UTHM
Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2019/2020

COURSE NAME	:	HEATING, VENTILATING & AIR CONDITIONING SYSTEM
COURSE CODE	:	BNB 31203
PROGRAMME CODE	:	BNB
EXAMINATION DATE	:	DECEMBER 2019/JANUARY 2020
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTIONS

THIS QUESTION PAPER CONSISTS OF **SIXTEEN (16)** PAGES

Q1 (a) Define the term of heating, ventilating and air-conditioning.

(3 marks)

(b) **Figure Q1 (b)** shows the basic cycle of the refrigeration system. Explain the process from point (1) until point (8).

(8 marks)

(c) Disscus the effect of thermal conductivity in heat transfer.

(6 marks)

(d) Differentiate between natural and mechanical ventilation. Give **TWO (2)** example for each categories.

(8 marks)

Q2 (a) A cooling tower is the basic piece of equipment used in a cooling system. Illustrate and briefly describe the cooling tower working principle.

(5 marks)

(b) Differentiate between all air system, all water system and air-water system.

(9 marks)

(c) Putra Holding Company Limited uses a centralized air conditioning system. It uses ducting system to deliver and distribute cold air. There are several numbers of offices and meeting rooms which receive the cold air exceeding the required capacity of a room.

(i) List **TWO (2)** reasons of the above problems.

(2 marks)

(ii) Propose **THREE (3)** solution for these issues. Use aid of diagram to support your answer.

(9 marks)

Q3 (a) Explain the purpose of cooling load calculation.

(4 marks)

(b) The floor plan of a mid-floor classroom in a multi-floor university as shown in **Figure Q3 (b).** Calculate the total heat gain by using:

(i) Rule of thumb. (Refer **Appendix 1**)

(4 marks)

(ii) Calculation. (Refer **Appendix 2** and **Appendix 3**)

(12 marks)

(c) Determine the overall coefficient of heat transmission (U) for a face brick consisting of 2 inch cement plaster on both side, and 4.5 inch face brick as shown in **Figure Q3 (c)**. (Refer **Appendix 4** and **Apppendix 5)**

(5 marks)

Q4 (a) Describe **TWO (2)** importance of Psychrometric chart in HVAC industries.

(4 marks)

(b) Outside air at a 40°F DB temperature and 60% RH is heated to a 90°F DB temperature. If no humidification equipment is used. Determine:
(Attach **Appendix 6** to support your answer)

(i) the RH of the treated air.

(3 marks)

(ii) the heat added per lb. of air.

(3marks)

(iii) with same condition as above, if a humidifier is operated to maintain 50% RH. Calculate the heat added per lb. of air.

(4 marks)

(c) District cooling system (DCS) is a future-proof system that efficiently cools buildings through centralized distribution of chilled water.

(i) With aid of diagram, explain the work principle of DCS.

(5 marks)

(ii) Discuss the relation of DCS and energy efficiency.

(6 marks)

