MECH4880

Refrigeration and Air Condition

Assignment 1 Part A

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Executive Summary

To complete the part A of project, the whole process can be divided into following steps:

(1) Define the design day for summer and winter.

(2) Calculate the U-value and R- value of the specific walls.

(3) Calculate the heat load caused by solar transmission

(4) Calculate the external load of partition.

(5) Calculate the external load of the rooms in winter.

(6) Calculate the internal load of the rooms in summer.

(7) Calculate the internal load of the rooms in winter.

(8) Figure out the cooling and heating load of room 212 and room 213.

(9) Painting the psychrometric chart of both 2 rooms in condition of summer.

After finishing these 9 steps, the HVAC system can be designed for these two rooms, the result of part A are shown in Table 1,Table 2 , Table 3, and table4

These four tables contains all the important figures of part A, which are U-value of each part of rooms, the storage mass of room212 and room213,the external load of room212 and room213, the internal load of room212 and room213, and total heat load of room212 and room213. Furthermore, the cooling coil load of room212 and room213 are also shown.

Table 1 Summer condition of room212

	summer										
		U-value(W/m^2.℃)	Storage Mass(kg/m^2)	External load(w)		Internal load(kw)		Cooling load		cooling coil load
				external wall	partition	sensible	latent	sensible	latent	
room212	ceiling+roof	0.185	79191.45kg	864.79				864.79		75kw
	floor	0.201	61372kg		-72			-72		
	Eastwall	0.333	22755.4kg	292				292		
	North wall	0.93	16603.2kg							
	South wall	0.77	41968.8kg							
	west wall	2.923		4468				4468		
	Window			1642.9				1642.9		
	people					5040	4320	5040	4320	
	light					9781.2		9781.2		
	equipment					12168.5	3710	12168.5	3710	
	infiltration					8719	6880	8719	6880	
	Total		415	7267.69	-72	35708.7	14910	42904.39	14910	

Table 2 Winter condition of room212

	winter									
		U-value(W/m^2.℃)	Storage Mass(kg/m^2)	External load(w)		Internal load(kw)		Heating load	
				external surfaces	partition	sensible	latent	sensible	latent
room212	ceiling+roof	0.17	79191.45kg	1253.07				1253.07	
	floor	0.201	61372kg		36			36	
	Eastwall	0.335	22755.4kg	658.4				658.4	
	North wall	0.94	16603.2kg						
	South wall	0.78	41968.8kg						
	west wall	3.048		8986				8986	
	Window			2995				2995	
	people					0		0	
	light					-3912		-3912	
	equipment					-640	0	-640	
	infiltration					9445	10578	9445	10578
	Total		415					18821.47	10578

Table 3 Summer condition of room213

	summer											
			U-value(W/m^2.℃)	Storage Mass(kg/m^2)	External load(w)		Internal load(w)		Cooling load		cooling coil load
					external surfaces	partition	sensible	latent	sensible	latent	
room213	ceiling+roof		0.185	96622.2kg	853				853		204.75kw
	floor		0.201	68453.775kg		-183.75			-183.75		
	Eastwall		0.333	25380.8kg	320				320		
	North wall		0.77	41968.8kg							
	South wall		0.442	16595.08kg	48				48		
	west wall	glazing	2.923		2406				2406		
		partition	0.93								
	Window				2647.5				2647.5		
	people						6840	6840	6840	6840	
	light						10596		10596		
	equipment						95879	24900	95879	24900	
	infiltration						9258	7305	9258	7305	
	Total			464	6274.5	-183.75	122573	39045	128663.8	39045	

Table 4 Winter condition of room212

	winter									
			U-value(W/mˆ2.℃)	Storage Mass(kg/mˆ2)	External load(w)		Internal load(w)		Heating load	
					external surfaces	partition	sensible	latent	sensible	latent
room213	ceiling+roof		0.17	96622.2kg	1397.655				1397.655	
	floor		0.201	68453.775kg		91			91	
	Eastwall		0.335	25380.8kg	734.4				734.4	
	North wall		0.78	41968.8kg						
	South wall		0.444	16595.08kg	537				537	
	west wall	glazing	3.048		4839				4839	
		partition	0.94							
	Window				4839				4839	
	people									
	light						-4238.6		-4238.64	
	equipment						-2160		-2160	
	infiltration						9633	10839	9633	10839
	Total			464			3234.36	10839	15672.42	10839

Contents

1 Introduction

1.1 Project scope

The objective of this project is to design a HVAC system for a two storey building which has a basement carpark. The whole project can be divided into Part A and Part B. The purpose of Part A is to calculate the heat load of shop 212 and 213 in both season of summer and winter. The purpose of part B is to calculate the heat load of the entire building by using Camel, moreover, duct design and unit selection also should be complete.

1.2 Introduction of Building

This two storey mall which is composed of 52 different shops and a basement carpark is in 30° South latitude, climate zone 6. The whole area of the shopping centre is about 33400m^2. There is a courtyard in the first floor, and the perimeter of the food court is curved .The building layout is shown below.

Figure 1 Ground floor layout

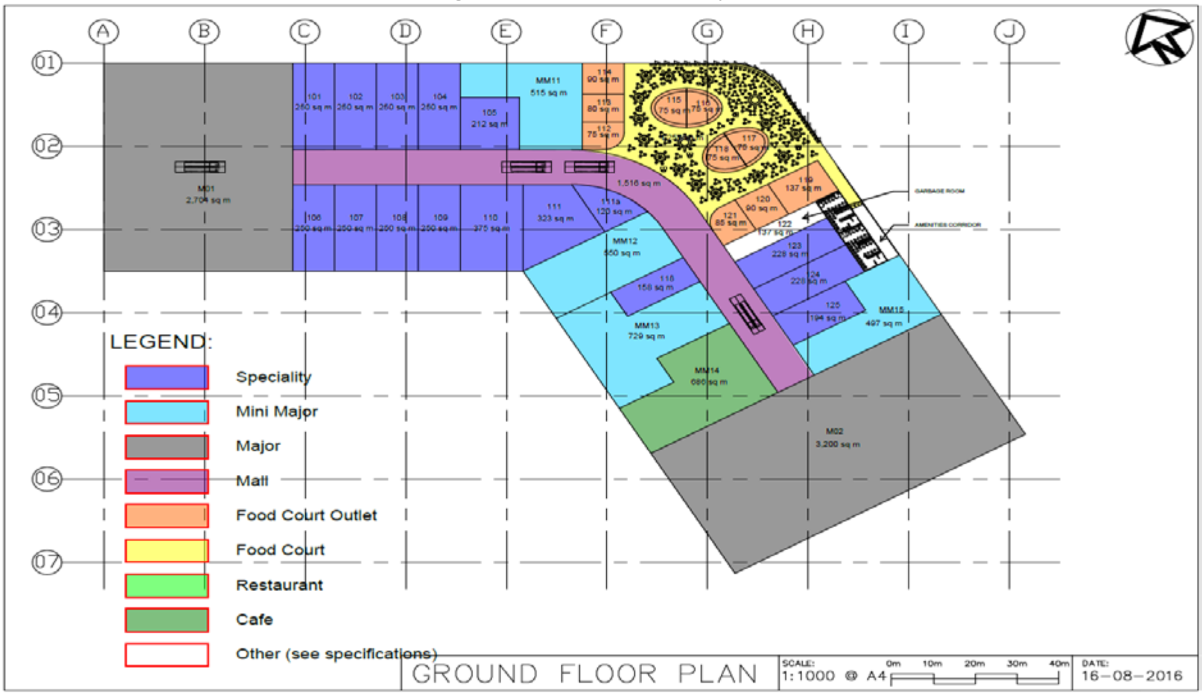
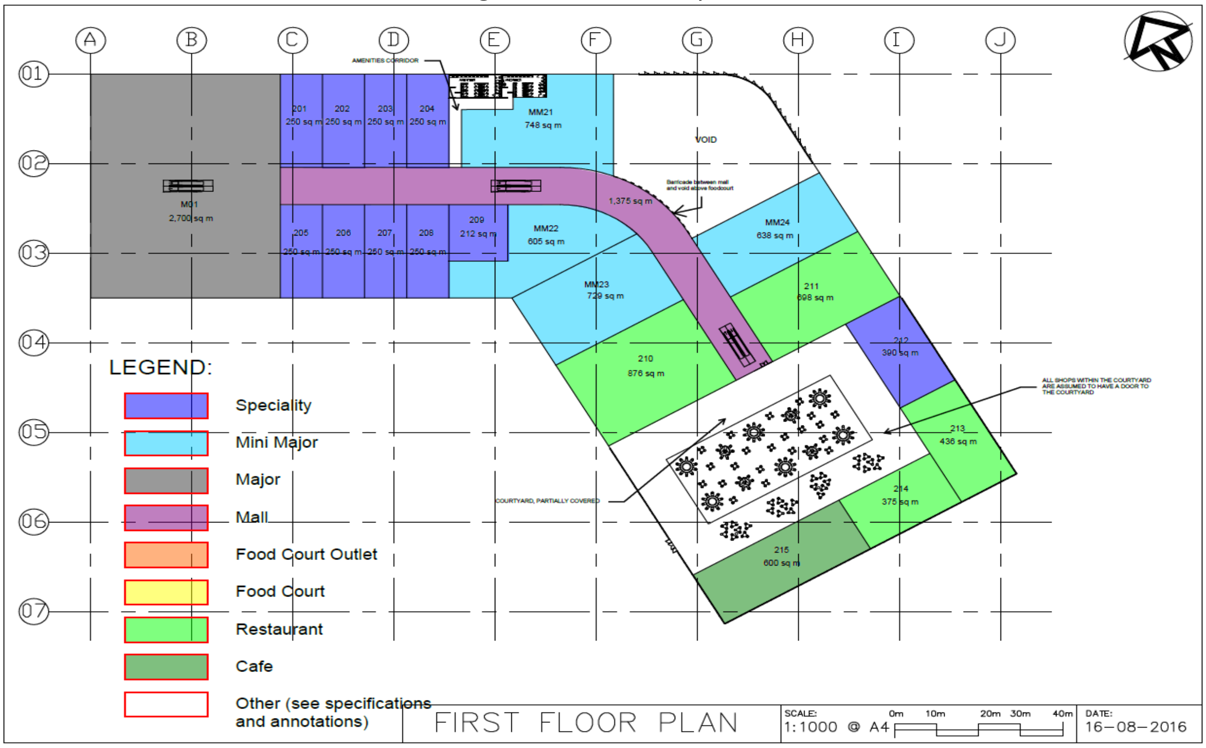


Figure2 First floor layout



2 Assumptions & Justification

2.1 Assumptions of design day

(1) June 21 and December 22 are the design day.

Since June 21and December 22are Summer Solstice and Winter Solstice respectively, they are the hottest day and coldest day.

(2) 3pm is the design time for summer; 7am is the design time for winter.

Since in summer, the solar heat gain of room is high at 3pm, at the same time, the amount of people and equipment turned on are large. The heat load of room is high.

In winter, the temperature at 7 am is low, there is no people in room212 and room213, equipment are turned off, and the room has not experienced sun light for a whole night, the temperature of rooms is the lowest at 7am.

2.2 Assumptions of walls

(1) The thickness of the carpet is 6mm.

According to the information on internet the usual thickness of carpet is changing from5 to 8 mm.

(2) The false ceiling is made of 15mm plasterboard.

Plasterboard is a king of gypsum with good capacity of absorbing moist air and noise, and it's cheap.

(3) The density of concrete slab is 961kg/m^3.

The density of concrete cellular provided byDA09 is ranging from 320 to 1601kg/m^3, taking weight and R-value into consideration, the chose material has a high density which can prevent damage, and it has a relative high resistivity, which is helpful to keep temperature.

(4) The thickness of metal deck is 10mm.

According to information from internet, the average thickness of metal deck is changing from 2mm to 10mm. Meanwhile the deck with 10mm thickness is cheap.

(5) The density of wood deck is 529 kg/m^3

This kind of deck is chose from DA09, which is plywood. Plywood has a good capacity of endurance which makes it can be used for a long time.

(6) The density of wood rafter is 561 kg/m^3

This kind of deck belongs to plywood with fire proofed capacity, wood rafter will suffer high temperature during summer, so it would be safe to choose this kind of deck.

(7) All the brick veneer is composed of 90mm brick and 150mm air gap, and 12mm plaster board.

The brick veneer is chose from DA09. It has a high R-value, which can be helpful to keep room temperature unchanging.

(8) The density of the thin marble is 2700kg/m^3, the thick of the marble is 12mm.

Taking the thickness requirement into consideration, the thickness of marble is chose as 12mm. The density of marble is changing from2643kg/m^3 to 2804kg/m^3.

(9) The density of plaster is 1410kg/m^3, and the thickness of the plaster is 12mm.

This kind of plaster is chose from DA09, with a high density, so its firm and the thickness of plaster changes from 8-12mm.

(10) The thickness of crushed rock is 100mm.

This kind of crushed rock is chosen from DA09, it has a small thickness, but high R-value.

(11)The air gap of the double brick is 50mm; the thickness of the double brick is 270mm.

The thickness of brick is 110mm, which is more firm.

(12) The material of insulation is batts whose density is 32kg /m^3, resistivity is 31.52m.℃/W, thickness is 0.015m.

Batts can be used to make insulation. The density of batts provided by DA09 changes from $32kg/m^3$ to $104kg/m^3$, but the resistivity doesn't change a lot. So choosing a light one to be the insulation.

(13) The type of glass made into window is double glazing.

Double glazing have capacity of sound insulation and heat insulation, it's suitable to be the material of window.

(14) The opening time of these two rooms is 16hours.

The mall would open from 7am to 11pm

(15) In winter, only 40% of the light would be turn on in room 212 and room213.

According to NCC Volume One, the proportion of light turned on is 0.4 at 7am.

(16) In summer the window is dry

In summer, temperature is high; it would be difficult for vapour to condense on window, so it's dry.

(17) In winter the window is wet

Since in winter outside temperature is lower than that of room, there would be moist air condensing on the window.

3. Definitions of design days

3.1 Select design days

On the design day the condition which contains heat load derived from sun light, occupants, and devices in the building is the most severe in the whole year. It can be simply defined as the hottest day and coldest day in the year. So if the HVAC system can dispose the condition of the design day, then the system can guarantee a comfortable condition of the room in the whole year.

The summer design day of the project can be chose as December 22, and winter design day can be chosen as June 21. Since, these two days are Summer Solstice and Winter Solstice.

According to table14 from DA09, the solar heat gain at 7am is 0; meanwhile, the amount of occupants in shop or restaurant is zero, as shop is not opened. So 7am is the coldest time in the day.

According to table14 from DA09, solar heat gain is high at 3pm. simultaneously, taking occupants and equipment into consideration, 3pm is the hottest time. Since, there would be a large amount of people in the shop and restaurant, all the equipment are also turned on.

Table 5 Design day selection

	Summer	Winter
Design day	December 22th	June 21
Design time	3pm	7am

3.2 Defining the design conditions

Design conditions contains outside door conditions, inside door condition. According assignment helper and Camel, the design conditions are shown in the Table 6

Table 6 Design conditions

	external conditions	Internal condition
Summer	33.8℃ DB 22.9WB	24℃ DB 55%RH
Winter	2.1℃ DB 80%RH	21℃ DB 80%RH

3.3 Defining the ceiling height and true floor height

Ceiling height is the height from the floor to the under surface of the ceiling, and the true floor height is the distance from the floor to the upper surface of the ceiling. The two lateral figure of building which is summarized from DA09 are shown below.

Figure 3 lateral view from south west

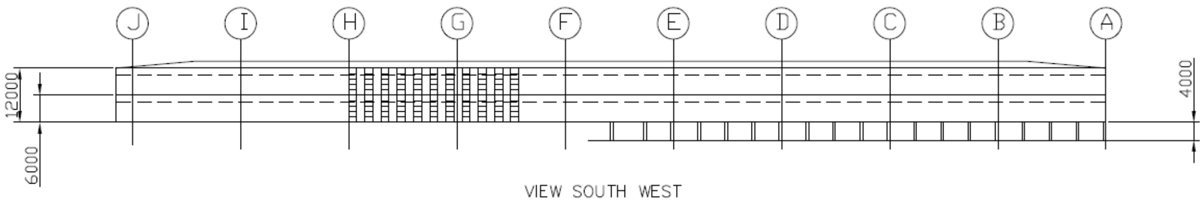
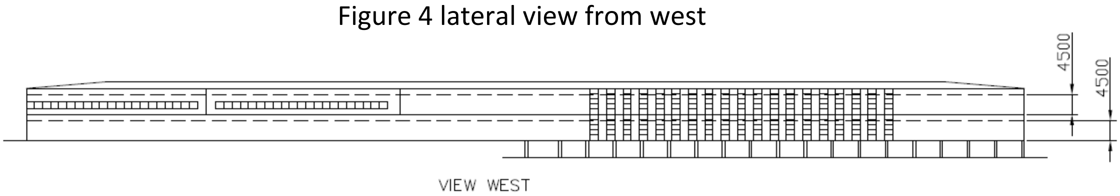


Figure 4 lateral view from west



According to these two figures, the ceiling height is 6000mm, and the true height is 4500mm.

