UNIVERSITY OF JOHANNESBURG

PROGRAM	:	**B.ING** *MECHANICAL ENGINEERING SCIENCE*
SUBJECT	:	**THERMAL SYSTEMS 4B**
CODE	:	**TML4B**
DATE	:	23 NOVEMBER 2016
DURATION	:	(1st-PAPER) 08:30 - 11:30
WEIGHT	:	50: 50
TOTAL MARKS	:	130

EXAMINER	:	DR. S KRUGER
MODERATOR	:	PROF. L PRETORIUS (UP)
NUMBER OF PAGES	:	6 PAGES AND 9 ANNEXURES

Attachments:

- Psychrometric Charts (1400m & Sea level)
- Temperature pressure concentration diagram of saturated LiBr water solutions
- Enthalpy of LiBr by percentage
- Water properties
- Formula Sheet
- Pressure – enthalpy diagram 134 a
- R134a Saturated properties
- R134a Pressure-Enthalpy Diagram

INSTRUCTIONS TO CANDIDATES:

PLEASE ANSWER ALL THE QUESTIONS.
SUBMIT YOUR PSHYCHROMETRIC CHART WITH THE ANSWER BOOK

QUESTION 1 [39]

The air in a conference room located at an altitude of 1400m is to be air conditioned using two cooling coils. The air in the conference room is to be maintained at a temperature of 25°C and a relative humidity of 40%. The temperature of the outside air is 31°C at its relative humidity is 50%. In the system 2.25m^3/s of outside air is mixed with 8m^3/s of return air. The mixture flows into the first cooling coil which has a dew point temperature of 9°C. The bypass factor for the first coil is 50%. The mixture then flows to the second coil which has a dew point of 3°C. The dry bulb temperature of the mixture leaving the second coil is 7°C.

a) Plot the process on a psychrometric chart

b) By calculation, determine the dry bulb temperature and humidity ratio of the mixture and check the properties on a psychrometric chart

c) By calculation, determine the temperature of the mixture leaving the first cooling coil

d) By calculation, determine the bypass ratio of the second coil +

e) Calculate the cooling capacity of the first coil

f) Calculate the cooling capacity of the second coil

g) Calculate the room sensible heat factor

QUESTION 2 [40]

A cooling and dehumidifying coil is supplied with 2.4 m^3/s of air at 29°C dry-bulb and 24°C wet-bulb temperatures, and its cooling capacity is 52 kW. The face velocity is 2.5 m/s. and the coil is of the direct expansion type provided with refrigerant evaporating at 7°C. The coil has an air-side heat-transfer area of 15m^2 per square meter of face area per row of tubes. The ratio of the air-side to refrigerant-side area is 14. The values of h_r and h_c are 2050 and 65 W/m^2.K, respectively. Calculate:

a) The face area,
b) The enthalpy of outlet air,
c) The wetted-surface temperatures at the air inlet, air outlet, and at the point where the enthalpy of air is midway between its entering and leaving conditions,
d) The total surface area,
e) The number of rows of tubes, and
f) The outlet dry-bulb temperature of the air.

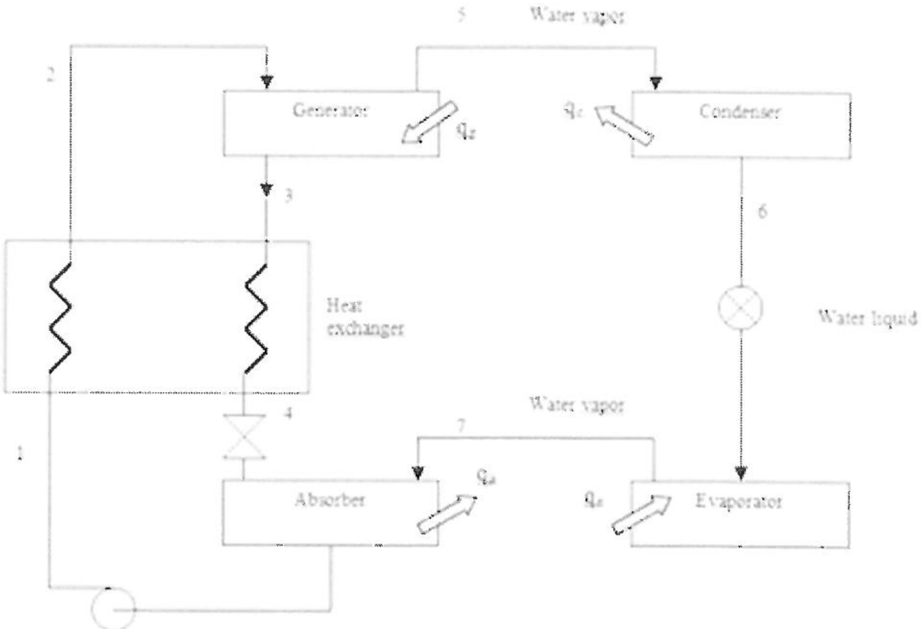
QUESTION 3 [25]

