Approach

The approach below gives a guideline in how to solve the problems presented during this course. Correctly applying this approach will lead to a good understanding of the concepts presented in this course.

Analysis

1. Explain the problem: which physical phenomena are important in this problem?
2. Make a sketch of the problem
3. Give the known variables (with the appropriate units!)

Approach

1. Explain the assumptions you make to solve the problem
2. Show the solution method for solving the problem

Elaboration

1. Show the calculation steps and explain the equations you use
2. Give references if values are found online or in tables

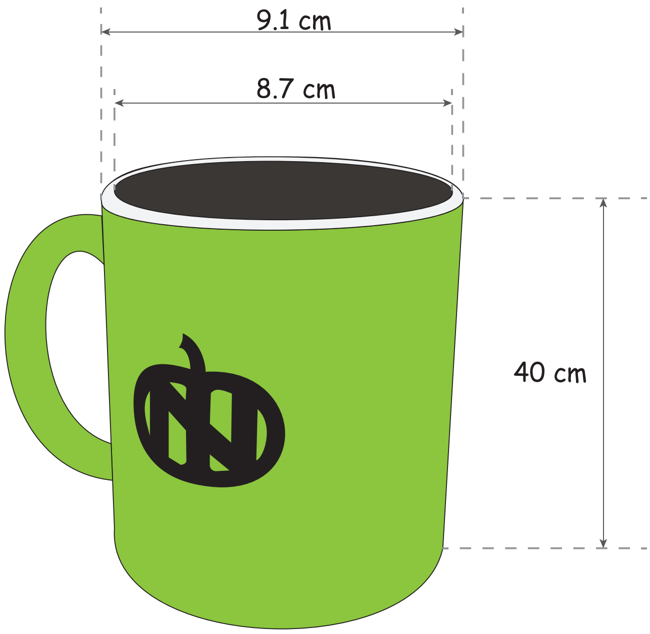
Evaluation

1. Check the units of your solution
2. Is the answer realistic/expected?
3. Did you answer all the questions asked?
4. Iterate if this is required

Lecture 6

6.1 Warm coffee

A student has made a nice warm cup of coffee in a mug that has a heating element in it to keep the coffee warm. The heating element is in the coffee and keeps the coffee at a constant temperature of 66 °C. The thermal conductivity of the mug is 3.8 W m^{-1} K^{-1}. All heat is lost through convection and there is no heat loss through the ground. The outside temperature is 20 °C. Calculate the power needed for the heating element to keep the coffee at the same temperature. You may assume that the flat plate assumption is true for the convection at the sides of the mug.



6.2 Food truck

During scorching summer days, the food truck crafted by UT IDE students sets up near the sports center. The outdoor temperature sizzles at $T_{\mathrm{i}} = 35\ °\mathrm{C}$, with still air and a sunny blast of solar energy at $G = 1100\ \mathrm{W\,m^{-2}}$. In the original design, captured in Figure 6.1 (a), the roof of the food truck compartment embraces a composite structure. This blend involves insulation ($t_2 = 60$ mm, $k_2 = 0.036\ \mathrm{W\,m^{-1}\,K}$), snugly nestled between a steel panel ($t_1 = 4$ mm, $k_1 = 130\ \mathrm{W\,m^{-1}\,K}$) atop, boasting a reflectivity of 0.9. Beneath, an interior plastic panel ($t_3 = 5$ mm, $k_3 = 0.26\ \mathrm{W\,m^{-1}\,K}$) wraps up the ensemble.

The roof, spanning $L = 3$ m in length and $W = 2$ m in width, maintains a consistent inner plastic surface temperature, aligned with the interior at $T_{\mathrm{s,in}} = 22°\mathrm{C}$, thanks to some clever roof paint that curbs radiation losses to insignificance.