– END OF QUESTIONS –

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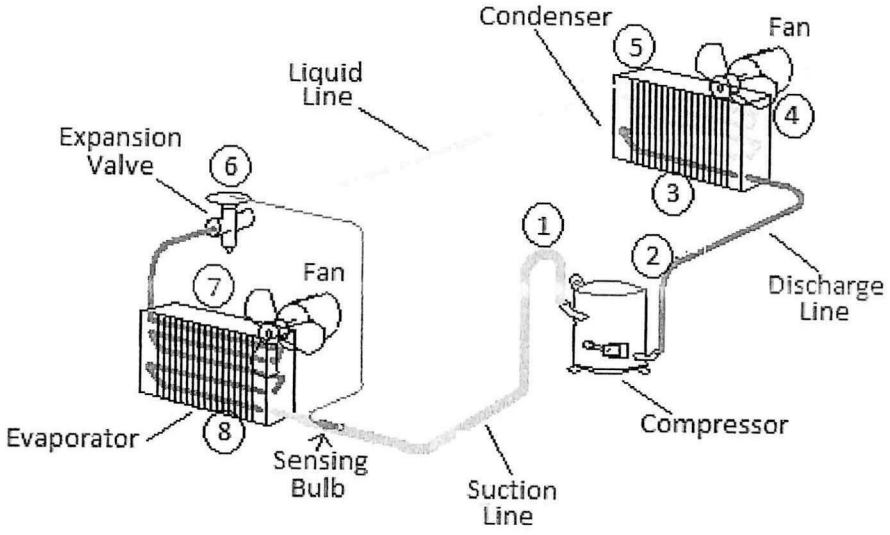
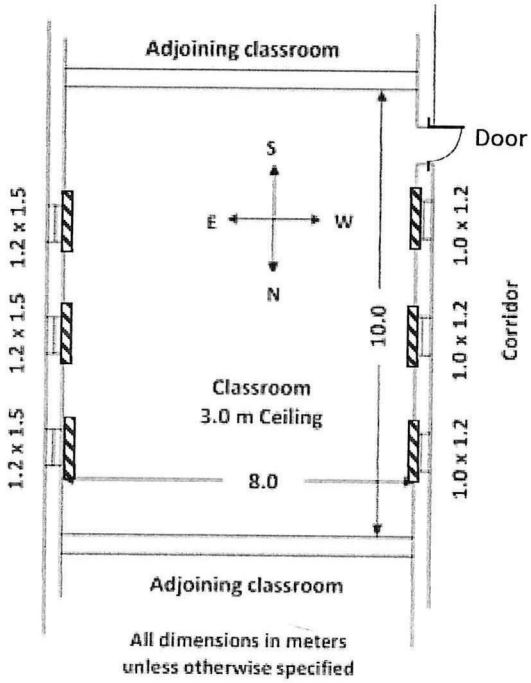


Figure Q1 (b)



Specifications of construction

Building	:	Five-story building
Outside wall	:	Medium construction (concrete block 150mm t)
Window glass	:	Normal (6mm t) with blind
Floor	:	Concrete with linoleum
Ceiling	:	Only concrete
Lights	:	Flurescent light (40w×20=800w)
Persons	:	15 (working)
Area	:	Standard temperature area

* * * Adjoined upper and lower rooms are not cooled.

Figure Q3 (b)

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Surface emittance $\varepsilon = 0.9$

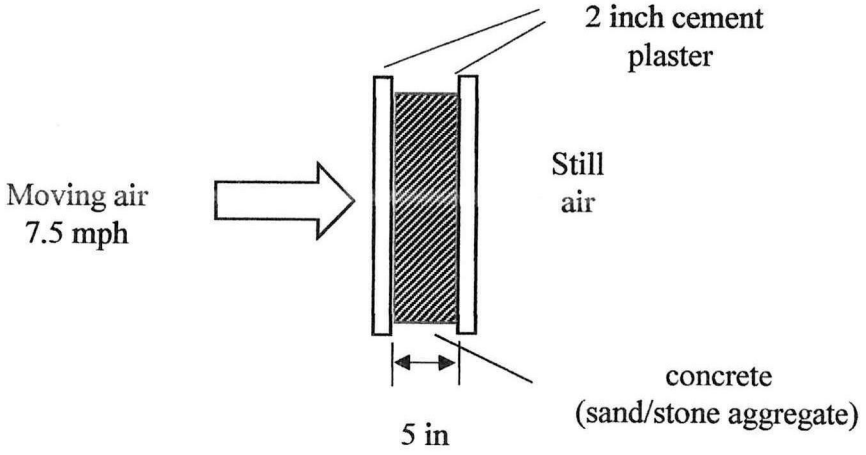

Figure Q2 (a)

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Table I — Design and Cooling Load Check Figures

