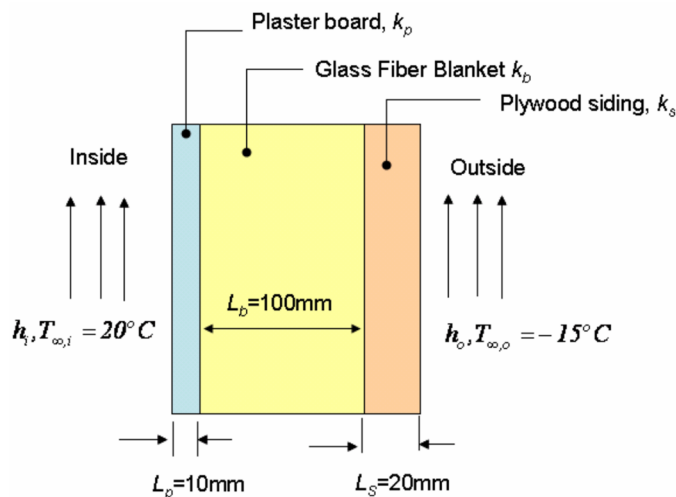


ABE 30800 - Heat and Mass Transfer

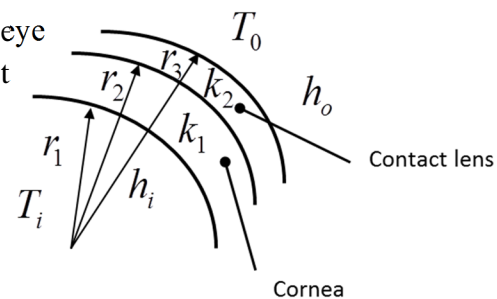
Steady State Conduction Examples

Example 1. A house has a composite wall of plasterboard, fiberglass insulation and plywood siding, as indicated in the figure below. On a cold winter day the convection heat transfer coefficients outside and inside the house are $h_o=150\text{W/m}^2\cdot\text{K}$ and $h_i=20\text{W/m}^2\cdot\text{K}$. The total wall surface area is 400m^2 . Values of thermal conductivity for the plasterboard, the glass fiber blanket and the plywood siding are $0.1\text{ W/m}\cdot\text{K}$, $0.04\text{W/m}\cdot\text{K}$ and $0.15\text{ W/m}\cdot\text{K}$, respectively.

- (a) Determine the total heat loss through the wall.
- (b) For design purposes, you will like to know the temperature of the material at the boundary between the glass fiber blanket and the plywood siding but it is becoming difficult to inset a thermometer so **you would need to estimate that temperature**
- (c) It is recommended to reduce the heat loss through the wall by 30% and since the glass fiber blanket is the best insulator, you will need to estimate the new thickness of this material of glass fiber blanket to achieve that reduction in the heat flow.



Example 2. The heat transferred from the anterior chamber of the eye through the cornea varies considerably depending on whether a contact lens is worn. Assume the eye as a spherical surface and assume the heat transfer to be at steady state and that the convection coefficient outside h_o is not changed with and without the contact lens in place. The cornea and the lens cover $1/3$ of the spherical surface area. A schematic is given below:



jjjjjkjk Values of the parameters in the figure above are:

$$r_1 = 10.2\text{mm}$$

$$T_o = 21^\circ\text{C}$$

$$r_2 = 12.7\text{mm}$$

$$k_1 = 0.35\text{ W/m}\cdot\text{K}$$

$$r_3 = 16.5\text{mm} \quad k_2 = 0.80 \text{ W/m.K}$$

$$T_i = 37^\circ\text{C} \quad h_i = 12 \text{ W/m}^2.\text{K} \quad h_o = 6 \text{ W/m}^2.\text{K}$$