3.4 Definitions of terminologies

To calculating the heat load, some elements of the room is significant: glazing, partition, infiltration, and AHU.

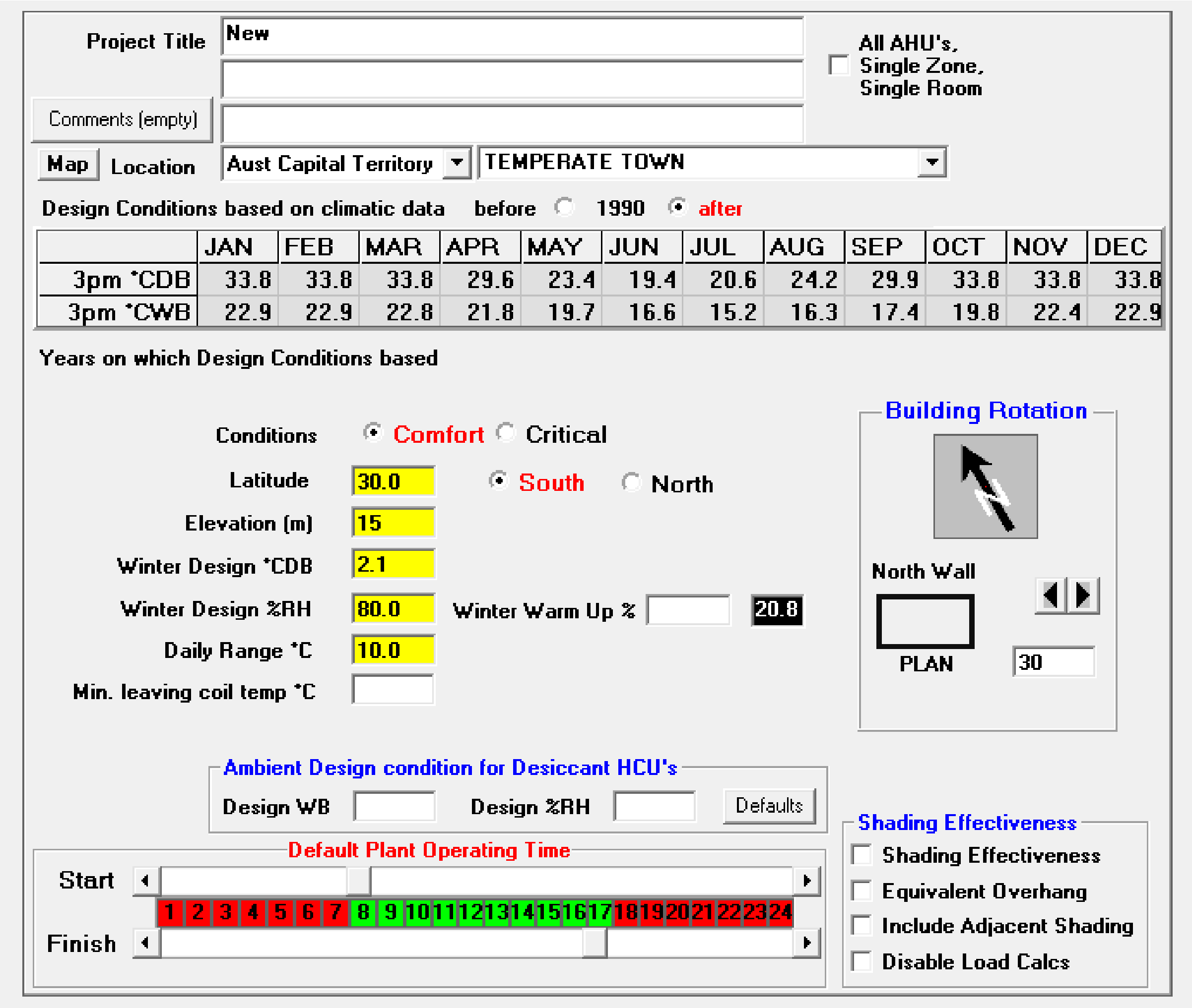
(1) Glazing means a kind of glass material, which is transparent and usually used as windows.

(2) Partition is the internal wall between two rooms.
(3) Infiltration means the phenomenon that outside air come into the room.
(4) AHU means a system which is used to control the supplied air to the building.

3.5 Temperature range

According to information from camel shown in the below figure, the largest temperature in summer is 33.8℃, the lowest temperature in winter is 2.1℃, so the yearly temperature range is 31.7℃. As shown in camel the daily range is 10℃.

Figure 5 Information from camel



4Wall specification

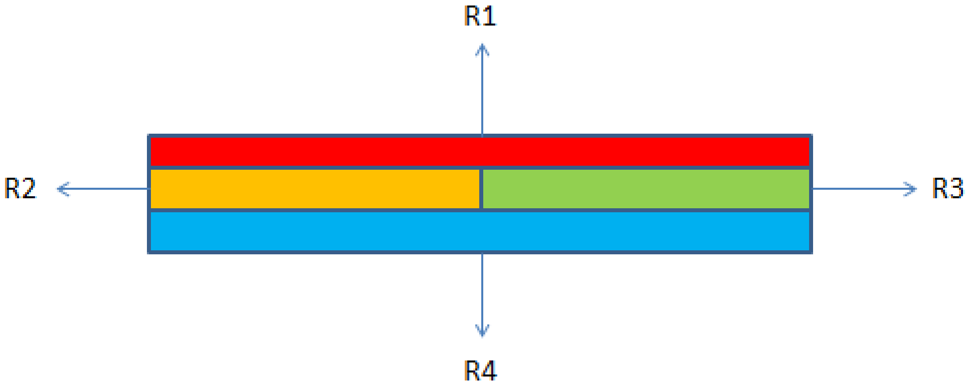
4.1 Definition of U –value and R-value

R-value means thermal resistance; it's the resistance existing in the period of heat transfer. U – Value is the inverse of R-value, which represents the ability of heat conduction of the material.

To calculate the U-value, R-value should firstly be figured out. Taking a wall which is composed of several layers as an example. The Figure 6 Structure of a wall of the wall is shown below.

R-value will be influenced by temperature, and speed of wind. So R –value will change in summer and winter, hence U-value is different in summer and winter.

Figure 6 Structure of a wall



$$\mathrm{R}_{total} = R_1 + R_{parallel} + R_4$$

$$R_{parallel} = \frac{1}{\frac{1}{R_2} + \frac{1}{R_3}}$$

$$R_{total} = R_1 + \frac{1}{\frac{1}{R_2} + \frac{1}{R_3}} + R_4$$

4.2 Calculation of all surfaces

4.2.1 Calculation of Floor

The floor of these two rooms is the same. It is composed of 150mm concrete slab, which is covered by 6mm carpet, and there is a false ceiling blows the floor. The false ceiling is made by 120mm plasterboard. There is still air in both side of the floor. The information of the floor is shown in the below chart. The structure of the wall is shown in the below Figure 7 structure of floor**. (The information of material are quoted from DA09 table 37)**

Figure 7 structure of floor

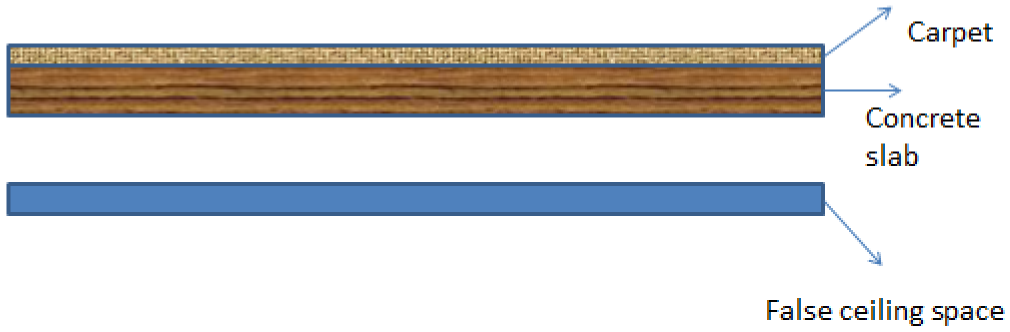


Table 7 Information of floor

floor		
component	R-value$(m^2.℃/W)$	Reference
2×Air Film	0.324	Table37 Page75 DA09
carpet	0.1	Table37 Page76 DA09
150mm concrete slab	0.5775	Table37 Page76 DA09
1500mm Air space	3.255	Table37 Page75 DA09
false ceiling	0.71	Table37 Page78 DA09
total R-value$(m^2.℃/W)$	4.729	
total U-value$(W/m^2.℃)$	0.211	

$$R_{total} = 2 \times R_{air\ film} + R_{carpet} + R_{concrete\ slab} + R_{air\ space} + R_{false\ ceiling}$$

$$= 2 \times 0.162 + 0.1 + 0.5775 + 3.255 + 0.71$$

$$= 4.96(m^2.℃/W)$$

$$U = \frac{1}{R}$$

$$= 0.201(W/m^2.℃)$$

4.2.2 Calculation of Ceiling/Roof

The ceiling of these two rooms has the same structure which is composed of 100mm timber rafters. 12mm plaster whose density is 1410kg/m^3 is below the rafters. There is insulation between the rafters, which is topped by deck of timber and metal. There is a 150mm concrete slab below the plaster. The insulation is made by 100mm batts. Meanwhile there is a 1500mm air gap between the roof and false ceiling. **(The information of material are quoted from DA09 table 37)**

There is a layer of air flow in the outside of the ceiling, and a layer of still air in the other side of the ceiling.

The structure is shown in the below Figure 8. The information of the ceiling is shown in the below Table 8.

Figure 8 Structure of ceiling

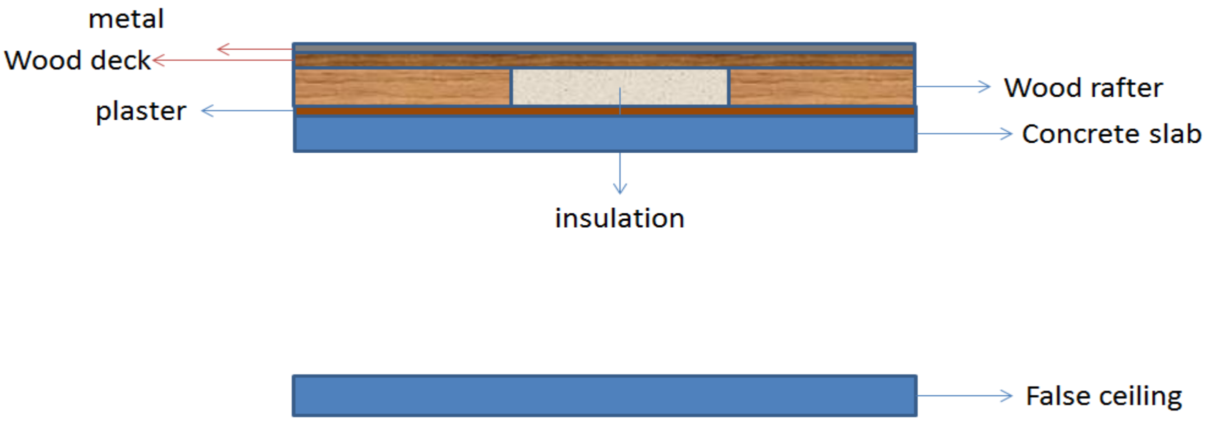


Table 8 Information of ceiling

Ceiling			
Component		R-value($m^2.°C/W$)	References
Air film	Summer	0.044	Table37 Page75 DA09
	Winter	0.03	Table37 Page75 DA09
Metal Deck		0.14	Table37 Page81 DA09
Wood Deck		0.165	Table37 Page82 DA09
Wood Rafter		0.722	Table37 Page82 DA09
Fibreglass		3.15	Table37 Page79 DA09
plaster		0.01848	Table37 Page78 DA09
Concrete slab		0.5775	Table37 Page76 DA09
1500mm air space		3.255	Table37 Page75 DA09
false ceiling		0.71	Table37 Page78 DA09
still air		0.162	Table37 Page75 DA09
total R-value($m^2.°C/W$)	summer	5.38	
	winter	5.872	
total U-value($W/m^2.°C$)	summer	0.185	
	winter	0.172	

$$R_{total(summer)} = R_{airfilm(summer)} + R_{metal} + R_{wood\ deck} + R_{parallel} + R_{plaster} + R_{concrete\ slab} + R_{air\ space} + R_{false\ ceiling} + R_{still\ air}$$

$$R_{parallal} = \frac{1}{\frac{R_{wood\ rafter}*R_{fibreglass}}{R_{wood\ rafter}+R_{fibreglass}}} + \frac{1}{R_{wood\ rafter}} = 0.323882085(m^2.°C/W)$$

$$R_{total(summer)} = 0.044 + 0.14 + 0.165 + 0.323882085 + 3.255 + 0.5775 + 0.01848 + 0.71 + 0.162$$

$$= 5.38(m^2.℃/W)$$

$$U_{value(summer)} = \frac{1}{R_{total(summer)}}$$

$$= 0.185(W/m^2.℃)$$

$$R_{total(winter)} = R_{airfilm(winter)} + R_{metal} + R_{wood\ deck} + R_{parallel} + R_{plaster} + R_{concrete\ slab} + R_{air\ space} + R_{false\ ceiling} + R_{still\ air}$$

$$R_{total(winter)} = 0.03 + 0.14 + 0.66 + 0.323882085 + 3.255 + 0.5775 + 0.01848 + 0.71 + 0.162$$

$$= 5.872(m^2.℃/W)$$

$$U_{value(winter)} = \frac{1}{R_{total(winter)}}$$

$$= 0.172(W/m^2.℃)$$

4.2.3 Calculation of East wall (213,212)

The east wall of room212 and room213 is the same, whose structure is composed of 240mm brick veneer and 12mm marble whose resistivity is 0.6 m. ℃/W. The brick veneer is made by 90mm brick, 150mm air gap.

There is a 12mm plaster layer whose density is 1410 kg/m^3 putted on the one side of the brick veneer. The information of the material of east wall is shown in the below Table 9. The structure of the wall is shown in the below Figure 9. **(The information of material are quoted from DA09 table 25)**

The R-value of air space and air film has been taken into the consideration of R-value of brick veneer.

Figure 9 Structure of east wall

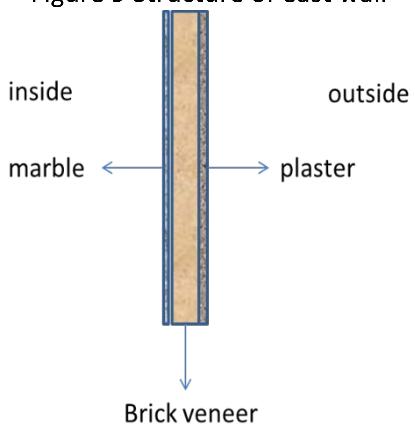


Table 9 Information of east wall

East Wall(213)			
component		R-value($m^2.°C/W$)	Reference
brick veneer	summer	0.492	Table37 Page63 DA09
	winter	0.478	Table37 Page63 DA09
marble		0.0072	Table37 Page79 DA09
total R-value($m^2.°C/W$)	summer	0.4992	
	winter	0.4852	
total U-value($W/m^2.°C$)	summer	2	
	winter	2.06	

$$R_{total(summer)} = R_{brick\ veneer(summer)} + R_{marble}$$

$$= 0.492 + 0.0072$$

$$= 0.4992(m^2.°C/W)$$

$$U_{summer} = \frac{1}{R_{total(summer)}}$$

$$= \quad 2(W/m^2.°C)$$

$$R_{total(winter)} = R_{brick\ veneer(winter)} + R_{marble}$$

$$= 0.478 + 0.0072$$

$$= 0.4852(m^2.°C/W)$$

$$U_{winter} = \frac{1}{R_{total(winter)}}$$

$$= 2.06\left(\frac{W}{m^2}.°C\right)$$

4.2.4 Calculation of West Wall (213)

The west wall of the room 213 has two parts, one is external wall composed of glazing, and the other part is a partition which is composed of brick veneer between room213 and room214. According to assignment helper the U-value of glazing is 5.62, so the R-value of glazing is 0.178.

The brick veneer is made by 90mm brick, 150mm air gap. There is a 12mm plaster layer putted on the one side of the brick veneer. Because one part of the west wall of room213 is an external wall, there are air films existing in the both side of the wall.

The other part of the west wall is partition, but the R-value of brick veneer contains the R-value of outside air film. Hence the R-value of brick veneer should firstly minus the R-value of outside film, and then add the R-value of still air.

