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

048

Study Programme	: Bachelor of Technology Honours in Engineering
Name of the Examination	: Final Examination
Course Code and Title	**: DMX5205 Applied Thermodynamics II**
Academic Year	: 2020/21
Date	:23 January 2022
Time	: 9.30 am – 12.30 pm
Duration	: **3 hours**

General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **Six (6)** questions.
3. Answer any **Five (5)** questions only. All questions carry equal marks.

Q1 (a) Sketch simple saturated refrigeration cycle indicating the refrigerating effect and the compressor work on p – h and T – s coordinates. (5 marks)

(b) A refrigerating plant works between temperature limits of - 10^0 C and 30^0C. The dryness fraction of the refrigerant at entry to the compressor is 0.75. The refrigerant leaving the condenser is at saturated condition. Thermodynamic properties of the refrigerant are given in the below table. Calculate the following.

(i) Compressor work (2 marks)

(ii) Refrigerating Effect (2 marks)

(iii) Coefficient of Performance (COP) (2 marks)

(iv) Mass flow rate of the refrigerant if the capacity of the plant is 20 TR. (5 marks)

(c) In the above refrigerating plant, the refrigerant leaving the condenser is subcooled by 5 °C. (4 marks)

Calculate the new value of the COP.

Specific heat capacity (cp) of the liquid refrigerant at 30°C is 0.8081 kJ/kgK

Thermodynamic properties of the refrigerant:

Sat. Temperature (°C)	Pressure (kPa)	Enthalpy (kJ/kg)		Entropy (kJ/kgK)	
		hf	hg	sf	sg
-10	200.7	38.53	244.55	0.1550	0.9378
30	770.6	93.58	266.71	0.3479	0.9190

Q2 Figure Q2 shows a refrigeration system having a single compressor and two evaporators.

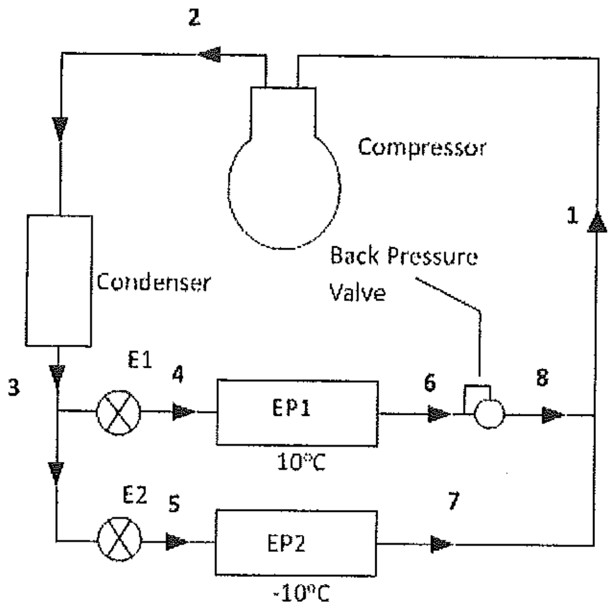

Figure Q2

The capacities of the evaporators are 30 TR and 10 TR, and the corresponding temperatures are -10°C and 10°C respectively. The condenser pressure is 9.608 bar. The enthalpy of the refrigerant after compression is 208.5 kJ/kg. The liquid refrigerant leaving the condenser is subcooled to 30°C. The vapors leaving the evaporators are dry saturated. Compression processes can be assumed as isentropic.

(a) Show all the processes on a sketch of p-h coordinates (4 marks)

(b) Find the following.

(i) Mass flow rate of refrigerant through each evaporator (4 marks)

(ii) Power required for the compressor (4 marks)

(iii) Coefficient of Performance of the system (4 marks)

Use the following thermodynamic properties of the refrigerant used in the system.

1 TR = 210 KJ/min.

Sat. Temperature (°C)	Pressure (bar)	Enthalpy (kJ/kg)		Entropy (kJ/kgK)	
		h_f	h_g	s_f	s_g
-10	2.191	26.87	183.19	0.1080	0.7019
10	4.234	45.37	191.74	0.1752	0.6921
40	9.608	74.59	203.20	0.2718	0.6825

Specific heat capacity (c_p) of the liquid refrigerant at condenser pressure is 0.8 kJ/kg K.

Q3 (a) Define the following terms referred to in moist air. (6 marks)

- Dew point
- Relative humidity
- Specific humidity

(b) Atmospheric air at 34°C with 30% relative humidity passes through an evaporative cooler. Exit temperature of air is 25°C. The process is a constant enthalpy process.

