

Fall'10
1.044J, 2.45J, 4.42J
Homework Set #6

- 1.** A low density fiberglass insulation has an R value of $11 \text{ (BTU/hr ft}^2 \text{ }^\circ\text{F)}^{-1}$ when used in a standard 2x4 wall cavity. To achieve a higher insulation, a contractor compresses the fiberglass so that there are two layers of the insulation in the 2 x 4 wall cavity. He states that the wall has an R value of 22. Do you agree? Explain.

- 2.** A flat roof insulation system uses aluminum screws to hold down flat insulation panels. The screws are 1/4 inch diameter, 2 inches long and spaced 4 inches on center in a square array. The top of the insulation uses a thin aluminum sheet as a weather barrier and a reflective layer. Underneath the insulation is a corrugated steel roof. The insulation is two inches thick and has a conductivity of $0.015 \text{ BTU/hr ft }^\circ\text{F}$. The screws pass through the insulation and are anchored in the corrugated roof. The effective U value of the insulation system plus screws is defined as $U=q(\text{total})/A(\text{total})\Delta T$ where $q(\text{total})$ is the sum of the heat transfer through the aluminum screws and the insulation. Assume that the convective heat transfer coefficient on the inside of the corrugated surface and on the outside over the top of the thin aluminum sheet is $2 \text{ BTU/hr ft}^2 \text{ }^\circ\text{F}$. Calculate the U value for two limiting cases: 1) There is large lateral heat transfer and the corrugated sheet and the thin aluminum are each at a uniform temperature and ; 2) there is no lateral heat transfer through the corrugated sheet and the aluminum panel, heat transfer through the screws and the insulation occur in parallel with no interaction between the heat flows in the respective cross-sections.

- 3.** A window has two vertical panes of glass separated by an one inch air gap. The glass panes can be considered black bodies at uniform temperatures of 40°F and 60°F , respectively. Estimate the total heat transfer, convection plus radiation, through the window space. Note: convection through a vertical space is a very weak function of the layer height, as a first approximation this effect can be neglected.

- 4.** How much does the result of problem 3 change if one glass pane has a low emissivity coating which reduces its emissivity to 0.2. Instead of the low emissivity coating, a third layer of opaque glass is placed midway between the two; how much is the convective heat transfer changed, is the radiation also changed?

- 5.** Estimate the total heat loss from a wood frame house in the Boston area for the heating season of one year. Boston averages 5634 degree days for a typical heating year. The walls are 2 x 4 filled with fiberglass and covered with one inch of polyurethane foam insulation sheathing. The windows are double glazed with a low e coating. The attic has 10 inches of low density fiberglass insulation. Neglect heat loss from the foundation. The house is a single story with 2000 ft^2 of floor area. The perimeter is 220 ft. and the outside walls are 12 feet high. Fifteen percent of the outside walls are windows. There are 0.3 air changes per hour in the house. Neglect additional losses through doorways, etc. Use values from other homework problems or reference tables to determine U values.

6. A person is seated in a room which has still air. The room surfaces are all black and at the same temperature as the air, 70°F. The person is now seated in front of a large window which is cold, 50°F. The window and the person can both be considered as a black body. The rest of the room walls are still at 70°F. Estimate how much the room air temperature must be increased for the person to have the same net heat loss from their entire body surface as in the original case without the window? In both cases the surface temperature of the person is unchanged. You will need to estimate some values of the convective and radiative heat.

7. Estimate the surface temperatures of all of the components in a typical 2 X 4 frame wall as seen in class. Estimate the average heat transfer rate per square foot of wall area. Take the inside air temperature as 68°F and the outside air temperature as 30°F. Be sure to include heat transfer through the wood stud.

8. A forced hot air system has 6 inch diameter ducts installed in an uninsulated attic. Heated air at 100F flows through the ducts at 10 ft/s velocity. The ducts are made of aluminum and the contractor neglects to insulate them. If the attic is at 40F estimate the U value from the heated air inside the duct to the cold attic air. If the duct is 10 feet long what is the rate of heat loss from the duct? Neglect radiation. How much will the air temperature inside the duct change due to this heat loss?

