**B.E (Mechanical) 7$^{th}$ Semester Examination, September 2011**

**Subject- Refrigeration and Air Conditioning (ME-702)**

i) **The questions are of equal value.**

ii) **Answer six questions taking three from each half.**

iii) **Assume suitable data wherever necessary.**

**Time 3hrs** **Full Marks: 70**

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**Ist Half**

1. A vapour compression refrigerator uses Methyl Chloride (R-40) as refrigerant and operates between pressure limits of 177.4 kPa and 967.5 kPa. At entry to the compressor, the methyl chloride is dry saturated and undergoes isentropic compression. The compressor has a bore and stroke of 75 mm and runs at 8 rev/s with a volumetric efficiency of 80%. The temperature of the liquid refrigerant as it leaves the condenser is 35$^0$C and its specific heat capacity is 1.624 kJ/kgK. The specific heat capacity of the superheated vapour may be assumed to be 1.062 kJ/kgK. Determine the following:

i) COP of the refrigerator ii) Mass flow rate of refrigerant iii) cooling water required by the condenser if the temperature rise is limited to 12$^0$C. Specific heat capacity of cooling water is 4.187 kJ kgK.

The relevant properties of Methyl Chloride (R-40) are as follows:

| Sat Temp ($^0$C) | Pressure kPa | Specific Volume (m$^3$/kg) | | Specific Enthalpy (kJ/kg) | | Specific Entropy (kJ/kg K) | |
|---|---|---|---|---|---|---|---|
| | | Liquid | Vapour | Liquid | Vapour | Liquid | Vapour |
| -10 | 177.4 | 0.00102 | 0.233 | 45.38 | 460.76 | 0.183 | 1.762 |
| 45 | 967.5 | 0.00115 | 0.046 | 132.98 | 483.6 | 0.485 | 1.587 |

2.a) Discuss the effect of sub-cooling of refrigerant on the performance of a vapour compression refrigeration cycle. Draw such a cycle on p-h and TS diagram.

b) Write the various methods of improvement in performance of a simple saturation vapour compression refrigeration cycle. Describe with a sketch a simple saturation cycle

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having flash chamber. Also, state the effect of addition of flash chamber on the thermodynamic performance of the cycle.

3 a) Explain with a neat sketch the Boot Strap Evaporative cooling system used in aircrafts. Also, draw the corresponding T-S diagram.

b) A regenerative air cooling system is used for an air plane to take 20 tonnes of refrigeration load. The ambient air at pressure of 0.8 bar and temperature $10^0$C is rammed isentropically till the pressure rises to 1.2 bar. The air bled off the main compressor at 4.5 bar is cooled by the ram air in the heat exchanger whose effectiveness is 60%. The air from the heat exchanger is further cooled to $60^0$C in the regenerative heat exchanger with a portion of the air bled after expansion in the cooling turbine. The cabin is to be maintained at a temperature of $25^0$C and a pressure of 1 bar. If the isentropic efficiencies of the compressor and turbine are 90% and 80% respectively, find

i) Mass of air bled from cooling turbine to be used for regenerative cooling

ii) Power required for maintaining the cabin at the required condition.

iii) C.O.P of the system.

4. a) With a neat sketch describe the operation of a simple vapour absorption refrigeration system. Also, derive an expression for COP of a vapour absorption refrigeration system.

b) An air refrigerator works between the pressure limits of 1 bar and 5 bar. The temperature of air entering the compressor and expansion cylinder are $10^0$C and $25^0$C respectively. The expansion and compression follow the law $pv^{1.3}$= Constant. Determine the following:

i) Theoretical C.O.P of the cycle.

ii) If the load on the refrigerating machine is 10 TR, find the amount of air circulated per minute through the system assuming that the actual C.O.P is 50% of the Theoretical C.O.P..

iii) The stroke length and piston diameter of single acting compressor if the compressor runs at 300 rpm and volumetric efficiency is 85%.

