Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2022/2023

COURSE NAME	: AIR CONDITIONING SYSTEM DESIGN
COURSE CODE	: BBA 40603
PROGRAMME CODE	: BBG
EXAMINATION DATE	: JULY/AUGUST 2023
DURATION	: 3 HOURS
INSTRUCTIONS	1. ANSWER ALL QUESTIONS 2. THIS FINAL EXAMINATION IS CONDUCTED VIA **CLOSED BOOK.** 3. STUDENTS ARE **PROHIBITED** TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RESOURCES DURING THE EXAMINATION CONDUCTED VIA CLOSED BOOK

THIS QUESTION PAPER CONSISTS OF **TWENTY EIGHT (28)** PAGES

Q1 Heating and cooling load estimation play an important role in designing HVAC system.

(a) List **THREE (3)** purposes of HVAC load estimation.

(3 marks)

(b) Discuss relationship of people and the increase of load in a particular space.

(2 marks)

(c) Illustrates infiltration process in a building.

(5 marks)

(d) Discuss free convection and forced convection in heat transfer process and give **ONE (1)** example.

(5 marks)

(e) Discuss the advantages and disadvantages of natural ventilation and mechanical ventilation in a building.

(6 marks)

(f) Determine **TWO (2)** internal load and **TWO (2)** external loads in estimating cooling load in a building.

(4 marks)

Q2 Heat transmission through a building depended on the heat transmission value (U). From a case study, a brick of 4.5 inch consisting 5/8 inch cement plaster on both side. The air moving moving air towards the brick is 7.5 mph with surface emittance $\varepsilon = 0.9$.

(a) Construct the typical layout of the brick with moving air towards the brick with still air on the other side.

(6 marks)

(b) Determine heat transfer resistance of R for all the properties involves in the case study.

(6 marks)

(c) Examine the heat transmission value of U if the outsides air is moving air with 7.5 mph.

(5 marks)

(d) List **THREE (3)** factors that influence the increasing of load apart from number of people.

(3 marks)

(e) Illustrates heat gains in the space or building.

(5 marks)

Q3 **Figure Q3(a)** below shows layout for a first floor building of an office. Referring to the building specification of **Table Q3** on page 5, investigate cooling load of a meeting room using rules of thumb method. Use cooling load form to access specific load in the area.

(a) Wall facing to the outdoor.

(4 marks)

(b) Window glass.

(4 marks)

(c) Partition.

(4 marks)

(d) Ceiling and floor.

(4 marks)

(e) Plan suitable HVAC system to be located in the office based on total load estimation.

(4 marks)

(f) Illustrates air handling unit system for centralized air conditioning system complete with components location.

(5 marks)

Q4 (a) The principal purpose of HVAC system is to provide conditions for human thermal comfort. Define the term 'Thermal Comfort" and give **THREE (3)** parameters related to thermal comfort.

(3 marks)

(b) Discuss the importance of good air distribution system in HVAC system and building.

(2 marks)

(c) As an engineer in XY Company, you need to determine the ductwork size of a sketch as shown in **Figure Q4 (c)** for public building. By using velocity reduction method take a consideration of uniform duct depth 14 inch in the main duct, calculate the friction loss for each duct. Duct calculator can be used as well.

(20 marks)

-END OF QUESTIONS –

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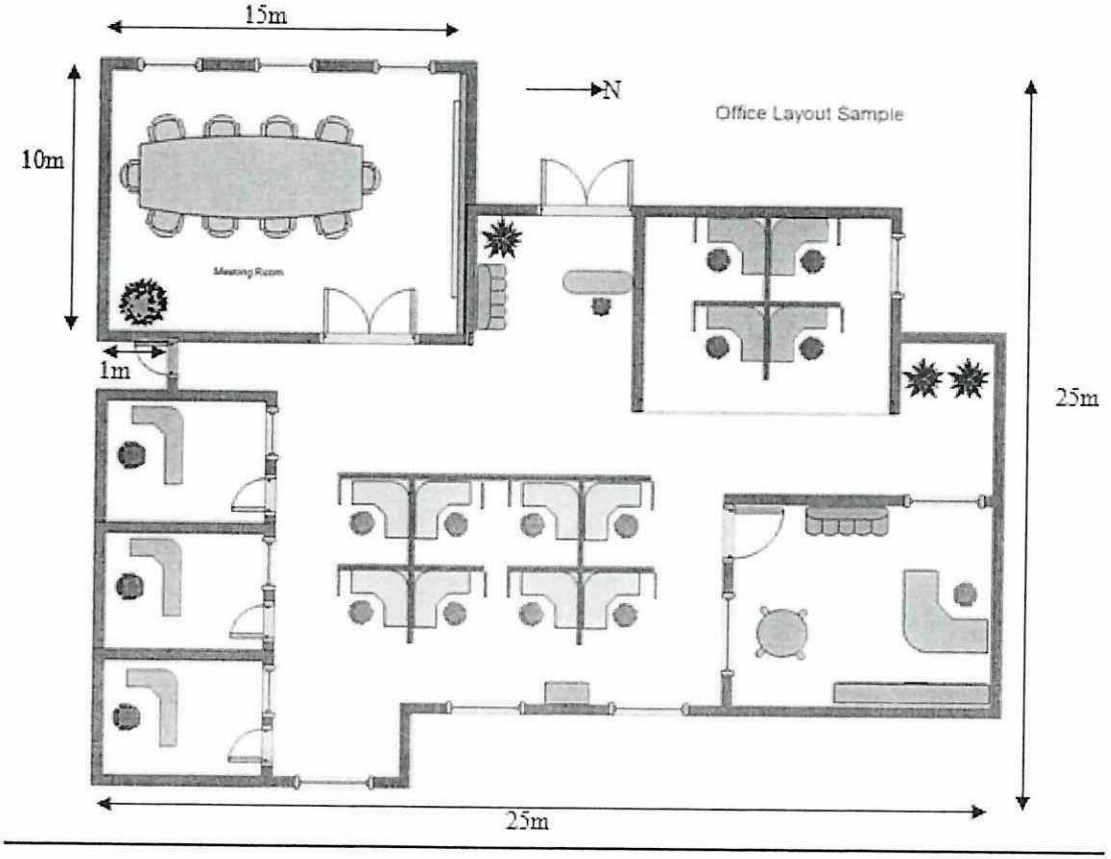

