5.6 Exercises

Molecules

Ex 5.1. Prove that the equilibrium distance in Lenard-Jones potential is $r = 2^{1/6}\sigma$.

Ex 5.2. Consider a hypothetical one-dimensional ionic solid Na^+ and Cl^- are placed alternately a distance b apart. Find the electrostatic energy that will be required to remove an ion from this crystal. Hint: $\ln(1+x) = x - x^2/2 + x^3/3 + x^4/4 - \cdots$.

Ex 5.3. Consider on cell of the NaCl crystal and obtain the total mass per unit cell. make sure your calculation makes use of the fact that charge per unit cell is zero. Data: distance between Na^+ and Cl^- = 0.282 nm, $m_{\text{Na}} = 23$ u, $m_{\text{Cl}} = 35.5$ u, where 1 u $= 1.66 \times 10^{-27}$ kg.

Structures of Solids

Ex 5.4. A particular set of crystal planes in a sodium chloride crystal are separated by $d = 2.52$ nm. Find the angles at which different order diffraction diffraction will occur for an X ray beam of wavelength 0.71 AA?

Ex 5.5. A crystal of copper is being analyzed by a monochromatic X rays of wavelength 0.056 nm. It is found that the smallest angle at which the diffraction occurs is 7.74°. (a) Find the spacing of crystal planes from which the X rays are reflecting off. (b) Find all other angles the diffraction would occur.

Ex 5.6. A crystal of copper is mounted so that the crystal planes will be separated by $d = 0.361$ nm. An X ray source has strong diffraction at 15° and again at 18°. Decide whether the two diffractions correspond to different orders of the same wavelength or to two different wavelengths. If you decide the two correspond to two different wavelengths then find out the wavelength assuming they are first orders in each, and if you decide the two correspond to the same wavelength then figure out the two orders assuming the smaller angle corresponds to the first order.

Classical Model of Conduction

Ex 5.7. How many conduction electrons are there in 10 gram sample of (a) pure silver, (b) pure copper, and (c) pure gold. Data: atomic weights: Ag 107.86, Cu 63.55, Au 196.97. Assume one electron per atom in each element is conduction electron.

Ex 5.8. Compute the density of conduction electrons in (a) pure silver, (b) pure copper, and (c) pure gold. Data: mass density of metals, Ag 10.49 g/cm^3, Cu 8.96 g/cm^3, Au 19.30 g/cm^3.

Ex 5.9. A copper wire of cross-section area 4 mm^2 carries a current of 2 A. (a) What is the current density J? (b) What is the drift velocity of the electrons? Use the data from last problem.

Ex 5.10. Evaluate the ratio of the thermal conductivity to electrical conductivity of copper at 0°C?

Ex 5.11. The electrical conductivity of copper at room temperature (27°C) is $5.96 \times 10^7\ \Omega^{-1}\text{m}^{-1}$. (a) Find the average time between collisions of electrons. (b) Find electron's (rms) thermal velocity. (c) What is the mean free path of electrons at room temperature?

Quantum Model of Conduction

Ex 5.12. Assuming each atom of the (a) Ag, (b) Cu, and (c) Au contribute to the conduction, find the Fermi energy of these metals. Data: atomic weights: Ag 107.86, Cu 63.55, Au 196.97; mass density of metals, Ag 10.49 g/cm^3, Cu 8.96 g/cm^3, Au 19.30 g/cm^3.

Ex 5.13. The electrical conductivity of copper at room temperature (27°C) is $5.96 \times 10^7\ \Omega^{-1}\text{m}^{-1}$. (a) Find the average time between collisions of electrons using quantum mechanical treatment. (b) What is the Fermi energy of copper. (c) What is the Fermi velocity of electrons of copper? (d) What is the mean free path of electrons at room temperature? Data: atomic weight Cu 63.55, mass density Cu 8.96 g/cm^3.

Semiconductors

Ex 5.14. The energy gap in the Germanium is 0.67 eV. (a) What will be the longest wavelength of the photon that can excite an electron from the valence band to the conduction band? (b) What will happen if you expose a sample of Germanium to a light of longer wavelength? (c) What will happen if you expose a sample of Germanium to a light of shorter wavelength?

Ex 5.15. Often the band gap in a semiconductor is measured by absorption spectrum. It is found that the longest wavelength that a semiconductor will absorb is 1.1 μm. What is the band gap?

Ex 5.16. Silicon has a band gap of 1.14 eV. If the Fermi level is taken to be halfway between the Conduction and Valence bands, what is the probability that a state at the bottom of the conduction band will be occupied at (a) T=250 K, (b) T=300 K, (c) 350 K?