Week 15 Lecture 37 Quiz:
High-Field Transport

ECE 656: Electronic Conduction In Semiconductors
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Student's name: _____

Answer the **multiple choice questions** below by choosing the **one, best answer**. Then **ask a question** about the lecture.

1) For high-field transport in a bulk semiconductor, we write the Einstein relation as $D_n/\mu_n = 2u_{xx}/q$. What is u_{xx} for a non-degenerate semiconductor with parabolic energy bands? (Assume that the drift energy is negligible).
    a) $u_{xx} = nk_B T_e/2$, where T_e is the electron temperature.
    b) $u_{xx} = nk_B T_e$, where T_e is the electron temperature.
    c) $u_{xx} = 3nk_B T_e/2$, where T_e is the electron temperature
    d) $u_{xx} = k_B T_e/2$, where T_e is the electron temperature.
    e) $u_{xx} = 3k_B T_e/2$, where T_e is the electron temperature.

2) In practice, one commonly extends the near-equilibrium drift-diffusion equation to high-fields by replacing the mobility and diffusion coefficients by electric field dependent quantities, as in $J_{nx} = nq\mu_n(\mathcal{E})\mathcal{E}_x + qD_n(\mathcal{E})dn/dx$. What assumption is necessary to write the DD equation in this form?
    a) Parabolic energy bands.
    b) Non-degenerate carrier statistics.
    c) The microscopic relaxation time approximation.
    d) That the energy relaxation time is shorter than the momentum relaxation time.
    e) That the shape of the distribution, whatever it is, does not vary with position.

3) Assume that there is a dominant optical (or intervalley) phonon scattering process that dominates under high electric fields. How does the saturated velocity depend on the optical phonon energy, $\hbar\omega_0$?
    a) $v_{SAT} \propto \hbar\omega_0$.
    b) $v_{SAT} \propto (\hbar\omega_0)^2$.
    c) $v_{SAT} \propto \sqrt{\hbar\omega_0}$.
    d) $v_{SAT} \propto 1/\hbar\omega_0$.
    e) $v_{SAT} \propto 1/\sqrt{\hbar\omega_0}$.

4) Which of the following statements is true when the drift energy is small compared to the thermal energy?

   a) $\langle \tau_m \rangle \approx \langle \tau_E \rangle$.
   b) $\langle \tau_m \rangle \gg \langle \tau_E \rangle$.
   c) $\langle \tau_m \rangle \ll \langle \tau_E \rangle$.
   d) $\langle \tau_m \rangle$ and $\langle \tau_E \rangle$ both increase with increasing energy.
   e) $\langle \tau_m \rangle$ and $\langle \tau_E \rangle$ are independent of energy.

5) In the classic description of the velocity vs. electric field characteristic in bulk Si, $v_d = \mu_{n0} \mathcal{E} / \sqrt{1 + (\mathcal{E}/\mathcal{E}_C)^2}$, approximately what is the magnitude of the critical electric field, $\mathcal{E}_C$?
   a) $\approx 0.1 \, \text{kV/cm}$.
   b) $\approx 1 \, \text{kV/cm}$.
   c) $\approx 10 \, \text{kV/cm}$.
   d) $\approx 100 \, \text{kV/cm}$.
   e) $\approx 1000 \, \text{kV/cm}$.

6) What question do you have about this lecture?

You will NOT need to turn this quiz in