Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2023/2024

COURSE NAME	:	THERMODYNAMICS
COURSE CODE	:	DAK 20703
PROGRAMME CODE	:	DAK
EXAMINATION DATE	:	JULY 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

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 thermodynamic processes.

(3 marks)

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

(3 marks)

(b) A tank with unknown volume is divided into two parts and is separated by a partition. One side of the tank contains 0.05 m^3 of water (saturated liquid) at 400 kPa, while the other side is evacuated. The partition is then removed, and the water fills the entire tank. If the final state of the water is 200 °C and 800 kPa. Calculate the volume of the tank.

(7 marks)

(c) A piston-cylinder device contains 0.3 m^3 of liquid R-134 and 0.7 m^3 of vapor R-134 in equilibrium at 600 kPa. Heat is transferred at constant pressure until the temperature reaches 80 °C.

(i) Find the initial temperature of the R-134.

(1 mark)

(ii) Calculate the total mass of the R-134.

(8 marks)

(iii) Calculate the final volume of the R-134.

(3 marks)

Q2 The First Law, also known as the Law of Conservation of Energy, states that energy cannot be generated or destroyed, but only altered between states.

(a) 0.087 kg of 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 under 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)

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

(8 marks)

(b) A frictionless piston–cylinder device initially contains 0.3 m^3 of saturated liquid refrigerant-134a. The piston is free to move, and its mass is such that it maintains a pressure of 0.8 MPa on the refrigerant. The refrigerant is now heated until its temperature rises to 70 °C. Calculate the work done during this process.

(8 marks)

Q3 The second law of thermodynamics states that the total entropy of an isolated system can never decrease over time. In simpler terms, it means that in any energy transfer or transformation, the total entropy of a closed system will always increase, and this process is irreversible. This law has important implications for understanding the direction of natural processes and the efficiency of energy conversion.

(a) The Carnot cycle is a theoretical thermodynamic cycle that represents the most efficient way of converting heat into work.

(i) Identify four (4) reversible mechanisms that comprise the Carnot cycle.

(4 marks)

(ii) Explain three (3) reversible mechanisms in **Q4(a)(i)**.

(6 marks)

(b) The refrigerated space in the food container will be kept at 4 °C. A Carnot refrigerator uses 5 kW of power and runs at 25 °C. Calculate the rate of heat evacuation from the food container.

(5 marks)

(c) Steam enters an adiabatic turbine at 6 MPa and 400 °C with a mass flow rate of 2.5 kg/s and leaves at 25 kPa. The isentropic efficiency of the turbine is 80 %. Calculate the actual temperature at the exit turbine. The kinetic energy of the steam is neglected.

(10 marks)

Q4 Any material that can be burned to release thermal energy. Most familiar fuels consist primarily of hydrogen and carbon. They are called hydrocarbon fuels.

(a) Ethane is burned with 20 % 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) Ethane can be produced from graphite (carbon) and hydrogen through a process called hydrogenation. From the following data,

$$C\ (graphite) + O_2(g) \rightarrow CO_2\ (g) \qquad \Delta H^o_{rxn} = -393.5kJ$$

$$H_2\ (g) + \tfrac{1}{2}\ O_2\ (g) \rightarrow H_2O(l) \qquad \Delta H^o_{rxn} = -285.8kJ$$

$$2C_2H_6\ (g) + 7O_2\ (g) \rightarrow 4CO_2\ (g) + 6H_2O\ (l) \qquad \Delta H^o_{rxn} = -3119.6kJ$$

Calculate the heat released per mole of 100 g ethane for the reaction, [Given: Relative atomic mass C=12; H=1]

$$2C\ (graphite) + 3H_2\ (g) \rightarrow C_2H_6\ (g)$$

(10 marks)

(c) Sulfur dioxide gas burns in oxygen to produce sulfur trioxide (SO_3) gas. Calculate the heat release (in kilojoules) per gram of the compound reacted with oxygen. The standard enthalpy of formation of sulfur trioxide is -395.2 kJ/mol. [Relative atomic mass S=32; O=16. ΔH^o_f of SO_2 = -296 kJ/mol].

(5 marks)

- END OF QUESTIONS -

APPENDIX A
FORMULA

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

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

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

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

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

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

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

$$P_1V_1 = P_2V_2$$

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

$$Q - W = \Delta U$$

$$\dot{m} = \frac{1}{v}(\mathcal{V}A)$$

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

$$PV = mRT$$

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

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

$$W = VI\Delta t$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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 = 5×10^{-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 = 4.4482×10^5 dynes

Pressure 1 atm = 1.01325×10^5 N/m^2 (Pa) = 101.325 kPa = 1.01325 bars

= 1.01325×10^6 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

= 2.778×10^{-7} kW.h = 0.23901 cal

= 0.7376 ft-lb_f = 9.486×10^{-4} Btu

Power 1 W = 1 J/s = 0.23901 cal/s = 0.7376 ft.lb_f/s = 9.486×10^{-4} Btu/s

= 1.341×10^{-3} hp