1) Show that the following relation (eqn. (4.119) in *Fundamentals of Carrier Transport*) is true:
\[ e \frac{\pi}{\rho S_{\text{NR}}} + e \frac{\pi}{\rho S_{\text{SM}}} = 1 \]

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-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 \text{ cm}^2. Make reasonable assumptions, but clearly state them.

3) It is tempting to estimate the momentum relaxation time, \( \langle \tau_m \rangle \), 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 \( \langle \tau_m \rangle \) 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, $\rho_c$, in Ω-cm$^2$. A good value is $\rho_c \approx 10^{-8}$Ω-cm$^2$. Consider n$^+$Si at room temperature and doped to $N_D = 10^{20}$ cm$^{-3}$. What is the lower limit to $\rho_c$? (Assume a fully degenerate semiconductor and use appropriate effective masses for the conduction band of Si.)