The information of the material of west wall and R-value of air films are shown in the below Table 10. **(The information of material are quoted from DA09 table 25 and table37)**

Table 10 Information of west wall

West Wall(213)			
component		R-value$(m^2.\text{°C}/W)$	Reference
Air film	summer	0.044	Table37 Page75 DA09
	winter	0.03	Table37 Page75 DA09
15mmGlazing		0.178	Table37 Page78 DA09
Internal air film		0.12	Table37 Page75 DA09
total R-value$(m^2.\text{°C}/W)$	summer	0.342	
	winter	0.328	
total U-value$(W/m^2.\text{°C})$	summer	2.923977	
	winter	3.04878	
West Wall(213)			
component		U-value	
Brick Veneer	summer	1.76	Table25 Page64 DA09
	winter	1.78	Table25 Page64 DA09

Part 1

$$R_{total(summer)} = R_{air\ film(summer)} + R_{glazing} + R_{internal\ air\ film}$$

$$= 0.044 + 0.178 + 0.12$$

$$= 0.342(m^2.\text{°C}/W)$$

$$U_{summer} = \frac{1}{R_{total(summer)}}$$

$$= 2.923977(W/m^2.\text{°C})$$

$$R_{total(winter)} = R_{air\ film(winter)} + R_{glazing} + R_{internal\ air\ film}$$

$$= 0.03 + 0.178 + 0.12$$

$$= 0.328(m^2.\,℃/W)$$

$$U_{winter} = \frac{1}{R_{total(winter)}}$$

$$= 3.04878(W/m^2.\,℃)$$

Part 2

$$R_{partition(summer)} = R_{brick\ veneer(summer)} - R_{air\ films(summer)} + R_{still\ air}$$

According to DA09, the U-value of brick veneer in summer is 2.03($W/m^2.$ ℃).

Hence $R_{brick\ veneer(summer)} = \frac{1}{2.03} = 0.49(m^2.\,℃/W)$

$$R_{partition(summer)} = 0.49 - 0.044 + 0.12$$

$$= 0.566(m^2.\,℃/W)$$

$$U_{summer} = \frac{1}{R_{partition(summer)}}$$

$$= 1.76(W/m^2.\,℃)$$

$$R_{partition(winter)} = R_{brick\ veneer} - R_{air\ films(winter)} + R_{still\ air}$$

According to DA09, the U-value of brick veneer in winter is 2.09($W/m^2.$ ℃).

Hence $R_{brick\ veneer(winter)} = \frac{1}{2.09} = 0.47(m^2.\,℃/W)$

$$R_{partition(winter)} = 0.47 - 0.03 + 0.12$$

$$= 0.56(m^2.\,℃/W)$$

$$U_{winter} = \frac{1}{R_{partition(winter)}}$$

$$= 1.78\left(\frac{W}{m^2}.\,℃\right)$$

4.2.5 Calculation of West Wall (212)

The west wall of room212 is made of glazing. Because west wall of room212 is an external wall, there are air films existing in the both side of the wall. The information of material of west wall and R-value of air films are shown in the below Table 11. **(The information of material are quoted from DA09 table 37)**

Table 11 Information of West wall of 212

west wall (212)			
component		R-value($m^2.℃/W$)	Reference
Air film	summer	0.044	Table37 Page75 DA09
	winter	0.03	Table37 Page75 DA09
15mmGlazing		0.178	Table37 Page78 DA09
Internal air film		0.12	Table37 Page75 DA09
total R-value($m^2.℃/W$)	summer	0.342	
	winter	0.328	
total U-value($W/m^2.℃$)	summer	2.923977	
	winter	3.04878	

$$R_{total(summer)} = R_{air\ film(summer)} + R_{glazing} + R_{internal\ air\ film}$$

$$= 0.044 + 0.178 + 0.12$$

$$= 0.342(m^2.℃/W)$$

$$U_{summer} = \frac{1}{R_{total(summer)}}$$

$$= 2.923977(W/m^2.℃)$$

$$R_{total(winter)} = R_{air\ film(winter)} + R_{glazing} + R_{internal\ air\ film}$$

$$= 0.03 + 0.178 + 0.12$$

$$= 0.328(m^2.℃/W)$$

$$U_{winter} = \frac{1}{R_{total(winter)}}$$

$$= 3.04878(W/m^2.℃)$$

4.2.6 Calculation of South Wall (213)

The south wall is composed of 100mm crushed rock whose density is 2400kg/m^3, and 12mm plaster whose density is 1410kg/m^3, resistivity is 1.54($m.℃/W$).

The R-value of crushed rock has contained the R-value of outside air film and R-value of still air.

The R-value is shown in the below Table 12 Information of South wall of 213. The structure of the wall is shown in the below Figure 10. **(The information of material are quoted from DA09 table 24)**

Figure 10 Structure of south wall of room213

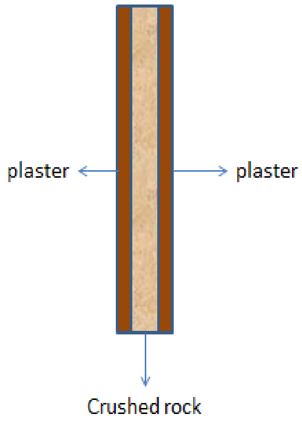


Table 12 Information of South wall of 213

South Wall (213)			
component		R-value$(m^2.°C/W)$	Reference
plaster		0.01848	Table37 Page80 DA09
plaster		0.01848	Table37 Page80 DA09
100mm Crushed Rock Aggregate	summer	0.233	Table24 Page63 DA09
	winter	0.217	Table24 Page63 DA09
total R-value$(m^2.°C/W)$	summer	0.26	
	winter	0.25	
total U-value$(W/m^2.°C)$	summer	3.84	
	winter	4	

$$R_{total(summer)} = 2 \times R_{plaster} + R_{crushed\ rock\ (summer)}$$

$$= 0.01848 \times 2 + 0.233$$

$$= 0.26(m^2.°C/W)$$

$$U_{summer} = \frac{1}{R_{total(summer)}}$$

$$= 3.84(W/m^2.°C)$$

$$R_{total(winter)} = 2 \times R_{plaster} + R_{crushed\ rock\ (winter)}$$

$$= 0.01848 \times 2 + 0.217 = 0.25(m^2.°C/W)$$

$$U_{winter} = \frac{1}{R_{total(winter)}}$$

$$= 4(W/m^2.℃)$$

4.2.7Calculation of North Wall (213)

The north wall of room213 is composed of 270mm double brick, which is plastered in both sides. The double brick is composed of two 90mm bricks and 60mm air gap.

The density of the plaster is 1410kg/m^3, resistivity is 1.54$(m.℃/W)$.

Since the wall is a partition, there are two layer of still air in the both side of the wall.

The R-value is shown in the below Table 13. The structure of the wall is shown in the below Figure 11. **(The information of material are quoted from DA09 table 24 and table37)**

Figure 11Structure of north wall of room213

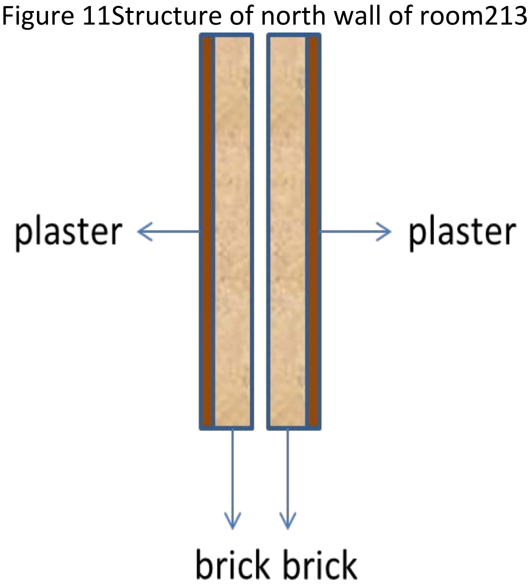


Table 13 Information of North wall of 213

North Wall (213)			
component		R-value$(m^2.\,℃/W)$	Reference
Still air		0.12	Table37 Page75 DA09
plaster		0.01848	Table37 Page80 DA09
double brick	summer	0.51	Table24 Page63 DA09
	winter	0.507	Table24 Page63 DA09
plaster		0.01848	Table37 Page80 DA09
Still air		0.12	Table37 Page75 DA09
total R-value$(m^2.\,℃/W)$	summer	0.79	
	winter	0.78	
total U-value$(W/m^2.\,℃)$	summer	1.26	
	winter	1.27	

$$R_{total(summer)} = R_{plaster} * 2 + R_{double\ brick(summer)} + 2 \times R_{still\ air}$$

$$= 0.01848 \times 2 + 0.51 + 2 \times 0.12$$

$$= 0.79(m^2.\,℃/W)$$

$$U_{summer} = \frac{1}{R_{total(summer)}}$$

$$= 1.26(W/m^2.\,℃)$$

$$R_{total(winter)} = R_{plaster} \times 2 + R_{double\ brick(winter)} + 2 \times R_{still\ air}$$

$$= 0.01848 \times 2 + 0.507 + 2 \times 0.12$$

$$= 0.78(m^2.\,℃/W)$$

$$U_{winter} = \frac{1}{R_{total(winter)}}$$

$$= 1.27(W/m^2.\,℃)$$

4.2.8 Calculation of North Wall (212)

The north wall of room 212 is composed of 240mm brick veneer. The brick veneer is composed of 90mm brick and 150mm air gap. There is a plaster board putted on the one side of the brick veneer.

The density of the plaster is 1410kg/m^3, resistivity is 1.54m. ℃/W .

Because the wall is a partition, there are two layers of still air in the both sides of the wall.

The wall is a partition, but the R-value of brick veneer summarized from DA09 contains the R-value of outside air film. Hence the R-value of brick veneer should firstly minus the R-value of outside film, and then add the R-value of still air.

The information of R-value is shown below. **(The information of material are quoted from DA09 table 25)**

Figure 12Structure of north wall of room212

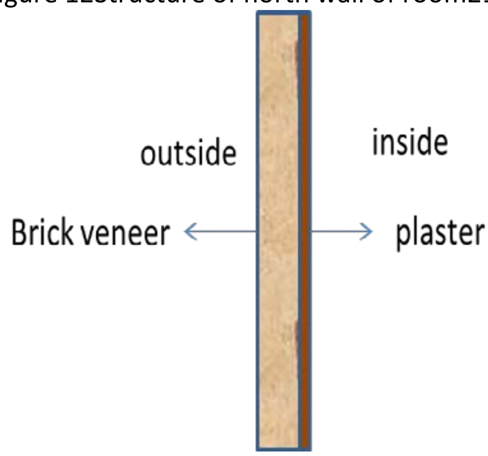


Table 14 Information of North wall of 212

North Wall (212)			
component		R-value($m^2.°C/W$)	Reference
brick veneer	summer	0.492	Table24 Page64 DA09
	winter	0.478	Table24 Page64 DA09
total R-value($m^2.°C/W$)	summer	0.566	
	winter	0.56	
total U-value($W/m^2.°C$)	summer	1.76	
	winter	1.78	

$$R_{partition(summer)} = R_{brick\ veneer(summer)} - R_{air\ films(summer)} + R_{still\ air}$$

According to DA09, the U-value of brick veneer in summer is 2.03($W/m^2.°C$).

Hence $R_{brick\ veneer(summer)} = \frac{1}{2.03} = 0.49(m^2.°C/W)$

$$R_{partition(summer)} = 0.49 - 0.044 + 0.12$$

$$= 0.566(m^2.°C/W)$$

$$U_{summer} = \frac{1}{R_{partition(summer)}}$$

$$= 1.76(W/m^2.°C)$$

$$R_{partition(winter)} = R_{brick\ veneer(winter)} - R_{air\ films(winter)} + R_{still\ air}$$

According to DA09, the U-value of brick veneer in winter is $2.09(W/m^2.℃)$.

Hence $R_{brick\ veneer(winter)} = \frac{1}{2.09} = 0.47(m^2.℃/W)$

$$R_{partition(winter)} = 0.47 - 0.03 + 0.12$$

$$= 0.56(m^2.℃/W)$$

$$U_{winter} = \frac{1}{R_{partition(winter)}}$$

$$= 1.78(W/m^2.℃)$$

4.3 Revision of U-value

The calculated R-value must meet the requirement of NCC 2016 Volume One which determine the minimum R-value of every structure of room, like ceiling, external wall, and floor. If the calculated R-value of the material doesn't meet the minimum requirement, then insulation whose R-value is $0.5(m^2.℃/W)$ should be put on the material, until requirement has been meted.

The material of insulation is batts whose resistivity is $31.52(m.℃/W)$, density is 32kg/m^3. So the thickness of one layer of the insulation is 15.86mm.

4.3.1 Revision of external wall

The external walls of room212 and room213 contain east wall and south wall of room213. **According to the rule of NCC 2016 Volume One shown in Figure 13, the minimum R-value of external wall should be 2.8$(m^2.℃/W)$.**

Figure 13

Table J1.5a OPTIONS FOR EACH PART OF AN EXTERNAL WALL THAT IS PART OF AN ENVELOPE

Climate zone	Options
1, 2 and 3	(a) (i) Achieve a minimum *Total R-Value* of 3.3. (ii) The minimum *Total R-Value* in (i) is reduced— (A) for a wall with a surface density of not less than 220 kg/m^2, by 0.5; and (B) for a wall that is— (aa) facing the south orientation as described in Figure J2.3, by 0.5; or (bb) shaded with a projection shade angle in accordance with Figure J1.5 of— (AA) 15 degrees to not more than 45 degrees, by 0.5; or (BB) more than 45 degrees, by 1.0; and (C) if the outer surface solar absorptance value is not more than 0.6, by 0.5.
	(b) Where the only space for insulation is provided by a furring channel, top hat section, batten or the like— (i) achieve a minimum *Total R-Value* of 1.4; and (ii) satisfy *glazing* energy index Option B of Table J2.4a.
4, 5 and 6	(a) (i) Achieve a minimum *Total R-Value* of 2.8. (ii) The minimum *Total R-Value* in (i) is reduced— (A) for a wall with a surface density of not less than 220 kg/m^2, by 0.5; and (B) for a wall that is— (aa) facing the south orientation as described in Figure J2.3, by 0.5; or (bb) shaded with a projection shade angle in accordance with Figure J1.5 of— (AA) 30 degrees to not more than 60 degrees, by 0.5; or (BB) more than 60 degrees, by 1.0.
	(b) Where the only space for insulation is provided by a furring channel, top hat section, batten or the like— (i) achieve a minimum *Total R-Value* of 1.4; and (ii) satisfy *glazing* energy index Option B of Table J2.4a.

Table J1.5a OPTIONS FOR EACH PART OF AN EXTERNAL WALL THAT IS PART OF AN ENVELOPE— continued

Climate zone	Options
7	(a) Achieve a minimum *Total R-Value* of 2.8.
	(b) Where the only space for insulation is provided by a furring channel, top hat section, batten or the like— (i) achieve a minimum *Total R-Value* of 1.4; and (ii) satisfy *glazing* energy index Option B of Table J2.4a.
8	(a) Achieve a minimum *Total R-Value* of 3.8.
	(b) Where the wall is an earth retaining wall or earth-berm, achieve a minimum *Total R-Value* of 2.0.

(1) East wall:

East wall is composed of brick veneer and marble. The mass per unit area of brick veneer is 184kg/m^2. The density of the marble is 2804kg/m^3, since the thickness of the thin marble is 12mm, the mass per unit area of marble is 33.648kg/m^3. So the surface density of east wall must smaller than 220kg/m^3. **(The information of material are quoted from DA09 table 25 and table37)**

In conclusion, the minimum R-value of east wall should be $2.8(m^2.℃/W)$. The revision of east wall is shown in the Table 15. Since the R-value of this wall is smaller than the minimum R-value. At least five layers of insulation should be put on the wall.

Table 15 Correction of R-value of east wall

East wall						
calculation result of R-value$(m^2.℃/W)$			Minimum R-value $(m^2.℃/W)$	insulation amount	R-value correction $(m^2.℃/W)$	U-value correction $(W/m^2.℃)$
total R-value	summe r	0.499	2.8	5	2.999	0.333
	winter	0.485		5	2.985	0.335

$$R_{correction(summer)} = R_{calculation(summer)} + 0.5 \times A_{(insulation\ amount)}$$

$$= 0.499 + 0.5 \times 5$$

$$= 2.999(m^2.℃/W)$$

$$R_{correction(winter)} = R_{calculation(winter)} + 0.5 \times A_{(insulation\ amount)}$$

$$= 0.485 + 0.5 \times 5$$

$$= 2.985(m^2.℃/W)$$

$$U_{correction(summer)} = \frac{1}{R_{correction(summer)}} = 0.333(W/m^2.℃)$$

$$U_{correction(winter)} = \frac{1}{R_{correction(winter)}} = 0.335(W/m^2.℃)$$

(2) Revision of south wall of room213

The south wall of room213 is made of crushed rock and plaster. The surface density of crushed rock is 240kg/m^2, the thickness of plaster is 12mm, and density of plaster is 1410kg/m^3, hence the surface density of plaster is 16.92kg/m^2. The surface density of south wall of room213 is larger than 220kg/m^2. **(The information of material are quoted from DA09 table 24 and table37)**

Meanwhile, this wall facing south orientation.

Hence the minimum R-value of this wall should be 1.8$(m^2.℃/W)$. The revision of south wall of room213 is shown in the Table 16.

Since the R-value of this wall is smaller than the minimum R-value. At least four layers of insulation should be put on the wall.

