ME 491 THERMAL SYSTEMS DESIGN

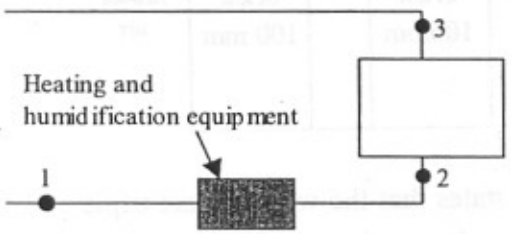
Midterm Exam

KH 144, 146 October 25, 2002 (Time: 2 hours)

This is an **open book** exam (text, notes and any other relevant material are allowed).
Answer **all 5 questions** and please note that psychrometric charts for sea level are attached.
State all **assumptions** and justify, where possible.
Reference all data used.

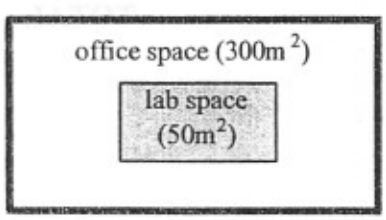
Marks

1. A building is supplied with 100% outdoor air (10 kg/s). The indoor conditions are 22°C and 30% RH and the outdoor temperature is –20°C and 0.5 g/kg. Calculate the rate at which the heating and humidifying equipment must supply **(a)** heat and **(b)** moisture if the supply air conditions are $T_2 = 35°C$ and $W_2 = 6$ g/kg. (8)



2. A constant volume, single zone air handling system with no recirculation air must maintain indoor conditions between 24°C and 26°C using a supply air temperature that cannot be below 15°C. If the space sensible heat factor (SHF) is 0.8 and the minimum SHF of the cooling coil is 0.5, what is the minimum indoor relative humidity that can be achieved when the outdoor conditions are 38°C db and 27°C wb. (10)

3. You are an IAQ consultant for a new office building that includes a research laboratory where toxic chemicals are stored and mixed in experiments. The owner proposes to use a floor plan as shown below. **(a)** How much outdoor ventilation air would you recommend for the office space? **(b)** Determine a minimum ventilation rate for the lab space. **(c)** What factors would you consider when recommending an actual outdoor ventilation rate for the lab space? **(d)** How and where would you supply and exhaust the outdoor ventilation air to minimize contamination of the office space? **(e)** Do you consider the owner's floor plan to be ideal for IAQ? Explain. (10)

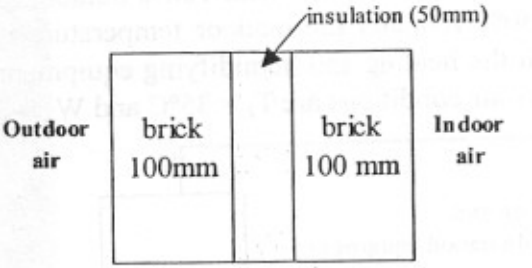


4. You are designing a heating system for a single story office building in Ottawa, Ontario. The company has 20 employees. The architect has calculated the overall U-values of the components using manufacturers data and provides this information to you in a tabular format together with the surface area of each component. The architect tells you that he will perform an airtightness measurement to ensure that the airtightness is less than 1 ach (volume = 600 m^3) at 75Pa and less than 0.25 ach at the design conditions. **(a)** Calculate the design heating load for the building including the ventilation heating load using the architects data. (15)

component	U-value $W/(m^2 \cdot K)$	area (m^2)
Walls	0.3	180
Roof	0.18	200
Floor	0.90*	60**
Windows	2.6	20
Doors	2.2	5

* W/(m·K)
** perimeter (m)

Wall section



During the design process you notice documentation that states that the windows are triple pane windows and that the cross section of the wall is as shown above. **(b)** Are the U-values of the windows and wall provided by the architect realistic?

5. At a recent IEA/ECBCS Annex 37 meeting, a demonstration case study of 18 ecological dwellings in Maastrict, Netherlands was presented. The houses are described in the attached Annex "fact sheet". Based on the information in the Annex "fact sheet" and an outdoor design temperature of –10°C, estimate the heating degree days in Maastrict from October 1998 to November 1999. Assume that the "specific heat load" quoted in the fact sheet is the maximum measured heat demand of the building and occurs during a time when the building is being heated up after a period of temperature set-back. Assume that the quoted specific heat load is 40% greater than the heat loss from the north-facing houses at design conditions and 20% greater than the heat loss from the south-facing houses at design conditions. (7)

TOTAL 50

ME 491 THERMAL SYSTEMS DESIGN

Midterm Exam

KH 144, February 13, 2002 (Time: 2 hours)

This is an **open book exam** (text, notes and any other relevant material are allowed).
Answer **all 5 questions** and please note that psychrometric charts (sea level and 1500 m) are attached.
State all **assumptions** and justify, where possible.
Reference all data used.

