

Quiz 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) $v_{SAT} \propto \hbar\omega_0$.
 - 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) $v_{SAT} \propto 1/\sqrt{\hbar\omega_0}$.

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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) $\langle \tau_m \rangle \gg \langle \tau_E \rangle$.
- 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) ≈ 0.1 kV/cm .
- b) ≈ 1 kV/cm .
- c) ≈ 10 kV/cm .
- d) ≈ 100 kV/cm .
- e) ≈ 1000 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?
- When transport is ballistic .
 - When transport is quasi-ballistic.
 - When the momentum relaxation time is much shorter than the energy relaxation time.
 - When the momentum relaxation time is much longer than the energy relaxation time.
 - 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?
- The drift velocity overshoots its steady-state value.
 - The carrier energy overshoots its steady-state value.
 - The drift velocity and carrier energy overshoot their steady-state values.
 - The drift velocity overshoots its steady-state value and the carrier energy undershoots its steady-state value.
 - 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)?
- The drift energy overshoots its steady-state value.
 - The thermal energy overshoots its steady-state value.
 - The drift energy and thermal energy overshoot their steady-state values.
 - The drift energy overshoots its steady-state value and the thermal energy undershoots its steady-state value.
 - 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?
- Temporal velocity overshoot is stronger than s.s. spatial velocity overshoot.
 - Diffusion effects are much stronger in steady-state than in transient situations.
 - Ensemble effects are much stronger in steady-state than in transient situations.
 - All of the above.
 - None of the above.