Quiz Answers: Week 4
ECE 656: Electronic Conduction In Semiconductors
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1) Compare the typical acoustic phonon (sound) velocity, v_S, to the average thermal velocity of electrons, v_{th}. Which of the following is true?
   a) $v_S \approx v_{th}$.
   b) $v_S < v_{th}$.
   c) $v_S \ll v_{th}$.
   d) $v_S > v_{th}$.
   e) $v_S \gg v_{th}$.

2) Comparing optical and acoustic phonons near the center of the Brillouin zone, which of the following is true?
   a) Optical phonon velocity **much less** than acoustic phonon velocity and optical phonon energy **much less** than acoustic phonon energy.
   b) Optical phonon velocity <u>much less</u> than acoustic phonon velocity and optical phonon energy <u>much greater</u> than acoustic phonon energy.
   c) Optical phonon velocity **much greater** than acoustic phonon velocity and optical phonon energy **much less** than acoustic phonon energy..
   d) Optical phonon velocity **much greater** than acoustic phonon velocity and optical phonon energy **much greater** than acoustic phonon energy..
   e) Optical phonon velocity **roughly equal** to acoustic phonon velocity and optical phonon energy **roughly equal** to acoustic phonon energy..

3) Which phonons are most responsible for **intravalley** scattering?

   a) Longitudinal modes near the zone center.
   b) Transverse modes near the zone center.
   c) Longitudinal modes near the zone boundary.
   d) Transverse modes near the zone boundary.
   e) Both longitudinal and transverse modes near the zone center.

4) What is "deformation potential" scattering?

   a) Scattering by acoustic phonons that is due to the change in bandgap (or band edge) due to a change in lattice spacing.
   b) Scattering by optical phonons that is due to the change in bandgap (or band edge) due to a change in lattice spacing.
   c) **Scattering by either acoustic or optical phonons that is due to the change in bandgap (or band edge) due to a change in lattice spacing.**
   d) Scattering by defects in the crystal.
   e) Scattering by an electrostatic dipole in the crystal.

5) Which of the following scattering mechanisms occur in GaAs but not in Si?
   a) Acoustic deformation potential scattering.
   b) Optical deformation potential scattering.
   c) Ionized impurity scattering.
   d) Polar optical phonon scattering.
   e) **None of the above**

6) How does the acoustic phonon (sound) velocity of a material, v_S, depend on the density (kg/m³) of the material?
   a) The sound velocity is proportional to the square root of the density.
   b) **The sound velocity is proportional to one over the square root of the density.**
   c) The sound velocity is proportional to the density.
   d) The sound velocity is proportional to one over the density..
   e) The sound velocity is independent of the density.

7) If the change in momentum from the initial state for which the magnitude of crystal momentum is $p = \hbar k$ to the scattered state with $p' = \hbar k'$ is $\hbar q$, what type of scattering does the relation $0 < \hbar q < 2p$ imply?
   a) **Elastic scattering.**
   b) Inelastic scattering.
   c) Isotropic scattering.
   d) Anisotropic scattering.
   e) Inelastic <u>and</u> anisotropic scattering.

8) Why is it that optical phonon emission requires the initial kinetic energy to be greater than the optical phonon energy?

a) So that phonon absorption does not occur.
b) So that that phonon absorption is greater than phonon emission.
c) **So that there are final states to scatter to.**
d) So that that stimulated phonon emission equals spontaneous phonon emission.
e) None of the above.

9) In the expression for the transition rate,

$$S(\vec{p},\vec{p}') = \frac{2\pi}{\hbar}\left|K_q\right|^2\left|A_q\right|^2\delta(\vec{p}' - \vec{p} \mp \hbar\vec{q})\delta(E' - E \mp \hbar\omega)$$

what does $\left|A_q\right|^2$ represent?

a) The electron-phonon coupling constant.
b) The matrix element (magnitude squared) for scattering.
c) The magnitude squared of the overlap integral.
d) **The magnitude squared of the lattice vibration.**
e) The scattering rate.

