

1. (2 pts) (a) Why do impurities decrease the conductivity of metals. (b) How can impurities increase the conductivities of semiconductors and insulators?
2. (5 pts) The conduction band in silicon is about 13 eV wide. (a) The number of energy levels in the conduction band is equal to four times the number of atoms in the crystal. What is the average spacing between adjacent energy levels in the band in a cube of silicon 1 mm on a side. (b) How small must the length of the side of a cube be for the spacing to be equal to $kT/10$ at room temperature (300 K)? The isotopically averaged mass of a silicon atom is 28.09 amu, and the density of solid silicon is 2330 kg/m³.
3. (3 pts) What type of semiconductor (p or n) do I get if I dope Ge with Ga, As, and Al?
4. (4 pts) The band-gap at room temperature is 1.11eV for Si and 0.67 for Ge. (a) If I made an LED by doping Si or Ge, about what wavelengths of light would you expect them to produce? (b) If I made a photodiode by doping Si or Ge, what would be the longest wavelength that they could detect?
5. (4 pts) (a) Explain why there is an electric field in the depletion region of a $p-n$ junction. (b) Explain why current flows when the diode is forward biased. (c) Explain why current doesn't flow when it is reversed biased.
6. (4 pts) This problem covers everything you need to know about section 10.8. (a) Take a look at figure 10.44. This plot shows that there are gaps in the spectrum of allowed energies that an electron in a solid can have. How does the size in the energy gaps relate to the size of the gaps in the allowed momentum that an electron could have? (hint: this is a trick question) (b) Explain what m^* , the effective mass of an electron is, and how you would calculate it from curves such as the ones shown in figures 10.44 and 10.47.
7. (6 pts) Metals, as a result of their conductivity, tend to reflect light very well. When I learned about superconductors, I wondered why the sample shown to me in class looked dark grey instead of shiny. If they were perfect conductors, they should act like super-mirrors! In fact, superconducting mirrors are used to make very good microwave reflectors, but they don't make super-reflectors of visible light. (a) Why don't they reflect visible light well? (b) What is the shortest wavelength that a lead (Pb) mirror will super-reflect at absolute zero temperature? (c) What would the critical temperature of a BCS superconductor have to be for it to be a super-mirror for visible light with a wavelength of 600 nm?
8. (2 pts) Explain why the isotope effect is a sign that superconductivity has something to do with lattice vibrations (i.e. phonons).

Extra problems I recommend you work (not to be turned in)

- Explain how a tunnel diode works.
- Re-write section 10.8 in English.
- If you put too much current through a superconductor, it will stop being a superconductor. Can you think of why this would occur? (Hint, currents generate magnetic fields).