

**ME-415**  
**REFRIGERATION AND BUILDING MECHANICAL SYSTEMS**

**TOPIC : COOLING LOAD ESTIMATION**

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## 1 CAD model of Room

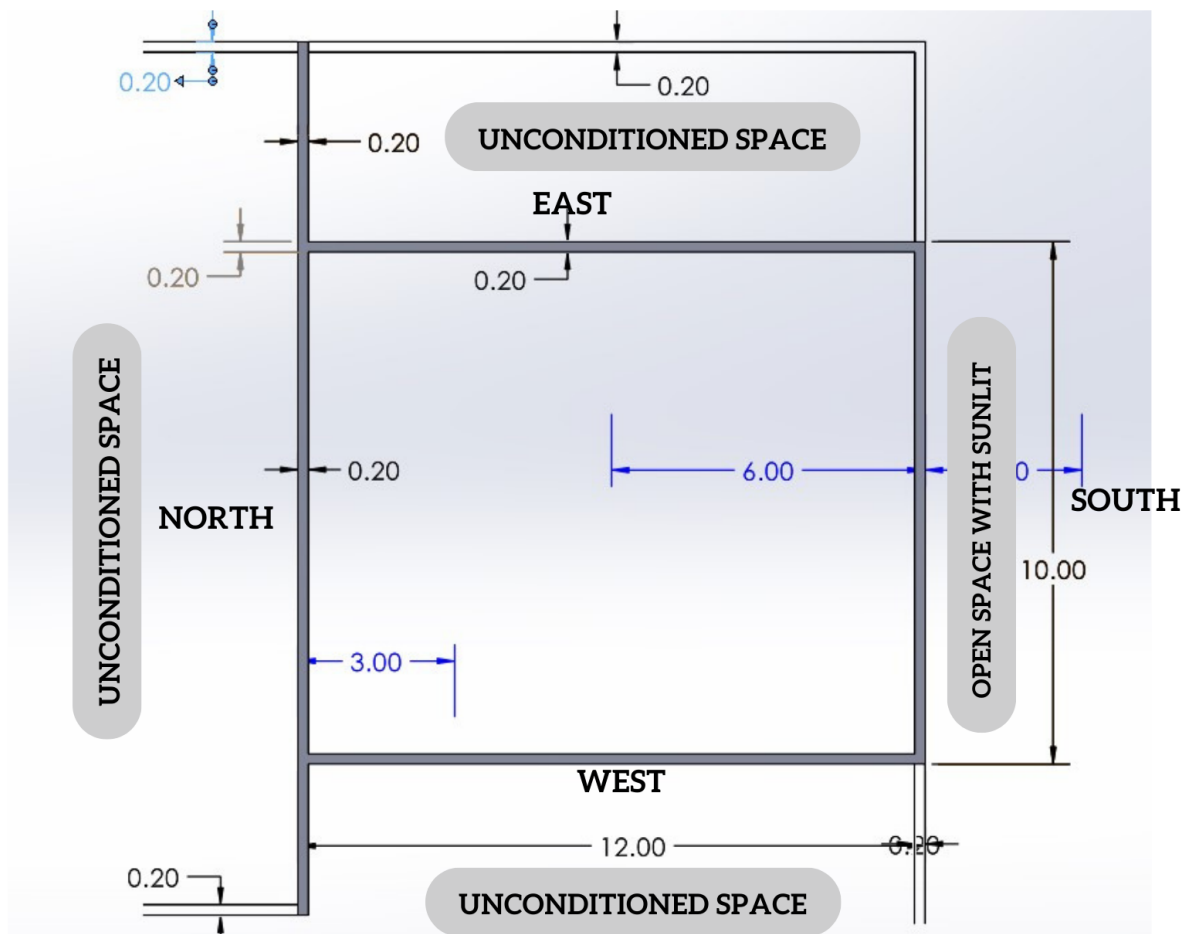


Figure 1: Top View of Room

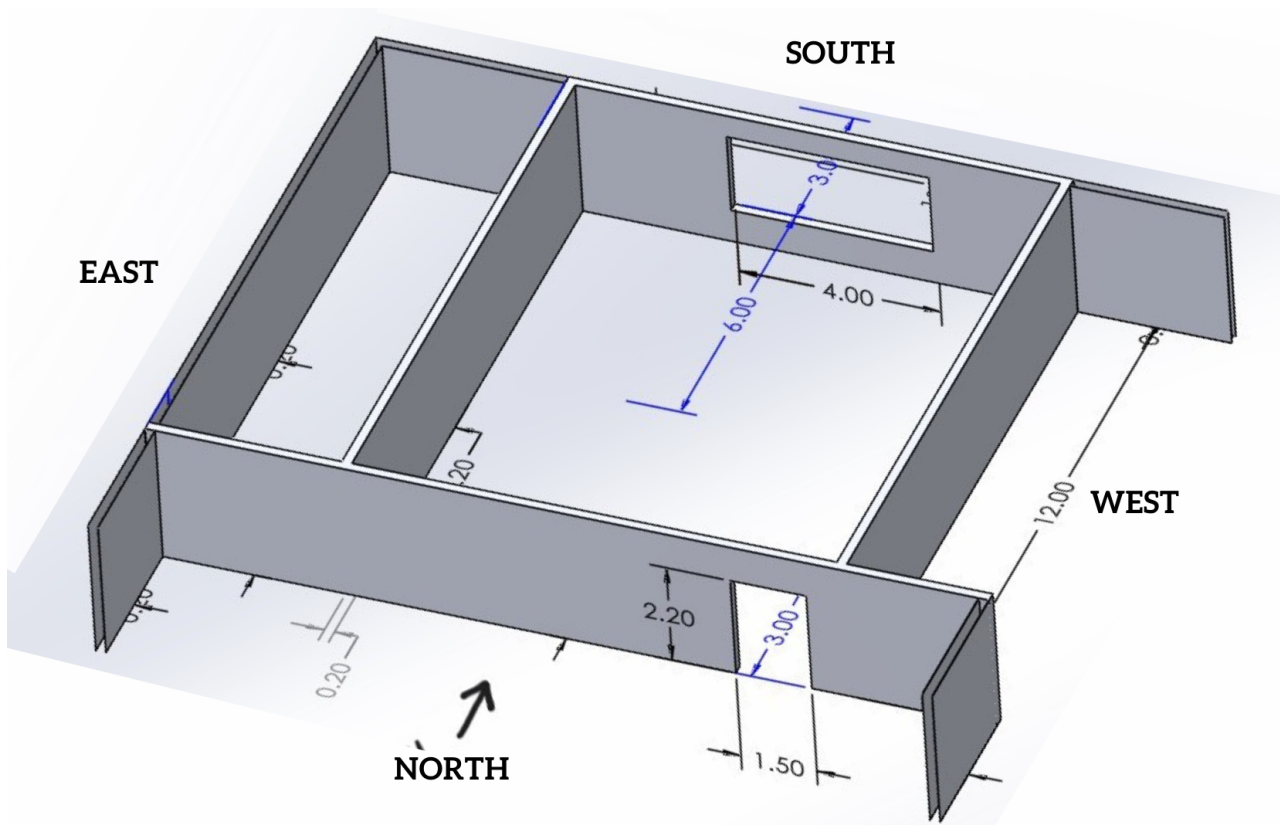


Figure 2: North to south view of Room

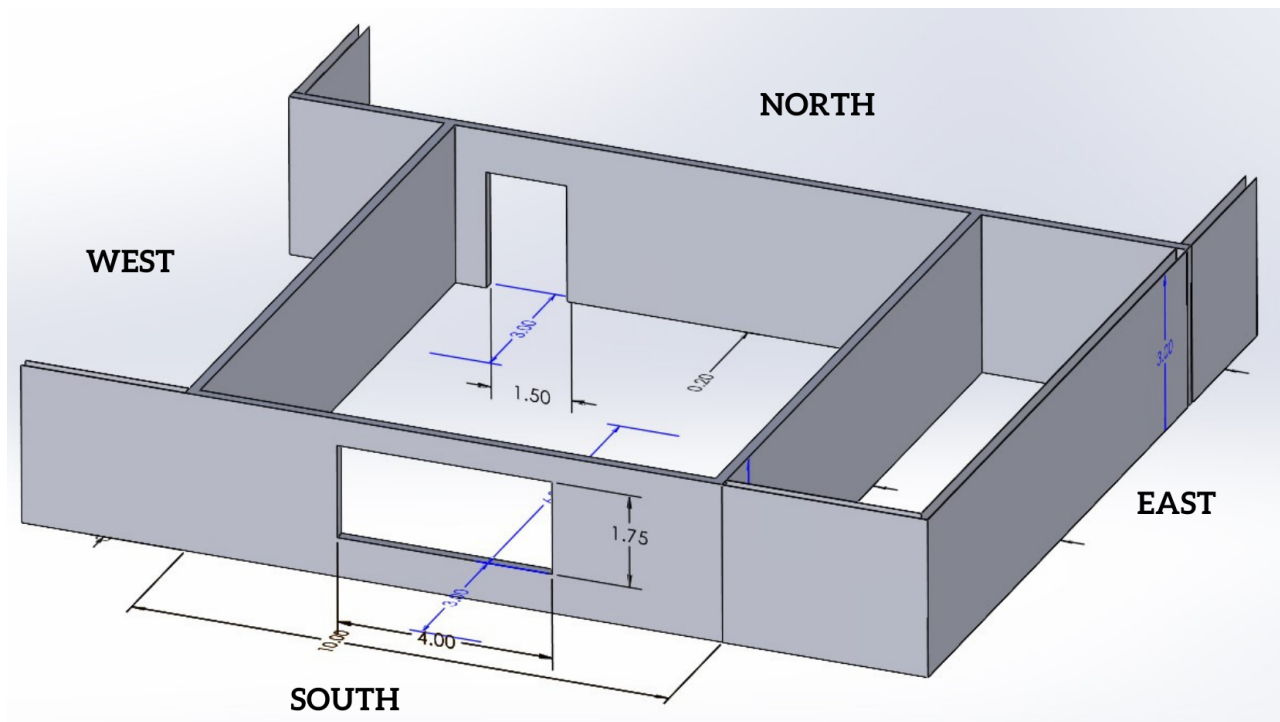


Figure 3: South to North view of Room

## 2 Model Specification

1. **Date & Time:** April Month, at 5 pm
2. **Location:** Lakshmipur, Bangladesh
3. **Temperature:** 25.5 °C
4. **Relative Humidity:** 50%
5. **Dimensions:**
  - Length : 4 m
  - Width : 3 m
  - Height : 3 m
