National Exams December 2013

07-Bld-A4, Building Engineering Systems

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.

2. This is an CLOSE BOOK EXAM.
   Any non-communicating calculator is permitted.

3. FIVE (5) questions constitute a complete exam paper.
   The first five questions as they appear in the answer book will be marked.

4. Each question is of equal value (20 marks).

5. Some questions require an answer in essay format. Clarity and organization of the answer are important.

6. Some questions involve calculations. It is important to show clear process and to be consistent with the unit system.

(20%) Question 1

An air conditioning system is shown in the following figure. ΔH, ΔW are the total and moisture load of the space respectively. T, RH are dry-bulb temperature and relative humidity of humid air respectively. □ is mass flow rate. Subscript: A – indoor air, SA – Supply Air, RA – Return Air, FA – Fresh Air, MA – Mixing Air, EA- Exhaust Air.

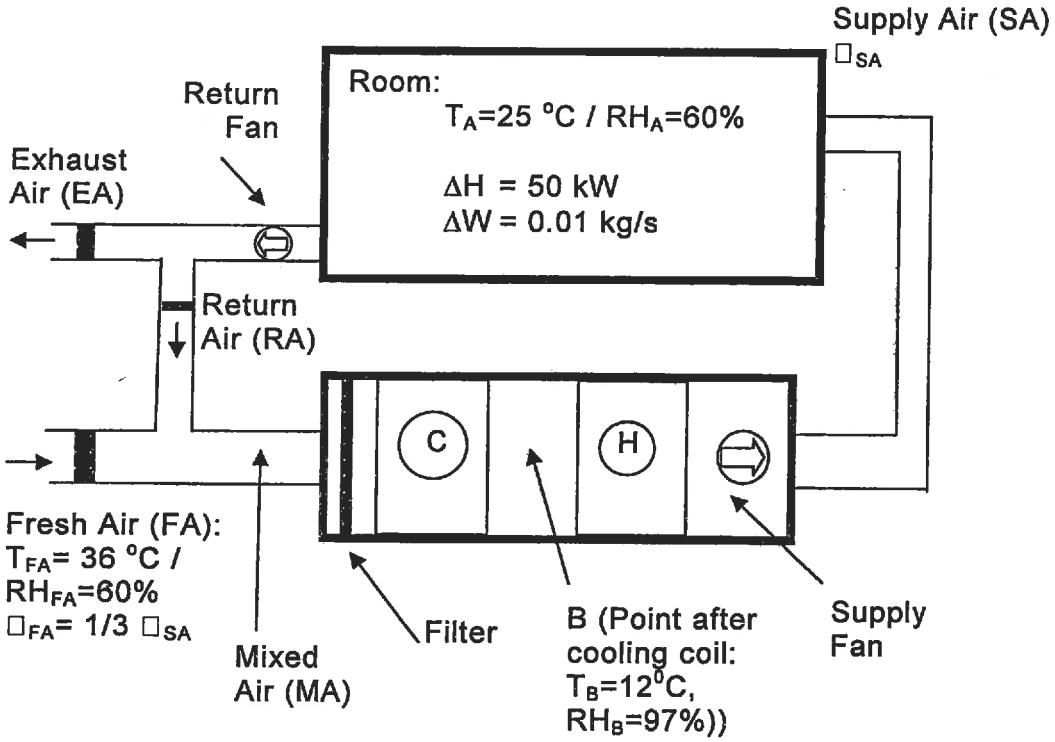
Two copies of Psychrometric Chart are provided.

(1) Present the air handling processes on the Psychrometric Chart and show the temperature and relative humidity of all key points (A, SA, MA, and B).

(2) What is the total mass flow rate of the supply air $\square_{SA}$ (kg/s)?

(3) What is the output of the cooling coil C (Q_C: kW)?

(4) What is the output of the re-heating coil H (Q_H: kW)?



(20%) Question 2

A school classroom is 12m long, 10m wide and 4m high. The density of occupant is 65 persons per 100 m^2 of floor area.

(1) Calculate the outdoor air rate (m^3/hr).

