UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2018/2019

COURSE NAME	:	THERMODYNAMICS I
COURSE CODE	:	BDA 20202
PROGRAMME	:	BDD
EXAMINATION DATE	:	DECEMBER 2018 / JANUARY 2019
DURATION	:	3 HOURS
INSTRUCTION	:	**PART A**: ANSWER **TWO (2)** QUESTIONS **ONLY** FROM **THREE (3)** QUESTIONS. **PART B**: ANSWER **ALL** QUESTIONS.

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

PART A: ANSWER TWO (2) QUESTIONS ONLY FROM THREE (3) QUESTIONS.

Q1 (a) Explain, what is the compressed liquid (sub cooled liquid), saturated liquid, saturated vapor, saturated liquid–vapor mixture and superheated vapor

(8 marks)

(b) Two (2) kilograms of water at 120 °C with a quality of 25% has its temperature raised 20 °C in a constant-volume process as in **Figure Q1(b)**. What are the heat transfer and work in the process and sketch P-*v* or T-*v* diagram?

(17 marks)

Q2 (a) Steam in a closed rigid container of 1 m^3 of volume has initial pressure and temperature of 800 kPa and 500 °C respectively. The temperature drops as a result of heat transfer to the surroundings.

(i) Sketch the process on a *P-v* diagram;
(ii) Determine the temperature at which condensation starts;
(iii) Calculate the quality when the pressure reaches 50 kPa; and
(iv) Find the volume occupied by the saturated liquid at the final state.

(12 marks)

(b) An insulated horizontal rigid cylinder is divided into two compartments by a piston. Initially, one side of the cylinder contains 1 m^3 of N_2 gas at 500 kPa and 95 °C while the other side contains 1 m^3 of He gas at 500 kPa and 25 °C. When heat is transferred through the piston, thermal equilibrium is established in the cylinder. Using constant specific heat at room temperature, determine the final equilibrium temperature in the cylinder. State your assumptions.

(13 marks)

Q3 (a) In energy analysis for closed system, work boundary (W_b) is given by integral of pressure (P) multiply with change of volume (V). During actual expansion and compression processes of gases, pressure and volume related by $PV^n = C$. Please show and prove that

$W_b = mR(T_2 - T_1) / (1 - n)$ when $n \neq 1$

Please show this process in P–*v* diagram.

(10 marks)

(b) Refrigerant-134a is to be cooled by water in a condenser as in **Figure Q3(b)**. The refrigerant enters the condenser with a mass flow rate of 6 kg/min at 1 MPa and 70 °C and leaves at 35 °C. The cooling water enters at 300 kPa and 15 °C and leaves at 25 °C. Determine;

(i) the mass flow rate of the cooling water required; and
(ii) the heat transfer rate from the refrigerant to water.

(15 marks)

PART B : ANSWER ALL QUESTIONS.

Q4 (a) Explain four (4) main characteristics of heat engine.

(4 marks)

(b) Demonstrate how does the violation of the Kelvin-Planck statement lead to violation of Clausius statement? Support your explanation with the appropriate diagrams.

(6 marks)

(c) A 22 MW geothermal power plant that uses geothermal liquid water at 160 °C at a specified rate as the heat source and the surrounding's temperature is stabilized at 25 °C. The power plant operates steadily with flow rate of approximately 26,400 kg/min. It can be assumed that there are no changes in kinetic and potential energies, while the operating working fluid having similar properties as steam. Determine the actual and maximum possible thermal efficiency and the rate of heat rejected from this power plant.

(15 marks)

Q5 (a) Steam enters an actual adiabatic turbine steadily at 7 MPa, 500 °C, and 45 m/s, and leaves at 100 kPa and 75 m/s.

i) As the steam flows through this turbine, will the entropy increase, decrease or remain the same?

ii) Sketch the process on a T-*s* diagram with respect to the saturation lines. Be sure to label the data states and the lines of constant pressure.

(10 marks)

(b) If the actual power output of the turbine in (a) is 5 MW and the isentropic efficiency is 77 percent, determine:

i) the mass flow rate of steam through the turbine.

ii) the temperature at the turbine exit.

iii) the rate of entropy generation during the process.

(15 marks)

– END OF QUESTION –

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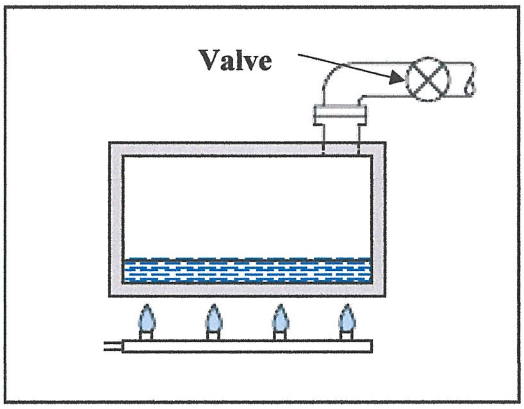

Figure Q1(b) Closed system (Valve is closed)

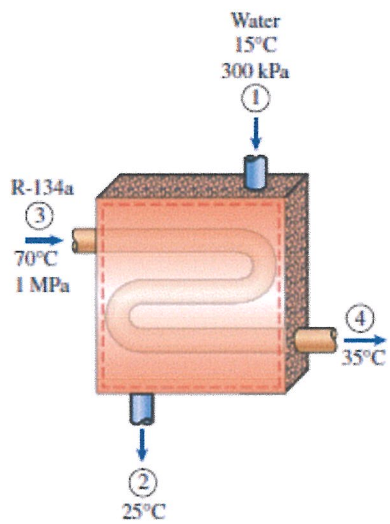

Figure Q3(b)

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List of Equations

General Equations:

$$x = \frac{m_g}{m_T}$$

$$v = \frac{\mathrm{V}}{m}$$

$$v = v_f + x(v_g - v_f)$$

$$u = u_f + x \cdot u_{fg}$$

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

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

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

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

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

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

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

$$pe = gz \equiv \left[\frac{\mathrm{J}}{\mathrm{kg}}\right]$$

$Q_{net} = W_{net}$, For cyclic process in a closed system

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

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

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

Ideal Gas Equation of State, $PV = mRT$

$$c_P = c_\mathrm{V} + R$$

$$k = \frac{c_P}{c_\mathrm{V}}$$

Entropy:

Total heat transfer during internally reversible process,

$Q_{\text{int rev}} = \int_1^2 TdS$, general equation

$q_{\text{int rev}} = T_\circ(s_2 - s_1)$, in isothermal process

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

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

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

Entropy Change:

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

For ideal gas (constant specific heat):

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

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

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:

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

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

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