Refrigeration and Air conditioning Engineering.

3rd year – refrigeration and Air conditioning Course

M.Sc. Zahraa F. Hussain

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COOLING AND HEATING LOAD ESTIMATION
Heat Gain Through Wall

Lecture -2

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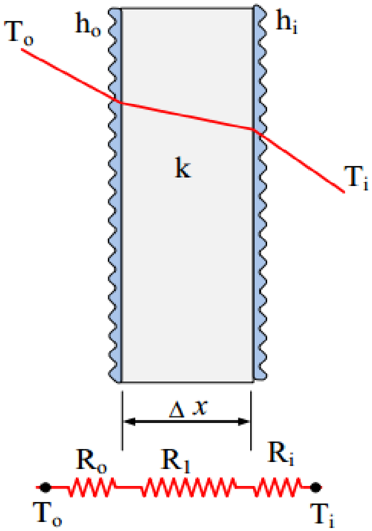
1.4 Heat Transfer Topics

1.4.1 Single layered wall **The overall heat transfer coefficient for single layered wall can be calculated as follows:**



$$R_o = \frac{1}{h_o} \ , \qquad R_i = \frac{1}{h_i} \ , \qquad R_1 = \frac{\Delta x}{k}$$

$$R_t = R_o + R_1 + R_i$$

$$U_o = \frac{1}{R_t} = \frac{1}{R_o + R_1 + R_i} = \frac{1}{\frac{1}{h_i} + \frac{\Delta x}{k} + \frac{1}{h_o}}$$

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Heat Transfer Topics

Where:

h_o: Outdoor heat transfer coefficient W/m^2 K

outdoor heat transfer coefficient for summer is 17.0 W/(m^2·K),and 29.7 W/m^2 K for winter

h_i: Indoor heat transfer coefficient W/m^{2}K.

indoor coefficient 8.3 W/(m^2·K)

Δx: wall thickness m

k: thermal conductivity W/m K

U_o: Overall heat transfer coefficient W/m^2 K

R: Thermal resistance m^2 K/W

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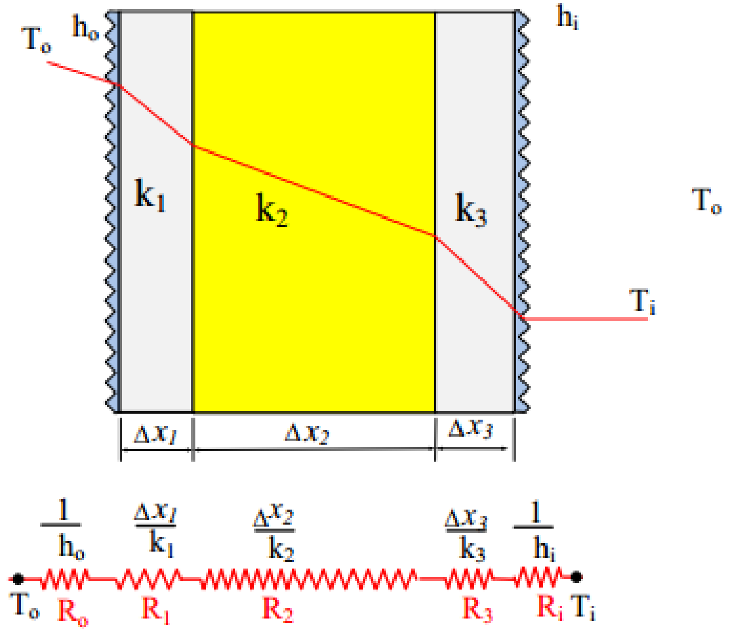
1.4.2 Multi layered wall:

If the wall consist of more than one layer, the heat transfer coefficient can be calculated as follows:



$$R_o = \frac{1}{h_o}\ , \quad R_i = \frac{1}{h_i}\ , \quad R_1 = \frac{\Delta x_1}{k_1}, \quad R_2 = \frac{\Delta x_2}{k_2}, \quad R_3 = \frac{\Delta x_3}{k_3}$$

$$R_t = R_o + R_1 + R_2 + R_3 + R_i$$

$$U_o = \frac{1}{R_t} = \frac{1}{R_o + R_1 + R_2 + R_3 + R_i} = \frac{1}{\frac{1}{h_i} + \frac{\Delta x_1}{k_1} + \frac{\Delta x_2}{k_2} + \frac{\Delta x_3}{k_3} + \frac{1}{h_o}}$$

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Example 1:

Find the overall heat transfer coefficient for outdoor wall in summer, the wall consist of 5 mm cement plaster, 24 cm common brick and 10 mm gypsum plaster.

