PROJECT REPORT

Project No. 7 – Heat Transfer analysis of a residential structure

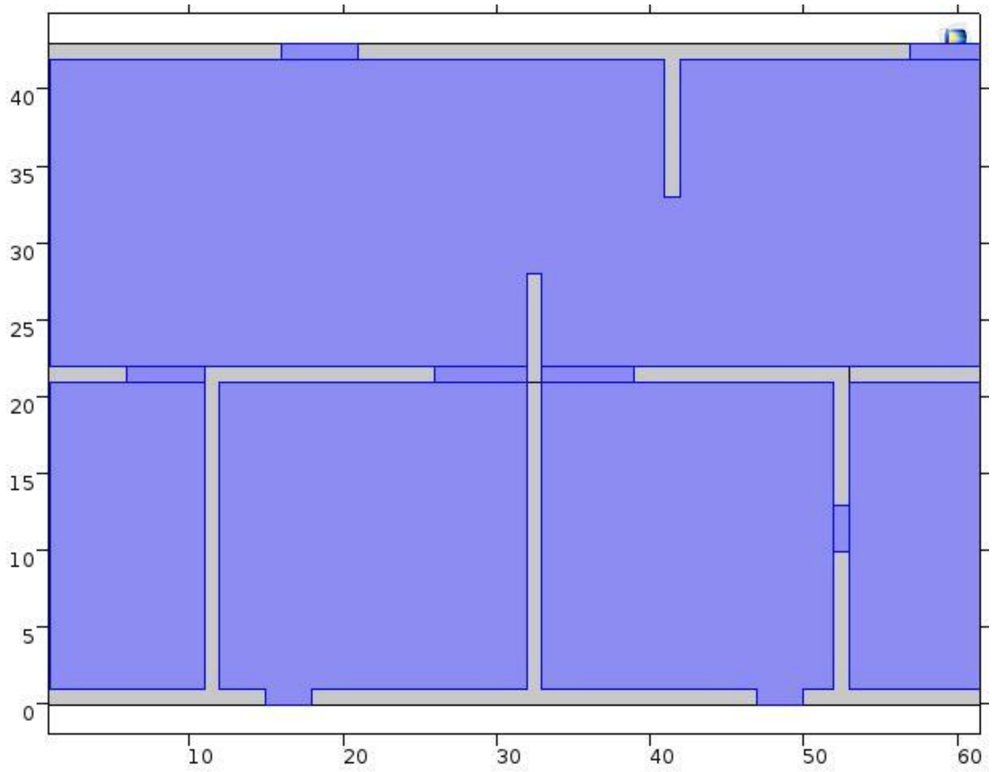
Group: CE-5

Objective:

The objective of the project is to analyse the temperature evolution in a typical layout of a residential structure. The structure had to be modelled in COMSOL using the equation based modelling framework.

Introduction:

Studying the heat transfer in a residential structure helps us reduce the use of energy and resources needed in either heating up or cooling down the house. By doing this we would also be following the theme of Green Urban Planning. As high- performance buildings use less operating energy, internal energy has assumed much importance. The layout of the residential structure is given below.



Formulation of the Problem:

- **Assumptions:**
  - The pressure inside and outside the structure is constant.
    The air inside is inviscid and ideal.
  - The material constants (k, h, rho) are constant with respect to temperature.
  - The walls are thin sheets.
  - The fireplace is a heat source fixed at a higher temperature than its surroundings.
  - The walls extending inside the structure act as heat sinks.
  - The windows and doors transfer heat outside at a rate based on their material properties.

We are considering the outer surface of the wall to be a constant heat source. This is done in an attempt to model the heat provided by the Sun.

- **Initial Conditions:**
  - The initial temperature of the structure is 300K.
  - There is no heat transfer occurring prior to the start of observation of the system.
  - The fireplace has a constant higher temperature of 1000K.

- ## Equations:

  We require equations for the convection of heat within the fluid mass in the structure, as well as out through the windows and door.

  For this the equation to be modeled is

$$\rho C_p \frac{\partial T}{\partial t} = k \frac{\partial^2 T}{\partial^2 x}$$

Where, ρ = Density of the material
C_p = Specific Heat at constant pressure
k = Thermal Conductivity of material (here air)

The above equation needed to be related to the General Equation in COMSOL, which is

$$e_a\frac{\partial^2 T}{\partial t^2} + d_a\frac{\partial T}{\partial t} + \nabla\cdot(-c\nabla T - \alpha T + \gamma) + \beta\cdot\nabla T + aT = f$$

$$\nabla = [\frac{\partial}{\partial x}, \frac{\partial}{\partial y}]$$

On comparing the coefficients of the two equations we get,

$e_a = 0$
$\alpha = 0$
$\beta = 0$
$\gamma = 0$
$a = 0$
$f = 0$
$d_a = \rho C_p$
$c = k$

- **Boundary Conditions:**

For the **Fireplace** a Dirichlet Boundary condition was given where the value of 'r' was initialized to 1000K. This sets the boundary to be fixed at a pre-determined temperature.