The following system temperatures apply to a LiBr water solution absorption refrigeration system:

Temperature in generator	110 °C
Temperature in condenser	42 °C
Temperature in evaporator	5 °C
Temperature in absorber	25 °C
The refrigeration capacity	250 kW
Lithium-bromide flow	0.5kg/s

a) Calculate the flow rates of the system
b) Calculate all the heat transfers and COP of the system
c) If a heat exchanger is installed as shown in the sketch below, calculate the outlet temperature from the heat exchanger of the flow of the flow to the generator from the

heat exchanger if the COP is to be increased by 10%



QUESTION 4 [26]

In a 134 a system one evaporator is to provide 250 kW of refrigeration at -25 °C and another evaporator is to provide 100 kW at 5 °C. The system uses two-stage compression with an intercooler indicated on the figure underneath. The condensing temperature is 45 °C. Assume the ideal refrigeration cycle and isentropic compression. The discharge pressure of the low stage compressor and the suction pressure of the high stage compressor are the same as the pressure in the +5°C evaporator.

4.1 Sketch the system on the pressure enthalpy diagram

4.2 Establish the enthalpies at all state points. For the state points after compression isentropic compression can be assumed

4.3 Determine the mass flows of the -25°C evaporator system

4.4 Calculate the mass flow of the high stage compressor by making a heat and mass balance about the high stage compressor and intercooler and make a sketch of the high stage evaporator and the intercooler

4.5 Calculate the power input in both compressors.

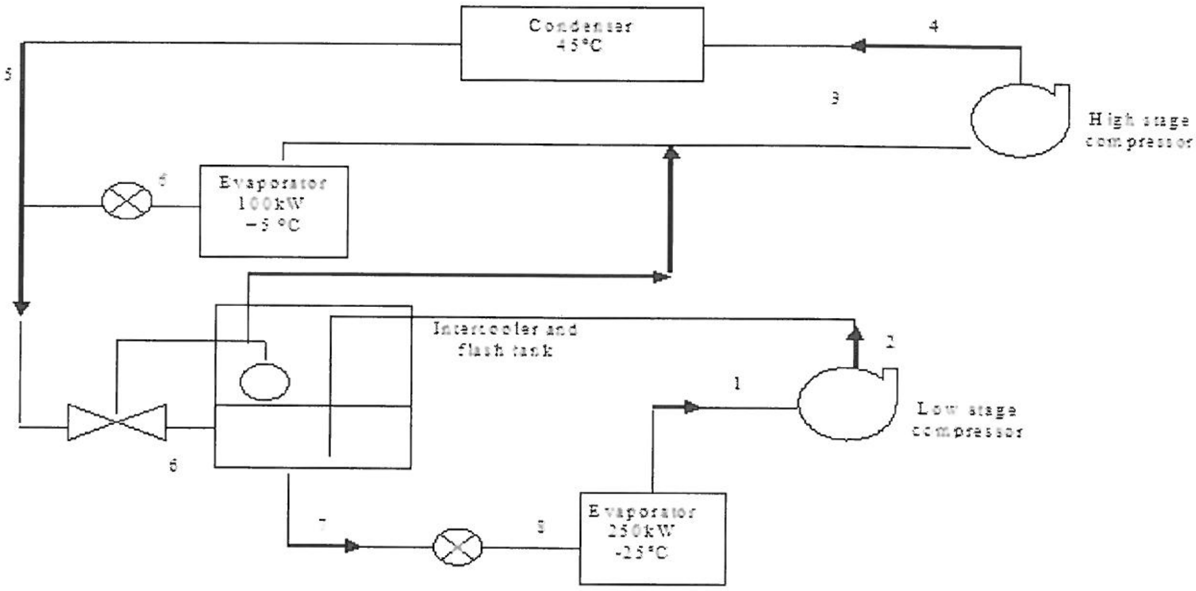
4.6 If we would have a system with one compressor and two evaporators with a pressure reducing valve to maintain a high temperature in the air conditioning evaporator what would be the absorbed power of the compressor.

