UNIVERSITY OF RUHUNA

B.Sc. General Degree Level III (Semester I) Examination – August/September 2017

Subject: PHYSICS
Course Unit: PHY 3114

Time: 02 hours & 30 minutes

Part II

Answer FIVE (05) Questions only.

(All symbols have their usual meaning)

Charge of electron, $e = 1.6 \times 10^{-19}$ C

Planck's constant, $h = 6.626 \times 10^{-34}$ Js

Avogadro's number, $N_A = 6.022 \times 10^{23}$

Speed of light, $c = 3 \times 10^{8}$ ms^{-1}

1 eV = 1.6 02 x 10^{-19} J

Boltzmann constant, $k_B = 1.38 \times 10^{-23}$ JK^{-1}

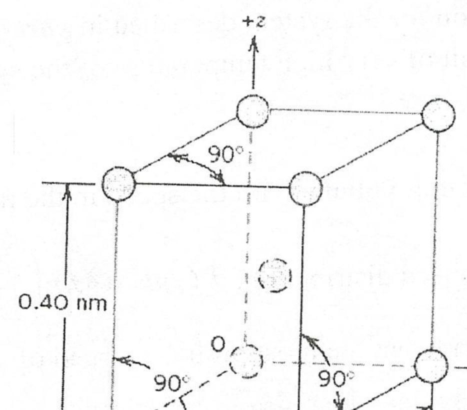
Mass of an electron, $m_e = 9.1 \times 10^{-31}$ kg

Rydberg constant, $R = 2.2 \times 10^{-18}$ J

1 a.m.u = 1.66×10^{-27} kg

PART A

1. A unit cell of a hypothetical metal is shown below.
   (a) To which crystal system does this unit cell belong? **[02-marks]**
   (b) What would this crystal structure be called? **[02-marks]**
   (c) Calculate the density of the metal, given that its atomic weight is 141 gmol^{-1}. **[04-marks]**
   (d) List the point coordinates for all atoms that are associated with the unit cell. **[04-marks]**
   (e) Write down the equation for separation between neighboring planes (interplanar spacing) in the crystal lattice. **[04-marks]**
   (f) Calculate the interplanar spacing for (220) set of planes in the metal. **[04-marks]**
   (g) When monochromatic X-rays having wavelength 0.1442 nm is incident on the (220) set of planes in the metal, compute the angle of diffraction for the first-order reflection. **[05-marks]**



2.

(a) Derive an expression for the electrical conductivity of a metal. **[10-marks]**

(b) Aluminum has three valence electrons per atom, atomic weight of 0.02698 kg/mol, density of 2700 kg/m^3, and conductivity of 3.54 10^7 Ω/m. Assume that all three valence electrons of each atom are free.

(i) Calculate electron density of aluminum. **[05-marks]**

(ii) Calculate electron mobility in aluminum. **[05-marks]**

(iii) Estimate the mean collision time for an electron. **[05-marks]**

PART B

3. Consider a system of two particles in thermal equilibrium with a heat reservoir at absolute temperature ***T***. Each particle can occupy in three different quantum states $(s = 1, 2 \,\&\, 3)$ with energies $0, \varepsilon$ *and* 2ε.

(a) If particles are distinguishable and obey Maxwell Boltzmann distribution, list all possible quantum states of the two particles by completing the following table. **[07-marks]**

State of the system (r)	$s = 1$	$s = 2$	$s = 3$	Total energy of the system $\mathbf{E_r}$
r = 1				
r = 2				
r = 3				
.				
.				
.				

(b) Write down the partition function for the system described in ***part (a)***. **[05-marks]**

(c) If particles are indistinguishable and obey Fermi Dirac statistics, list all possible quantum states of the two particles by completing the table shown in ***part (a)***. **[03-marks]**

(d) Write down the partition function for the system described in ***part (c)***. **[03-marks]**

(e) Find the mean energy at the limit of very high temperature of the system described in ***part (c)***. **[07-marks]**

4. The mean number of molecules per unit volume with the speed in the range between v and $v + dv$ is given by Maxwell speed distribution, $F(v)dv = 4\pi n\left(\frac{m}{2\pi kT}\right)^{\frac{3}{2}} v^2 e^{-\frac{mv^2}{2kT}} dv$.

(a) Using the speed distribution, show that the most probable speed of a gas molecule moving in 3-dimention is $\tilde{v} = \sqrt{\frac{2kT}{m}}$ **[06-marks]**

(b) If the mass of one mole of gas is $28g$, calculate the most probable speed of a gas molecule at room temperature. **[05-marks]**

(c) For a monoatomic ideal gas, show that the mean number of molecules per unit volume whose energy lies in the range between E and $E+dE$ is

$$F(E)dE = 2\pi n\left(\frac{1}{\pi kT}\right)^{\frac{3}{2}} E^{\frac{1}{2}} e^{-\frac{E}{kT}} dE$$

[06-marks]

(d) Using the distribution in ***part (c)*** or by some other means find the mean kinetic energy of a gas molecule.

[04-marks]

$$\text{Note:} \quad \int_0^{\infty} E^{\frac{3}{2}} e^{-\frac{E}{kT}} dE = \frac{3}{4}\sqrt{\pi k^5 T^5}$$

(e) Explain why the average speed of a gas molecule is higher than the most probable speed of a molecule of the same gas.

[04-marks]

PART C

5.

(a)

(i) State the de-Broglie equation for matter waves. **[03-marks]**

(ii) Derive an equation for de-Broglie wavelength of an electron in terms of potential difference V through which it is accelerated. **[07-marks]**

(iii) Televisions made in the 20th century used cathode ray tubes (or CRTs) to display images. In such a television, assume that an electron beam is accelerated through the television receiver tube by applying a potential difference of 12,000 V. Calculate the de-Broglie wavelength of the electron. **[05-marks]**

(b)

(i) State Heisenberg's uncertainty principle in mathematical form. **[04-marks]**

(ii) A particle of mass 10^{-6} g has a speed of 1 ms^{-1}. The speed is uncertain by 0.01%. What is the minimum uncertainty in the position of the particle? **[06-marks]**

6. A particle of mass m and energy E travelling along x-axis from left to right approaches a finite potential barrier given below.

$$V(x) = \begin{cases} 0, & x < 0 \\ V_0, & x \geq 0 \end{cases}$$

where $E < V_0$.

(a) Solve the Schrödinger equation to obtain physically acceptable solutions for the particle. **[07-marks]**

(b) Apply boundary conditions to find ratios of the relevant constants. **[04-marks]**

(c) Find the probability density of the particle in the region $x > 0$. **[05-marks]**

(d) An electron and a proton of same energy E approach a potential barrier of height V which is greater than E. Do they have the same probability of getting through? Explain. **[05-marks]**

(e) Use the results obtain in ***part (a)*** to discuss what happens to the particle if $V_0 \to \infty$. **[04-marks]**