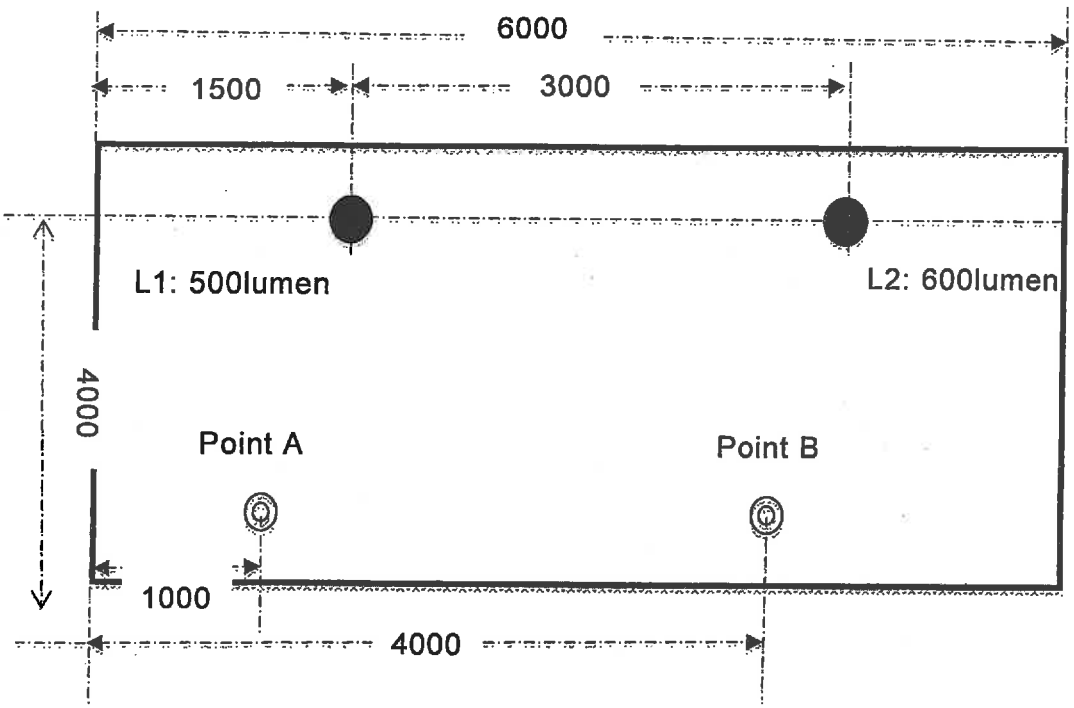
(2) If the recommended air change rate is 12 (1/hr), what is the total air flow-rate (m^3/hr) ?

Note: You may need use information from the following table:

Space/Building Type	People Outdoor Air Rate (R_p: l/s.person)	Area Outdoor Air Rate (R_A: l/s.m^2)
School Classrooms	3.8	0.3
Libraries	2.5	0.6
Office Spaces	2.5	0.3

(20%) Question 3

Figure below shows the vertical section of a room, in which there are two lamps (L1, L2) installed on the ceiling. Calculate the illumination level at points A and B, which are both on the floor. All dimensions in Figure are measured in mm.



(20%) Question 4

Conditioned air is supplied into a room through an air diffuser that is installed in one of the top corners of the room. The diffuser is connected to the fan by a branch air duct (3.4 meters long), a bend in branch air duct, main air duct (6 meters long), and a bend in the main air duct.

The following table gives values of relevant variables.

Variable	Value
Sound Pressure Level (SPL) of fan	90 dB
Attenuation of main air duct	0.35 dB/m
Attenuation of branch air duct	0.45 dB/m
Attenuation of bend in main duct	6 dB
Attenuation of bend in branch duct	3 dB
End reflection of diffusor	3 dB
Reverberation time of the room	0.8 second
Length of room	8 m
Width of room	6 m
Height of room	4 m

What is the SPL at a location on the floor that is 5 meters away from the diffuser.

Hint:

(1) The reverberation time (T: second) of a space is computed using Sabine's Equation:

T = 0.16*V/A

where V is the volume of space (m^3). A is the area of acoustic absorption (m^2)

Average absorption coefficient $\bar{\alpha} = A/S$, where S is the surface area of the room.

Room constant is calculated using $R_C = S\,\bar{\alpha}/(1-\bar{\alpha})$

(2) SPL at a point within a direct and reverberant field is calculated by:

$$SPL = L_W + 10\log_{10}\left(\frac{8}{4\pi r^2} + \frac{4}{R_C}\right)$$

L_w is SPL at the sound source. r is the distance from the sound source.

(20%) Question 5

An external wall assembly is consisted of the following layers (from interior to exterior):

- Interior finishing (ignore its R value)
- 150 mm concrete
- A layer of EPS insulation
- 25 mm of airspace
- 90 mm of clay brick

The design condition is: Indoor temperature: 20 °C, External temperature: -19 °C.

(1) In order to control the rate of heat loss to be below 9.0 W/m^2, what is the minimum depth of the insulation layey?
(2) Calculate the temperature distribution across the assembly under the design condition.

