UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2022/2023

COURSE NAME	:	THERMODYNAMICS I
COURSE CODE	:	BDA 20703
PROGRAMME CODE	:	BDD
EXAMINATION DATE	:	JULY / AUGUST 2023
DURATION	:	3 HOURS
INSTRUCTION		1. PART A: ANSWER FOUR (4) QUESTIONS ONLY, AND PART B: ANSWER ALL QUESTIONS. 2. THIS FINAL EXAMINATION IS CONDUCTED VIA **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 **SEVEN (7)** PAGES

PART A: ANSWER FOUR (4) QUESTIONS ONLY FROM FIVE (5) QUESTIONS.

Q1 (a) Explain the differences between the specific gravity and the specific weight in terms of definition, the symbol and unit assigned, and the related equation.

(5 marks)

(b) As shown in **Figure Q1(b)**, it is expected that a water pump with pump-motor efficiency of 75% can take water from a lake, and deliver it to a pool whose free surface is 30 metres higher than the free surface of the lake, and at a rate of 50 litres per second (L/s). The engineer claims the operation of the pump requires electric power consumption of 2 kW. Justify whether or not this claim is reasonable.

(15 marks)

Q2 The initial contents of a closed rigid tank with a capacity of 400 L are 2.065 kg of saturated liquid-vapor mixture of water at 110°C (State 1). A gradual amount of heat is introduced into the tank until the substance reaches its final state, which is either a saturated liquid or a saturated vapor (State 2). Determine:

(i) whether the final state is saturated liquid or saturated vapor and justify your answer with appropriate calculation and comparison;

(ii) the temperature and pressure at State 2; and

(iii) show the heating process from State 1 to State 2 on a T-v diagram. Label all the states, show property values, and indicate appropriate lines of constant pressure.

You need to initially draw a schematic diagram, identify system boundaries, list relevant assumptions (if any), and provide solutions with appropriate basic equations.

[Note: You are advised to take the reading to 4 decimal places of the data from the tables and calculations].

(20 marks)

Q3 (a) The air in the rigid tank is initially maintained at 500 kPa and 150°C. Later, the temperature inside the tank drops to 65°C, and the pressure falls to 400 kPa as a result of the heat transfer into the surrounding environment. Is there any boundary work that must be done during the process? Justify your answer using a *P-v* diagram to describe the energy involved during the process.

(5 marks)

(b) The spring load piston-cylinder device depicted in **Figure Q3(b)** is filled with 1 kg of water with 10% quality at 90°C. The device is then heated until the temperature reaches 250°C with a pressure of 800 kPa. Determine the total work produced during this process in kJ.

(15 marks)

Q4 (a) The air compressor increases the pressure and temperature of 6 L of air from 120 kPa and 20°C to 1000 kPa and 400°C through a compression process. Find the compressor's flow work in kJ/kg.

(5 marks)

(b) A steady-operated air conditioning system involves the mixing of cold and warm outdoor air before delivering it to the conditioned room. The cold air enters the mixture chamber at 78°C and 105 kPa at a rate of 0.55 m^3/s, while the warm air enters at 348°C and 105 kPa. The air mixture exits the chamber at 248°C. If the mass flow rates ratio of the hot-to-cold air streams is 1.6, and using variable specific heats, determine:

(i) the mixture temperature at the inlet of the room; and

(ii) the rate of "heat gain" in the conditioned room.

(15 marks)

Q5 (a) We know that heat actually flows from a higher-temperature source to a lower-temperature reservoir. This heat transfer process occurs without human intervention and it should be noted that the opposite process cannot take place by itself. To make this feasible, we must utilize specialized devices such as refrigerators and heat pumps. Based on this fact, describe:

(i) the objectives of a refrigerator and a heat pump; and

(ii) sketch a schematic of the refrigerator and heat pump.

(10 marks)

(b) A heat source at 1100 K is transferred to a reservoir at 500 K using a cyclic machine. From the high-temperature source to the low-temperature reservoir, a total of 350 kJ of heat is transferred, with a corresponding loss of approximately 150 kJ of heat to the environment. The device generates a useful work output of 200 kJ. Explain why you think such a machine is considered reversible, irreversible, or impossible.

(5 marks)

(c) The illustration shown in **Figure Q5(c)** depicts how an air-conditioner can act as a refrigerator by cooling a room on a hot day. The system should remove 4 kW of heat from the room with a temperature of 24°C to the ambient air outside, which is 35°C. Determine the maximum coefficient of performance (COP) of the air-conditioner and the minimum amount of work input required.

(5 marks)

PART B: ANSWER ALL QUESTIONS.

Q6 (a) Work has no entropy, and it is sometimes claimed that work does not modify the entropy of a fluid moving through an adiabatic steady-flow system with a single input and output. Is this a valid claim??

