DEPART OF MECHANICAL ENGINEERING

INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR

Time: **2 hours** | Full Marks: **100** | No. of students: **23**

Mid-Sem., **Spring 2018** | Sub. No. **ME60096** | Sub. Name: **Air conditioning & Ventilation**

Given data: Barometric Pressure, p_t = 101 kPa, Universal gas constant: 8.314 kJ/kmol.K

Molecular weights (kg/kmol): Dry air = 28.966; Water = 18.02

C_p(kJ/kg.K): Dry air=1.005, moist air (avg.): 1.0216; Water vapor=1.88; Liquid water = 4.18

Latent heat of vaporization of water, $h_{fg}(t)$ = 2501 –2.368*t; h_{fg} in (kJ/kg) and t in °C

1 met = 58.2 W/m², **1 clo** = 0.155 m².K/W; $f_{cl} = (A_{cl}/A_D) = 1+0.3*I_{cl}$, I_{cl} in clo

Du-Bois area, $A_D = 0.202 m^{0.425} h^{0.725}$; m in kg, h in m, A_D in m²

$$\text{Carrier Equation}: p_v = p_v' - \frac{1.8(p_t - p_v')(DBT - WBT)}{2800 - 1.3(1.8DBT + 32)}$$

where p_v, p_v' and p_t are vapour pressure, saturated vapour pressure at WBT and barometric pressure, respectively. DBT and WBT are in °C and units for pressures should be consistent.

1 TR (Ton of Refrigeration) = **3.517 kW**, Stefan-Boltzmann Constant, **σ = 5.678 X 10⁻⁸ W/m².K⁴**

Make suitable assumptions and state them clearly

1a. With the help of suitable equations and figures, explain why the process path followed by moist air as it flows over a wetted surface, maintained at a constant temperature is a straight line on a psychrometric chart that has dry bulb temperature on x-axis and humidity ratio on y-axis? **(10)**

1b. The condition of moist air changes from **26°C** (dry bulb) and **18°C** (wet bulb) to **12°C** and **90%** relative humidity as it flows over a cooling and dehumidification coil. a) Find the by-pass factor of the coil, b) Show the actual path followed by air on psychrometric chart if the cooling and dehumidification coil is a **counterflow type, chilled water coil**. Use the equation given below for calculating humidity ratio under saturated conditions (w_{sat} in kgw/kga) from dry bulb temperature t(in °C). **(6+4 = 10)**

$$w_{sat} = 3.193 \times 10^{-3} + 4.488 \times 10^{-4} t$$

2. A room measures **8 m x 8m x 4 m**. The room is initially at **26°C** (dry bulb) and **18°C** (wet bulb). It is now supplied with saturated steam at **120°C** (enthalpy of steam = **2726.6 kJ/kg**). Find the maximum amount of steam that can be added to the room. **Make necessary assumption, but verify its validity from the answer**. What will be the maximum amount of water vapour that can be added if instead of adding steam, water at **18°C** is sprayed into the room? **(12+8 = 20)**

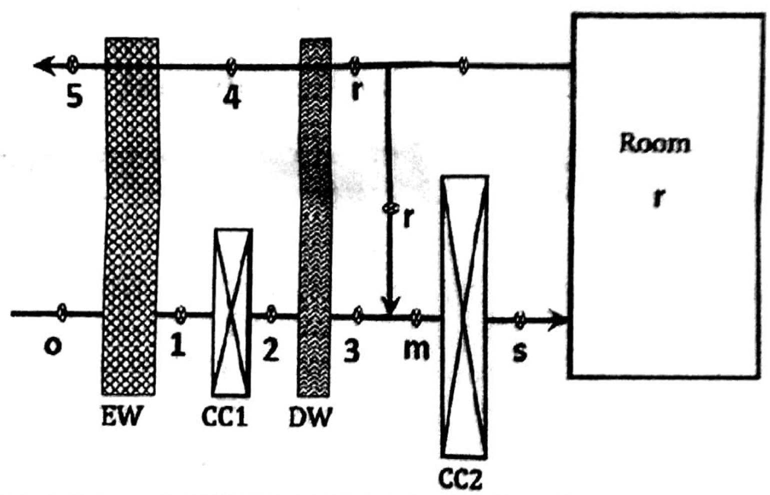
3. An air conditioned room has to be supplied steadily with **400 l/s** of air at **12°C** and **90%** relative humidity so as to maintain the room at **26°C** (dry bulb) and **18°C** (wet bulb). Find a) the sensible and latent cooling loads on the room (**in kW**) and the room sensible heat factor, and b) The required cooling capacity of the air conditioner (**in TR**), if **20 %** (on mass basis) of air supplied to the room comprises of fresh, outdoor air. The outdoor conditions are **42°C** (dry bulb) and **28°C** (wet bulb). **(12+8=20)**

4. A room is maintained at **26°C** (dry bulb) and **18°C** (wet bulb). The average height and weight of the occupants inside the room are **1.7 m** and **60 kg**, respectively. The average activity level of the occupants is **1.6 met** and clothing resistance (I_{cl}) is **0.3 clo**. The convective and radiative heat transfer coefficients between the occupants and the air and surroundings are **6.4 W/m².K and 4.7 W/m².K**, respectively. The evaporative heat loss from the skin is **40 %** of the total heat loss from skin. A) What should be the mean radiant temperature of the room so that the occupants are at neutral equilibrium and their skin temperature is **33°C?**, B) What is the mean clothing temperature?, and C) Assuming that **the clothes do not offer any resistance to evaporative heat transfer**, find the **skin wittedness**. Take the value of Lewis Ratio (LR) as **16.5 K/kPa**. Evaporative heat transfer coefficient, $h_{evp} = h_c * LR$, where h_c is the convective heat transfer coefficient. Use the following equations for estimating heat losses due to respiration. **(8+6+6 = 20)**

$$Q_{resp,sensible}\text{ (in W)} = 0.0014*M*A_D(34-t_a);\quad Q_{resp,latent}\text{(in W)} = 0.0173*M*A_D(5.87-p_v)$$

where M is metabolic rate in W/m²; A_D is Du-Bois area in m²; t_a is dry bulb temperature of air in °C, and p_v is water vapour pressure in air in kPa.

5a. Figure shown below represents the schematic of the air conditioning system used in Nalanda Classroom Complex, IIT Kharagpur. A) Explain briefly the working principle of the system, and B) Draw the complete process on a psychrometric chart. **(5+5 = 10)**



CC1 & CC2: **Chilled water coils; DW: Desiccant Wheel; EW: Enthalpy Wheel**
o: **Outside air** for ventilation; m: **mixed air**; s: **supply air**; r: room air; 5: **exhaust**

5b. For the above system, the following table gives the properties of air at each of the points. If the mass flow rates of **outdoor air** for ventilation and **recirculated** room air are **3.234 kg/s** and **11.39 kg/s**, respectively, find a) the required chilled water flow rates in coils CC1 and CC2, and b) Percentage savings in installed chiller capacity due to installation of enthalpy and desiccant wheels. The temperature rise of chilled water across each coil is **5K**. **(4+6 = 10)**

Parameter	O	1	2	3	m	s	r
DBT (°C)	37.8	27.8	10	14.4	23.3	15.8	26
W (kgw/kga)	0.0206	0.0146	0.00766	0.00635	0.0085	0.0085	0.0095
h (kJ/kga)	91.02	65.21	29.33	30.56	45.04	37.36	50.36

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