BIRLA INSTITUTE OF TECHNOLOGY & SCIENCE, PILANI
Second Semester 2016-17
ME F461 Refrigeration & Air conditioning
Comprehensive Examination
You have to answer Part-A (Closed Book) and Part –B (Open Book) in two different answer scripts. Once you complete Part –A, return the answer script and collect a new one for Part-B. Maximum time for Part-A is 1 hour

Max. Time: 3 hours **Weight age 40%; Max Marks: 80**

Make suitable assumptions and state them clearly

Common Data:
Molecular weights: Dry air =28.966 kg/kmol; water =18.02 kg/kmol
Specific heat, Cp: Dry air =1.005 kJ/kg. K; water vapor =1.88 kJ/kg. K
Specific heat of liquid water = 4.186 kJ/kg. K
Universal gas constant = 8.314 kJ/kg. K
Latent heat of vaporization of water = 2501 kJ/kg
Barometric pressure P_t = 101 kPa
1TR=3.5167 kW.
(a) Antoine's equation for saturation pressure of water p_{sat}

$$\ln(p_{sat}) = 16.54 - \left(\frac{3985}{T-39}\right) \quad \text{Where } P_{sat} \text{ in kPa and T in Kelvin}$$

(b) Apjohn Equation:

$$p_v = p_v' - \frac{1.8\, p_t (DBT - WBT)}{2700}$$

Where p_v is the vapor pressure, p_v' is the saturated vapor pressure at WBT and p_t is the barometric pressure (pressure units should be consistent). DBT and WBT should be measured in ^oC.

Part A (Closed Book)

Q.1 Taking necessary assumptions derive the following relation between degree of saturation, humidity ratio and relative humidity. Clearly state the assumptions. [2]

$$\mu = \frac{\omega}{\omega_s} = \phi\left(\frac{\omega + .622}{\omega_s + .622}\right)$$

Q.2 In an experiment you want to measure the dry bulb temperature of air using a thermometer. The thermometer reading is T_{DBT}. If the mean radiant temperature of the surrounding is T_s. The emissivity of the thermometer bulb is ε, h_c is the convective heat transfer coefficient between thermometer bulb and ambient air and h_r is the linearized radiative heat transfer coefficient (radiation heat transfer can be expressed as in the equation: $q_{rad} = \sigma\varepsilon(T_1^4 - T_2^4) = h_r(T_1 - T_2)$). Derive an expression for the actual Dry Bulb Temperature of air in terms of the measured temperature and other given parameters. [4]

Q.3 Write chemical formula of the following refrigerants.
(a) R1150 (b) R28 (c) R134a (d) R13 [2]

Q.4 Draw the outline of a psychrometric chart and show the following processes undergone by the air in an air washer on the psychrometric chart and explain the processes. [2+2+2]

1. Cooling and dehumidification
2. Adiabatic saturation
3. Heating and humidification

Q.5 Air is flowing over a wetted surface. The inlet state of air is shown by 'a' and the temperature of water on the wetted surface is indicated by T_i on the psychrometric chart in Figure 1 and 2. State the direction of sensible, latent and total heat transfer for case 1 and 2 as shown in figure 1 and 2 respectively and also identify the process undergone by air. [2+2]

