PROFESSIONAL ENGINEERS OF ONTARIO

ANNUAL EXAMINATIONS – December 2011

07-Mec-B2 Environmental Control in Buildings

3 hours duration

INSTRUCTIONS:

1. If doubt exists as to the interpretation of any of the questions, the candidate is urged to submit a clear statement of the assumption(s) that he/she has had made with the answer.

2. The examination paper is open book and so candidates are permitted to make use of any textbooks, references or notes that they wish.

3. Any non-communicating calculator is permitted. Candidates must indicate the type of calculator(s) that they have used by writing the name and model designation of the calculator(s) on the first inside left hand sheet of the first examination workbook. The usage of computers, internet and smart phones is prohibited.

4. Candidates are expected to have copies of both an environmental control book and steam tables, since it will be necessary to use information presented in the tables and graphs contained in books.

5. Candidates are required to solve five questions.

6. All questions carry the same value. Indicate which five questions are to be graded on the cover of the first examination workbook.

7. Psychrometric charts and the p-h diagram for the refrigerant are attached.
PROBLEM 1. (20 POINTS)

An air conditioning system operating on the winter heating cycle, is required to maintain inside conditions of 68°FdB (dry bulb), 50% RH (relative humidity), when the outdoor design conditions are 33°FdB and 10% RH. The sensible heat loss from the building is 240,000 Btu/hr, and the latent heat loss is 40,000 Btu/hr. The building will be heated using a system consisting of a heater and a steam humidifier. The mass ratio of outside air to the mixed air is 0.463. The supply air temperature is 100°FdB. The steam humidifier uses saturated steam at 20 psia.

a. Identify each characteristic point on the diagram,
b. Draw the operating cycle on the psychrometric chart provided, and show for each significant point its dry bulb temperature and relative humidity.
c. Determine the supply air conditions and quantity (lb/hr)
d. Calculate the Btu/hr rating of the heater.
e. Calculate the mass flow rate of steam.

PROBLEM 2. (20 POINTS)

An air conditioning system is schematically given below. The operating conditions are:
- Supply air 3,500 CFM at 55°F DB and 90%RH
- Return air 76°FDB and 60%RH

The minimum outside air requirement is 15% of the supply air by mass. Assume that the building is at sea level elevation. For simplicity ignore the duct heat transfer and the fan air temperature rise.

a. Make a diagram of the system; identify each characteristic point on the diagram, and show for each significant point its dry bulb temperature and relative humidity.
b. Draw the operating cycle on the psychrometric chart provided.
c. When the outdoor conditions are 74°FDB and 50% RH determine the cooling coil loads.
PROBLEM 3. (20 POINTS)

The exterior wall of a room in an office building has:
- a solid wood door without a storm door; 3 ft. by 6 ft. 8 inches, thick 1.75 inches;
- three 48 inches by 36 inches glass windows with no sash, double insulating glass with 0.5 inches air space, aluminium frames with thermal break.

The wall is 9 ft. high by 24 ft. long. The wall construction is such that it has a U (overall heat transfer) factor $0.19 \text{ Btu/hr. ft}^2\ ^\circ\text{F}$.

Assume parallel heat flow through the wall, windows and door, and calculate the overall thermal resistance and the overall U factor for the combined wall, windows and door.

PROBLEM 4. (20 POINTS)

The layout of a ductwork system is shown below. The centrifugal fan takes air at atmospheric pressure and supplies it through two branches which discharge to atmosphere.
Using the data provided below and duct friction charts, calculate the total air flow rate handled by the fan and the flow rates from the two outlets:

a. when the damper is fully open.
b. when both outlets are delivering equal flow rates after adjustment of the damper.

