

**UNIVERSITY COLLEGE TATI (UC TATI)****FINAL EXAMINATION QUESTION BOOKLET**

COURSE CODE	: DTC 2073
COURSE	: THERMODYNAMICS
SEMESTER/SESSION	: 1, 2023/2024
DURATION	: 3 HOURS

**Instructions:**

1. This booklet contains **FOUR (4)** questions. Answer **ALL** questions.
2. All answers should be written in answer booklet.
3. Write legibly and draw sketches wherever required.
4. If in doubt, raise your hands and ask the invigilator.

**DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO****THIS BOOKLET CONTAINS 6 PRINTED PAGES INCLUDING COVER PAGE**

**QUESTION 1 (25 marks)**

- (a) Complete the following table for water:

(10 Marks)

T, °C	P, kPa	U, kJ/kg	x	Phase description
	200	1719.26	0.6	Saturated mixture
125		1600		Saturated mixture
395.2	1000	2950	0.0	
172.9	850		0.0	Saturated liquid

- (b) An 80-L vessel contains 4 kg of refrigerant-134a at a pressure of 160 kPa. Determine

- (i) The temperature (3 Marks)
- (ii) The quality (4 Marks)
- (iii) The enthalpy of the refrigerant (4 Marks)
- (iv) The volume occupied by the vapor phase. (4 Marks)

**QUESTION 2 (25 marks)**

- (a) Identify in what forms can energy cross the boundaries of a closed system? (2 Marks)
- (b) State and explain 3 mechanisms of heat transfer (6 Marks)
- (c) Determine the power required to accelerate a 900 kg car from rest to a velocity of 80 km/h in 20 s on a level road. (5 Marks)

(d)

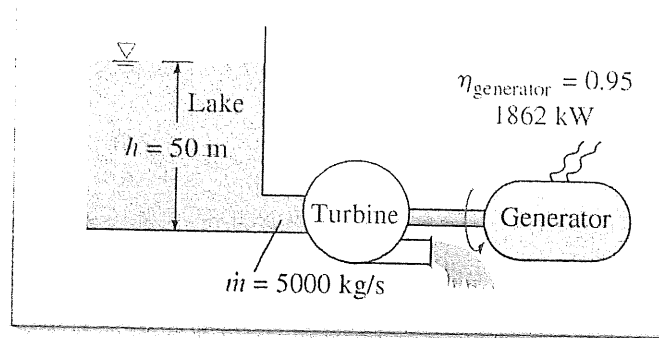


Figure 1

The water in a large lake is to be used to generate electricity by the installation of a hydraulic turbine-generator at a location where the depth of the water is 50 m as shown in Figure 1. Water is to be supplied at a rate of 5000 kg/s. If the electric power generated is measured to be 1862 kW and the generator efficiency is 95%, determine:

- (i) The overall efficiency of the turbine-generator (4 Marks)
- (ii) The mechanical efficiency of the turbine (4 Marks)
- (iii) The shaft power supplied by the turbine to the generator. (4 Marks)

### QUESTION 3 (25 marks)

(a) Define

- i. Heat capacity at constant volume (2 Marks)
- ii. Incompressible substance (2 Marks)

(b)

A piston-cylinder device contains 25 g of saturated water vapor that is maintained at a constant pressure of 300 kPa. A resistance heater within the cylinder is turned on and passes a current of 0.2 A for 5 minutes from a 120-V source. At the same time, a heat loss of 3.7 kJ occurs.

- i. Calculate electrical work,  $W_e$  (5 Marks)
- ii. Determine the final temperature of the steam (6 Marks)

- (c) A 50 kg iron block at 80°C is dropped into an insulated tank that contains 0.5 m<sup>3</sup> of liquid water at 25°C. Determine the temperature when thermal equilibrium is reached.

(10 Marks)

**QUESTION 4 (25 marks)**

- (a) Insulated piston-cylinder device with 0.05 m<sup>3</sup> of saturated R-134a vapor at 0.8 MPa. The refrigerant expands in a reversible process until the pressure drops to 0.4 MPa. Calculate:

i. Final temperature

(7 Marks)

ii. Work done.

(8 Marks)

- (b) A rigid tank contains 5 kg of refrigerant-134a initially at 20°C and 140 kPa. The refrigerant is now cooled while being stirred until its pressure drops to 100 kPa. Determine the entropy change of the refrigerant during this process.

(10 Marks)

----- End of questions -----

## Appendix

$$u_{\text{avg}} = u_f + xu_{fg} \quad (\text{kJ/kg})$$

$$h_{\text{avg}} = h_f + xh_{fg} \quad (\text{kJ/kg})$$

$$x = \frac{v_{\text{avg}} - v_f}{v_{fg}}$$

$$x = m_g/m_t$$

$$e_{\text{in}} - e_{\text{out}} = \Delta e_{\text{system}} \quad (\text{kJ/kg})$$

$$|\Delta \dot{E}_{\text{mech,fluid}}| = \dot{E}_{\text{mech,in}} - \dot{E}_{\text{mech,out}}$$

$$\eta_{\text{turbine}} = \frac{\text{Mechanical energy output}}{\text{Mechanical energy decrease of the fluid}} = \frac{\dot{W}_{\text{shaft,out}}}{|\Delta \dot{E}_{\text{mech,fluid}}|} = \frac{\dot{W}_{\text{turbine}}}{\dot{W}_{\text{turbine,e}}}$$

$$\eta_{\text{turbine-gen}} = \eta_{\text{turbine}} \eta_{\text{generator}} = \frac{\dot{W}_{\text{elect,out}}}{\dot{W}_{\text{turbine,e}}} = \frac{\dot{W}_{\text{elect,out}}}{|\Delta \dot{E}_{\text{mech,fluid}}|}$$

$$u_2 - u_1 = c_{v,\text{avg}}(T_2 - T_1)$$

For *solids*, the term  $v \Delta P$  is insignificant and thus  $\Delta h = \Delta u \cong c_{\text{avg}} \Delta T$ . For *liquids*, two special cases are commonly encountered:

1. *Constant-pressure processes*, as in heaters ( $\Delta P = 0$ ):  $\Delta h = \Delta u \cong c_{\text{avg}} \Delta T$
2. *Constant-temperature processes*, as in pumps ( $\Delta T = 0$ ):  $\Delta h = v \Delta P$

$$W_{\text{net,in}} = Q_H - Q_L \quad (\text{kJ})$$

$$\text{COP}_R = \frac{\text{Desired output}}{\text{Required input}} = \frac{Q_L}{W_{\text{net,in}}}$$

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

$$\eta_{\text{th}} = 1 - \frac{Q_L}{Q_H}$$

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

$$\Delta S = \frac{Q}{T_0}$$

$$\Delta S_{\text{sys}} = S_2 - S_1$$

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