Figure Q3 (a)

Table Q3: Building specifications

Specification Construction	
Building	: First floor office (below have basement)
Wall	: 12 inch dark brick (Door size 1m x 2.5m)
Window	: Single common window glass, 1m x 2.5 m (all part have awning)- 5 mm thickness
Floor	: Only concrete
Roof	: Medium weight construction, covered with tar and gravel
Ceiling	: Height 3.5m
Electrical apparatus	: 1 units electric teapot generated 790W each in the meeting room, 1 LCD projector generate 400W, 4 lamp generate 200W electricity each, and 1 PC generate 800W

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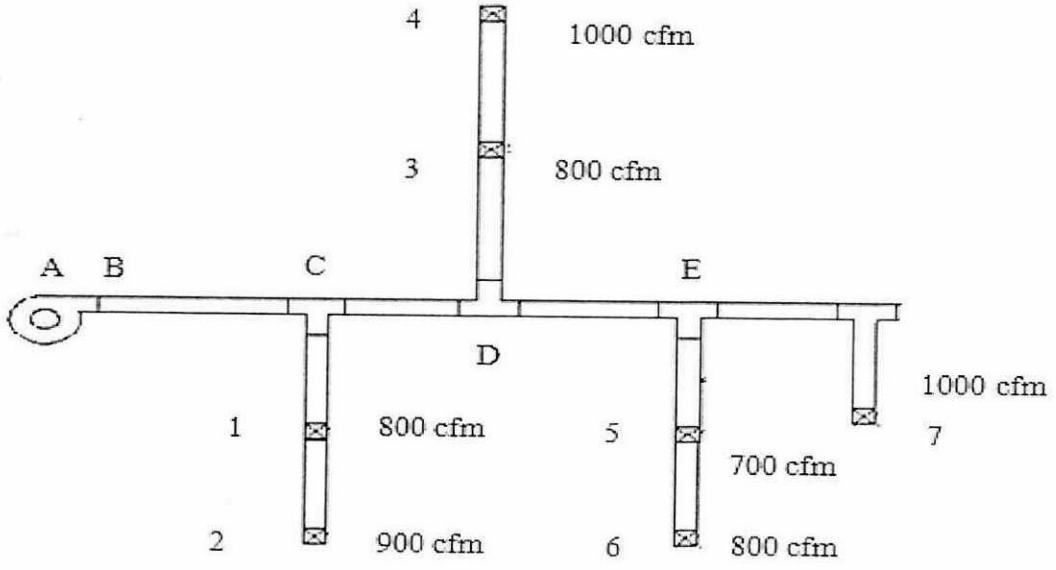

Figure Q4(C)

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Thermal Properties of Building and Insulating Materials at a Mean Temperature of 75F

MATERIAL	DESCRIPTION	Density ρ	Thermal conductivity k	Unit conductance C	Unit Resistance Per inch thickness 1/k	Unit Resistance for thickness listed 1/C	Specific heat
		lbm/ft3	Btu-in/ ft2.hr.F	Btu/hr.ft2.F	ft2.hr.F/Btu-in	hr.ft2.F/Btu	Btu/lbm.F
Building Board Boards,panels, subflooring, sheating, wood-based panel products.	Asbestos cement board	120	-	16.5	-	0.06	0.24
	Gypsum or plasterboard	50	-	3.1	-	0.32	0.26
	1/2in or 13mm	50	-	2.22	-	0.45	
	Plywood	34	0.8	-	1.25	-	0.29
	1/4 in or 6mm	34	-	3.2	-	0.31	0.29
	3/8in or 10mm	34	-	2.13	-	0.47	0.29
	1/2in or 13mm	34	-	1.6	-	0.62	0.29
	3/4in or 20mm	34	-	1.07	-	0.93	0.29
	Insulating board and sheating, regular density	18	-	0.76	-	1.32	0.31
	25/32in or 20mm	18	-	0.49	-	2.06	0.31
	Hashboard, high density, standard tempered	63	1.00	-	1.00	-	0.32
	Particle board						
	Medium Density	50	0.94		1.06	-	0.31
	Underlayment			1.22			
	5/8in or 16mm	40	-		-	0.82	0.29
	Wood subfloor						
	3/4in or 20mm	-	-	1.06	-	0.94	0.33
Building Paper	Vapor-permeable felt	-	-	16.7	-	0.06	
	Vapor-seal, two layers of mopped 15-lb felt	-	-	8.35	-	0.12	
Finish Flooring Materials	Carpet and fibrous pad	-	-	0.48	-	2.08	0.34
	carpet and rubber pad	-	-	0.81	-	1.23	0.33
	Tile-asphalt, linoleum, vinyl, or rubber	-	-	20	-	0.05	0.3