  - Window : 1.5 m  $\times$  1.25 m (on south wall)
  - Door : 2.2 m  $\times$  0.75 m (on north wall)
6. **Surroundings:**
  - South side : Open Space & sunlit presence
  - East side : Unconditioned Space
  - North side : Unconditioned Space
  - West side : Unconditioned Space
7. **Construction:**
  - **Roof** : Type-4 with 50 mm insulation without suspended ceiling.
  - **All walls (N, E, S, W)** : 150 mm brick with 25 mm plaster on both sides.
  - **Door** : 25 mm thick hard wooden door.
  - **Window** :  $U = 2.5 \text{ W/m}^2 - K$  with 15 mm thick glass of light construction.
  - **Floor** : No heat transfer through floor.
8. **Other factors:**
  - 2 occupants seated with 1 using Laptop
  - 1 light of 25 W with flourescence light
  - No other electronic devices
  - Lights and occupants from 11 am to 10 pm
  - Air change rate = 1.0 /hr

### 3 Heat Conduction through Partition walls / glasses

#### 3.1 Roof

**Type-4 with 50 mm insulation without suspended ceiling**

From Table-12(a), Layers : **A0 E2 E3 B6 C12 E0**

Now, reading the values from table-16,

Layers	Layers Details	Resistance
A0	Outside Surface Resistance	0.059
E2	12 mm slag or stone	0.099
E3	10 mm felt and membrane	0.050
B6	50 mm insulation	1.173
C12	50 mm heavy weight concrete	0.029
E0	Inside surface resistance	0.121

