Exercise sheet 1

Exercise 1 - Current–voltage characteristics of an ideal solar cell

A solar cell has a saturation current density of 1×10^{-9} mA/cm^2 and generates a current density of -20 mA/cm^2 under illumination of 100 mW/cm^2 and -1 V reverse bias. Assume that the solar cell behaves as an ideal diode ($n = 1$) which is described by the Shockley equation,

$$j_{illum} = j_0 \left(\exp\left(\frac{eV}{nkT} \right) - 1 \right) - j_{sc}. \tag{1}$$

a) Show how Eq. (1) can be transformed to calculate the open circuit voltage.

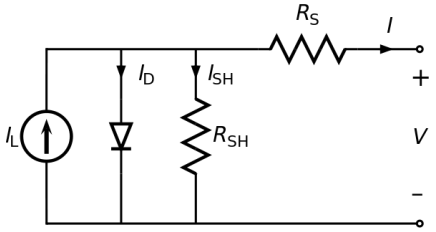
b) Calculate open circuit voltage at room temperature (300 K). What happens to the open circuit voltage if the short circuit current density is only 0.5 or 0.1 of the initial value?

c) Calculate power conversion efficiency and fill factor of the cell if the maximum power is at $dP/dV = 0$ (tip: use iteration to find the value of V_{max}).

d) In reality, the ideality factor n is in between 1 and 2. Assuming the ideality factor of 2, what is the value of short circuit current and open circuit voltage? Why does the ideality factor differ from unity?

Exercise 2 - Resistive effects in real solar cells

A real solar cell can be represented by the equivalent circuit with a diode, a current source and two resistors - series R_S and shunt R_{SH}.



a) Using the results from Exercise 1, draw the jV-curves of an ideal solar cell in the dark and under illumination in one diagram. Mark open circuit voltage, short circuit current, maximum power point and fill factor.

b) Rewrite Eq. (1) assuming that $R_{SH} = 0$ and $R_S \neq 0$. Draw dark and illuminated current–voltage curves. Mark maximum power point and fill factor.

c) Do the same for $R_S = 0$ and $R_{SH} \neq 0$.

Exercise 3 - Photoelectric effect

Electrons are being emitted from a plate of aluminum through the photo-electric effect. Workfunction of aluminum is 4.08 eV.

a) What is the minimum photon frequency that would cause electrons to be emitted? Calculate corresponding photon wavelength.

b) Calculate the momentum of these photons in SI units. What is the velocity of a free electron with the same momentum?

c) Is this wavelength in the visible spectrum? If not, in what part of the spectrum is this light found?

d) Consider a beam of light with a power of 1 Watt. Calculate the number of photons provided by the beam in one second.