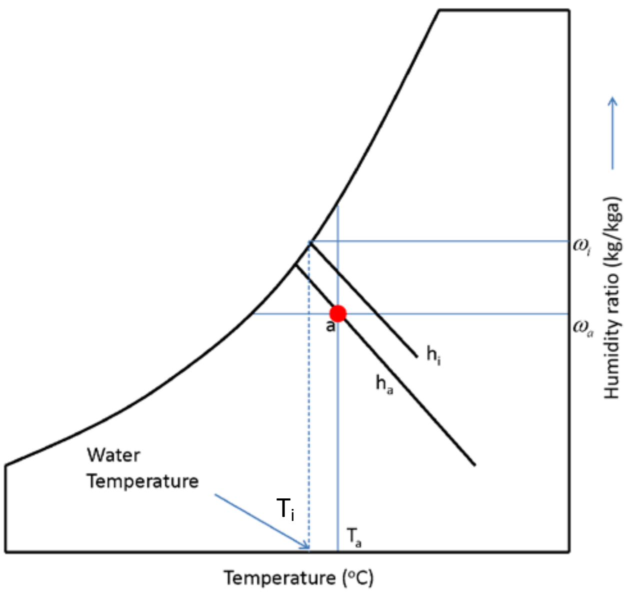

Fig.1

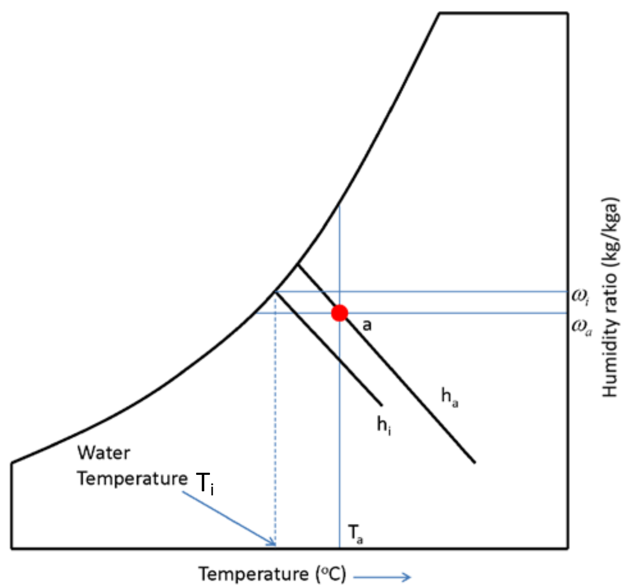

Fig.2

Q.6 Write a short note on **auto cascade** system. [2]

Part B (Open Book)

Q.1) In an evaporative cooler, air enters the cooler at 38 °C (DBT) and 15 °C (WBT) and leaves at 20 °C (DBT). The evaporative cooler maintains the conditioned room at temperature of 26 °C DBT and 50% relative humidity. If the total cooling load on the building is 2.0 kW. Find the sensible and latent loads on the space. If for the evaporative cooler the convective heat transfer coefficient is 80 $W/m^2.K$ and the interfacial area per unit internal volume is 60 m^2/m^3. Find(a) the required internal volume for the evaporative cooler. (b) The amount of make-up water to be added in kilogram per hour. [7+6+2]

Q.2) The sensible and latent heat load of a building are 80 kW and 15 kW respectively. The room is to be maintained at 26 °C DBT and 50% RH. The outdoor air condition are 45 °C (DBT) and 30% RH. Air from the cooling coil is supplied to the building at 15 ^oC (DBT) .For ventilation purpose 10% of the supply air by mass is taken as fresh outdoor air. The apparatus dew point temperature of the cooling coil is 8 ^oC. Number rows of the tube in the cooling coil are 2. Find the required capacity of the cooling coil. (b) the bypass factor of the coil.(c) effective sensible and latent load of the building. If in a new design the number rows of the coil is increased to 4, for the same ADP and coil inlet temperature what will be coil exit temperature.

[8+2+3+2]

Q.3) A H_2O-LiBr based vapor absorption refrigeration system has a refrigeration capacity of **1500 kW**. The system operates at an evaporator temperature of **5°C** (evaporator pressure= **0.872 kPa**) and a condensing temperature of **50°C** (condenser pressure=**12.33 kPa**). The temperature of weak solution leaving the absorber is **40°C**, while the temperature of strong solution leaving the generator is **110°C**. The strong and weak solution mass fractions are **0.66 and 0.578**, respectively. From solution property data the following enthalpy values are available: enthalpy of refrigerant at evaporator exit = **2510 kJ/kg**, enthalpy of refrigerant at condenser inlet = **2708 kJ/kg**, enthalpy of refrigerant at condenser exit= **209 kJ/kg**, enthalpy of weak solution at absorber exit= **–154 kJ/kg**, enthalpy of weak solution at generator inlet = **–37.5 kJ/kg** and enthalpy of strong solution at generator exit= **–13 kJ/kg**. The average density of the H_2O-LiBr solution is **1800 kg/m^3**. From the above data, find: a) COP; b) Power input to solution pump and c) Heat transfer rate in solution heat exchanger; (d) second law efficiency of the refrigeration system;(e) If the strong solution leaves the solution heat exchanger at 48**°C**, find the effectiveness of the solution heat exchanger. [5+2+2+4+2]

Q.4) It is proposed to use a simple, open air cycle refrigeration system for air conditioning a railway compartment. In this system air from the exit of turbine enters the compartment directly and after providing the required cooling is compressed in the compressor, cooled in the high temperature heat exchanger by rejecting heat to the surroundings and then flows into the turbine to complete the cycle. The refrigeration load on the compartment is **50 kW**. The system is to be designed such that the compartment can be maintained at **101 kPa and 25^{o}C,** the design ambient temperature is **40^{o}C** and a temperature difference of **7 K** is required for heat transfer in the high temperature heat exchanger. To avoid cold discomfort to the passengers, the temperature of air at the inlet to the compartment should be **10^{o}C**. The isentropic efficiencies of the compressor and turbine are **0.85 and 0.9**, respectively. There is a pressure drop of 0.5 bar in the high temperature heat exchanger. From the given information, find a) the required air flow rate, b) System COP and c) Entropy generation rate in each component and total entropy generation rate. Take: c_p = 1.005 kJ/kg.K and c_v = 0.718 kJ/kg.K. [2+7+6]

**********************************End of the Paper*****************************