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MATERIAL	DESCRIPTION	Density ρ	Thermal conductivity k	Unit conductance C	Unit Resistance Per inch thickness 1/k	Unit Resistance for thickness listed 1/C	Specific heat
		lbm/ft3	Btu-in/ ft2.hr.F	Btu/hr.ft2.F	ft2.hr.F/Btu-in	hr.ft2.F/Btu	Btu/lbm.F
Insulating Materials							
Blanket and batt	Mineral fiber- fibrous form processed from rock, slag, or glass						
	Approximately 2-2 $^{1/4}$ in or 50-70mm	0.3-2.0	-	0.143	-	7	0.17-0.23
	Approximately 3-3 $^{1/2}$ in or 75-90mm	0.3-2.0	-	0.091	-	11	0.17-0.23
	Approximately 5 $^{1/4}$-6 $^{1/2}$ in or 135-165mm	0.3-2.0	-	0.053	-	19	0.17-0.23
Board and slabs	Cellular glass	8.5	0.38	-	2.63	-	0.24
	Glass fiber, organic bonded	4-9	0.25	-	4	-	0.23
	Expanded polystyrene-molded beads	1	0.28	-	3.57	-	0.29
	Expanded polyurethane-R11 expanded	1.5	0.16	-	6.25	-	0.38
	Mineral fiber with resin binder	15	0.29	-	3.45	-	0.17
Loose Fill	Mineral fiber- rock, slag or glass						
	Approximately 3.75-5 in or 75-125mm	0.6-2.0	-		-	11	0.17
	Approximately 6.5-8.75 in or 165-222mm	0.6-2.0	-		-	19	0.17
	Approximately 7.5-10in or 191-254mm	-	-		-	22	0.17
	Approximately 7 $^{1/4}$ in or 185mm	-	-		-	30	0.17
	Silica aerogel	7.6	0.17	-	5.88	-	
	Vermiculite (expanded)	7-8	0.47	-	2.13	-	

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MATERIAL	DESCRIPTION	Density ρ	Thermal conductivity k	Unit conductance C	Unit Resistance Per inch thickness 1/k	Unit Resistance for thickness listed 1/C	Specific heat
		lbm/ft3	Btu-in/ ft2.hr.F	Btu/hr.ft2.F	ft2.hr.F/Btu-in	hr.ft2.F/Btu	Btu/lbm.F
Roof Insulation	Preformed, for use above deck	-	-	-	-	-	
	Approx 1/2in or 13mm	-	-	0.72	-	1.39	
	Approx 1in or 25mm	-	-	0.36	-	2.78	
	Approx 2in or 50mm	-	-	0.19	-	5.56	
	Cellular glass	9	0.4	-	2.5	-	0.21
Masonry Materials							
Concretes	Lightweight aggregates including	200	5.2	-	0.19	-	
	expanded shale,clay, or slate;	100	3.6	-	0.28	-	
	expanded slags; cinders;	80	2.5	-	0.4	-	
	pumice;vermiculite;also	40	1.15	-	0.86	-	
	cellular concretes	20	0.7	-	1.43	-	
	Sand and gravel or stone	140	12	-	0.08	-	
	aggregate (not dried)						
Masonry Units	Brick, common	120	5.00	-	0.2	-	
	Brick, face	130	9.00	-	0.11	-	
	Concrete blocks,three-oval						
	core-sand and gravel						
	aggregate						
	4 in or 100mm			1.4	-	0.71	
	8 in or 200mm			0.9	-	1.11	
	12 in or 300mm			0.78		1.28	

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MATERIAL	DESCRIPTION	Density ρ	Thermal conductivity k	Unit conductance C	Unit Resistance Per inch thickness 1/k	Unit Resistance for thickness listed 1/C	Specific heat
		lbm/ft3	Btu-in/ ft2.hr.F	Btu/hr.ft2.F	ft2.hr.F/Btu-in	hr.ft2.F/Btu	Btu/lbm.F
	Lightweight aggregate (expanded shale, clay slate or slag; pumice)						
	3 in or 75mm	-	-	0.79	-	1.27	-
	4 in or 100mm	-	-	0.67	-	1.5	-
	8 in or 200mm	-	-	0.5	-	2.00	-
	12 in or 300mm	-	-	0.44	-	2.27	-
Plastering Materials	Cement plaster, sand , aggregate	116	5.00	-	0.2	-	-
	Gypsum plaster:						
	Lightweight aggregate						
	1/2 in or 13mm	45	-	3.12	-	0.32	-
	5/8 in or 16mm	45	-	2.67	-	0.39	-
	Lightweight aggregate metal lath						
	3/4 in or 20mm	-	-	2.13	-	0.47	-
Roofing	Asbestos-cement shingles	120	-	4.76	-	0.21	-
	Asphalt roll roofing	70	-	6.5	-	0.15	-
	Asphlat shingles	70	-	2.27	-	0.44	-
	Built-in roofing						
	1/8in or 10mm	70	-	3.00	-	0.33	0.35
	Slate, 1/2in or 13mm	-	-	20.00	-	0.05	-
	wood shingles-plain or plastic film faced	-	-	1.06	-	0.94	0.31

