Warmup Project

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Quantatative Engineering Analysis 2 | Fall 2020

This is the first project of QEA2 at Olin College of Engineering.

In order to solidify our understanding of differential equations and heat transfer, we are designing a passive solar house for Vermont. A passive solar house combines interior features, exterior landscaping, and architectural design choices to ultimately heat the house with minimal electricity and fossil fuels.

The basic principles of a passive solar house are an aperture (window) to let solar radiation in, an aborber and thermal mass to absord and store the heat from the sun, and some components of heat transfer to evenly distribute the heat throughout the house. Additionally, there are often some control elements to adjust the amount of solar radiation coming in throughout the changing seasons, and thermal insulation can be useful to retain heat in colder climates.

For our house, we plan on starting with a simple house design to get a feel for how heat moves throughout the building. We plan on utilizing a south facing window with an overhang roof to let the sun in when we need it during the winter and block it out during the summer when it is naturally warmer. This is because in the northeast the sun takes a lower southern path during the winter, and a higher path during the summer. To absorb and store all of this solar radiation, we plan on and using a large slab of tile as our floor. Additionally, Vermont can get quite cold during the winter, so we will be insulating all of our walls and our floor.

Some sections for the future:

- Minimum Viable Project
- Some Math (and MATLAB)
- Moonshot
- Lessons Learned

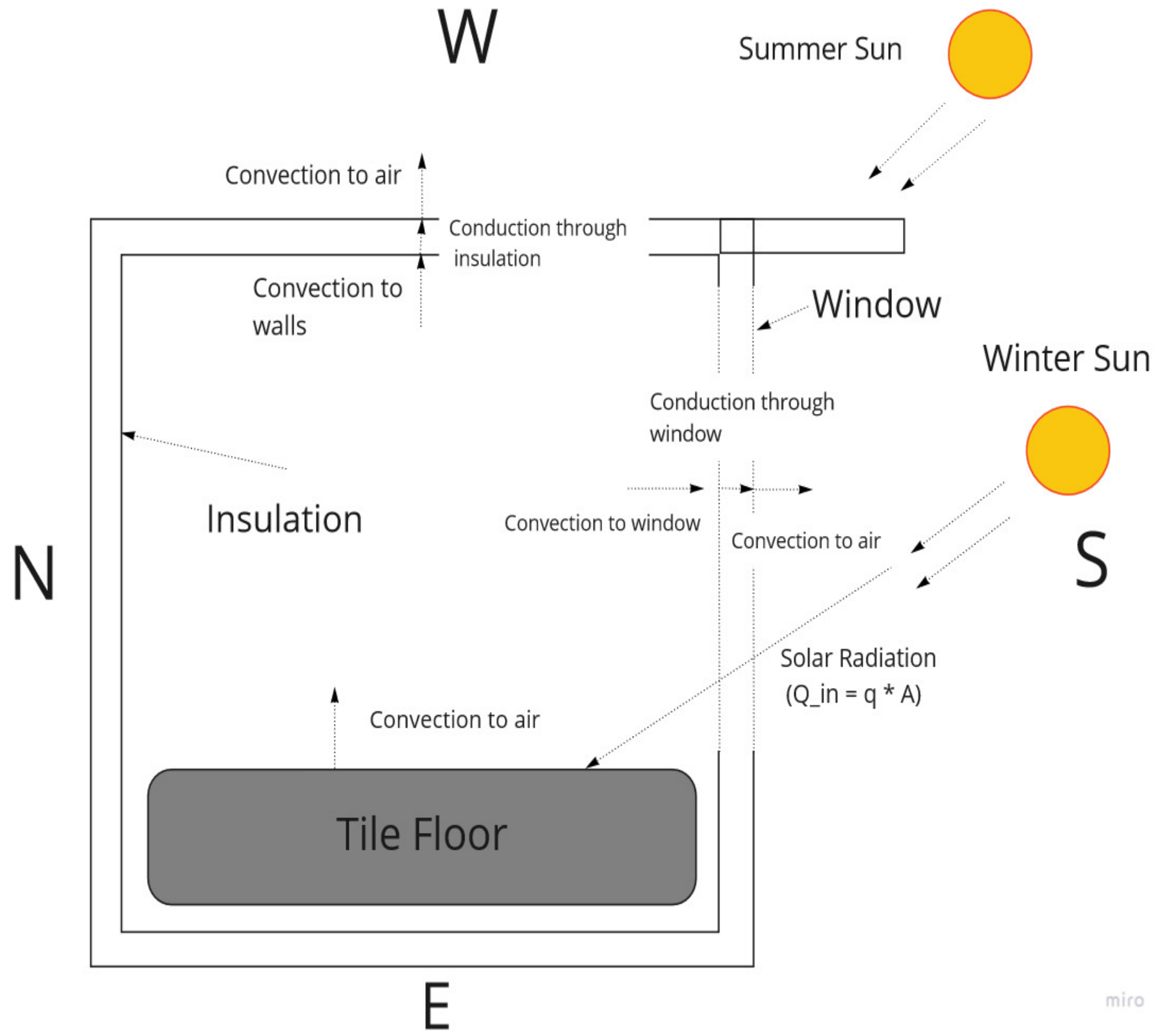
Minimum Viable Project

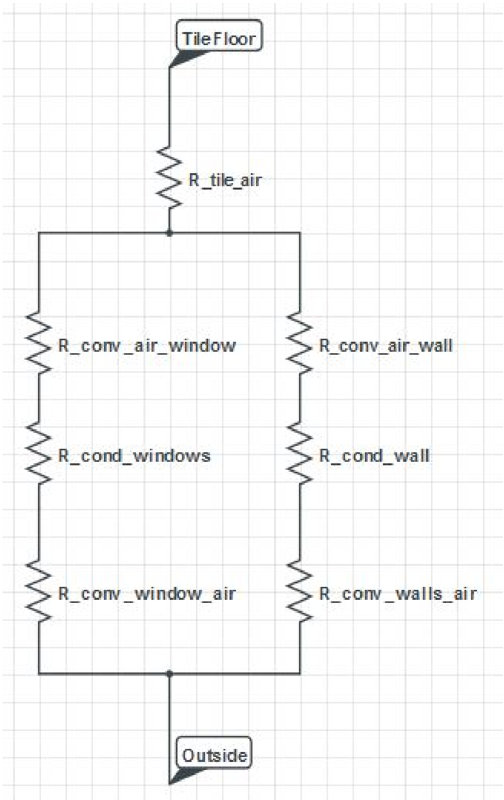