Table 16 Revision of south wall of room213

South wall of room213							
calculation result of R-value$(m^2.℃/W)$			Minimum R-value $(m^2.℃/W)$	insulation amount	R-value correction $(m^2.℃/W)$	U-value correction $(W/m^2.℃)$
total R-value	summer	0.26	1.8	4	2.26	0.442
	winter	0.25		4	2.25	0.444

$$R_{correction(summer)} = R_{calculation(summer)} + 0.5 \times A_{(insulation\ amount)}$$

$$= 0.26 + 0.5 \times 4$$

$$= 4.26(m^2.℃/W)$$

$$R_{correction(winter)} = R_{calculation(winter)} + 0.5 \times A_{(insulation\ amount)}$$

$$= 0.25 + 0.5 \times 4$$

$$= 2.25(m^2.℃/W)$$

$$U_{correction(summer)} = \frac{1}{R_{correction(summer)}} = 0.442(W/m^2.℃)$$

$$U_{correction(winter)} = \frac{1}{R_{correction(winter)}} = 0.443(W/m^2.℃)$$

4.3.2 Revision of Internal wall

Internal wall contains north wall of room212, north wall of room213, and partition between room213 and room214. **According to rule of NCC 2016 Volume One shown in the Figure 14, the minimum R-value of internal wall is 1$(m^2.℃/W)$.**

Figure 14 Minimum R-value of internal wall

Table J1.5b AN ENVELOPE WALL OTHER THAN AN EXTERNAL WALL – MINIMUM TOTAL R-VALUE

Location		Climate zone 1	2	3	4	5	6	7	8
(a)	Where the adjacent enclosed non-*conditioned space* has— (i) ventilation of not more than 1.5 air changes per hour of outside air during occupied hours; and (ii) glazing in the external *fabric* as *required* by Part J2; and (iii) *roof lights* in the external *fabric* as *required* by J1.4.	1.0	1.0	Nil	Nil	1.0	1.0	1.5	2.5
(b)	For other than (a)	2.3	2.3	2.3	1.8	1.8	1.8	2.8	3.8
Note:	When assessing the glazing and *roof lights* as *required* by Part J2 and J1.4, assess the glazing and *roof lights* as if the non-*conditioned space* is the same separate *conditioned space*.								

(1)Revision of North wall of room212

The revision of this wall is shown in the Table 17. Since the R-value of this wall is smaller than the minimum R-value. At least one layer of insulation should be put on the wall.

Table 17 Revision of north wall of room212

North wall of room212						
calculation result of R-value$(m^2.℃/W)$			Minimum R-value $(m^2.℃/W)$	insulation amount	R-value correction $(m^2.℃/W)$	U-value correction $(W/m^2.℃)$
total R-value	summe r	0.57	1	1	1.07	0.93
	winter	0.56		1	1.06	0.94

$$R_{correction(summer)} = R_{calculation(summer)} + 0.5 \times A_{(insulation\ amount)}$$

$$= 0.57 + 0.5 \times 1$$

$$= 1.07(m^2.℃/W)$$

$$R_{correction(winter)} = R_{calculation(winter)} + 0.5 \times A_{(insulation\ amount)}$$

$$= 0.56 + 0.5 \times 1$$

$$= 1.06(m^2.℃/W)$$

$$U_{correction(summer)} = \frac{1}{R_{correction(summer)}} = 0.93(W/m^2.℃)$$

$$U_{correction(winter)} = \frac{1}{R_{correction(winter)}} = 0.94(W/m^2.℃$$

(2)Revision of North wall of room213

The revision of this wall is shown in the Table 18. Since the R-value of this wall is smaller than the minimum R-value. At least one layer of insulation should be put on the wall.

Table 18 Revision of north wall of room213

North wall of room213						
calculation result of R-value$(m^2.℃/W)$			Minimum R-value $(m^2.℃/W)$	insulation amount	R-value correction $(m^2.℃/W)$	U-value correction $(W/m^2.℃)$
total R-value	summe r	0.79	1	1	1.29	0.77
	winter	0.78		1	1.28	0.78

$$R_{correction(summer)} = R_{calculation(summer)} + 0.5 \times A_{(insulation\ amount)}$$

$$= 0.79 + 0.5 \times 1$$

$$= 1.29(m^2.℃/W)$$

$$R_{correction(winter)} = R_{calculation(winter)} + 0.5 \times A_{(insulation\ amount)}$$

$$= 0.78 + 0.5 \times 1$$

$$= 1.28(m^2.℃/W)$$

$$U_{correction(summer)} = \frac{1}{R_{correction(summer)}} = 0.77(W/m^2.℃)$$

$$U_{correction(winter)} = \frac{1}{R_{correction(winter)}} = 0.78(W/m^2.℃$$

(3)Revision of partition between roon213 and room214

The revision of the partition is shown in the Table 19. Since the R-value of this wall is smaller than the minimum R-value. At least one layer of insulation should be put on the wall.

Table 19 Revision of north wall of room212

Partition between roon213 and room214						
calculation result of R-value$(m^2.℃/W)$			Minimum R-value $(m^2.℃/W)$	insulation amount	R-value correction $(m^2.℃/W)$	U-value correction $(W/m^2.℃)$
total R-value	summer	0.57	1	1	1.07	0.93
	winter	0.56		1	1.06	0.94

$$R_{correction(summer)} = R_{calculation(summer)} + 0.5 \times A_{(insulation\ amount)}$$

$$= 0.57 + 0.5 \times 1$$

$$= 1.07(m^2.℃/W)$$

$$R_{correction(winter)} = R_{calculation(winter)} + 0.5 \times A_{(insulation\ amount)}$$

$$= 0.56 + 0.5 \times 1$$

$$= 1.06(m^2.℃/W)$$

$$U_{correction(summer)} = \frac{1}{R_{correction(summer)}} = 0.93(W/m^2.℃)$$

$$U_{correction(winter)} = \frac{1}{R_{correction(winter)}} = 0.94(W/m^2.℃$$

4.3.3 Revision of floor

According to the calculation result, the R-value of floor is $4.96(m^2.℃/W)$. The floor of room212and room213 is made by concrete slab. **According to the NCC 2016 Volume One shown in the Figure 15, the minimum R-value is 1.25**$(\boldsymbol{m^2}.℃/\boldsymbol{W})$. Hence, the R-value of floor doesn't need to be modified.

Figure 15 Minimum R-value of floor

Table J1.6 FLOORS — MINIMUM TOTAL R-VALUE

Location	*Climate zone*							
	1	2	3	4	5	6	7	8
Direction of heat flow	Upwards	Downwards and upwards		Downwards				
(a) A slab on ground: (i) Without an in-slab or in-screed heating or cooling system	Nil	Nil	Nil	Nil	Nil	Nil	1.0	2.0
(ii) With an in-slab or in-screed heating or cooling system	1.25	1.25	1.25	1.25	1.25	1.25	1.25	2.25
(b) A suspended floor without an in-slab or in-screed heating or cooling system where the non-*conditioned space* is— (i) enclosed; and (ii) where mechanically ventilated by not more than 1.5 air changes per hour.	1.0	1.0	Nil	Nil	1.0	1.0	1.5	2.5

4.3.4 Revision of glazing.

The glazing of these two rooms contains west wall of room212 and west wall of room213, which has the same structure. According to the project specification, the U-value of glass should be $5.62(W/m^2.℃)$, so the minimum R-value should be $0.178(m^2.℃/W)$.

According the calculation, the R-value of the glazing is $0.178(m^2.℃/W)$. Hence the R-value of glazing doesn't need to be modified.

4.3.5 Revision of ceiling

According to the project specification, the minimum R-value of roof should be $3.2(m^2.℃/W)$. According to calculation result, the summer R-value and winter R-value are$5.38(m^2.℃/W)$ and $5.875\ (m^2.℃/W)$ respectively. So the R-value of ceiling doesn't need to be modified.

4.3.6 Summarization of R-value correction

Table 20 shows the comparison between the result of calculation R-value, U-value and the correction of R-value.

Table 20Summarization of R-Value correction

		Calculation R-value ($m^2.°C/W$)		**Calculation U-value** ($W/m^2.°C$)		**Correction R-value** ($m^2.°C/W$)		**Correction U-value** ($W/m^2.°C$)	
Wall		summer	winter	summer	winter	summer	winter	summer	Winter
Floor		4.96		0.201		4.96		0.201	
Ceiling		5.38	5.875	0.185	0.17	5.38	5.875	0.185	0.17
Eastwall212		0.499	0.485	2	2.06	2.999	2.985	0.333	0.335
Eastwall213		0.499	0.485	2	2.06	2.999	2.985	0.333	0.335
West wall(213)	glazing	0.342	0.328	2.923	3.048	0.342	0.328	2.923	3.048
	partition	0.566	0.56	1.76	1.78	1.07	1.06	0.93	0.94
West wall(212)		0.342	0.328	2.923	3.048	0.342	0.328	2.923	3.048
South wall(213)		0.26	0.25	3.84	4	2.26	2.25	0.442	0.444
North wall(213)		0.79	0.78	1.26	1.27	1.29	1.28	0.77	0.78
North wall(212)		0.566	0.56	1.76	1.78	1.07	1.06	0.93	0.94

4.4 Storage mass

Storage mass is a capacity of heat storage. When it is high, it means the room can store more heat.

4.4.1 Mass of room212

4.4.1.1 Mass of east wall212

The east wall 212 is composed of thin marble, brick veneer, and 5 layers of insulation. According to Figure 4. The width of the east wall212 is 26m, and the height of east wall 6m, the height of window 2m, meanwhile the width of window is equal to the width of east wall212.

The surface density of brick veneer is 184kg/m^3, the density of insulation is 32kg/m^3, the density of marble is 2700kg/m^3. **(The information of material are quoted from DA09 table 25)**

The thickness of insulation is 0.015m; the thickness of marble is 0.012m.

$$M_{eastwall212} = M_{brick\ veneer} + M_{insulation} + M_{marble}$$

$$M_{brick\ veneer} = 184 \times 26 \times (6-2)$$

$$= 19136(\text{kg})$$

$$M_{insulation} = 5 \times (32 \times (26 \times 6 \times 0.015 - 26 \times 2 \times 0.015))$$

$$= 249.6(\text{kg})$$

$$M_{marble} = 2700 \times 26 \times 0.012 \times (6 - 2)$$

$$= 3369.6(\text{kg})$$

$$M_{eastwall212} = 19136 + 249.6 + 3369.6.4$$

$$22755.4(\text{kg})$$

4.4.1.2 Mass of north wall212

The north wall of room 212 is composed of brick veneer, and 1 layer of insulation. The width of the wall is 15m; the height of the wall is 6m.

The surface density of brick veneer is 184kg/m^2, the density of insulation is 32kg/m^3, the thickness of insulation is 0.015m. **(The information of material are quoted from DA09 table 25)**

$$M_{northwall212} = M_{brick\ veneer} + M_{insulation}$$

$$M_{brick\ veneer} = 184 \times 15 \times 6$$

$$= 16560kg$$

$$M_{insulation} = 32 \times 0.015 \times 15 \times 6$$

$$= 43.2kg$$

$$M_{norththwall212} = 16560 + 43.2$$

$$= 16603.2kg$$

4.4.1.3Mass of south wall of room212

The north wall of room213 is composed of double brick, which is plastered in both sides and 1 layer of insulation. The width of the wall is 15m, and the height of the wall is 6m.

The surface density of double brick is 423kg/m^3, the density of plaster is 1410kg/m^3, the thickness of plaster is 0.012m. The density of insulation is 32kg/m^3, the thickness of insulation is 0.015m. **(The information of material are quoted from DA09 table 24)**

$$M_{southwall212} = M_{double\ brick} + 2 \times M_{plaster} + M_{insulation}$$

$$M_{double\ brick} = 423 \times 15 \times 6$$

$$= 38880(kg)$$

$$M_{plaster} = 1410 \times 0.012 \times 15 \times 6$$

$$= 1522.8(kg)$$

$$M_{insulation} = 32 \times 0.015 \times 15 \times 6$$

$$= 43.2(kg)$$

$$M_{southwall212} = 38880 + 2 \times 1522.8 + 43.2$$

$$= 41968.8(kg)$$

4.4.1.4 Mass of ceiling of room212

The ceiling of room212 is composed of metal deck, wood deck, wood rafter, insulation, plaster, and false ceiling. The length of the ceiling is 26m; the width of the ceiling is 15m.

The thickness of metal is 15mm; the density of metal is 48kg/m^3.

The thickness of wood deck is 25mm; the density of wood deck is 561kg/m^3.

The thickness of wood rafter is 100mm; the density of wood rafter is 529kg/m^3.

The thickness of insulation is 100mm; the density of insulation is 32kg/m^3.

The thickness of plaster is 12mm; the density of plaster is 1410kg/m^3.

The thickness of concrete slab is 150mm; the density of concrete slab is 961kg/m^3

The thickness of false ceiling is 15mm; the density of false ceiling is 881kg/m^3.

(The information of material are quoted from DA09 table 37)

$$M_{ceiling\ 212} = M_{metal\ deck} + M_{wood\ deck} + M_{rafter} + M_{insulation} + M_{plaster} + M_{concrete\ slab} + M_{false\ ceiling}$$

$$M_{metal\ deck} = 48 \times 0.015 \times 26 \times 15$$

$$= 280.8(kg)$$

$$M_{wood\ deck} = 561 \times 0.025 \times 26 \times 15 = 5469.75(kg)$$

$$M_{rafter} = 529 \times 0.1 \times 13 \times 15$$

$$= 10315.5(kg)$$

$$M_{insulation} = 32 \times 0.1 \times 13 \times 15$$

$$= 624(kg)$$

$$M_{plaster} = 1410 \times 0.012 \times 26 \times 15$$

$$= 6598.8(kg)$$

$$M_{concrete\ slab} = 961 \times 0.15 \times 26 \times 15$$

$$= 56218.5(kg)$$

$$M_{false\ ceiling} = 881 \times 0.015 \times 26 \times 15$$

$$= 5153.85(kg)$$

$$M_{ceiling} = 79191.45kg$$

4.4.1.5 Mass of floor of room212

The floor of room212 is composed of concrete slab, and false ceiling. The width of floor is 15m; the length of floor is 26m. Since carpet is so light, its mass is not being considered.

The density of concrete slab is 961kg/m^3, the thickness of concrete slab is 150mm.

The density of false ceiling is 881kg/m^3, the thickness of false ceiling is 15mm.

(The information of material are quoted from DA09 table 37)

$$M_{floor} = M_{concrete\ slab} + M_{false\ ceiling}$$

$$M_{concrete\ slab} = 961 \times 0.15 \times 26 \times 15$$

$$= 56218.5kg$$

$$M_{false\ ceiling} = 881 \times 0.015 \times 26 \times 15$$

$$= 5153.85(kg)$$

$$M_{floor} = 56218.5 + 5153.85$$

$$= 61372kg$$

4.4.1.6 Storage mass of room212

$$M_{storage\ 212} = \frac{\left(M_{eastwall212} + M_{ceiling\ 212}\right) + 0.5 \times (M_{southwall212} + M_{norththwall212} + M_{floor})}{A_{floor}}$$

$$A_{floor} = 26 \times 15$$

$$= 390m^2$$

$$M_{storage\ 212} = 415kg/m^2$$

4.4.2 Mass of room213

5.4.2.1Mass of eastwall213

The east wall 213 is composed of thin marble, brick veneer, and 5 layers of insulation. According to figure 4.The width of the east wall212 is 29m, and the height of east wall 6m, the height of window 2m, meanwhile the width of window is equal to the width of east wall213.

The surface density of brick veneer is 184kg/m^3, the density of insulation is 32kg/m^3, the density of marble is 2700kg/m^3.

The thickness of insulation is 0.015m; the thickness of marble is 0.012m.

(The information of material are quoted from DA09 table 25 and table 37)

$$M_{eastwall213} = M_{brick\ veneer} + M_{insulation} + M_{marble}$$

$$M_{brick\ veneer} = 184 \times 29 \times (6-2)$$

$$= 21344(\text{kg})$$

$$M_{insulation} = 5 \times (32 \times (29 \times 6 \times 0.015 - 29 \times 2 \times 0.015))$$

$$= 278.4(\text{kg})$$

$$M_{marble} = 2700 \times 29 \times 0.012 \times (6-2)$$

$$= 3758.4(\text{kg})$$

$$M_{eastwall212} = 21344 + 278.4 + 3758.4$$

$$25380.8(\text{kg})$$

5.4.2.2 Mass of southwall213

The south wall is composed of crushed rock whose surface density is 240kg/m^3, 2 layers of 12mm plaster whose density is 1410kg/m^3, and 4 layers of insulation whose thickness of is 0.015m, density is 32kg/m^3. **(The information of material are quoted from DA09 table 24 and table 37)**

According to instruction of assignment, the width of southwall213 is 15m, the height of this wall is 6m, the height of window is 2m, and the width of window is equal to the width of wall.

$$M_{southwall213} = M_{crushed\ rock} + 2 \times M_{plaster} + 4 \times M_{insulation}$$

$$M_{crushed\ rock} = 240 \times (15 \times 6 - 13 \times 2)$$

$$= 15360(\text{kg})$$

$$M_{plaster} = 1410 \times (15 \times 6 \times 0.012 - 13 \times 2 \times 0.012$$

$$= 1112.2(kg)$$

$$M_{insulation} = 4 \times 32 \times (0.015 \times 6 \times 15 - 0.015 \times 2 \times 13)$$

$$= 122.88(\text{kg})$$

$$M_{southwall213} = 15360 + 1112.2 + 122.88$$

$$= 16595.08(\text{kg})$$

5.4.2.3 Mass of partition of room213

The partition of room213 is made by brick veneer. The width of the wall is 15m; the height of the wall is 6m.