Solution:

From table 19

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Table 19 Properties of building materials

Description	L mm	K W/mK	P kg/m^3	R m^{2}K/W	Mass kg/m^2
Outside surface resistance, Summer	---	0.000	---	0.059	0.00
Outside surface resistance, winter	---	0.000	---	0.041	
Stucco	25	0.692	1858	0.037	47.34
Face brick	100	1.333	2002	0.076	203.50
Face brick	100	1.333	2002	0.076	203.50
Clay tile	100	0.571	1121	0.178	113.70
low density concrete block	100	0.381	609	0.266	61.98
high density concrete block	100	0.813	977	0.125	99.06
Common brick	100	0.727	1922	0.140	195.20
high density concrete	100	1.731	2243	0.059	227.90
Clay tile	200	0.571	1121	0.352	227.90
low density concrete block	200	0.571	609	0.352	123.46
high density concrete block	200	1.038	977	0.196	198.62
Common brick	200	0.727	1922	0.279	390.40
high density concrete	200	1.731	2243	0.117	455.79
high density concrete	300	1.731	2243	0.176	683.20
high density concrete	50	1.731	2243	0.029	113.70
high density concrete	150	1.731	2243	0.088	341.60
low density concrete	100	0.173	641	0.587	64.90
low density concrete	150	0.173	641	0.880	97.60
low density concrete	200	0.173	641	1.173	130.30
low density concrete block (filled)	200	0.138	288	1.467	58.56
high density concrete block (filled)	200	0.588	849	0.345	172.75
low density concrete block (filled)	300	0.138	304	2.200	92.72
high density concrete block (filled)	300	0.675	897	0.451	273.28
Inside surface resistance	---	0.000	---	0.121	0.00
Plaster or gypsum	20	0.727	1602	0.026	30.74
Ceiling air space	---	0.000	---	0.176	0.00
Asphalt Roll Roofing			1120	0.09	
Carpet and Fibrous Pad				1.20	
Carpet and Rubber Pad	25			0.71	
Ceramic Tile	7			0.05	
Concrete Tile	10	0.27	1921	0.037	23
Sand	130		1681	0.016	21
Sand	160		1681	0.019	27
Cement plaster	13		1680	0.05	105.6
Expanded polyurethane		0.04	16		

10 mm gypsum plaster

K=0.727 W/m.K

$$R_1 = \frac{\Delta x}{K} = \frac{0.01}{0.727} = 0.0137\ m^2K/W$$

24 cm common brick

K=0.727 W/m.K

$$R_2 = \frac{\Delta x}{K} = \frac{0.24}{0.727} = 0.33 m^2K/W$$

5 mm cement plaster

R=0.05 $\frac{m^2K}{W}$ for **13** mm

For 5 mm

$$R_3 = 0.05 * \frac{5}{13}$$

$$= 0.01923\ \frac{m^2K}{W}$$

$$R_o = \frac{1}{h_o} = \frac{1}{17} = 0.0588\, m^2K/W \quad R_i = \frac{1}{h_i} = \frac{1}{8.3} = 0.1204\, m^2K/W$$

$$R_t = R_o + R_1 + R_2 + R_3 + R_i$$

$$R_t = 0.0588 + 0.0137 + 0.33 + 0.01923 + 0.1204 =$$

$$R_t = 0.542\, m^2K/W$$

$$U_o = \frac{1}{R_t}$$

$$U_t = \frac{1}{0.542} = 1.845 W/m^2K$$

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1.5 Heat gain through wall

- The heat gain through a wall is the sum of the relatively steady-state flow that occurs because the inside air temperature is less than that outside, and the unsteady-state gain resulting from the varying intensity of solar radiation on the outer surface of the wall. The phenomenon of unsteady-state heat flow through a wall is complicated by the fact that a wall has a thermal capacity, and so a certain amount of the heat passing through it is stored, being released to the interior (or exterior) at some later time. Two environmental factors are to be considered when assessing the amount of heat entering the outer surface of a wall: 1. the diurnal variation of air temperature, and 2. the sinusoidal-type variation of solar intensity.

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1.5 Heat gain through wall

Figure 3 presents a simplified picture.

At (a), under steady-state conditions, the graph of temperature through the wall is a straight line. The calculation of heat gain under such circumstance is exactly the same as for the more familiar case of steady-state loss. At (b) the effect of raising the outer surface temperature. The temperature at the point (Pb) is greater than that at point (Pa). Such an increase could be caused by the outer wall surface receiving solar radiation. Heat flows away from (Pb) in both directions because its temperature is higher than both the air and the material of the wall in its vicinity. If the intensity of solar radiation then diminishes, the situation in Figure (3c) arises. Since heat flowed away from (Pb), the value of the temperature at (Pc) is now less than it was at (Pb).

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When the surface temperature rises again, the situation is as shown at (d). It can be seen that the crest of the wave, represented by points (Pa), (Pb), (Pc), (Pd) etc., is travelling to the right and that its magnitude is reducing. The wave will reach the inner surface of the wall and will produce similar fluctuations in surface temperature. The inner surface temperature will have a succession of values corresponding to the point (Pr) as it rises and falls. Thick walls with a large thermal capacity will damp the temperature wave considerably, whereas thin walls of small capacity will have little damping effect, and fluctuations in outside surface temperature will be apparent, almost immediately, as similar changes in inner surface temperature. It is possible for the inner surface temperatures to be less than room air temperatures, at certain times of the day, for walls of sufficiently heavy construction. A wide diurnal range of temperature can give this result. This outside surface temperature falls at night, by radiation to the black vault of the sky, and the effect of this is felt as a low inside surface temperature at some time later. At such a time, the air conditioning load will be reduced because of the heat lost into the wall from the room. Figure 7.15 presents a simplified picture of this.

