W02

This assignment is dedicated to heat transfer by conduction. The equation for thermal conduction is given by

$$\dot{Q} = -kA\frac{\Delta T}{\Delta x} \tag{1}$$

and

$$\dot{q} = -k\frac{\Delta T}{\Delta x} \tag{2}$$

It is important to know how to apply these equations, but it is just as important to understand how the equations work, so therefore:

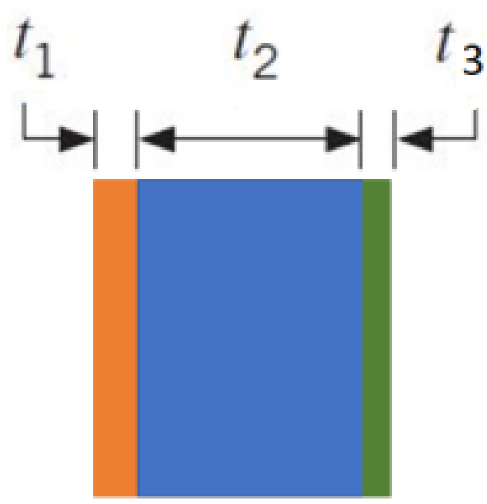
1. Explain the difference between equation 1 and 2
2. What does each term ($\dot{Q}$, $\dot{q}$, A, k, $\frac{\Delta T}{\Delta x}$) represent in equation 1 and 2 and what are its corresponding units?
3. Why is there a minus sign in equation 1 and 2?

Have a look at this video about the heat transfer of various objects https://www.youtube.com/watch?v= hNGJ0WHXMyE (If the link is not working search for "veritasium misconceptions about heat" on Youtube). In this video, an example is given of the rate of heat transfer of a book and a hard drive. Most people are convinced that the hard drive is at a lower temperature than the book since it feels colder.

4. Equipped with your knowledge and equations about heat transfer, explain the differences and similarities between touching the book and the hard drive.

With the previous questions you have developed some insight into thermal conduction. Now it is time to apply this knowledge to the following case. In order to keep drinks hot or cold, thermoflasks use insulation. This minimizes the heat transfer between the liquid and the outside environment.

(a) Crossection of a thermosflask



(b) Schematic representation

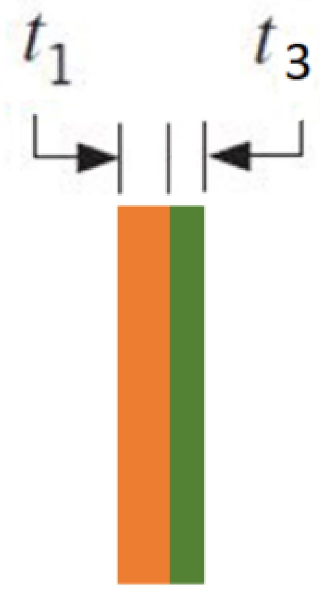
Figure 1: Thermos flask to keep liquids hot or cold

Assume that the outside wall is made out of plastic, and the inside wall of the thermos flask is made out of aluminium, which is represented in figure 1b. In this schematic, the orange section represents the aluminium, the blue section represents the insulation material and the green section represents the plastic. The aluminium has a thickness of 2 mm and a thermal conductivity of 247 $Wm^{-1}K^{-1}$. The insulation, made out of mineral wool, has a thickness of 1 cm and a thermal conductivity of 0.047 $Wm^{-1}K^{-1}$. Finally, the plastic has a thickness of 4 mm and a thermal conductivity of 21 $Wm^{-1}K^{-1}$.

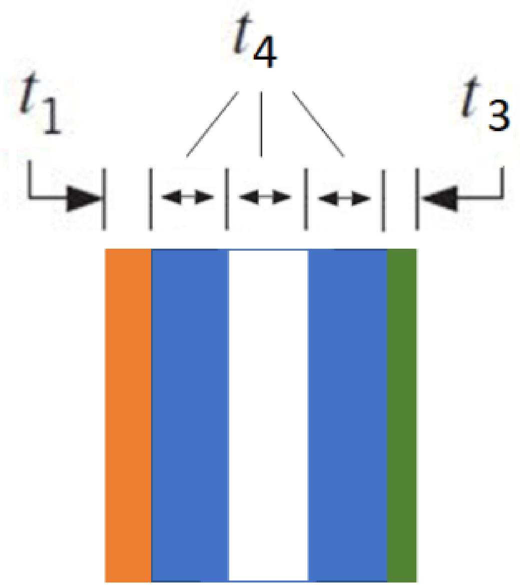
Assume that the thermos flask is filled with hot coffee at a temperature of 80 ^{o}C, and the outside temperature is quite chilly with 3 ^{o}C. The area of the thermos flask is 0.035 m^2.

5. Sketch the temperature profile through the wall, and also explain the different slopes of temperature for the different layers.
6. Determine how much heat is conducted through the flask. Assume a height of 10 cm and that no heat is transferred through the bottom and top of the flask. Furthermore, the diameter of the water compartment, thus the inner diameter of the aluminium hull equals 6 cm.
7. Imagine that there was no insulation used as depicted in figure 2a. How much **more** heat would be conducted compared to the insulated thermos flask?
8. As a (hopeful) improvement, one engineer suggests to decrease the thermal conductivity as well as the production costs of the flask by adding a layer of nitrogen in between two layers of insulation. The thermal conductivity of nitrogen is 0.02589 $Wm^{-1}K^{-1}$. All three sections of the insulating material, denoted as t_4 in figure 2b, have a combined thickness of 1.2 cm. Determine how much heat is lost through the wall.

9. If your answers to question 6) and 8) are different, how thick or thin can the nitrogen pocket be to get the same amount of heat conducted as your answer to question 6)?
Hint: Assume the resistance of other layers to be the same



(a) Thermos flask without insulation



(b) Insulating layer with nitrogen

Figure 2: Schematic overview of no insulation and insulation using an nitrogen pocket