Week 7 Quiz Answers
ECE 606: Solid State Devices
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Quiz 1:

1) The “Drude” expression for mobility is one you want to remember. What is it?
   a) $\mu = qm^*\tau$
   b) $\mu = q\tau/m^*$
   c) $\mu = qm^*/\tau$
   d) $\mu = m^*/q\tau$
   e) $\mu = 1/q\tau m^*$

2) What is the temperature dependence of the mobility due to ionized impurity scattering?

   a) $\mu \propto T^{-3/2}$
   b) $\mu \propto T^{-1/2}$
   c) $\mu \propto T^{0}$
   d) $\mu \propto T^{+1/2}$
   e) $\mu \propto T^{+3/2}$

3) What is the temperature dependence of the mobility due to phonon (lattice) scattering?

   a) $\mu \propto T^{-3/2}$
   b) $\mu \propto T^{-1/2}$
   c) $\mu \propto T^{0}$
   d) $\mu \propto T^{+1/2}$
   e) $\mu \propto T^{+3/2}$

4) If we have scattering times due to 3 different processes, then what is the total scattering time when all three mechanisms operate at the same time?
   a) $\tau_{tot} = \tau_1 + \tau_2 + \tau_3$
   b) $\tau_{tot} = \tau_1 \times \tau_2 \times \tau_3$
   c) $1/\tau_{tot} = 1/\tau_1 + 1/\tau_2 + 1/\tau_3$
   d) $1/\tau_{tot} = 1/\tau_1 \times 1/\tau_2 \times 1/\tau_3$
   e) $\tau_{tot} = \max(\tau_1, \tau_2, \tau_3)$

Continued

Quiz 2:

4) Why are "4-probe" resistivity measurements used?

   a) To measure the longitudinal and transverse mobility.
   b) To simultaneously deduce the resistivity and carrier density.
   [✓ c) To eliminate the effect of the contacts.]
   d) To provide two measurements that can be averaged.
   e) To provide redundancy, in case some of the contacts are poor.

5) What does a Hall effect measurement measure?

   a) The mobility
   b) The Hall mobility
   c) The carrier density and carrier type
   [✓ d) The Hall carrier density and the carrier type]
   e) The effective mass

3) Diffusion involves random thermal motion and scattering. If the thermal velocity is υ_T and the average distance between electron (or hole) scattering events is λ, what is the diffusion coefficient in cm^2/s? (It's useful to remember this as well as the mobility expression.)

   [✓ a) $D = \upsilon_T \lambda / 2$]
   b) $D = \upsilon_T / (2\lambda)$
   c) $D = \lambda / 2\upsilon_T$
   d) $D = \upsilon_T^2 \lambda / 2$
   e) $D = \upsilon_T \lambda^2 / 2$

4) The Einstein Relation, $D/\mu = k_B T/q$, relates the mobility to the diffusion coefficient. Under what conditions is it valid?

   a) always
   [✓ b) only at equilibrium or very near equilibrium]
   c) only for parabolic band semiconductors
   d) only for direct gap semiconductors
   e) only for indirect gap semiconductors

Quiz 3:

1) What is the continuity equation in words?

   a) Rate of increase = (inflow – outflow) + drift - diffusion
   b) Rate of increase = (inflow – outflow) + generation - recombination
   c) Rate of increase = (inflow - outflow)
   d) Rate of increase = (inflow + outflow)
   e) Rate of increase = (outflow + inflow) + generation - recombination

2) What approximations / assumptions are made in deriving the minority carrier diffusion equation.

   a) Steady-state conditions
   b) No recombination
   c) No generation
   d) Low level injection
   e) Validity of Einstein Relation

3) If minority carrier electrons are injected at the left face of a p-type semiconductor, and there is **no recombination-generation** in the semiconductor, and the right contact enforces equilibrium conditions (i.e. $\Delta n = 0$), how does the steady-state minority electron profile, $\Delta n(x)$, vary with position?

   a) $\Delta n(x)$ decreases linearly with position from left to right.
   b) $\Delta n(x)$ increases linearly with position from left to right.
   c) $\Delta n(x)$ decreases as the square of distance from left to right.
   d) $\Delta n(x)$ increases as the square of distance from left to right.
   e) $\Delta n(x)$ decreases exponentially with position from left to right.

4) If minority carrier electrons are injected at the left face of a p-type semiconductor, and there is **significant recombination** in the semiconductor, and the right contact enforces equilibrium conditions (i.e. $\Delta n = 0$), how does the steady-state minority electron profile, $\Delta n(x)$, vary with position?

   a) $\Delta n(x)$ decreases linearly with position from left to right.
   b) $\Delta n(x)$ increases linearly with position from left to right.
   c) $\Delta n(x)$ decreases as the square of distance from left to right.

d) $\Delta n(x)$ increases as the square of distance from left to right.

e) $\Delta n(x)$ decreases exponentially with position from left to right

Quiz 4:

1) What are the three "semiconductor equations"?

   a) Electron current, hole current, Poisson equation.
   b) Electron continuity equation, hole continuity equation, Poisson equation.
   c) Electron continuity equation, hole continuity eqn., SRH recombination formula.
   d) Electron minority carrier diffusion equation, hole minority carrier diffusion equation, Poisson equation.
   e) Electron current, electron continuity equation, Poisson equation.

2) What are the three unknowns in the semiconductor equations?

   a) Electron current, hole current, electric field.
   b) Electron current, hole current, electrostatic potential.
   c) Electron current, hole current, recombination rate.
   d) Electron current, hole current, generation rate.
   e) Electron density, hole density, electrostatic potential.

3) What is meant by the term "control volume"?

   a) It is the part of the device that controls the performance of the device.
   b) It refers to a region about a specific grid point for which the discretized equations are formulated.
   c) It is another term for "finite difference approximation".
   d) It refers to "finite element" rather than "finite difference" discretization.
   e) It refers to the need to control the size of volume being simulated so that the computational burden is manageable.

4) To numerically solve the semiconductor equations, we must iterate. Why?

   a) Because it is more efficient computationally.
   b) Because the three equations are coupled.
   c) Because the three equations are nonlinear.
   d) Because the three equations are coupled and nonlinear.
   e) Because the computer operates with finite precision arithmetic.