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MATERIAL	DESCRIPTION	Density ρ	Thermal conductivity k	Unit conductance C	Unit Resistance Per inch thickness 1/k	Unit Resistance for thickness listed 1/C	Specific heat
		lbm/ft3	Btu-in/ft2.hr.F	Btu/hr.ft2.F	ft2.hr.F/Btu-in	hr.ft2.F/Btu	Btu/lbm.F
Siding Materials (on flat surface)	Shingles						
	Asbestos-cement	120	-	4.76	-	0.21	0.31
	Siding						
	Wood, drop, 1in or 25mm	-	-	1.27	-	0.79	0.29
	wood, plywood,3/8 in or 10mm, lapped	-	-	1.59	-	0.59	
	aluminium or steel, over sheathing, hollowbacked	-	-	1.61	-	0.61	
	Insulating board-backed nominal, 3/8in or 10mm	-	-	0.55	-	1.82	
	Insulating board-backed nominal, 3/8 in or 10mm, foil-backed	-	-	0.34	-	2.96	
	Architectural glass	-	-	10.00	-	0.10	
Woods	Maple, oak, and similar hardwoods	45	1.10	-	0.91	-	0.30
	Fir, pine, and similar softwoods	32	0.80	-	1.25	-	0.33
Metals	Aluminium (1100)	171	1536	-	0.000065	-	0.214
	Steel, mild	489	314	-	0.00318	-	0.120
	Steel, stainless	494	108	-	0.00926	-	0.109

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

Position of Surface	Direction of Heat Flow	Surface Emittances											
		$\epsilon = 0.9$				$\epsilon = 0.2$				$\epsilon = 0.05$			
		h		*R*		*h*		*R*		*h*		*R*	
		$\frac{Btu}{hr\text{-}ft^2\text{-}F}$	$\frac{W}{m^2\text{-}C}$	$\frac{hr\text{-}ft^2\text{-}F}{Btu}$	$\frac{m^2\text{-}C}{W}$	$\frac{Btu}{hr\text{-}ft^2\text{-}F}$	$\frac{W}{m^2\text{-}C}$	$\frac{hr\text{-}ft^2\text{-}F}{Btu}$	$\frac{m^2\text{-}C}{W}$	$\frac{Btu}{hr\text{-}ft^2\text{-}F}$	$\frac{W}{m^2\text{-}C}$	$\frac{hr\text{-}ft^2\text{-}F}{Btu}$	$\frac{m^2\text{-}C}{W}$
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.

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1.3 Coefficient of cooling load

1.3.1 Wall faced to the outdoor

able 11-1

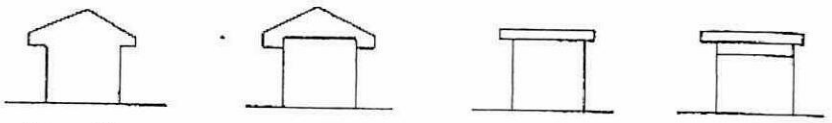
Sort of wall	Coefficient B (kcal/m²h)								Coefficient E (kcal/m²h deg.)
	N	E	S	W	NE	SE	SW	NW	
Light construction wooden, mortar)	17	37	29	51	28	34	43	42	2.5
Medium construction concrete block)	15	40	34	56	32	38	48	45	
Heavy construction concrete 200mm t)	16	34	31	37	29	34	40	26	3.0

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

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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 A×B 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

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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.	8×(1.5~2)	0.3×(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

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OUTDOOR DESIGN CONDITIONS

STATE	DB (°F)	WB (°F)	L_{loc}	Latitude
Kuching	95	82	110°25'E	1°44'N
Johore Bahru	94	82	103°44' E	1°63'N
Kuala Lumpur	95	82	101°42' E	3°12'N
Penang	93	82	100°48' E	5°30'N
K.Terengganu	92	82	103°09' E	5°33'N
Kota Bharu	94	81	102°15' E	6°17'N
Ipoh	96	79	101°07' E	4°57'N
Kuantan	94	81	102°25' E	3°78'N
Malacca	95	80	102°23' 4" E	2°27'N
K.Kinabalu	95	83	116°'11 E	5°97'N
Miri	95	83	113°'59 E	4°33'N
Bandar Baru Bangi	94	82	101°48' E	2°56'N

Table 6-1 Solar Data for 21st Day of Each Month

Month	Equation of Time, min	Declination, degrees	A ($Btu/hrft^2$)	B	C
				(dimensionless ratios)	
Jan	-11.2	-20.0	381.2	0.141	0.103
Feb	-13.9	-10.8	376.4	0.142	0.104
Mar	-7.5	0.0	369.1	0.149	0.109
Apr	1.1	11.6	358.3	0.164	0.120
May	3.1	20.0	350.7	0.177	0.130
June	-1.4	23.45	346.3	0.185	0.137
July	-6.2	20.6	346.6	0.186	0.138
Aug	-2.4	12.3	351.0	0.182	0.134
Sep	7.5	0.0	360.2	0.165	0.121
Oct	15.4	-10.5	369.7	0.152	0.111
Nov	13.8	-19.8	377.3	0.142	0.106
Dec	1.6	-23.45	381.8	0.141	0.103

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TABLE B3.2 SOLAR REFLECTANCE OF VARIOUS FOREGROUND SURFACES

FOREGROUND SURFACE, $\S$	INCIDENT ANGLE (deg), θ					
	20	30	40	50	60	70
Asphalt parking lot	0.09	0.09	0.1	0.1	0.11	0.12
Concrete, new	0.31	0.31	0.32	0.32	0.33	0.34
Concrete, old	0.22	0.22	0.22	0.23	0.23	0.25
Gravel and birumen roof	0.14	0.14	0.14	0.14	0.14	0.14
Green grass or other vegetarian	0.21	0.22	0.23	0.25	0.28	0.31
Red brick	0.45	0.45	0.45	0.45	0.45	0.45
Sand, dry	0.18	0.18	0.18	0.18	0.18	0.18
Snow	0.75	0.75	0.75	0.75	0.75	0.75
Tar paper (black)	0.07	0.07	0.08	0.08	0.08	0.09
Water	0.06	0.24	0.41	0.59	0.76	0.94