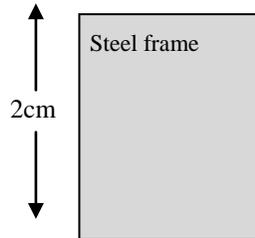
9. Try to determine the thermal resistance of a typical MIT window facing Killian Court. On a cold night use the IR camera to measure the exterior surface temperature of the various window components. Then using your estimate of the radiation and convection heat transfer from the exterior surface make an estimate of the U value of the specific component, e.g. glass, frame, etc.
Repeat this for the exterior surface of the masonry wall.
What is your recommendation to increase the energy efficiency of the entire exterior envelope?

10. The courtyard in the center of the Gardner Museum in Boston is enclosed with a glass roof. The glass is supported by a steel frame. The steel, 2 cm thick, extends in a solid piece from the inside to the outside as shown in the figure. The outside surface of the steel is painted black and has a convective heat transfer coefficient of 5 W/m²K. The inside air temperature is 0 °C. Assume the inside surface of the steel is painted with a silver paint that has an emissivity of 0.1. The inside convective heat transfer coefficient is 3 W/m²K. The inside air temperature is 20 °C and the relative humidity is 45 percent. Assume the steel surface on the inside radiates to a black body at 20 °C and the steel surface on the outside radiates to a black body at 0 °C.

- a) Draw the electric analogy for the heat transfer through the steel frame by using the linear form for radiation heat transfer (h_r).

- b) What is the inside temperature of the steel frame?
- c) Will water condense on the inside surface of the steel frame?
- d) If the inside surface of the steel is painted black, will this cause worse condensation problems?

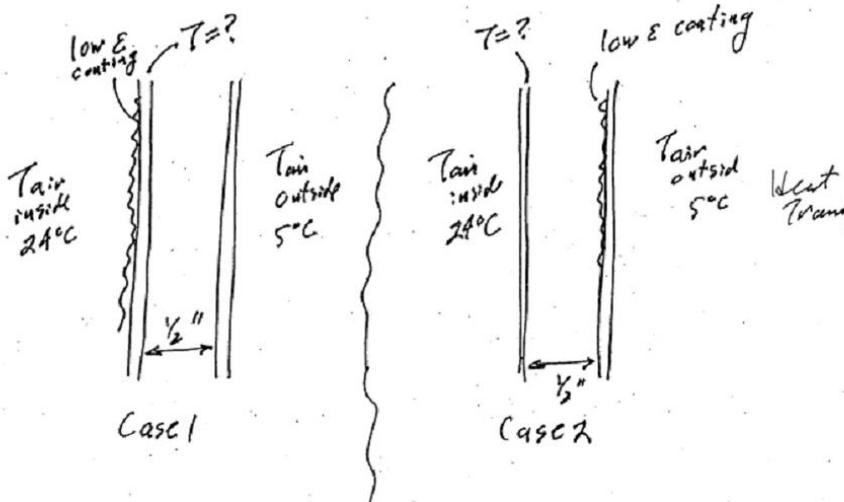
Outside air $T_{\text{out}} = 0\text{ }^{\circ}\text{C}$
Black surface, $h(\text{convection}) = 5\text{ W/m}^2\text{K}$



Inside air $T_{\text{in}} = 20\text{ }^{\circ}\text{C}$, $\text{RH} = 45\%$
Silver surface, emissivity = 0.1
 $h(\text{convection}) = 3\text{ W/m}^2\text{K}$

11. A manufacturer of double glazed windows will put a low emissivity coating on either the inside surface of the interior glass layer, shown in the figure as case 1 or alternatively will put the low emissivity coating on the inside surface of the outermost glass layer, shown in the figure as case 2. You are asked to consider means to determine the relative temperature of the inside glass layer surface for both cases. Assume wintertime conditions with the interior air temperature at 24 C and the exterior surroundings is a black body at 5 C. In both cases the spacing between the two glass layers is 1/2 inch.

- a) Sketch the electrical resistance network for the two cases.
- b) Estimate the numerical values of the resistance elements.
- c) Based on the relative value of the resistances can you make a qualitative judgment of which case yields a lower temperature for the inside layer of glass?
- d) How would you estimate the inside glass temperature steady state? Give the relevant expressions but do not solve or evaluate numerically.



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Fall 2010

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