Quiz ANSWERS Week 14
ECE 656: Electronic Conduction in Semiconductors
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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) $\upsilon_{SAT} \propto \hbar\omega_0$.
   b) $\upsilon_{SAT} \propto (\hbar\omega_0)^2$.
   c) $\upsilon_{SAT} \propto \sqrt{\hbar\omega_0}$.
   d) $\upsilon_{SAT} \propto 1/\hbar\omega_0$.
   e) $\upsilon_{SAT} \propto 1/\sqrt{\hbar\omega_0}$.

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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) $\langle \tau_m \rangle >> \langle \tau_E \rangle$.
c) $\langle \tau_m \rangle << \langle \tau_E \rangle$.
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, $\upsilon_d = \mu_{n0}\mathcal{E} \Big/ \sqrt{1+\left(\mathcal{E}/\mathcal{E}_C\right)^2}$, approximately what is the magnitude of the critical electric field, $\mathcal{E}_C$?

a) $\approx 0.1\,\mathrm{kV/cm}$.
b) $\approx 1\,\mathrm{kV/cm}$.
c) $\approx 10\,\mathrm{kV/cm}$.
d) $\approx 100\,\mathrm{kV/cm}$.
e) $\approx 1000\,\mathrm{kV/cm}$.

6) What is meant by the term, "non-local" semiclassical transport.

a) Transport that cannot be described by a DD equation with a field-dependent mobility and diffusion coefficient.
b) Transport in an electric field that varies more rapidly in space than the energy relaxation length, where T_e is the electron temperature.
c) Transport in an electric field that varies more rapidly in time than the energy relaxation time.
d) All of the above.
e) None of the above.

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7) Under what conditions does velocity overshoot occur for a rapidly varying electric field?

   a) When transport is ballistic .
   b) When transport is quasi-ballistic.
   c) When the momentum relaxation time is much shorter than the energy relaxation time.
   d) When the momentum relaxation time is much longer than the energy relaxation time.
   e) When the momentum relaxation time is nearly equal to the energy relaxation time.

8) Assume that a strong electric field is switched on at $t = 0$. Which of the following statements is true about the velocity vs. time transient?

   a) The drift velocity overshoots its steady-state value.
   b) The carrier energy overshoots its steady-state value.
   c) The drift velocity and carrier energy overshoot their steady-state values.
   d) The drift velocity overshoots its steady-state value and the carrier energy undershoots its steady-state value.
   e) The drift velocity undershoots its steady-state value and the carrier energy overshoots its steady-state value.

9) Which of the following statements is true about the drift and thermal energies during a velocity vs. time transient like that in questions 3)?

   a) The drift energy overshoots its steady-state value.
   b) The thermal energy overshoots its steady-state value.
   c) The drift energy and thermal energy overshoot their steady-state values.
   d) The drift energy overshoots its steady-state value and the thermal energy undershoots its steady-state value.
   e) The drift energy undershoots its steady-state value and the thermal energy overshoots its steady-state value.

10) When comparing velocity vs. time transient to a steady-state velocity vs. position transient, which of the following is true?

   a) Temporal velocity overshoot is stronger than s.s. spatial velocity overshoot.
   b) Diffusion effects are much stronger in steady-state than in transient situations.
   c) Ensemble effects are much stronger in steady-state than in transient situations.
   d) All of the above.
   e) None of the above.