Quiz 1:

1) Given an energy band diagram, how do we find the electric field?
   a) It is proportional to $E_c$.
   b) It is proportional to minus $E_c$.
   c) It is proportional to the slope of $E_c$.
   d) It is proportional to minus the slope of $E_c$.
   e) It is proportional to the second derivative of $E_c$.

2) Given an energy band diagram, how do we find the electrostatic potential?
   a) It is proportional to $E_c$.
   b) It is proportional to minus $E_c$.
   c) It is proportional to the slope of $E_c$.
   d) It is proportional to minus the slope of $E_c$.
   e) It is proportional to the second derivative of $E_c$.

3) A donor atom used to dope silicon n-type comes from which column of the periodic table?
   a) II
   b) III
   c) IV
   d) V
   e) VI

4) What is an amphoteric dopant?
   a) A dopant that contributes two electrons to the conduction band
   b) A dopant that contributes two holes to the valence band
   c) A dopant that contributes an electron to the conduction band and a hole to the valence band
   d) A dopant with an energy level near the middle of the bandgap
   e) A dopant that can act as either a donor or acceptor depending on which lattice site it occupies.

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Quiz 2:

1) What is the Law of Mass Action?
   a) \( n = p = n_i \)
   b) \( n = N_C \)
   c) \( np = N_C N_V \)
   d) \( np = n_i^2 \)
   e) \( np = \frac{1}{n_i^2} \)

2) 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) \( n + N_A^- + p + N_D^+ = 0 \)

3) What is the probability that a donor atom at energy \( E_D \) is ionized (i.e. empty)? (Note that \( g_D = 2 \) is the standard value.)
   a) \( \frac{N_D^+}{N_D} = \frac{1}{1 + e^{(E_D-E_F)/k_BT}} \)
   b) \( \frac{N_D^+}{N_D} = \frac{1}{1 + g_D e^{(E_D-E_F)/k_BT}} \)
   c) \( \frac{N_D^+}{N_D} = \frac{1}{1 + g_D e^{(E_F-E_D)/k_BT}} \)
   d) \( \frac{N_D^+}{N_D} = \frac{1}{1 + \frac{1}{g_D} e^{(E_D-E_F)/k_BT}} \)
   e) \( \frac{N_D^+}{N_D} = \frac{1}{1 + \frac{1}{g_D} e^{(E_F-E_D)/k_BT}} \)

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4) What is the probability that an acceptor atom at energy $E_A$ is ionized (i.e. full)? (Note that $g_A = 4$ is the standard value.)

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\begin{align*}
\text{a) } N_A^- & = \frac{1}{1 + e^{(E_A - E_F)/k_BT}} \\
\text{b) } N_A^- & = \frac{1}{1 + g_A e^{(E_A - E_F)/k_BT}} \\
\text{c) } N_A^- & = \frac{1}{1 + g_A e^{(E_F - E_A)/k_BT}} \\
\text{d) } N_A^+ & = \frac{1}{1 + e^{(E_A - E_F)/k_BT}} \\
\text{e) } N_A^- & = \frac{1}{1 + e^{(E_F - E_A)/k_BT}}
\end{align*}
\]

**Quiz 3:**

1) As temperature increases from 0K 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

2) Consider a semiconductor doped N-type but at $T = 0$K. Where do you expect the Fermi level to be?
   a) inside the valence band.
   b) near the middle of the bandgap.
   c) inside the conduction band.
   d) at the donor level, $E_D$.
   e) between the donor level and the conduction band.

3) Consider a semiconductor doped N-type but at a very high temperature. Where do you expect the Fermi level to be?
   a) inside the valence band.
   b) near the middle of the bandgap.
   c) inside the conduction band.
   d) at the donor level, $E_D$.
   e) between the donor level and the conduction band.
4) Consider a semiconductor moderately doped N-type but at a moderate temperature so that the dopants are fully ionized. Where do you expect the Fermi level to be?
   a) in the lower half of the bandgap.
   b) near the middle of the bandgap.
   c) **in the upper half of the bandgap**
   e) inside the conduction band.