ELEG 340 - Fall 08
Solid-State Electronics
Quiz 1

25 September 2008 NAME Solution

Time Limit: 30 minutes

Closed Books and Notes. You may use your own calculator, but you may not loan or borrow calculators (ask proctor if you have questions). Put expression in a final form as best you can, and indicate final units (dimensions).

Guidelines:

I. Full credit requires giving the final dimensions/ units for all numerical quantities that you calculate.

II. Show all work and calculations for full credit.

III. Accuracy to 2 significant figures is sufficient.

IV. Assume that the material is silicon at room temperature (300 K or 296 K), unless otherwise stated.

V. At room temperature (300K), assume that the thermal energy $k_BT = 0.0258$ eV (or 0.026 eV), and that silicon has intrinsic concentration $n_i = 1$ (or 1.5) x 10^{10} cm^{-3}.

Note permittivity of free space $\varepsilon_o = 8.85\times10^{-14}$ F/cm; magnitude of electron charge $q = 1.6\times10^{-19}$ Coul

VI. Equations:

$p_{op} = i\hbar d/dx$ $f_{FD}(E) = 1/[1 + \exp(E-E_F)/k_BT]$

$n = n_i\exp[(E_F-E_i)/k_BT]$. $p = n_i\exp[(E_i-E_F)/k_BT]$

$J_n = q\mu_n n\mathcal{E} + qD_n dn/dx$ $J_p = q\mu_p p\mathcal{E} - qD_p dp/dx$

$U_n = (n_p-n_{po})/\tau_n$ $U_p = (p_n-p_{no})/\tau_p$

$C = \varepsilon_s / W$ $E = Q V$

24 total

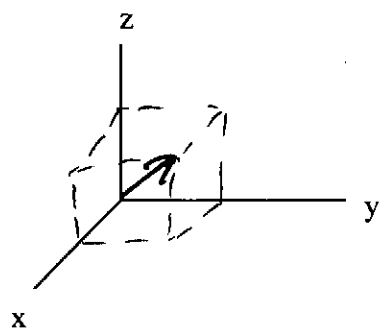
One-sided step junction:

$W = [2\kappa_s\varepsilon_o (\phi_{bi} - V_f)/qN_A]^{1/2}$ or; $W = [2\kappa_s\varepsilon_o (\phi_{bi} - V_f)/qN_D]^{1/2}$

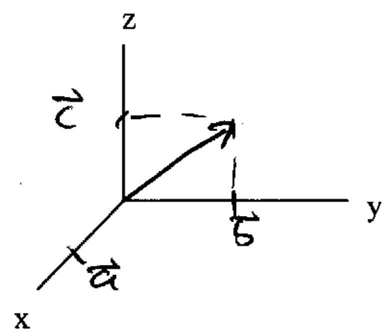
pnp transistors: $I_E = I_C + I_B$

$I_{pE} = A_E q^2 n_i^2 D_p/Q_{B0} \exp[(qV_{BE})/k_BT]$ $Q_{B0} = q \int_0^{W_B} N_D(x)dx$

1. . On the x-y-z axes below, draw and indicate the following crystal directions for a cubic crystal with unit vectors **a**, **b**, **c** that are equal in length:



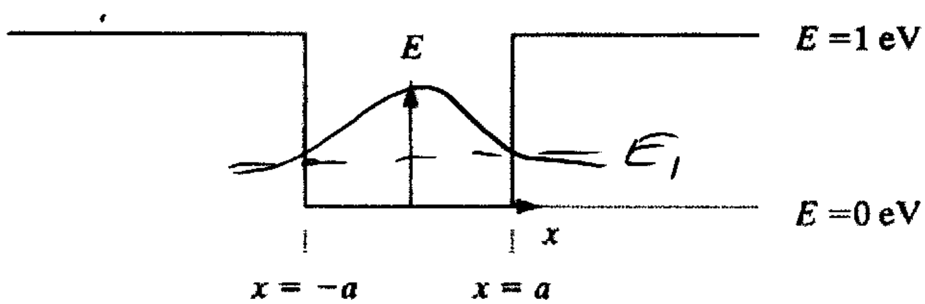
(a) [111]



(b) [011]

2. Multiple choice (circle your answers): Silicon has the following crystal properties: (a) hexagonal structure; (b) face-centered cubic structure with a 2 atom basis; (c) amorphous, non-crystalline structure.

3. . Consider the following drawing of a 1-dimensional quantum well, of width, $2a$, on the order of n electron wavelength. (a) indicate qualitatively the energy of the ground state for an electron that is confined to the well; (b) sketch the magnitude and shape of the electron wave function in the ground state.



4.

2 An electron plane wave has functional dependence: exp(*ikx*) in 1-dimension. What is the momentum of this wave in the x direction?

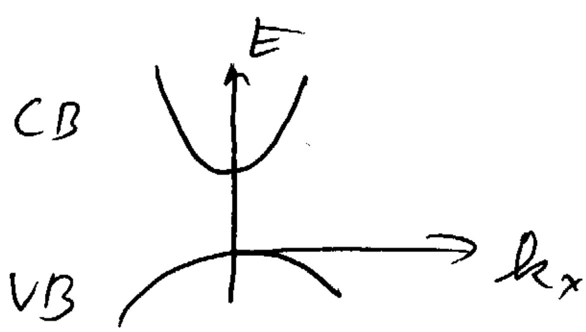
$p = \hbar k$

2 5. An electron has a kinetic energy of 1 eV (electron volt). What is its energy in Joules?

$W = qV$

$= 1.6 \times 10^{-19}$ Joules

2 6. Energy bands can be either direct or indirect in *k*-space. On a graph of energy versus k, draw a direct band configuration, and label both the valence and conduction bands.



7. A piece of silicon at room temperature (300K) is doped with a concentration of 10^{17} cm^{-3} of donor impurities. Assume that all of the donors are ionized at this temperature. (a) what is the concentration of electrons in the conduction band?

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$$n = N_D = 10^{17}\ cm^{-3}$$

8. Using the Fermi-Dirac distribution function, calculate the probability that a state at the conduction band edge E_C is occupied by an electron if the energy separation is given by: $E_C - E_F = 10\ k_BT$. Hint: you may use the approximations: $e^z = 10^{z/2.3}$; and $10^{0.3} = 2$. Assume that T = 300 K if you think that you need the temperature.

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$$f(E_c) = \frac{1}{1 + e^{(E_c - E_F)/kT}}$$

$$= \frac{1}{1 + e^{10 k_BT/k_BT}} = \frac{1}{1 + e^{10}}$$

$$= \frac{1}{1 + 10^{10/2.3}} = 10^{-10/2.3}$$

$$= 10^{-4.3} = 10^{0.7 - 5} = 5 \times 10^{-5}$$

$$2.3 \overline{)10.00} = 4.3 \qquad 92 \qquad 80$$

9. Consider the following energy band diagram. Based on where the Fermi level E_F is located with respect to the band edges and the intrinsic level E_i, which charge carrier has a greater concentration; electrons in the conduction band, or holes in the valence band?

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