

ECE 656 Homework (Week 12)

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- 1) Show that the following relation (eqn. (4.119) in *Fundamentals of Carrier Transport*) is true:

$$e^{-\frac{\pi}{\rho_S} R_{MN,OP}} + e^{-\frac{\pi}{\rho_S} R_{NO,PM}} = 1$$

- 2) For n-type, bulk silicon doped at $N_D = 10^{17} \text{ cm}^{-3}$ the room temperature mobility is $800 \text{ cm}^2/\text{V}\cdot\text{s}$. Answer the following questions. Some potentially useful information is:

$$N_C = 3.23 \times 10^{19} \text{ cm}^{-3} \quad N_V = 1.83 \times 10^{19} \text{ cm}^{-3} \quad E_G = 1.11 \text{ eV} \quad v_T = 1.05 \times 10^7 \text{ cm/s}$$

- 2a) Estimate the mean-free-path for backscattering. Make reasonable assumptions, but clearly state them.
- 2b) Estimate the Seebeck coefficient. Make reasonable assumptions, but clearly state them.
- 2c) Estimate the number of conduction channels per cm^2 . Make reasonable assumptions, but clearly state them.
- 3) It is tempting to estimate the momentum relaxation time, $\langle\langle\tau_m\rangle\rangle$, from the mobility and then to multiply by a velocity to get the mean-free-path. Give the correct expression for the mfp for backscattering in 2D – in terms of $\langle\langle\tau_m\rangle\rangle$ as extracted from the measured mobility. You may assume a non-degenerate semiconductor.
- 4) The purpose of this homework assignment is to solve the Boltzmann Transport Equation for a particle with charge $+Zq$, where Z is an integer > 1 . This may occur in problems like the flow of ions through channels in cell walls or the flow of ions inside a battery.

- 4a) Solve the BTE in the relaxation time approximation assuming a constant relaxation time, and a small electric field, but no concentration gradient. Use the result to derive an equation for the drift current.
- 4b) Solve the BTE in the relaxation time approximation assuming a constant relaxation time, and a small concentration gradient, but no electric field.
- 4c) Use the result from 4a) to derive an equation for the diffusion current.
- 4d) Find the Einstein relation for these charged particles.
- 5) A Hall effect experiment is performed on a n-type semiconductor with a length of 2.65 cm, a width of 1.70 cm, and a thickness of 0.0520 cm, in a magnetic field of 0.5 T. The current in the sample along its length is 200 μA . The potential difference along the length of the sample is 195 mV and across the width is 21.4 mV.
- 5a) What is the carrier concentration of the sample?
- 5b) What is the mobility?
- 5d) If the scattering time is 1ps, find the magnetic field for which this classical analysis of Hall effect is no longer valid?
- 6) Contact resistances are important. They can complicate measurements of semiconductor transport parameters, and they can degrade device performance. The constant resistance is specified by the interfacial contact resistivity, ρ_c in $\Omega\text{-cm}^2$. A good value is $\rho_c \approx 10^{-8} \Omega\text{-cm}^2$. Consider n⁺ Si at room temperature and doped to $N_D = 10^{20} \text{ cm}^{-3}$. What is the lower limit to ρ_c ? (Assume a fully degenerate semiconductor and use appropriate effective masses for the conduction band of Si.)