ME 491 THERMAL SYSTEMS DESIGN

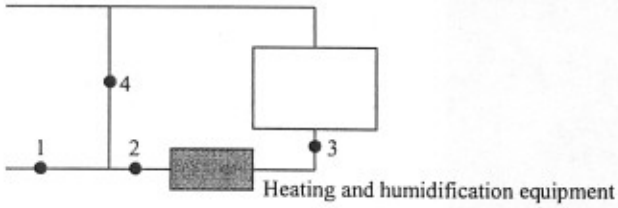
Final Exam

ENG 1C70, April 12, 2002 (Time: 3 hours)

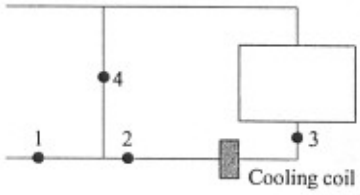
This is an **open book** exam (text, notes and any other relevant material are allowed).
Answer **all 7 questions** using the attached psychrometric charts (sea level) as needed.
State all **assumptions** and justify, where possible.
Reference all data used.

Marks

(10) 1. During a cold weak in February, the radiant heating panels in the SIAST Heavy Duty Mechanics Training Facility fail. The building operators find that in order to maintain indoor conditions of 22°C and 30% RH, they must reduce the outdoor ventilation rate and supply the building with 10 kg/s of air at 35°C and W=6 g/kg. Calculate the sensible heat loss from the building. How much steam (i.e., mass flow rate) must the humidification system deliver to maintain the indoor humidity if the air entering the heating and humidification equipment is at 10°C and 40% RH?



(15) 2. A building in Birmingham, Alabama has a sensible cooling load of 100 kW and no latent load. The building is conditioned with an air conditioning system that has a cooling coil with an apparatus dew point of 10°C. The air entering the cooling coil is 50% recirculated air and 50% outdoor ventilation air. Determine the temperature of the air that must be supplied to the building in order to maintain indoor conditions at T_{db} = 25°C and T_{wb} = 17°C. If the minimum temperature of the supply air was 18°C, what would be the minimum indoor wet bulb temperature at design conditions? (Assume that the supply flow rate is increased to maintain an indoor dry bulb temperature of 25°C and that state point 2 is unchanged.)



(25) 3. Your father is building a house with a floor area of 200 m^2 (2150 ft^2) and a volume of 550 m^3 in Prince Albert, SK and is trying to decide whether to use double pane or triple pane windows. Since Prince Albert has a cold climate (99% winter design temperature of –34.1°C and 6300 Celsius degree-days for heating, your father would like to know how much energy can be saved with triple pane windows and how much the triple pane windows will reduce condensation. The house is insulated with 150 mm (6 inches) of fiberglass insulation giving an exterior wall U-value of 0.28 W/(m^2·K). The window manufacturer informs you that the triple pane and double pane windows have U-values of 2.2 W/(m^2·K) and 3.1 W/(m^2·K) respectively. Using the house plans, you have calculated the surface area of the exterior walls to be 220 m^2 (including a window area of 30 m^2). The average internal heat gain during the heating season is 1.1 kW. Calculate the design heating load with triple-pane and double-pane windows, assuming that the heat loss through the basement and roof is 50% of the heat loss through the plain walls and the ventilation rate (including infiltration) of the house is 0.5 ach. How much less natural gas do you

expect the house with triple pane windows to use, assuming the natural gas consumption in Saskatchewan houses can be estimated as:

$$F = 1.8\,DD\,q/(T_i - T_o)$$

where F is the consumption (m^3/year), DD is the degree-days (°C-days), q is the heat loss at design conditions (kW), T_o is the outdoor design temperature (°C) and T_i is the indoor design temperature (°C). How much less will it cost to heat the house with triple pane windows if price of natural gas price is \$0.50 per m^3. At what outdoor temperature do you expect condensation on the different windows, assuming the indoor relative humidity is 40% RH? Finally comment on whether the window U-values provided by the manufacturer are realistic.

4. (25) Calculate the space cooling load (not including ventilation) at 15:00 for an office space with a floor area of 60 m^2 using the Radiant Time Series Method. The office space is located on the 3rd floor of an 8 storey building in Regina, SK and has one external wall. The total conduction heat gain through the external wall (plain wall + windows) is given below and infiltration can be assumed to be negligible. The windows have a U-value of 2.6 W/(m^2·K), a total area of 15 m^2 and solar heat gain coefficients (SHGC) as given below. The total incident solar radiation on the external wall (G_t) as a function of time and the radiant time factors for the lightweight construction are given below. Assume the lights are unventilated fluorescent lights with a special allowance factor of 1.2.

Time	G_t (W/m^2)	SHGC	q_{cond} (W)
13:00	400	0.76	1100
14:00	440	0.74	1400
15:00	430	0.71	1550
16:00	370	0.68	1300

Radiant time factors for the office area	Nonsolar	Solar
r_0	0.65	0.55
r_1	0.35	0.45

5. (5) When designing thermal systems for buildings, many decisions are made based on design conditions, which are exceeded for only a short time during the year (e.g., 99% and 1% design conditions are each exceeded for an average of 3.65 days per year). List 5 things that the HVAC designer must consider when designing a system for optimal performance during all operating conditions (i.e., minimum energy consumption and maximum indoor comfort and air quality during all occupied hours).

6. (5) The energy required to condition ventilation air is often 30% to 50% of the total energy required to heat or cool a building. Recovering energy from the exhaust air is one method of reducing the energy required to condition ventilation air. What type of air-to-air energy recovery system is best suited for application in Caribou, Maine? Explain. List one other technique that can be used to ensure adequate outdoor ventilation and indoor air quality, without excessive energy costs. (Hint: One such method was seen in both the SIAST Heavy Duty Mechanics Training Facility and the Agriculture building on the U of S campus.)

7. (15) A new True Value Hardware store is being built in Atlanta, Georgia with a floor space of 5000 m^2. As a consulting engineer you are required to design a ventilation system to maintain adequate indoor air quality in the facility. What is the minimum outdoor ventilation rate you would recommend for the building during normal store hours? The total space cooling load for the store is 45 kW at summer design conditions and the owner wants to supply 100% outdoor air to the space for maximum shopper satisfaction. Would you recommend an air-to-air energy recovery device for the building? What facts (including values) would you present to the owner of the hardware store to support your recommendation?