The surface density of brick veneer is 184kg/m^2.

$$M_{partition\ 213} = 184 \times 15 \times 6$$

$$= 16560kg$$

5.4.2.4 Mass of floor of room 213

The floor of room213 is composed of concrete slab, and false ceiling. The width of floor is 15m; the length of floor is 29m. Since carpet is so light, its mass is not being considered.

The density of concrete slab is 961kg/m^3, the thickness of concrete slab is 150mm.

The density of false ceiling is 881kg/m^3, the thickness of false ceiling is 15mm.

(The information of material are quoted from DA09 table 37)

$$M_{floor} = M_{concrete\ slab} + M_{false\ ceiling}$$

$$M_{concrete\ slab} = 961 \times 0.15 \times 29 \times 15$$

$$= 62705.25kg$$

$$M_{false\ ceiling} = 881 \times 0.015 \times 29 \times 15$$

$$= 5748.525(kg)$$

$$M_{floor} = 5748.525 + 62705.25$$

$$= 68453.775kg$$

5.4.2.5 Mass of ceiling of room213

The ceiling of room213 is composed of metal deck, wood deck, wood rafter, insulation, plaster, and false ceiling. The length of the ceiling is 29m; the width of the ceiling is 15m.

The thickness of metal is 10mm; the density of metal is 48kg/m^3.

The thickness of wood deck is 25mm; the density of wood deck is 561kg/m^3.

The thickness of wood rafter is 100mm; the density of wood rafter is 529kg/m^3.

The thickness of insulation is 100mm; the density of insulation is 32kg/m^3.

The thickness of plaster is 12mm; the density of plaster is 1410kg/m^3.

The thickness of concrete slab is 150mm; the density of concrete slab is 1281kg/m^3

The thickness of false ceiling is 120mm; the density of false ceiling is 881kg/m^3.

(The information of material are quoted from DA09 table 37)

$$M_{ceiling\ 212} = M_{metal\ deck} + M_{wood\ deck} + M_{rafter} + M_{insulation} + M_{plaster} + M_{concrete\ slab} + M_{false\ ceiling}$$

$$M_{metal\ deck} = 48 \times 0.12 \times 29 \times 15$$

$$= 2505.6(kg)$$

$$M_{wood\ deck} = 561 \times 0.025 \times 29 \times 15$$

$$= 6100.875(kg)$$

$$M_{rafter} = 529 \times 0.1 \times 14.5 \times 15$$

$$= 11505.75(kg)$$

$$M_{insulation} = 32 \times 0.1 \times 14.5 \times 15$$

$$= 696(kg)$$

$$M_{plaster} = 1410 \times 0.012 \times 29 \times 15$$

$$= 7360.2(kg)$$

$$M_{concrete\ slab} = 961 \times 0.15 \times 29 \times 15$$

$$= 62705.25(kg)$$

$$M_{false\ ceiling} = 881 \times 0.015 \times 29 \times 15$$

$$= 5748.525(kg)$$

$$M_{ceiling} = 96622.2kg$$

5.4.2.6 Result of storage mass of room213

$$M_{storage\ 213} = \frac{\left(M_{eastwall213} + M_{southwall213} + M_{ceiling\ 213}\right) + 0.5 \times (+M_{norththwall213} + M_{floor} + M_{partition\ 213})}{A_{floor}}$$

$$A_{floor} = 29 \times 15$$

$$= 435m^2$$

$$M_{storage\ 213} = 464\text{Kg/m2}$$

Table 21 Storage mass of room212 and room213

	Storage Mass kg/m^2
Room212	415
Room213	464

6 Solar transmission

Only external walls which contain east wall of these rooms, south wall of room213, and roof can experience solar transmission.

Because the external wall will experience conduction heat transfer and radiation heat transfer at the same time. ΔT is only used for conduction, so temperature difference need to be changed. When temperature is modified the heat load will increase.

The calculation of heat load for external glazing should use the below formula.

Conduction:

$$Q = U \times A \times \Delta T$$

Radiation:

$$Q = (Peak\ solar\ heat\ gain) \times SF \times k1 \times k2 \times k3 \times k4 \times k5$$

SF is storage factor

K1 is sash correction factor

K2 is haze correction factor

K3 is altitude correction factor

K4 is dew point correction factor

K5 is glass factor

6.1 Heat load of east wall of room212 (except window)

Outside temperature yearly range is 31.7℃. **According to table 3 in DA09, the outside air temperature doesn't need to be corrected.**

The design condition shows that the design temperature of room212 is 24℃. So the temperature difference of indoor and outdoor is $33.8 - 24 = 9.8$℃

Average daily range in temperate town is 10℃.

According to Average daily range and temperature between outside and inside, and according to Table 23 in DA09, addition to equivalent temperature is -0.2℃.

$$M_{eastwall212} = 22755.4\text{kg}$$

$$Surface\ density = 22755.4 \div (26 \times (6 - 2))$$

$$= 218kg/m^2$$

$$\Delta t_{em} = 9.4 - 0.2 = 9.2℃$$

$$\Delta t_{es} = 7.602℃$$

According to Table 14 in DA09:

$$\sigma_s = 540W/m^2$$

$$\sigma_m = 550W/m^2$$

$$\Delta t_e = 0.55 \times \frac{\sigma_s}{\sigma_m} \times \Delta t_{em} + \left(1 - 0.55\frac{\sigma_s}{\sigma_m}\right) \times \Delta t_{es}$$

$$= 0.55 \times \frac{540}{550} \times 9.2 + \left(1 - 0.55 \times \frac{540}{550}\right) \times 8.39$$

$$= 8.46℃$$

$$Q = U \times A \times \Delta t_e$$

$$= 0.333 \times 26 \times (6 - 2) \times 8.46$$

$$= 292w$$

6.2 Heat load of east wall of room213 (except window)

Outside temperature yearly range is 31.7℃. **According to table 3 in DA09, the outside air temperature doesn't need to be corrected.**

The design condition shows that the design temperature of room213 is 24℃. So the temperature difference of indoor and outdoor is $33.8 - 24 = 9.8℃$

Average daily range in temperate town is 10℃.

According to Average daily range and temperature between outside and inside, and according to Table 23 in DA09, addition to equivalent temperature is -0.2℃.

$$M_{eastwall213} = 25380.8\text{kg}$$

$$Surface\ density = 25380.8 \div (29 \times (6 - 2))$$

$$= 218kg/m^2$$

$$\Delta t_{em} = 9.4 - 0.2 = 9.2℃$$

$$\Delta t_{es} = 7.602 - 0.2$$

$$= 7.4℃$$

According to Table 14 in DA09:

$$\sigma_s = 540W/m^2$$

$$\sigma_m = 550W/m^2$$

$$\Delta t_e = 0.55 \times \frac{\sigma_s}{\sigma_m} \times \Delta t_{em} + \left(1 - 0.55\frac{\sigma_s}{\sigma_m}\right) \times \Delta t_{es}$$

$$= 0.55 \times \frac{540}{550} \times 9.2 + \left(1 - 0.55 \times \frac{540}{550}\right) \times 7.4$$

$$= 8.3℃$$

$$Q = U \times A \times \Delta t_e$$

$$= 0.333 \times 29 \times (6 - 2) \times 8.3$$

$$= 320w$$

6.3 Heat load of south wall of room213 (except window)

Outside temperature yearly range is 31.7℃. **According to table 3 in DA09, the outside air temperature doesn't need to be corrected.**

The design condition shows that the design temperature of room213 is 24℃. So the temperature difference of indoor and outdoor is $33.8 - 24 = 9.8℃$

Average daily range in temperate town is 10℃.

According to Average daily range and temperature between outside and inside, and according to Table 23 in DA09, addition to equivalent temperature is -0.2℃.

$$M_{southwall213} = 15530.4\text{kg}$$

$$Surface\ density = 15530.4 \div (15 \times 6 - 13 \times 2)$$

$$= 242kg/m^2$$

$$\Delta t_{es} = 7.3 - 0.2$$

$$= 7.1℃$$

$$\Delta t_{es} = \Delta t_{em}$$

According to Table 14 in DA09:

$$\sigma_s = 110W/m^2$$

$$\sigma_m = 80W/m^2$$

$$\Delta t_e = 0.55 \times \frac{\sigma_s}{\sigma_m} \times \Delta t_{em} + \left(1 - 0.55\frac{\sigma_s}{\sigma_m}\right) \times \Delta t_{es}$$

$$= 0.55 \times \frac{110}{80} \times 7.1 + \left(1 - 0.55 \times \frac{110}{80}\right) \times 7.1$$

$$= 7.06℃$$

$$Q = U \times A \times \Delta t_e$$

$$= 0.442 \times (15 \times 6 - 13 \times 2) \times 7.06$$

$$= 199W$$

6.4 Heat load of the ceiling of room212

Outside temperature yearly range is 31.7℃. **According to table 3 in DA09, the outside air temperature doesn't need to be corrected.**

The design condition shows that the design temperature of room212 is 24℃. So the temperature difference of indoor and outdoor is $33.8 - 24 = 9.8℃$

Average daily range in temperate town is 10℃.

According to Average daily range and temperature between outside and inside, and according to Table 23 in DA09, addition to equivalent temperature is -0.2℃.

$$M_{ceiling212} = 141422.95kg$$

$$Surface\ density = 141422.95 \div (26 \times 15)$$

$$= 362.6kg/m^2$$

$$\Delta t_{em} = 18.39 - 0.2$$

$$= 18.19℃$$

According to Table 14 in DA09:

$$\sigma_s = 840W/m^2$$

$$\sigma_m = 790W/m^2$$

$$\Delta t_e = 0.55 \times \frac{\sigma_s}{\sigma_m} \times \Delta t_{em} + \left(1 - 0.55\frac{\sigma_s}{\sigma_m}\right) \times \Delta t_{es}$$

$$= \left(0.55 \times \frac{840}{790}\right) \times 18.19$$

$$= 10.6℃$$

$$Q = U \times A \times \Delta t_e$$

$$= 0.185 \times 26 \times 15 \times 10.6$$

$$= 764.79W$$

6.5 Heat load of the ceiling of room213

Outside temperature yearly range is 31.7℃. **According to table 3 in DA09, the outside air temperature doesn't need to be corrected.**

The design condition shows that the design temperature of room212 is 24℃. So the temperature difference of indoor and outdoor is $33.8 - 24 = 9.8℃$

Average daily range in temperate town is 10℃.

According to Average daily range and temperature between outside and inside, and according to Table 23 in DA09, addition to equivalent temperature is -0.2℃.

$$M_{ceiling213} = 157741.875kg$$

$$Surface\ density = 157741.875 \div (29 \times 15)$$

$$= 362.6kg/m^2$$

$$\Delta t_{em} = 18.39 - 0.2$$

$$= 18.19℃$$

According to Table 14 in DA09:

$$\sigma_s = 840W/m^2$$

$$\sigma_m = 790W/m^2$$

$$\Delta t_e = 0.55 \times \frac{\sigma_s}{\sigma_m} \times \Delta t_{em} + \left(1 - 0.55\frac{\sigma_s}{\sigma_m}\right) \times \Delta t_{es}$$

$$= \left(0.55 \times \frac{840}{790}\right) \times 18.19$$

$$= 10.6℃$$

$$Q = U \times A \times \Delta t_e$$

$$= 0.185 \times 29 \times 15 \times 10.6$$

$$= 853W$$

6.6 Heat load of west wall of room212

Since the west wall of room212 is totally shaded, there is only conduction existing. The design condition shows that the design temperature of room212 is 24℃. So the temperature difference of indoor and outdoor is $33.8 - 24 = 9.8$℃

$$Q = U \times A \times \Delta T$$

$$= 2.923 \times 26 \times 6 \times 9.8$$

$$= 4468W$$

6.7 Heat load of west wall of room213

Since the west wall of room213 is totally shaded, there is only conduction existing. The design condition shows that the design temperature of room212 is 24℃. So the temperature difference of indoor and outdoor is $33.8 - 24 = 9.8$℃

$$Q = U \times A \times \Delta T$$

$$= 2.923 \times 14 \times 6 \times 9.8$$

$$= 2406W$$

6.8 Heat load of window in room212

There are two sources for the heat load of window, which are conduction and radiation. The design condition shows that the design temperature of room212 is 24℃. So the temperature difference of indoor and outdoor is $33.8 - 24 = 9.8$℃

Conduction:

$$Q = U \times A \times \Delta T$$

$$= 2.9 \times 26 \times 2 \times 9.8$$

$$= 1477.8W$$

Radiation:

$$Q = (Peak\ solar\ heat\ gain) \times SF \times k1 \times k2 \times k3 \times k4 \times k5 \times A \times SHGC$$

According to Table 14 in DA09:

$$Peak\ solar\ heat\ gain = 47W$$

$$k1(sash\ factor) = 1.17$$

$$k2(haze\ correction\ factor) = 1 - 0.02 = 0.98$$

According to Figure 5, the altitude of temperate town is 15m.

$$k3(altitude) = 1 + \left(\frac{15}{1000}\right) \times 0.023 = 1.000345$$

According to psychrometric chart, the dew point temperature is 14.5℃

$$k4(dew\ point\ factor) = 1 + 0.13 \times \frac{20 - 14.5}{10} = 1.0715$$

$$k5(glass\ factor) = 0.5$$

$$Surface\ density\ of\ floor = \frac{M_{floor}}{A_{floor}}$$

$$= \frac{61372}{26 \times 15}$$

$$= 157kg/m^2$$

According to table 9 in DA09: SF=0.18

$$A_{window} = 52m^2$$

$$Q_{radiation} = 47 \times 0.18 \times 1.17 \times 0.98 \times 1.000345 \times 1.0715 \times 0.5 \times 52 \times 0.611$$

$$= 165W$$

$$Q_{heat\ load} = Q_{conduction} + Q_{radiation}$$

$$= 1642.9W$$

6.9 Heat load of eastern window in room213

There are two sources for the heat load of window, which are conduction and radiation. The design condition shows that the design temperature of room212 is 24℃. So the temperature difference of indoor and outdoor is $33.8 - 24 = 9.8$℃

Conduction:

$$Q = U \times A \times \Delta T$$

$$= 2.9 \times 29 \times 2 \times 9.8$$

$$= 1648.36W$$

Radiation:

$$Q = (Peak\ solar\ heat\ gain) \times SF \times k1 \times k2 \times k3 \times k4 \times k5 \times A \times SHGC$$

According to Table 14 in DA09:

$$Peak\ solar\ heat\ gain = 540W$$

$$k1(sash\ factor) = 1.17$$

$$k2(haze\ correction\ factor) = 0.98$$

According to Figure 5, the altitude of temperate town is 15m.

$$k3(altitude) = 1 + \left(\frac{15}{1000}\right) \times 0.023 = 1.000345$$

According to psychrometric chart, the dew point temperature is 14.5℃

$$k4(dew\ point\ factor) = 1 + 0.13 \times \frac{20 - 14.5}{10} = 1.0715$$

$$k5(glass\ factor) = 0.5$$

$$Surface\ density\ of\ floor = \frac{M_{floor}}{A_{floor}}$$

$$= \frac{68453}{29 \times 15}$$

$$= 157kg/m^2$$

According to table 9 in DA09: SF=0.18

$$A_{window} = 58m^2$$

$$Q_{radiation} = 47 \times 0.18 \times 1.17 \times 0.98 \times 1.000345 \times 1.0715 \times 0.5 \times 58 \times 0.611$$

$$= 184W$$

$$Q_{heat\ load} = Q_{conduction} + Q_{radiation}$$

$$= 1832.5W$$

6.10 Heat load of southern window in room213

There are two sources for the heat load of window, which are conduction and radiation. The design condition shows that the design temperature of room212 is 24℃. So the temperature difference of indoor and outdoor is $33.8 - 24 = 9.8$℃

Conduction:

$$Q = U \times A \times \Delta T$$

$$= 2.9 \times 13 \times 2 \times 9.8$$

$$= 738.9W$$

Radiation:

$$Q = (Peak\ solar\ heat\ gain) \times SF \times k1 \times k2 \times k3 \times k4 \times k5 \times A \times SHGC$$

According to Table 14 in DA09:

$$Peak\ solar\ heat\ gain = 110W$$

$$k1(sash\ factor) = 1.17$$

$$k2(haze\ correction\ factor) = 0.98$$

According to Figure 5, the altitude of temperate town is 15m.

$$k3(altitude) = 1 + \left(\frac{15}{1000}\right) \times 0.023 = 1.000345$$

According to psychrometric chart, the dew point temperature is 14.5℃

$$k4(dew\ point\ factor) = 1 + 0.13 \times \frac{20 - 14.5}{10} = 1.0715$$

$$k5(glass\ factor) = 0.5$$

$$Surface\ density\ of\ floor = \frac{M_{floor}}{A_{floor}}$$

$$= \frac{68453}{29 \times 15}$$

$$= 157kg/m^2$$

According to table 9 in DA09: SF=0.18

$$A_{window} = 26m^2$$

$$Q_{radiation} = 44 \times 0.18 \times 1.17 \times 0.98 \times 1.000345 \times 1.0715 \times 0.5 \times 26 \times 0.611$$

$$= 77.3W$$

$$Q_{heat\ load} = Q_{conduction} + Q_{radiation}$$

$$= 815W$$

6.11 Summary of heat load of external wall

The heat load of external wall is shown in the Table 22.