10) When we write $\left|A_q\right|^2 \rightarrow \frac{\hbar}{2\rho\Omega\omega}(N_\omega + 1/2 \mp 1/2)$ what are we doing?

a) Changing a classical expression to a quantum mechanical expression.
b) Properly accounting for stimulated absorption.
c) Properly accounting for stimulated emission.
d) Properly accounting for spontaneous emission.
e) **All of the above.**

11) Emission is proportional to the number of phonons and absorption to the number plus one. Why?
a) To conserve phonons.
b) To ensure that detailed balance is satisfied in equilibrium.
c) To ensure that energetic carriers relax to the lowest energy states.
d) Answers (a) and (b) above.
e) **Answers (b) and (c) above.**

12) The scattering rate and the momentum relaxation rate are equal for which of the following cases?
   a) ADP, II, and ODP scattering.
   b) ADP, ODP, and POP scattering.
   c) POP, IV, ADP and ODP scattering.
   d) ADP, ODP, IV, and POP scattering.
   e) ADP, ODP, and IV scattering.

13) Which of the following scattering mechanisms favor small angle scattering?
   a) ADP and II.
   b) ODP and II.
   c) IV and II.
   d) POP and II.
   e) II.

14) Electron-electron scattering is usually ignored when analyzing semiconductor devices. How is this justified?
   a) Because it is typically weak compared to charged impurity and phonon scattering.
   b) Because it conserves the momentum of the electron ensemble.
   c) Because it conserves the energy of the electron ensemble.
   d) Because it conserves the number of electrons.
   e) Because it is just to difficult to compute.

15) Consider the II-VI semiconductor, ZnSe. What do you expect the dominant scattering mechanism to be if it is undoped and at room temperature?
   a) ADP scattering.
   b) ODP scattering.
   c) PZ scattering.
   d) POP scattering.
   e) IV scattering.

16) ADP scattering in 3D is proportional to the 3D density of final states. ADP scattering in 2D is proportional to the 2D density of final states, but something else changes. What is it?
   a) We must be careful about momentum conservation in the direction of confinement.
   b) We must be careful about momentum conservation in the plane.
   c) We must be careful about energy conservation in the direction of confinement..
   d) We must be careful about energy conservation in the plane.
   e) All of the above.

17) What is a "form factor"?
   a) Another name for the overlap integral.
   b) Another name for the shape of the confined wavefunction.
   c) An integral that depends on the shape of the confined wavefunction and that modifies momentum conservation for confined carriers.
   d) An integral that depends on the shape of the confined wavefunction and that modifies energy conservation for confined carriers..
   e) The factor used to normalize the wavefunction of the confined carrier to 1.

18) ADP scattering can be expressed in power law form, $\tau(E) = \tau_0 \left(E/k_B T \right)^s$. What is the characteristic exponent, s, in 3D, 2D, and 1D for a **parabolic band** semiconductor?
   a) $s_{3D} = 3/2, s_{2D} = 1, s_{1D} = 1/2$.
   b) $s_{3D} = 3, s_{2D} = 2, s_{1D} = 1$.
   c) $s_{3D} = 3/2, s_{2D} = 1/2, s_{1D} = -1/2$.
   d) $s_{3D} = +1/2, s_{2D} = 0, s_{1D} = -1/2$.
   e) $s_{3D} = -1/2, s_{2D} = 0, s_{1D} = +1/2$.

19) ADP scattering can be expressed in power law form, $\tau(E) = \tau_0 \left(E/k_B T \right)^s$. What is the characteristic exponent, s for **graphene**?

   a) $s = 1/2$.
   b) $s = 0$.
   c) $s = -1/2$.
   d) $s = -1$.
   e) $s = -3/2$.

20) The 2D density of states for parabolic energy bands is independent of energy, but for electrons in the 2D quantum well, the scattering rate generally increases with energy. Why?
   a) Because of conduction non-parabolicity.
   b) Because of carrier degeneracy.
   c) Because the electron-phonon coupling parameter is enhanced.
   d) Because overlap integral increase with quantum confinement.
   e) Because inter-subband scattering can occur in addition to intra-subband scattering.