Take L/d=1.5, $C_p$=1.005 kJ/kg K, $C_v$=0.71 kJ/kgK

5. Write short note on the following (any two):

a) Desirable properties of refrigerant b) Comparison of Vapour Absorption and Vapour compression system c) Alternative refrigerants d) Multi-stage compression with flash intercooling

# BENGAL ENGINEERING & SCIENCE UNIVERSITY, SHIBPUR

## B.E. (Mechanical) Part IV 7th Semester Examination, 2011

### Refrigeration & Air-Conditioning (ME-702)

**Time: 3 hours** **Full Marks: 70**

### Second Half

Attempt any three questions from this half. All questions are of equal value. Use of property tables/diagrams permitted

1. (a) Define Room Sensible Heat Factor (RSHF) and show that it can be expressed as:

$$RSHF = \frac{1}{\left(1 + 2451\frac{\Delta w}{\Delta t}\right)}$$

Where, $\Delta w$ and $\Delta t$ are the associated changes in specific humidity and dry bulb temperature respectively.

(b) The indoor air of a room is maintained at 26°C DBT and 50% RH. The room has a sensible heat gain 20kW and a latent heat gain of 5.0 kW. If 200 $m^3$/min of conditioned air is supplied to the room, calculate the required supply air condition. Avoid using psychrometric chart for the solution. Assume air density and $C_p$ appropriately.

2. (a) Schematically show a simple room summer air conditioning system involving ventilation as well as partial recirculation of indoor air and without considering any coil bypass. Draw the corresponding psychrometric diagram and state the relevant energy equations and the expression for coil sensible heat factor (CSHF).

(b) An air-conditioning system maintains an indoor air condition of 25°C DBT and 50% RH while the outdoor condition is 40°C DBT, 27°C WBT. The room has a sensible heat factor (SHF) of 0.8. Recirculated air is mixed with outdoor air at 1:1 ratio. If the outdoor air flow rate is 100 cmm, determine, assuming a zero coil bypass factor:

(i) room sensible and latent heat loads,
(ii) loads due to outside air
(iii) coil ADP and
(iv) condition of mixed stream at the coil inlet

3. (a) Briefly describe with a neat sketch and a psychrometic diagram how an indirect evaporative air-conditioning system works.

(b) A large hall with a seating capacity of 1200 is to be supplied with conditioned outside air. The supply air condition is 20°C DBT, 60% RH while the outside air is at 40°C DBT, 20°C WBT. The ventilation requirement is 0.3 cmm per person.

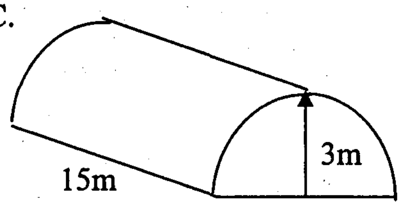
The supply condition is to be achieved by applying adiabatic humidification first followed by sensible cooling. Find the capacity of the humidifier and also that of the cooling coil.

4. (a) Explain how the bypass factor affects the room sensible and latent heat loads in summer air conditioning when ventilation of outdoor air is involved. How the effective sensible heat factor (ESHF) is estimated for the conditioned space in such a situation?

   (b) The summer air conditioning system for a hall caters to a ventilation rate of 70 cmm and maintains an indoor condition of 25°C DBT, 50% RH against an outdoor condition of 40°C DBT, 27°C WBT. The room sensible and latent heat loads are 58 kW and 15 kW respectively. Assuming a bypass factor of 0.15 for the cooling coil, estimate the effective room sensible heat (ERSH), effective room latent heat (ERLH) and the effective sensible heat factor (ESHF).