Ideal orientation is true north but orientations of up to 20° west of north and 30° east of north still allow good passive sun control

Some assumptions that we make with our model are:

- The house is on stilts and therefore the heat loss from all sides of the house are equal
- Heat capacity of our tile floor is much greater than the rest of the house, therefore we can ignore the rest.
- Our tile floor is suspended above our insulation (no conduction of heat)
- Air flow in and out of the house is negligible
- All solar radiation hitting the windows is absorbed, and solar radiation on other parts of the house is negligible
- Heat storage unit is at a spatially uniform temperature

Some Math (and MATLAB)


W
Summer Sun
Convection to air
Conduction through
insulation
Convection to
walls
Window
Winter Sun
Conduction through
window
Insulation
Convection to window
Convection to air
N
S
Solar Radiation
(Q_in = q * A)
Convection to air
Tile Floor
E
miro


Tile Floor
R_tile_air
R_conv_air_window
R_conv_air_wall
R_cond_windows
R_cond_wall
R_conv_window_air
R_conv_walls_air
Outside

Heat Transfer Equations

ODE for temperature inside the house:

$$q \cdot A - \frac{(T_{in} - T_{out})}{(R_{tot})} = m \cdot c \cdot \frac{dT_{in}}{dt}$$

where

$$R_{tot} = \frac{1}{h_{tile-air} \cdot A_{tile}} \left(\frac{1}{h_{air-wall} \cdot A_{wall}} \frac{L_{wall}}{K_{wall} \cdot A_{wall}} \frac{1}{h_{wall-air} \cdot A_{wall}} \right)^{-1} \left(\frac{1}{h_{air-window} \cdot A_{window}} \frac{L_{window}}{K_{window} \cdot A_{window}} \frac{1}{h_{window-air} \cdot A_{window}} \right)^{-1}$$

This equation tells us that given a set of house material properties, sizes, and solar radiation we can determine the temperature over time of the house. Some major assumptions are that solar radiation and the outside temperature are constant.

Moonshot

Stretch goal of weird offset house?

