National Exams May 2017

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 a CLOSED BOOK EXAM. Any non-communicating calculator is permitted.

3. There are two sections: Section 1 consists of FOUR (4) short questions, Section 2 consists of ten multiple-choice questions.

4. Each question in Section 1 is of equal value (20 marks) and require an answer in essay format. Clarity and organization of the answer are important.

5. Each question in Section 2 is of equal value (2 marks). There is only one correct answer for each question and no penalty for wrong answers. Please circle your answers directly on the question book.

Section 1

Question 1.1

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. $\dot{m}$ is mass flow rate. Subscript: IA – indoor air, SA – Supply Air, RA – Return Air, OA – Outdoor Air, MA – Mixing Air, EA- Exhaust Air.

RA is mixed adiabatically with OA to form MA (mixed air) that passes through the filter in AHU, then a cooling coil C1. Humid Air (Point A) at the outlet of the cooling coil C_1 is diverted into two parts: 50% goes through a bypass and the remaining 50% goes through a desiccant dehumidifier D. The humid air at the outlet of the desiccant dehumidifier is Point B. Air from the bypass is then mixed adiabatically with humid air from Point B to form air at Point C, which goes through another cooling coil C_2 to be processed to SA required to maintain the desire indoor thermal environment (T_{IA} and RH_{IA}).

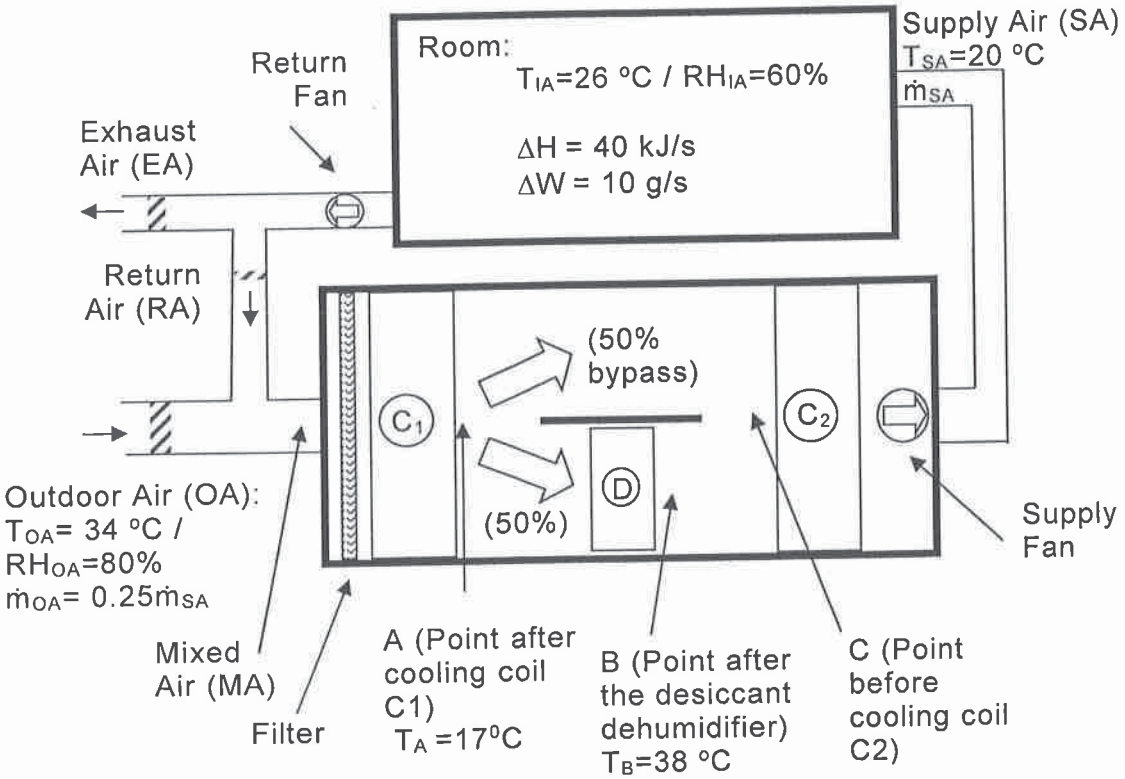
A Psychrometric Chart is provided (the atmospheric pressure is 101.325 kPa).

