Department of Electrical and Computer Engineering
UNIVERSITY OF BRITISH COLUMBIA

EECE 480—SEMICONDUCTOR DEVICES

MIDTERM EXAM (October 19, 2004)

Time: 75 minutes
ANSWER PARTS 1 AND 2, AND ONLY ONE OF 3 OR 4.
This exam has 2 pages.
All parts have equal weight.
No notes, calculators, or books allowed.

1. **Short answer questions:**

   (a) Specify the units for:
      i. the permittivity of free space, ϵ_0;
      ii. the mobility, μ;
      iii. the diffusivity, D;
      iv. Planck's constant, h;
      v. potential energy;
      vi. potential.

   (b) Provide a description of what each of the following represents:
      i. f_T;
      ii. $f_{\max}$;
      iii. $\psi^*\psi$, where ψ is the wavefunction;
      iv. m^*.

   (c) Sketch the one-dimensional dispersion relation for a particle under the effective-mass approximation.

   (d) The drift-diffusion and continuity equations in a bulk semiconductor are:

$$\begin{aligned}
\mathbf{J}_h &= \alpha_1 q p \mu_h \mathcal{E} + \alpha_2 q D_h \nabla p \\
\mathbf{J}_e &= \alpha_3 q n \mu_e \mathcal{E} + \alpha_4 q D_e \nabla n \\
\frac{\partial p}{\partial t} &= \alpha_5 \frac{1}{q} \nabla \cdot \mathbf{J}_h + \alpha_6 U \\
\frac{\partial n}{\partial t} &= \alpha_7 \frac{1}{q} \nabla \cdot \mathbf{J}_e + \alpha_8 U \,,
\end{aligned}$$

   where each α has unity magnitude. What are the signs of each α?

2. **Diodes:**

   Consider three p-n diodes with "long" p and n regions. The doping on the n-side is $10^{16}\,\mathrm{cm}^{-3}$ for each diode, and their physical dimensions are identical. The doping on the p-side is:

   - $10^{18}\,\mathrm{cm}^{-3}$ for Diode A;
   - $10^{17}\,\mathrm{cm}^{-3}$ for Diode B;
   - $10^{16}\,\mathrm{cm}^{-3}$ for Diode C.

Without resorting to detailed calculations:

(a) which diode has the highest breakdown voltage, and why?

(b) for a particular on-current, which diode requires the highest applied voltage, and why?

(c) which diode has the shortest time for switching off, and why?

(d) which diode has the largest parasitic series resistance, and why?

(e) sketch the equilibrium energy band diagrams for each diode. Be sure to clearly show any differences between your diagrams.

3. **Option #1—BJTs:**

(a) Discuss the effect of vertical and lateral shrinking on f_T and $f_{\max}$ in a real BJT.

(b) Discuss basewidth modulation, and whether you would either suppress or enhance this effect in order to obtain better device performance in a single-stage, linear amplifier. What design choices could you make in order to achieve this goal? Be sure to indicate any negative side-effects of your design choices, if any.

4. **Option #2—Deep, deep submicron BJTs:**

(a) For extremely short basewidth BJTs in the active mode:

i. specify, in words, equations, and/or pictures, appropriate conditions on the electron concentrations, velocities, and currents;

ii. under what specific conditions does the final result for the current density reduce to the familiar Shockley expression?

(b) Sketch the current density as a function of basewidth, and compare it to the predictions of the Shockley theory.