UNIVERSITY OF RUHUNA

B.Sc. General Degree Level III (Semester I) Examination – June/July 2013

Subject: PHYSICS
Course Unit: PHY 3114 **Time: 02 hours & 30 minutes**

Part II

Answer FIVE (05) Questions only.

Answer at least 01 (ONE) question from each of the parts A, B and C.

(All symbols have their usual meaning)

Planck's constant, $h = 6.626 \times 10^{-34}$ Js, 1 eV = $1.6\,02 \times 10^{-19}$ J, Boltzmann constant, $k_B = 1.38\times10^{-23}$ JK^{-1}
Avogadro's number, $N_A = 6.\ 022\times10^{23}$, Mass of an electron = 9.1×10^{-31} kg

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Part A

1. (a) Though both graphite and diamond are made up of carbon atoms, their electrical, mechanical and thermal properties are completely different from each other. Explain this briefly.
   (b) Describe, briefly, atomic structures of amorphous and crystalline solids. What is a polycrystalline? What is meant by a "grain"?
   (c) The Bravais lattice of Aluminum is *fcc* with side "*a*".
   i. How many atoms are there in the unit cell?
   ii. What is the volume of the conventional cell?
   iii. Obtain the value of the packing fraction.
   (d) Atomic mass of Aluminum is 26.98 g (density is 2698 kg/m^3).
   i. How many gram-moles of aluminum are contained in 1 cm^3 of the solid?
   ii. How many atoms are in 1 cm^3 volume of the solid?
   iii. Calculate the size of the unit cell and the atomic radius of aluminum.

2. Structure of a crystal can be determined by X- ray diffraction.
   (a) Discuss, briefly, the X-ray diffraction techniques used in Laue powder and rotating crystal methods and compare their applications.

   (b) i. Write down the Bragg law in crystal diffraction. Define all terms.
   ii. Write down the relation for distance "*d*" between two neighboring planes of the family (*h,k,l*) in terms of unit cell parameter "*a*" for a cubic lattice. The lattice parameter "*a*" for copper (*fcc*) is 3.61Å. Determine the wavelength of X-rays used if the first order Bragg reflection from (1,1,1) planes appears at an angle of 21.7°.

(c) In addition to X-rays, neutrons and electrons are used as radiation sources in crystallography.

i. Compare physical properties of the three radiation sources.

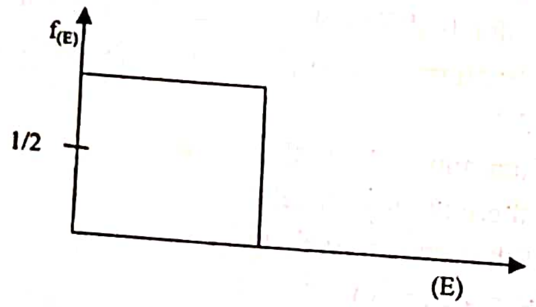
ii. Describe, briefly possible information that can be revealed using these radiation sources in crystallography experiments.

(d) When sharpening hard tools like knives, blacksmiths heat them up to a very high temperature in forge and cool the forged knives immersing in water at once. But when preparing ductile m[aterials] like wires the heated forged material cooled slowly. Explain briefly, how strengths vary in the situations.

3. (a) State major assumptions used in the free electron model.

(b) An electron gas is in its ground state at absolute zero temperature. Write down the Fermi probability function, $f_{(E)}$, if the gas has energy E at temperature, $T > 0K$. Define all terms expression.

(c) Following figure shows the variation of $f_{(E)}$ Vs E at very low temperatures (~0 K). Discuss the using the Fermi-Dirac function in part (b). Sketch variation of $f_{(E)}$ Vs E at higher temperatures temperature and more). Discuss what you would expect if $T \rightarrow \infty$.



(d) Find the temperature at which there is a 10% probability of having free electron energy of silver above the Fermi level. The Fermi energy of silver is 5.5 eV.

PART B

4. (a) What is meant by the "state of a system" in statistical physics? Further explain your answer by giving a suitable example.

(b) What are basic postulates, which define an isolated system and its equilibrium state?

