Physics 412 EXAM 2 REVIEW
Chapters 5 and 6 and Sect. 7.1
TAKE HOME DUE: Monday, November 19

Chapter 5

Be able to describe both ρ and σ for pure and impure metals as functions of T. Be able to sketch careful graphs of the functions $\rho(T)$ and $\sigma(T)$ for various choices of Debye temperature and/or impurity resistance.

Know how to determine both the sign and concentration of carriers from Hall effect results (ie, polarity of V_H, i, and B).

Know what is meant by the functions and quantities: $g(\varepsilon)$, $f(\varepsilon)$, $n(\varepsilon)$, ε_F, n, μ, m^*, etc. Know the relationship between n and ε_F. Be able to derive expressions for n, ε_F, and $<\varepsilon>$ (the average electron energy at T=0) if given the function $g(\varepsilon)$.

Know how to obtain the electronic heat capacity expression and how to use it to obtain a value for ε_F. You should know why the classical and quantum models give different electronic heat capacity results. Be able to compare C_{el} and C_{lat} at low temperatures. Be able to use the expression for C_{el} to obtain the change in electron kinetic energy as temperature changes. And be able to compare the models.

Chapter 6

Know the basic ideas of the band theory of solids. Know the relationships between bonding mechanisms and the valence and conduction bands. Be able to describe the essential results of the "atomic bonding" and nearly free electron models.

Be able to describe the differences between conductors and non-conductors in terms of the band theory. Know how to relate the various graphical representations of energy bands: Energy vs atomic spacing, ε vs k, density of states, etc, and the role of the Fermi energy in how describing how the electrons are distributed.

Be able to describe <u>why</u> the conductivity should depend on $g(\varepsilon_F)$ in metals. Know how to compare the conductivities given the ε vs k diagrams or $g(\varepsilon)$ functions. Be able to describe what is meant by the "effective mass" of an electron and why it should depend on the shape of ε vs k. Be able to compare effective masses and hence the mobilities of electrons given the ε vs k diagrams.

Be able to describe how monovalent and band overlap metals differ. Be able to explain why monovalent metals are usually better conductors than band overlap metals - and why trivalent metals are usually better than divalent - but not as good as monovalent.

Be able to describe why it is *possible* that electrons in both the valence and conduction bands can participate in the conductivity of a solid - and why those in the valence band that do participate do so as if they were positively charged carriers (ie, "holes"). Know how to compare the effective masses of the conduction and valence electrons and how that relates to the mobilities of those carriers.

Know how to describe the Hall effect - and be able to determine the polarity of the Hall voltage given the current and magnetic field and the sign of the carriers. Be able to explain why some divalent metals have positive Hall coefficients based on band theory arguments.

Chapter 7 - Sect. 1

Be able to explain why both electrons and "holes" contribute to the conductivity of semiconductors - and why you would expect their concentrations to be the same (assuming they are "intrinsic"). Be able to describe optical absorption in semiconductors and insulators - and the significance of the "absorption edge" in determining ε_g.

HOMEWORK FROM CHAPTERS 5, 6, and Sect. 7.1:

Chapter 5:	Sects. 1,3-5	Problems 1, 3, 5, 6, 7, 9, 10, 11, 13, 14, 15, 18, 20
Chapter 6:	Sects. 1-3,5	Problems 1, 2, 4, 7, 8
Chapter 7:	Sect. 1	Problems 1, 2, 3a

SOME USEFUL EQUATIONS TO HELP YOUR REVIEW

You should know what these equations mean - what they are telling you and what the quantities in them represent as well as what their limitations are (ie, when they are applicable). Think of them as representing the main ideas of the material of these chapters.

$$\sigma = \frac{ne^2\tau}{m} = ne\mu \qquad \mu = \frac{e\,\tau}{m^*} \qquad \rho = \frac{1}{\sigma} \qquad \rho = \left(\frac{m}{ne^2}\right)\left(\frac{1}{\tau_{imp}} + \frac{1}{\tau_{lat}}\right) \qquad \rho = \rho_{res} + \rho_{lat}(T)$$

$$\rho_{lat}(T) \propto \left(\frac{m}{ne^2}\right)\frac{T}{M_{ion}\,\theta_D^2}\,\mathrm{G}\left(\theta_D/T\right) \qquad \Rightarrow \frac{T^5}{M_{ion}\,\theta_D^6} \quad \text{or} \quad \frac{T}{M_{ion}\,\theta_D^2}$$

$$\vec{\mathbf{E}}_H = -R_H\,\vec{\mathbf{j}} \times \vec{\mathbf{B}} \qquad R_H = \frac{1}{nq} \quad \text{or} \quad -\frac{1}{ne} \qquad R_H = -\frac{n\mu_e^2 - p\mu_h^2}{\left(n\mu_e + p\mu_h\right)^2}\frac{1}{e}$$

$$g(\varepsilon) = \frac{1}{2\pi^2}\left(\frac{2m}{\hbar^2}\right)^{3/2}\varepsilon^{1/2} \qquad f(\varepsilon) = \frac{1}{e^{(\varepsilon-\varepsilon_F)/k_BT} + 1} \qquad n = \int_0^\infty g(\varepsilon)f(\varepsilon)\,d\varepsilon \qquad \varepsilon_F = \frac{\hbar^2}{2m}\left(3\pi^2 n\right)^{2/3}$$

$$u = E_{el}/\mathrm{vol} = \int_0^\infty \varepsilon\, n(\varepsilon)\,d\varepsilon = \int_0^\infty \varepsilon\, g(\varepsilon)f(\varepsilon)\,d\varepsilon \qquad \varepsilon_{Avg}(T) = \frac{3}{5}\,\varepsilon_F + \Delta\varepsilon_{Avg}(T) \qquad \Delta\varepsilon_{Avg}(T) = \frac{1}{N_A}\int C_{el}\,dT$$

$$C_{meas} = C_{lat} + C_{el} \qquad C_{el} = \frac{\pi^2 N_A k_B^2 T}{2\,\varepsilon_F} = \frac{\pi^2}{2}R\,\frac{k_BT}{\varepsilon_F} \qquad C_{lat} = \frac{12\pi^4}{5}R\left(\frac{T}{\theta_D}\right)^3$$

$$\varepsilon(k) = \frac{\hbar^2k^2}{2m} + \Delta\varepsilon(k) \approx \frac{\hbar^2k^2}{2m^*} \qquad m^* = \frac{\hbar^2}{d^2\varepsilon/dk^2} \qquad \sigma = \frac{2}{3}\frac{e^2}{m^*}\tau\,\varepsilon_F\; g(\varepsilon_F) \Rightarrow \sigma = \frac{n_{eff}e^2\tau}{m^*}$$

$$\sigma = ne\mu_e + pe\mu_h \qquad \mu = \frac{e\,\tau}{m^*} \qquad \varepsilon_{photon} = h\nu = \frac{hc}{\lambda} = \frac{(1240\ \mathrm{ev\text{-}nm})}{\lambda} \qquad \lambda_c = \frac{hc}{\varepsilon_g}$$