

# Homework #3 - EE 531

due 4/28/09

- Use the effective mass tensor to show that the overall average acceleration of electrons in the conduction band of silicon is in the direction of the electric field as long as the carrier concentrations in the respective  $k$ -space minima are all equal.
  - If due to lattice strain the minima in the  $\pm z$  directions ( $(001)$  and  $(00\bar{1})$ ) are reduced in energy by 0.06 eV below the minima in the  $\pm x$  and  $\pm y$  directions:
    - What would be the effective mass for electric fields in the  $x$  direction? The  $z$  direction? How do these compare to the effective mass in unstrained silicon?
    - What would be the direction of average electron acceleration for a field in the  $(011)$  direction?
    - For what field directions (if any) would the acceleration be parallel to the field?
- Derive the density of states per volume per energy as a function of energy for a 1D system ( $g_{1D}(E)$ ) with scalar effective mass  $m^*$  and compare on a plot to the 2D and 3D density of states. Assume that dimensions in the confinement direction(s) are 5nm.
- Calculate the transmission (tunnelling) probability for a free electron ( $V = 0$ ) with energy  $E$  incident upon a rectangular potential with height  $V_b > E$  and width  $x_b$ . To solve, consider incident and reflected plane waves on one side and just transmitted wave on the other. You will have to match boundary conditions at two interfaces (4 constraints, magnitude and 1st derivative at each interface) to calculate 4 unknowns, coefficients of reflected and transmitted waves plus those of decaying and increasing exponentials inside of barrier. You can assume fixed value (e.g., 1) for coefficient of incident wave since you are just looking for ratio (actually magnitude squared) of transmitted versus incident wave.
- A reasonable approximate solution for the ground-state wavefunction of an electron in a triangular potential well with  $V(x) = q\mathcal{E}x$  for  $x > 0$  (infinite for  $x < 0$ ) is  $Cx \exp(-\gamma x/2)$ . The variational principle says that optimum choice for  $\gamma$  is the value that minimizes expected value of energy ( $E$ ).
  - As function of electric field  $\mathcal{E}$ , what is the ground state energy and associated value of  $\gamma$ .
  - For Si, what is the expected value of the distance of electrons from the surface? Consider lowest sub-band for all six minima. Compare this to the classical solution (assume constant electric field). What is the equivalent effective oxide thickness?