## Midterm Exam

1. A semiconductor sample with a volume of $10^{-3}$ mm$^3$ uniformly absorbs all light of a light source emitting an optical power of 250 mW at the wavelength 450 nm. The sample emits photons with energy 1 eV at a rate of $10^{17}$ s$^{-1}$.
   (a) What is the electron-hole (e-h) pair generation rate (in units of cm$^{-3}$ s$^{-1}$) in this sample?
   (b) What is the optical power emitted by the sample?
   (c) What is the sample's quantum efficiency (QE)?
   (d) What is the sample's power efficiency (i.e. output-power divided by input-power)?
   (e) Name a physical mechanism that reduces the quantum efficiency.

2. Circle the correct answer:
   (a) For a semiconductor sample with quantum efficiency of 1, the wavelength of the absorbed light cannot be longer than the wavelength of the emitted light. T F I
   (b) The Einstein relation suggests that particles that have a high mobility diffuse very little (and vice versa). T F I
   (c) In a constant electric field electrons propagate with a drift velocity that is constant over time. T F I
   (d) Generally, charge carriers diffuse more rapidly at $T$ = 300 K than they do at 200 K. T F I
   (e) A silicon (Si) pn junction can be intentionally doped with phosphorus (P) donors, and carbon (C) acceptors. T F I
   (f) The continuity equation expresses the fact that all carriers must be accounted for. T F I

   *T = True; F = False; I = Impossible to answer with information provided*

3. A Si sample with an equilibrium electron concentration of $10^{10}$ cm$^{-3}$ is subjected to an electric field of 100 V/cm.
   (a) What is the equilibrium hole concentration?
   (b) What is the drift velocity of electrons?
   (c) What is the drift velocity of holes?
   (d) What is the electron drift current density?
   (e) What is the hole drift current density?
   (f) Assume that the electron drift current is compensated by an equally large electron diffusion current. Give the gradient in electron concentration that accomplishes the compensation.

4. A Si pn junction has a donor concentration of $10^{18}$ cm$^{-3}$ and an acceptor concentration of $10^{16}$ cm$^{-3}$.
   (a) What is the depletion width $W_D$?
   (b) For a pn junction, list the types of currents that should be considered.
   (c) For the pn junction considered here, under forward-bias conditions, is there any specific current that dominates? If yes, give the name of this current.
   (d) For the pn junction considered here, under zero-bias conditions, is there any specific current that dominates? If yes, give the name of this current.
   (e) A design engineer considers the reverse saturation current to be too large. Which parameters of the pn junction can be changed to reduce the reverse saturation current?