Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2019/2020

COURSE NAME	:	COOLING LOAD CALCULATION AND AIR DUCTING DESIGN
COURSE CODE	:	BBA 40103
PROGRAMME CODE	:	BBG
EXAMINATION DATE	:	DECEMBER 2019 / JANUARY 2020
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTIONS

THIS QUESTION PAPER CONSISTS OF **NINE (9)** PAGES

S1 (a) One of the most important considerations when designing a building is the extent to which it provides an environment that is comfortable for its occupants. State factors that affect human thermal comfort.

(5 marks)

(b) Described the process of transferring heat due to air moving across the surface of the skin?

(5 marks)

(c) A wall is made up of the following materials. Given the associated thermal resistance (R-value) for each material, calculate the U-factor for this wall.

Materials	Thermal resistance $(m^2 \cdot °K/W)$
Outdoor-air film resistance , f_o	0.044
100mm face brick	0.141
Permeable-felt vapor membrane	0.011
140mm fiberglass insulation	3.67
12.7mm gypsum board	0.079
Indoor-air film resistance, f_i	0.12

(5 marks)

(d) Explain what is sensible heat and latent heat? Categorise which component of the space cooling load contributes to sensible heat and/or latent heat.

(10 marks)

S2 (a) Referring to the following information, **Figure S2 (a)** and **Table S2 (a)**, calculate the heat gain by conduction through an east-facing wall at Hour 12 in July for Room 102.

- Wall type 9
- Floor-to-ceiling height = 3.7 m
- U-factor of the wall = 0.284 $W/m^2 \cdot °K$
- Indoor dry-bulb temperature = 25.6 °C
- Outdoor dry-bulb temperature = 35 °C

(5 marks)

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(b) Referring to the following information, **Figure S2 (a), Figure S2 (b), Table S2 (b-i),** and **Table S2 (b-ii),** calculate the heat gain by solar radiation through the windows on west-facing wall at Hour 14 in July for Room 101.

- Space Type A
- Eight clear, uncoated double glazing (6.4mm) windows mounted in aluminum frames. Each window is 1.2 m wide x 1.5 m high.
- U-factor of the window = 3.75 $W/m^2 \cdot °K$
- Indoor dry-bulb temperature = 25.6 °C
- Outdoor dry-bulb temperature = 35 °C

(5 marks)

(c) Referring to the following information, calculate both the sensible and latent heat gains due to infiltration of air from outdoors for Room 101.

- Area of floor = 23 m^2
- Floor-to-ceiling height = 3.7 m
- Amount of infiltration = 0.5 air change/hour
- Indoor conditions = 23.9 °C dry-bulb temperature and 9.3grams of water/kg dry air
- Outdoor conditions = 37.8 °C dry-bulb temperature and 13.1 grams of water/kg dry air.

(10 marks)

(d) Referring to the following information and **Table S2 (d)**, calculate the internal heat gains from people and lighting.

- Number of people = 10 with peoples participating in moderately active office work.
- CLF = 1
- Amount of lighting in space = 21.5W/m^2
- Area of floor = 23 m^2
- Ballast factor = 1.2 (fluorescent lights)
- Amount of infiltration = 0.5 air change/hour

(5 marks)

S3 (a) Given the following components of cooling load;

	Sensible heat gain (W)	Latent heat gain (W)
Conduction through roof	2050	
Conduction through exterior walls	150	
Conduction through windows	400	
Solar radiation through windows or skylights	3600	
Heat gain from people	1300	1050
Heat gain from lights	6500	
Heat gain from office equipments	2800	
Air infiltration through cracks from outdoors	800	850
Cooling load due to ventilation brought in by the central HVAC system	1750	1900
Heat gains from the supply fan	1000	

i. Calculate the sensible heat ratio for the space?

(4 marks)

ii. Assuming the air is supplied to the space at 12.2°C dry-bulb and the space dry-bulb temperature is 23.9°C, calculate quantity of air must be supplied to the space?

(6 marks)

iii. Calculate the total cooling load on the coil?

(4 marks)

(b) The following sensible heat gains exist for three spaces being served by the same centralized HVAC systems;

	Total space sensible heat gain (W)	
	9.00 am	**4.00 pm**
Room 201	20,500	6,000
Room 202	3,000	25,000
Room 203	4,500	6,000

i. Explain when does the block load occur? (Block load is used to size a variable-air-volume (VAV) supply fan)

(4 marks)

ii. Calculate the block space sensible load?

(4 marks)

iii. Suppose that you are sizing a constant-volume supply fan. Calculate the "sum-of-peaks" space sensible load?

(3 marks)

S4 (a) Explain advantages and disadvantages of low velocity duct systems.