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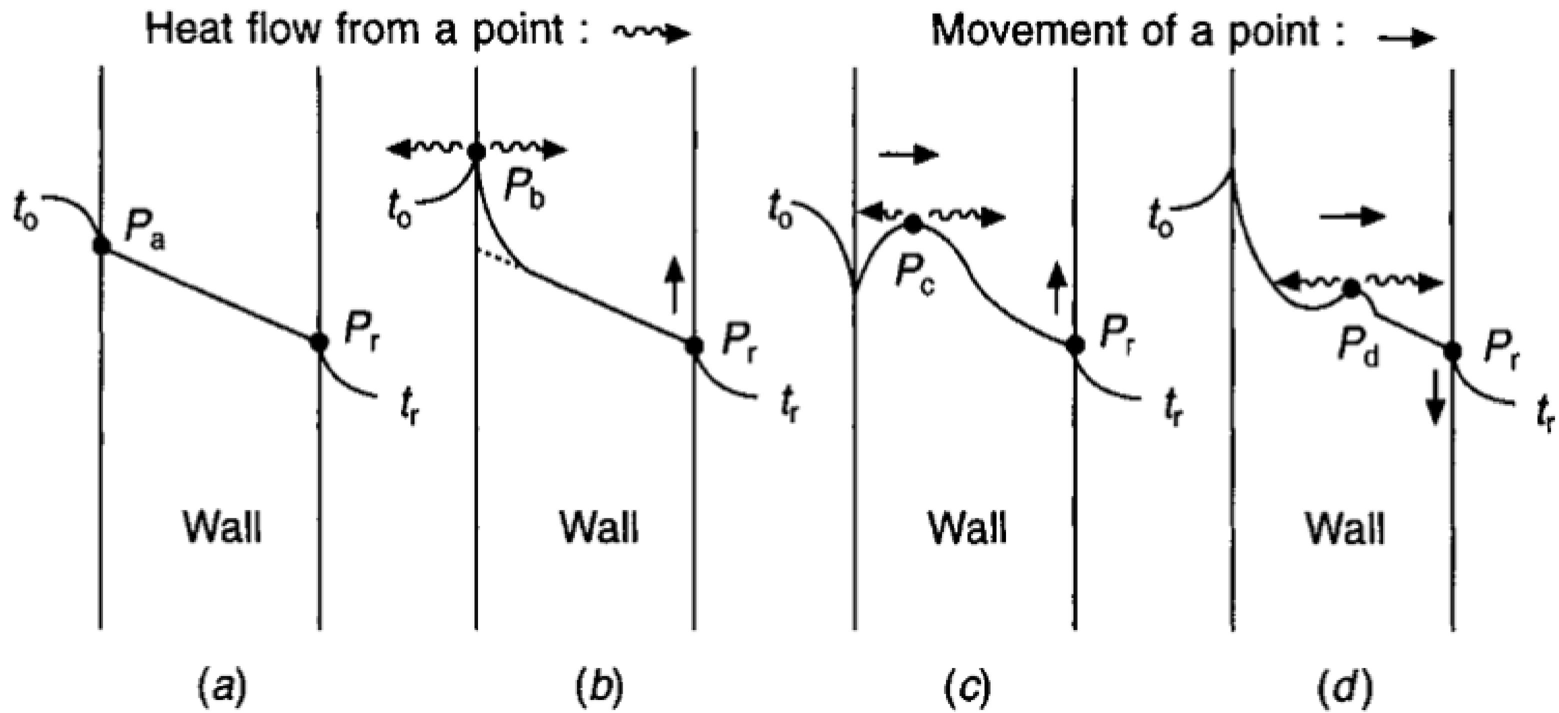

Fig. 3 Temperature gradients in a wall subjected to an unsteady heat input on the outside.

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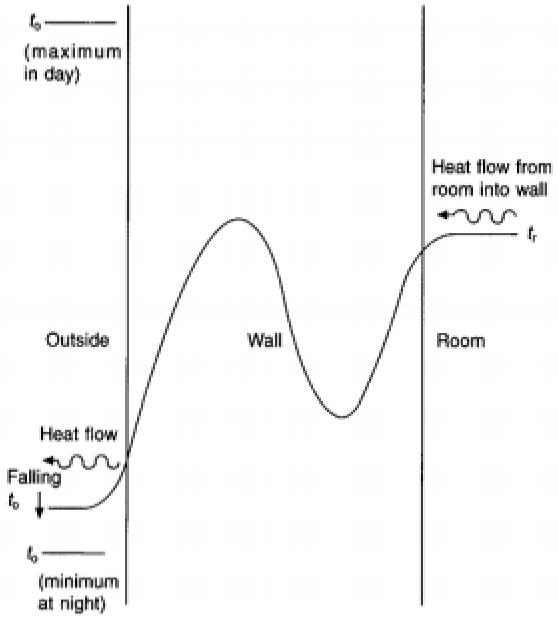

Fig. 4 Temperature gradient in a wall showing the possibility of heat flow outwards under unsteady state conditions.

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Equivalent Temperature Difference ΔT_e

Equivalent temperature difference (ΔT_e) takes into account the combined effects of

1- Solar radiation

2- The outside temperature and

3- the flywheel effect of heat storage in the wall or roof.

