UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 5 Examination in Engineering: December 2020

Module Number: ME5305

Module Name: Refrigeration and Air-Conditioning (C-18)

[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 is provided.

Q1 a) Define the following terms.

i) Closed system
ii) Isolated system
iii) Open system
iv) Specific heat
v) Thermal equilibrium

[2.5 Marks]

b) Briefly explain the terms "Refrigeration" and "Refrigerator".

[2.0 Marks]

c) Briefly explain the difference between sensible heat and latent heat.

[1.5 Marks]

d) The various non-flow processes which take place in the thermodynamic cycle of a closed system are isochoric process, isobaric process, isothermal process, and isentropic process. Briefly explain above mentioned non-flow processes providing neat sketches.

[2.0 Marks]

e) Volume, temperature, pressure, and density are the quantities, which identify the state of a system, are called properties. The thermodynamic properties of a system may be divided in to two general classes. Briefly explain those two general classes.

[2.0 Marks]

Q2 a) Relative humidity (φ) of air and water vapour mixer can be defined as the ratio of actual mass of water vapour in a given volume of moist air to the mass of water vapour in the same volume of saturated air at the same temperature and pressure. Show that relative humidity can be expressed as a function of degree of saturation of the air mixer and it is given by,

$$\varphi = \frac{\mu}{1 - (1 - \mu)\frac{p_s}{p_b}}$$

where,
μ – degree of saturation
p_s – partial pressure of water vapour in saturated air

p_b - Barometric pressure or total pressure exerted by air and water vapour mixer.

[4.0 Marks]

b) The atmospheric air at 30 °C dry bulb temperature and 75% relative humidity enters a cooling coil at the rate of 200 m^3/min. The coil dew point temperature is 14 °C and the by-pass factor of the coil is 0.1. Determine:

i) The temperature of air leaving the cooling coil.

[1.0 Mark]

ii) The capacity of the cooling coil in tonnes of refrigeration.

[3.0 Marks]

iii) The amount of water vapour removed per minute.

[1.0 Mark]

iv) The sensible heat factor for the process.

[1.0 Mark]

Q3 a) Briefly explain the functions of a heat engine, refrigerator, and heat pump with the aid of sketches.

[1.5 Marks]

b) Two refrigerators, X and Y, operate in series. The refrigerator X absorbs energy at the rate of 1.5 kJ/s from a body at temperature 310 K and rejects energy as heat to a body at temperature T. The refrigerator Y absorbs the same quantity of energy which is rejected by the refrigerator X from the body at temperature T, and rejects energy as heat to a body at temperature 900 K. If both the refrigerators have the same Coefficient of Performance (COP), calculate:

i) The temperature T of the body.

[1.5 Marks]

ii) The COP of the refrigerators.

[1.0 Mark]

iii) The rate at which energy is rejected as heat to the body at 900 K.

[1.5 Marks]

c) A refrigerating system operates on a reversed Carnot cycle. The higher temperature of the refrigerant in the system is 35 °C and the lower temperature is -15 °C. The capacity of the system is to be 12 tonnes. Determine the followings of the refrigerating system:

i) Coefficient of Performance.

[1.5 Marks]

ii) Power requirement.

[1.5 Marks]

iii) Heat rejection per hour.

[1.5 Marks]

Q4 a) Briefly explain the mechanism of a simple vapour compression refrigeration system with the aid of sketches.

[2.0 Marks]

b) What are the advantages and disadvantages of vapour compression refrigeration system over air refrigeration system?

[1.5 Marks]

c) R-22 is used as a refrigerant in a vapour compression refrigerator. The liquid refrigerant evaporates in the evaporator at -10 °C. The temperature of this refrigerant at the delivery from the compressor is 18 °C when the vapour is condensed at 12 °C. Calculate:

i) The COP of the refrigerator if there is no sub-cooling

[4.5 Marks]

ii) The COP of the refrigerator if the liquid is cooled by 3 °C before expansion by throttling.

[2.0 Marks]

Take specific heat at constant pressure for the superheated vapour as 0.64 kJ/kg K and that for liquid as 0.94 kJ/kg K. The other properties of refrigerant are as follows:

Temperature (°C)	Enthalpy (kJ/kg)		Specific Entropy (kJ/kg K)	
	Liquid	Vapour	Liquid	Vapour
-10	22.3	180.88	0.0904	0.7051
12	45.4	191.76	0.1750	0.6921

Q5 a) Briefly explain five applications of refrigeration and air-conditioning systems.

[3.0 Marks]

b) The simple vapour absorption refrigeration system is not very economical. In order to make the system more practical, it is fitted with three accessories. What are those accessories? Draw a schematic diagram of the practical vapour absorption refrigeration system and briefly explain the functions of those three accessories.

[4.0 Marks]

c) In a vapour absorption refrigerator, the heat is supplied to ammonia generator by condensing steam at 2 bar and 95% dry. The temperature in the refrigerator is to be maintained at -8 °C. Find the maximum COP of the system.
Take temperature of the atmosphere as 30 °C and the saturation temperature of steam as 120 °C at a pressure 2 bar.

[3.0 Marks]

PSYCHROMETRIC CHART

NORMAL TEMPERATURES

STANDARD ATMOSPHERIC PRESSURE (760 mm Hg)

(Below 0 °C Properties and Enthalpy Deviation Lines are for ice)