Applications	Occupancy Sq Ft/Person			Lighting Watts/Sq Ft			Fresh CFM/Person			Air CFM/Sq Ft			Room Sensible Btuh/Sq Ft			Room Total Btuh/Sq Ft			Grand Total Btuh/Sq Ft			Refrigeration Sq Ft/Ton*			Supply Air CFM/Sq Ft		
	Lo	Avg	Hi	Lo	Avg	Hi	Lo	Avg	Hi	Lo	Avg	Hi	Lo	Avg	Hi	Lo	Avg	Hi	Lo	Avg	Hi	Lo	Avg	Hi	Lo	Avg	Hi
Apartments (Flats)	150	100	50	1.0	2.0	4.0	25	35	40	.25	.35	.50	15	25	45	20	30	50	30	40	60	400	300	200	.75	1.25	1.75
Auditoriums, Theaters	15	10	5	1.0	2.0	3.0	5.0	15	30	.50	1.5	2.5	25	35	50	45	55	70	60	80	120	200	150	100	1.25	1.5	2.5
Educational Facilities																											
Classrooms	30	25	20	2.0	4.0	6.0	5.0	7.5	10	.20	.30	.40	25	40	55	35	50	65	45	60	80	275	200	150	1.0	1.4	1.8
Laboratories	75	60	40	2.0	3.0	6.0	10	15	20	.20	.40	.60	30	40	55	35	45	65	45	60	75	275	200	160	1.0	1.4	1.8
Cafeteria – Coffee House	20	15	10	1.5	3.0	4.5	7.5	10	15	.40	.60	.80	25	45	65	35	60	75	55	80	110	225	150	110	1.0	1.5	2.1
Factories	50	35	25	3.0	4.5	6.0	5.0	10	15	.10	.25	.50	20	45	75	30	60	85	50	80	130	240	150	90	1.0	2.25	3.0
Public Areas	200	150	100	9.0‡	10.0‡	12.0‡	5.0	10	15	.05	.10	.15	35	55	75	40	60	80	60	80	120	200	150	100	1.5	2.75	3.0
Light Manufacturing	300	250	200	15.0‡	45.0‡	60.0‡	5.0	10	15	.03	.08	.10	75	115	155	80	120	160	120	150	200	100	80	60	3.0	4.0	6.5
Heavy Manufacturing**	20	15	10	1.0	1.5	2.0	5.0	10	15	.50	.75	1.0	30	35	50	40	50	70	60	85	120	200	150	100	1.0	1.1	1.4
Hospitals																											
Patient Rooms†	100	60	40	1.0	2.0	3.0	75	90	100	.75	1.6	2.5	15	35	50	20	40	55	60	120	165	200	100	75	.75	1.2	1.7
Public Areas	130	100	65	2.0	3.0	4.0	10	20	30	.25	.75	1.5	10	15	35	15	20	40	30	45	100	400	275	120	.75	1.2	1.7
Laboratories	150	100	50	2.0	5.0	10.0	20	30	50	.20	.50	1.0	25	45	60	30	55	70	45	70	100	275	175	120	1.0	1.5	2.0
Libraries	150	100	50	2.0	4.0	6.0	5.0	7.5	10	.10	.20	.30	20	30	50	25	35	55	30	45	70	400	275	175	1.0	1.1	1.7
Doctors Clinics	150	100	50	2.0	4.0	6.0	20	25	30	.25	.40	.60	20	40	60	25	45	65	40	60	80	300	200	150	1.0	1.4	2.0
Offices																											
Private	150	125	100	4.0	6.0	8.0	20	25	30	.25	.40	.60	25	50	75	30	55	80	40	75	90	300	175	135	1.0	1.7	2.4
General – Perimeter	125	100	75	4.0	6.0	8.0	10	15	20	.15	.25	.40	20	35	70	25	40	75	30	50	85	400	250	150	1.0	1.2	2.3
General – Interior	125	100	75	4.0	6.0	8.0	10	15	20	.15	.25	.40	15	20	30	20	25	35	25	30	40	475	400	300	.75	1.0	1.1
Conference Rooms	45	30	15	4.0	6.0	8.0	20	30	50	.40	1.0	1.5	30	55	80	40	65	90	60	85	120	200	150	100	1.0	1.8	2.7
Restaurants	25	20	15	1.5	1.7	2.0	10	15	20	.50	.75	1.0	30	35	50	40	50	70	60	85	120	200	150	100	1.25	1.5	2.0
Shopping Centers																											
Beauty & Barber Shops	45	40	25	3.0‡	5.0‡	9.0‡	7.5	15	20	.20	.50	1.0	25	35	55	30	40	60	50	60	80	250	200	150	1.25	1.5	2.0
Department Stores – Basement	40	30	20	3.0	4.0	5.0	5.0	7.5	10	.10	.20	.25	20	30	45	25	35	50	35	45	60	325	275	200	1.0	1.4	1.75
– Main Floor	40	25	20	4.0	6.0‡	9.0‡	5.0	7.5	10	.15	.25	.35	25	35	45	30	40	50	40	50	60	300	250	200	1.0	1.5	2.0
– Upper Floors	80	50	40	2.0	4.0	6.0‡	5.0	5.0	7.5	.05	.10	.15	15	25	35	20	30	40	30	40	50	400	300	250	.80	1.0	1.2
	40	30	25	2.0	3.0	4.0	10	15	20	.25	.35	.50	30	35	45	40	45	55	60	65	75	200	180	160	1.25	1.5	2.0
	40	25	20	3.0	4.0	6.0	5.0	7.5	10	.15	.25	.35	25	35	45	30	40	50	40	50	60	300	250	200	1.0	1.4	2.0
	60	40	30	1.0	1.5	2.0	5.0	7.5	10	.10	.20	.30	10	15	25	15	20	30	25	30	40	500	400	300	.75	1.2	1.5
Specialty Shops	60	50	40	2.0	3.0	4.0	5.0	7.5	10	.10	.20	.30	25	35	45	30	40	50	40	50	60	300	250	200	1.2	1.4	2.0

