ECE 656: Fall 2009
Lecture 9 Homework SOLUTION

1) For an n-type silicon resistor at $T = 300\text{K}$ and doped to $N_D = 10^{16}\ \text{cm}^{-3}$, 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:

$$S_{3D} = \left(\frac{k_B}{-q}\right)\left(\frac{2\mathcal{F}_1(\eta_F)}{\mathcal{F}_0(\eta_F)} - \eta_F\right)$$

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

HW9 Solution

$n_0 << N_C \simeq 3.23\times10^{19}\ cm^{-3}$ Pierret, Adv. Semic. Fundamentals, 2nd Ed., Table 4.2, p. 113

non-degenerate statistics apply

$$S = -\left(\frac{k_B}{q}\right)(2-\eta_F)$$

$$n_0 = N_C e^{\eta_F} \rightarrow \eta_F = \ln(n/N_C) = -8.1$$

$$S = -86\frac{\mu V}{K}\times 10.1 = 869\ \mu V/K$$

$\sigma = n_0 q \mu_n \quad \mu_n \simeq 1200\ cm^2/V\text{-}s$ Pierret, Fig. 6.5 p. 184

$$= 10^{16}(1.6\times10^{-19})1200$$
$$= 1.92\ (\Omega\text{-}cm)^{-1}$$

$K_L = ?$ see www.ioeffe.rssi.ru/SVA/NSM/Semicond/Si/thermal.htm

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

$$ZT = S^2\sigma/K_L = 3.4\times10^{-4}$$

Lecture 11: $\Delta T/T)_{max} = \frac{1}{2}ZT \Rightarrow \Delta T|_{MAX} = 0.05\,^{\circ}K$

Silicon is NOT a good TE!