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Thermal properties assumed for roof and wall construction details in Tables 7.7, A7.3, and A7.5—USCS units. (*From ASHRAE, 1989, with permission.*)

1 lb_m/ft^3 = 16.02 kg/m^3, 1 ft = 0.3048 m, 1 Btu/(lb_m · °F) = 4.1868 kJ/(kg · K), 1 Btu/(h · ft · °F) = 1.731 W/(m · K), 1 lb_m = 0.45356 kg, 1 Btu/(h · ft^2 · °F) = 5.678 W/(m^2 · K)

Code No.	Description	Thickness and thermal properties					Mass
		L	k	ρ	c_p	R	
A0	Outside surface resistance	0.0	0.0	0.0	0.0	0.33	0.0
A1	1-in stucco	0.0833	0.4	116.0	0.20	0.21	9.7
A2	4-in Face brick	0.333	0.77	125.0	0.22	0.43	41.7
A3	Steel siding	0.005	26.0	480.0	0.10	0.00	2.4
A4	½-in slag	0.0417	0.11	70.0	0.40	0.38	2.2
A5	Outside surface resistance	0.0	0.0	0.0	0.0	0.33	0.0
A6	Finish	0.0417	0.24	78.0	0.26	0.17	3.3
A7	4-in face brick	0.333	0.77	125.0	0.22	0.43	41.7
B1	Airspace resistance	0.0	0.0	0.0	0.0	0.91	0.0
B2	1-in insulation	0.083	0.025	2.0	0.2	3.33	0.2
B3	2-in insulation	0.167	0.025	2.0	0.2	6.67	0.3
B4	3-in insulation	0.25	0.025	2.0	0.2	10.00	0.5
B5	1-in insulation	0.0833	0.025	5.7	0.2	3.33	0.5
B6	2-in insulation	0.167	0.025	5.7	0.2	6.67	1.0
B7	1-in wood	0.0833	0.07	37.0	0.6	10.00	3.1
B8	2.5-in wood	0.2083	0.07	37.0	0.6	2.98	7.7
B9	4-in wood	0.333	0.07	37.0	0.6	4.76	12.3
B10	2-in wood	0.167	0.07	37.0	0.6	2.39	6.2
B11	3-in wood	0.25	0.07	37.0	0.6	3.57	9.3
B12	3-in insulation	0.25	0.025	5.7	0.2	10.00	1.4
B13	4-in insulation	0.333	0.025	5.7	0.2	13.33	1.9
B14	5-in insulation	0.417	0.025	5.7	0.2	16.67	2.4
B15	6-in insulation	0.500	0.025	5.7	0.2	20.00	2.9
B16	0.15-in insulation	0.0126	0.025	5.7	0.2	0.50	0.1
B17	0.3-in insulation	0.0252	0.025	5.7	0.2	1.00	0.1
B18	0.45-in insulation	0.0379	0.025	5.7	0.2	1.50	0.2
B19	0.61-in insulation	0.0505	0.025	5.7	0.2	2.00	0.3
B20	0.76-in insulation	0.0631	0.025	5.7	0.2	2.50	0.4
B21	1.36-in insulation	0.1136	0.025	5.7	0.2	4.50	0.6
B22	1.67-in insulation	0.1388	0.025	5.7	0.2	5.50	0.8
B23	2.42-in insulation	0.2019	0.025	5.7	0.2	8.00	1.2
B24	2.73-in insulation	0.2272	0.025	5.7	0.2	9.00	1.
B25	3.33-in insulation	0.2777	0.025	5.7	0.2	11.00	1.6
B26	3.64-in insulation	0.3029	0.025	5.7	0.2	12.00	1.7
B27	4.54-in insulation	0.3786	0.025	5.7	0.2	15.00	2.2

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Code No.	Description	Thickness and thermal properties					
		L	k	ρ	c_p	R	Mass
C1	4-in clay tile	0.333	0.33	70.0	0.2	1.01	23.3
C2	4-in lightweight concrete block	0.333	0.22	38.0	0.2	1.51	12.7
C3	4-in heavyweight concrete block	0.333	0.47	61.0	0.2	0.71	20.3
C4	4-in common brick	0.333	0.42	120.0	0.2	0.79	40.0
C5	4-in heavyweight concrete	0.333	1.0	140.0	0.2	0.33	46.7
C6	8-in clay tile	0.667	0.33	70.0	0.2	2.00	46.7
C7	8-in lightweight concrete block	0.667	0.33	38.0	0.2	2.00	25.3
C8	8-in heavyweight concrete block	0.667	0.6	61.0	0.2	1.11	40.7
C9	8-in common brick	0.667	0.42	120.0	0.2	1.59	80.0
C10	8-in heavyweight concrete	0.667	1.0	140.0	0.2	0.67	93.4
C11	12-in heavyweight concrete	1.0	1.0	140.0	0.2	1.00	140.0
C12	2-in heavyweight concrete	0.167	1.0	140.0	0.2	0.17	23.3
C13	6-in heavyweight concrete	0.5	1.0	140.0	0.2	0.50	70.0
C14	4-in lightweight concrete	0.333	0.1	40.0	0.2	3.33	13.3
C15	6-in lightweight concrete	0.5	0.1	40.0	0.2	5.00	20.0
C16	8-in lightweight concrete	0.667	0.1	40.0	0.2	6.67	26.7
C17	8-in lightweight conc. blk. (filled)	0.667	0.08	18.0	0.2	8.34	12.0
C18	8-in heavyweight conc. blk. (filled)	0.667	0.34	53.0	0.2	1.96	35.4
C19	12-in lightweight conc. blk. (filled)	1.000	0.08	19.0	0.2	12.50	19.0
C20	12-in heavyweight conc. blk. (filled)	1.000	0.39	56.0	0.2	2.56	56.0
E0	Inside surface resistance	0.0	0.0	0.0	0.0	0.69	0.0
E1	$\frac{3}{4}$-in plaster or gypsum	0.0625	0.42	100.0	0.2	0.15	6.3
E2	$\frac{1}{2}$-in slag or stone	0.0417	0.83	55.0	0.40	0.05	2.3
E3	$\frac{3}{8}$-in felt and membrane	0.0313	0.11	70.0	0.40	0.29	2.2
E4	Ceiling airspace	0.0	0.0	0.0	0.0	1.00	0.0
E5	Acoustic tile	0.0625	0.035	30.0	0.2	1.79	1.9