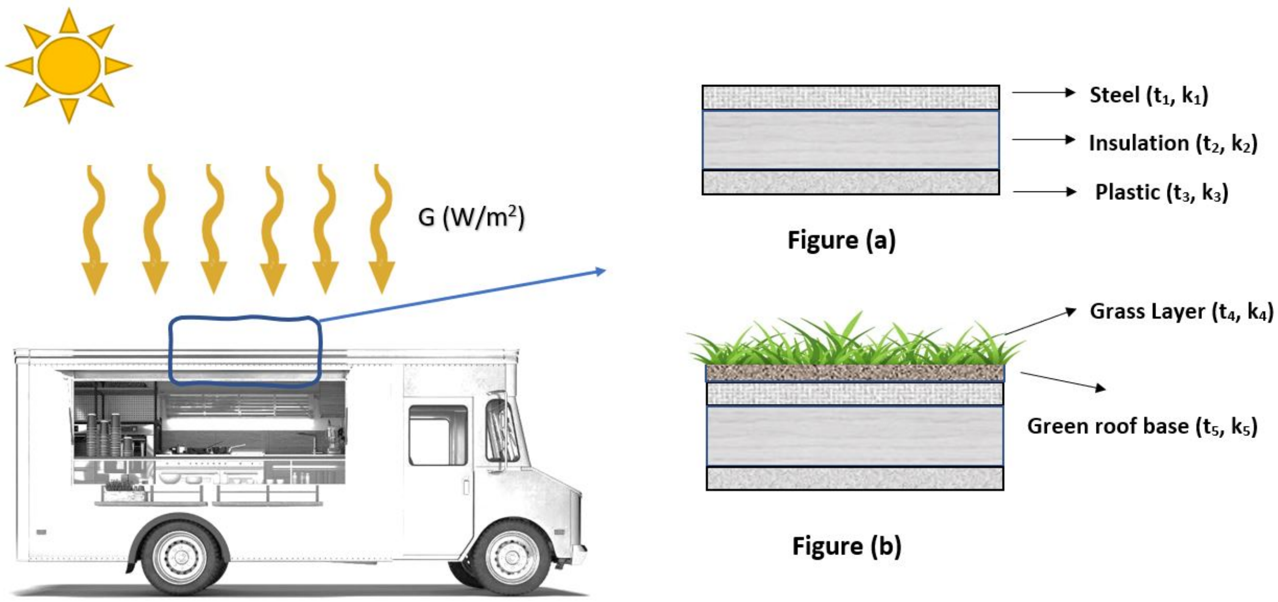


Figure 6.1: Cross-section of the food truck roof.

a) Determine the roof surface's temperature and each layer's temperatures, and then draw a temperature profile within the roof structure and outside air.

b) One of the group members suggested using a green roof for the food truck, as shown in Figure 6.1 (b), to save energy for cooling by adding grass layer ($t_4 = 10$mm, $k_4 = 0.038\ \mathrm{W\,m^{-1}\,K}$) with reflectivity of 0.95 and green roof base layer ($t_5 = 15$mm, $k_5 = 0.36\ \mathrm{W\,m^{-1}\,K}$). Determine the temperature of the roof surface and the temperatures of each layer, and then draw a temperature profile within the roof structure and outside air.

c) The heat generated by the cooking and other appliances inside the food truck is $45\ \mathrm{kJ\,min^{-1}}$. On this day, an AC is used to cool down the inside and keep the temperature constant, reaching equilibrium for 8 hours using electricity at a cost of 0.7 €/kW h. How much money would be saved by using the green roof for the food truck on this particular day? The losses from the truck's sides and bottom are insignificant.

6.3 Pizza oven - <u>Hand in</u>

Henk designed a pizza oven in the shape of a cylinder, using clay ($k_{\text{clay}} = 0.1$ W/mK). The cylinder has a diameter of $d_{\text{i}} = 32$ cm, has a height of $h = 50$ cm, and has a clay layer thickness of $\delta_{clay} = 29$ mm.

To insulate the oven, Henk wrapped it with Rockwool ($k_{\text{rw}} = 0.03$ W/mK) of thickness $\delta_{\text{rw}} = 14$ mm. For a polished look, a sheet of brushed aluminum, with an emissivity of $\epsilon_{\text{alum}} = 0.83$ and thickness $\delta_{\text{alum}} = 2$ mm, was added.

To ensure the oven is safe for pizza night, the outer aluminum sheet's temperature shouldn't exceed 55 °C. Inside, the temperature is regulated at a constant 220 °C using a temperature regulator. The heat inside the oven transfers to the inner wall efficiently with $h_{\text{in}} = 11$ W/m^{2}K.

Model the oven's top as an unknown resistor, while the bottom is perfectly insulated. The oven releases heat to the surroundings, at 10 °C, by a mix of radiation and natural convection.

a) Sketch the thermal resistance network for the complete oven and give a clear description for all components.

b) Sketch the temperature profile starting from the air on the inside all the way to the outside, through all the layers of the cylinder wall.

c) Check with calculations that the outside aluminum wall of the oven will not get hotter than 40 °C. Define all parameters with clear distinctive symbols.

d) Henk claims: "to keep the outside of the oven even cooler, I could paint the aluminum using radiator paint. This way the oven can give off its heat even better and as a result, it will stay cooler this way." Ingrid agrees with Henk that the emissivity of radiator paint is higher than that of brushed aluminum, but does not think the wall will become cooler after the oven is painted. Who is correct?