

The Open University of Sri Lanka
Faculty of Engineering Technology
Department of Mechanical Engineering



Study Programme : Bachelor of Science Honours in Engineering
Name of the Examination : Final Examination
Course Code and Title : DMX5205 Applied Thermodynamics II
Academic Year : 2023/24
Date : 14th February 2025
Time : 1400hrs - 1700hrs
Duration : **3 hours**

General instructions

1. This question paper consists of Five (5) questions.
2. Answer all Five (5) questions. All questions carry equal marks.
3. The answer to each question should commence from a new page.
4. This is a Closed Book Test (CBT).
5. Answers should be in clear handwriting.
6. Do not use a red pen.
7. A psychrometric chart is provided.

Question 01

- (i) Explain the subcooling and superheating processes in refrigeration. Why is superheating considered to be good in certain cases?
- (ii) Explain the effect of sub-cooling on a vapor compression refrigeration cycle with the aid of a temperature-entropy diagram.
- (iii) In a vapor compression refrigeration cycle, the evaporator and condenser temperatures are -14°C and 40°C respectively. The refrigerant enters the compressor as a dry saturated vapor. The refrigerant leaving the condenser has a temperature of 30°C .

You may use the following refrigerant data.

Saturated temperature ($^{\circ}\text{C}$)	Enthalpy (kJ/kg)		Entropy (kJ/kg K)	
	Liquid	Vapor	Liquid	Vapor
-14	187.14	346.32	0.9520	1.5662
40	239.03	368.81	1.1315	1.5459

1 tonne of refrigeration = 3.5 kW

Specific heat capacity of the refrigerant at constant pressure:

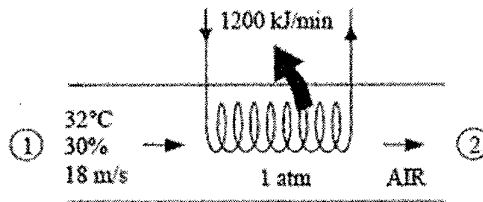
For superheated vapor – 0.762 kJ/kg K

For liquid - 1.03 kJ/kg K.

- (a) Draw the T-S or P-h diagrams.
- (b) Determine the temperature of refrigerant at the delivery from the compressor.
- (c) Calculate the compressor work.
- (d) Determine the refrigerating effect.
- (e) What is the mass flow rate needed for 1 ton of refrigeration capacity (1TR)?
- (f) Calculate the Coefficient of Performance (COP) of the cycle.

Question 02

- (i) How do relative humidity and specific humidity change during a simple heating process of moist air? Answer the same question for a simple cooling process.
- (ii) What are humidification and dehumidification?
- (iii) As shown in the figure given below air enters a 40 cm diameter cooling section at 1 atm pressure, 32°C temperature, and 30 percent relative humidity at 18 m/s velocity. Heat is removed from the air at a rate of 1200 kJ/min. Consider that the process involves no humidification or dehumidification.



Mark states 1 and 2 of the process on the given Psychrometric Chart and determine the following.

- (a) Enthalpy of exit air at state 2.
- (b) The mass flow rate of air through the cooling section.
- (c) Exit temperature of the air.
- (d) Exit relative humidity of the air.
- (e) Exit velocity of the air.

Question 03

- (i) When a choice has to be made between parallel flow and counter flow arrangement for a heat exchanger, which arrangement would you prefer? Justify your answer giving reasons.
- (ii) Draw the temperature distribution of hot and cold fluids flowing through a counter-flow heat exchanger and define Logarithmic Mean Temperature Difference (LMTD).
- (iii) A counter flow double pipe heat exchanger is to heat water from 20°C to 80°C at a rate of 1.2 kg/s. The heating is to be accomplished by geothermal water available

at 160°C at a mass flow rate of 2 kg/s. The inner tube is thin-walled and has a diameter of 1.5 cm.

