Homework 6 Solar PV Energy
MAE 119 W2017
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1. What is the most likely wavelength and frequency of light emitted from the sun which has a black body temperature of about 6600 deg K? What photon energy does this correspond to?

2. Plot the blackbody spectrum of emission from the sun, and identify the photon wavelength or frequency that corresponds to the bandgap energy of Si. Identify which region has photons with enough energy to create charge carrier pairs in a SI based solar cell.

3. 2. If the bandgap energy of Si is 1.1 eV, estimate the intrinsic or maximum efficiency for a Si-based solar cell exposed to the sun's blackbody emission spectrum.

4. 3. A typical Si-based PV cell will have a form factor, FF=0.7, and an open circuit voltage V_{OC}=0.6 V and a short-circuit current density J_{SC}=30 mA/cm^2. What is the maximum real efficiency of this cell? Suppose now that by improving the manufacturing process, you are able to increase the carrier lifetime by a factor of 3. Since the open-circuit voltage doesn't depend on defect density, what will be the new short-circuit current density if nothing else is changed in the PV cell design? By how much will the efficiency improve?

5. Estimate the solar PV system area and electrical energy storage required to power the UCSD campus purely by sunlight. If a solar PV system with a capacity factor of 15% can be installed for $3/Watt, and the energy storage costs are $200/kW-hr, what would be the up-front installation cost of such a system? If it lasts for 20 years and performs to its ideal specifications year-round (i.e. you don't have to consider losses due to bad weather, clouds, fog etc) and interests costs for money are zero so that the present value and future value of money is equal (really an ideal world!)), how much does the electrical energy cost per kW-hr? How does this compare against conventional electrical energy costs?

6. The San Diego region is considering the installation of a pumped hydro storage system to smooth out the time-variation of renewable energy sources. Suppose the upper and lower storage level reservoirs both have a surface area of 3 km^2, and a uniform depth of 100m. The vertical displacement between the center-of-gravity of the two reservoirs is 300m. You have been asked to design a system to provide constant power from this system to San Diego over a 12 hour night interval, and then recharge the

system with excess solar PV power. How much power can you promise to deliver? How much energy does this correspond to? What is the water flow rate through the system? How much solar PV power do you need to divert to the pumps to recharge the system during the day?

7. Estimate the maximum energy storage capacity of a 1m diameter, 20 cm thick flywheel made of high strength steel, operating with stresses at the periphery of the flywheel that are approaching the ultimate tensile strength of the material. What is the specific energy storage (i.e. J/kG) of this device? How does this compare to batteries? To liquid fuels? *Hint:* The flywheel will fail when the tensile strength of the material at the perimeter approaches the kinetic energy density of that region. How might you modify the design of the flywheel to increase the specific energy storage capacity?

8. High temperature superconducting cables are beginning to be available for commercial use. Investigate their performace on the Internet, and estimate the energy storage capability of a solenoidal magnet constructed with these materials. Suppose the coil is 1m long, and has an inner bore of 10 cm. The coil operation will be limited by the maximum current density in the cables, the maximum allowable magnetic field, and the mechanical strength of the structure holding the coil together. [Note: this is an open ended problem … no single solution. Just want to get you thinking].