ECE 656 Homework (Weeks 15-16)
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1) Monte Carlo simulations of high-field transport in bulk silicon with an electric field of 100,000 V/cm show the following results for the average velocity and kinetic energy:

$$\upsilon_d = \langle \upsilon \rangle = 1.04 \times 10^7 \text{ cm/s}$$
$$u = \langle KE \rangle = 0.364 \text{ eV}$$

Estimate the average momentum relaxation time, $\langle \tau_m \rangle$ and energy relaxation time, $\langle \tau_E \rangle$.

2) The suggested exercise on slide 32 of Lecture 39a (Lecture 29 Fall 2011) asks how the states are occupied in the source of a ballistic nanowire (1D) MOSFET. Answer the following questions.

   2a) Draw a sketch like that in slide 29 of the lecture, but illustrate how the states in the $E(k)$ are occupied from contact 1 (left) or contact 2 (right).
   2b) Sketch the corresponding distribution function, $f(k_x)$, assuming Boltzmann statistics.
   2c) Give analytical expressions for the local density of states in the source. Assume a 2D density of states and express your answer in terms of E_{TOP}, the energy at the top of the barrier.

3) The classic expression for the base transit time of a bipolar transistor is $W_B^2 / 2D_n$. This expression does not comprehend ballistic or quasi-ballistic transport. High frequency transistors have thin base widths for which these effects could become important. Answer the following questions.

   3a) Derive an expression for the base transit time when the base is one mean-free-path thick and compare it to the classic expression, $W_B^2 / 2D_n$.

   3b) Estimate the thickness of a Si base doped at $N_A = 10^{18}$ cm^{-3} if it is one mean-free-path thick.

   HINT: review the discussion in Sec. III and IV of Lecture 12 Fall 2011.