(c) Write down the canonical distribution. Hence, show that the mean energy $\overline{E}$ of the system is given by $-\frac{\partial \ln Z}{\partial \beta}$ and the dispersion of energy is given by $-\frac{\partial \overline{E}}{\partial \beta}$, where Z is the partition function.

(d) Show that the entropy of the system is given by $k(\ln Z + \overline{E}\beta)$.

Consider a system of three particles in equilibrium at absolute temperature T, each having a magnetic moment μ_o, placed in an external magnetic field B.

(a) What are the possible energy states of the system?

(b) Write down the partition function of the system.

(c) Find the mean energy of the system.

(d) Find the probability that the system is found having energy $\mu_o B$.

(e) Obtain the ratio of the probabilities that the system can be found having minimum and maximum energies.

Maxwell velocity distribution is given by $f(\vec{v})d^3\vec{v} = n\left(\frac{m}{2\pi kT}\right)^{\frac{2}{3}} e^{-\frac{\beta mv^2}{2}} d^3\vec{v}$

(a) Find an expression for the mean number of molecules per unit volume with x-component of velocity in the range between v_x and $v_x + dv_x$. What is the mean value of the x-component of velocity?

(b) By Using Maxwell velocity distribution find an expression for mean number of molecules per unit volume with the speed in the range between v and $v + dv$. Hence, find the average speed of the molecules.

(c) Consider a gas consisting of two particles (A, B). Assume that each particle can be in one of three possible quantum states, s = 1, 2 and 3. Describe how these two particles are arranged in above three quantum states according to Maxwell- Boltzmann, Bose-Einstein and Fermi-Dirac statistics.

You can use the following integrals:

(1) $\int_0^\infty e^{-\alpha x^2} dx = \frac{1}{2}\sqrt{\frac{\pi}{\alpha}}$ (2) $\int_0^\infty xe^{-\alpha x^2} dx = \frac{1}{2\alpha}$ (3) $\int_0^\infty x^3 e^{-\alpha x^2} dx = \frac{1}{2\alpha^2}$ (4) $\int_0^\infty x^4 e^{-\alpha x^2} dx = \frac{3}{8\alpha^2}\sqrt{\frac{\pi}{\alpha}}$

PART C

(a) What is meant by the work function of a metal? The threshold frequency for photo-electric emission in copper is 1.1×10^{15} Hz. Calculate the work function of the metal.

(b) Find the incident energy of a photon when light of frequency 1.2×10^{15} Hz is directed on a copper surface. Find the maximum energy of the ejected electrons.

(c) An electron is travelling with a speed of 10^3 ms^{-1} with 0.05% accuracy. Calculate the uncertainty with which the position of the electron can be located.

8. (a) Consider the one-dimensional potential well given below.

$V(x) = 0; \quad 0 < x < l$

$V(x) = \infty$; outside

Assume that a particle with energy E and mass m is inside the well. Solve the time indepen[dent] Schrödinger equation and find possible energy levels and eigen functions for the particle.

(b) Using the answer obtained in part (a), write down possible energy levels for a particle in a 3-D [box] of side l. Evaluate the first three energy levels of an electron enclosed in a cubical box of side 1[0 ...] Assuming a marble of 1g enclosed in a cubical box of side length 20 cm can be treated using quan[tum] mechanics, compare the values of the first three energy levels to that of the electron with those of a [...] marble. Can these energy levels of the marble be measured experimentally? Give reasons to y[our] answer.

9. (a) What is meant by an eigen function and an eigen value?

(b) The operator for z – component of angular momentum is $\hat{L}_z = -i\hbar \frac{\partial}{\partial \phi}$. Determine whether or not $\sin m\phi$ is an eigen function of $\hat{L}_z$.

(c) (i) What is meant by degeneracy? Discuss, briefly, using energy levels of the Hydrogen atom as example.

(ii) Write down the set of quantum numbers for the level n=3 in the Hydrogen atom.

(d) The ground state wave function for hydrogen atom is $\varphi = \frac{1}{\pi} \frac{1}{a_0^{3/2}} e^{-r/a_0}$. Show that the average distance of the electron from the nucleus is $1.5a_0$, where a_0 is the Bohr radius.

(use the integral $\int_0^\infty e^{-bx} x^n dx = \frac{n!}{b^{n+1}}$)

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