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Basis of Tables 15 and 16

- Equivalent Temperature Difference for Sunlit and Shaded Walls and Roofs

Table 15 and 16 are based on the following conditions:

1. Solar heat in July at 40° North latitude.
2. Outdoor daily range of dry-bulb temperatures, 11°C.
3. Maximum outdoor temperature of 35 °C db and a design indoor temperature of 26.5 °C, i.e. a design difference of 8.5°C
4. 4. Dark color walls and roofs with absorptivity of 0.90. For light color, absorptivity is 0.50; for medium color, 0.70.
5. 5. Sun time. The specific heat of most construction materials is approximately 0.9 kJ/kg K; the thermal capacity of typical walls or roofs is proportional to the weight m^2; this permits easy interpolation.

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SUMMER

To calculate the equivalent temperature difference for any wall or roof at any orientation, the following procedures must be considered:

1. Calculate the weight of wall or roof per m^2 **Table 19**
2. Select the equivalent temperature difference depending on orientation, weight of wall and day time.(Table 15)
3. Select the outdoor design conditions for summer (Table 1)
4. Select the outdoor design conditions for winter (Table 1)
5. Find the yearly range (Step 3 –step 4).
6. Find the daily range (Table 1).
7. Find the difference between (outdoor design condition for month at 3P.M.) – Room design condition .
8. Find the correction of equivalent temp. diff. (Table 16 A)
9. Find the equivalent temperature difference for wall or roof exposed to the sun for desired time of day for the given wall from the following equation:

$$\Delta t_{em} = (Step\ 2 + step\ 8)$$

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10. Find equivalent temperature difference for same wall or roof in shade Δt_{es} at desired time of day.

$$\Delta t_{es} = equiv.temp.diff.(Table\ 15\ at\ north\ shade) + step\ (8)$$

11. Find the maximum solar radiation maximum solar heat gain through glass for wall facing or horizontal for roofs, for month and latitude desired R_s (Table 12A)
12. Find the maximum solar heat gain through glass for wall facing or horizontal for roofs, for July at 40 North latitude R_m, Table (12B).
13. The correct equivalent temperature difference is:

a- For light color walls and roofs

$$\Delta t_e = 0.55\frac{R_s}{R_m}.\Delta t_{em} + (1-0.55)\frac{R_s}{R_m}.\Delta t_{es}$$

b- For medium color walls and roofs

$$\Delta t_e = 0.78\frac{R_s}{R_m}.\Delta t_{em} + (1-0.78)\frac{R_s}{R_m}.\Delta t_{es}$$

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Ex/

Find the overall heat transfer coefficient for outdoor wall in summer, and the equivalent temperature difference for the wall for the orientation West, and (Roof) horizontal. The wall consists of 13 mm cement plaster, 200 mm common brick and 10 mm gypsum plaster. and The roof is built from outside to inside from 10 mm concrete tail, 130 mm sand, 10 mm Expanded polyurethane, Asphalt shingles, 150 mm concrete and 20 mm gypsum.

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Common brick	100	0.727	1922	0.140	195.20
high density concrete	100	1.731	2243	0.059	227.90
Clay tile	200	0.571	1121	0.352	227.90
low density concrete block	200	0.571	609	0.352	123.46
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Common brick	200	0.727	1922	0.279	390.40
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Cement plaster	13		1680	0.05	105.6
Expanded polyurethane		0.04	16[illegible]		

The Wall

10 mm gypsum plaster

K=0.727 W/m.K

$$R_1 = \frac{\Delta x}{K} = \frac{0.01}{0.727} = 0.0137\, m^2K/W$$

$$W_1 = 30.74 * \frac{10}{20} = 15.37 \frac{kg}{m^2}$$

200 mm common brick

$$R_2 = 0.279\, m^2K/W$$

$$W_2 = 390.4 \frac{kg}{m^2}$$

13 mm cement plaster

$$R_3 = 0.05 \frac{m^2K}{W}$$

$$W_3 = 105.6 \frac{kg}{m^2}$$

$$R_o = \frac{1}{h_o} = \frac{1}{17} = 0.0588\, m^2K/W \quad R_i = \frac{1}{h_i} = \frac{1}{8.3} = 0.1204\, m^2K/W$$

$$R_t = R_o + R_1 + R_2 + R_3 + R_i$$

$$R_t = 0.1204 + 0.0137 + 0.279 + 0.05 + 0.0588 =$$

$$R_t = 0.5219\ m^2K/W$$

$$U_o = \frac{1}{R_t} \qquad U_w = \frac{1}{0.5219} = 1.916\, W/m^2K$$

The weight of the wall

$$W_t = 105.6 + 390.4 + 15.37 = 511.37 \frac{\text{kg}}{\text{m}^2}$$

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Concrete Tile	10	0.27	1921	0.037	23
Sand	130		1681	0.016	21
Sand	160		1681	0.019	27
Cement plaster	13		1680	0.05	105.6
Expanded polyurethane		0.04	16		

