

- (20) 1. "Ultimate efficiency" of a single-gap solar cell. The goal of this problem is to derive an upper bound on the power conversion efficiency—defined here as the ratio of output electrical power to input radiative power—of a photovoltaic (PV) device with a single band gap, E_g . Consider an idealized solar cell, a pn junction with surface area 1 m^2 , held at $T = 0\text{K}$. Assume the sun is a blackbody with $T = 6000\text{K}$.
- (a) Compute the incident power (energy/sec) due to the blackbody radiation, assuming for simplicity, all the black body radiation is focused on the 1m^2 area.
 - (b) On an average sunny day around lunchtime, incident sunlight has an intensity of about 1000 W/m^2 . Why does the number in (a) differ?
 - (c) Assuming each incident photon with energy greater than E_g produces a single electron-hole pair ("detailed balance"), each charge producing a voltage of magnitude $h\nu_g/e$, derive an expression for the output electrical power in terms of the band gap E_g . (Hint: If each of the number of absorbable photons resulted in electron-hole pairs at the band gap, what would be the output power?)
 - (d) Using (a) and (c), determine the band gap that maximizes the device efficiency.
 - (e) In a real single-band solar cell, the efficiency depends on the resistive load, and the maximum efficiency is typically written $I_m V_m / P_{in}$. The "ultimate efficiency" you computed in (d) differs just a little from the oft-quoted "Shockley-Queisser limit" ($\sim 30\%$), which is derived from an analysis that also accounts for a "perfectly matched" resistive load. As discussed in class, this can also be modeled using a model I-V characteristic (i.e., $I(V)$) for a pn junction. State two physical reasons why the Shockley-Queisser limit is less than the "ultimate efficiency."
- (20) 2. (a) Find an expression for the difference in entropy ΔS between the normal and superconducting states in terms of the critical field and its derivative with respect to temperature.
- (b) Do the same exercise as in part (a) for ΔC , the heat capacity difference between the normal and superconducting states.
- (c) What is $\Delta C(T_c)$?
- (20) 3. Consider a superconducting cylinder of radius, R , in a magnetic field, H_0 , along the axis of the cylinder. Calculate the current density, j , and the magnetic field, H , as a function of r ; plot your results.
- (20) 4. Show that the flux in a superconductor is quantized in units of $hc/2e$. Discuss the stability of the flux.
- (20) 5. Describe and discuss the advantages of a room temperature superconductor.