(1) (10%) Present the air handling processes on the Psychrometric Chart and show the temperature and relative humidity of all key points (IA, OA, MA, A, B, C, and SA).

(2) (5%) What is the total mass flow rate of the supply air $\dot{m}_{SA}$ (kg/s)?

(3) (5%) What is the output of the cooling coil C_1 (Q_{C1}: kW)?

(4) (5%) What is the output of the cooling coil C_2 (Q_{c2}: kW)?



Question 1.2

(1) (5%) Define the Heat Gains and Cooling Load of a space to be conditioned. Draw a graph to compare the Heat Gains and Cooling Load of a conditioned space in a typical summer day. Elaborate on how the relationship between the heat gains and the cooling load is affected by the thermal performance of building envelope and interior building contents.

(2) (10%) A typical HVAC system in each residential unit of a high-rise condominium building in Toronto is based on a water-source heat pump (WSHP) and a heat recovery ventilator (HRV). Draw a diagram to illustrate the structure of such a WSHP and explain how it works in the heating mode and cooling mode. How does it changeover between the two modes.

(3) (5%) Using a residential unit with one single space as example, draw diagrams to illustrate the air-side arrangement is made to integrate HRV and WSHP in order to control the indoor thermal environment and to maintain indoor air quality.

Question 1.3

A 45W flood lamp has a 45° beam angle and the luminous efficacy is 15lm/W. It is installed 4 m above the floor, pointing down to the floor.

(1) Construct an illuminance cone diagram for 1 m intervals of distance from the lamp, down to the floor. Show the height above the floor, and the diameter of light spot and peak illuminance (lux) at all levels.

(2) A circular horizontal display of diameter of 1.8m needs to be lit such that it is just within the cone. At what height above the floor this display should be located?

Question 1.4

A machine is installed on the floor in the center of a room that measures 15m long, 8m wide and 5m high. The noise from the machine is predominantly in the 500 Hz band and the sound power level in this band is 89 dB. The reverberation time of the room is 0.9 seconds. The machine radiates omni-directionally.

Calculate the SPL in this band at distances of 2m, 4m from the machine respectively.

Hint:

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).

Section 2

There are ten multiple-choice questions that each is of equal value (2 marks). There is only one correct answer and no penalty for wrong answers.

Information for Question 2.1 to 2.2:

- The recommended ventilation rate is given in the following table.

Room	Bedroom	Living Room	Bathroom	Kitchen
ACH (1/hr)	2	3	6	15

- Unit conversion: 1 m^3/hr = 0.5886 CFM

(1) Question 2.1: A two bedroom condominium unit is consisted of the following rooms: living/dining room: 15 m^2, Bedroom 1: 12 m^2, bedroom 2: 10 m^2, Bathroom: 4 m^2, kitchen: 6 m^2. The ceiling height of all rooms is 2.8m. What is the flow rate of the indoor air circulation?

a. 512.2 (m^3/hr)
b. 568.4 (m^3/hr)
c. 599.6 (m^3/hr)
d. 632.5 (m^3/hr)
e. 772.3 (m^3/hr)

(2) Question 2.2: Which one of the FCU modes shown in the following table should be selected for use in this two bedroom unit?

Carrier FCU AIRSTREAM 42S

Unit Size	03	04	06	08	10	12	14	16
Nominal Airflow (CFM)	300	400	600	800	1000	1200	1400	1600

a. Unit Size 16
b. Unit Size 12
c. Unit Size 08
d. Unit Size 06
e. Unit Size 04

Information for Question 2.3 to 2.4

- Table Minimum Outdoor Air Rates in Breathing Zone

Occupancy	People Outdoor Air Rate R_P(l/s/person)	Area Outdoor Air Rate R_A(l/s/m^2)
Classrooms	3.8	0.3

