ME 491 THERMAL SYSTEMS DESIGN

Final Exam

December 16, 2008 (Time: 3 hours)

This is an **open book** exam (text, notes and any other relevant material are allowed).
Answer **all 5 questions**.
State all **assumptions** and justify, where possible.
Reference all data used.
ASHRAE outdoor design conditions and ventilation rates and psychrometric charts are attached.

Marks

1. A figure that appeared in both the "Integrated Design Methodology" and "Factor 10 Residential High-rise Retrofit" lectures is shown on the right. Briefly explain: **(a)** the main message of the figure, and **(b)** why the "Envelope Design" is in the centre of the Venn diagram. **(c)** Provide 3 examples of how the envelope design could affect the other design parameters. (5)

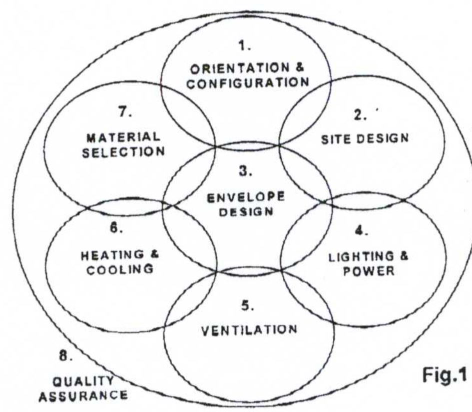
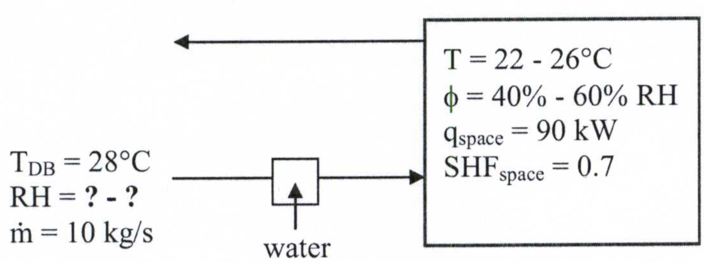


Fig.1 Pro

2. An evaporative cooling system is used to condition a building with a space cooling load of 90 kW and a SHF of 0.7. The indoor conditions in the space must be maintained between 22°C and 26°C and between 40% and 60% RH. If the air handling system provides a constant airflow rate of 10 kg/s, what is the range of outdoor humidities for which the system can maintain the design indoor conditions when the outdoor temperature is 28°C? (15)



3. Analysis of grades from exams in the College of Engineering at the University of Texas (U of T) has shown that students that write their exams in Room 305 have significantly lower grades than those students that write in Room 300. Both rooms have moveable tables with similar occupant densities. The students writing in Room 305 have formed an action committee, which is lobbying the U of T to increase their marks because they feel their performance has been adversely affected by the comfort and air quality in Room 305. To prove that there is no difference between the conditions in each room, the U of T has hired a consultant. The consultant has measured the supply airflow rates to be the same for each room (1500 L/s of which 50% is outdoor air). The consultant has also measured the temperature and humidity data as shown below. As a last resort, the action (10)

committee has hired you to evaluate the situation because they have heard that ME 491 students at the U of S are excellent HVAC specialists. **(a)** Do you agree with the U of T's position that the consultant's measurements prove there is no difference between the air quality and comfort in the two rooms. Explain. **(b)** What is the minimum outdoor ventilation rate you would recommend for Room 300 when the classroom is used as a lecture room?

	Room 300	**Room 305**
floor area	15m x 15m	40m x 40m
air temperature	23°C	25°C
mean radiant temperature	25°C	23°C
relative humidity	50%	75%
supply airflow rate	1500 L/s	1500 L/s

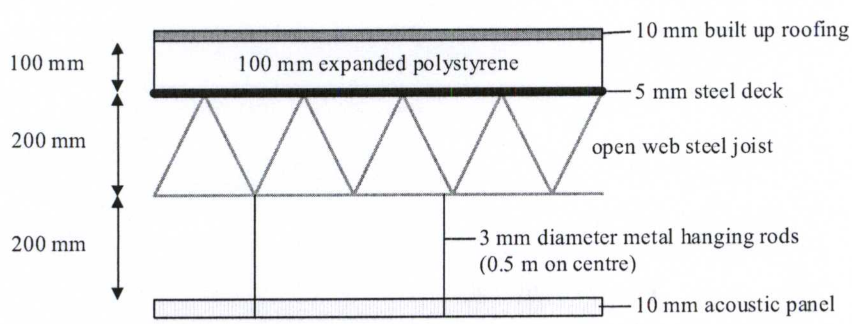
4. You are designing a heating system for a small office building in Edmonton, Alberta for a company with 50 employees. The architect has calculated the overall U-values and surface areas of the components using manufacturers' data and the average heat gains during the heating season (see table below). The architect tells you that the air leakage will be less than 1 air-changes per hour (ach) at 75Pa and less than 0.25 ach at design conditions. The volume of the building is 1,500 m^3. **(a)** Calculate the design heating load for the building using the data provided by the architect. During the design process you notice documentation that states that the windows are double-pane windows and that the cross section of the roof is as shown below. **(b)** Are the U-values of the windows and the roof provided by the architect realistic? Explain and justify. **(c)** Estimate the annual energy consumption for heating assuming that the seasonal efficiency of the heating equipment is 80%. (20)

component	U-value ($W/(m^2 \cdot K)$)	Area (m^2)
Walls	0.25	400
Roof	0.15	450
Floor	0.90*	150**
Windows	1.1	50
Doors	2.2	10

* W/(m·K) ** perimeter (m)

Component	Ave. heat gain (W)
People	2,500
Lights	2,000
Equipment	1,500

Roof cross section



5. Your consulting company has been contracted to design the cooling system for an addition to the high security correctional facility in Prince Albert which will contain 100 cells for male prisoners and a floor area of 400 m^2. Determine the design space cooling load for this addition. The heavy concrete structure will be very well insulated and tightly sealed, which means that you can neglect the conduction heat gains through the walls and roof and infiltration. The only windows in the facility are 10 m^2 of unshaded security glass on the south facing wall ($U = 3$ W/(m^2·K), SHGC = 0.7, SHGCd = 0.65). To assist your design calculations, the solar irradiances for the south facing wall are tabulated for part of the design day together with the radiant time series factors for the addition. (20)

time	E_D (W/m^2)	E_d (W/m^2)	E_r (W/m^2)
10:00	240	80	50
11:00	360	90	60
12:00	400	100	70
13:00	450	110	80
14:00	450	110	80
15:00	380	90	60
16:00	270	80	50
17:00	140	70	45

RTS factors (solar)	
	r
r_0	70%
r_1	30%

RTS factors (non-solar)	
	r
r_0	60%
r_1	30%
r_2	10%

TOTAL 70