ECE 656 Homework (Week 2)

Mark Lundstrom
Purdue University

1) Assume T = 0K and work out the electron density per unit area for two cases:

   i) A 2D semiconductor with parabolic energy bands and an effective mass of m^*. (Assume a valley degeneracy of 2.)

   ii) Graphene, where we consider $E > 0$ to be the conduction band. ($E = 0$ is where the bands cross, the so-called Dirac point.) (Assume a valley degeneracy of 2.)

   1a) Express your two answers in terms of the Fermi energy, and show that they are **different.**

   1b) Express your two answers in terms of the Fermi wavevector and show that they are **the same**.

2) Assume a finite temperature and work out the sheet carrier densities, n_S, for:

   2a) Electrons in the conduction band of a 2D parabolic band semiconductor
   2b) Electrons in the conduction band ($E > 0$) of graphene.

   Your answers to these questions should be in terms of material parameters and the Fermi level.

3) Assume T = 0K and work out the average +x-directed velocity for electrons in:

   3a) A 2D semiconductor with a parabolic conduction band and
   3b) The conduction band ($E > 0$) of graphene.

   Your answer should be in terms of the Fermi energy, E_F.

4) Assume a nonparabolic, 1D energy bandstructure described by:

$$E(k_x)\left[1+\alpha E(k_x)\right] = \frac{\hbar^2 k_x^2}{2m^*(0)}.$$

where

$$\frac{1}{m^*(0)} = \frac{1}{\hbar^2}\frac{d^2E(k_x)}{dk_x^2}\bigg|_{k_x=0}.$$

ECE 656 Homework (Week 2) (continued)

4a) Sketch (or produce a Matlab plot) of $E(k)$ vs. k for two cases: i) $\alpha = 0$ and ii) $\alpha > 0$. If you are producing a Matlab plot, the energy range should be from 0 to 1 eV, and you can assume $\alpha = 0.5$ eV.

4b) For this bandstructure, derive an expression for the velocity, $\upsilon_x(k_x)$ as a function of k_x.

5) For parabolic energy bands, the 2D density of states is

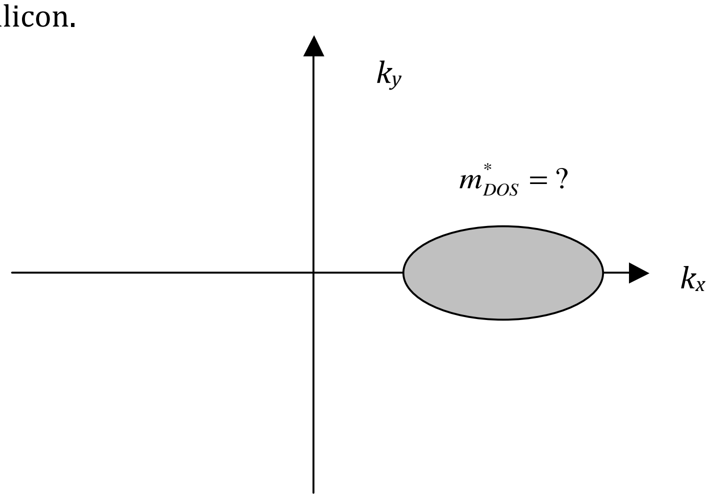
$$D_{2D}(E) = \frac{m^*}{\pi\hbar^2}\Theta(E - \varepsilon_1)$$
.

Assume a non-parabolic band described by the so-called Kane dispersion,

$$E(k)\left[1 + \alpha E(k)\right] = \frac{\hbar^2 k^2}{2m^*(0)}$$
,

and derive the 2D density of states.

6) Derive an expression for the 2D density of states for one of the conduction band ellipsoids in silicon.



HINT: You may find the discussion in Pierret (*Advanced Semiconductor Fundamentals*) on pp. 94-95 helpful.

ECE 656 Homework (Week 2) (continued)

7) Assume an ultra thin body (100) silicon structure with a thickness of 3 nm. Assume no bandbending within the structure and infinitely high energy barriers at the oxide-silicon interfaces. Compute and plot the 2D density of states vs. energy.