The Roof

10 mm concrete tail

$$R_1 = 0.037\ m^2K/W$$

$$W_1 = 23\ \frac{kg}{m^2}$$

130 mm sand

$$R_2 = 0.016 m^2K/W$$

$$W_2 = 21\ \frac{kg}{m^2}$$

10 mm Expanded polyurethane

$$R_3 = \frac{\Delta x}{K} = \frac{0.01}{0.04} = 0.25\ m^2\ K/W$$

Asphalt shingles

$$R_4 = 0.09 m^2K/W$$

150 mm concrete

$$R_5 = 0.088\ m^2K/W$$

$$W_5 = 341.6\ \frac{kg}{m^2}$$

20 mm gypsum plaster

$$R_6 = 0.026\ m^2K/W$$

$$W_6 = 30.74\ \frac{kg}{m^2}$$

$$R_o = \frac{1}{h_o} = \frac{1}{17} = 0.0588\ m^2K/W \quad R_i = \frac{1}{h_i} = \frac{1}{8.3} = 0.1204\ m^2K/W$$

$$R_t = R_0 + R_1 + R_2 + R_3 + R_4 + R_5 + R_6 + R_i$$

$R_r = 0.1204 + 0.037 + 0.016 + 0.25 + 0.09 + 0.088 + 0.026 + 0.0588 =$
$R_t = 0.6862\ m^2K/W$

$$U_o = \frac{1}{R_t} \quad U_r = \frac{1}{0.6862} = 1.457\ W/m^2K$$

The weight of the Roof

$$W_t = 23 + 21 + 341.6 + 30.74 = 416.34\,\frac{\text{kg}}{\text{m}^2}$$

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TABLE 15 -EQUIVALENT TEMPERATURE DIFFERENCE (°C) FOR DARK COLORED , SUNLIT AND SHADED WALLS

Based on Dark Colored Walls; 35 °C DBT Outdoor Design Temp; Constant 26.5 °C Inside DBT 11 °C Daily Range; 24-hour Operation; July and 40 N. Lat.

EXPOSURE	Weight of wall kg/m²	SUN TIME											
		PM											
		1	2	3	4	5	6	7	8	9	10	11	12
Northeast	98	7.2	6.7	**7.2**	7.8	7.8	7.8	6.7	5.6	4.4	3.3	2.2	1.1
	293	8.3	5.6	**6.1**	6.7	7.2	7.8	7.2	6.7	6.1	5.6	4.4	3.3
	488	8.3	7.8	**6.7**	5.6	6.1	6.7	6.7	6.7	6.1	5.6	5.0	4.4
	683	5.6	7.8	**8.9**	7.8	6.7	5.6	5.6	5.6	5.6	5.6	5.6	5.6
East	98	11.1	6.7	**7.2**	7.8	7.8	7.8	6.7	5.6	4.4	3.3	2.2	1.1
	293	10.6	7.8	**7.2**	6.7	7.2	7.8	7.2	6.7	6.1	5.6	4.4	2.8
	488	13.9	13.3	**11.1**	10.0	8.9	7.8	7.8	7.8	7.2	6.7	6.1	5.6
	683	8.3	10.0	**10.6**	10.0	9.4	8.9	7.8	6.7	7.2	7.8	7.8	7.8
Southeast	98	14.4	13.3	**10.6**	8.9	8.3	7.8	6.7	5.6	4.4	3.3	2.2	1.1
	293	14.4	13.9	**11.7**	10.0	8.3	7.8	7.2	6.7	6.1	5.6	4.4	3.3
	488	9.4	10.0	**10.6**	10.0	8.9	7.8	7.2	6.7	6.1	5.6	5.6	5.6
	683	6.1	7.8	**8.8**	8.9	10.0	8.9	8.3	7.8	7.2	6.7	6.7	6.7
South	98	15.0	16.7	**15.6**	14.4	11.1	8.3	6.7	5.6	3.9	3.3	1.7	1.1
	293	11.1	13.3	**13.9**	14.4	12.8	11.1	8.3	6.7	5.6	4.4	3.3	2.2
	488	4.4	6.7	**8.3**	8.9	10.0	10.0	8.3	7.8	6.1	5.6	4.4	4.4
	683	2.2	2.2	**3.9**	5.6	7.2	7.8	8.3	8.9	8.9	7.8	6.7	5.6
Southwest	98	10.6	14.4	**18.9**	22.2	22.8	23.3	16.7	13.3	6.7	3.3	2.2	1.1
	293	4.4	6.7	**13.3**	17.8	19.4	20.0	19.4	18.9	11.1	5.6	3.9	3.3
	488	3.9	4.4	**6.7**	7.8	10.6	12.2	12.8	13.3	12.8	12.2	8.3	5.6
	683	3.3	3.3	**3.9**	4.4	5.0	5.6	8.3	10.0	10.6	11.1	7.2	4.4
West	98	7.8	11.1	**17.8**	22.2	25.0	26.7	18.9	12.2	7.8	4.4	2.8	1.1
	293	3.9	5.6	**10.6**	14.4	18.9	22.2	22.8	20.0	15.6	8.9	5.6	3.3
	488	3.9	4.4	**5.6**	6.7	9.4	11.1	13.9	15.6	15.0	14.4	10.6	7.8
	683	5.0	5.6	**5.6**	5.6	6.1	6.7	7.8	8.9	11.7	12.2	12.8	12.2
Northwest	98	5.6	6.7	**10.6**	13.3	18.3	22.2	20.6	18.9	10.0	3.3	2.2	1.1
	293	3.3	4.4	**5.6**	6.7	11.7	16.7	17.2	17.8	11.7	6.7	4.4	3.3
	488	2.2	2.2	**2.8**	3.3	5.0	6.7	9.4	11.1	11.7	12.2	7.8	4.4
	683	3.3	3.3	**3.8**	3.3	3.9	4.4	5.0	5.6	7.8	10.0	10.6	11.1
North (Shade)	98	4.4	5.6	**6.7**	7.8	7.2	6.7	5.6	4.4	3.3	2.2	1.1	0.0
	293	1.7	3.3	**4.4**	5.6	6.1	6.7	6.7	6.7	5.6	4.4	3.3	2.2
	488	0.6	1.1	**1.7**	2.2	2.8	2.8	2.8	4.4	3.9	3.3	2.8	2.2
	683	0.0	0.0	**0.6**	1.1	1.7	2.2	2.8	3.3	3.9	4.4	3.9	3.3
Time		1	2	**3**	4	5	6	7	8	9	10	11	12
		PM											