L = thickness, ft; k = thermal conductivity, Btu/(h · ft · °F); ρ = density, lb/ft^3; c_p = specific heat, Btu/(lb · °F); R = thermal resistance, (°F · ft^2 · h)/Btu; mass = unit mass, lb/ft^2.

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Table 8.4 Roof Classifications for Use with Table 8.2

Mass Location **	Suspended Ceiling	R- factor (ft^2.h.F/Btu)	B7, Wood 1inch	C12, HW Concrete 2inches	A3, Steel Deck	Attic-Ceiling Combination
Mass inside the insulation	Without	0 to 5	*	2	*	*
		5 to 10	*	2	*	*
		10 to 15	*	4	*	*
		15 to 20	*	4	*	*
		20 to 25	*	5	*	*
		25 to 30	*	*	*	*
	With	0 to 5	*	5	*	*
		5 to 10	*	8	*	*
		10 to 15	*	13	*	*
		15 to 20	*	13	*	*
		20 to 25	*	14	*	*
		25 to 30	*	*	*	*
Mass evenly placed	Without	0 to 5	1	2	1	1
		5 to 10	2	*	1	2
		10 to 15	2	*	1	2
		15 to 20	4	*	2	2
		20 to 25	4	*	2	4
		25 to 30	*	*	*	*
	With	0 to 5	*	3	1	*
		5 to 10	4	*	1	*
		10 to 15	5	*	2	*
		15 to 20	9	*	2	*
		20 to 25	10	*	4	*
		25 to 30	10	*	*	*
Mass outside the insulation	Without	0 to 5	*	2	*	*
		5 to 10	*	3	*	*
		10 to 15	*	4	*	*
		15 to 20	*	5	*	*
		20 to 25	*	5	*	*
		25 to 30	*	*	*	*
	With	0 to 5	*	3	*	*
		5 to 10	*	3	*	*
		10 to 15	*	4	*	*
		15 to 20	*	5	*	*
		20 to 25	*	*	*	*
		25 to 30	*	*	*	*

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Table 8.2 Cooling Load Temperature Differences for Calculating Cooling Load from Flat Roofs 3Degrees North Latitude, May

Roof No	Solar Time, hr																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	-1	-2	-4	-5	-6	-7	-6	2	18	37	56	72	82	89	88	81	68	50	31	19	11	7	4	1
2	1	-1	-3	-4	-5	-6	-7	-3	7	23	41	59	73	83	87	85	77	63	46	30	19	12	7	4
3	10	6	4	1	-1	-3	-3	-1	6	17	30	43	55	64	70	72	69	62	51	41	33	25	19	14
4	14	9	5	2	0	-2	-4	-5	-4	1	10	22	36	50	62	71	76	76	70	61	49	38	28	20
5	18	14	10	7	4	2	0	-1	1	6	15	26	37	48	57	64	67	65	60	53	44	36	30	23
8	25	21	18	15	12	10	7	6	7	11	16	23	31	39	45	50	53	54	51	47	42	38	33	29
9	27	22	18	14	10	7	5	3	2	3	7	13	22	32	42	50	57	61	61	58	53	46	39	33
10	32	28	24	20	16	13	10	8	6	6	8	12	18	26	34	41	48	52	54	54	51	47	42	37
13	30	27	25	22	20	17	15	13	13	13	16	19	24	29	35	39	43	45	45	44	42	39	36	33
14	31	29	26	24	22	20	18	17	16	16	18	20	24	28	32	36	39	41	42	41	39	37	35	33

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Table 2.1C Climatic Conditions for Other Countries