4.7 Sketch the system on the ph diagram

4.8 If each evaporator would be served individually by one separate compressor with the same condensing temperature, what would have been the mass flow through each system and what would have been the power requirement for both compressors.

4.9 Sketch the system on the ph diagram

4.10 For which system is the power consumption lower and explain?



FORMULA SHEET

$$\dot{m}\left(h_1 + \frac{V_1^2}{2} + gz_1\right) + \dot{Q} - \dot{m}\left(h_2 + \frac{V_2^2}{2} + gz_2\right) - \dot{W} = \frac{dE}{dt}$$

$$h_v \cong h_g(T) \qquad h = h_a + Wh_v \qquad h_a = C_{pa}t$$

$$SHR = \frac{\dot{Q}_S}{\dot{Q}_{Coil}} = \frac{\dot{Q}_S}{\dot{Q}_S + \dot{Q}_L}$$

Contact Factor: $$(\beta) = \frac{\omega_a - \omega_b}{\omega_a - \omega_c} = \frac{h_a - h_b}{h_a - h_c} = \frac{t_a - t_b}{t_a - t_c}$$

Bypass Factor: $$BPF = (1-\beta) = \frac{t_b - t_c}{P_a - P_c}$$

$$\frac{\dot{m}_{a1}}{\dot{m}_{a2}} = \frac{h_2 - h_3}{h_3 - h_1} = \frac{\omega_2 - \omega_3}{\omega_3 - \omega_1} \qquad \omega = \frac{m_v}{m_a} \qquad P = P_a + P_v \qquad \phi = \frac{P_v/P}{P_s/P} = \frac{P_v}{P_s}$$

$$v = \frac{R_a T}{P_a} = \frac{R_a T}{P_t - P_v} \qquad \omega = 0.6129\frac{p_v}{(p_t - p_v)} \qquad \frac{\dot{m}_{a2}}{\dot{m}_{a3}} = \frac{h_3 - h_1}{h_2 - h_1}$$

$P_s = 0.6105\, e^{\frac{17.27 x t}{237.3+t}}$ kPa : t in °C $\qquad \omega = 0.622 \dfrac{p_v}{p_t - p_v}$

$h = 1.005 \times t + \omega h_g$: h_g = enthalpy of sat.steam at t°C

$v = \dfrac{287T}{p_t - p_v}$: T in K

$p_v = p_{sw} - \dfrac{1.8(p_t - p_{sw})(t_{db} - t_{wb})}{2800 - 1.3t_{wb}}$ or

$$t_{wb} = \frac{t_{db} + \frac{2800}{1.8}\left(\frac{p_v - p_{sw}}{p_t - p_{sw}}\right)}{1 + \frac{1.3}{1.8}\left(\frac{p_v - p_{sw}}{p_t - p_{sw}}\right)}$$

$$q_{1-2} = \frac{A_{1-2}h_c}{c_{pm}}\left(\frac{h_{a1} + h_{a2}}{2} - \frac{h_{i1} + h_{i2}}{2}\right)$$

$$h_i = 9.3625 + 1.7861\, t_i + 0.01135\, t_i^2 + 0.00098855 t_i^3$$

$$f_i = \frac{t_i}{R} - \frac{t_r}{R} - h_a + 9.3625 + 1.7861\, t_i + 0.01135\, t_i^2 + 0.00098855 t_i^3$$

$$R = \frac{h_c}{c_{pm}h_r}\frac{dA}{dA_i} \qquad t_{i+1} = t_i - \frac{f_i}{\left(\frac{df}{dt}\right)_i}$$

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EXAMINER	:	DR. S KRUGER
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- Sea level psychrometric chart
- Steam Tables
- Pressure – enthalpy diagram 134 a
- R134a Saturated properties
- R134a Pressure-Enthalpy Diagram
- Temperature-pressure concentration diagram of LIBr- water solution
- Enthalpy of LiBr water solutions

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QUESTION 1 [10]

Name and discuss four airborne contaminants that may cause problems in both industrial and nonindustrial indoor environments.

QUESTION 2 [19]

Outside air at 15°C, 1 bar, and 50% relative humidity enters an air-conditioning device operating at steady state. Liquid water is injected at 7°C and a moist air stream exits with a volumetric flow rate of 0.75 m3 / s at 35°C, 1 bar and a relative humidity of 50%. Neglecting kinetic and potential energy effects, determine:

a. The rate water is injected, in kg/s.
b. The rate of heat transfer to the moist air, in kJ/s.

