ECE 656 Homework 2 (Week 2)
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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.)

   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.

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

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

ECE 656 Homework 2 (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.

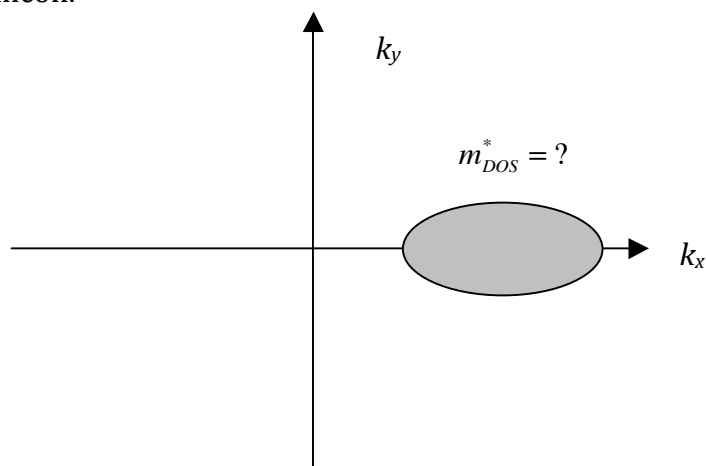5)   For parabolic energy bands, the 2D density of states is

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

.

    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 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 he discussion in Pierret (Advanced Semiconductor Fundamentals) on pp. 94-95 helpful.

ECE 656 Homework 2 (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.