Electronic Properties in Solids (Final Examination):

December 18, 2010

Name: _____ Student ID: _____

1. An electron passes through a potential difference of 10 Volts. (20 points)

   (a) What is its kinetic energy in eV?
   (b) What is its velocity?
   (c) What is its wavelength when considered as a wave?

2. The harmonic wave solution of the wave equation, (30 points)

$$\frac{\partial^2 \Psi}{\partial x^2} = a\frac{\partial^2 \Psi}{\partial t^2} + b\frac{\partial \Psi}{\partial t}$$

   consists of a travelling wave multiplied by an attenuation factor: exp(-βx).
   In terms of a and b,
   (a) What is the velocity of the travelling wave?
   (b) What is the value of β?

3. At a particular radiation frequency, a material has an electrical conductivity of 10^4(ohm-cm)$^{-1}$, and index of refraction of 4.5, and a dielectric constant of 9 at 300 K. If the conductivity varies as T^{-1}, where T is the temperature, what is the index of refraction at this frequency at 600K? (20 points)
   Note that $r^2 = \frac{1}{2}[\varepsilon_r + \sqrt{\varepsilon_r^2 + \frac{16\pi^2\sigma^2}{\omega^2}}]$

4.
   (a) Both an $E(k)=Ak^2$ dependence and a $(E_{max}-E)=Bk^2$ dependence, where A and B are constants, correspond to free electron like behavior. What is the effective mass in the two cases? (10 points)
   (b) In the literature you will come across the phrase:
   "heavy holes with negative effective mass"
   Sketch E vs. k curves that illustrate what is meant by this phrase, i.e., what does "heavy" means, and what is "negative effective mass" for a hole? Contrast an E vs. k curve corresponding to heavy holes with negative effective mass, with a curve corresponding to light holes with negative effective mass. (20 points)

5. Suppose that ZnS (E_g=3.7 eV) and CdTe (E_g= 1.4 eV) form a complete range of solid

solutions: $(ZnS)_{1-x}(CdTe)_x$ such that

$$E_g(x) = 3.7 - 2.3x \text{ (eV)}$$

Make a table that gives the color seen by the eye by transmission (looking through) selected crystals from this set as a function of x, for increments of x of 0.2 from 0 to 1.0 (30 points)

6. The density of free electrons in In_2O_3 can be increased appreciably by reducing the material by heating in hydrogen. If the oxygen is reduced, it is believed that the oxygen vacancy is formed which is electrically charged. In this case, the material becomes highly n-type doped, degenerated semiconductor (meaning that the Fermi energy locates inside of the conduction band). The optical absorption edge is observed to shift from 3.1 eV when the free electron density n is 7.4×10^{19} to 3.4 eV when the free electron density is 3.8×10^{20} cm^{-3}. (30 points)
   (a) Schematically draw the energy diagram for these two cases and show which energy is become 3.1 eV and 3.4 eV, respectively.
   (b) What is the band gap of In_2O_3 for n=0. Note that the energy (E) versus n relationship for conduction band and valence band is expressed as free-electron like.
   (c) If the effective mass of the holes is 0.5m, what is the effective mass of electrons?

7. A degenerate semiconductor has a direct band gap of 2.0 eV at k=0, $m_e^*=0.2m$, $m_h^*=0.5m$. If there are $3 \times 10^{19} cm^{-3}$ free electrons in the conduction band, give the value of: (30 points)
   (a) The location of Fermi energy level
   (b) The value of k at the Fermi energy
   (c) The lowest energy indirect optical transition from valence to conduction band
   (d) The lowest energy direct optical transition from valence to conduction band

8. Explain the behavior of susceptibility for the following magnetic properties with respect to temperature and how it appears like that (30 points)
   .
   (a) Diamagnetic
   (b) Paramagnetic
   (c) Ferromagnetic
   (d) Antiferromagnetic
   (e) Ferrimagentic

9. Derive the equation for the spin paramagnetism susceptibility by using the E vs density of

states at Fermi energy $Z(E_F)$. (20 points)

10. Draw the magnetic hysteresis curve of the ferromagnetic materials and explain in detail why it appears like that. Would you expect to have the similar hysteresis curve for the antiferromagnetic materials and for the ferromagnetic materials? (20 points)

11. Explain why Cu shows diamagnetism even though it has many valence electrons by using the energy band diagram. (20 points)

12. During the class, I asked you to think about the difference between 색의 삼원색 and 빛의 삼원색. Can you tell me the differences of them and why the basic color elements are different? (20 points)

Refer the attached constant table.