Col. 1 Country and Station	Col. 2 Latitude and Longitude	Col. 3 Elevation, Ft	Winter			Summer						
			Col. 4			Col. 5 Design Dry-Bulb			Col. 6 Outdoor Daily Range F deg	Col. 7 Design Wet-Bulb		
			Mean of Annual Extremes	99%	97½%	1%	2½%	5%		1%	2½%	5%
IRAN												
Abadan	30 21N/48 16E	7	32	39	41	116	113	110	32	82	81	81
Meshed	36 17N/59 36E	3104	3	10	14	99	96	93	29	68	67	66
Tehran	35 41N/51 25E	4002	15	20	24	102	100	98	27	75	74	73
IRAQ												
Baghdad	33 20N/44 24E	111	27	32	35	113	111	108	34	73	72	72
Mosul	36 19N/43 09E	730	23	29	32	114	112	110	40	73	72	72
IRELAND												
Dublin	53 22N/6 21W	155	19	24	27	74	72	70	16	65	64	62
Shannon	52 41N/8 55W	8	19	25	28	76	73	71	14	65	64	63
ISRAEL												
Jerusalem	31 47N/35 13E	2485	31	36	38	95	94	92	24	70	69	69
Tel Aviv	32 06N/34 47E	36	33	39	41	96	93	91	16	74	73	72
ITALY												
Milan	45 27N/09 17E	341	12	18	22	80	87	84	20	76	75	74
Naples	40 53N/14 18E	220	28	34	36	91	88	86	19	74	73	72
Rome	41 48N/12 36E	377	25	30	33	94	92	89	24	74	73	72
IVORY COAST												
Abidjan	5 19N/4 01W	65	64	67	69	91	90	88	15	83	82	81
JAPAN												
Fukuoka	33 35N/130 27E	22	26	29	31	92	90	89	20	82	80	79
Sapporo	43 04N/141 21E	56	− 7	1	5	86	83	80	20	76	74	72
Tokyo	35 41N/139 46E	19	21	26	28	91	89	87	14	81	80	79
JORDAN												
Amman	31 57N/35 57E	2548	20	33	36	97	94	92	25	70	69	68
KENYA												
Nairobi	1 16S/36 48E	5971	45	48	50	81	80	78	24	66	65	65
KOREA												
Pyongyang	39 02N/125 41E	186	−10	− 2	3	89	87	85	21	77	76	76
Seoul	37 34N/126 58E	285	− 1	7	9	91	89	87	16	81	79	78
LEBANON												
Beirut	33 54N/35 28E	111	40	42	45	93	91	90	15	78	77	76
LIBERIA												
Monrovia	6 18N/10 48W	75	64	68	69	90	89	88	19	82	82	81
LIBYA												
Bengasi	32 06N/20 04E	82	41	46	48	97	94	91	13	77	76	75
MADAGASCAR												
Tananarive	18 55S/47 33E	4531	39	43	46	86	84	83	23	73	72	71
MALAYSIA												
Kuala Lumpur	3 07N/101 42E	127	67	70	71	94	93	92	20	82	82	81
Penang	5 25N/100 19E	17	66	72	73	93	93	92	18	82	81	80
Singapore	1 18N/103 50E	33	69	71	72	92	91	90	14	82	81	80
MARTINIQUE												
Fort de France	14 37N/61 05W	13	62	64	66	90	89	88	14	81	81	80
MEXICO												
Guadalajara	20 41N/103 20W	5105	35	39	42	93	91	89	29	68	67	66
Mérida	20 58N/89 38W	72	56	59	61	97	95	94	21	80	79	77
Mexico City	19 24N/99 12W	7575	33	37	39	83	81	79	25	61	60	59
Monterrey	25 40N/100 16W	1732	31	38	41	98	95	93	20	79	78	77
Vera Cruz	19 12N/96 08W	184	55	60	62	91	89	88	12	83	83	82
MOROCCO												
Casablanca	33 35N/7 39W	164	36	40	42	94	90	86	50	73	72	70
NEPAL												
Katmandu	27 42N/85 12E	4388	30	33	35	89	87	86	25	78	77	76
NETHERLANDS												
Amsterdam	52 23N/4 55E	5	17	20	23	79	76	73	10	65	64	63
NEW GUINEA												
Manokwari	0 52S/134 05E	62	70	71	72	89	88	87	12	82	81	81
Point Moresby	9 29S/147 09E	126	62	67	69	92	91	90	14	80	80	79
NEW ZEALAND												
Auckland	36 51S/174 46E	140	37	40	42	78	77	76	14	67	66	65
Christ Church	43 32S/172 37E	32	25	28	31	82	79	76	17	68	67	65
Wellington	41 17S/174 46E	394	32	35	37	76	74	72	14	66	65	64
NICARAGUA												
Managua	12 10N/86 15W	135	62	65	67	94	93	92	21	81	80	79
NIGERIA												
Lagos	6 27N/3 24E	10	67	70	71	92	91	90	12	82	82	81
NORWAY												
Bergen	60 24N/5 19E	141	14	17	20	75	74	73	21	67	66	65
Oslo	59 56N/10 44E	308	− 2	0	4	79	77	74	17	67	66	64

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PROGRAMME CODE : BBG
COURSE CODE : BBA 40603

COOLING LOAD FORM

NAME OF CONSTSRUCTOR:
ADDRESS:
NAME OF ROOM:
FLOOR:
NAME OF PERSON INCHARGE:
ROOM AREA:
ROOM VOLUME:

ITEMS				AREA (A)	COOLING			
					coefficient (B)	Cv A x B	coefficient (F)	Load ,Qs 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	INVESION OF OUTDOOR AIR		Room Volume	$m3$			area corr.	
HEAT GENERATION IN THE ROOM	PERSON		Number				1	
	LIGHT	Electric light		kW	860		area of wall	1
		Fluorescent light		kW	1000			1
	ELECTRIC APPARATUS			kW	860			1
	GAS	L.N.G		m^3/h	10000			1
		L.P.G		m^3/h	21700			1

TOTAL COOLING LOAD: Q= _____ kcal/hr
_____ Btu/hr

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

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TABLE 8.11 SUGGESTED VELOCITIES IN LOW VELOCITY AIR CONDITIONING SYSTEMS

