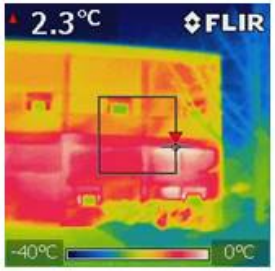
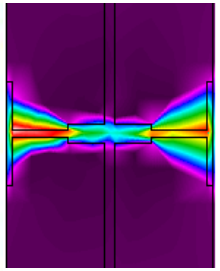
CAE 331/513 Building Science

Fall 2015





Week 4: September 15, 2015

Heat transfer review problems

Hosted by: Akram Ali

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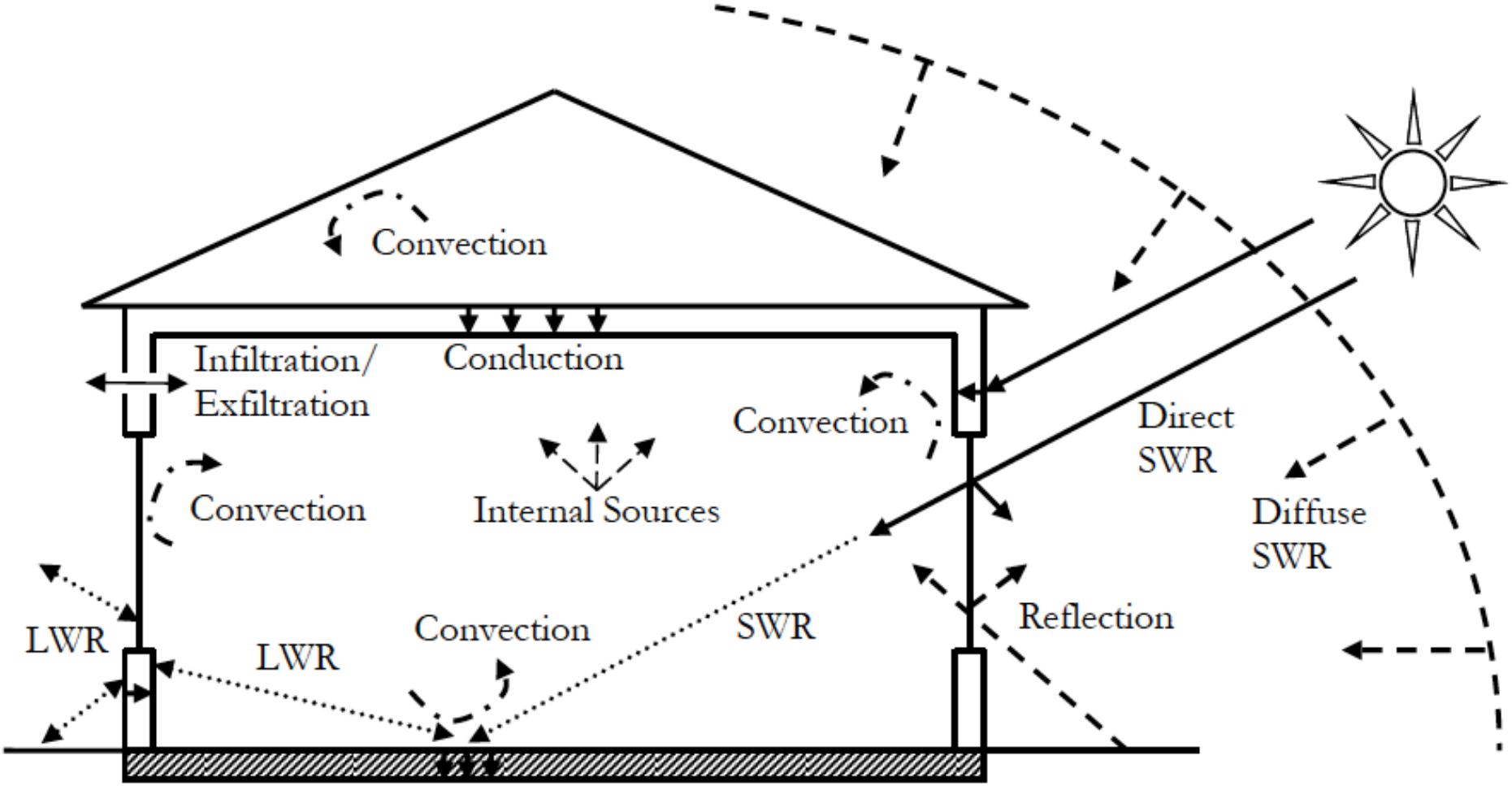
Modes of heat transfer in a building



Heat transfer in building science: Summary

Conduction

$$q = \frac{k}{L}\left(T_{surf,1} - T_{surf,2}\right)$$

$$\frac{k}{L} = U = \frac{1}{R}$$

$$R_{total} = \frac{1}{U_{total}}$$

$$R_{total} = R_1 + R_2 + R_3 + \ldots$$

For thermal bridges and combined elements:

$$U_{total} = \frac{A_1}{A_{total}}U_1 + \frac{A_2}{A_{total}}U_2 + \ldots$$

Convection

$$q_{conv} = h_{conv}\left(T_{fluid} - T_{surf}\right)$$

$$R_{conv} = \frac{1}{h_{conv}}$$

Radiation

Long-wave

$$q_{1\to 2} = \frac{\sigma\left(T_{surf,1}^4 - T_{surf,2}^4\right)}{\frac{1-\varepsilon_1}{\varepsilon_1} + \frac{A_1}{A_2}\frac{1-\varepsilon_2}{\varepsilon_2} + \frac{1}{F_{12}}}$$

$$q_{rad,1\to 2} = h_{rad}\left(T_{surf,1} - T_{surf,2}\right)$$

$$h_{rad} = \frac{4\sigma T_{avg}^3}{\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1} \qquad R_{rad} = \frac{1}{h_{rad}}$$

$$q_{1\to 2} = \varepsilon_{surf}\sigma F_{12}\left(T_{surf,1}^4 - T_{surf,2}^4\right)$$