(4 marks)

(b) Differentiate the use of round ducts and rectangular ducts in the design of building ducting systems.

(6 marks)

S4 (a) The following **Figure S4 (c)** shows a typical duct layout.

i. Using Velocity method, determine the size of each ducting (A – F) if using round ducts by taking the velocity of air in the main duct (A) as 8 m/s and select a velocity of 5 m/s for the downstream and branches.

ii. Assume a dynamic loss coefficient of 0.3 for upstream to downstream and 0.8 for upstream to branch and for the elbow. Calculated the pressure drop in section A-B.

(15 marks)

- **END OF QUESTIONS** -

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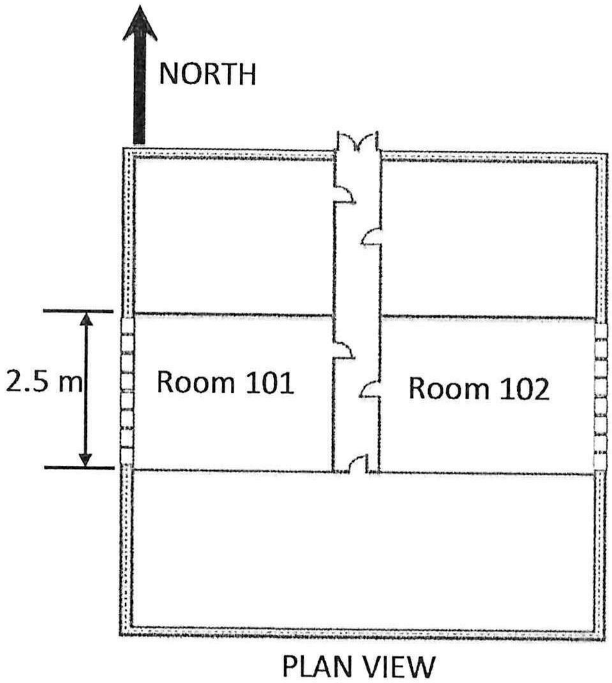

Figure S2 (a)

Table S2 (a): CLTDs for Sunlit Walls (40° North Latitude, July 21), °C

	Wall Type 9																							
	Hour																							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
N	9	8	7	6	5	4	3	2	2	2	3	4	4	6	7	8	9	11	12	12	13	13	12	11
NE	10	8	7	6	5	4	3	3	3	6	9	11	13	14	14	15	15	16	16	15	14	14	13	11
E	11	9	8	7	6	4	3	3	4	7	11	14	18	20	21	21	21	20	19	18	17	16	14	13
SE	11	9	8	7	6	4	3	3	3	5	7	11	14	17	19	20	21	20	19	19	18	16	14	13
S	12	10	8	7	6	4	3	3	2	2	2	3	6	8	11	14	16	18	19	19	18	17	15	13
SW	17	14	12	10	8	7	5	4	3	3	3	3	4	6	8	11	14	18	22	24	25	24	22	20
W	19	17	14	12	9	8	6	4	4	3	3	4	4	6	7	9	12	17	21	24	27	27	25	23
NW	16	14	12	9	8	6	5	4	3	3	3	3	4	5	6	8	10	12	16	19	21	21	20	18

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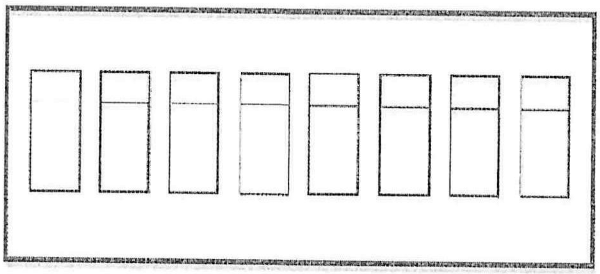

Elevation view (Room 101)

Figure S2 (b)

Table S2 (b-i): Shading coefficient of the window

	Shading Coefficient At Normal Incidence			
	Aluminum frame		Other frames	
	Operable	Fixed	Operable	Fixed
Uncoated single glazing				
6.4 mm clear	0.82	0.85	0.69	0.82
6.4 mm green	0.59	0.61	0.49	0.59
Reflective single glazing				
6.4 mm SS on clear	0.26	0.28	0.22	0.25
6.4 mm SS on green	0.26	0.28	0.22	0.25
Uncoated double glazing				
6.4 mm clear - clear	0.70	0.74	0.60	0.70
6.4 mm green - clear	0.48	0.49	0.40	0.47
Reflective double glazing				
6.4 mm SS on clear - clear	0.20	0.18	0.15	0.17
6.4 mm SS on green - clear	0.18	0.18	0.15	0.16

SS = stainless-steel reflective coating

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Table S2 (b-ii): SCL for Sunlit Glass (40° North Latitude, July 21), W/m^2