* Refrigeration loads are for entire application.
† Air quantities shown are for all-air systems.
‡ Includes other equipment loads expressed in watts/sq ft.
** Air quantities for heavy manufacturing areas are based on supplementary means to remove excessive heat.

Appendix 1

FINAL EXAMINATION

SEMESTER / SESSION : SEM I 2019/2020
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COOLING LOAD FORM

NAME OF COSNTRUCTOR:
ADDRESS:
NAME OF ROOM:

NAME OF PERSON INCHARGE:
ROOM AREA:
ROOM VOLUME:

ITEMS			AREA (A)	COOLING			
				Coefficient (B)	C = A x B	Coefficient (F)	Load, Q = F x C
WALL FACED TO THE OUTDOOR			m^2			1	
			m^2				
			m^2				
			m^2				
ROOF			m^2				
WINDOW GLASS			m^2			Coefficient of blind	
			m^2				
			m^2				
			m^2				
PARTITION			m^2			1	
			m^2				
			m^2				
			m^2				
			m^2				
			m^2				
CEILING			m^2				
FLOOR			m^2				
OUTDOOR AIR	INVASION OF OUTDOOR AIR	Room Volume	m^3			Area corr.	
	PERSON	Number				1	
	LIGHT	Electric Light		kW	860	Rate of using	1
		Fluorescent Light		kW	1000		1
	ELECTRIC APPARATUS			kW	860		1
	GAS	L.N.G		m^3/h	1000		1
		L.P.G		m^3/h	21700		1

TOTAL COOLING LOAD: Q = _____ Kcal/hr

_____ Btu/hr

*kcal/hr → btu/hr x 3.968

Appendix 2

FINAL EXAMINATION

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1.3 Coefficient of cooling load

1.3.1 Wall faced to the outdoor

able 11-1

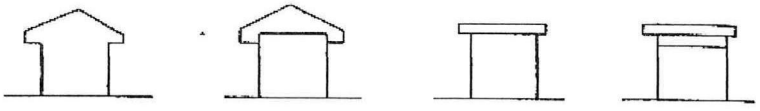
Sort of wall	Coefficient B (kcal/m²h)								Coefficient E (kcal/m²h deg.)
	N	E	S	W	NE	SE	SW	NW	
Light construction wooden, mortar)	17	37	29	51	28	34	43	42	2.5
Medium construction concrete block)	15	40	34	56	32	38	48	45	
Heavy construction concrete 200mm t)	16	34	31	37	29	34	40	26	3.0