(3) Question 2.3: A classroom measures 8m wide, 10m deep, and 3.5m high. The density of students is 55 persons per 100m^2 of floor area. Calculate the required Outdoor Air Rate (measured in m^3/hr):

a. 345.5

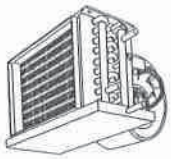
b. 498.6
c. 688.3
d. 766.4
e. 854.3

(4) Question 2.4: Table below shows the capacity of three HRV made by a major HVAC manufacturer. Please select a model for use in this classroom.
a. VC5BAB015
b. VC5BAB020
c. VC5BAB027
d. Any of these three modes
e. None of these three modes is sufficient

Capacity of high-efficiency HRC:

Model No.	VC5BAB015	VC5BAB020	VC5BAB027
Capacity (m^3/Hr)	108 ~ 216	216 ~ 306	306 ~450

(5) Question 2.5: Which one of the following HVAC equipment is not a FCU?


(a)


(b)


(c)


(d)


(e)

(6) Question 2.6: the efficiency of a HRV is defined by: $\eta = \frac{t_{OA}-t_{OA'}}{t_{OA}-t_A}$ if the mass flow rate of the exhaust air is the same as that of supply air. Note: t_{OA}, t_A are outdoor air temperature and indoor air temperature respectively, and $t_{OA'}$ is the temperature of outdoor air leaving the HRV.

If t_{OA} = 36 °C, t_A=26 °C, the efficiency is 60%, what is the value of $t_{OA'}$:

a. 30 °C
b. 32 °C
c. 34 °C
d. 36 °C
e. 38 °C

(7) Question 2.7: Which one of the following HVAC equipment has to be installed outdoor or in a space where external air circulation can be easily maintained?
a. Fan-Coil Unit
b. Water-Source Heat Pump
c. Air Handling Unit
d. Furnace
e. Air-cooled chiller

(8) Question 2.8: the function of a cooling tower is:

a. To generate chilled water that is distributed to terminal devices
b. To release heat contained in the coolant water that is transferred from high pressure refrigerant through the condenser
c. To release heat contained in the coolant water that is transferred from the high pressure refrigerant through the evaporator
d. To generate hot water that is distributed to the terminal devices
e. To absorb heat from the external air that is to be transferred to the refrigerant through the evaporator.

(9) Question 2.9: Humid Air (1) and (2) have the same dry-bulb temperature, which one of the following can't be true:

a. $T_{dpt1} > T_{dpt2}$ if $RH_1 > RH_2$
b. $RH_1 > RH_2$ if $h_1 > h_2$
c. $Ws_1 > Ws_2$ if $h_1 > h_2$
d. $W_1 > W_2$ if $RH_1 > RH_2$
e. $h_1 > h_2$ if $T'_1 > T'_2$