Table 22 heat load of external wall

external wall	heat load (summer)/W
East wall of room212	292
east wall of room213	320
south wall of room213	48
ceiling of room212	864.79
ceiling of room213	853
west wall of room212	4468
west wall of room213	2406
window in room212	1642.9
eastern window in room213	1832.5
southern window in room213	815

7 External load of partition

The difference between partition and external wall is that partition would not experience the solar light. So there is only conduction among partitions.

The partition contains the north wall of room212, north wall of room213, partition between room 213 and room 214, floor of room212 and floor of room213.

7.1 External load of partition in summer

There is no temperature difference between room211, room212, room213, room214, so there is heat transfer between these rooms.

According to assignment helper, the temperature of roomM02 is different from that of room212, and room213. The temperature of M02 is 22℃.

(1) Heat load of floor of room212

$$Q = U \times A \times \Delta T$$

Because only part of floor is between room212 and M02.The area is$A = 11.5 \times 15 = 172.5m^2$.

$$Q = 0.211 \times 172.5 \times (22 - 24)$$

$$= -72W$$

(2) Heat load of floor of room213

$$Q = U \times A \times \Delta T$$

$$Q = 0.211 \times 15 \times 29 \times (22 - 24)$$

$$= -183.57W$$

7.2 External load of partition in winter

There is no temperature difference between room211, room212, room213, room214, so there is heat transfer between these rooms.

According to assignment helper, the temperature of roomM02 is different from that of room212, and room213. The temperature of M02 is 20℃.

(1) External load of floor of room212

$$Q = U \times A \times \Delta T$$

Because only part of floor is between room212 and M02.The area is$A = 11.5 \times 15 = 172.5m^2$.

$$Q = 0.211 \times 172.5 \times (21 - 20)$$

$$= 36W$$

(2)External load of floor of room213

$$Q = U \times A \times \Delta T$$

$$Q = 0.211 \times 15 \times 29 \times (21 - 20)$$

$$= 91W$$

The external load of partition is shown in the Table 23.

Table 23 External load of partition

season	external load(W)	
	External load of floor of room212	External load of floor of room213
summer	−72	−183. 57
winter	36	91

8 External load for winter

In winter the temperature of room is higher than outside environment, so rooms need to be heated; meanwhile there is no sun light in the design day, which results in no radiation.

The temperature difference of summer and winter is different; meanwhile the U-value can change from summer to winter.

8.1 External load of east wall of room 212(except window)

Because the outside temperature is 2.1℃, the temperature difference between inside and outside is 18.9℃. According to Table 20 the U-value of the wall is 0.335.

$$Q = U \times A \times \Delta T$$

$$= 0.335 \times 26 \times (6 - 2) \times 18.9$$

$$= 658.4W$$

8.2 External load of east wall of room 213(except window)

Because the outside temperature is 2.1℃, the temperature difference between inside and outside is 18.9℃. According to Table 20 the U-value of the wall is 0.335.

$$Q = U \times A \times \Delta T$$

$$= 0.335 \times 29 \times (6 - 2) \times 18.9$$

$$= 734.4W$$

8.3 External load of south wall of room 213(except window)

Because the outside temperature is 2.1℃, the temperature difference between inside and outside is 18.9℃. According to Table 20 the U-value of the wall is 0.444.

$$Q = U \times A \times \Delta T$$

$$= 0.444 \times (15 \times 6 - 13 \times 2) \times 18.9$$

$$= 537W$$

8.4 External load of ceiling of room 212

Because the outside temperature is 2.1℃, the temperature difference between inside and outside is 18.9℃. According to Table 20 the U-value of the ceiling is 0.195.

$$Q = U \times A \times \Delta T$$

$$= 0.17 \times 15 \times 26 \times 18.9$$

$$= 1253.07W$$

8.5 External load of ceiling of room 213

Because the outside temperature is 2.1℃, the temperature difference between inside and outside is 18.9℃. According to Table 20 the U-value of the ceiling is 0.195.

$$Q = U \times A \times \Delta T$$

$$= 0.17 \times 15 \times 29 \times 18.9$$

$$= 1397.655W$$

8.6 External load of window of room 212

Because the outside temperature is 2.1℃, the temperature difference between inside and outside is 18.9℃. According to Table 20 the U-value of the window is 3.048.

$$Q = U \times A \times \Delta T$$

$$= 3.048 \times 26 \times 2 \times 18.9$$

$$= 2995W$$

8.7 External load of window of room 213

Because the outside temperature is 2.1℃, the temperature difference between inside and outside is 18.9℃. According to Table 20 the U-value of the window is 3.048.

$$Q = U \times A \times \Delta T$$

$$= 3.048 \times (29 \times 2 + 13 \times 2) \times 18.9$$

$$= 4839W$$

8.8 External load of west wall of room 212

Because the outside temperature is 2.1℃, the temperature difference between inside and outside is 18.9℃. According to Table 20 the U-value of the wall is 3.048.

$$Q = U \times A \times \Delta T$$

$$= 3.048 \times 26 \times 6 \times 18.9$$

$$= 8986W$$

8.9 External load of west wall of room 213

Because the outside temperature is 2.1℃, the temperature difference between inside and outside is 18.9℃. According to Table 20 the U-value of the wall is 3.048.

$$Q = U \times A \times \Delta T$$

$$= 3.048 \times 14 \times 6 \times 18.9$$

$$= 4839W$$

The summary of external load in winter is shown in the Table 24

Table 24 External load in winter

Wall	external load(W)
east wall of room 212(except window)	658.4
wall of room 213(except window)	734.4
south wall of room 213(except window)	537
ceiling of room 212	1253.07
ceiling of room 213	1397.655
window of room 212	2995
window of room 213	4839
west wall of room 212	8986
west wall of room 213	4839

9 Internal loads for summer

Light, people, and equipment are the three main sources of internal load. Light can only provide sensible heat, people and equipment can provide both latent and sensible heat.

9.1 Internal load of room212

9.1.1 Internal load caused by people

According to assignment helper the maximum of people in room212 is 80. The sensible load and latent load per person is 70W and 60W respectively. Because the design time is 3pm, which is a peak time. The amount of people in room212 can get the biggest. Since the summer condition should be considered as the hottest. According to table 13 in DA09 the diversity factor is 0.9.

(1)Sensible heat

$$Q_{sensible} = HeatGain \times Diversity\ Factor$$

$$Q_{sensible} = 80 \times 70 \times 0.9$$

$$= 5040W$$

(2)Latent heat

$$Q_{latent} = HeatGain \times Diversity\ Factor$$

$$Q_{latent} = 80 \times 60 \times 0.9$$

$$= 4320W$$

9.1.2 Internal load caused by light

According to assignment helper, the sensible heat caused by light is 35W/m^2, according to the storage mass of room212 and table 11 in DA09, the storage factor is chosen to be 0.836. Summer condition should be considered to be the hottest, so according to table 13 in DA09, the diversity factor is chosen to be 1.

$$Q_{sensible} = HeatGain \times Storage\ factor \times diversity\ factor$$

$$Q_{sensible} = 30 \times 26 \times 15 \times 0.836 \times 1$$

$$= 9781.2W$$

9.1.3 Internal load caused by equipment

According to assignment helper and ASHRAE hand book, the equipment and their sensible and latent heat are shown in Table 25. Because the design time is 3pm, which is the peak time, every equipment would be used.

Table 25 Information of equipment in room 212(From ASHRAE)

room212			
equipment	amount	Sensible(W)	Latent(W)
desktop computer(2.3GHZ processor, 3GB RAM)	20	180	0
laptop computer(2.3 GHz processor, 3GB RAM)	15	32.5	0
colour A3 laser printer(speed:24 pages per minute)	1	130	0
large plotter	1	456	0
small steam kettle(35L)	1	21	14
Toaster(small pop-up)-4 slice	2	1310	1160
Microwave oven (residential type)	1	1400	0
Freezer(small)	2	320	0
Coffee maker,10 cups	2	1050	450

(1)Heat load of desktop computer

According to table 17, the heat load of desktop computer is calculated in accordance with the below formula.

$$Q_{sensible} = 20 \times 180$$
$$= 3600W$$
$$Q_{latent} = 0W$$

(2)Heat load of laptop computer

According to table 17, the heat load of laptop computer is calculated in accordance with the below formula.

$$Q_{sensible} = 15 \times 32.5$$
$$= 487.5W$$
$$Q_{latent} = 0W$$

(3)Heat load of colour A3 laser printer

According to table 17, the heat load of laser printer is calculated in accordance with the below formula

$$Q_{sensible} = 1 \times 130$$
$$= 130W$$

$$Q_{latent} = 0W$$

(4)Heat load of large plotter

According to table 17, the heat load of laser printer is calculated in accordance with the below formula.

$$Q_{sensible} = 1 \times 456$$

$$= 456$$

$$Q_{latent} = 0W$$

(5)Heat load of small steam kettle.

According to table 17, since the heat load gathered from ASHRAE bases on per litre of capacity, the heat load of small steam kettle is calculated in accordance with below formula.

$$Q_{sensible} = 35 \times 1 \times 21$$
$$= 735W$$
$$Q_{latent} = 35 \times 1 \times 14$$
$$= 490W$$

(6)Heat load of toaster

According to table 17, the heat load of toaster is calculated in accordance with the below formula.

$$Q_{sensible} = 2 \times 1310$$

$$= 2620W$$

$$Q_{latent} = 2 \times 1160$$

$$= 2320W$$

(7) Heat of microwave oven

According to table 17, the heat load of toaster is calculated in accordance with the below formula.

$$Q_{sensible} = 1 \times 1400$$

$$= 1400W$$

$$Q_{latent} = 0W$$

(8) Heat of freezer

According to table 17, the heat load of freezer is calculated in accordance with the below formula.

$$Q_{sensible} = 2 \times 320$$

$$= 640W$$

$$Q_{latent} = 0W$$

(9) Heat of coffee maker

According to table 17, the heat load of coffee maker is calculated in accordance with the below formula.

$$Q_{sensible} = 2 \times 1050$$

$$= 2100W$$

$$Q_{latent} = 450W$$

The summary of heat load of equipment in room212 is shown in the Table 26.

Table 26 Heat load of equipment in room212

room212			
equipment	amount	Sensible(W)	Latent(W)
desktop computer(2.3GHZ processor, 3GB RAM)	20	3600	0
laptop computer(2.3 GHz processor, 3GB RAM)	15	487.5	0
colour A3 laser printer(speed:24 pages per minute)	1	130	0
large plotter	1	456	0
small steam kettle(35L)	1	735	490
Toaster(small pop-up)-4 slice	2	2620	2320
Microwave oven (residential type)	1	1400	0
Freezer(small)	2	640	0
Coffee maker,10 cups	2	2100	900
total		12168.5	3710

9.1.4 Internal load caused by infiltration

The infiltration is caused by the difference of pressure between outside and inside , and temperature difference between outside and inside. Usually the air will come through windows and doors.

1 infiltration from windows:

According to table 44 in DA09, the infiltration rates should be calculated in the following steps.

Since the windows are exposed, $rate_1 = 0.25$

Since the window is dry, $rate_2 = 0.5$

Since the window is located on one wall, $rate_3 = 0$

Since the type of window is gasket , $rate_4 = 0$

Since the area proportion of window is 33%, $rate_5$=0.083

Since the partition is nail, $rate_6 = 0$

$$Rate_{total} = rate_1 + rate_2 + rate_3 + rate_4 + rate_5 + rate_6$$

$$= 0.833$$

$$Q_{sensible} = 1.2 \times V \times \Delta T \times Rate \div 3600$$

$$= 1.2 \times (26 \times 15 \times 6 \times 1000) \times (33.8 - 24) \times 0.833 \div 3600$$

$$= 6367W$$

According to psychrometric chart, the moisture content of room 212 is 10.2g/kg, the moisture of content of outside air is 13.4kg/g.

$$Q_{latent} = 2.9 \times V \times \Delta w \times Rate \div 3600$$

$$= 2.9 \times (26 \times 15 \times 6 \times 1000) \times (13.4 - 10.2) \times 0.833 \div 3600$$

$$= 5024W$$

2 infiltration from door

According assignment helper, the volume of air infiltrating into room is 200L/s.

$$Q_{sensible} = 1.2 \times V \times \Delta T$$

$$= 1.2 \times 200 \times (33.8 - 24)$$

$$= 2352W$$

$$Q_{latent} = 2.9 \times V \times \Delta w$$

$$= 2.9 \times 200 \times (13.4 - 10.2)$$

$$= 1856W$$

$$Q_{sensible} = Q_{sensible\ (people)} + Q_{sensible(light)} + Q_{sensible(equipment)} + Q_{sensible\ (infiltration)}$$
$$= 5040 + 9781.2 + 12168.5 + 6367 + 2352$$

$$= 35708.7W$$

$$Q_{latent} = Q_{latent\,(people)} + Q_{latent\,(equipment)} + Q_{latent(infiltration)}$$

$$= 4320 + 3710 + 5024 + 1856$$

$$= 14910W$$

9.2 Internal load of room213

9.2.1 Internal load caused by people

According to assignment helper the maximum of people in room212 is 90. The sensible load and latent load per person are both 80W. Because the design time is 3pm, which is a peak time. The amounts of people in room213can get the biggest. Since the summer condition should be considered as the hottest, according to table 13 in DA09 the diversity factor is 0.9.

(1)Sensible heat

$$Q_{sensible} = 90 \times 80 \times 0.9$$

$$= 6480W$$

(2)Latent heat

$$Q_{latent} = 90 \times 80 \times 0.9$$

$$= 6480W$$

9.2.2 Internal load caused by light

According to assignment helper, the sensible heat caused by light is 30W/m^2, according to the storage mass of room213 and table 11 in DA09, the storage factor is chosen to be 0.812. Summer condition should be considered to be the hottest, so according to table 13 in DA09, the diversity factor is chosen to be 1.

$$Q_{sensible} = HeatGain \times Storage\ Factor \times Diversity\ Factor$$

$$Q_{sensible} = 30 \times 29 \times 15 \times 0.812$$

$$= 10596.6W$$

9.2.3 Internal load caused by equipment

According to assignment helper and ASHRAE hand book, the equipment and their sensible and latent heat are shown in Table 27. Because the design time is 3pm, which is the peak time, every equipment would be used.

Table 27 equipment information of room213 (from ASHRAE)

room213			
Equipment	amount	Sensible(W)	Latent(W)
Barbeque(pit) 50kg	6	57	31
Blender-2L	2	310	160
coffee heater-2burners	1	440	230
Dishwasher(hood type, chemical sanitizing)-1000dishes/hour	1	50	110
Display case(refrigerated) 1.5m^3	2	640	0
Food warmer(shelf type) 1m^3	8	2330	600
Griddle/grill(large) 0.5m^2	4	1940	1080
Ice maker(large) 100kg/day	2	2730	0
Microwave oven(heavy duty, commercial) 20L	1	2630	0
Mixer(larger) 77L	1	29	0
Steam kettle(larger) 200L	1	7	5
Waffle iron 0.05m^2	2	700	940
Broiler(conveyor infrared) 2m^2	1	12100	0
Fryer(pressurized) 6kg	2	38	0
Oven(pizza) 1m^2	4	1970	690
Freezer(large) 2m^3	4	540	0
Water cooler 30L/h	2	700	0
Hot water urn(large) 50L	1	50	16

(1)Heat load of barbeque

Since the heat load gathered from ASHRAE bases on the per litre of capacity, the heat load of barbeque should be calculated according to the below formula.

$$Q_{sensible} = 6 \times 57 \times 50$$

$$= 17100W$$

$$Q_{latent} = 6 \times 31 \times 50 = 9300W$$

(2)Heat load of blender

Since the heat load gathered from ASHRAE bases on the per litre of capacity, the heat load of blender should be calculated according to the below formula.

$$Q_{sensible} = 2 \times 310 \times 2$$

$$= 1240W$$

$$Q_{latent} = 2 \times 160 \times 2$$

$$= 640W$$

(3)Heat load of coffee heater

Since the heat load gathered from ASHRAE bases on the per boiling burner, the heat load of coffee heater should be calculated according to the below formula.

$$Q_{sensible} = 2 \times 1 \times 440$$

$$= 880W$$

$$Q_{latent} = 2 \times 1 \times 230$$

$$= 460W$$

(4)Heat load of dishwasher

Since the heat load gathered from ASHRAE bases on the per 100 dishes/h, the heat load of dishwasher should be calculated according to the below formula.

$$Q_{sensible} = 10 \times 1 \times 50$$

$$= 500W$$

$$Q_{latent} = 10 \times 1 \times 110$$

$$= 1100W$$

(5)Heat load of display case

Since the heat load gathered from ASHRAE bases on the per cubic metre of interior, the heat load of display case should be calculated according to the below formula.