11.3.2 Roof

Table 11-2

Sort of roof		Coefficient B (kcal/m²h)	Coefficient E (kcal/m²h deg.)
Light construction (slate, mortar or sheet zinc)	No Ceiling	165	3
	Ceiling	60	1.5
Medium construction (thin concrete insulation)	No Ceiling	92	2
	Ceiling	38	1.5
Heavy construction (thick concrete insulation)	No Ceiling	43	1
	Ceiling	23	1

(Reference)



No ceiling Ceiling No ceiling Ceiling

Appendix 3

FINAL EXAMINATION

SEMESTER / SESSION : SEM I 2019/2020
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11.3.3 Window glass

Table 11-3

Sort of glass	Coefficient B (kcal/m²h)									Coefficient E (kcal/m²h deg.)
	Shady window	Sunny window								
		N	E	S	W	NE	SE	SW	NW	
Normal glass plate (3 mm thick)	60	150	590	310	710	440	430	530	540	
Normal glass plate (6 mm thick)	55	140	540	290	650	400	390	480	490	5.5
Insulation type (3 mm thick)	35	90	370	220	440	270	270	340	340	
Dual glass (6 mm thick inside)	30	70	290	170	340	215	210	260	260	2.2
Glass block	25	40	330	130	360	200	190	230	240	2.5

Note:
In case more than two windows are provided in different directions, the coefficient B of the window having the largest value of AxB only is taken from the column of "Sunny window" and those of other windows are taken from the column of "Shady window".
A: Area of window
B: Coefficient B

11.3.4 Coefficient of blind attached to window

Table 11-4

Sort of blind	Coefficient f
Venetian blind attached to inside of the window.	0.7
In case of drawing curtain	0.8~0.7

11.3.5 Partition of the room (In case adjoind rooms are not cooled)

Table 11-5

Sort of partition	Coefficient B (kcal/m²h)	Coefficient E (kcal/m²h deg.)
Glass or wooden plate	13	4.5
Others	8	2.7

Continue Appendix 3

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11.3.6 Ceiling and floor
(In case upper and lower rooms are not cooled)

Table 11-6

Sort of ceiling and floor	Coefficient B (kcal/m²h)	Coefficient E (kcal/m²h deg.)
Only concrete	10	3
Linoleum or carpet placed on the floor	7	2
Grass mat placed on the wooden floor	4	1
Floor attached on the ground directly	0	1

11.3.7 Invasion of outdoor air
Table 11-7

	Coefficient B (kcal/m²h)	Coefficient E (kcal/m²h deg.)
Standard	8	0.3
Many entrances are in the room. Two or more walls are faced to the outdoor.	8X(1.5~2)	0.3X(1.5~2)

11.3.8 Area correction for outdoor temperature
Table 11-8

Area (district)	Coefficient f
Standard	1.0
Higher temperature area	1.1
Highest temperature area	1.2

11.3.9 Occupants
Table 11-9

Condition of occupants	Application	Coefficient B (kcal/h·person)
Sitting on the chair	Theater, tea room	100
Office working	Office, hotel, restaurant, department store	120
Physical working	Factory, dance-hall	200

Continue Appendix 3

FINAL EXAMINATION

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Table 5-2a Surface Unit Conductances and Unit Resistances for Air[a]