	Recommended Velocities, FPM			Maximum Velocities, FPM		
Designation	Residences	Schools, Theaters, Public Buildings	Industrial Buildings	Residences	Schools, Theaters, Public Buildings	Industrial Buildings
Outside air intakes[a]	500	500	500	800	900	1200
Filters[a]	250	300	350	300	350	350
Heating coils[a]	450	500	600	500	600	700
Air washers	500	500	500	500	500	500
Suction connections	700	800	1000	900	1000	1400
Fan outlets	1000–1600	1300–2000	1600–2400	1700	1500–2200	1700–2800
Main ducts	700–900	1000–1300	1200–1800	800–1200	1100–1600	1300–2200
Branch ducts	600	600–900	800–1000	700–1000	800–1300	1000–1800
Branch risers	500	600–700	800	650–800	800–1200	1000–1600

Application	Place	Air Change Rate (time/H)
General Homes	Living Room	6
	Toilets	10
	Kitchens	15
Hotels	Guest Rooms, Corridors	5
	Dining Room, Restaurants	6
	Dance Halls	8
	Banquet Rooms, Wash Rooms, Toilet	10
	Cooking Rooms, Washing Shop	15
	Cuisines, Engine Rooms, Boiler Rooms	20
Scholls	Classrooms, Libraries, Auditoriums, Chemical Laboratories	6
	Gymnasiums	8
	Toilets	12
	Cooking Rooms	15
Hospitals	Consulation Rooms, Sickrooms, Office Corridor	6
	Waiting Rooms Bathrooms, Dining Rooms, Toilets, Respiratory Sick Rooms	10
	Operation Rooms, Disinfecting Rooms, Washing Rooms, Cooking Rooms	15
	Engine Rooms, Boiler Rooms	20
Theatres	Audience Rooms, Corridor	6
Cinema House	Smoking Room, Toilets	12
General Building	Office	6
	Waiting Rooms, Show Rooms, Toilets	10
	Meeting Rooms	12
Public Toilet		20

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ED4-1 Transition, Round to Round, Exhaust/Return Systems

	C_o Values												
	θ												
A_o/A_1	0	3	5	10	15	20	30	45	60	90	120	150	180
0.063	0.0	0.18	0.18	0.20	0.29	0.38	0.60	0.84	0.88	0.88	0.88	0.88	0.88
0.10	0.0	0.20	0.18	0.20	0.27	0.38	0.59	0.76	0.80	0.83	0.84	0.83	0.83
0.167	0.0	0.18	0.17	0.18	0.25	0.33	0.48	0.66	0.77	0.74	0.73	0.73	0.72
0.25	0.0	0.20	0.17	0.16	0.21	0.30	0.46	0.61	0.68	0.64	0.63	0.62	0.62
0.50	0.0	0.15	0.13	0.11	0.13	0.19	0.32	0.33	0.33	0.32	0.31	0.30	0.30
1.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.00	0.0	0.30	0.26	0.21	0.19	0.19	0.19	0.23	0.27	0.51	0.73	0.90	0.95
4.00	0.0	1.60	1.14	0.75	0.70	0.70	0.70	0.90	1.09	2.78	4.29	5.63	6.53
6.00	0.0	3.89	3.02	1.73	1.58	1.58	1.58	2.12	2.66	6.62	10.01	13.03	15.12
10.00	0.0	11.80	9.30	5.30	5.00	5.00	5.00	6.45	7.90	19.00	28.50	36.70	42.70

coefficient for 90 ° elbow						
R/D	**0.5**	**0.75**	**1.0**	**1.5**	**2.0**	**2.5**
C'	**0.71**	**0.33**	**0.22**	**0.15**	**0.13**	**0.12**

Angle Correction Factors K_θ

θ	0	20	30	45	60	75	90	110	130	150	180
K_θ	0	0.31	0.45	0.60	0.78	0.90	1.00	1.13	1.20	1.28	1.40

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Various formula

(i) $\sum R = Ro + R1 + R2 + R3 + Rí$

(ii) $R' = \Delta x / k$

(iii) $U = 1 / \sum R$

(iv) $Q = \text{Area } (ft^2) \times \text{Coefficient } (Btu.hr/ft^2)$

(v) *Air Flow rate* $Q = VA$

(vi) *Air Flow Rate for Heating Load* $Q = L_h / [\Delta T * 1.08]$

(vii) *Static loss of straight section duct* $h_L = L * C_{L\_100}$ [in.w.g]

(viii) *Dynamic Loss for fitting or transformation* $h_L = C [V/4005]^2$

(ix) *Dynamic loses coefficient for round fitting duct* $C = K_\theta C'$

Fan Law [Frist Law]

$$\frac{Q_1}{Q_2} = \frac{N_1}{N_2} \qquad \frac{P_1}{P_2} = \left(\frac{N_1}{N_2}\right)^2 \qquad \frac{Hp_1}{Hp_2} = \left(\frac{N_1}{N_2}\right)^3$$

Fan Law [Second Law]

$$\frac{Q_1}{Q_2} = \left(\frac{D_1}{D_2}\right)^3 \qquad \frac{P_1}{P_2} = \left(\frac{D_1}{D_2}\right)^2 \qquad \frac{Hp_1}{Hp_2} = \left(\frac{D_1}{D_2}\right)^5$$

System Characteristics : Pressure loss calculation $H_{f2} = H_{f1} * [cfm_2/cfm_1]^2$