Please limit your answer to 10 minutes
(5 min presentation + 5 min for eventual questions)

Exercise 1.1 (PV for family Müller)

Please describe (preferably as a PPT presentation with 3-4 slides):

Family Müller in Lausanne consumes 3500 kWh of electricity in a year.

a) What should be the nominal power of a PV system in order to generate this amount of energy? (assume south orientation of modules)

b) What module area is required when the modules have an efficiency of 20%?

c) What is return-on-investment time for a grid-connected system?

Use lecture notes and web resources

Exercise 1.2 (Shockley–Queisser limit)

Please explain the main steps in derivation of the theoretical limit for the conversion efficiency for unconcentrated light (the Shockley–Queisser limit or detailed balance limit)

Literature:

W. Shockley and H.J. Queisser, "Detailed Balance Limit of Efficiency of p-n Junction Solar Cells", *Journal of Applied Physics*, Volume 32 (March 1961), pp. 510-519

"Handbook of Photovoltaic Science and Engineering", 2011 http://onlinelibrary.wiley.com/book/10.1002/9780470974704

L.C. Hirst and N.J. Ekins-Daukes "Fundamental losses in solar cells", Prog. Photovolt: res. Appl. 2011, 19, 286-293

Exercise 1.3 (Solar module degradation and failure)

Please describe (preferably as a PPT presentation):

- Possible failures of PV modules
- Mechanisms of degradation (light-induced, potential-induced, long-term)

Literature:

"Handbook of Photovoltaic Science and Engineering",
http://onlinelibrary.wiley.com/book/10.1002/9780470974704

PVeducation.org
http://pveducation.org/pvcdrom/modules/degradation-and-failure-modes

web references

Exercise 2.1. (Electrodes for organic solar cells and inverted structure)

Please describe (preferably as a PPT presentation with 3-4 slides):

To achieve high efficiency in organic bulk heterjunctions, the electrodes should be highly selective for either electrons or holes.

a) Make a schematic drawing of the energy diagrams of the "standard oPV cell configuration" and the so-called "inverted structure" for a PCBM/P3HT solar cell.
b) What are good electrode materials? Why?
c) Why are frequently additional interfacial layers implemented?
d) What are the advantages of the inverted architecture?

Literature:

M. D. Irwin, D. B. Buchholz, A. W. Hains, R. P. H. Chang, and T. J. Marks, p-Type semiconducting nickel oxide as an efficiency-enhancing anode interfacial layer in polymer bulk-heterojunction solar cells, PNAS, 105 (8), 2783–2787 (2008)

N. Chander, S. Singh, S. S. Kumar Iyer, Stability and reliability of P3HT:PC61BM inverted organic solar cells, Solar Energy Materials & Solar Cells 161, 407–415 (2017).

Exercise 2.2 (Mixed halide solar cells)

Lead halide perovskite semiconductors offer several possibilities to tune the bandgap and to alter the band gap energy.

a) Explain by which way the band gap in these semiconductors can be tuned and give the achievable range of energies.

b) Why is it interesting to vary the bandgap in solar cells?

One issue concerns structural stability of the perovskite crystal.

c) Explain the concept of "tolerance factor", calculate the tolerance factors for $MAPbI_3$, NaPb I_3, and $EDAPbB_3$ and explain with these examples how that is related to structural stability.

Literature:

Noh et al., Nano Lett. 2013, 13, 1764−1769;

Meloni et al., J. Mater. Chem. A 2016, 4, 15997–16002;

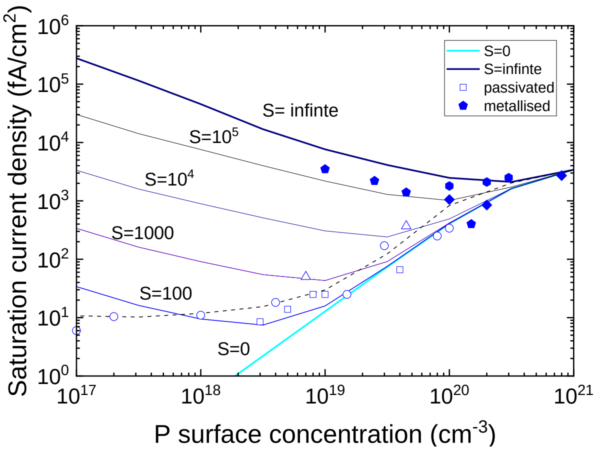
Han et a., J. Phys. Chem. C 2018, 122, 13884−13893

Exercise 3.1: Selective emitter (5-7 min)

In the development of c-Si solar cells, much of effort was devoted to the front contact. Highly diffused emitters like the phosphorous diffusion profiles shown in the course were already very early replaced by *passivated emitters*, and eventually further improved on by the introducing *selective emitters*.

a) Design a sketch of the front region of a c-Si solar cell, showing the *pn*-junction between wafer and the diffused region, the local contacts to the silver finger metallisation, and the passivated region between the fingers.

b) Using the diagram below,[1] explain the working principle of a passivated emitter. Discuss what motivated the development of passivated emitters.



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c) Assume a *passivated emitter* with reduced surface concentration of $N_D = 10^{19}\ \mathrm{cm}^{-3}$. Project the j_0 by using an area weighted sum of $j_{0,met}$ and $j_{0,pass}$, assuming that the silver fingers cover an area of 10%.

d) Explain the working principle of a *selective emitter* that combines highly doped regions below the fingers and lowly doped regions with passivation. Point out the additional improvement that is possible.

[1] The symbols refer to experimental data digitized from King, TED (1980) and from Kerr, JAP (2001). The lines refer to a simple model with the geometry factor G_F, assuming constant donor density N_D equal to the surface concentration.