Exercise 8

Exercise 1: Solar light is coming from air ($n_{air} = 1$) to the upper glass layer of a solar cell ($n_{glass} = 1.5$).

a) The light has an angle of incidence of $\Theta_i = 0°$. What is the reflectivity at the air-glass interface? Assume that the solar light is randomly polarized.

b) Now assume that the solar light reaches a silicon solar cell at an angle of incidence of $\Theta_i = 0°$. Refractive index of silicon, $n_{Si} = 3.5$. What percentage of light would be loss due to reflection at the air-silicon interface?

c) Using the refractive index library of the PVLighthouse website (`https://www.pvlighthouse.com.au/`), which thickness of the following materials to apply as antireflecting coating on silicon is required to minimize the reflectance at 600 nm?

  (a) Highly doped ITO (ITO sputtered $6.1 \times 10^{20}\,\mathrm{cm}^{-3}$)
  (b) Lowly doped ITO (ITO sputtered $3 \times 10^{19}\,\mathrm{cm}^{-3}$)
  (c) MgF2 evaporated

d) What would be the optimal (i.e. $R = 0\%$) refractive index of the anti-reflection layer to place between silicon and air?

Exercise 2: Front TCO + grid design: to minimize power losses, the TCO and the design of the metallic grid used as a front contact of a solar cell has to be optimized. Two competing mechanisms are resistive losses and shading losses, which depend on the length l and the width w of the fingers, on the distance between two adjacent fingers and the resistivity of the TCO.
Solar cell parameters:

- $J_{mpp} = 30\,\mathrm{mA\,cm^{-2}}$
- $V_{mpp} = 600\,\mathrm{mV}$

Front TCO:

- Tin doped InO (ITO):
  - Resistivity $\rho = 1 \times 10^{-4}\,\Omega\,\mathrm{cm}$
  - Thickness $d = 80\,\mathrm{nm}$
- Aluminium doped ZnO (AZO):
  - Resistivity $\rho = 1.5 \times 10^{-3}\,\Omega\,\mathrm{cm}$

– Thickness $d = 80\,\text{nm}$

Metal fingers:

- Resistivity $\rho_F = 0.028\,\mu\Omega\,\text{cm}$
- Finger length $l = 0.6\,\text{cm}$
- Finger height $h_F = 4\,\mu\text{m}$

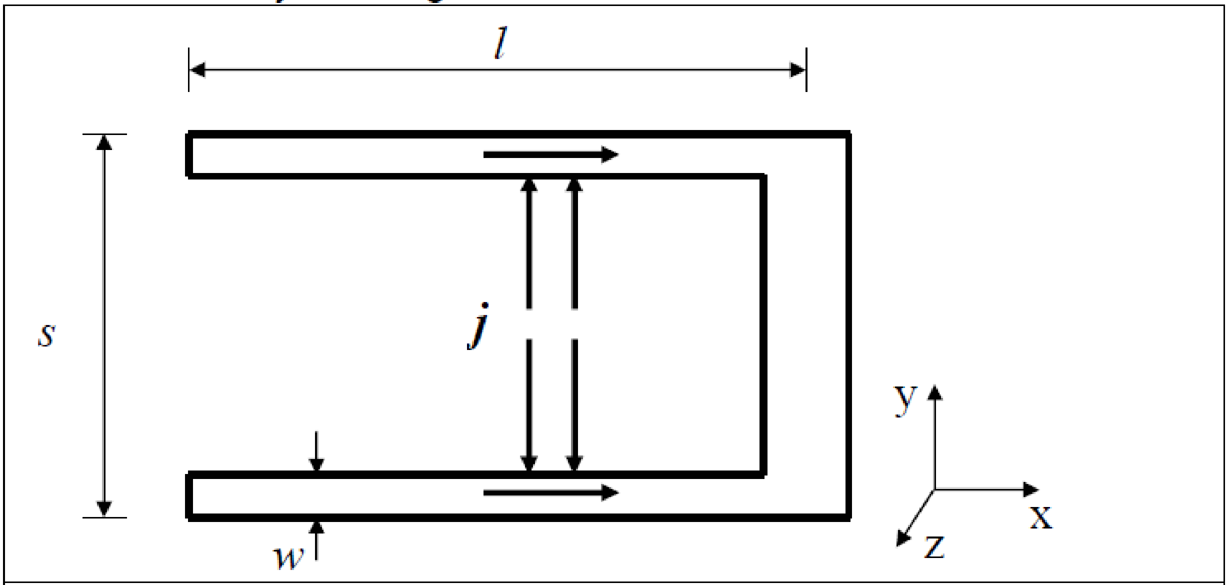

figure 1: cut-out of the top view on the front-grid. The grid consists of a thick busbar, in which the losses can be neglected, and of several (of which only two are depicted here) equidistant fingers with length *l* and width *w*. The distance between two fingers is *s*.

Calculate the relative power losses (P_{TCO}/P_{el}) in each of the TCO front contacts (ITO and AZO). Use $P_{el} = s \cdot l \cdot J_{mpp} \cdot V_{mpp}$, the total electrical power generated between two fingers at the maximum power point mpp. Assume that the current density, $j_Z = J_{mpp}$ is constant over the whole area and that the current (I_y) increments is $dI_y = j_Z \cdot l \cdot dy$, and the power increment is $dP_{TCO}(y) = I^2(y)dR(y)$.