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 ( \( N_D \approx 10^{15} \text{ cm}^{-3} \), \( E_C - E_D = 0.045 \text{ eV} \)). Where is the Fermi level located at \( T = 0 \text{ K} \)?
   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 ( \( N_D \approx 10^{15} \text{ cm}^{-3} \), \( E_C - E_D = 0.045 \text{ eV} \)). Where is the Fermi level located at \( T = 300 \text{ K} \)?
   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 ( \( N_D \approx 10^{15} \text{ cm}^{-3} \), \( E_C - E_D = 0.045 \text{ eV} \)). Where is the Fermi level located at \( T = 600 \text{ K} \)? (HINT: \( n_i(600 \text{ K}) = 4 \times 10^{15} \text{ cm}^{-3} \).)
   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) \( p = n_i e^{(E_f - E_i) / k_B T} \).

b) \( p = n_i e^{(E_f - E_i) / k_B T} \).

c) \( p = n_i e^{E_f / k_B T} \).

d) highlighted, \( p = n_i e^{E_f / k_B T} \).

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) \( p = N_V e^{(E_f - E_i) / k_B T} \).

b) \( p = N_V e^{(E_f - E_i) / k_B T} \).

c) \( p = N_V e^{E_f / k_B T} \).

d) \( p = N_V e^{E_f / k_B T} \).

e) \( p = N_V e^{(E_f + E_i) / k_B T} \).

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

a) \( n = 10^{10} \text{ cm}^{-3} \).

b) \( n = 10^{17} \text{ cm}^{-3} \).

c) \( n = 10^3 \text{ cm}^{-3} \).

d) \( n = 10^6 \text{ cm}^{-3} \).

e) \( n = 10^9 \text{ cm}^{-3} \).

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

a) \( n = p \).

b) \( n = N_D \).

c) \( n = N_D^+ - N_A^- \).

d) highlighted, \( n + N_A^- = p + N_D^+ \).

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) \textbf{freezeout, extrinsic, intrinsic}

e) intrinsic, freezeout, extrinsic