Data:

Velocity pressure factors:
Bend: 0.3
Branch: flow to main: 0.2 (applied to downstream velocity pressure)
flow to branch: 0.5 (applied to velocity pressure in off-take)
Discharge grill: 0.4
Expander: 0.25 (applied to maximum velocity)
Damper (fully open): 0.2
Fan characteristic: $P_f = 200 - 12V^2$ ($V$ is volumetric flow)
PROBLEM 5. (20 POINTS)

a. 10 points

How many people could occupy a room where the concentration level of carbon dioxide CO\textsubscript{2} is to be kept below 1000 ppm, if air with a concentration of 200 ppm CO\textsubscript{2} is being supplied to the room at a rate of 5000 cfm (cubic feet per minute). State your assumptions.

b. 5 points

Explain the ASHRAE comfort chart and the perception of thermal comfort.

c. 5 points

It is proposed, that in order to save energy in summer, for large office building using chilled water cooling systems, to increase the temperature of the water circulating in the system. Comment on feasibility of this method and how it will affect the comfort conditions in the building.

PROBLEM 6. (20 POINTS)

The figure below shows a simplified vertical section through a building 30 m long, consisting of offices and stores separated by a corridor. The offices are maintained at 21°C and the stores at 5°C when ambient air temperature is -5°C. The corridor is unheated. The ventilation is from ambient to the offices, from the offices to the corridor, and from the corridor to the ambient. There is a negligible flow of air between the corridor and the store.

Data:

- Heat transfer coefficient of store external wall 0.7 W/m\textsuperscript{2}K
- Heat transfer coefficient of corridor external wall 0.5 W/m\textsuperscript{2}K
- Heat transfer coefficient of both internal walls 2.0 W/m\textsuperscript{2}K
- Heat transfer coefficient of the floor 0.3 W/m\textsuperscript{2}K
- Heat transfer coefficient of the external office walls (excluding glazing) 0.5 W/m²K
- Heat transfer coefficient of the office windows 5.0 W/m²K
- Conductance of the roof 1.0 W/m²K
- Windows area is 20% of the external office walls
- External heat transfer coefficient for the outside surface of the roof 20 W/m²K
- Internal resistance of the roof 0.2 m²K/W
- Air changes per hour in the office 1.0

Calculate:

a. The temperature in the corridor
b. The heat input required for the offices
c. The heat input required for the stores

PROBLEM 7. (20 POINTS)

A home heating system uses an air heat pump with R-134a as the refrigerant. The maximum heating load results when the temperature of 1000 ft³/min of inside home circulation air is raised 45°F.

The refrigerant R-134a, enters the compressor at 30 psia dry saturated, and leaves it at 160 psia, there is no subcooling in the condenser. Consider isentropic efficiency of the compressor as 0.9.

a. Draw a simple diagram of the system and show the complete cycle on the p-h chart attached.
b. Calculate the coefficient of performance COP.
c. Calculate the mass flow of the refrigerant
d. Calculate the cost of heating per hour if the overall efficiency (compressor/motor) is 87% and the cost of electricity is 0.10 $/kWh. Compare with electric heating with electrical radiators. Comment.
e. Describe the limitations of this system. If you must use this system in Ottawa, Ontario, what you suggest to be done.

PROBLEM 8 (20 POINTS)

a. 10 points

Determine the instantaneous heat gain through a 1m x 2 m west-facing window at 5 p.m. solar time, on a clear day, July 21, at 40 deg. north latitude. The window has two sheets of glass with 1.7 cm air space between them. The outer layer is grey heat absorbing glass; the inner layer is standard glass. Assume an interior film coefficient of 7 W/m²K, an outdoor temperature of 32°C and an indoor temperature of 25 °C.
b. 10 points

A large office space has an average occupancy of 20 people from 8:00 a.m. to 5:00 PM. Lighting is 2.5 W/ft$^2$ recessed, unvented fluorescent fixtures from 8:00 a.m. to 6:00 p.m. Computers, photocopiers, fax machines, etc. create a heat gain of 1.5 W/ft$^2$. Calculate the sensible and latent heat gain at 4:00 p.m. for the space, assuming a floor area of 4000 ft$^2$. 
Chart 1a

SEA LEVEL

SHRAE PSYCHROMETRIC CHART NO. 1

NORMAL TEMPERATURE
NORMAL PRESSURE 29.92 INCHES OF MERCURY

MEXICAN SOCIETY OF HEATING, VENTILATING, AND AIR-CONDITIONING ENGINEERS, INC.

ENTHALPY (H) Btu per pound of dry air

OF WATER 96.8° F.
OF DRY AIR 100° F.
OF WATER TEMPERATURE 70° F.