The following information is given:
Conductivity of clay brick: 1.25 W/m.°C
Conductivity of concrete: 1.82 W/m.°C
Conductivity of EPS: 0.023 W/m.°C

Thermal resistance of the airspace: 0.15 m^2.°C/W
Thermal resistance of the interior air film: 0.12 m^2.°C/W
Thermal resistance of the exterior air film: 0.06 m^2.°C/W

(20%) Question 6

You are commissioned to design a HVAC system for a high-rise residential building to be located in downtown Toronto.

(1) Analyze the characteristics of this building in relation to appropriate selection of HVAC system and equipment.

(2) Develop a design strategy for optimizing the design of the terminal system. You need outline what are the options available, what are the relevant variables, what are the objective functions, and elaborate on the process through which optimal design can be achieved.

Question 1

(1) 8%
(2) 4%
(3) 4%
(4) 4%

Question 2

(1) 12%
(2) 8%

Question 3

(1) Process of calculation: 10%
(2) Point A: 5%, Point B: 5%

Question 4

Correctly calculate the relevant variables of the space: 8%
Correctly calculate the room constant: 4%
Correctly calculate the SPL at two locations: 8%

Question 5

(1) 12%
(2) 8%

Question 6

(1) 8%
(2) 12%

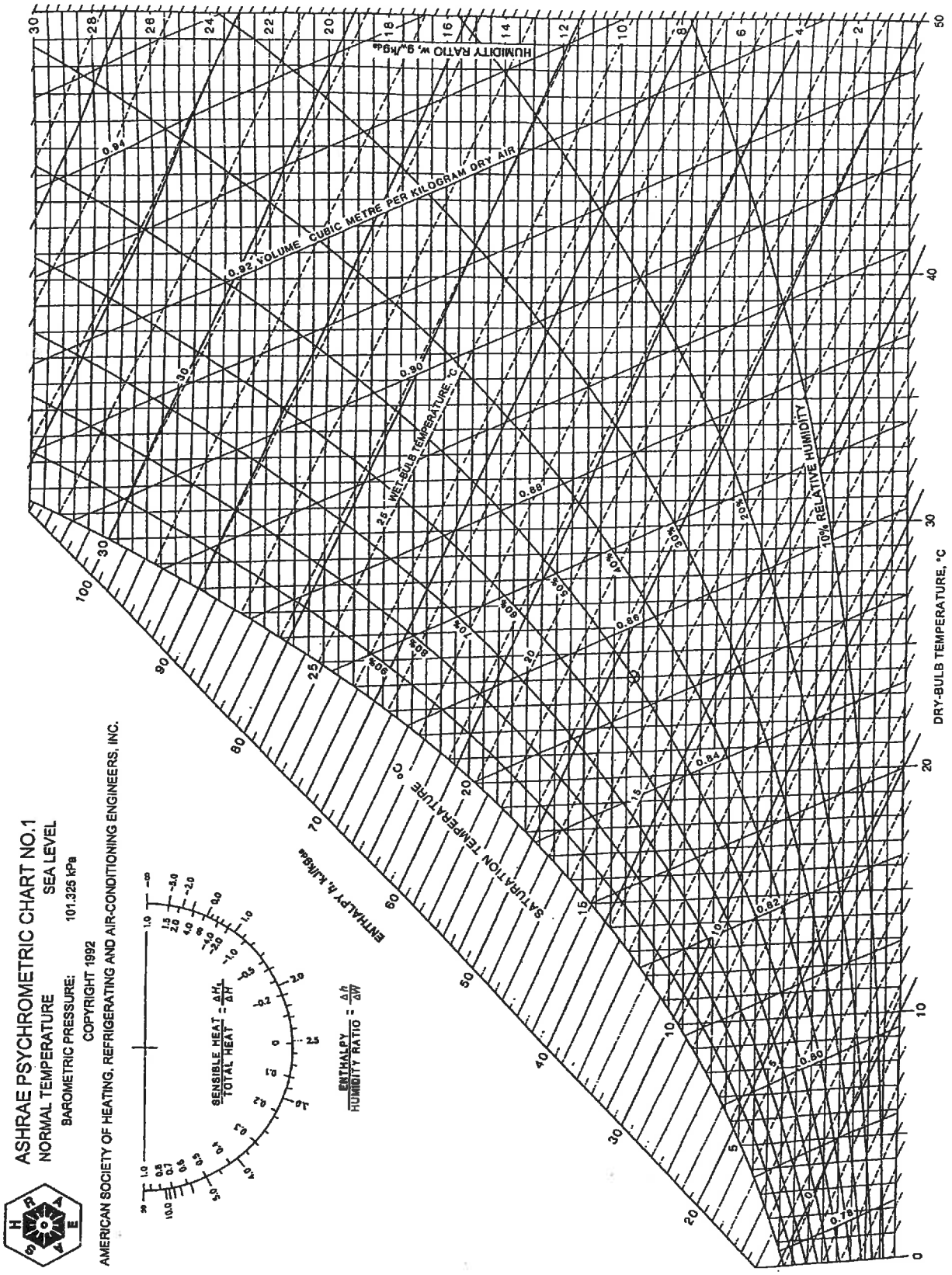


Fig. 1 ASHRAE Psychrometric Chart No. 1

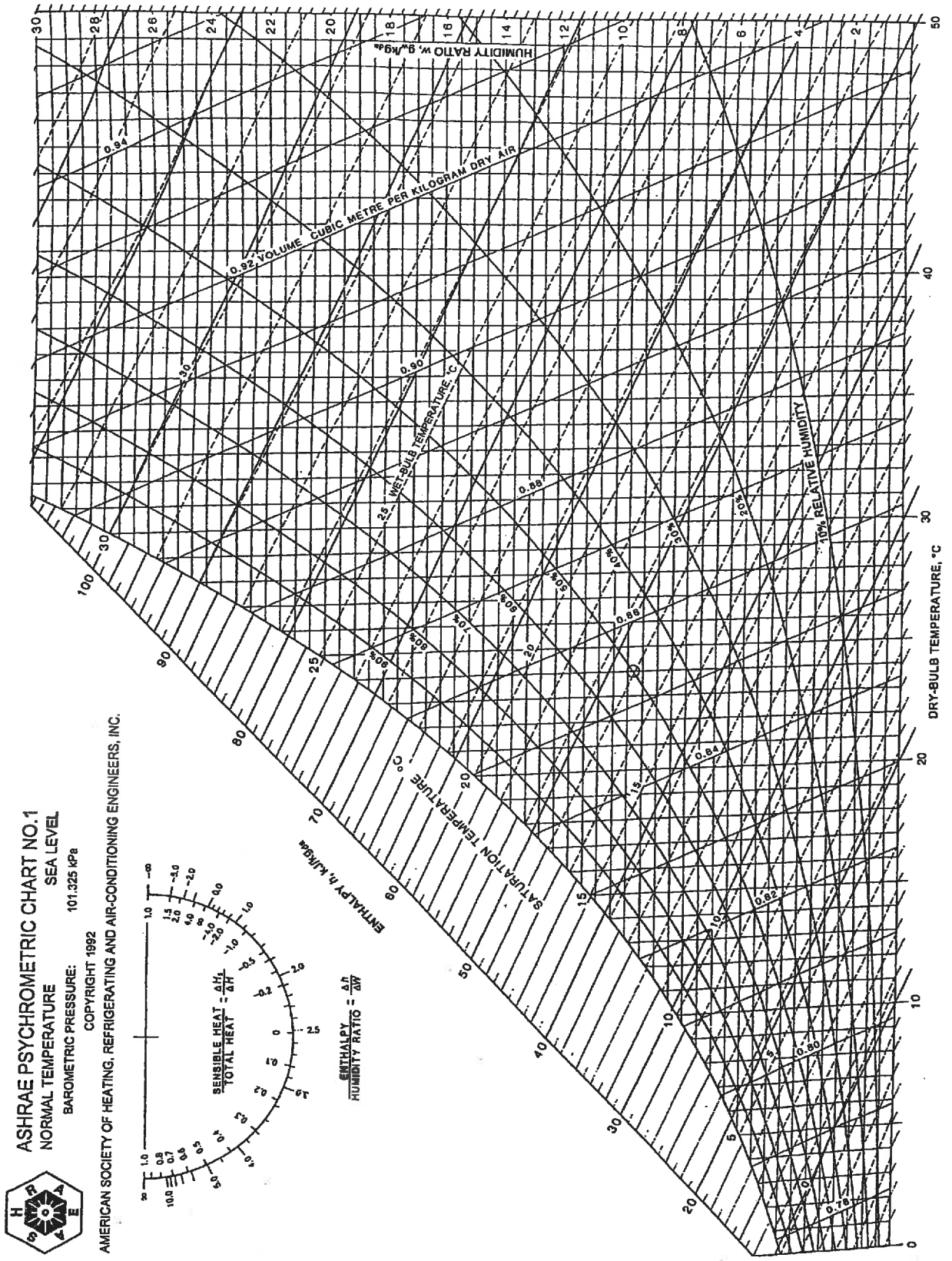


Fig. 1 ASHRAE Psychrometric Chart No. 1