Solar radiation: (opaque surface) $q_{solar} = \alpha I_{solar}$

Transmitted solar radiation: (transparent surface) $q_{solar} = \tau I_{solar}$

Window (combined modes)

$$Q_{window} = UA_{pf}\left(T_{out} - T_{in}\right) + I_{solar}A_{pf}SHGC \cdot IAC$$

Example problems

- Calculating R-values with and without studs
- Combined conduction, convection and long-wave radiation
- Heat transfer through windows

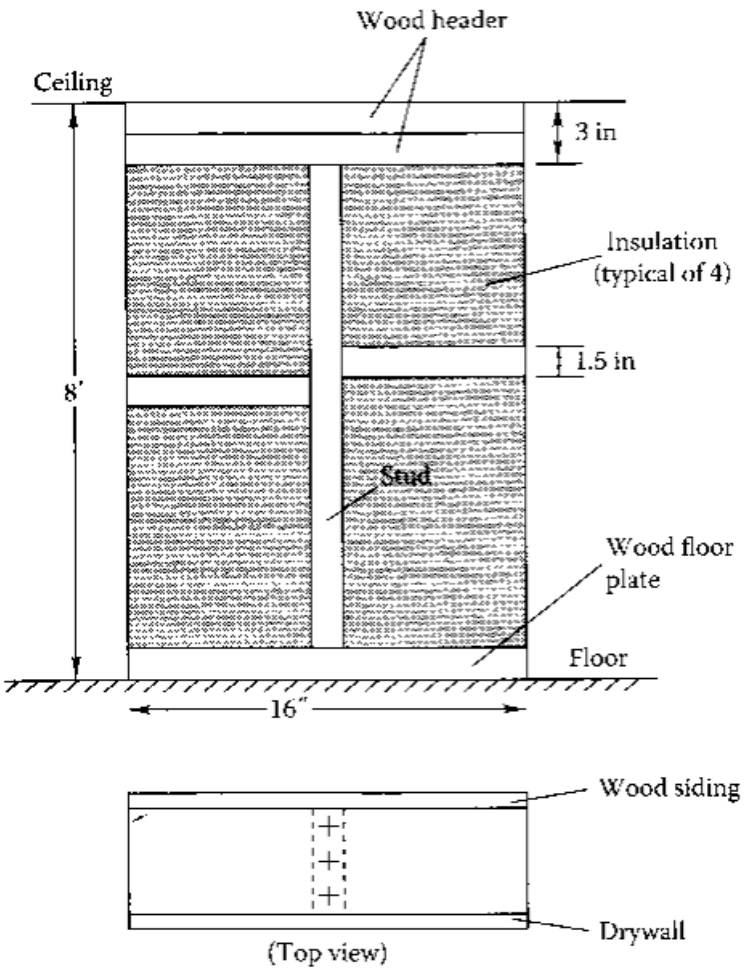
Example 1: Conduction

Calculate the thermal resistance of the typical wall shown in the figure.

The inside surface is 0.5 inch (1.2 cm) drywall and the outside wall surface is 0.5 inch (1.2 cm) thick hardboard siding. The studs, headers, and floor plates in the wall are nominal 2 inch by 6 inch wood studs (the true finished-wood dimensions are 1.5 by 5.5 inches or 3.8 by 13.5 cm). The wall cavities are insulated with 5.5 inches (13.5 cm) of fiberglass batt insulation.

Be sure to include typical convective film resistances on the inner and outer wall surfaces for typical winter conditions.

Provide answer in both SI and IP units.



Example 2: Conduction and convection

In an energy audit of a building, you find that a 6 inch (0.15 m) diameter pipe located in the 78°F (25.6°C) mechanical room is carrying superheated steam at 400°F (205°C). The pipe is insulated with 2 inches (5 cm) of fiberglass insulation.

Assume that the mechanical room is under natural convection conditions.

Assume that the view factor between the pipe surface and all other surfaces in the room is 1.0.

Assume that all other surfaces in the room are at 78°F (25.6°C) as well.

Ignore the heat transfer resistance offered by the pipe wall.

Find the <u>outer surface temperature of the insulation</u> and comment on the safety of this installation

Example 3: Window heat transfer

- Calculate the U-value of a clear, double-glazed, air-filled fixed window of gross area 0.5-m x 1-m with low-emissivity coating on surface 3 and an aluminum spacer and aluminum frame (no thermal break) in both SI and IP units

- Assume:
  - Air gap is 9 mm
  - Glaze thickness is 3 mm
  - Low-e coating has an emissivity of 0.2
  - Frame width is 5 cm
  - Edge width and spacer width are both 1 cm

Example 4: Window heat transfer

- The window in Example 3 is installed in a building where it is 22°C inside and -10°C outside
  - <u>What is the rate of heat loss</u> through this window?

- The same window is subject to 600 W/m^2 of solar radiation striking normal to its surface
  - <u>What is the rate of heat gain via solar radiation</u> through this window?

- What is the <u>net heat gain or loss</u> through this window at these conditions?