VE320 Intro to Semiconductor Devices
Summer 2022 — Problem Set 1

May 21, 2022

Exercise 1.1

The lattice constant of a single crystal is 4.73$\mathring{A}$. Calculate the surface density (#/cm^2) of atoms on the (i) (100), (ii) (110), and (iii) (111) plane for a (a) simple cubic, (b) body-centered cubic, and (c) face-centered cubic lattice.

Exercise 1.2

The work function of a material refers to the minimum energy required to remove an electron from the material. Assume that the work function of gold is 4.90eV and that of cesium is 1.90eV. Calculate the maximum wavelength of light for the photoelectric emission of electrons for gold and cesium.

Exercise 1.3

According to classical physics, the average energy of an electron in an electron gas at thermal equilibrium is $3kT/2$. Determine, for $T = 300$ K, the average electron energy (in eV), average electron momentum, and the de Broglie wavelength.

Exercise 1.4

An electron is described by a wave function given by $\psi(x) = \sqrt{\frac{2}{a}} \cos\left(\frac{\pi x}{a}\right)$ for $\frac{-a}{2} < x < \frac{+a}{2}$. The wave function is zero elsewhere. Calculate the probability of finding the electron between $(a) 0 < x < \frac{a}{4}$, (b) $\frac{a}{4} < x < \frac{a}{2}$, and $(c) \frac{-a}{2} < x < \frac{+a}{2}$.

Exercise 1.5

Consider the wave function $\Psi(x,t) = A\left(\cos\left(\frac{\pi x}{2}\right)\right)e^{-j\omega t}$ for $-1 \leq x \leq +3$. Determine A so that $\int_{-1}^{+3} |\Psi(x,t)|^2 dx = 1$.

Exercise 1.6

An electron is bound in a one-dimensional infinite potential well with a width of $10\mathring{A}$. (a) Calculate the first three energy levels that the electron may occupy. (b) If the electron drops from the third to the second energy level, what is the wavelength of a photon that might be emitted?

Exercise 1.7

Consider the one-dimensional potential function shown in Figure 1. Assume the total energy of an electron is $E < V_0$. (a) Write the wave solutions that apply in each region. (b) Write the set of equations that result from applying the boundary conditions. (c) Show explicitly why, or why not, the energy levels of the electron are quantized.

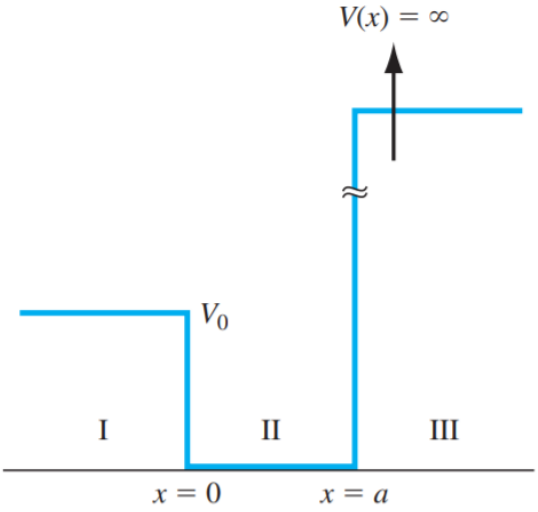

Figure 1: Potential function for Problem 1.7

Exercise 1.8

The bandgap energy in a semiconductor is usually a slight function of temperature. In some cases, the bandgap energy versus temperature can be modeled by

$$E_g = E_g(0) - \frac{\alpha T^2}{(\beta + T)}$$

where $E_g(0)$ is the value of the bandgap energy at $T = 0$ K. For silicon, the parameter values are $E_g(0) = 1.170\text{eV}, \alpha = 4.73 \times 10^{-4}\text{eV/K}$, and $\beta = 636$ K. Plot E_g versus T over the range $0 \leq T \leq 600$ K. In particular, note the value at $T = 300$ K.

Reference

1. Neamen, Donald A. Semiconductor physics and devices: basic principles. McGraw-hill, 2003.