Exam 1 ECE-656 Fall 2009
(Revised: October 3, 2009)

NAME_________________________________

ID_____________________________________

This is a take home exam due at 10:30AM, Wednesday, October 7, 2009

The exam consists of 10 questions on the attached pages.

1) Show your work for each problem CLEARLY.

2) Mark your answers CLEARLY.

3) Make reasonable assumptions when necessary, but be sure to state them.

DO NOT DISCUSS THIS EXAM WITH ANYONE. IT SHOULD BE YOUR WORK AND YOUR WORK ALONE.

When you hand in your exam, attach this sheet as a cover sheet stapled to your work.

You must also sign the following statement.

I attest that the attached work for Exam 1, ECE-656, Fall 2009 is my work and my work alone. I have not discussed this exam with anyone and received no help with the exam.

SIGNED:_____________________________________

DATE:____

ECE-656 Take Home Exam 1: Fall 2009

1) For a 3D semiconductor with parabolic energy bands, the electron density is

$$n = N_C \mathcal{F}_{1/2}(\eta_F) \quad N_C = \frac{1}{4}\left(\frac{2m^* k_B T}{\pi\hbar^2}\right)^{3/2} .$$

Work out the corresponding result for 2D electrons.

2) For a nondegenerate, 3D semiconductor with parabolic energy bands, the average kinetic energy per electron is

$$\langle E - E_C \rangle = \frac{3}{2} k_B T .$$

Work out the corresponding result for 2D and $T = 0\text{K}$.

3) The average x-directed thermal velocity for 3D, non-degenerate electrons is

$$\langle \upsilon_x^+ \rangle = \sqrt{\frac{2k_B T}{\pi m^*}}$$

Work out the corresponding result for 2D electrons.

4) For a non-degenerate, 3D semiconductor with a constant mean-free-path, the diffusion coefficient is

$$D_n = \frac{\upsilon_T \lambda_0}{2}$$

Work out an expression for the 2D diffusion coefficient assuming a non-degenerate, parabolic band semiconductor with power law scattering.

5) Derive a drift-diffusion equation for a 2D semiconductor with parabolic energy bands assuming $T = 0\text{K}$.

6) Repeat problem 5) for electrons in the conduction band of graphene.

7) For a 3D, non-degenerate semiconductor, we found the mobility to be

$$\mu_n = \frac{q\left\langle\left\langle \tau_f \right\rangle\right\rangle}{m^*} \qquad \left\langle\left\langle \tau_f \right\rangle\right\rangle = \frac{\left\langle E\tau_f \right\rangle}{\left\langle E \right\rangle} \qquad \left\langle\left\langle \tau_f \right\rangle\right\rangle = \tau_0 \frac{\Gamma\left(s+5/2\right)}{\Gamma\left(5/2\right)}$$

Work out the corresponding results for a 2D, non-degenerate semiconductor.

8) The so-called transport distribution is

$$\Sigma(E) = \frac{h}{L^2}\sum_{\vec{k}} \upsilon_x^2 \tau_f \delta\left(E - E_k\right)$$

Work out this expression for a 2D semiconductor with parabolic energy bands.

9) The Seebeck coefficient is given by

$$S = \left(\frac{k_B}{-q}\right)\frac{I_1}{I_0}$$

where

$$I_j = \int \left(\frac{E - E_F}{k_B T}\right)^j M\left(E\right) T\left(E\right)\left(-\frac{\partial f_0}{\partial E}\right) dE$$

Work out S for a 2D semiconductor with parabolic energy bands and a constant mean-free-path.

10) Assume that the channel resistance and inversion layer density of a MOSFET are known. Assume that one subband is occupied. Develop a procedure to estimate the "average" or "effective" number of modes and mean-free-path from the measured data. Your procedure should be valid whether the semiconductor is non-degenerate, degenerate, or anywhere in between. Your procedure should be CLEARLY described.