UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 5 Examination in Engineering: May 2023

Module Number: ME5305 **Module Name: Refrigeration and Air-Conditioning**

[Three Hours]

[Answer **all questions**, each question carries **10** marks]

Note: Provide neat sketches and state any reasonable assumptions made; Symbols have their usual meaning; Psychometric chart and steam table are provided.

Q1 a) Briefly explain the term "Refrigeration" and provide its **four** practical applications.

[2.0 Marks]

b) Briefly explain the thermal equilibrium of a system.

[1.0 Mark]

c) Thermodynamic system can be defined as a definite area or a space where some thermodynamic process is taking place. Briefly explain three types of thermodynamic systems with the aid of sketches.

[3.0 Marks]

d) What are the **four** non-flow process which take place in the thermodynamic cycle of a closed system? Briefly explain those four processes providing neat sketches.

[4.0 Marks]

Q2 a) What is the main difference between open air refrigeration cycle and dense air refrigeration cycle?

[1.0 Mark]

b) Draw the p-v diagram and T-s diagram of the Bell-Coleman cycle.

[2.0 Marks]

c) Prove that the Coefficient of Performance (C.O.P.) of the Bell-Coleman cycle can be expressed as;

$$C.O.P. = \frac{1}{(r_p)^{\frac{\gamma-1}{\gamma}} - 1}$$

where,
r_p – compression or expansion ratio
γ – isentropic index.

[4.0 Marks]

d) The atmospheric air at pressure 1 bar and temperature -5 °C is drawn in the cylinder of the compressor of a Bell-Coleman refrigerating machine. It is compressed isentropically to a pressure of 5 bar. In the cooler, the compressed air is cooled to 15 °C, pressure remaining the same. It is then expanded to a pressure of 1 bar in an expansion cylinder, from where it is passed to the cold chamber. The work done on the system is 40.7 kJ/kg. Find the C.O.P. of the plant.

For air assume law for expansion, isentropic index and specific heat of air at constant pressure are 1.2 and 1 kJ/kg K, respectively.

[3.0 Marks]

Q3 a) Draw the schematic diagram of the vapour compression refrigeration system and briefly explain its working process.

[3.0 Marks]

b) An ammonia refrigerating machine fitted with an expansion valve works between the temperature limits of -10 °C and 30 °C. The vapour is 95 % dry at the end of the isentropic compression and the fluid leaving the condenser at 30 °C temperature. Assuming actual C.O.P. as 60 % of the theoretical, calculate the kg of ice produced per kW hour at 0 °C from water at 10 °C. Latent heat of ice is 335 kJ/kg. Take specific heat of water as 4.187 kJ/kg K. Ammonia has the following properties:

Temperature °C	Liquid heat (h_f) kJ/kg	Latent heat (h_{fg}) kJ/kg	Liquid entropy (s_f)	Total entropy of dry saturated vapour
30	323.08	1145.80	1.2037	4.9842
-10	135.37	1297.68	0.5443	5.4770

[6.0 Marks]

c) Draw the *T-s* diagram of the actual vapour compression refrigeration cycle.

[1.0 Mark]

Q4 a) The simple vapour absorption refrigeration system consists of an absorber, a pump, a generator, and a pressure reducing valve to replace the compressor of the vapour compression system.

i) Draw the schematic diagram of the ideal vapour absorption refrigeration system.

[1.5 Marks]

ii) Draw the schematic diagram of the practical vapour absorption refrigeration system.

[1.5 Marks]

iii) Briefly explain the functions of additional components that exist in the practical system instead of the ideal system.

[3.0 Marks]

b) In an absorption type refrigerator, the heat is supplied to ammonia generator by condensing steam at 2 bar and 90% dry. The temperature in the refrigerator is to be maintained at -5 °C. The saturation temperature of the steam at a pressure of 2 bar is 120.2 °C. The atmosphere temperature is 30 °C. Take the gas constant as 287 J/kg K.

i) Find the maximum C.O.P. possible.

[1.0 Mark]

ii) If the refrigeration load is 20 tonnes and the actual C.O.P. is 70% of the maximum C.O.P., find the mass of steam required per hour.
Take the latent heat of steam at 2 bar is 2201.6 kJ/kg.

[2.0 Marks]

c) What are the three fluids used in Domestic Electrolux refrigeration system?