(4 marks)

(b) A 300 kW reversible heat pump is capable of heating a 24°C home. The source is 78°C air from the outdoors. If the source is the outside air, which is at 78°C. Determine whether this heat pump complies with the second law following the growth of entropy principle by calculating the rate of entropy change of the two reservoirs.

(16 marks)

– END OF QUESTION –

FINAL EXAMINATION

SEMESTER / SESSION	: SEM 2 / 2022-2023	PROGRAMME CODE	: BDD
COURSE NAME	: THERMODYNAMICS I	COURSE CODE	: BDA20703

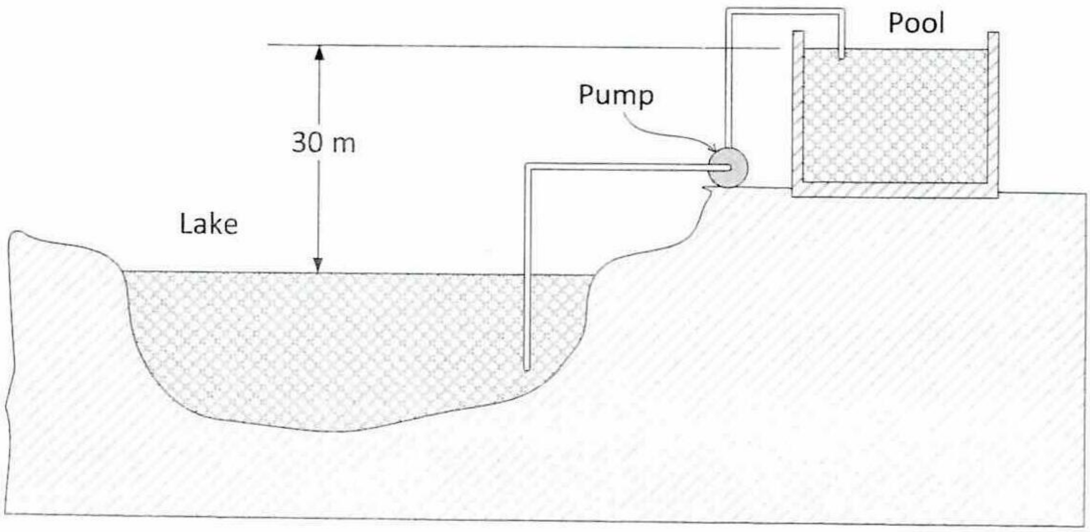

Figure Q1(b)

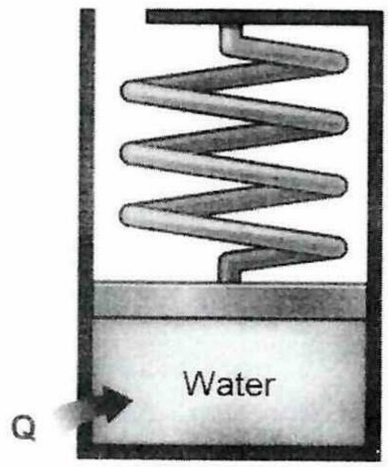

Figure Q3(b)