The weight of the wall

$$W_t = 105.6 + 390.4 + 15.37$$

$$= 511.37 \frac{\text{kg}}{\text{m}^2}$$

Peak time =3 pm

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TABLE 16-EQUIVALENT TEMPERATURE DIFFERENCE (°C) FOR DARK COLORED! SUNLIT AND SHADED ROOFS

Based on Dark Colored Walls; 35 °C DBT Outdoor Design Temp; Constant 26.5 °C Inside DBT 11 °C Daily Range; 24-hour Operation; July and 40 N. Lat.

EXPOSURE	Weight of wall kg/m^2	SUN TIME											
		PM											
		1	2	3	4	5	6	7	8	9	10	11	12
Exposed to Sun	49	13.3	17.8	18.3	23.9	25.6	25.0	22.8	19.4	15.6	12.2	8.9	5.6
	98	12.8	16.7	20.0	22.8	23.9	23.9	22.2	19.4	16.7	13.9	11.1	8.3
	195	12.8	12.8	18.3	21.1	22.2	22.8	21.7	19.4	17.8	15.6	13.3	11.1
	293	12.2	15.0	17.2	19.4	21.1	21.7	21.1	20.0	18.9	17.2	15.6	13.9
	390	12.2	14.4	15.6	17.8	19.4	20.6	20.6	19.4	18.9	18.9	17.8	16.7
Covered with Water	98	10.6	12.2	11.1	10.0	8.9	7.8	6.7	5.6	3.3	1.1	0.6	0.6
	195	7.2	8.3	8.3	8.9	8.3	8.3	7.8	6.7	5.6	3.9	2.8	1.7
	293	3.9	5.6	6.7	7.8	8.3	8.9	8.3	7.8	6.7	5.6	4.4	3.3
Sprayed	98	8.3	10.0	9.4	8.9	8.3	7.8	6.7	5.6	3.3	1.1	0.6	0.0
	195	5.0	7.2	7.8	7.8	7.8	7.8	7.2	6.7	5.0	3.9	2.8	1.7
	293	2.8	4.4	5.6	6.7	7.2	7.8	7.2	6.7	6.1	5.6	4.4	3.3
Shaded	98	5.0	6.7	7.2	7.8	7.2	6.7	5.6	4.4	2.8	1.1	0.6	0.0
	195	2.8	4.4	5.6	6.7	7.2	6.7	6.1	5.6	4.4	3.3	2.2	1.1
	293	1.1	2.2	3.3	4.4	5.0	5.6	5.6	5.6	5.0	4.4	3.3	2.2
		1	2	3	4	5	6	7	8	9	10	11	12

The weight of the Roof

$$W_r == 416\ \frac{kg}{m^2}$$

Peak time =3 pm

TABLE 16 A-CORRECTIONS TO EQUIVALENT TEMPERATURES (°C)

OUTDOOR DESIGN CONDITION FOR MONTH AT 3 P.M. MINUS ROOM TEMP	Daily Range oC												
	8.9	10.0	11.1	12.2	13.3	14.4	15.6	16.7	17.8	18.9	20.0	21.1	22.2
-16.7	-23.9	-24.4	-25.0	-25.6	-26.1	-26.7	-27.2	-27.8	-28.3	-28.9	-29.4	-30.0	-30.6
-11.1	-18.3	-18.9	-19.4	-20.0	-20.6	-21.1	-21.7	-22.2	-22.8	-23.3	-23.9	-24.4	-8.3
-5.6	-12.8	-13.3	-13.9	-14.4	-15.0	-15.6	-16.1	-16.7	-17.2	-17.8	-18.3	-18.9	-19.4
0.0	-7.2	-7.8	-8.3	-8.9	-9.4	-10.0	-10.6	-11.1	-11.7	-12.2	-12.8	-13.3	-13.9
2.8	-4.4	-5.0	-5.6	-6.1	-6.7	-7.2	-7.8	-8.3	-8.9	-9.4	-10.0	-10.6	-11.1
5.6	-1.7	-2.2	-2.8	-3.3	-3.9	-4.4	-5.0	-5.6	-6.1	-6.7	-7.2	-7.8	-8.3
8.3	1.1	0.6	0.0	-0.6	-1.1	-1.7	-2.2	-2.8	-3.3	-3.9	-4.4	-5.0	-5.6
11.1	3.9	3.3	2.8	2.2	1.7	1.1	0.6	0.0	-0.6	-1.1	-1.7	-2.2	-2.8
13.9	6.7	6.1	5.6	5.0	4.4	3.9	3.3	2.8	2.2	1.7	1.1	0.6	0.0
16.7	9.4	8.9	8.3	7.8	7.2	6.7	6.1	5.6	5.0	4.4	3.9	3.3	2.8
19.4	12.2	11.7	11.1	10.6	10.0	9.4	8.9	8.3	7.8	7.2	6.7	6.1	5.6
22.2	15.0	14.4	13.9	13.3	12.8	12.2	11.7	11.1	10.6	10.0	9.4	8.9	8.3

