1) For an n-type silicon resistor at $T = 300$K and doped to $N_D = 10^{16}$ cm$^{-3}$, determine the maximum temperature difference that can be produced by Peltier cooling. Assume an energy-independent mean-free-path for electrons so that the Seebeck coefficient is:

$$S_{3D} = \left( \frac{k_B}{-q} \right) \left( \frac{2F_1(\eta_F)}{F_0(\eta_F)} - \eta_F \right)$$

Assume that the heat conduction is entirely carried by the lattice, and make use reasonable numbers for the other parameters.
HW9 Solution

\[ n_0 \ll N_c \approx 3.23 \times 10^{19} \text{ cm}^{-3} \]  

From Pienet, Adv. Semicond. Fundamentals, 2nd Ed., Table 4.2, p. 113

Non-degenerate statistics apply

\[ S = -\left( \frac{k_B}{q} \right)(2 - n_F) \]

\[ n_0 = N_c e^{n_F} \rightarrow n_F = \ln(n/n_0) = -8.1 \]

\[ S = -8.6 \times 10^{-4} \times 10.1 = 869 \mu \text{V/K} \]

\[ \sigma = n_0 \mu_n = \frac{1200}{\text{cm}^2/\text{v-s}} \]  

From Pienet, Fig. 6.5, p. 184

\[ = 10^{16} (1.6 \times 10^{19}) / 1200 \]

\[ = 1.92 \Omega^{-1} \text{-cm}^{-1} \]

\[ K_L = 2 \text{, see www.ioeffe.rssi.ru/SVA/NSM/Semicond/Si/thermal.htm} \]

\[ K_L = 1.3 \text{ W/(cm-K)} \]

\[ ZT = \frac{2}{K_L} = 3.4 \times 10^{-4} \]

Lecture II: \( \Delta T / T \)_{max} = \( \frac{1}{2} ZT \rightarrow \Delta T |_{\text{max}} = 0.05^\circ \text{K} \)

Silicon is NOT a good TE!