Week 3 Quiz Answers
ECE 606: Solid State Devices
Mark Lundstrom
Purdue University, Spring 2013

Quiz 1:

1) Bloch's theorem is about the wavefunction of an electron in a periodic potential. In the lecture, this is stated as: $\psi(x+a) = \psi(x)e^{ika}$. (Prof. Alam uses "$p$" for the lattice spacing, which is "a" here and in Pierret, ASF). In ASF, the Bloch theorem is also stated in a different, but mathematically equivalent way as:

a) $\psi(x) = u(x)e^{ikx}$, where $u(x)$ is the periodic, crystal potential: $u(x+a) = u(x)$

b) $\psi(x) = u(x)e^{ik(x+a)}$

c) $\psi(x+a) = u(x)e^{ikx}$

d) $\psi(x+a) = u(x+a)e^{ika}$

e) $\psi(x) = e^{ikx}$

2) We saw earlier that when we impose boundary conditions on an electron confined in a quantum well, only discrete values of k are permitted. When we impose periodic boundary conditions on a string of N atoms, the same thing happens. How many discrete values of k are there and what is their spacing?

a) 2N discrete values spaced $2\pi/Na$

b) 2N discrete values spaced π/Na

c) N discrete values spaced $2\pi/Na$

d) N discrete values spaced π/Na

e) $N/2$ discrete values spaced $\pi/2Na$

3) Solving the wave equation for a given periodic potential, $u(x)$, can be challenging. In the lecture and in ASF, a periodic system of finite, rectangular quantum wells is solved. Even for this simple problem, the math is non-trivial, but the solutions display the general features of all periodic crystal potentials. What is the name of this classic, model problem for bandstructure?

a) The WKB Approximation
b) Fermi's Golden Rule
c) The Debye model
d) The Kronig-Penney Model
e) The Pierret Model

4) What is a Brillouin zone?

   a) A region of energy-space that encompasses all of the unique values of energy
   b) A region of position-space that the electron is allowed to reside within
   c) Another name for the unit cell of the crystal
   d) A region of k-space that contains all of the unique solutions of the wave equation
   e) A region of k-space where the group velocity is positive

Quiz 2:

1) Exactly what is a "hole" in semiconductor terminology?

   a) another name for a positron.
   b) a fictitious particle that is really just an empty state in a nearly filled band
   c) a fictitious particle that is really just an empty state in a nearly empty band
   d) an H^+ ion
   e) an impurity (in small concentration) in the crystal lattice

2) Effective mass is a widely-used concept in semiconductors (even though it is not necessary). Consider a 1D bandstructure given by $E(k_x) = \hbar v_F |k_x|$, where v_F is a velocity. What is the effective mass?

   a) $m^* = \hbar v_F$
   b) $m^* = m_0$
   c) $m^* = 0$
   d) $m^* = \infty$
   e) not really defined

3) The force on a particle with an effective mass of m^* could be written as $\vec{F} = m^* \vec{a}$, but the effective mass depends on the bandstructure, and effective mass may not even be defined. More generally, how is the force defined? (Refer to the assigned reading for this lecture n ASF.)

   a) $\vec{F} = \vec{L} \times \vec{r}$
   b) $F = m^* v^2$
   c) $\vec{F} = \hbar \dfrac{d\vec{k}}{dt}$
   d) $\vec{F} = m_0 \vec{a}$
   e) $\vec{F} = \hbar^2 k\vec{k}$

4) For a bandstructure with $E\left(k_x, k_y\right) = \hbar^2 k_x^2 / 2m^* + \hbar^2 k_y^2 / 2m^*$ what is the shape of the constant energy "surface."
   a) a line
   b) a circle
   c) an ellipse
   d) a sphere
   e) an ellipsoid

Quiz 3:

1) The name of the point at the center of the Brillouin zone for a diamond lattice is called:
   a) X
   b) L
   c) K
   d) Λ
   e) Γ

2) Silicon, Germanium, and Gallium Arsenide have different bandstructures. Which of the following is true?

   a) The conduction bands for them are similar in shape.
   b) The valence bands for them are similar in shape.
   c) The conduction and valence bands are different all three.
   d) Si and GaAs have similar conduction bands but different valence bands.
   e) Ge and GaAs have similar conduction bands but different valence bands

3) The bandgap is an important property of a semiconductor, but the type of bandgap is also important. Which of the three semiconductors, Ge, Si, and GaAs, has a direct bandgap?

   a) Ge
   b) Si
   c) GaAs
   d) Ge and Si
   e) Ge and GaAs

4) Constant energy surfaces consisting of six ellipsoids along {100} directions occur for which of the following?

   a) the Ge valence band
   b) the Ge conduction band
   c) the Si valence band
   d) the Si conduction band
   e) the GaAs valence band