ME 491 THERMAL SYSTEMS DESIGN

Final Exam

December 8, 2003 (Time: 3 hours)

This is an **open book** exam (text, notes and any other relevant material are allowed).
Answer **all 6 questions** and please note that psychrometric charts for sea level are attached.
State all **assumptions** and justify, where possible.
Reference all data used.

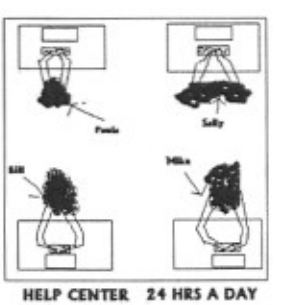
Marks

1. Air flowing at 2 m^3/s is to be humidified from 20°C and 10% RH to a humidity ratio of 11 g/kg using saturated steam at 100°C. **(a)** Determine the required mass flow rate of steam. **(b)** Could the steam humidify the air to a humidity ratio of 19 g/kg? If it could, sketch the process on the psychrometric chart. If it couldn't, briefly explain why. (10)

2. You are building a new, 1500 ft^2 (139 m^2) single-story house in Saskatoon. The house will be 30 ft wide by 50 ft long and the exterior walls are 12 ft high. The windows and doors have a total surface area of 150 ft^2. You are trying to decide whether to use 2 x 6 studs or 2 x 4 studs in the exterior walls. The exterior walls will be insulated with fiberglass insulation giving a U-value of 0.30 $W/(m^2 \cdot K)$ for the 2 x 6 construction and 0.40 $W/(m^2 \cdot K)$ for the 2 x 4 construction. How much lower would your annual heating costs be if you choose the 2 x 6 construction? Assume the efficiency of the natural gas furnace is 90% and the cost of heating with natural gas is \$0.04 per kW·h. (10)

Heating degree days for some Canadian Cities (°C-day from NBC (1995), Appendix C)			
Edmonton	5400	Whitehorse	6900
Saskatoon	5950	Yellowknife	8500

3. When calculating cooling loads using the radiant time series method, the building construction and contents affect the radiant time factors (r_i), which typically delay and reduce the design cooling load. **(a)** What are the main properties of the building envelope and contents that affect the radiant time factors? **(b)** In a help center that is open 24 hours a day (with constant occupation), would the building construction and contents affect the design cooling load due to people? Explain briefly. (5)



4. Determine the sol-air temperature for the roof of a building in Orlando, Florida at 4:00 pm on July 21 when the solar altitude (β) is 40°, the solar azimuth (ϕ) is 69° and the normal direct irradiation (G_{ND}) is 810 W/m^2. (10)

Marks

5. The owner of a building at Innovation Place has asked you to complete the cooling design of a new 5-story office building because of difficulties with the previous HVAC designer. The owner and the previous designer have settled their disagreement, but have decided that a new HVAC designer should complete the calculations and design. The previous designer has done some of the cooling load calculations and provides you with the data in the following tables. The owner has approved these data and you can assume they are correct. Your task is to complete the cooling load calculation. Determine the maximum space cooling load (not including ventilation) for this building, which has a total floor area of 5000 m^2 and office hours from 8:00 to 16:00. (15)

time	Transmitted direct solar heat gain (kW)	Transmitted diffuse + absorbed solar heat gain (kW)	Conduction heat gain (walls, windows & roof) (kW)	Infil-tration heat gain (kW)	time	Transmitted direct solar heat gain (kW)	Transmitted diffuse + absorbed solar heat gain (kW)	Conduction heat gain (walls, windows & roof) (kW)	Infil-tration heat gain (kW)
1:00	0	0	1	0.5	13:00	110	11	9	0.5
2:00	0	0	-9	0.5	14:00	125	12	28	0.5
3:00	0	0	-19	0.5	15:00	133	13	46	0.5
4:00	0	0	-27	0.5	16:00	124	12	62	0.5
5:00	0	0	-34	0.5	17:00	99	10	72	0.5
6:00	0	0	-40	0.5	18:00	79	8	77	0.5
7:00	3	0	-44	0.5	19:00	56	6	75	0.5
8:00	21	2	-45	0.5	20:00	31	3	67	0.5
9:00	45	4	-42	0.5	21:00	9	1	54	0.5
10:00	69	7	-35	0.5	22:00	0	0	40	0.5
11:00	91	9	-24	0.5	23:00	0	0	26	0.5
12:00	102	10	-9	0.5	24:00	0	0	26	0.5

Radiant time factors	r_0	r_1	r_2
Non-solar	0.6	0.3	0.1
Solar	0.5	0.4	0.1

6. A 1200 m^2 office building in Atlanta, Georgia has a maximum space cooling load of 40 kW sensible and 10 kW latent at 5:00 pm. **(a)** Design a cooling coil (e.g., cooling capacity and SHF) to cool this building. **(b)** Would you recommend an air-to-air energy exchanger for the ventilation air in this building? Justify your answer. (10)

TOTAL 60