Quiz ANSWERS Week 11
ECE 656: Electronic Conduction In Semiconductors

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1) The equation of motion for an electron in k-space is $d\left(\hbar\vec{k}\right)/dt = \vec{F}_e$. What assumptions are necessary for this equation to be valid?

a) Parabolic energy bands.
b) Non-degenerate conditions.
c) No quantum mechanical reflections.
d) No B-field.
e) No temperature gradients.

2) Under what conditions is this equation valid? $\frac{\partial f}{\partial t} + \vec{\upsilon} \bullet \nabla_r f + \vec{F}_e \bullet \nabla_p f = 0$

a) No recombination-generation.
b) Equilibrium.
c) No scattering.
d) Position independent effective mass.
e) All of the above.

3) What is the quantity, $-\left(\frac{f(\vec{p}) - f_0(\vec{p})}{\tau_m}\right)$?

a) The collision operator.
b) The collision operator in the Relaxation Time Approximation.
c) The solution to the steady-state Boltzmann equation.
d) The in-scattering term of the collision operator.
e) The out-scattering terms of the collision operator.

4) In the solution to the steady-state Boltzmann equation, $\delta f = \tau_m\left(-\partial f_0/\partial E\right)\vec{\upsilon} \bullet \vec{\mathcal{F}}$, what is the term $\vec{\mathcal{F}}$ called?

a) The electrochemical potential.
b) The chemical potential.
c) The statistical force.
d) **The generalized force.**
e) The electric field.

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5) What is the quantity: $\frac{1}{A}\sum_{\vec{k}}(E-F_n)\vec{\upsilon}(\vec{k})f(\vec{r},\vec{k})$? ($E$ is the total energy.)

a) The energy density.
b) The energy flux.
c) The heat density.
d) **The heat flux.**
e) The kinetic energy flux.

6) In this equation, $\hat{C}f = -\left(\frac{f(\vec{p})-f_S(\vec{p})}{\tau_m}\right)$, what is $f_S(\vec{p})$?

a) The distribution function.
b) The equilibrium distribution function.
c) **A distribution with the shape of the equilibrium distribution function.**
d) The Bose-Einstein distribution.
e) The anti-symmetric part of the distribution function.

7) How do we interpret the quantity, $(\vec{\upsilon}\vec{\upsilon})$?

a) As a scalar.
b) As a vector.
c) **As a second rank tensor.**
d) As a third rank tensor.
e) None of the above.

8) For spherical bands, how is the average scattering time, $\langle\langle\tau_m\rangle\rangle$ defined?

a) $\langle\upsilon_x^2\tau_m\rangle/\langle\upsilon_x^2\rangle$.
b) $\langle\upsilon^2\tau_m\rangle/\langle\upsilon^2\rangle$.
c) $\langle(E-E_C)\tau_m\rangle/\langle(E-E_C)\rangle$.
d) **All of the above.**
e) None of the above.

9) What is $\frac{1}{\mu_{tot}}=\frac{1}{\mu_1}+\frac{1}{\mu_2}$ called?

a) The Thompson relation.
b) The Kelvin relation.
c) The Wiedemann-Franz law.
d) The Lorenz number.
e) Mathiessen's rule.

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10) Why is the BTE harder to solve in the presence of a B-field?
   a) Because we are no longer near equilibrium.
   b) Because non-degenerate statistics must be used.
   c) Because the cross product makes the math more difficult.
   d) Because the gradient in momentum space can no longer be approximated by the gradient of f_S.
   e) Because the gradient in position space can no longer be approximated by the gradient of f_S.

11) In this equation, $\vec{J}_n = \sigma_S \vec{\mathcal{E}} - \sigma_S \mu_H \left(\vec{\mathcal{E}} \times \vec{B} \right)$, what is μ_H ?
   a) The mobility.
   b) The effective mobility.
   c) The conductivity mobility.
   d) The chemical potential.
   e) The Hall mobility.

12) What is the quantity, $\langle\langle \tau_m^2 \rangle\rangle / \langle\langle \tau_m \rangle\rangle^2$, called?
   a) The Hall mobility.
   b) The Hall coefficient.
   c) **The Hall factor.**
   d) The Hall concentration.
   e) The Hall parameter.

13) What quantity does a Hall effect measurement find?
   a) The Hall mobility.
   b) The mobility.
   c) **The Hall concentration.**
   d) The carrier concentration.
   e) The Hall resistivity.

14) What does the criterion $\omega_c \tau_m << 1$ imply?
   a) Electrons scattering many times before completing a cyclotron orbit.
   b) The magnetic field is low.
   c) Shubnikov-deHaas oscillations will not be observed.
   d) **All of the above.**
   e) None of the above.

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15) Electron-electron scattering is often treated to first order by assuming an **equilibrium** (Maxwellian or Fermi-Dirac) distribution with one change. What is the change?

a) **The Fermi level is replaced by the quasi-Fermi level.**
b) The lattice temperature is replaced by the electron temperature.
c) The magnitude of the distribution is re-normalized.
d) The Fermi-function is replaced by the Bose-Einstein function.
e) None of the above.

(The assumption here is that we are still near equilibrium)

16) When we write the collision integral in the Relaxation Time Approximation,

$$\hat{C}f(\vec{r},\vec{p},t) = -\frac{(f - f_S)}{\tau_m(\vec{r},\vec{p})},$$

why do we use f_S rather than the equilibrium, f_0?
a) Because we are not exactly at equilibrium.
b) To be sure that the number of carriers is conserved.
c) To the sure that the momentum of the carriers is conserved.
d) To the sure that the energy of the carriers is conserved.
e) To the sure that the heat of the carriers is conserved.

17) Under what conditions is the Relaxation Time Approximation, $\hat{C}f(\vec{r},\vec{p},t) = -(f - f_S)/\tau_f(\vec{r},\vec{p})$, valid?
a) Near equilibrium.
b) Near equilibrium with Maxwell-Boltzmann statistics with elastic scattering.
c) Near equilibrium with Maxwell-Boltzmann statistics with isotropic scattering.
d) **Near equilibrium with elastic scattering or isotropic scattering with Maxwell Boltzmann statistics.**
e) Near equilibrium with isotropic scattering or inelastic scattering with Maxwell Boltzmann statistics.

18) Which of the following statements is true in equilibrium?
a) The electrostatic potential is independent of position.
b) The chemical potential is independent of position.
c) The carrier density potential is independent of position.
d) The electrochemical potential is independent of position.
e) The electrochemical potential and temperature are independent of position.