Exercise 2.1

Speed of electrons. Estimate the average random speed of an electron gas in a semiconductor at 300 K. *Note*: The free electron mass $m_e = 9.10938356 \times 10^{-31}$ kg.

Exercise 2.2

*Transmission electron microscope.*Electron beams are used to study the atomic structure of crystals, as in the transmission electron microscope (TEM). The resolution of the microscope depends on the energy of the electrons, which determines the corresponding wavelength of the electrons. The minimum focal point of the electron beam depends on its wavelength. Determine the electron wavelength if they have an energy of:

a) 100 keV

b) 1 MeV

Exercise 2.3

Electron energy states in a potential wire. Determine (a)the energy levels of an electron in a two-dimensional square box of length D, assuming an infinitely high potential barrier around the box, (b) the allowable energy levels for D = 5 nm, and (c) the degeneracy of the first four energy levels.

Exercise 2.4

*Electron density of states inside quantum wires.*Derive the expression for density of states inside a quantum wire and plot this expression for $L_x = L_y = 5\ nm$

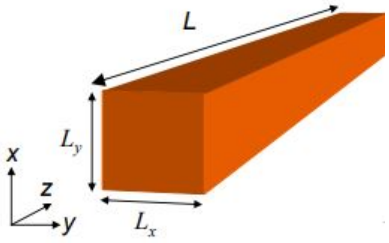

Figure 1: In a quantum wire, electron is free to move in one direction and confined in the other two directions.

Exercise 2.5

Unit cell in real and reciprocal space. A body-centered cubic lattice has the following primitive translation vector:

$$\boldsymbol{a_1} = \frac{1}{2}a(-\hat{x} + \hat{y} + \hat{z}) \quad \boldsymbol{a_2} = \frac{1}{2}a(\hat{x} - \hat{y} + \hat{z}) \quad \boldsymbol{a_3} = \frac{1}{2}a(\hat{x} + \hat{y} - \hat{z})$$

a) Construct the Wigner-Seitz cell in real space.

b) Find out the corresponding primitive translation vector in the reciprocal space and prove that the reciprocal lattice is an fcc structure.

c) Sketch the Wigner-Seitz cell in the reciprocal space, that is, the first Brillouin zone.