$$Q_{sensible} = 1.5 \times 2 \times 640 = 1920W$$

$$Q_{latent} = 0W$$

(6)Heat load of food warmer

Since the heat load gathered from ASHRAE bases on the per cubic metre of interior, the heat load of food warmer should be calculated according to the below formula.

$$Q_{sensible} = 8 \times 2330$$

$$= 18640W$$

$$Q_{latent} = 8 \times 600$$

$$= 4800W$$

(7)Heat load of griddle

Since the heat load gathered from ASHRAE bases on the per square metre of cooking surface, the heat load of griddle should be calculated according to the below formula.

$$Q_{sensible} = 0.5 \times 4 \times 1940$$

$$= 3880W$$

$$Q_{latent} = 0.5 \times 4 \times 1080$$

$$= 2160W$$

(8)Heat load of Ice maker

Since the heat load gathered from ASHRAE bases on the100kg/day, the heat load of Ice maker should be calculated according to the below formula.

$$Q_{sensible} = 2 \times 2730$$

$$= 5460W$$

$$Q_{latent} = 0W$$

(9)Heat load of Microwave oven

According to Table 27, the heat load of microwave oven should be calculated according to the below formula.

$$Q_{sensible} = 1 \times 2630$$

$$= 2630W$$

$$Q_{latent} = 0W$$

(10)Heat load of Mixer

Since the heat load gathered from ASHRAE bases on per litre of capacity, the heat load of Mixer should be calculated according to the below formula.

$$Q_{sensible} = 77 \times 29$$

$$= 2233W$$

$$Q_{latent} = 0W$$

(11)Heat load of Steam kettle

Since the heat load gathered from ASHRAE bases on per litre of capacity, the heat load of steam kettle should be calculated according to the below formula.

$$Q_{sensible} = 1 \times 200 \times 7$$

$$= 1400W$$

$$Q_{latent} = 1 \times 200 \times 5$$

$$= 1000W$$

(12)Heat load of Waffle iron

According Table 27, the heat load of waffle iron should be calculated according to the below formula.

$$Q_{sensible} = 2 \times 700$$

$$= 1400W$$

$$Q_{latent} = 2 \times 940$$

$$= 1880W$$

(13)Heat load of broiler

Since the heat load gathered from ASHRAE bases on per square metre of cooking area, the heat load of broiler should be calculated according to the below formula.

$$Q_{sensible} = 1 \times 2 \times 12100$$

$$= 24200W$$

$$Q_{latent} = 0W$$

(14)Heat load of fryer

Since the heat load gathered from ASHRAE bases on per kilogram of fat capacity, the heat load of fryer should be calculated according to the below formula.

$$Q_{sensible} = 2 \times 6 \times 38$$

$$= 456W$$

$$Q_{latent} = 0W$$

(15)Heat load of oven

Since the heat load gathered from ASHRAE bases on per kilogram of fat capacity, the heat load of oven should be calculated according to the below formula.

$$Q_{sensible} = 4 \times 1 \times 1970$$

$$= 7880W$$

$$Q_{latent} = 4 \times 1 \times 690 = 2760W$$

(16)Heat load of freezer

According to Table 27, the heat load of freezer should be calculated according to the below formula.

$$Q_{sensible} = 4 \times 540$$

$$= 2160W$$

$$Q_{latent} = 0W$$

(17)Heat load of water cooler

Since the heat load gathered from ASHRAE bases on per kilogram of fat capacity, the heat load of water cooler should be calculated according to the below formula.

$$Q_{sensible} = 2 \times 700$$

$$= 1400W$$

$$Q_{latent} = 0W$$

(18)Heat load of hot water urn

Since the heat load gathered from ASHRAE bases on per litre of capacity, the heat load of hot water urn should be calculated according to the below formula.

$$Q_{sensible} = 1 \times 50 \times 50$$

$$= 2500W$$

$$Q_{latent} = 1 \times 50 \times 16$$

$$= 800W$$

The summary of heat load of equipment in room213 is shown in the Table 28.

Table 28 Heat load of equipment in room213

room213			
equipment	amount	sensible(W)	latent(W)
Barbeque(pit)	6	17100	9300
blender	2	1240	640
coffee heater	1	880	460
Dishwasher(hood type, chemical sanitizing)	1	500	1100
Display case(refrigerated)	2	1920	0
Food warmer(shelf type)	8	18640	4800
Griddle/grill(large)	4	3880	2160
Ice maker(large)	2	5460	0
Microwave oven(heavy duty, commercial)	1	2630	0
Mixer(larger)	1	2233	0
Steam kettle(larger)	1	1400	1000
Waffle iron	2	1400	1880
Broiler(conveyor infrared)	1	24200	0
Fryer(pressurized)	2	456	0
Oven(pizza)	4	7880	2760
Freezer(large)	4	2160	0
Water cooler	2	1400	0
Hot water urn(large)	1	2500	800
total		95879	24900

9.2.4 Internal load caused by infiltration

Because the windows of east wall and south wall, and doors in west wall. There is also infiltration in room 213.

1 infiltration from windows :

According to table 44 in DA09, the infiltration rates should be calculated in the following steps.

Since the windows are exposed, $rate_1 = 0.25$(the room is halfway between sheltered and exposed)

Since the window is dry, $rate_2 = 0.5$

Since the window is located on one wall, $rate_3 = 0$

Since the type of window is gasket , $rate_4 = 0$

Since the area proportion of window is ($\frac{13\times2+29\times2}{15\times6+29\times6}$)=0.31, $rate_5$=0.06

Since the partition is nail, $rate_6 = 0$

$$Rate_{total} = rate_1 + rate_2 + rate_3 + rate_4 + rate_5 + rate_6$$

$$= 0.81$$

$$Q_{sensible} = 1.2 \times V \times \Delta T \times Rate \div 3600$$

$$= 1.2 \times (29 \times 15 \times 6 \times 1000) \times (33.8 - 24) \times 0.81 \div 3600$$

$$= 6906W$$

According to psychrometric chart, the moisture content of room 213 is 10.2g/kg; the moisture content of outside air is 13.4g/kg.

$$Q_{latent} = 2.9 \times V \times \Delta w \times Rate \div 3600$$

$$= 2.9 \times (29 \times 15 \times 6 \times 1000) \times (13.4 - 10.2) \times 0.81 \div 3600$$

$$= 5449W$$

2 infiltrations from door

According assignment helper, the volume of air infiltrating into room is 200L/s.

$$Q_{sensible} = 1.2 \times V \times \Delta T$$

$$= 1.2 \times 200 \times (33.8 - 24)$$

$$= 2352W$$

$$Q_{latent} = 2.9 \times V \times \Delta w$$

$$= 2.9 \times 200 \times (13.4 - 10.2)$$

$$= 1856W$$

$$Q_{sensible} = Q_{sensible\ (people)} + Q_{sensible(light)} + Q_{sensible(equipment)} + Q_{sensible\ (infiltration)}$$
$$= 6840 + 10596 + 95879 + 6906 + 2352$$

$$= 122573W$$

$$Q_{latent} = Q_{latent\ (people)} + Q_{latent\ (equipment)} + Q_{latent(infiltration)}$$

$$= 6840 + 24900 + 5449 + 1856$$

$$= 39045W$$

Table 29 Internal load of two rooms in summer

Internal load in summer		
Heat load	room212	room213
sensible	35708.7	122573
latent	14910	39045

10 Internal load for winter

The difference of internal load calculation between summer and winter has some factors. First, the amount of people is less. The amount of equipment turned on is less; the direction of heat transfer from infiltration is from room to outside.

10.1 Internal load of room212

10.1.1 Internal load caused by people

Because the design time is 7am, usually there are no people in room 212; the heat load caused by people is zero.

10.1.2 Internal load caused light

Because the design time is 7am, it's not necessary to turn on all the light. According to NCC volume One, the proportion of light turning on should be 40%. According to assignment helper, the sensible heat caused by light is $30W/m^2$, according to the storage mass of room212 and table 11 in DA09, the storage factor is chosen to be 0.836. Summer condition should be considered to be the hottest, so according to table 13 in DA09, the diversity factor is chosen to be 0.9, because the condition should be the coldest.

$$Q_{sensible} = HeatGain \times Storage\ Factor \times Diversity\ Factor \times 0.4$$

$$Q_{sensible} = 30 \times 26 \times 15 \times 0.836 \times 0.4$$

$$= 3912W$$

10.1.3 Internal load caused by equipment

Because the time is 7 am, most of equipment hasn't been turned on, except freezer. The food stored in freezer must be kept fresh, so the freezer should be turn on all the time. According to table 17, the heat load of freezer is calculated in accordance with the below formula.

$$Q_{sensible} = 2 \times 320$$

$$= 640W$$

$$Q_{latent} = 0W$$

10.1.4 Internal load caused by infiltration

The infiltration is caused by the difference of pressure between outside and inside, and temperature difference between outside and inside. Usually the air will come through windows and doors.

1 infiltration from windows:

According to table 44 in DA09, the infiltration rates should be calculated in the following steps.

Since the windows are exposed, $rate_1 = 0.25$

Since the window is wet, $rate_2 = 0$

Since the window is located on one wall, $rate_3 = 0$

Since the type of window is gasket, $rate_4 = 0$

Since the area proportion of window is 33%, $rate_5$=0.083

Since the partition is nail, $rate_6 = 0$

$$Rate_{total} = rate_1 + rate_2 + rate_3 + rate_4 + rate_5 + rate_6$$

$$= 0.333$$

$$Q_{sensible} = 1.2 \times V \times \Delta T \times Rate \div 3600$$

$$= 1.2 \times (26 \times 15 \times 6 \times 1000) \times (21 - 2.1) \times 0.333 \div 3600$$

$$= 4909W$$

According to psychrometric chart, the moisture content of room 212 is 12.4g/kg, the moisture content of outside air is 3.6g/kg.

$$Q_{latent} = 2.9 \times V \times \Delta w \times Rate \div 3600$$

$$= 2.9 \times (26 \times 15 \times 6 \times 1000) \times (12.4 - 3.6) \times 0.333 \div 3600$$

$$= 5474W$$

2 infiltrations from door

According assignment helper, the volume of air infiltrating into room is 200L/s.

$$Q_{sensible} = 1.2 \times V \times \Delta T$$

$$= 1.2 \times 200 \times (21 - 2.1)$$

$$= 4536W$$

$$Q_{latent} = 2.9 \times V \times \Delta w$$

$$= 2.9 \times 200 \times (12.4 - 3.6)$$

$$= 5104W$$

$$Q_{sensible} = Q_{sensible\,(people)} + Q_{sensible(light)} + Q_{sensible(equipment)} + Q_{sensible\,(infiltration)}$$
$$= 0 - 3912 - 640 + 4909 + 4536$$

$$= 4893W$$

$$Q_{latent} = Q_{latent\,(people)} + Q_{latent\,(equipment)} + Q_{latent(infiltration)}$$

$$= 0 - 0 + 5474 + 5104$$

$$= 10578W$$

10.2 Internal load of room213

10.2.1 Internal load caused by people

Because the design time is 7am, usually there are no people in restaurant; the heat load caused by people is zero.

10.2.2 Internal load caused by light

Because the design time is 7am, it's not necessary to turn on all the light. According to NCC volume one, the proportion of light turning on should be 40%. According to assignment helper, the sensible heat caused by light is 30W/m^2, according to the storage mass of room213 and table 11 in DA09, the storage factor is chosen to be 0.812. Winter condition should be considered to be the coldest, so according to table 13 in DA09, the diversity factor is chosen to be 0.9, because the condition should be the coldest.

$$Q_{sensible} = HeatGain \times Storage\ Factor \times Diversity\ Factor \times 0.4$$

$$Q_{sensible} = 30 \times 29 \times 15 \times 0.812 \times 0.4 = 4238.64W$$

10.2.3 Internal load caused by equipment

Because the time is 7 am, most of equipment hasn't been turned on, except freezer. The food stored in freezer must be kept fresh, so the freezer should be turn on all the time. According to table 18, the heat load of freezer should be calculated according to the below formula.

$$Q_{sensible} = 4 \times 540$$

$$= 2160W$$

$$Q_{latent} = 0W$$

10.2.4 Internal load caused by infiltration

The infiltration is caused by the difference of pressure between outside and inside, and temperature difference between outside and inside. Usually the air will come through windows and doors.

1 infiltration from windows:

According to table 44 in DA09, the infiltration rates should be calculated in the following steps.

Since the windows are exposed, $rate_1 = 0.25$

Since the window is wet, $rate_2 = 0$

Since the window is located on adjacent wall, $rate_3 = 0$

Since the type of window is gasket, $rate_4 = 0$

Since the area proportion of window is ($\frac{13\times2+29\times2}{15\times6+29\times6}$)=0.31, $rate_5$=0.06

Since the partition is nail, $rate_6 = 0$

$$Rate_{total} = rate_1 + rate_2 + rate_3 + rate_4 + rate_5 + rate_6$$

$$= 0.31$$

$$Q_{sensible} = 1.2 \times V \times \Delta T \times Rate \div 3600$$

$$= 1.2 \times (29 \times 15 \times 6 \times 1000) \times (21 - 2.1) \times 0.31 \div 3600$$

$$= 5097W$$

According to psychrometric chart, the moisture content of room 212 is 12.4g/kg, the moisture content of outside air is 3.6g/kg.

$$Q_{latent} = 2.9 \times V \times \Delta w \times Rate \div 3600$$

$$= 2.9 \times (29 \times 15 \times 6 \times 1000) \times (12.4 - 3.6) \times 0.31 \div 3600$$

$$= 5735W$$

2 infiltrations from door

According assignment helper, the volume of air infiltrating into room is 200L/s.

$$Q_{sensible} = 1.2 \times V \times \Delta T$$

$$= 1.2 \times 200 \times (21 - 2.1)$$

$$= 4536W$$

$$Q_{latent} = 2.9 \times V \times \Delta w$$

$$= 2.9 \times 200 \times (12.4 - 3.6)$$

$$= 5104W$$

$$Q_{sensible} = Q_{sensible\ (people)} + Q_{sensible(light)} + Q_{sensible(equipment)} + Q_{sensible\ (infiltration)}$$
$$= 0 - 4238.64 - 2160 + 5097 + 4536$$

$$= 3234.36W$$

$$Q_{latent} = Q_{latent\ (people)} + Q_{latent\ (equipment)} + Q_{latent(infiltration)}$$

$$= 0 - 0 + 5735 + 5104$$

$$= 10839W$$

Table 30 Internal load of two rooms in winter

Internal load in winter(W)		
Heat load	room212	room213
sensible	4893	3234.36
latent	10578	10839

11 Cooling and heating load summary

In summer, to cooling down the temperature of a room, the heat load of the room should be moved out; the heat which must be removed out is cooling load. In winter, heat added into room to keep room warm is heating load.

11.1 Cooling load for room 212

The cooling load of room 212 mainly contains three parts which are external load of external surfaces, external load of partition, and internal load.

According to Table 22, the external load of room212 is shown in Table 31

Table 31 External load of room212 in summer

External wall	Heat load (summer)/W
East wall of room212	292
ceiling of room212	864.79
west wall of room212	4468
window in room212	1642.9

$$Q_{external\ load} = 292 + 864.79 + 4468 + 1642.9$$

$$= 7267.69W$$

According to table 15, the external load of partition of room212 in summer is -72W.

According to, the internal load of room212 in summer is:

$$Q_{sensible} = 35708.7\text{W}$$

$$Q_{latent} = 14910\text{W}$$

$$Q_{cooling\ load(sensible)} = Q_{external\ load} + Q_{external\ load\ of\ partition} + Q_{internal\ load}$$

$$= 7267.69 - 72 + 35708.7$$

$$= 42904.39W$$

$$Q_{cooling\ load(latent)} = 14910W$$

11.2 Cooling load for room213

The cooling load of room 213 mainly contains three parts which are external load of external surfaces, external load of partition, and internal load.

According to Table 22, the external load of room213 is shown in Table 32

Table 32 External load of room 213 in winter

external wall	heat load (summer)/W
east wall of room213	320
south wall of room213	48
ceiling of room213	853
west wall of room213	2406
eastern window in room213	1832.5
southern window in room213	815

$$Q_{external\ load} = 320 + 48 + 853 + 2406 + 1832.5 + 815$$

$$= 6274.5W$$

According to Table 23, the external load of partition of room212 in summer is -183.75W.

According to Table 29 , the internal load of room212 in summer is:

$$Q_{sensible} = 122573\text{W}$$

$$Q_{latent} = 39045\text{W}$$

$$Q_{cooling\ load(sensible)} = Q_{external\ load} + Q_{external\ load\ of\ partition} + Q_{internal\ load}$$

$$= 6274.5 - 183.75 + 122573$$

$= 128663.75W$

$$Q_{latent} = 39045\text{W}$$

11.3Heating load for room212

Heat load of room212 contains external load of partition, external load of external walls, and internal load.

According to Table 15, the external load of partition of room212 in winter is 36W.

According to Table 16, the external load of external walls of room212 is shown in Table 33.

