Uva Wellassa University, Sri Lanka
End Semester Examination – February 2012
SCT 351-3
Materials Physics

Time: Three (03) hours

Total 06 Questions
Answer ALL questions
Each question contains 25 marks

Boltzmann constant - 1.38×10^{-23} JK^{-1}
Avogadro number - 6.022×10^{23} mol^{-1}
Plank's constant (h) - 6.626×10^{-34} Js
Electron charge (e) - 1.602 $\times$ 10^{-19} *C*
Electron mass (m) = 9.109 $\times$ 10^{-31} *kg*

01) a) i. Describe three concepts including Compton scattering that leads for the development of Quantum Mechanics.

ii. A 100 kV photon collides with an electron at rest. It is scattered through 90^0. What is its energy after the collision? What is the kinetic energy in eV of the collision and what is the direction of its recoil?

b) i. What is normalization of a wave function? Normalize the one dimensional wave function given by

$$\Psi(x) = A\sin\left(\frac{\pi x}{a}\right) \qquad 0 < x < a$$
$$\Psi(x) = 0 \qquad \text{outside}$$

ii. Show that the eigenkets of any hermition operator are orthogonal to each other if the eigenvalues are different.

02) a) Explain the phenomenon of "barrier tunneling" or "quantum mechanical tunneling of electron" by considering a particle encountering a square barrier of height V_0.

b) Obtain an expression, identifying all the parameters, for the tunneling probability T (which is also known as transmission probability) by solving the 1D Schrodinger equation (TISE) for all three regions when a stream of particle with energy E is impinging on a potential barrier with height V_0, where $E <<< V_0$, and width *a*.

c) Show that decreasing the width of the potential barrier increases the T of the electrons exponentially. Explain how a scanning tunneling microscope (STM) works.

03) a) Explain the free nature of the valence electrons in the free electron gas model.

b) Define density of states and Fermi-energy. Explain the variation of density of electronic states $D(E)$ with energy, for a one-dimensional metallic crystal.

c) Show that at the Fermi level, D(E) may be expressed as

$$D(E) = \frac{3}{2}\frac{N}{E_F}$$

$E_F =$ Fermi energy
$N =$ Total number of free (valence) electrons

04) a) Describe Band theory of solids.

b) Show that the solutions of the wave equation in a periodic lattice are in the Bloch form.

c) Explain metals, semiconductors and insulators on the basis of the Band theories.

05) a) What is statistical ensemble?

b) Write down three types of ensembles. Compare and contrast them.

c) Explain the distinguishing features of Maxwell-Boltzmann, Bose-Einstein and Fermi-Dirac statistics.

d) What are the number of ways to arrange two particles x and y in three energy states according to Maxwell-Boltzmann, Bose-Einstein and Fermi-Dirac statistics. Write in tabular form and explain.

e) State which statistics (classical Maxwell-Boltzmann; Fermi-Dirac; or Bose-Einstein) would be obeyed by the followings and explain why.

i. Free electrons in metals
ii. Photons
iii. Molecules of N_2 gas at N.T.P.

06) Consider a gas of N_0 non-interacting molecules enclosed in a container of volume V_0. Consider any subvolume V of this container and let N be the number of molecules located within V. Each molecule is equally like to be located anywhere within the container and hence the probability that a given molecule is located within V is simply equal to V/V_0.

a) What is the mean number $\bar{N}$ of molecules located within V?

b) Find the relative dispersion $\overline{(N-\bar{N})^2}/(\bar{N})^2$ in the number of molecules located within V. Express your answer in terms of $\bar{N}$, V_0 and V.

c) What does the above answer become when $V \ll V_0$?