Lessons Learned

8.1)

1) · Aperture — windows

· Surface to absorb heat - absorber

· Thermal mass to hold the heat

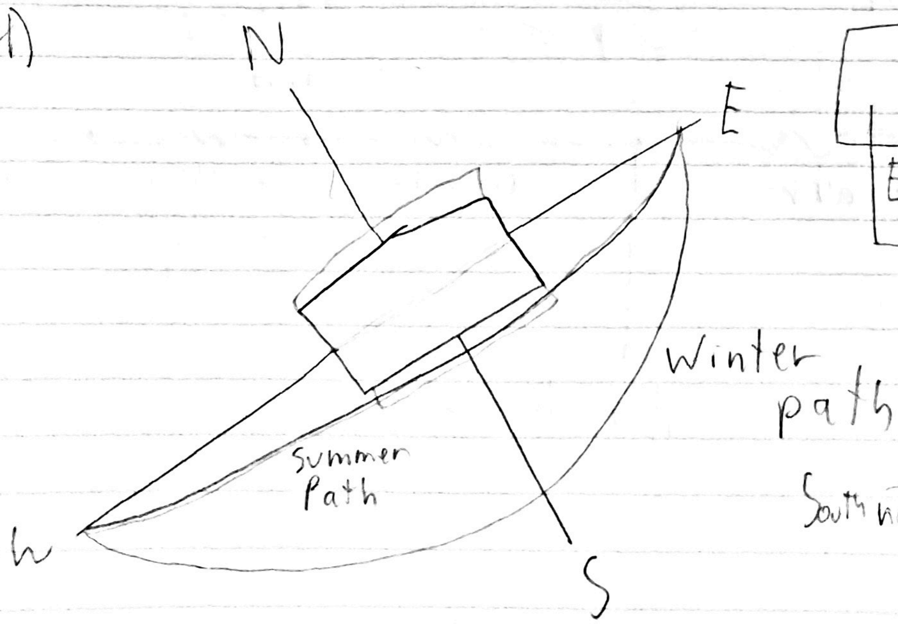
· Natural heat transfer → conv → cond → radiation

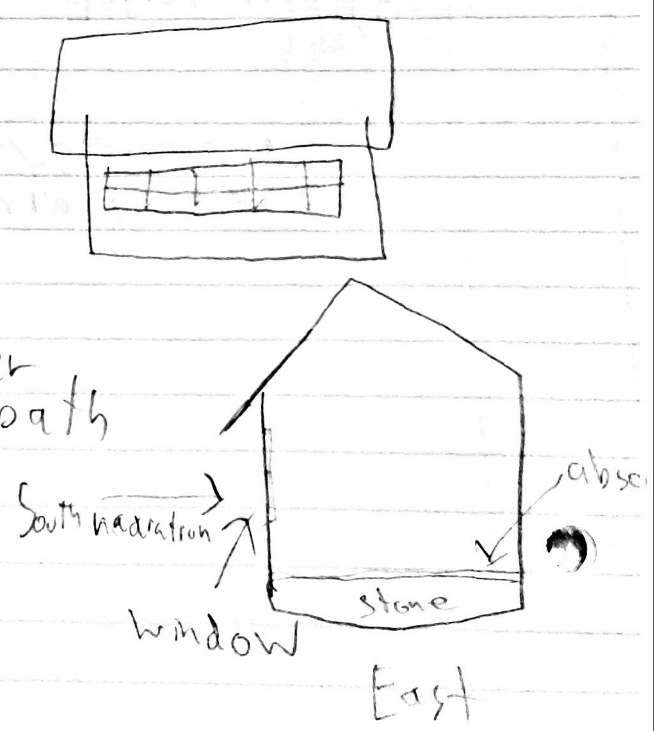
· Control → blinds or trees or angles

2) · High heat capacity - specific heat

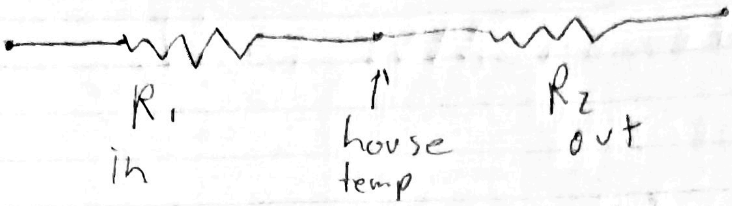
3) Thermal insulation will keep the heat in, and make the house have a larger R.
~~heat~~ keep cold out

4)





6)



Equations: $Q_{in} - Q_{out} = \frac{dU}{dt}$

$$m C_v \frac{dT}{dt} = \frac{dU}{dt} \qquad Q = \frac{KA}{L}(\Delta T)$$

$$Q = \frac{\Delta T}{R_{tot}} \qquad R_{conv} = \frac{1}{hA}$$

$$R_{cond} = \frac{L}{KA}$$

8.2) Key objectives: Reasonably comfortable in winter 17-25°C

Constraints: size 100-400 ft^2
No direct sunlight through south windows 12:00 summer

1) Optimize radiating surfaces to distribute heat

2) Optimize our control over temp

3) Add a basement for heat storage

Goal: create an MVP quickly