Table 1: Roof Layers

Total resistance,  $R = 1.581$

$\therefore U = 1/R = 0.653$

#### 3.2 Walls

**North, East, South & West Walls:**

**150 mm brick with 25 mm plaster on both sides**

From table 16,

- For C4 : 100 mm common brick,  $k = 0.727 \text{ W/m} - K$   
Now, resistance for 150 mm brick,  
 $R_2 = 0.150/0.727 = 0.206$
- For E1 : 20 mm plaster,  $k = 0.7277 \text{ W/m} - K$   
Now, resistance for 25 mm plaster,  
 $R_1 = R_3 = 0.025/0.7277 = 0.0344$
- Total resistance,  $R = R_o + R_1 + R_2 + R_3 + R_i$   
 $= 0.059 + 0.0344 + 0.206 + 0.0344 + 0.121$   
 $= 0.4548$
- $U = 1/R = 2.199 \text{ W/m}^2 - K$

#### 3.3 Window

**15 mm thick glass of light construction**

- $U = 2.5 \text{ W/m}^2 - K$

#### 3.4 Door

**25 mm thick hard wooden door**

- Door size :  $2.2 \text{ m} \times 0.75 \text{ m}$
- From table-17.6, Hard wood : Oak,  $k = 0.16 \text{ W/m} - K$   
Now, resistance for 25 mm thick door,  
 $R_{door} = 0.025/0.16 = 0.156$

- Total resistance,  $R = R_o + R_{door} + R_i$   
 $= 0.059 + 0.156 + 0.121$   
 $= 0.336$
- $U = 1/R = 2.976 \text{ W/m}^2 - K$

### 3.5 Calculation Table

- Assuming,  $T_o = 30.5^\circ C$  and  $T_i = 25.5^\circ C$ .
- $T_{o,max} = 33^\circ$  for Bangladesh [From table : 9]

Sl. no.	Item	Description	A	U	TD	Q (watt)
1	Partition wall	North	7.35	2.199	5.0	80.81
2	Partition wall	East	12	2.199	5.0	131.94
3	Partition wall	West	12	2.199	5.0	131.94
4	Partition wall	South	7.125	2.199	7.5	117.51
5	Partition glass	South	1.875	2.50	7.5	35.16
6	Door	North	1.65	2.976	5.0	24.552
						521.902

Table 2: Heat conduction through partition walls / glasses

## 4 Heat Conduction through roof & sunlit walls / glasses

### 4.1 Roof

Parameters:

$$\begin{aligned}
 T_i &= 25.5^\circ C && \text{Correction for Latitude \& month, LM=0 [Table : 13]} \\
 T_{o,max} &= 33^\circ C && \text{Attic Fan Factor, f = 1} \\
 T_{o,av} &= 33 - 11/2 = 27.5^\circ C \text{ [Table : 9]} && \text{Color adjustment factor, K = 1 [dark color]} \\
 CLTD &= 37 \text{ [Table: 12(b)]}
 \end{aligned}$$

$$\begin{aligned}
 CLTD_c &= [(CLTD + LM)K + (25.5 - T_i) + (T_{o,av} - 29.4)] f \\
 &= [(37 + 0)1 + (25.5 - 25.5) + (27.5 - 29.4)] 1 \\
 &= 35.1
 \end{aligned}$$

### 4.2 South Wall

Parameters:

$$\begin{aligned}
 T_i &= 25.5^\circ C && \text{Correction for Latitude \& month, LM= -1.6 [Table:13]} \\
 T_{o,max} &= 33^\circ C && \text{Attic Fan Factor, f = 1} \\
 T_{o,av} &= 33 - 11/2 = 27.5^\circ C \text{ [Table : 9]} && \text{Color adjustment factor, K = 1 [dark color]} \\
 CLTD &= 17 \text{ [Table: 15]}
 \end{aligned}$$

$$\begin{aligned}
 CLTD_c &= [(CLTD + LM)K + (25.5 - T_i) + (T_{o,av} - 29.4)] f \\
 &= [(17 - 1.6)1 + (25.5 - 25.5) + (27.5 - 29.4)] 1 \\
 &= 13.5
 \end{aligned}$$

### 4.3 Glass

From Table-20:

At 5 pm, CLTD = 7 [No correction needed]

### 4.4 Calculation Table

Sl. no.	Item	Description	A	U	TD	Q (watt)
1	Roof	Type 4	12	0.653	35.1	275.04
2	South wall	Type C4	7.125	2.199	13.5	211.52
3	Sunlit glass	South	1.875	2.50	7.0	32.81
						519.37

