Exercise 1.1

Phonon mean free path and relaxation time. Given the thermal conductivity of Si at room temperature as $145\,\mathrm{Wm^{-1}K^{-1}}$, the speed of sound as $6400\,\mathrm{ms^{-1}}$, the volumetric specific heat as $1.66 \times 10^6\,\mathrm{Jm^{-3}K^{-1}}$,

a) Estimate the phonon mean free path in Si at room temperature from the kinetic theory. In reality, this estimation usually leads to a much shorter mean free path (about a factor of 10 shorter) than with more sophisticated modelling.

b) Estimate the relaxation time of phonons in silicon.

Exercise 1.2

k_BT energy. One unit for energy is the electron-volt (eV). It is the energy difference of one electron under a potential difference of 1 V. Convert 1 k_BT at 300 K into milli-eV (meV).

Note: The Boltzmann constant $k_B = 1.38064852 \times 10^{-23}\,\mathrm{J/K}$.

Exercise 1.3

Fick's Law. Using a simple kinetic argument that is similar to the derivation of the Fourier law, derive the Fick's law of diffusion, which gives the mass flux for species i under a concentration gradient as:

$$J_i = -\rho D \frac{dm_i}{dz}$$

where D is the mass diffusivity, p is the density of the mixture, and m_i the local mass fraction of species i. Also, state the assumptions made during this analysis.

Exercise 1.4

Planck-Einstein relations.

(1) An argon laser emits light at 514 nm and at a power of 1 W. Calculate:

a) The frequency of the photons in Hz

b) Their wavelength, expressed as a wavenumber

c) The energy of each photon

d) The momentum of each photon

e) The number of photons generated per second

(2) If the photons are completely absorbed by a $1mm^2$ surface, calculate

a) The pressure exerted on the surface by the photons

b) The heat flux generated by the photon absorption