Marks

1. Determine the condition of the mixed air stream that results from mixing 3 000 L/s of recirculated air at 24°C and 50% RH with 500 L/s of outdoor air at 35°C and 50% RH. (8)

2. Design a cooling coil (total cooling capacity and apparatus dew point) to cool 2.6 kg/s of air from 29°C and 60% RH to 15°C and 90% RH. (7)

3. A space in a textile factory is to be maintained at a high humidity to prevent drying of the fabric. The space is to be kept at a constant dry bulb temperature of 25°C and a wet bulb temperature of 22°C and has a total cooling load of 20 kW of which 6 kW is a sensible cooling load. Determine whether the factory could be cooled with an evaporative cooling system in the following climates. Also, design an evaporative cooler (specify mass flow rate of water and air) to provide the cooling for the space in the textile factory for the most favorable location. (10)

Location	T_{db} (°C)	T_{wb} (°C)	elevation (m)
Saskatoon, SK	28.6	17.1	504
Edmonton, AB	25.6	16.5	723
Vancouver, BC	23.2	17.6	2
Prescott, AZ	32.7	15.6	1537
Dallas, TX	36.4	23.5	182

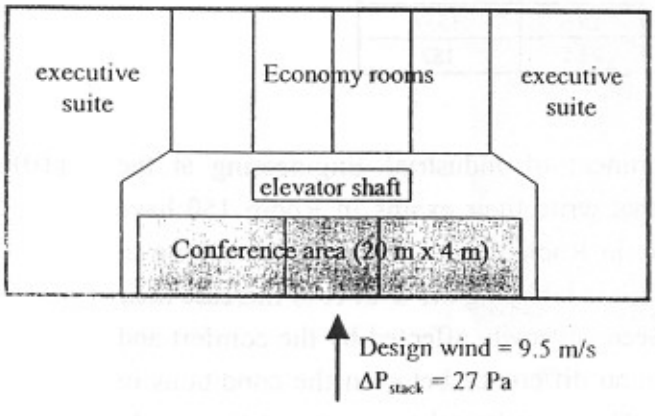
4. Analysis of grades from exams in the Department of Industrial Engineering at the University of Regina has shown that students that write their exams in Room 150 have significantly higher grades than those who write in Room 140. The students writing in Room 140 have formed an action committee, which is lobbying the U of R to increase their marks because they feel their performance has been adversely affected by the comfort and air quality in Room 140. To prove that there is no difference between the conditions in each room, the U of R has hired a consultant. The consultant has measured the supply (10)

airflow rates to be the same for each room (1000 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 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. Do you agree with the U of R's position that the consultants measurements prove there is no difference between the air quality and comfort in the two rooms. Explain. What is the minimum outdoor ventilation rate you would recommend for Room 150 when it is used as a lecture room?

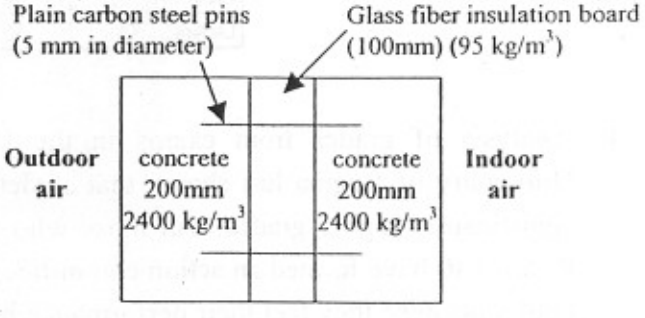
	Room 140	Room 150
floor area	40m x 40m	20m x 20m
air temperature	23°C	21°C
mean radiant temperature	21°C	23°C
relative humidity	80%	40%
supply airflow rate	1000 L/s	1000 L/s

5. Calculate the design heating load (including ventilation) for an area of conference rooms ($80m^2$) on the 5th floor of a hotel in Montreal (see figure). The exterior wall of the conference room area is 3 m high and has an average pressure difference of 27 Pa due to the stack effect. The exterior wall is on the windward side of the building and the design wind speed is 9.5 m/s in Montreal. The conference room has fixed, double-pane windows with a 12.7 mm air space and a vinyl frame. The windows are average-fitting and make up 50% of the exterior surface area and have a perimeter of 90m. The envelope of the building is a concrete sandwich envelope made of 100 mm of rigid board insulation with a density of 95 kg/m^3 sandwiched between 200 mm of normal density concrete (2400 kg/m^3). The wall construction also includes steel pins (5 mm in diameter). These pins are spaced at intervals of 10 m in the horizontal direction and 5m in the vertical direction. (15)

Plan view of 5th floor



Wall section



TOTAL 50