First Semester Examination
2021/2022 Academic Session

February/March 2022

EME431 – Refrigeration and Air Conditioning

Duration : 3 hours

Please ensure that this examination paper contains **EIGHT (8)** pages and **FIVE (5)** question before you begin the examination.

Instructions :

1. Answer **ALL** questions.
2. Answer all questions in **English** OR **Bahasa Malaysia** OR a combination of both.
3. Each question must begin from a new page.
4. Use properties tables and diagrams in E-Learn.

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1. A fishing boat equipped with a vapour absorption refrigeration system, the generator, condenser, evaporator, and absorber of the refrigeration system operate at the temperatures of 110°C, 38°C, -5°C and 32°C, respectively. The power of generator and pump are 48 kW, and 2 kW, respectively, and the mass flow rate at the pump is 0.2 kg/s. Refer to the given properties diagram and data sheets, calculate;

   a) Pressure at the condenser and evaporator.
   (20 marks)

   b) Refrigerant concentration at the generator and absorber.
   (20 marks)

   c) Mass flow rate of the absorbent from generator to absorber.
   (10 marks)

   d) Mass flow rate of the refrigerant from generator to condenser.
   (10 marks)

   e) Cooling capacity of the system.
   (30 marks)

   f) COP of the whole system.
   (10 marks)

2. Albert Einstein designed a 3.8 kW cooling capacity refrigerator (as shown in Figure Q2) operates at 0.4 MPa using butane, ammonia, and water. The temperature at generator, condenser and evaporator are 100°C, 35°C, and 5°C, respectively. Given the mass flow rate, m1, m3, and m5 are 4.3 g/s, 3 g/s, and 2.8 g/s, respectively, and void fraction at the bubble pump is 0.8. Assuming no heat loss from bubble pump and tank, and only water is pumped to the tank from generator. Refer to the given properties diagram and data sheets.

   a) Specify the role of the three working fluids
   (15 marks)

   And calculate:

   b) Mass flow rate from tank, m6 and m7
   (15 marks)

   c) Heat input to the generator
   (20 marks)

   d) Heat input to the bubble pump
   (20 marks)

   e) Heat rejection from the condenser
   (25 marks)

   f) COP of the system
   (5 marks)

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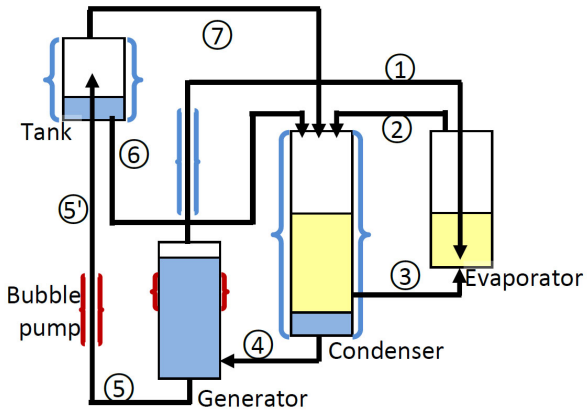

Figure Q2

3. Table Q3 shows the temperature of two cities. According to the given information, determine the following:

   a) The minimum pressure of the condenser for the R134a refrigeration system in these cities, respectively. Justify your answer.

   (30 marks)

   b) The minimum achievable temperature through air cooler at these cities during daytime, respectively,

   (20 marks)

Table Q3

Location	Penang					Abu Dhabi				
	Temperature, °C			Humidity, %RH		Temperature, °C			Humidity, %RH	
Month	Min	Mean	Max	Min	Max	Min	Mean	Max	Min	Max
Jan	23	26	29	53	85	12	24	18	36	81
Feb	23	27	30	53	87	13	25	19	39	86
Mar	23	27	31	58	93	16	29	22	28	74
Apr	24	29	33	65	93	19	33	26	21	64
May	24	29	33	70	93	23	38	31	19	76
Jun	24	29	33	70	93	25	40	32	25	75
Jul	24	28	32	70	93	28	42	35	22	63
Aug	24	28	32	70	95	29	42	35	20	75
Sep	23	28	32	70	93	26	40	33	23	79
Oct	24	28	31	67	93	22	36	29	29	79
Nov	23	27	30	65	92	18	31	24	36	77
Dec	23	26	29	60	90	14	26	20	37	76

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Notes:

E-learn shuffle among 4 questions (Q3 c) with the following ***<renewable energy sources>****:*

1- *Geothermal Heat Pump (GHP) system*
2- *Solar thermal energy system*
3- *Biomass thermal energy system*
4- *Geothermal high temperature (steam) system*

3. c) As a designer you were tasked to design air conditioning system for a green building that depends partially on ***<renewable energy resource>***.

i) Choose the category of air conditioning system that you will enhance from the following:

- Compression cooling split unit,
- Compression cooling central all air system,
- Absorption cooling central all air system,
- Hydronic all water system.

ii) Draw a schematic drawing of the system.

iii) Discuss the use of ***<renewable energy resource>*** system to enhance your air conditioning system by showing the integration between your air conditioning system and ***<renewable energy resource>*** in your schematic drawing.

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(50 marks)

Notes:

E-learn automatically generate the numbers {Z1} to {Z8}.
E-learn automatically shuffle Figure 4b.