Position of Surface	Direction of Heat Flow	ε = 0.9 h Btu/hr-ft²-F	ε = 0.9 h W/m²-C	ε = 0.9 R hr-ft²-F/Btu	ε = 0.9 R m²-C/W	ε = 0.2 h Btu/hr-ft²-F	ε = 0.2 h W/m²-C	ε = 0.2 R hr-ft²-F/Btu	ε = 0.2 R m²-C/W	ε = 0.05 h Btu/hr-ft²-F	ε = 0.05 h W/m²-C	ε = 0.05 R hr-ft²-F/Btu	ε = 0.05 R m²-C/W
Still Air													
Horizontal	Upward	1.63	9.26	0.61	0.11	0.91	5.2	1.10	0.194	0.76	4.3	1.32	0.232
Sloping—45 degrees	Upward	1.60	9.09	0.62	0.11	0.88	5.0	1.14	0.200	0.73	4.1	1.37	0.241
Vertical	Horizontal	1.46	8.29	0.68	0.12	0.74	4.2	1.35	0.238	0.59	3.4	1.70	0.298
Sloping—45 degrees	Downward	1.32	7.50	0.76	0.13	0.60	3.4	1.67	0.294	0.45	2.6	2.22	0.391
Horizontal	Downward	1.08	6.13	0.92	0.16	0.37	2.1	2.70	0.476	0.22	1.3	4.55	0.800
Moving Air													
(any position) Wind is 15 mph or 6.7 m/s (for winter)	Any	6.0	34.0	0.17	0.029								
Wind is $7\frac{1}{2}$ mph or 3.4 m/s (for summer)	Any	4.0	22.7	0.25	0.044								

[a]Conductances are for surfaces of the stated emittance facing virtual blackbody surroundings at the same temperature as the ambient air. Values are based on a surface–air temperature difference of 10 F and for a surface temperature of 70 F.

Source: Adapted by permission from *ASHRAE Handbook, Fundamentals Volume*, 1989.

Appendix 4

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COURSE NAME : HEATING, VENTILATING & AIR CONDITIONING SYSTEM COURSE CODE : BNB 31203

Thermal Properties of Building and Insulating Materials at a Mean Temperature of 75°F (English Units)

Material	Description	Density ρ $\frac{lbm}{ft^2}$	Thermal Conductivity k $\frac{Btu \cdot in}{ft^2 \cdot hr \cdot F}$	Unit Conductance C $\frac{Btu}{hr \cdot ft^2 \cdot F}$	Unit Resistance: Per Inch Thickness 1/k $\frac{ft^2 \cdot hr \cdot F}{Btu \cdot in}$	Unit Resistance: For Thickness Listed 1/C $\frac{hf \cdot ft^2 \cdot F}{Btu}$	Specific Heat $\frac{Btu}{lbm \cdot F}$
Building Board Boards, panels, subflooring, sheathing, wood-based panel products	Asbestos-cement board						
	¼ in. or 6 mm	120	-	16.5	-	0.06	0.24
	Gypsum of plasterboard						
	⅜ in. or 10 mm	50	-	3.10	-	0.32	0.26
	½ in. or 13 mm	50	-	2.22	-	0.45	
	Plywood	34	0.80	-	1.25	-	0.29
	¼ in. or 6 mm	34	-	3.20	-	0.31	0.29
	⅜ in. or 10 mm	34	-	2.13	-	0.17	0.29
	½ in. or 13 mm	34	-	1.60	-	0.62	0.29
	¾ in. or 20 mm	34	-	1.07	-	0.93	0.29
	Insulating board and sheathing, Regular density						
	½ in. or 13 mm	18	-	0.76	-	1.32	0.31
	¾ in. or 20 mm	18	-	0.49	-	2.06	0.31
	Hardboard, high density, standard tempered	63	1.00	-	1.00	-	0.32
	Particle board						
	Medium density	50	0.94	-	1.06	-	0.31
	Underlayment						
	⅝ in. or 16 mm	40	-	1.22	-	0.82	0.29

Appendix 5

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Thermal Properties of Building and Insulating Materials at a Mean Temperature of 75°F (English Units) *(continued)*