QUESTION 3 [40]

A terminal-reheat air conditioning plant located at sea-level provides air to a number of zones in which the total sensible heat load is 300kW and the latent heat load is 100kW. In the system 6kg/s of outside air is mixed with 25kg/s of return air. The DB temperature of the outside air is 30°C with a RH of 60%. The design condition for the controlled zones is a DB temperature of 24°C and a relative humidity of 50%. The apparatus dew point temperature of the cooling coil is 6°C. The temperature of the air after passing through the cooling coil is 13°C. The re-heaters are also fitted with humidifiers:

a) Draw the process on a psychrometric chart
b) Calculate the mixture properties
c) Calculate the cooling coil load of the cooling coil
d) Calculate the load of the heaters
e) Calculate the humidifier load
f) Calculate the rate at which water must be removed from the cooling coil.
g) Calculate the rate at which water is added to the system by the humidifiers

QUESTION 4 [12]

The following data apply to a cooling and de-humidification direct expansion type cooling coil in which the refrigerant is maintained at a constant temperature. The following data are given:

a. Enthalpy of entering air = 82 kJ/kg
b. Temperature of wetted surface at entrance 16°C
c. Temperature at wetted surface at leaving side of coil 10°C
d. Convection coefficient h_c = 60 W/m².K
e. Specific heat of air mixture c_{pm} = 1.03 kJ/kg.K
f. Rate of heat transfer d_q per unit of heat exchange area = 1200 W/m²

Calculate the approximate enthalpy of the air leaving the coil, using the mean enthalpy difference.

QUESTION 5 [19]

Calculate the power requirement by the two compressors in a R-134a system which serves a 200 kW evaporator at -15°C shown in Figure 1. The system uses two stage compression with inter cooling and flash gas. The condensing temperature is 45°C and the compression is isentropic.

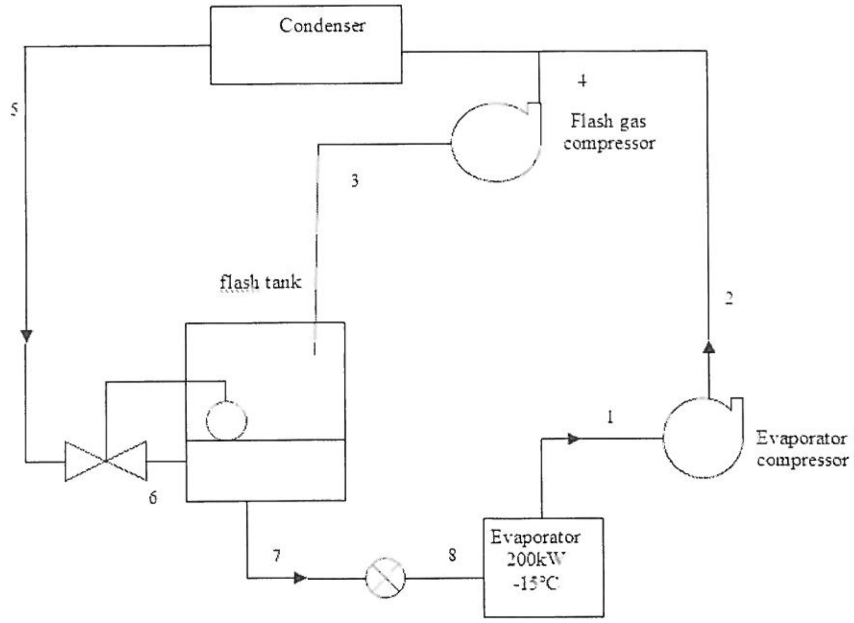

Figure 1

a) Draw the pressure-enthalpy diagram of the system

b) Calculate the intermediate pressure of the intercooler for optimum economy, which can be calculated from equation :

i. $p_i = \sqrt{p_s \cdot p_d}$

p_i = intercooler pressure
p_s = suction pressure of low stage compressor
p_d = discharge pressure of high stage compressor

c) Determine all enthalpy values h_1 to h_7

d) Determine the mass flow rate through the low stage compressor

e) Calculate the flow rate through the high stage compressor by means of the heat and mass balance around the intercooler

f) Determine the power requirement of the low and high stage Compressor and the total power for the system

g) Compare the power requirement to a single compressor system without inter-cooler

FORMULA SHEET

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$$R = \frac{h_c}{c_{pm}h_r}\frac{dA}{dA_i} \qquad t_{i+1} = t_i - \frac{f_i}{\left(\frac{df}{dt}\right)_i}$$