Specific heat capacity of water = 4.18 kJ/kg K

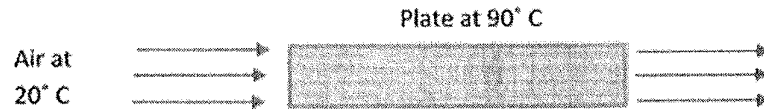
Specific capacity of geothermal water = 4.31 kJ/kg K

- (a) Calculate the exit temperature of geothermal water.
- (b) Determine the LMTD.
- (c) If the overall heat transfer coefficient of the heat exchanger is 640 W/m²K, determine the length of the tube required to achieve the desired heating.
- (d) Comment on the tube length determined above for its practicability. If it is not practicable, what recommendations would you make to use this tube length effectively?

Question 04

- (i) Define Nusselt, Reynolds, and Prandtl numbers with their usual notations.
- (ii) A glass plate manufacturing company produces glass plates having an area of 1m² and 4mm thick. In the manufacturing process, the glass plate is heated uniformly to 90°C. Then the plate is cooled by air at 20°C flowing over both sides of the plate as shown in the figure given below. Air flows parallel to the plate at 2m/s. Neglect the temperature gradient in the glass plate and assume only forced convection.

Take for glass $\rho = 2500 \text{ kg/m}^3$ and $C_p = 0.67 \text{ kJ/kg K}$



The average heat transfers co-efficient for the air flow parallel to the plate is given by

$$N_u = \frac{hL}{k} = 0.664(Re_L^{1/2})(Pr^{1/3})$$

Take the following properties for air.

$$\rho = 1.076 \text{ kg/m}^3$$

$$C_p = 1005 \text{ J/kg K}$$

$$k = 0.0286 \text{ W/m}^\circ\text{C}$$

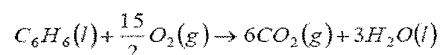
$$\mu = 19.8 \times 10^{-6} \text{ N. s/m}^2$$

Calculate the following:

- (a) Reynold number (R_{eL}) Prandtl (Pr) number and average heat transfer coefficient (h).
- (b) Heat flow (Q) from both sides of the plate in W.
- (c) Mass of the glass plate.
- (d) Write down the equation for heat lost by the plate and hence find the rate of cooling the plate in $^{\circ}\text{C}/\text{min}$

Question 05

- (i) A small gas turbine uses Octane C_8H_{18} as the fuel and is burnt with 200% theoretical air. Assuming the complete combustion determine the Air/Fuel ratio on a mass basis. (Assume each mole of oxygen in the combustion air is accompanied by 3.76 moles of nitrogen)
- (ii) Define the term "standard enthalpy of reaction".
- (iii) Calculate the standard enthalpy change for the combustion of 1 mole of benzene, $\text{C}_6\text{H}_6(\text{liquid})$ to $\text{CO}_2(\text{gas})$ and $\text{H}_2\text{O}(\text{liquid})$ as given in the equation below.



Standard enthalpies of formation (ΔH_f°) are:

Benzene $\text{C}_6\text{H}_6(l) = 49.0 \text{ (kJ/mol)}$

Carbon dioxide $\text{CO}_2(g) = -393.5 \text{ (kJ/mol)}$

Water $\text{H}_2\text{O}(l) = -285.8 \text{ kJ/mol}$

- (iv) What is Fick's law of diffusion? Write down the equation of Fick's law of diffusion and identify each term.
- (v) Helium diffuses through a plane plastic membrane 1 mm thick. The concentration of helium in the membrane is 0.02 kmol/m^3 at the inner surface and 0.005 kmol/m^3 at the outer surface. If the binary diffusion coefficient of helium for the plastic is $10^{-9} \text{ m}^2/\text{s}$, what is the diffusion flux of helium through the plastic?

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Psychrometric Chart
Normal temperatures
Standard atmospheric pressure
(760 mm of Hg or 1.013 bar)

