EECE 480 Assignment 3

Due date: November 3; hand-in at the beginning of the class.

Objective: To appreciate some practical factors that affect the efficiency of solar cells and LEDs.

1. Consider a silicon solar cell made from a wafer of diameter 10 cm. Under AM1.5G illumination the photocurrent density is $40\,\mathrm{mA\,cm^{-2}}$, and the open-circuit voltage is 0.7 V.
   (a) Compute I_0, the diode saturation current.
   (b) Plot the *I-V* characteristic under AM1.5G illumination. Explain how you obtained this characteristic.
   (c) On a separate plot show the power-voltage characteristic. Explain how you obtained this characteristic.
   (d) Evaluate the fill-factor FF and the conversion efficiency η_{pv}.

2. The emitter of the cell is 200 nm thick and has a doping density of $5 \times 10^{19}\,\mathrm{cm^{-3}}$. The top-contact grid pattern is such that the series resistance of the cell can be represented by a slice of the emitter material that is $14.66\,\mu$m long and 1 cm wide.
   (a) Evaluate the series resistance R_s of the cell.
   (b) Plot the new *I-V* characteristic for the cell on the same graph as for the cell with $R_s = 0$. Explain how you obtained this characteristic.
   (c) Plot the new *P-V* characteristic for the cell on the same graph as for the cell with $R_s = 0$. Explain how you obtained this characteristic.
   (d) Evaluate the new η_{pv}.

3. Consider a P^+pN^+ $\mathrm{In}_y\mathrm{Ga}_{1-y}\mathrm{P}/\mathrm{Al}_x\mathrm{Ga}_{1-x}\mathrm{As}/\mathrm{In}_y\mathrm{Ga}_{1-y}\mathrm{P}$ LED.
   (a) Choose the mole fractions x and y for a diode that would emit at the extreme end of the red spectrum, *e.g.*, at 743 nm.
   (b) Choose a forward bias to obtain a voltage efficiency of 96%.
   (c) Use Bandprof to obtain an energy band diagram for the diode operating at your chosen applied voltage. Include your input file and the band diagram.
   A template file for designing and analyzing such a device in Bandprof can be found on the course website:
   - note how the mole fraction in a ternary compound is specified;
   - the notation '(h) anode' refers the hole quasi-Fermi level in the active region to the anode.