DEPARTMENT OF MECHANICAL ENGINEERING

INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR

Time: 3 hours | Full Marks: **100** | No. of students: **23**

End-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 = 29.0; Water = 18.0

C_p(kJ/kg.K): Dry air=1.0, moist air (avg.): 1.02; Water vapor=1.9; Liquid water = 4.2

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

1 TR (Ton of Refrigeration) = **3.517 kW**, Stefan-Boltzmann Constant, **σ = 5.678 X 10^{-8} W/m^2.K^4**

Make suitable assumptions and state them clearly

1a. Suppose that the authorities decide to build a fully air conditioned **500 room, multi-story, students' hostel** in IIT Kharagpur, and you have been entrusted with the job of air conditioning consultant responsible for the entire process! a) **List and discuss briefly all the steps** that are involved in this entire process, starting with receipt of request for air conditioning from the authorities to the final process of handing over the air conditioned hostel to the authorities, b) What **type of system** you think would suit the application best? Justify your selection briefly. **(15+5 = 20)**

1b. A building has a U-value of **0.5 W/m².K** and a total exposed surface area of **420 m²**. The building is subjected to a total heat addition of **4.2 kW** (only sensible). If the required internal temperature is **25°C**, state whether a cooling system or a heating system is required when the external temperature is **5°C**. How the results will change, if the U-value of the building is reduced to **0.36 W/m.K**? **(4+1 = 5)**

2a. State few typical applications for which accurate estimation of infiltration is important, and few applications for which infiltration may not be of major concern. Draw the pressure vs building height diagram and show the location of the openings and the direction in which infiltration and exfiltration take place in buildings due to the combined effects of wind and stack effects. Assume inside temperature to be higher than outside temperature. **(4+6 = 10)**

2b. An air conditioned house of **400 m³** internal volume is at a dry bulb temperature (DBT) of **27°C** and a humidity ratio of **10 grams of water/kg dry air**. The infiltration rate for this building in terms of air changes per hour (**ACH**) is given by: $ACH = 0.2 + 0.015V_w + 0.014(t_o - t_i)$ where the wind speed V_w is in m/s, t_o and t_i are outdoor and indoor dry bulb temperatures in °C. Find the sensible and latent cooling loads on the building due to infiltration when outside conditions are: **40°C** (DBT) and a humidity ratio of **18 grams of water/kg dry air**. The wind speed is **24 kmph**. **(5)**

2c. The sol-air temperature for the horizontal roof of an air conditioned building is given by the equation: $t_{sol\text{-}air}(^\circ C) = 42 + 23.3 * \cos(15\theta - 192)$, where θ is the solar time in hours measured from the midnight (i.e., θ = 0 hours at 12'0 clock, midnight). The roof has an area of **84 m²** and is made up of **150 mm thick** concrete **(k=1.73 W/m.K)** with **6mm thick** plaster **(k=8.65 W/m.K)** on both sides of the roof. The internal and external surface conductance values for the roof are **8.3 W/m².K and 23.3 W/m².K**, respectively. The roof has a time lag of **5.2 hours** and a decrement factor of **0.6**. If the air conditioned space is maintained at a dry bulb temperature of **26°C**, find the **minimum and maximum cooling loads** on the building due to the roof and the **corresponding solar times**. **(10)**

3a. Find the outdoor air required (**in Air Changes per Hour**) for ventilation in an air conditioned room which has an internal volume of **1400 m³**. The ventilation is considered to be proper if the concentration of CO_2 inside the building does not exceed **1000**

parts per million (ppm). The building has occupancy of **400 persons** with an average CO_2 generation rate of **5.0 cm³/second/person**. The air supplied to the air conditioning system consists of **80%** of room air and **20 %** of outdoor air (by volume). Assume that **10 %** of the supply air **bypasses the occupied zone**. The CO_2 concentration of outdoor air is **350 ppm**. **(10)**

3b. An air-water system shown in the figure given below is used to maintain the conditioned space of a building at **26°C** (dry bulb) and a humidity ratio of **10 grams of water/kg dry air**. The building has a sensible load of **300 kW** and a latent load of **80 kW**. For ventilation purpose, **20 %** of the air (by mass) supplied to the conditioned space consists of outside air. The outdoor air is at **42°C** (dry bulb) and a humidity ratio of **18 grams of water/kg dry air**. The cooling coil used in the primary air system (Coil 1) handles the entire latent load on the building and some part of the sensible load. It has a coil ADP of 7°C and a bypass factor of **0.15**. In the chilled water system, chilled water at **7°C** is supplied to the fan coil unit (FCU) kept inside the building. After extracting the required amount of sensible heat, the chilled water leaves the FCU at **16°C**. Find a) Required sensible and latent cooling capacities of coil 1, b) Chilled water flow rate through FCU, and c) How do we ensure that **no condensation takes place in the FCU**? **(10+3+2 = 15)**

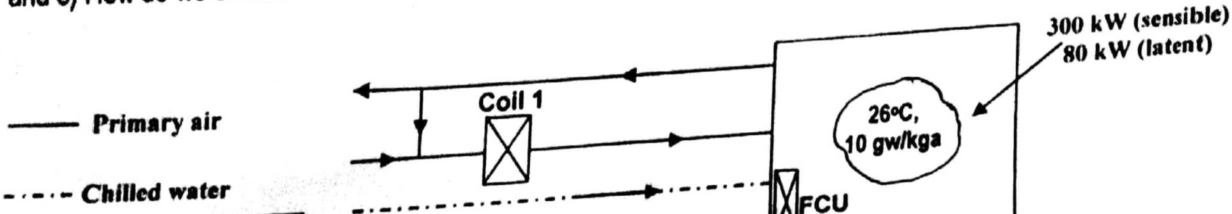

Figure for Problem 3

4a. Find the minimum **life cycle cost** of a ducting system by optimizing the duct diameter. Use the data given below:

a) Thickness of the duct material : **1.2 mm**
b) Density of the duct material : **8000 kg/m³**
c) Cost of the ducting material : **Rs. 60/- per kg**
d) Volumetric flow rate of air : **1.2 m³/s**
e) Density of air : **1.2 kg/m³**
f) Friction coefficient, f : **0.02**
g) Number of operating hours : **80000 hours**
h) Cost of electricity : **Rs. 9 per kWh**
i) Efficiency of fan : **85%**
j) Total length of duct : **150 m**

Assume the cost of fan, fan efficiency, density of air and friction coefficient to remain constant independent of the duct diameter. **(10)**

4b. What should be the **diameter of a circular outlet**, which provides an entrainment ratio of **40** at **throw**, when the flow rate at the outlet is **0. 2 m³/s**? The following equation gives velocity distribution for a circular free jet. **(15)**

$$V(x,r) = \frac{7.41 \ V_o \ \sqrt{A_o}}{x\left[1+57.5\left(r^2/x^2\right)\right]^2};$$ V_o and A_o are velocity and area of opening at supply air outlet

Throw is defined as the horizontal distance from the air outlet at which, the **centerline velocity** is **0.25 m/s**.

End of the paper