UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2019/2020

COURSE NAME	:	THERMODYNAMICS I
COURSE CODE	:	BDA 20703
PROGRAMME	:	BDD
EXAMINATION DATE	:	DECEMBER 2019 / JANUARY 2020
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

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

Q1 (a) Explain the characteristics of an open and a closed thermodynamic system in terms of the system mass and energy flow and include an example for each system.

(8 marks)

(b) The pressure drop of air across a pipe section is measured by a differential manometer which is connected through pressure tappings on the pipe wall as shown in **Figure Q1 (b)**. Oil with a specific gravity of $SG_{oil} = 0.96$ is used as the manometer fluid. The differential height h is measured to be 45 mm while the distance a is 50 mm. Taking the density of air to be $\rho_{air} = 1.225$ kg/m3 and $\rho_{water} = 998$ kg/m^3 respectively, determine:

(i) the density of the manometer fluid;

(ii) the pressure drop ΔP along the pipe section; and

(iii) the differential height, h if the manometer fluid is replaced with mercury with specific gravity $SG_{Hg} = 13.6$.

(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 nitrogen gas at 500 kPa and 95 °C while the other side contains 1 m^3 of helium 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) Polytropic process is an actual expansion and compression of gases, where its pressure and volume are often related by $PU^n = C$, where n is polytropic index and C is a constants. Prove that the boundary work for an ideal gas equation is,

$$W_b = \frac{mR\,(T_2 - T_1)}{1-n}, \quad n \neq 1$$

and

$$W_b = P_1 U_1 \ln\frac{U_2}{U_1}, \quad n = 1$$

(10 marks)

(b) A stream of refrigerant-134a at 1 MPa and 20 °C is mixed with another stream at 1 MPa and 80 °C. If the mass flow rate of the cold stream is twice that of the hot one, determine the temperature and the quality of the exit stream.

(15 marks)

PART B: ANSWER ALL QUESTIONS.

Q4 (a) Describe briefly the four (4) processes that make up the Carnot cycle. Illustrate and label the process of Carnot cycle on a P-V diagram.

(4 marks)

(b) It is well established that the thermal efficiency of a heat engine increase as the temperature TL at which heat is rejected from the heat engine decrease. In an effort to increase the efficiency of a power plant, somebody suggests refrigerating the cooling water before it enters the condenser, where heat rejection takes place.

Is this a good or bad idea? Explain why?

(4 marks)

(c) A complete reversible heat engine operates with a source at 800 K and a sink at 280 K. At what rate must heat be supplied to this engine, in kJ/h, for it to produce a 4 kW of the power.

(4 marks)

(d) Refrigerant-134a enters the condenser of a residential heat pump at 800 kPa and 35°C at a rate of 0.018 kg/s and leave at 800 kPa as a saturated liquid. If the compressor consumes 1.2 kW of power, determine:

(i) the COP of the heat pump; and

(ii) the rate of the heat absorbed from the outside air.

(13 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) Nitrogen gas (N_2) is compressed from 80 kPa and 27°C to 480 kPa by a 10-kW compressor. Determine the mass flow rate of nitrogen through the compressor, assuming the compression process to be:

i) isentropic.

ii) polytropic with $n = 1.3$.

iii) isothermal.

iv) ideal two-stage polytropic with $n = 1.3$

(15 marks)

– END OF QUESTION –

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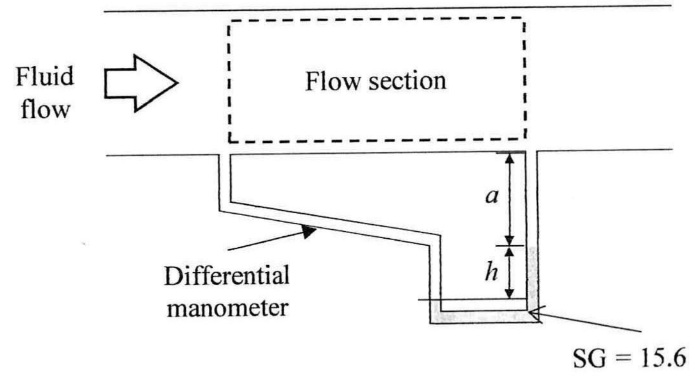

Figure Q1(b)

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List of Equations

General Equations:

$$x=\frac{m_g}{m_T},\ v=\frac{\mathrm{V}}{m},\ v=v_f+x\left(v_g-v_f\right)$$

$$u=u_f+x\cdot u_{fg},\ h=h_f+x\cdot h_{fg},\ s=s_f+x\cdot s_{fg}$$

$$w_{comp,isen}=\frac{kR(T_2-T_1)}{k-1}=\frac{kRT_1}{k-1}\left[\left(\frac{P_2}{P_1}\right)^{(k-1)/k}-1\right]$$

$$w_{comp,poly}=\frac{nR(T_2-T_1)}{n-1}=\frac{nRT_1}{n-1}\left[\left(\frac{P_2}{P_1}\right)^{(n-1)/n}-1\right]$$

$$w_{comp,iso}=RT\ ln\frac{P_2}{P_1}$$

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

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

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

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

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

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

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

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

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

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

Ideal Gas Equation of State, $P\mathrm{V}=mRT$

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

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

Entropy:

Total heat transfer during internally reversible process,

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

$q_{\text{int rev}}=T_{\circ}\left(s_2-s_1\right)$, 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:

$\Delta s=c_{avg}\ln\left(\dfrac{T_2}{T_1}\right)$, 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:

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

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

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

Isentropic Efficiency:

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

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

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