(i) Show the process on a sketch of a Psychrometric chart (4 marks)

(ii) Find the following

Amount of water added per kg of dry air (6 marks)

Relative humidity of exit air (4 marks)

Use following data and equations.

Properties of steam:

Temperature, t (°C)	Sat. Pressure, p_g (bar)	Enthalpy, hg (kJ/kg)
34	0.05318	2562.9
25	0.03166	2546.6

Specific heat capacity of dry air (c_p) = 1.005 kJ/kg K
Atmospheric pressure = 1.0132 bar

$$\text{Specific Humidity} = 0.622\left(\frac{p_{vs}}{p - p_{vs}}\right)$$

$Where, p_{vs} = partial\ vapor\ pressure\ \ and\ p = atmospheric\ pressure$

Q4 A hall with a capacity of 100 persons needs to be supplied with conditioned air at 20°C and 50% relative humidity. Outside air is at 32°C and 70% relative humidity. It has been estimated that air requirement per person is $0.5 m^3/min$.

The desired condition of air is achieved by sensible cooling, dehumidifying, and then heating.

(a) Mark the processes on a sketch of Psychrometric Chart (5 marks)

(b) Find the following.

(i) Capacity of the cooling coil in tonnes of refrigeration (5 marks)

(ii) Capacity of the heating coil in kW (5 marks)

(iii) Amount of water removed by the dehumidifier in kg/h (5 marks)

Use the Psychrometric Chart provided with the Question Paper to obtain the moist air properties.

Q5 (a) What is meant by Room Sensible Heat Factor (RSHF) in the context of air conditioning? (2 marks)

(b) A lecture hall is maintained at 26°C dry bulb temperature and 60% relative humidity (see Figure Q5). The ambient condition is 32°C dry bulb temperature and 65% relative humidity. The hall has a sensible heat load of 30 kW and a latent heat load of 10 kW. In the air conditioning system 50% of return air is mixed with fresh air after the cooling coil. The condition of air leaving the cooling coil is at 17°C.

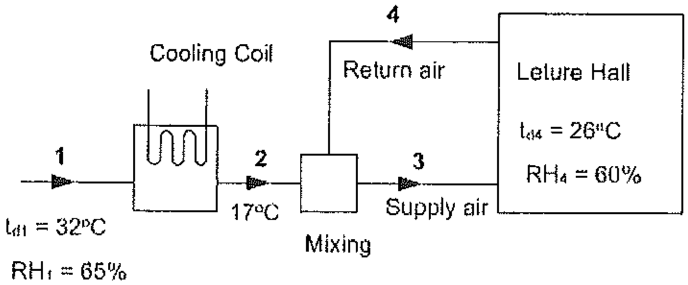

Figure Q5

(i) Calculate the Room Sensible Heat Factor (2 marks)

(ii) Mark the RSHF line on the given Psychrometric chart (3 marks)

(iii) Find the temperature and relative humidity of air entering the lecture hall (4 marks)

(iv) Find the capacity of the cooling coil in kJ per kg of dry air (4 marks)

Q6 (a) A steam pipe has outside diameter of 30 mm. This pipe is to be insulated with two layers of insulation, each of 20 mm thick. The thermal conductivity of one material is 3 times that of the other.

Find out the percentage increase of heat transfer by having the better insulation material next to the pipe compared to having it outside. Assume that the inner and outer temperature of the composite pipe is fixed. (10 marks)

You may use the following equation for radial heat transfer rate for cylinders with usual notation.

$$Q = \frac{2\pi k L \Delta T}{ln\frac{r_2}{r_1}}$$

(b) A steel pipe of outer diameter 100 mm and length 2 m has been positioned vertically in a room with ambient temperature of 32°C. The pipe surface is at 200°C. The emissivity of the pipe surface is 0.6. Calculate the heat loss from the pipe surface to the atmosphere by natural convection and by radiation. (10 marks)

Properties of air at the average temperature are:

Thermal conductivity: 0.035 W/m K, Prandtl Number:0.68, kinematic viscosity: 27.8 x 10^{-6} m^2/s, Coefficient of volumetric thermal expansion: 2.571 x 10^{-3}. Stefan Boltzmann Constant: 5.67 x 10-8 W/m^2 K^4

You may use the following equations with usual notation.

$$Gr = \frac{g\beta\theta L^3}{\nu^2}, \quad Nu = 0.13(GrPr)^{\frac{1}{3}}. \quad Nu = \frac{hL}{k}, Q_{rad} = \sigma A\epsilon(T_s^4 - T_\infty^4)$$