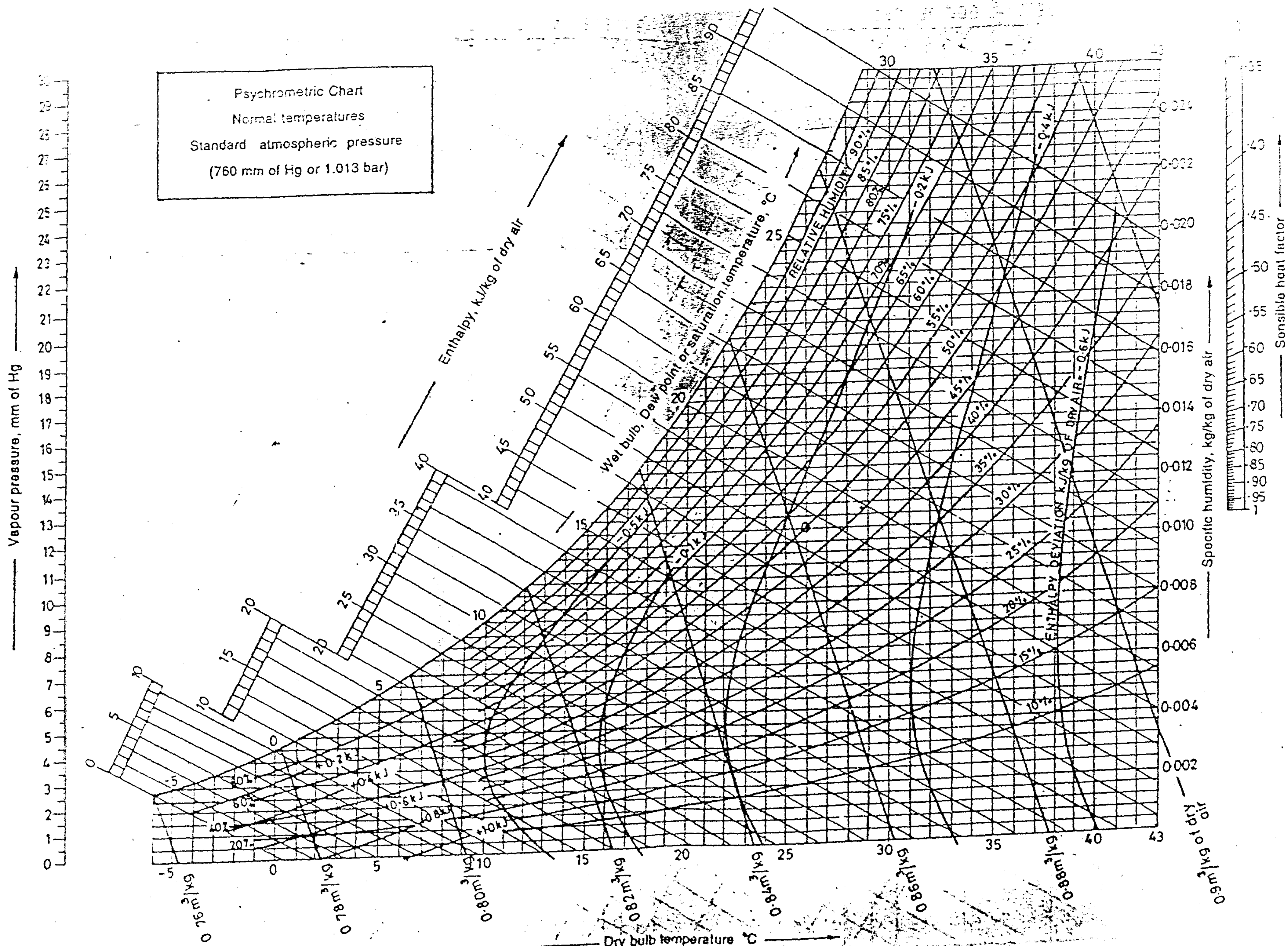
5. (a) Briefly state how solar heat gain through sunlit transparent covering (fenestration) is accounted for in load estimation for air conditioning systems.

   (b) A fiberglass house of semi circular cross-section has the dimensions as shown in the following figure (length 15m and central height 3m). Applicable solar heat gain factor is 300 W/m$^2$. The shading coefficient is 0.8 and the cooling load factor (CLF) is also 0.8. Allowable maximum inside temperature is 25°C DBT while the outside temperature is 10°C.




Comment, with supporting calculations, on the requirement of a cooling system, neglecting infiltration, internal heat generation and heat transfer through the ground. Consider the covered ground area as effective area for solar heat gain and assume an overall heat transfer coefficient of 4.2 W/m$^2$ for all transparent surfaces. What shading coefficient would enable a thermal equilibrium between the glasshouse and the ambient without intervention of any conditioning system?

**Note for COE:**
Attached psychrometic chart may please be distributed with the question paper.



Psychrometric Chart
Normal temperatures
Standard atmospheric pressure
(760 mm of Hg or 1.013 bar)
Vapour pressure, mm of Hg
Enthalpy, kJ/kg of dry air
Wet bulb, Dew point or saturation temperature, °C
RELATIVE HUMIDITY 90%
ENTHALPY DEVIATION kJ/kg OF DRY AIR
Specific humidity, kg/kg of dry air
Sensible heat factor
Dry bulb temperature °C
0.76 m³/kg
0.78 m³/kg
0.80 m³/kg
0.82 m³/kg
0.84 m³/kg
0.86 m³/kg
0.88 m³/kg
0.9 m³/kg of dry air