[1.0 Mark]

Q5 a) Briefly explain the following terms.

i) Saturated air
ii) Degree of saturation
iii) Relative humidity
iv) Absolute humidity
v) Wet bulb depression
vi) Dry air

[3.0 Marks]

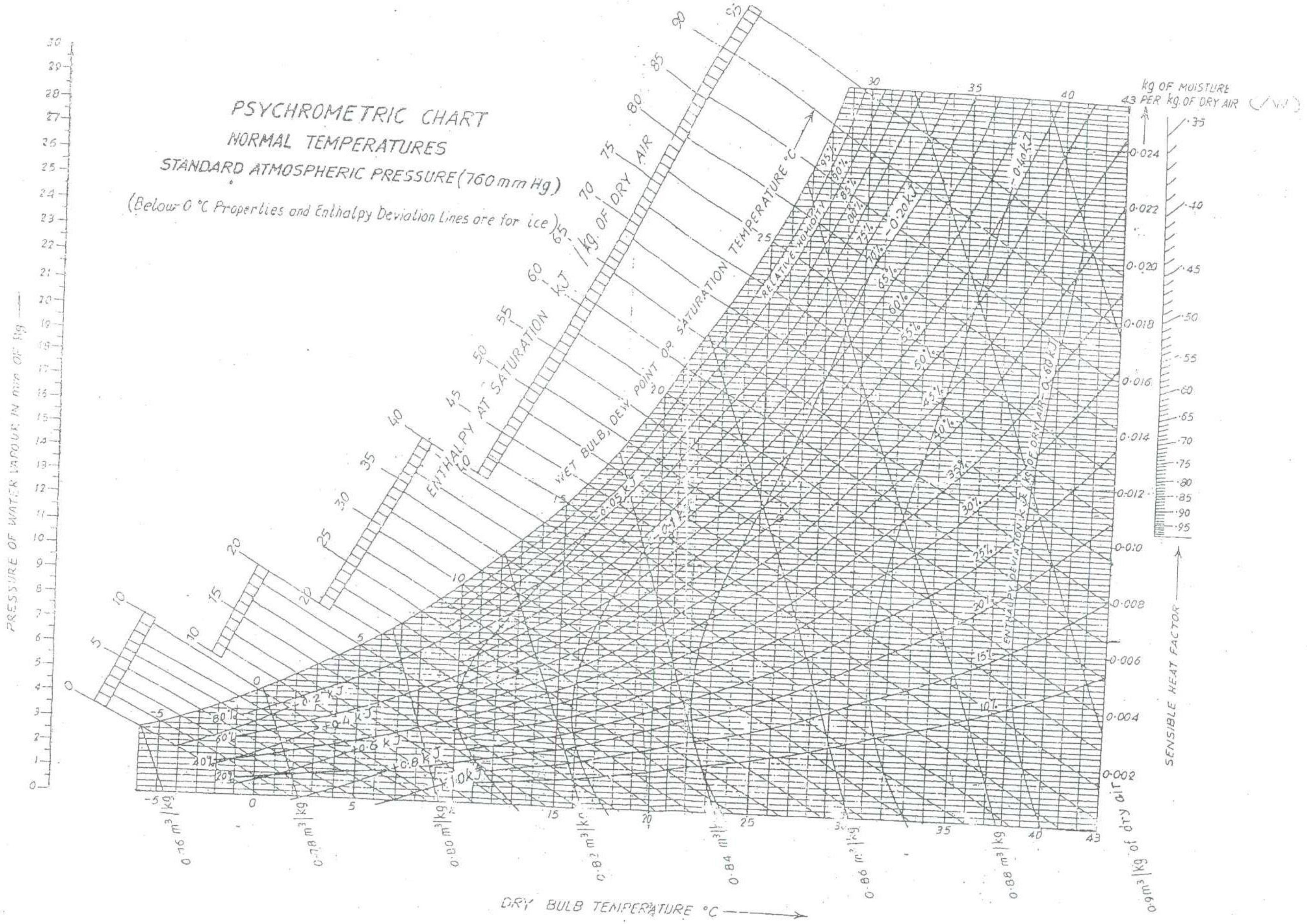
b) A room 7 m x 4 m x 4 m is occupied by an air-water mixture at 38 °C. The atmospheric pressure is 1 bar and the relative humidity is 70%.

i) Determine the humidity ratio, dew point temperature, mass of dry air, and mass of water vapour of the mixture.

[4.0 Marks]

ii) If the mixture of air-water vapour is further cooled at constant pressure until the temperature is 10 °C, find the amount of water vapour condensed. Take the gas constant of air as 287 J/kg K.

[3.0 Marks]



PSYCHROMETRIC CHART
NORMAL TEMPERATURES
STANDARD ATMOSPHERIC PRESSURE (760 mm Hg)
(Below 0 °C Properties and Enthalpy Deviation Lines are for ice)
PRESSURE OF WATER VAPOUR IN mm OF Hg
ENTHALPY AT SATURATION kJ / kg. OF DRY AIR
WET BULB, DEW POINT OR SATURATION TEMPERATURE °C
RELATIVE HUMIDITY
ENTHALPY DEVIATION kJ / kg OF DRY AIR
DRY BULB TEMPERATURE °C
kg OF MOISTURE PER kg OF DRY AIR
SENSIBLE HEAT FACTOR
0.76 m³/kg
0.78 m³/kg
0.80 m³/kg
0.82 m³/kg
0.84 m³/kg
0.86 m³/kg
0.88 m³/kg
0.9 m³/kg of dry air