Find the daily range (Table 1)	**18.7**
Find the difference between (outdoor design condition for month at 3P.M.)	**20**

Step 10

TABLE 15 -EQUIVALENT TEMPERATURE DIFFERENCE (°C) FOR DARK COLORED , SUNLIT AND SHADED WALLS

Based on Dark Colored Walls; 35 °C DBT Outdoor Design Temp; Constant 26.5 °C Inside DBT 11 °C Daily Range; 24-hour Operation; July and 40 N. Lat.

EXPOSURE	Weight of wall kg/m²	SUN TIME											
		PM											
		1	2	3	4	5	6	7	8	9	10	11	12
Northeast	98	7.2	6.7	7.2	7.8	7.8	7.8	6.7	5.6	4.4	3.3	2.2	1.1
	293	8.3	5.6	6.1	6.7	7.2	7.8	7.2	6.7	6.1	5.6	4.4	3.3
	488	8.3	7.8	6.7	5.6	6.1	6.7	6.7	6.7	6.1	5.6	5.0	4.4
	683	5.6	7.8	8.9	7.8	6.7	5.6	5.6	5.6	5.6	5.6	5.6	5.6
East	98	11.1	6.7	7.2	7.8	7.8	7.8	6.7	5.6	4.4	3.3	2.2	1.1
	293	10.6	7.8	7.2	6.7	7.2	7.8	7.2	6.7	6.1	5.6	4.4	2.8
	488	13.9	13.3	11.1	10.0	8.9	7.8	7.8	7.8	7.2	6.7	6.1	5.6
	683	8.3	10.0	10.6	10.0	9.4	8.9	7.8	6.7	7.2	7.8	7.8	7.8
Southeast	98	14.4	13.3	10.6	8.9	8.3	7.8	6.7	5.6	4.4	3.3	2.2	1.1
	293	14.4	13.9	11.7	10.0	8.3	7.8	7.2	6.7	6.1	5.6	4.4	3.3
	488	9.4	10.0	10.6	10.0	8.9	7.8	7.2	6.7	6.1	5.6	5.6	5.6
	683	6.1	7.8	8.3	8.9	10.0	8.9	8.3	7.8	7.2	6.7	6.7	6.7
South	98	15.0	16.7	15.6	14.4	11.1	8.3	6.7	5.6	3.9	3.3	1.7	1.1
	293	11.1	13.3	13.9	14.4	12.8	11.1	8.3	6.7	5.6	4.4	3.3	2.2
	488	4.4	6.7	8.3	8.9	10.0	10.0	8.3	7.8	6.1	5.6	4.4	4.4
	683	2.2	2.2	3.9	5.6	7.2	7.8	8.3	8.9	8.9	7.8	6.7	5.6
Southwest	98	10.6	14.4	18.9	22.2	22.8	23.3	16.7	13.3	6.7	3.3	2.2	1.1
	293	4.4	6.7	13.3	17.8	19.4	20.0	19.4	18.9	11.1	5.6	3.9	3.3
	488	3.9	4.4	6.7	7.8	10.6	12.2	12.8	13.3	12.8	12.2	8.3	5.6
	683	3.3	3.3	3.9	4.4	5.0	5.6	8.3	10.0	10.6	11.1	7.2	4.4
West	98	7.8	11.1	17.8	22.2	25.0	26.7	18.9	12.2	7.8	4.4	2.8	1.1
	293	3.9	5.6	10.6	14.4	18.9	22.2	22.8	20.0	15.6	8.9	5.6	3.3
	488	3.9	4.4	5.6	6.7	9.4	11.1	13.9	15.6	15.0	14.4	10.6	7.8
	683	5.0	5.6	5.6	5.6	6.1	6.7	7.8	8.9	11.7	12.2	12.8	12.2
Northwest	98	5.6	6.7	10.6	13.3	18.3	22.2	20.6	18.9	10.0	3.3	2.2	1.1
	293	3.3	4.4	5.6	6.7	11.7	16.7	17.2	17.8	11.7	6.7	4.4	3.3
	488	2.2	2.2	2.8	3.3	5.0	6.7	9.4	11.1	11.7	12.2	7.8	4.4
	683	3.3	3.3	3.3	3.3	3.9	4.4	5.0	5.6	7.8	10.0	10.6	11.1
North (Shade)	98	4.4	5.6	6.7	7.8	7.2	6.7	5.6	4.4	3.3	2.2	1.1	0.0
	293	1.7	3.3	4.4	5.6	6.1	6.7	6.7	6.7	5.6	4.4	3.3	2.2
	488	0.6	1.1	1.7	2.2	2.8	2.8	2.8	4.4	3.9	3.3	2.8	2.2
	683	0.0	0.0	0.6	1.1	1.7	2.2	2.8	3.3	3.9	4.4	3.9	3.3
Time		1	2	3	4	5	6	7	8	9	10	11	12
		PM											