	Space Type A																		
	Hour																		
	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
N	79	85	88	101	110	120	126	126	123	113	98	98	113	38	19	9	3	3	0
NE	268	406	422	353	236	173	151	139	126	117	101	82	57	22	9	6	3	0	0
E	293	495	583	576	485	334	211	167	142	123	104	82	57	22	9	6	3	0	0
SE	148	299	413	473	473	413	306	198	154	129	107	85	57	22	9	6	3	0	0
S	28	54	79	129	202	79	306	302	265	198	132	98	63	25	13	6	3	0	0
SW	28	54	76	95	110	76	202	318	419	476	479	419	293	110	54	25	13	6	3
W	28	54	76	95	110	76	126	205	359	498	589	605	491	180	85	41	19	9	6
NW	28	54	76	95	110	76	126	126	158	265	381	450	410	145	69	35	16	9	3
HOR	76	217	378	532	665	378	810	816	772	684	554	394	221	91	44	22	9	6	3

Table S2 (d): Heat Generated by People

Level Of Activity	Sensible Heat Gain	Latent Heat Gain
Moderately active work (Office)	75W	55W
Standing, light work, walking (Store)	75W	55W
Light bench work (Factory)	80W	140W
Heavy work (Factory)	170W	255W
Exercise (Gymnasium)	210W	315W

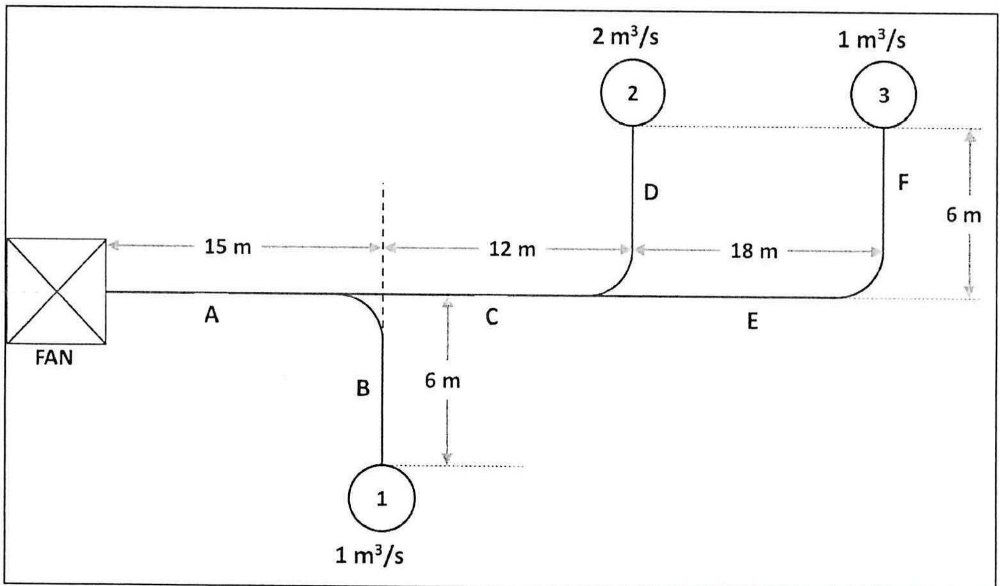

Figure S4 (c)

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LIST OF FORMULA

COOLING LOAD CALCULATION

$U = 1/R_{total}$

$Q = U \times A \times CLTD$

$Q_{solar} = A \times SC \times SCL$

$Q_{sensible}$ = *No. of people x sensible heat gain per person x CLF*

Q_{latent} = *No. of people x latent heat gain per person*

$Q_{lighting}$ = *watts x ballast factor x CLF*

Infiltration airflow = (volume of space x air change rate) / 3600

Heat gain from infiltration;

$Q_S = 1210 \times airflow \times \Delta T$

$Q_L = 3010 \times airflow \times \Delta W$

Supply airflow = sensible heat gain / [1210 x (room DB – supply DB)]

AIR DUCTING DESIGN

$\Delta P_{A\text{-}B} = \Delta P_{A,f} + \Delta P_{B,f} + \Delta P_{u\text{-}b} + \Delta P_{exit}$

$\Delta P_{A,f} = (0.022243 \times \bar{Q}^{1.852}_{air} \times L_A) / D^{4.973}_A$; L = length, D = diameter, $\bar{Q}$ = flow rate

$\Delta P_{u\text{-}b} = C_{u\text{-}b} (\rho V^2_d /2)$; *C = dynamic loss coefficient*, $\rho = 1.2$, *V = velocity*

$\Delta P_{exit} = C_{exit} (\rho V^2_1 /2)$

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