Table 3: Heat Conduction through Roof and Sunlit Walls/Glasses

## 5 Heat Gain

### 5.1 Solar Heat gain through glass

Shading factor,  $SF = 0.85$  [Table : 21, for 15 mm thickness clear glass]

$SHGF_{max} = 237$  [Table : 18(a), for south wall in April month]

$CLF = 0.59$  [Table : 19, for south wall at 5 pm]

Window area =  $1.5 \text{ m} \times 1.25 \text{ m} = 1.875 \text{ m}^2$

$$\begin{aligned} Q &= A \times SF \times SHGF_{max} \times CLF \\ &= 1.875 \times 0.85 \times 237 \times 0.59 \\ &= 222.85 \text{ watt} \end{aligned}$$

### 5.2 Cooling Load for Air Exchange

Volume of the room =  $4 \times 3 \times 3 = 36 \text{ m}^3$

Air change rate =  $1.0 / \text{hr}$

$\therefore$  Air change per hour,  $V = 36 \text{ m}^3/\text{hr} = 0.01 \text{ m}^3/\text{s}$

$W_o = 21.5 \times 10^{-3}$  at  $33^\circ$  dbt and  $27^\circ$  wbt

$W_i = 10 \times 10^{-3}$  at  $25.5^\circ$  dbt and 50% RH

$$\begin{aligned} \text{Sensible Heat Gain, } Q_s &= \rho \times C_p \times V \times (T_o - T_i) \\ &= 1200 \times 0.01 \times (33 - 25.5) \\ &= 90 \text{ watt} \end{aligned}$$

$$\begin{aligned} \text{Latent Heat Gain, } Q_L &= \rho \times h_{gf} \times V \times (W_o - W_i) \\ &= 3010 \times 10^3 \times 0.01 \times (21.5 - 10) \times 10^{-3} \\ &= 346.15 \text{ watt} \end{aligned}$$

### 5.3 Heat Gain due to Occupants

From Table : 28, for apartments,

Sensible heat = 75 W

Latent heat = 55 W

For 2 occupants,



$$Q_L = 55 \times 2 = 110 \text{ watt}$$

$$Q_S = 75 \times 2 = 150 \text{ watt}$$

## 5.4 Heat gain due to Equipments

For 1 laptop, power = 100 watt

Cooling load factor,  $CLF = 1$

$$Q = P \times CLF$$

$$= 100 \times 1$$

$$= 100 \text{ watt}$$

## 5.5 Cooling load due to Lights

For 1 light, Lighting power,  $PL = 25 \text{ W/m}^2 \times 12\text{m}^2 = 300 \text{ W}$

Cooling load factor,  $CLF = 0.85$  [assuming]

Ballast factor,  $BF = 1.2$  [flouroscent light]

Diversity factor,  $D = 1$  [assuming]

$$Q = PL \times BF \times D \times CLF$$

$$= 300 \times 1.2 \times 1 \times 0.85$$

$$= 306 \text{ watt}$$

## 6 Final Load Calculation

SI. no.	Items with Description	$Q_s$ (watt)	$Q_L$ (watt)	$Q_T$ (watt)
1	Heat conduction through partition walls / glasses	521.902	-	521.902
2	Heat conduction through roof & sunlit walls / glasses	519.37	-	519.37
3	Solar heat gain through glass	222.85	-	222.85
4	Cooling load for air exchange	90	346.15	436.15
5	Heat gain due to occupants	150	110	260
6	Heat gain due to equipments	100	-	100
7	Cooling load due to lights	306	-	306
		1910.122	456.15	2366.272

Table 4: Final Load Calculation

$$QT = 2366.272 \text{ watt}$$

$$= 2.37 \text{ kW}$$

$$= \frac{2.37}{3.516} \text{ TR}$$

$$= 0.674 \text{ TR}$$

$$\therefore QT \approx 0.7 \text{ TR}$$

**REMARK:** The required cooling load for the room is **0.7 TR**.

## 7 Additional Links

Github Links for the project:

The solidworks model, model images, L<sup>A</sup>T<sub>E</sub>X and PDF files included here:-

**<https://github.com/HasibRockie/cooling-load-estimation>**