Group Problems

1. One wall of a house has dimensions 4.0 m x 3.0 m. It is composed of brick (k = 0.60 W/m K) on the outside and wood (k = 0.35 W/m K) on the inside. The interior of the house is 24°C and the air outside is -2.0 °C. If the brick is 7.0 cm thick and the wood is 5.0 cm thick, find

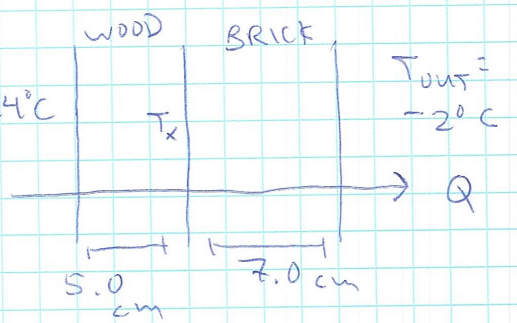
   a. the temperature at the brick/wood interface.
   b. the rate of heat conduction through this wall.

2. A house is a rectangle 10 m x 8.0 m with walls 5.0 m high. The flat roof and the floor have been very well insulated, so essentially no heat is lost through them. The walls are pierced by several windows, which have a total area of 40 m^2. The walls are of pine (k = 0.12 W/m K) 13 cm thick and the windows are plate glass 1.5 cm thick. On a winter day, the furnace is keeping the interior at 22°C while the outside is at 4.0 °C.

   a. find the area of the walls which is pine.
   b. find the rate of heat loss through the walls.
   c. find the rate of heat loss through the windows.
   d. find the total amount of heat lost by this house in one hour.

3. The owner of the house in problem 2 realizes that he can lower his electric bills by insulating. He opts to simply cover his windows with a window film, which traps a layer of still air 3.0 cm thick on the inside of the window. The window film itself does not reduce heat losses, but the still air acts as an insulating layer. Assume that the film itself is at the same temperature as the inside of the house, and find the rate of heat loss through the windows now. (Did the homeowner make a wise decision?)

1. $A = 12\ m^2$



$\frac{Q}{\Delta t}$ is same for both layers.

$$\left.\frac{Q}{\Delta t}\right]_{WOOD} = \left.\frac{Q}{\Delta t}\right]_{BRICK}$$

$$\left.\frac{k A \Delta T}{L}\right]_{WOOD} = \left.\frac{k A \Delta T}{L}\right]_{BRICK}$$

$$\frac{(0.35)(12)(24 - T_x)}{0.05} = \frac{(0.6)(12)(T_x - -2)}{0.07}$$

$$7(24 - T_x) = 8.57(T + 2)$$

$$168 - 7T_x = 8.57T_x + 17.14$$

$$150.9 = 15.57T_x$$

$$T_x = 9.69°C$$

$$\left.\frac{Q}{\Delta t}\right]_{WOOD} = \frac{(0.35)(12)(24 - 9.69)}{0.05} = 1200\ J/s$$

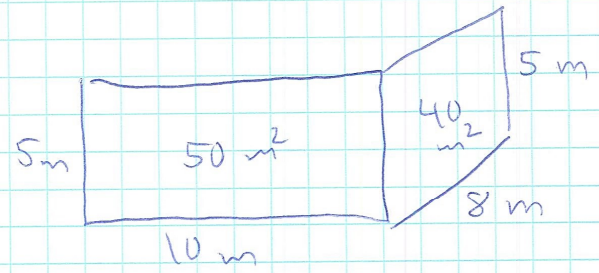
$$\left.\frac{Q}{\Delta t}\right]_{BRICK} = \frac{(0.6)(12)(9.69 - -2)}{0.07} = 1200\ J/s$$

Total $Q/\Delta t = 1200\ J/s$.

These are not two separate exits.

8.2.

Only losing heat through sides.



Total area of sides is $50 + 40 + 50 + 40 = 180\ m^2$

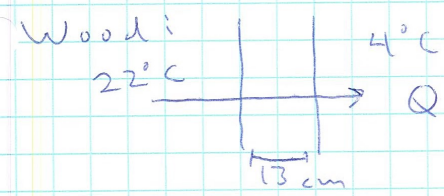
Of this, $40\ m^2$ is glass, $140\ m^2$ is pine.

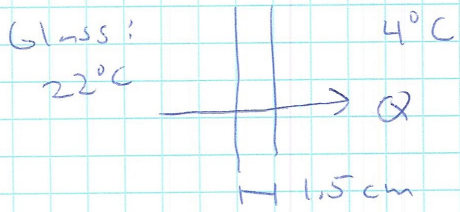
Wood: $\frac{Q}{\Delta t} = \frac{kA\Delta T}{L} = \frac{(0.12)(140)(22-4)}{0.13}$

$= 2326\ J/s$

Glass: $\frac{Q}{\Delta t} = \frac{kA\Delta T}{L} = \frac{(0.75)(40)(22-4)}{0.015}$

$= 36{,}000\ J/s$





total $\frac{Q}{\Delta t} = 36{,}000 + 2326\ J/s$

$= 38{,}326\ J/s$ since heat leaves separately by these two paths.

In one hour:

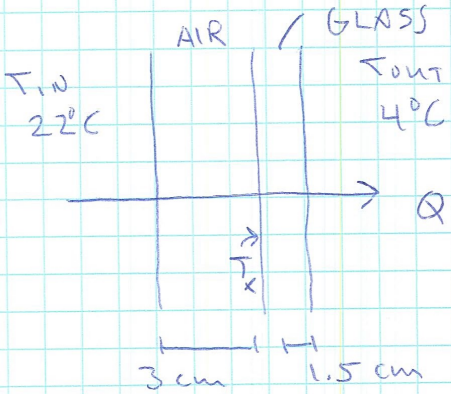
$Q = (38{,}326\ J/s)(3600\ s)$

$= 1.38 \times 10^8\ J$

Windows are the biggest problem here.

4.

3. Window film temps
3 cm of still air on inside of window.



$$\left.\frac{Q}{\Delta t}\right]_{AIR} = \left.\frac{Q}{\Delta t}\right]_{GLASS}$$

$k_{AIR} = 0.026$ w/m K

$k_{GLASS} = 0.75$ w/m K

$$\left.\frac{kA\Delta T}{L}\right]_{AIR} = \left.\frac{kA\Delta T}{L}\right]_{GLASS}$$

$$\frac{(0.026)\,A\,(22 - T_x)}{0.03} = \frac{(0.75)\,A\,(T_x - 4)}{0.015}$$

Areas are same

$$0.867(22 - T_x) = 50(T_x - 4)$$

$$19.07 - 0.867T_x = 50T_x - 200$$

$$219 = 50.87\,T_x$$

$$T_x = 4.3^\circ C$$

Glass allows heat to flow through it easily, so ΔT across glass is small.

Air insulates - so ΔT across it is large.

$$\frac{Q}{\Delta t}_{GLASS} = \frac{(0.75)(40)(4.3-4)}{0.015} = 600 \text{ J/s}$$

$$\frac{Q}{\Delta t}_{AIR} = \frac{(0.026)(40)(22-4.3)}{0.03} = 610 \text{ J/s}$$

Total $\frac{Q}{\Delta t}$ is ~ 600 J/s for whole window system of house.