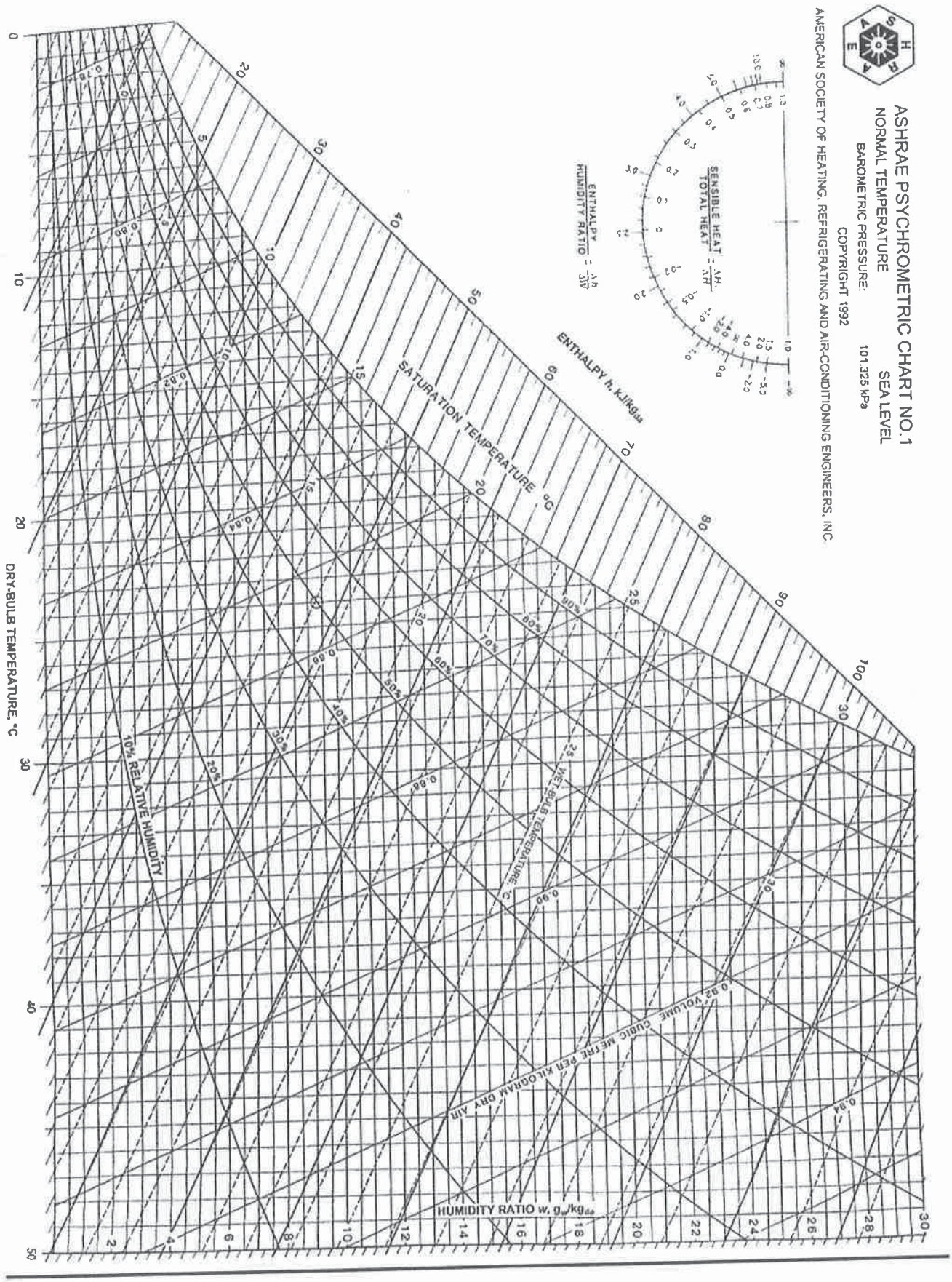
(Note: h is specific enthalpy, T is temperature, dpt refers to Dew Point Temperature, RH refers to Relative Humidity, Ws refers to the saturated moisture content, T' is wet-bulb temperature)

(10) Question 2.10: An external wall is consisted of four layers as shown in the following table. The R-value of this external wall is:

a. 2.786 (m^2.°C/W)
b. 3.276 (m^2.°C/W)
c. 3.354 (m^2.°C/W)
d. 3.615 (m^2.°C/W)
e. 3.870 (m^2.°C/W)

Layer	Material	Width (mm)	Specific heat (J/kg.°C)	Density (kg/m^3)	Thermal conductivity (W/m.°C)
1	Brick	200	0.8	1700	0.62
2	EPS panel	50	1.4	25	0.035
3	Gypsum board	12	.84	950	.16

Note: The exterior and interior surface thermal resistances are 0.06 and 0.12 (m^2.°C/W) respectively.


ASHRAE PSYCHROMETRIC CHART NO.1
NORMAL TEMPERATURE
SEA LEVEL
BAROMETRIC PRESSURE: 101.325 kPa
COPYRIGHT 1992
AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS, INC.
ENTHALPY h, kJ/kg$_{da}$
SATURATION TEMPERATURE, °C
DRY-BULB TEMPERATURE, °C
HUMIDITY RATIO w, g$_w$/kg$_{da}$
10% RELATIVE HUMIDITY
WET-BULB TEMPERATURE, °C
0.82 VOLUME, CUBIC METRE PER KILOGRAM DRY AIR
SENSIBLE HEAT / TOTAL HEAT = Δh / Δw
ENTHALPY / HUMIDITY RATIO = Δh / Δw