# Computer Simulation of Thermal Comfort for Far Infrared Heading


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## Introduction

In the United States, space heating alone uses 42% of all energy consumed by the average household Many modern convection heaters are fueled by gas, which is a very costly resource and has many negative effects on the environment. Infrared heaters have been slowly taking over and replacing many conventional space heaters in society. The benefits of infrared heaters lie within the ability to directly control the amount of heat being dissipated by the heating panels. The infrared radiation from the panels are capable of directly heating an area and any objects within the specified area. With regulated heating controls, consumers are able to control the amount of energy being used and greatly reduce electricity bills, as well as reducing the use of greenhouse gases.

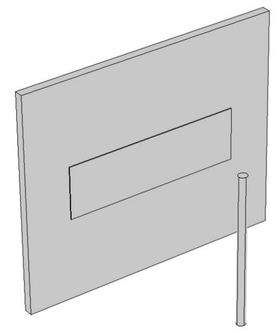
## Objective

The purpose of this project is to develop a software that is capable of calculating the amount of infrared radiation being emitted, tracking how this affects the mean radiant temperature in the room, determining the thermal comfort of an occupant in the room based on the mean radiant temperature, and modeling the distribution of heat in the room.

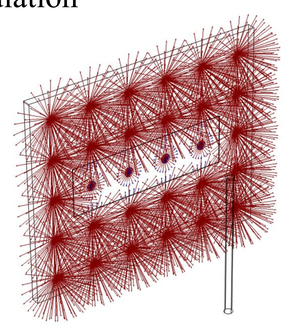
## Design

The simulation design was developed in COMSOL Multiphysics, an app used to model the effects of various physics and engineering concepts such as airflow, heat transfer, and electricity on a CAD model that the user make in the app or import from an external source. Our design involved a 3D model of a room with object models in the room representing people and panel on a wall representing the FIR panel

## COMSOL Models

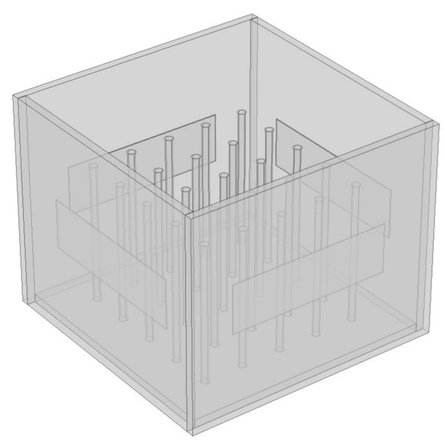


Model 1: Single Surface Representation of COMSOL simulation



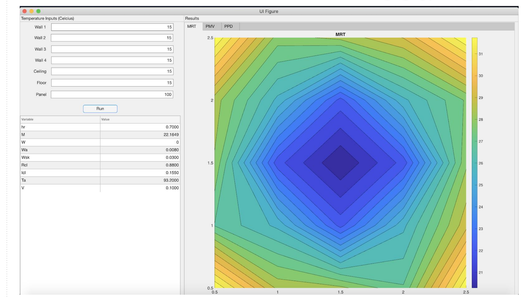
$$f(\theta,\varphi) = \frac{1}{2\pi}\sin\varphi$$
$$\varphi \in [0, \pi/2]$$
$$\theta \in [0, 2\pi]$$

Model 2: Ray Tracing Implemented with Hemispherical Grid Sources, with equations



Model 3: Room Model with 24 Individual Test Points

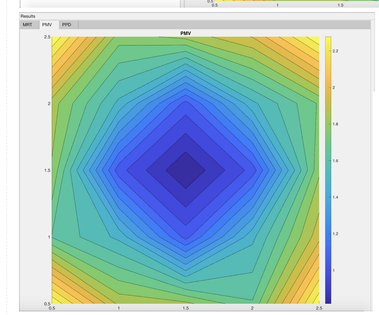
## Results



$$MRT(x,y) = \left( \sum_{ALL\ SURFACES} VF(x,y) \times (T_{SURFACE} + 273)^4 \right)^{1/4} - 273$$

| Value | Sensation |
|---|---|
| +3 | Hot |
| +2 | Warm |
| +1 | Slightly warm |
| 0 | Neutral |
| -1 | Slightly cool |
| -2 | Cool |
| -3 | Cold |

Figure for PMV Scale



$$PMV = 3.155(0.303e^{-0.114M} + 0.028)L$$

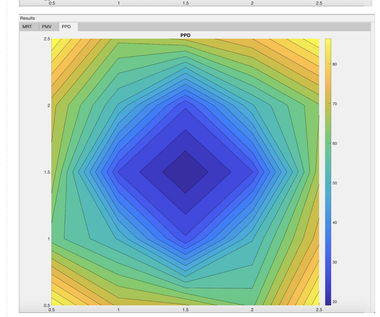
$$L = q_{met,heat} - f_{cl}h_c(T_{cl} - T_a) - f_{cl}h_r(T_{cl} - T_r) - 156(W_{sk,req} - W_a) - 0.42(q_{met,heat} - 18.43) - 0.00077M(93.2 - T_a) - 2.78M(0.0365 - W_a)$$

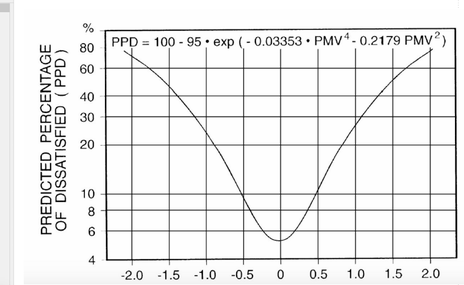
$$T_{cl} = \frac{T_{sk,req} + R_{cl}f_{cl}(h_cT_a + h_rT_r)}{1 + R_{cl}f_{cl}(h_c + h_r)}$$

$$f_{cl} = \begin{cases} 1.0 + 0.2I_{cl} & I_{cl} < 0.5 \text{ clo} \\ 1.05 + 0.1I_{cl} & I_{cl} > 0.5 \text{ clo} \end{cases}$$

$$h_c = \max\begin{cases} 0.361(T_{cl} - T_a)^{0.25} \\ 0.151\sqrt{V} \end{cases}$$

$$h_r = 0.7 \text{ Btu/h ft}^2\text{·F}$$






The ray count data is imported via MS Excel and from here we found the View Factors for each of the surfaces relative to the "person" in our COMSOL simulations. Once the user inputs the temperatures of each surface and of the panel, this calls a function to update the application's Contour Maps for MRT, PMV and PPD.

## Glossary

- FIR – Far Infrared Radiation
- MRT – Mean Radiant Temperature
- PPD – Percentage of People Dissatisfied, predicted percentage of people that would be uncomfortable in the room
- PMV – Predicted Mean Vote – on a scale of -3 to 3, how comfortable a person feels in the room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# Convection Industries