4. a) Fill in the blanks in the following table. Use the CBE thermal comfort online tool (ASHRAE Standard 55-2020).

Operative temperature (°C)	Relative humidity (%)	CLO	MET	Velocity (m/s)	PMV	Comfortable (Y/N)?	What should be the operative temperature to achieve near perfect neutral comfort?
{Z1}	50	1	1	0.1	?	?	?
{Z1}	40	0.5	1.1	0.1	?	?	?
{Z1}	55	0.6	1.3	0.3	?	?	?
{Z1}	35	1.5	1.4	0.9	?	?	?
{Z1}	60	0.6	2	0.3	?	?	?

(30 marks)

4. b) A lecture hall is shown in Figure 4(b). Consider the following values at the peak load. Calculate the peak gained heat in the lecture hall.

	Walls & Roof CLTD c (°C)	East or East-north Windows	
		CLTD c (°C)	MSHGF (W/m^2)
North	10	10	347
NE and NW	13	12	637
East and West	16	14	618
SE and SW	14	13	230
South	12	12	120
Roof	26	27	830

- Hall length (L) of {Z2} m, width (W) of {Z3} m and height of 3m. Consider heat transfer coefficient, U, for walls to be 1 ($W/m^2.K$) and for roof to be 0.7 ($W/m^2.K$). Ignore doors.
- Window area is {Z4} m^2.
- Number of occupants is {Z5} people. Take sensible heat, Q_s= 75 W/person and latent heat, Q_L = 55 W/person.

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- Light load is {Z6} W/m^2 of floor area with the use of 36W Fluorescent lamps.

- Infiltration flow rate is {Z7} L/s per m^2 of floor area. Take ambient conditions to be {Z8} °C and humidity ratio, ω, = 20 g/kg. Consider room temperature and humidity ratio to be lower than the ambient by 7 °C and 10 g/kg, respectively.
- Additional loads include: 200W TV; Two 300W computers; two 200 W printers; water boiler (1000W sensible & 500W latent). Consider suitable cooling load factor (CLF).

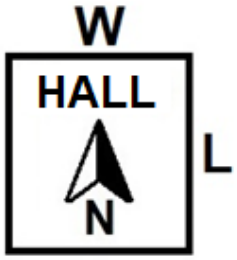

Figure 4b

Figure 4b

(70 marks)

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NOTES
E-learn shuffle among 6 questions (Q5 a) with the following ***<control mechanism>****:*

1- *Constant air volume (CAV) with dual duct control*
2- *Variable air volume (VAV) air duct control*
3- *Automatic expansion valve for refrigerant flow control*
4- *Thermostatic expansion valve for refrigerant flow control*
5- *Solenoid control valve for refrigerant flow control*
6- *Air bypass valve in AHU*

E-learn automatically generate the numbers {Z9} to {Z12}.

5. a) With the aid of schematic diagram, discuss the function of ***<control mechanism>*** in central air conditioning system. In the discussion, explain:

   i. how this ***<control mechanism>*** can maintain thermal comfort during part-lead operation,
   ii. how this ***<control mechanism>*** can reduce energy consumption to achieve green-building status.

(30 marks)

5. b) A central air conditioning system of {Z9} TR capacity is shown in Figure 5 (b). Air is entering the cooling coil at 24ºC and humidity ratio of 9 g/kg. The cooler coil dew point is at humidity ratio of 5 g/kg. The temperature and humidity ratio of air entering the room are 17°C and 6 g/kg, respectively. The air duct has 5 exits with equal air flow rate at each exit. The lengths of the duct sections are as following:

- A = {Z10} m.
- B = {Z11} m.
- C = {Z12} m.

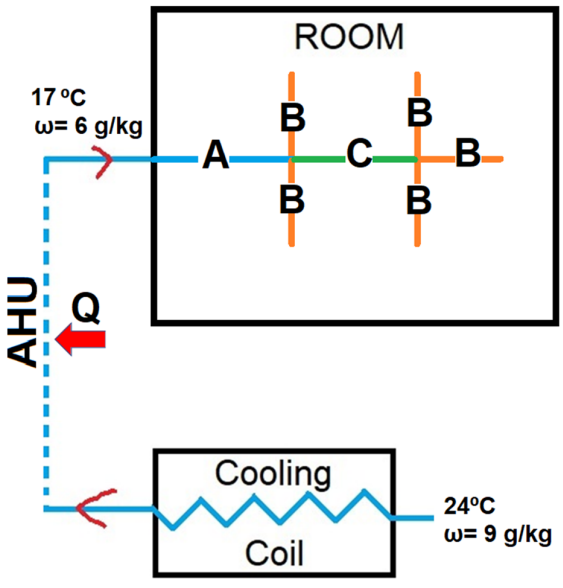

Figure Q5 [b]

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Use equal friction method and consider pressure drop of 1 Pa/m. Plot the process on the psychometric chart.

Calculate:

i. Cooling coil efficiency and actual mass flow rate of the supply air to the room.
ii. The velocity (m/s) and circular diameter (mm) for each section of the duct.
iii. Pressure losses in each duct and total pressure losses.
iv. Air blower power (Watts) if the motor efficiency is 90%.

(70 marks)

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