The **Windows, Doors** and the **Walls** are modeled to have an outward flux, thereby cooling the layout.
Window:
Boundary Flux(g)=1.05*300
Boundary Absorption(q)=1.05
Doors:
Boundary Flux(g)=0.2*300
Boundary Absorption(q)=0.2
Wall:
Boundary Flux(g)=0.02*300
Boundary Absorption(q)=0.02

The actual equation we are modeling above is

Heat conducted = Heat convected

$$kA\nabla T = hA(T - T_\infty)$$

On comparing it with the general Flux/Source equation we get,

$$c = k$$

$$g - qT = hT - hT_\infty$$

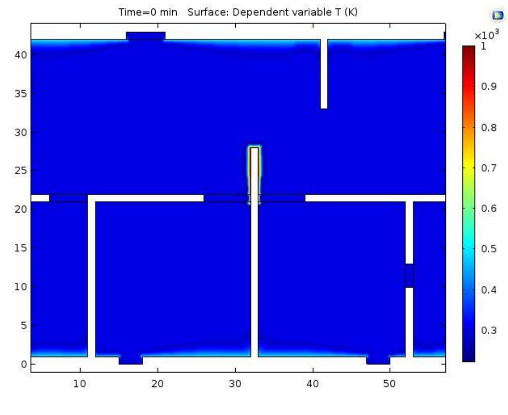
Where k the thermal conductivity of the material is, T is the temperature of the material boundary and
T_∞ is the initial temperature of 300K.

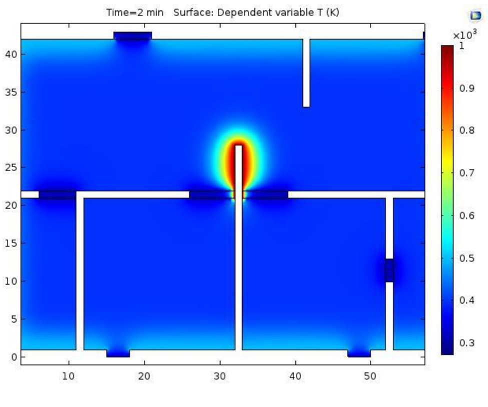
So, q is effectively heat transfer coefficient of respective material at 25°C and g will be q*T_∞.

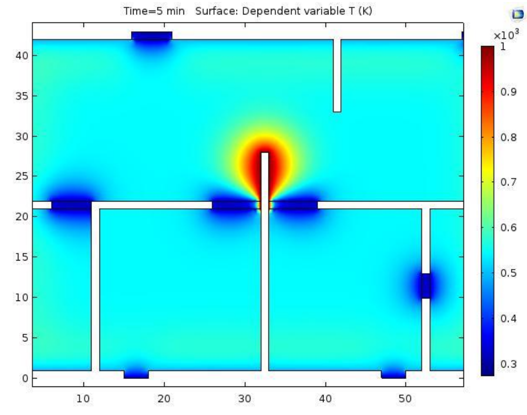
We also considered the influence of the Sun. This was done by introducing Dirichlet Boundary condition where the value of 'r' was set to 310K, implying the sun would be considered to be maintaining the walls of the structure at 310K.

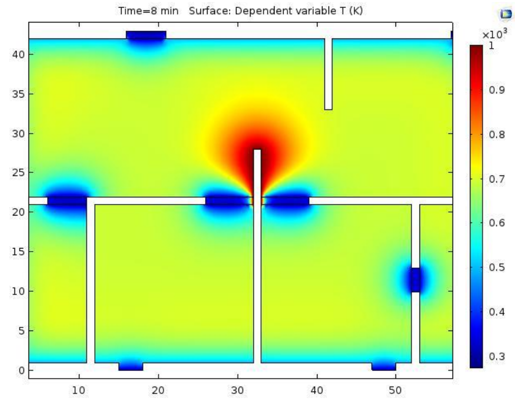
Results:

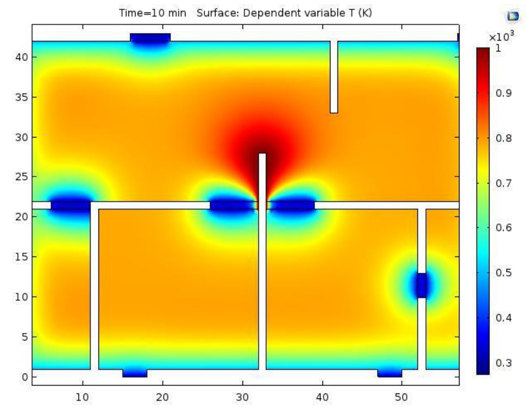
The following results are observed at different time intervals



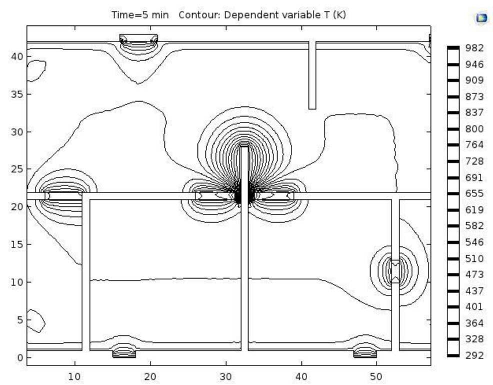








From the results we see that the heat slowly comes in from the outer walls due constant heat applied due to sun. The heat from the fireplace is slowly leached out by the outward flux at the windows, doors and inner walls. This is shown by the relatively cold regions right next to their boundaries.



The following contour plots are observed