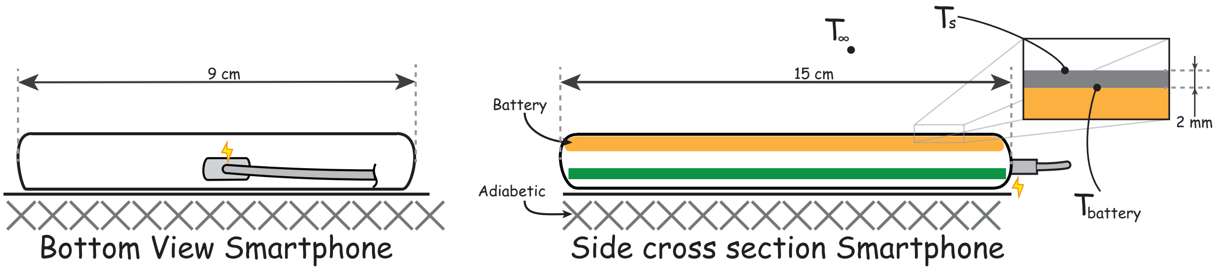
W04

The battery of a smartphone is being charged, while the device is laying outside during the day. It is a windstill day and the sun is shining. The dimensions of the phone are 15 cm x 9 cm and the smartphone is laying flat with the backside upwards towards the sky. The smartphone has a large battery that covers the entire backside of the device and between the battery is only covered by a thin 2 mm plastic backplate. The battery is not perfect and some part of the energy supplied by the charging cable is wasted into heat. The backplate is heated by the radiation of the sun and the warmth of the battery. It has a temperature of 42 K and only looses heat by convection. The outside temperature is 15 ^{o}C and the device absorbs an effective radiative heat flux of 79.6 W/m^2. Assume steady state-state heat (and energy) transfer.



a) Explain what the Grashof number physically represents.

b) Determine the convective heat transfer coefficient h of the backplate and calculate the convective heat flux to the environment $\dot{Q}_{\text{convection}}$

Most of the power supplied by the charging cable $\dot{E}_{cable}$ is stored in the battery. Therefore, the charging rate of the battery is $\dot{E}_{battery,stored}$. The rest of the electrical power supplied by the charging cable is wasted into heat $\dot{Q}_{battery,heat}$ and is lost fully by the backplate. The efficiency at which the battery is charged $\dot{\eta}_{battery} = \frac{\dot{E}_{battery,stored}}{\dot{E}_{cable}}$ is 95%.

c) Determine the conductive heat flux from the battery $\dot{Q}_{\text{battery,heat}}$
Hint:
$0 = \dot{Q}_{\text{battery,heat}} + \dot{Q}_{\text{radiation}} - \dot{Q}_{\text{convection}}$

d) Find the rate at which the charging cable $\dot{E}_{cable}$ supplies energy to the smartphone.
Hint:
The units of the electricity flows $\dot{E}$ and heat flows $\dot{Q}$ are the same; [W s^{-1}]!

e) Determine the temperature of the battery. The thermal conductivity of the plastic backplate is 0.12 W m^{-1} K^{-1}. It may be assumed that the temperature of the battery is constant.

The smartphone is accidentally nudged off the side off the table and now only hangs on the charging cable. The front of the smartphone is still adiabatic and the solar radiation on the backplate of the smartphone is still the same. Also, the charging rate has not changed. However, due to the now vertical position, the convective properties of the device have changed. The owner of the smartphone wants to know if this changes the temperature of the battery.

f) Recalculate the convective heat transfer coefficient h for this vertical scenario and compare it with the horizontal case. Argue, in words or a short additional calculation, how the difference in coefficients influence the temperature of the backplate and the battery of the smartphone. Will it be higher, lower or remain the same? You may neglect the change in the properties of the air.
Hint:
The surface temperature of the backplate is not known in the vertical case. You may - if you feel you need to - simplify the problem by neglecting this change when calculating the Grashof number aswell (and thus use the horizontal surface temperature).