Table (12A) Solar Irradiance (EDN) and Solar Heat Gain Factors (SHGF) for 32° North Latitude

Time of Year	Exposure	6	7	8	9	10	11	Noon	1	2	3	4	5	6
JULY 23 & MAY 21	N	69	63	44	41	44	44	44	44	44	**41**	44	63	69
	NE	293	413	388	281	145	50	44	44	44	**41**	38	28	13
	E	315	489	517	457	312	139	44	44	44	**41**	38	28	13
	SE	132	259	315	315	262	167	69	44	44	**41**	38	28	13
	S	13	28	38	44	63	85	95	85	63	**44**	38	28	13
	SW	13	28	38	41	13	44	44	167	262	**315**	315	259	132
	W	13	28	38	41	44	44	44	139	312	**457**	517	489	315
	NW	13	28	38	41	44	44	44	50	145	**281**	388	413	293
	Horizontal	47	208	388	555	675	744	776	744	675	**555**	388	208	47

Step 11

West=517 North= 69 South=95

East = 517 Horizontal = 776

Table (12AB) Solar Irradiance (EDN) and Solar Heat Gain Factors (SHGF) for 40° North Latitude

Time of Year	Exposure	6	7	8	9	10	11	Noon	1	2	3	4	5	6
AUG 24 & APR 20	N	22	25	35	41	44	**44**	44	44	44	41	35	25	22
	NE	215	322	259	145	50	44	44	44	44	41	35	25	9
	E	265	464	**511**	457	319	142	44	44	44	41	35	25	9
	SE	151	331	435	**461**	438	338	208	79	44	41	35	25	9
	S	9	25	76	161	281	306	**322**	306	218	161	76	25	9
	SW	9	9	35	9	44	79	208	338	438	**461**	429	331	151
	W	9	25	35	41	44	44	44	142	319	457	**511**	464	265
	NW	9	25	35	41	44	44	44	44	50	145	259	**322**	215
	Horizontal	28	148	315	473	584	647	**675**	647	568	473	315	148	28

Step 12

West= 511 North= 44 South =322

East = 511 Horizontal = 675

No.		W	N	E	S	H
1	Calculate the weight of wall or roof per m^2	511.37	511.37	511.37	511.37	416
2	Select the equivalent temperature difference (T15)	5.6	1.7	11.1	8.3	15.6
3	Select the outdoor design conditions for summer(T1)	45	45	45	45	45
4	Select the outdoor design conditions for winter(T1)	1.5	1.5	1.5	1.5	1.5
5	Find the yearly range	45-1.5	43.5	43.5	43.5	43.5
6	Find the daily range (Table 1)	18.7	18.7	18.7	18.7	18.7
7	Find the difference between (outdoor design condition for month at 3P.M.)	45-25	20	20	20	20
8	Find the correction of equivalent temp. diff. (T16A)	7.2	7.2	7.2	7.2	7.2
9	Find the equivalent temperature difference for wall or roof exposed to the sun (Dtem) (Step 8+step 2)	5.6+7.2 =12.8	8.9	18.3	15.5	22.8
10	Find equivalent temperature difference for same wall or roof in shade (DTes)(T15+step 8)	1.7+7.2 =8.9	8.9	8.9	8.9	8.9
11	Find the maximum solar radiation maximum solar heat gain through glass for wall (Rs) (T12A)	517	69	517	95	776
12	Find the maximum solar heat gain through glass for wall facing or horizontal for roofs, for July at 40 North latitud (Rm) T12B)	511	44	511	322	675

1	Calculate the weight of wall or roof per m_2	511
2	Select the equivalent temperature difference (T15)	5.6
3	Select the outdoor design conditions for summer	45
4	Select the outdoor design conditions for winter	1.5
5	Find the yearly range	43.5
6	Find the daily range (Table 1)	18.7
7	Find the difference between (outdoor design condition for month at 3P.M.)	20
8	Find the correction of equivalent temp. diff.	7.2
9	Find the equivalent temperature difference for wall or roof exposed to the sun (Dtem)	**12.8**
10	Find equivalent temperature difference for same wall or roof in shade (DTes)	**8.9**
11	Find the maximum solar radiation maximum solar heat gain through glass for wall (Rs)	**517**
12	Find the maximum solar heat gain through glass for wall facing or horizontal for roofs, for July at 40 North latitud (Rm)	**511**

$$\Delta t_e = 0.78 \frac{R_s}{R_m} . \Delta t_{em} + (1 - 0.78) \frac{R_s}{R_m} . \Delta t_{es}$$

$$\Delta t_e = 0.78 \frac{517}{511} . 12.8 + (1 - 0.78) \frac{517}{511} . 8.9 = 12.08$$

Homework:

Find the equivalent temperature difference for the wall mentioned in example 3 for the orientation South, North, east and (Roof) horizontal.

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