h_{2a}}{h_1 - h_{2s}}$

$\eta_C = \frac{w_s}{w_a} \cong \frac{h_{2s} - h_1}{h_{2a} - h_1}$

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APPENDIX B
CONVERSION OF UNITS

Mass	1 kg	= 1000 g = 0.001 metric ton = 2.20462 lb_m = 35.27392 oz
	1 lb_m	= 16 oz = 5 x 10^{-4} ton = 453.593 g = 0.453593 kg
Length	1 m	= 100 cm = 1000 mm = 10^6 microns (μm) = 10^{10} angstroms ($\overset{0}{A}$)
		= 39.37 in = 3.2808 ft = 1.0936 yd = 0.0006214 mile
	1 ft	= 12 in = 1/3 yd = 0.3048 m = 30.48 cm
Volume	1 m^3	= 1000 liters = 10^6 cm^3 = 10^6 ml
		= 35.3145 ft^3 = 220.83 imperial gallons = 264.17 gal
		= 1056.68 qt
	1ft^3	= 1728 in^3 = 7.4805 gal = 0.028317 m^3 = 28.317 liters
		= 28 317 cm^3
Force	1 N	= 1 kg.m/s^2 = 10^5 dynes = 10^5 g.cm/s^2 = 0.22481 lb_f
	1 lb_f	= 32.174 lb_m.ft/s^2 = 4.4482 N = 4.4482 x 10^5 dynes
Pressure	1 atm	= 1.01325 x 10^5 N/m^2 (Pa) = 101.325 kPa = 1.01325 bars
		= 1.01325 x 10^6 dynes/cm^2
		= 760 mm Hg at 0°C (torr) = 10.333 m H_2O at 4°C
		= 14.696 lb_f/in^2 (psi) = 33.9 ft H_2O at 4°C
		= 29.921 in Hg at 0°C
Energy	1 J	= 1 N.m = 10^7 ergs = 10^7 dyne.cm
		= 2.778 x 10^{-7} kW.h = 0.23901 cal
		= 0.7376 ft-lb_f = 9.486 x 10^{-4} Btu
Power	1 W	= 1 J/s = 0.23901 cal/s = 0.7376 ft.lb_f/s = 9.486 x 10^{-4} Btu/s
		= 1.341 x 10^{-3} hp

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