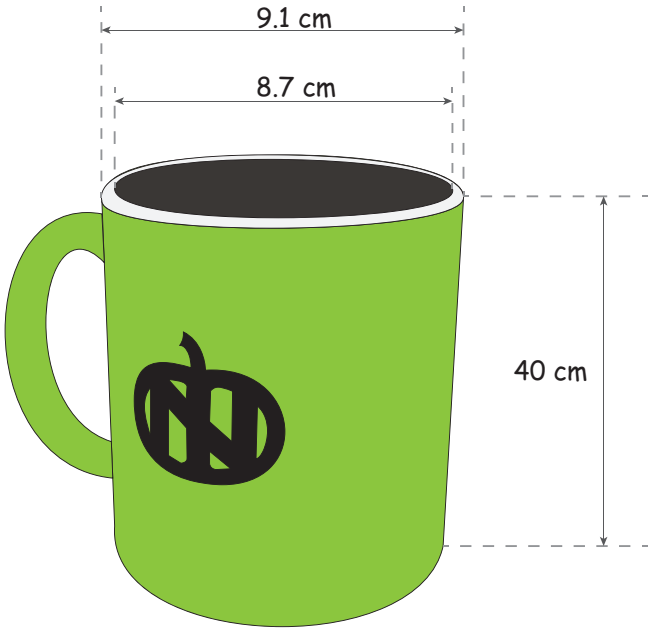
# Lecture 6

## 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 $T_\mathrm{i} = 35\ ^\circ\mathrm{C}$, 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 $T_{\mathrm{s,in}} = 22^\circ\mathrm{C}$, thanks to some clever roof paint that curbs radiation losses to insignificance.

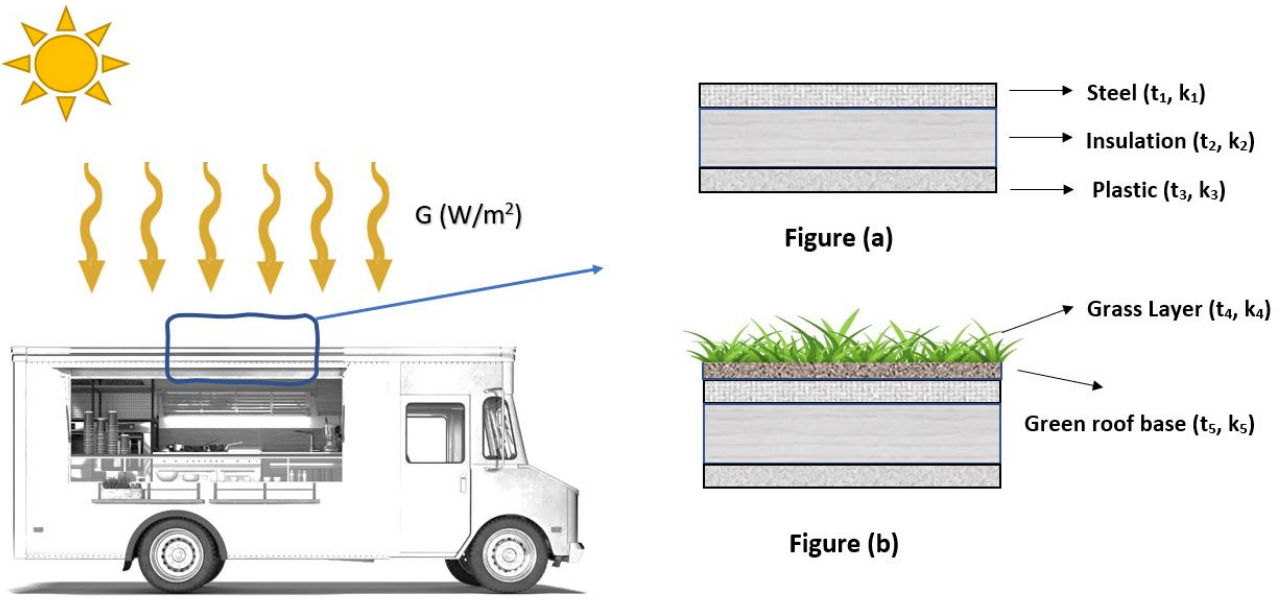



Figure 6.1: Cross-section of the food truck roof.

a) Determine the temperature of the roof surface and the temperatures of each layer, 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.