NAME:_____ **PUID:** _____

Week 3 Quiz ANSWERS Equilibrium Carrier Concentrations
ECE 305: Semiconductor Devices
Mark Lundstrom
Purdue University, Spring 2015

Answer the **multiple choice questions** below by choosing the **one, best answer**.

1) Consider Si doped with Phosphorous ($N_D \approx 10^{15}$ cm^{-3}, $E_C - E_D = 0.045$ eV). Where is the Fermi level located at T = 0 K?
   a) Near the middle of the bandgap.
   b) In the upper half of the bandgap.
   c) In the lower half of the bandgap.
   d) Below E_C and above E_D.
   e) Above E_C.

2) Consider Si doped with Phosphorous ($N_D \approx 10^{15}$ cm^{-3}, $E_C - E_D = 0.045$ eV). Where is the Fermi level located at T = 300 K?
   a) Near the middle of the bandgap.
   b) In the upper half of the bandgap.
   c) In the lower half of the bandgap.
   d) Below E_C and above E_D.
   e) Above E_C.

3) Consider Si doped with Phosphorous ($N_D \approx 10^{15}$ cm^{-3}, $E_C - E_D = 0.045$ eV). Where is the Fermi level located at T = 600 K? (HINT: $n_i(600\text{ K}) = 4\times10^{15}$ cm^{-3}.)
   a) Near the middle of the bandgap.
   b) In the upper half of the bandgap.
   c) In the lower half of the bandgap.
   d) Below E_C and above E_D.
   e) Above E_C.

4) Which of the following is true in equilibrium?
   a) $n = n_i = 1/p$
   b) $n = N_C$
   c) $np = N_C N_V$
   d) $np = n_i^2$
   e) $np = 1/n_i^2$

5) Which of the following is true for a non-degenerate semiconductor in equilibrium?

a) $p = n_i e^{(E_F - E_V)/k_B T}$.

b) $p = n_i e^{(E_V - E_F)/k_B T}$

c) $p = n_i e^{(E_F - E_i)/k_B T}$

d) $p = n_i e^{(E_i - E_F)/k_B T}$

e) $p = n_i e^{(E_F + E_i)/k_B T}$

6) Which of the following is true for a non-degenerate semiconductor in equilibrium?

a) $p = N_V e^{(E_F - E_V)/k_B T}$.

b) $p = N_V e^{(E_V - E_F)/k_B T}$

c) $p = N_V e^{(E_F - E_i)/k_B T}$

d) $p = N_V e^{(E_i - E_F)/k_B T}$

e) $p = N_V e^{(E_F + E_i)/k_B T}$

7) What is the **electron concentration** in Si at 300 K with a boron doping of $N_A = 10^{17}$ cm^{-3}?

a) $n = 10^{10}$ cm^{-3}

b) $n = 10^{17}$ cm^{-3}

c) $n = 10^{3}$ cm^{-3}

d) $n = 10^{6}$ cm^{-3}

e) $n = 10^{9}$ cm^{-3}

8) What is the mathematical statement of space charge neutrality?

a) $n = p$.

b) $n = N_D$.

c) $n = N_D^+ - N_A^-$.

d) $n + N_A^- = p + N_D^+$

e) $n + N_A^- + p + N_D^+ = 0$

9) As temperature increases from 0 K to high temperature, the carrier concentration goes through three regions. In what order does the transition occur?

a) intrinsic, extrinsic, freezeout

b) extrinsic, intrinsic, freezeout

c) freezeout, intrinsic, extrinsic

d) freezeout, extrinsic, intrinsic

e) intrinsic, freezeout, extrinsic