					Unit Resistance		
		Density ρ	Thermal Conductivity k	Unit Conductance C	Per Inch Thickness 1/k	For Thickness Listed 1/C	Specific Heat
Material	Description	$\frac{lbm}{ft^2}$	$\frac{Btu \cdot in}{ft^2 \cdot hr \cdot F}$	$\frac{Btu}{hr \cdot ft^2 \cdot F}$	$\frac{ft^2 \cdot hr \cdot F}{Btu \cdot in}$	$\frac{hf \cdot ft^2 \cdot F}{Btu}$	$\frac{Btu}{lbm \cdot F}$
	Lightweight aggregate (expanded shale, clay slate or slag, pumice)						
	3 in, or 75 mm	-	-	0.79	-	1.27	-
	4 in. or 100 mm	-	-	0.67	-	1.50	-
	8 in. or 200 mm	-	-	0.50	-	2.00	-
	12 in. or 300 mm	-	-	0.44	-	2.27	-
Plastering Materials	Cement plaster, sand, aggregate	116	5.0	-	0.20	-	-
	Gypsum plaster:						
	Lightweight aggregate						
	½ in. or 13 mm	45	-	3.12	-	0.32	-
	⅝ in. or 16 mm	45	-	2.67	-	0.39	-
	Lightweight aggregate on metal lath						
	¾ in. or 20 mm	-	-	2.13	-	0.47	-
Roofing	Asbestos-cement shingles	120	-	4.76	-	0.21	-
	Asphalt roll roofing	70	-	6.50	-	0.15	-
	Asphalt shingles	70	-	2.27	-	0.44	-
	Built in roofing						
	⅛ in. or 10 mm	70	-	3.00	-	0.33	0.35
	Slate, ½ in. or 13 mm	-	-	20.00	-	0.05	-
	Wood shingles – plain or plastic film faced	-	-	1.06	-	0.94	0.31

Continue Appendix 5

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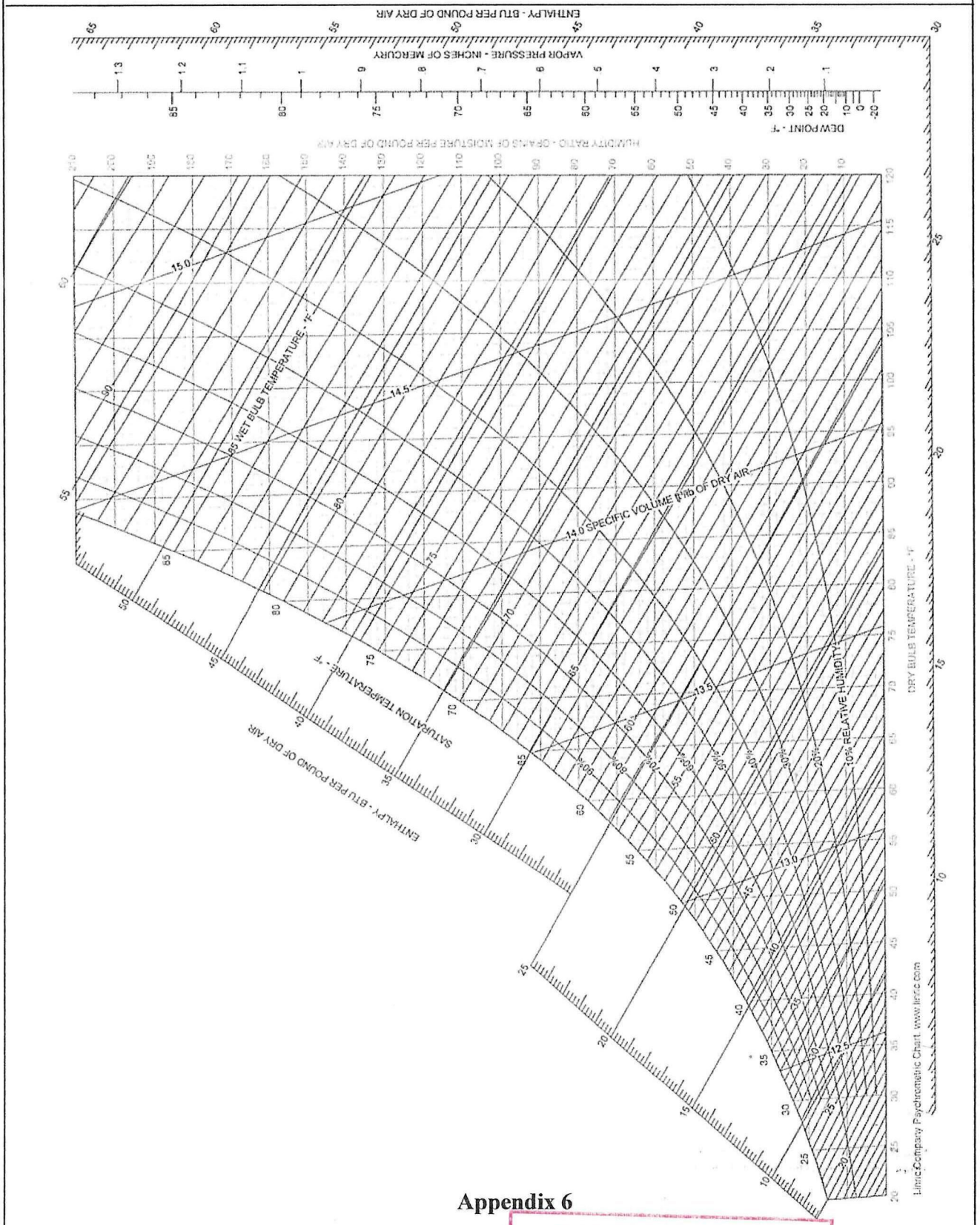
Thermal Properties of Building and Insulating Materials at a Mean Temperature of 75°F (English Units) *(continued)*