Table 33 External load of external surface of room212 in winter

Wall	external load(W)
east wall of room 212(except window)	658.4
ceiling of room 212	1253.07
window of room 212	2995
west wall of room 212	8986

$$Q_{external\ load} = 658.4 + 1253.07 + 2995 + 8986$$

$$= 13892.47W$$

According to table 21, the internal load of room212 in winter

$$Q_{sensible} = 4893W$$

$$Q_{latent} = 10578W$$

$$Q_{heating\ load\ sensible}$$
$$= Q_{external\ load\ of\ partition} + Q_{external\ load\ of\ external\ wall} + Q_{internal\ load}$$

$$= 36 + 13892.47 + 4893$$

$$= 18821.47W$$

$$Q_{latent} = 10578W$$

11.4Heating load for room213

Heat load of room213 contains external load of partition, external load of external walls, and internal load.

According to Table 23, the external load of partition of room213 in winter is 91W.

According to Table 24, the external load of external walls of room213 is shown in Table 34.

Table 34 External load of external surface of room213 in winter

Wall	external load(W)
wall of room 213(except window)	734.4
south wall of room 213(except window)	537
ceiling of room 213	1397.655
window of room 213	4839
west wall of room 213	4839

$$Q_{external\ load} = 734.4 + 537 + 1397.655 + 4839 + 4839$$

$$= 12347.055W$$

According to table 21, the internal load of room213 in winter

$$Q_{sensible} = 3234.36W$$

$$Q_{latent} = 10839W$$

$$Q_{heating\ load\ sensible} = Q_{external\ load\ of\ partition} + Q_{external\ load\ of\ external\ wall} + Q_{internal\ load}$$

$$= 91 + 12347.055 + 3234.36$$

$$= 15672.415W$$

$$Q_{latent} = 10839W$$

Table 35 Summary of cooling and heating load

		room212	room213
Cooling load(W)	sensible	42904.39	128663.75
	latent	14910	39045
Heating load(W)	sensible	18821.47	15672.415
	latent	10578	10839

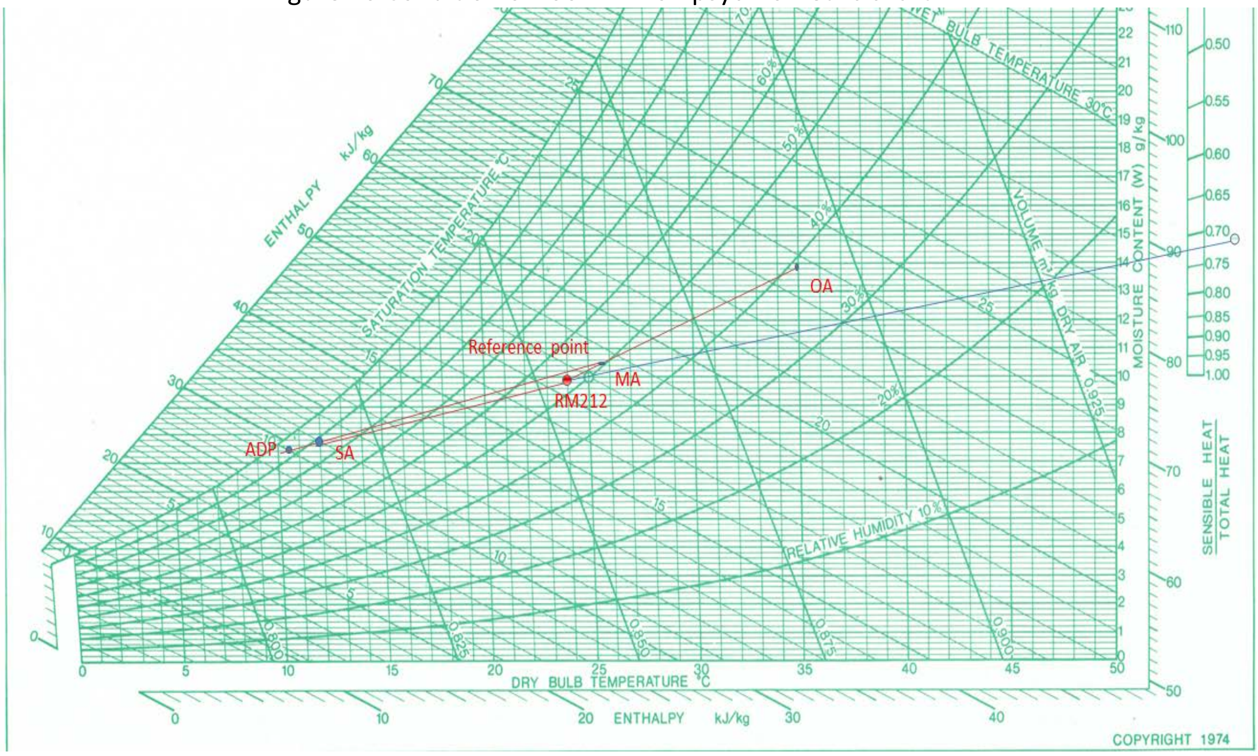
12Psychrometric chart calculation

Psychrometric chart can provide information of moist air, like dry bulb temperature, moisture content, enthalpy, wet bulb temperature, relative humidity, and volume of dry air.

12.1 Calculation for room212

The condition of room212 is shown in Figure 16 Condition of room212 on psychrometric chart.

Figure 16 Condition of room212 on psychrometric chart



According to assignment helper, the condition of room air and outside air can be got. The dry bulb temperature and wet bulb temperature of outside air is 33℃, and 22.9℃. The dry bulb temperature and relative humidity of room air is 24℃, and 55%. So the point of room air and outside air can be shown on the psychrometric chart.

According to Table 35, the sensible cooling load and latent cooling load of room 212 is 42904.39W and 14910W.

$$SHF = \frac{42904.39}{42904.39 + 14910}$$

$$= 0.74$$

According to assignment helper the minimum temperature of supply air is 12℃. Drawing the room load line on the psychrometric chart.

$$Q_{sensible} = C_p \times m_s \times \Delta T$$

$$C_p = 1.02 \frac{kJ}{kg}.K$$

$$m_s = \frac{42.904}{1.02 \times (24 - 12)}$$

$$= 3.505 \ kg/s$$

According to assignment helper the volume of outside air supplied to room 212 should be 10litres per second per person.

$$V = \frac{80 \times 10}{1000}$$

$$= 0.8 \, {m^3}/{s}$$

$$M_o = \frac{V}{\vartheta}$$

$$= \frac{0.8}{0.886}$$

$$= 0.9 \, {kg}/{s}$$

Hence $\frac{M_o}{M_s} = 0.257$

According psychrometric chart the moisture content of outside room is 13.2g/kg, the moisture content of room air is 10.4g/kg.

Hence $\frac{W_{mix} - 10.4}{13.2 - 10.4} = 0.257$

$$W_{mix} = 11.11$$

According to assignment helper, the cooling coil effectiveness is 0.85.

Hence

$$\frac{W_{mix} - W_s}{W_{mix} - W_{ADP}} = 0.85$$

$$W_{ADP} = 7.21 \, {g}/{kg}$$

So apparatus dew point can found on psychrometric chart.

According to psychrometric chart, the supply air point is on the cooling load line, so re heat is not necessary. The enthalpy of mix point and supply air point is 54kJ/kg and 33kJ/kg.

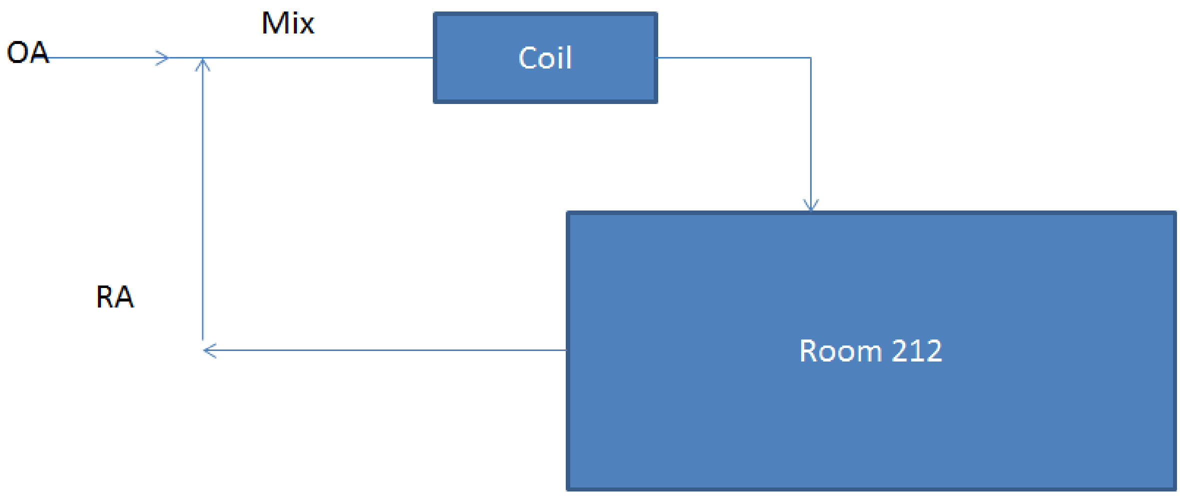
Hence

$$Q_{ref} = M_s \times (h_{mix} - h_w)$$

$$= 3.505 \times (54 - 33)$$

$$= 73.6\text{kw}$$

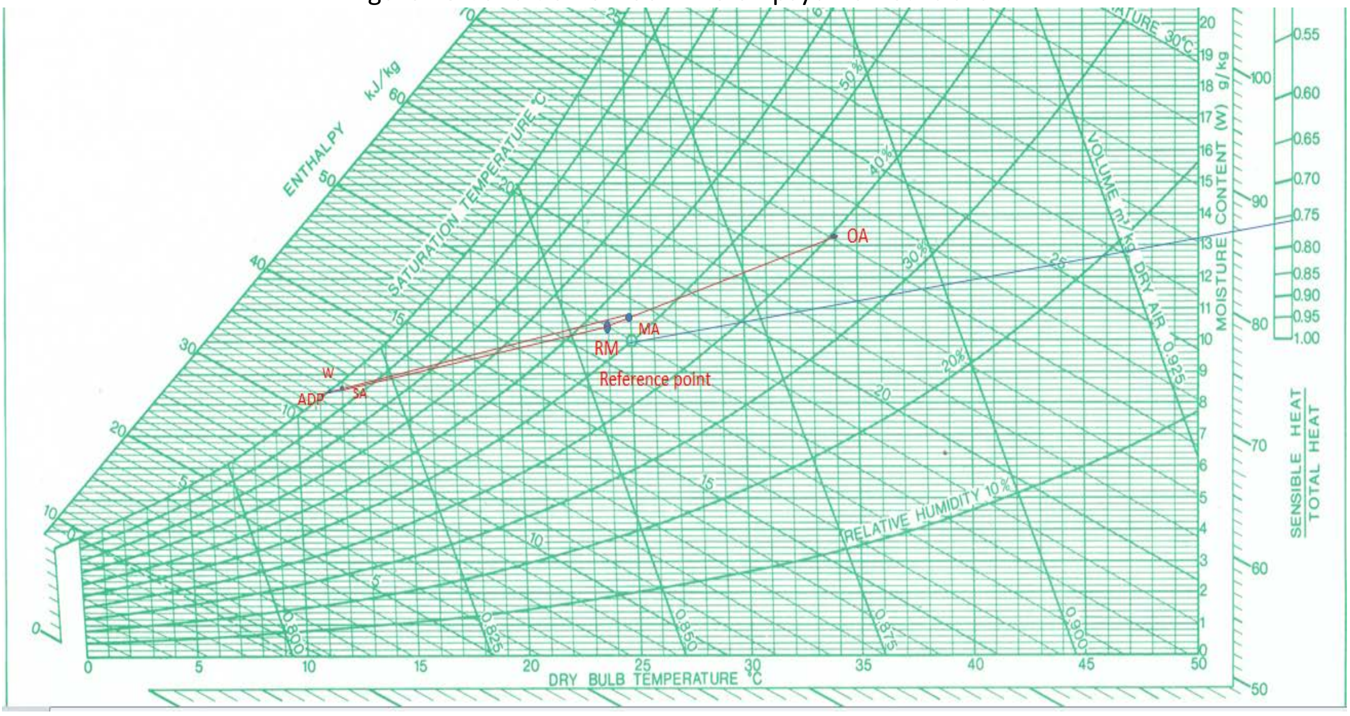
Figure 17 Schematic of summer air conditioning system for room 212



12.2 Calculation for room213

The condition of room213is shown in Figure 18.

Figure 18 Condition of room213 on psychrometric chart



According to assignment helper, the condition of room 213 is the same as room212. So the point of room air and outside air can be shown on the psychrometric chart.

According to Table 35, the sensible cooling load and latent cooling load of room 213 is 128663.75W and 39045W.

$$SHF = \frac{128663.75}{128663.75 + 39045}$$

$$= 0.76$$

According to assignment helper the minimum temperature of supply air is 12°C. Drawing the room load line on the psychrometric chart.

$$Q_{sensible} = C_p \times m_s \times \Delta T$$

$$C_p = 1.02 \frac{kJ}{kg}.K$$

$$m_s = \frac{128.66}{1.02 \times (24 - 12)}$$

$$= 10.5 \ kg/s$$

According to assignment helper the volume of outside air supplied to room 213 should be 10litres per second per person.

$$V = \frac{90 \times 10}{1000}$$

$$= 0.9\, {m^3}/{s}$$

$$M_o = \frac{V}{\vartheta}$$

$$= \frac{0.9}{0.886}$$

$$= 1.01\, {kg}/{s}$$

Hence $\frac{M_o}{M_s} = 0.096$

According psychrometric chart the moisture content of outside room is 13.2g/kg, the moisture content of room air is 10.4g/kg.

Hence $\frac{W_{mix} - 10.4}{13.2 - 10.4} = 0.096$

$$W_{mix} = 10.66\, {g}/{kg}$$

According to assignment helper, the cooling coil effectiveness is 0.85.

Hence

$$\frac{W_{mix} - W_s}{W_{mix} - W_{ADP}} = 0.85$$

$$W_{ADP} = 8.15\, {g}/{kg}$$

So apparatus dew point can found on psychrometric chart.

According to psychrometric chart, the supply air point is on the cooling load line, so re heat is not needed. The enthalpy of mix point and supply point is 52.5kJ/kg and 33kJ/kg.

Hence

$$Q_{ref} = M_s \times (h_{mix} - h_w)$$

$$= 10.5 \times (52.5 - 33)$$

$$= 204.75\text{kw}$$

Figure 19 Schematic of summer air conditioning system for room213

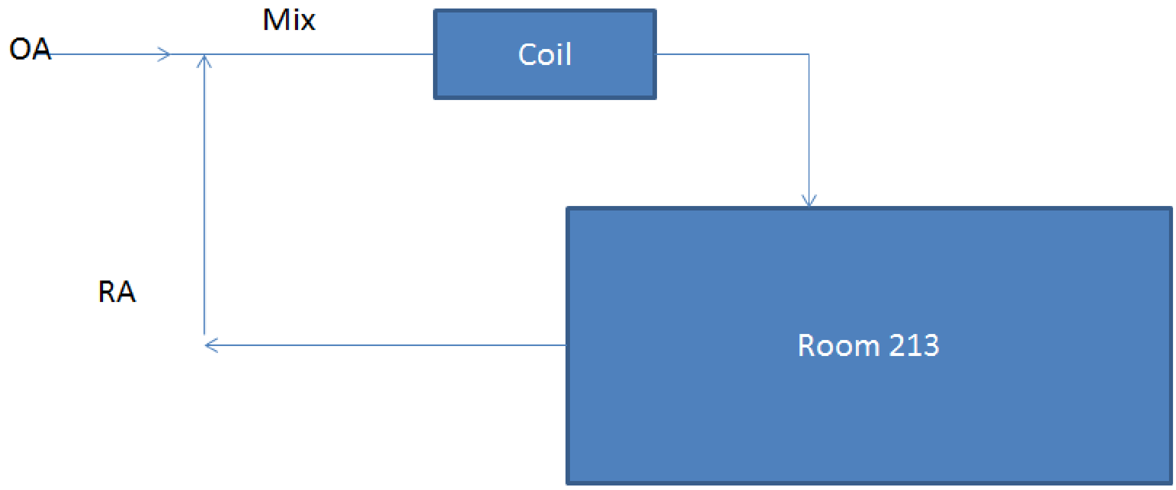


Table 36 Total cooling load of HVAC system for room212 and room213

	Room212	Room213
Cooling coil load (kw)	73.6	204.75

13Conclusion

According to the calculation result, as for room 212, in summer, the sensible coiling load is 42904.39W, the latent cooling load is 14910 W; in winter, the sensible heating load is 18821.47W, the latent heating load is 10578W.

As for room 213, in summer the sensible cooling load is 128663.8W, the latent cooling load is 39045 W; in winter the sensible heating load is 15672.42W, the latent heating load is 10839W.

The HVAC cooling system of room212 and room213 is composed of duct, and coil. The supply air is composed of room air and outside air.

The cooling coil load of room212 is 73.6KW.

The cooling coil load of room213 is 204.75KW.

The important figures are summarized in the table 28, table29, table30, and table31.

14 Reference

1 DA09 Air Conditioning Load Estimation.

2 NCC Volume One

3 2009 ASHRAE HANDBOOK

4 2001 ASHRAE Fundamentals Handbook

5 Assignment Helper