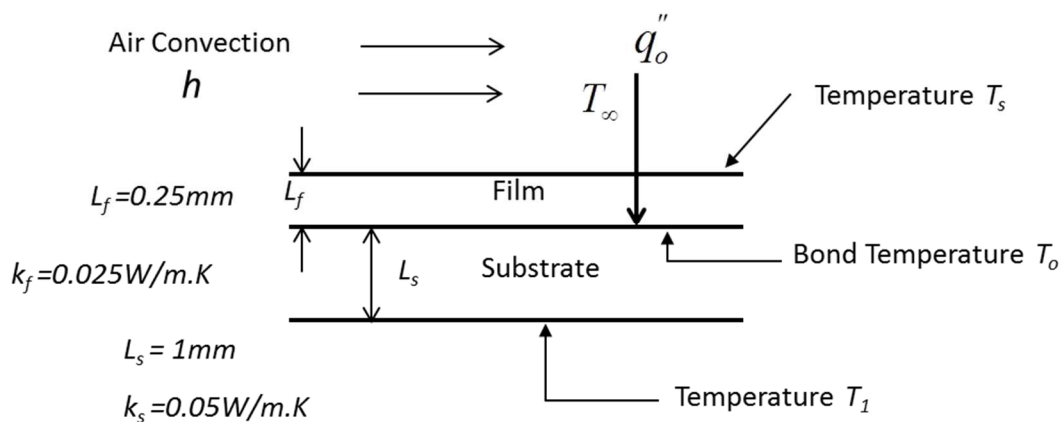
Determine the heat loss from the anterior chamber with and without the contact lens in place. Assume steady state, eye is 1/3 sphere.

Example 3. A stainless-steel tube is used to transport a chilled pharmaceutical fluid. The tube has an inner diameter of 36mm and a wall thickness of 2mm. The pharmaceutical fluid and ambient air are at temperatures of 6°C and 23°C respectively. The corresponding inner and outer convection coefficients are $400 \text{ W/m}^2.\text{K}$ and $6 \text{ W/m}^2.\text{K}$ respectively.

- What is the heat gain per unit tube length? Assume that the thermal conductivity of the tube is 15 W/m.K
- What is the heat gain per unit length if a 10mm-thick layer of calcium silicate insulation with a thermal conductivity of 0.050 W/m.K is applied to the tube?

Example 4. In a manufacturing process, a transparent film is being bonded to a substrate as shown in the sketch below. To cure the bond at a temperature T_o , a radiant source is used to provide a heat flux $q_o'' (\text{W} / \text{m}^2)$, all of which is absorbed at the bonded surface. The back of the substrate is maintained at T_I while the free surface of the film is exposed to air at T_∞ and a convection heat transfer coefficient h .

- Show the thermal circuit representing the steady state heat transfer
- Assume the following conditions $T_\infty = 20^\circ\text{C}$, $h=50 \text{ W/m}^2.\text{K}$ and $T_I=30^\circ\text{C}$. Calculate the heat flow $q_o'' (\text{W} / \text{m}^2)$ that is required to maintain the bonded surface at $T_o = 60^\circ\text{C}$.
- If the film is not transparent and all of the radiant heat flux is absorbed at it upper surface, determine the heat flux required to achieve bonding.



Example 5. Compare the heat loss (in Watts) from two different windows in a room. One window has a single sheet of glass 10mm thick whereas the other has two sheets of glass, 5mm each but separated by an air gap of 5mm. The second window is called a thermopane. The windows sizes are 1m x 1m. The air temperature in the room is 72°F and the outside temperature is 18°F. The thermal conductivity of the glass is 0.9 W/m.K and the average thermal conductivity of air is 0.03 W/m.K. The convection coefficient inside the room is $h_i = 10 \text{ W/m}^2\text{.K}$ and outside due to a strong wind is $h_o = 200 \text{ W/m}^2\text{.K}$.

- Compare the heat losses between these two windows designs, if the air in the gap is stagnant, i.e. heat through the air gap is only transmitted by conduction
- Consider that in the air gap you also have some radiation and that the radiation coefficient is $h_r = \sigma(T_1 + T_2)(T_1^2 + T_2^2)$, using the main equation used for radiation demonstrate the validity of the expression to estimate h_r .
- Assuming that $h_r \approx 4\sigma T_{avg}^3$, estimate and compare how the resistance to heat transfer changes when radiation is also considered in addition to conduction alone. Therefore, you have to estimate the differences in the resistance to the heat transfer considering and without considering radiation in the air gap, and what is the effect in the heat flow?

Example 6 (include convection too). The wind chill, which is experienced on a cold windy day, is related to increased heat transfer from exposed human skin to the surrounding atmosphere. Consider a layer of fatty tissue that is 3mm thick and whose interior surface is maintained at 36°C. On a calm day the convection heat transfer coefficient at the outer surface is 25 W/m².K, but with a 20 miles/h wind it reaches 65 W/m².K. In both cases the ambient temperature is -15°C.

- What is the ratio of the heat loss per unit area from the skin for the calm day to that for the windy day?
- What will be the skin outer surface temperature for the calm day?
- And what for the windy day?