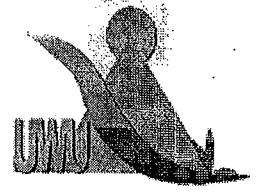




Uva Wellassa University, Sri Lanka  
End Semester Examination – February 2012  
SCT 351-3  
Materials Physics



Time: Three (03) hours

Total 06 Questions

Answer ALL questions

Each question contains 25 marks

*Boltzmann constant* -  $1.38 \times 10^{-23} \text{ JK}^{-1}$

*Avogadro number* -  $6.022 \times 10^{23} \text{ mol}^{-1}$

*Plank's constant (h)* -  $6.626 \times 10^{-34} \text{ Js}$

*Electron charge (e)* -  $1.602 \times 10^{-19} \text{ C}$

*Electron mass (m)* =  $9.109 \times 10^{-31} \text{ kg}$

- 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  $90^\circ$ . 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

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

$$\Psi(x) = 0 \quad \text{outside}$$

- ii. Show that the eigenkets of any hermitian 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  $E \ll V_0$ , 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  $V \ll V_0$ ?