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Problem Set #12

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1. Photons emitted by a light emitting diode (LED) come from the recombination of electrons and holes across the energy gap separating the valence and conduction bands. How large should the gap be in order to get green photons (wavelength = 500 nm)?

2. A phosphorous atom in silicon can be thought of as a hydrogen-like atom but with the electron orbiting in a dielectric medium with dielectric constant κ = 12. Measured relative to the bottom of the conduction band, the allowed (donor) energy levels of this atom are $E_n = -\frac{13.6}{\kappa^2 n^2}\,\mathrm{eV}$. How much energy is required to "ionize" this atom—that is, how much energy is required to promote the bound electron from its ground state into the conduction band?

3. At finite temperature, the electrons in the conduction band of an n-type doped semiconductor are partially due to thermal ionization from the conduction band of host atoms and from the states of donor atoms. In silicon the valence band is 1.10 eV below the conduction band and a typical donor level might be 0.05 eV below. For either, the number of electrons in the conduction band is given by $N = N_0 \exp\left(-E / 2k_B T\right)$, where N_0 = number of atoms from which the electrons emerge and E = energy below the conduction band of the electrons in those atoms. Find the ratio N_{0d}/N_{0h} of the number of impurity donor atoms to the number of host atoms in the solid if there is one donor electron in the conduction band for every host electron at T = 300 K.

4. The binding energy of a Cooper pair is $3.5 k_B T_C$, where T_C is the critical temperature for the onset of superconductivity. Suppose T_C = 10 K, what is the binding energy?

5. The magnetic field at the surface of a long wire of radius R carrying current I is $\mu_0 I / 2\pi R$. What is the maximum value of I for R = 0.05 mm if the wire is in a superconducting state with critical field strength of 0.2 T?