Material	Description	Density P	Thermal Conductivity k	Unit Conductance C	Unit Resistance: Per Inch Thickness 1/k	Unit Resistance: For Thickness Listed 1/C	Specific Heat
		$\frac{lbm}{ft^2}$	$\frac{Btu \cdot in}{ft^2 \cdot hr \cdot F}$	$\frac{Btu}{hr \cdot ft^2 \cdot F}$	$\frac{ft^2 \cdot hr \cdot F}{Btu \cdot in}$	$\frac{hf \cdot ft^2 \cdot F}{Btu}$	$\frac{Btu}{lbm \cdot F}$
Loose Fill	Mineral fiber – rock, slag or glass						
	Approximately 3.75 – 5 in. or 75 – 125 mm	0.6 – 2.0	-	-	-	11	0.17
	Approximately 6.5 – 8.75 in. or 165 – 222 mm	0.6 – 2.0	-	-	-	19	0.17
	Approximately 7.5 – 10 in. or 191 – 254 mm	-	-	-	-	22	0.17
	Approximately 7 ¼ in. or 185 mm	-	-	-	-	30	0.17
	Silica aerogel	7.6	0.17	-	5.88	-	-
	Vermiculite (expanded)	7 – 8	0.47	-	2.13	-	-
Roof Insulation	Preformed, for use above deck						
	Approximately ½ in. or 13 mm	-	-	0.72	-	1.39	-
	Approximately 1 in. or 25 mm	-	-	0.36	-	2.78	-
	Approximately 2 in. or 50 mm	-	-	0.19	-	5.56	-
	Cellular glass	9	0.4	-	2.5	-	0.21
Masonry Materials Concretes	Lightweight aggregates including expanded shale, clay or slate; expanded slags; cinders; pumice; vermiculite; also cellular concretes	200	5.2	-	0.19	-	-
		100	3.6	-	0.28	-	-
		80	2.5	-	0.40	-	-
		40	1.15	-	0.86	-	-
		20	0.70	-	1.43	-	-
	Sand and gravel or stone aggregate (not dried)	140	12.0	-	0.08	-	-

Continue Appendix 5

FINAL EXAMINATION

SEMESTER / SESSION : SEM I 2019/2020
COURSE NAME : HEATING, VENTILATING & AIR CONDITIONING SYSTEM
PROGRAMME CODE : 3BNB
COURSE CODE : BNB 31203



Appendix 6

FINAL EXAMINATION

SEMESTER / SESSION	: SEM I 2019/2020	PROGRAMME CODE	: 3BNB
COURSE NAME	: HEATING, VENTILATING & AIR CONDITIONING SYSTEM	COURSE CODE	: BNB 31203

FORMULA

$$U = 1 / \Sigma R$$

$$Rx = \Delta x / Kx$$

$$\Sigma R = Ro + \Delta X1/ K1 + \Delta X2/K2 + Ri$$