FINAL EXAMINATION

SEMESTER / SESSION	: SEM 2 / 2022-2023	PROGRAMME CODE	: BDD
COURSE NAME	: THERMODYNAMICS I	COURSE CODE	: BDA20703

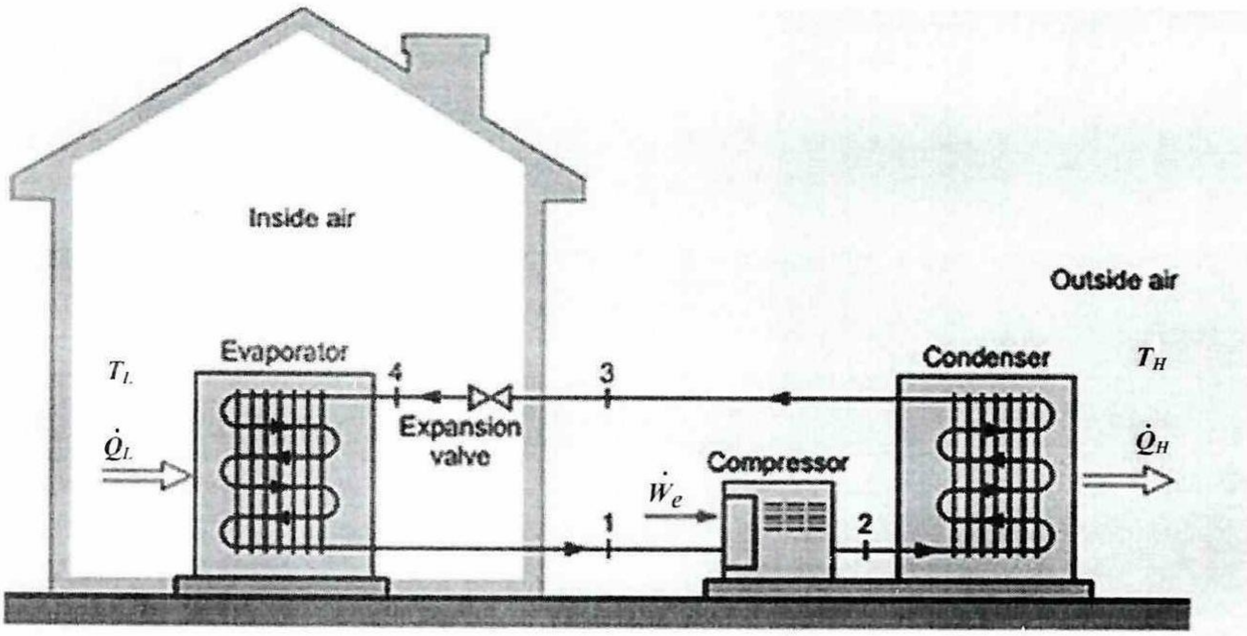

Figure Q5(c)

FINAL EXAMINATION

SEMESTER / SESSION : SEM 2 / 2022-2023
COURSE NAME : THERMODYNAMICS I
PROGRAMME CODE : BDD
COURSE CODE : BDA20703

List of Equations

General Equations:

$x = \frac{m_g}{m_T}$ $v = \frac{V}{m}$

$v = v_f + x(v_g - v_f)$ $u = u_f + x \cdot u_{fg}$

$h = h_f + x \cdot h_{fg}$ $s = s_f + x \cdot s_{fg}$

Work boundary, $W_b = \int_1^2 P \cdot dV$

$\Delta u = c_{V,avg}(T_2 - T_1)$

$\Delta h = c_{P,avg}(T_2 - T_1)$

$\dot{m} = \rho AV = \frac{AV}{v} = \frac{\dot{V}}{v}$

$ke = \frac{V^2}{2} \equiv \left[\frac{J}{kg}\right]$ $pe = gz \equiv \left[\frac{J}{kg}\right]$

$Q_{net} = W_{net}$, for cyclic process.

Thermal efficiency, $\eta_{th} = \frac{W_{net,out}}{Q_{in}} = \frac{Q_H - Q_L}{Q_H}$

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

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

$\left(\frac{Q_H}{Q_L}\right)_{rev} = \frac{T_H}{T_L}$, for reversible heat engine, refrigerator and heat pump.

Ideal Gas Equation of State, $PV = mRT$

$c_P = c_V + R$

$k = \frac{c_P}{c_V}$

Entropy:

Total heat transfer during an internally reversible process,

$Q_{int\,rev} = \int_1^2 T dS$, general equation

$q_{int\,rev} = T_o(s_2 - s_1)$, in the isothermal process

$\delta W_{int\,rev} = PdV$

$\Delta S_{sys} = S_2 - S_1 = \int_1^2 \frac{\delta Q}{T} + S_{gen}$

$S_{gen} = \Delta S_{total} = \Delta S_{sys} + \Delta S_{surr} \geq 0$

Entropy Change:

$\Delta s = c_{avg} \ln\left(\frac{T_2}{T_1}\right)$, For incompressible substances

For ideal gas (constant specific heat):

$\Delta s = c_{P,avg} \ln\left(\frac{T_2}{T_1}\right) - R\ln\left(\frac{P_2}{P_1}\right)$

$\Delta s = c_{V,avg} \ln\left(\frac{T_2}{T_1}\right) + R\ln\left(\frac{v_2}{v_1}\right)$

For ideal gas (variable specific heat):

$\Delta s = s_2^\circ - s_1^\circ - R\ln\left(\frac{P_2}{P_1}\right)$

During Isentropic:

$\left(\frac{T_2}{T_1}\right) = \left(\frac{v_1}{v_2}\right)^{k-1} = \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}}$, at constant specific heat

$\left(\frac{P_2}{P_1}\right) = \left(\frac{P_{r2}}{P_{r1}}\right)$, at variable-specific heat

$\left(\frac{v_2}{v_1}\right) = \left(\frac{v_{r2}}{v_{r1}}\right)$, at variable-specific heat

Isentropic Efficiency:

$\eta_T = \frac{\text{Actual turbine work}}{\text{Isentropic turbine work}} = \frac{w_a}{w_s} \cong \frac{h_1 - h_{2a}}{h_1 - h_{2s}}$

$\eta_C = \frac{\text{Isentropic compressor work}}{\text{Actual compressor work}} = \frac{w_s}{w_a} \cong \frac{h_{2s} - h_1}{h_{2a} - h_1}$

$\eta_N = \frac{\text{Actual KE at nozzle exit}}{\text{Isentropic KE at nozzle exit}} = \frac{V_{2a}^2}{V_{2s}^2} \cong \frac{h_1 - h_{2a}}{h_1 - h_{2s}}$