MACHAKOS UNIVERSITY

SCHOOL OF ENGINEERING AND TECHNOLOGY
DEPARTMENT OF MECHANICAL AND MANUFACTURING ENGINEERING

FOURTH YEAR FIRST SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE IN MECHANICAL AND MANUFACTURING ENGINEERING

EMM 408: REFRIGERATION AND AIR-CONDTIONING

DATE: TIME:

INSTRUCTIONS

1) **The paper consists of Five questions**
2) **Question ONE is Compulsory and carries Thirty Marks**
3) **Choose any TWO other questions from the paper**

QUESTION ONE (THIRTY MARKS)

a) List any **FIVE** desirable properties of an ideal refrigerant **(3marks)**

b) Explain the working principle of thermostatic expansion valve with the help of a neat diagram. **(8marks)**

c) List any **FIVE** methods of defrosting an evaporator **(3marks)**

d) List the classification of air conditioning systems **(3marks)**

e) The temperature limits of an ammonia refrigeration system are 25°C and -10°C. If the gas is dry at the end of compression, calculate the coefficient of performance of the cycle assuming no undercooling of the liquid ammonia. Use the following table for properties of ammonia: **(5marks)**

Temperature (°C)	*Liquid heat (kJ/kg)*	*Latent heat (kJ/kg)*	*Liquid entropy (kJ/kg K)*
25	*298.9*	*1166.94*	*1.1242*
–10	*135.37*	*1297.68*	*0.5443*

f) Two refrigerators A and B operate in series. The refrigerant A absorbs energy at the rate of 1 kJ/s from a body at a temperature of 300 K and rejects energy as heat to a body at temperature T. The refrigerator B absorbs the same Quantity of energy which is rejected

by the refrigerator A from the body at a temperature T, and rejects energy as heat to a body at temperature 1000 K. If both the refrigerators have the same C.O.P., calculate:

(8marks)

i. The temperature T of the body,
ii. The C.O.P. of the refrigerators, and
iii. The rate at which energy is rejected as heat to the body at 1000 K.

QUESTION TWO (20 MARKS)

a) A refrigerating machine of 6 tonnes capacity working on bell-coleman cycle has an upper limit of pressure of 5.2 bar. The pressure and temperature at the start of compression are 1 bar and 16°Crespectively. The compressed air is cooled at constant pressure to a temperature of 41°C, enters the expansion cylinder. Assuming both expansion and compression processes to be isentropic with $\gamma = 1.4$, Calculate: **(12marks)**

i. Coefficient of performance,
ii. Quantity of air in circulation per minute,
iii. Piston displacement of compressor and expander,
iv. Bore of compressor and expansion cylinders. The unit runs at 240 r.p.m and is double acting. Stroke length is 200mm, and
v. Power required to drive the unit.
For air, take $\gamma = 1.4$ and $c_p = 1.003$ KJ/Kg K

b) A single-stage, single acting reciprocating compressor has a bore of 200 mm and a stroke of 300 mm. it receives vapour refrigerant at 1 bar and delivers it at 5.5 bar. If the compression and expansion follows the law pv1.3 = constant and the clearance volume is 5 percent of the stroke volume, determine: 1. The power required to drive the compressor, if it runs at 500 r.p.m, and 2. The volumetric efficiency of the compressor. **(8marks)**

QUESTION THREE (20 MARKS)

a) In an aqua-ammonia absorption refrigeration system of 10TR capacity, the vapours leaving the generator are 100% NH_3 saturated at 40°C. The evaporator, absorber, condenser and generator temperatures are -20°C, 30°C, 40°C and 70°C respectively. At absorber exit (strong solution), the concentration of ammonia in solution is x = 0.38 and enthalpy h = 22 kJ/kg. At generator exit (weak solution) x = 0.1 and h = 695 kJ/kg.
(10marks)

i. Determine mass flow rate of ammonia in the evaporator

ii. Carry out overall mass conservation and mass conservation of ammonia in absorber to determine mass flow rates of weak and strong solutions,
iii. Determine the heat rejection in absorber and condenser,
iv. Heat added in generator, and
v. C.O.P

b) A vapour compression refrigerator uses methyl chloride (R-40) and operates between pressure limits of 177.4 kPa and 967.5 kPa. At entry to the compressor, the methyl chloride is dry saturated and after compression has a temperature of 102°C. The compressor has a bore and stroke of 75 mm and runs at 8 rev/s with a volumetric efficiency of 80%. The temperature of the liquid refrigerant as it leave the condenser is 35°C and its specific heat capacity is 1.624 kJ/kg K. the specific heat capacity of the superheated vapour may be assumed to be constant. Determine: 1. Refrigerator C.O.P, 2. Mass flow rate of refrigerant, and 3. cooling water required by the condenser if its temperature rise is limited to 12°C. Specific heat capacity of water = 4.187 kJ/kg K.
The relevant properties of methyl chloride are as follows: **(10marks)**

Sat. temp. °C	*Pressure kPa*	*Specific volume m^3/kg*		*Specific enthalpy kJ/kg*		*Specific entropy kJ/kg K*	
		Liquid	*Vapour*	*Liquid*	*Vapour*	*Liquid*	*Vapour*
– 10	*177.4*	*0.00102*	*0.233*	*45.38*	*460.76*	*0.183*	*1.762*
45	*967.5*	*0.00115*	*0.046*	*132.98*	*483.6*	*0.485*	*1.587*

QUESTION FOUR (20 MARKS)

a) A single-stage, double-acting air compressor has a FAD of 14 m^3/min measured at 1.013 bar and 15°C. The pressure and temperature in the cylinder during induction are 0.95 bar and 32°C. The delivery pressure is 7 bar and the index of compression and expansion, n, is equal to 1.3. Calculate the indicated power required and the volumetric efficiency. The clearance volume is 5% of the swept volume. **(8marks)**

b) An air-conditioning plant is designed to maintain a room at a condition of 20°C dry bulb and specific humidity 0.0079 when the outside condition is 30°C dry bulb and 40% percentage saturation and the corresponding heat gains are 18000 W (sensible), and 3600 W (latent). The supply air contains one-third outside air by mass and the supply temperature is to be 15°C dry bulb.

The plant consists of a mixing chamber for fresh and recirculated air, an air washer with chilled spray water with an efficiency of 80%, an after heater battery and supply fan.

Neglecting temperature changes in fan and ducting, calculate: **(12marks)**

i. The mass flow rate of supply air necessary

ii. The specific humidity of the supply air

iii. The cooling duty of the washer

iv. The heating duty of the after heater

Use the psychrometric chart assuming the barometric pressure is 1.01325 bar.

QUESTION FIVE (20 MARKS)

a) An air-water vapour mixture at 38°C occupies a room 7 m × 4 m × 4 m. The atmospheric pressure is 1 bar and the relative humidity is 70% determine the humidity ratio, dew point, mass of dry air and mass of water vapour. 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. **(8marks)**

b) In an air-conditioning system, the inside and outside conditions are dry bulb temperature 25°C, relative humidity 50% and dry bulb temperature 40°C, wet bulb temperature 27°C respectively. The room sensible heat factor is 0.8. 50% of the room air is rejected to the atmosphere and an equal quantity of fresh air added before air enters the air conditioning apparatus. If the fresh air added is 100 m^3/min, determine: **(12marks)**

i. Room sensible and latent heat load,
ii. Sensible and latent heat load due to fresh air,
iii. Apparatus dew point
iv. Humidity ratio and dry bulb temperature of air conditioning apparatus.

Assume by-pass factor as zero, density of air as 1.2 kg/m^3 at a total pressure of 1.01325 bar.