UNIVERSITY OF RUHUNA

B.Sc. General Degree Level III (Semester I) Examination – June/July 2016

Subject: PHYSICS
Course Unit: PHY 3114

Time: 02 hours & 30 minutes

Part II

Answer FIVE (05) Questions only – (25 points per question)

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

(All symbols have their usual meaning)

Planck's constant, $h = 6.6 \times 10^{-34}$ Js
Avogadro's number, $N_A = 6.022 \times 10^{23}$
Speed of light, $c = 3 \times 10^{8}$ ms^{-1}
1 eV = 1.6×10^{-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) (i) Describe, briefly, atomic structures of amorphous and crystalline solids. ..... **(06)**
(ii) What is a polycrystalline? .... **(02)**

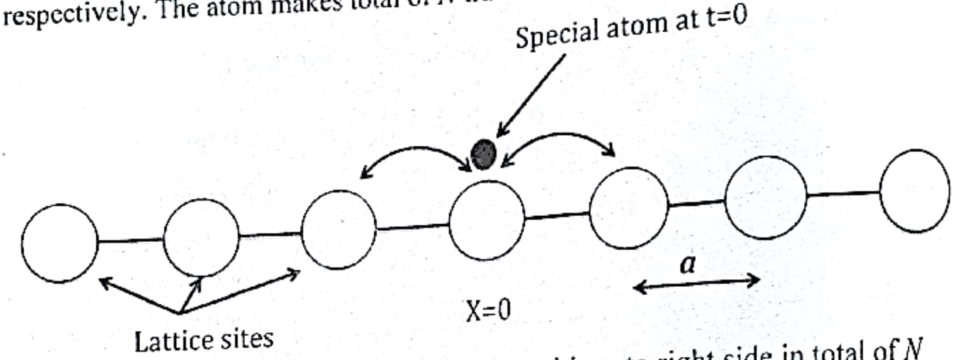
(b) The lattice of Lithium is a BCC structure with side length a.
(i) What is the volume of the conventional unit cell? .... **(04)**
(ii) How many atoms are in the unit cell? ..... **(01)**
(iii) What are primitive lattice translational vectors? Hence, find the volume of the primitive cell. ...**(07)**
(iv) Obtain the value of the packing fraction. ....**(03)**
(v) Write down the fractional coordinates of lattice points in conventional cell. ....**(02)**

2. (a) A beam of electrons with kinetic energy 1 KeV is diffracted as it passes through a polycrystalline metal foil which has a cubic crystal structure with interplaner spacing of 1 Å.
(i) Calculate the wavelength of the electrons. .....**(05)**
(ii) Calculate the Bragg angle for the first order diffraction maximum. .....**(05)**

(b) An electron is confined to a three dimensional box of length L.
(i) Express electron's energy using relevant quantum numbers? ...**(02)**
(proportional constant is $\frac{\hbar^2\pi^2}{2mL^2}$)
(ii) Obtain an expression for the momentum of the electron. ....**(04)**
(iii) Calculate energy and momentum in the state immediately above the lowest level. ....**(09)**

PART B

3. As shown in the figure below, there exists a one-dimensional lattice with lattice constant a. one special atom on the lattice is able to transit to its nearest-neighbor site randomly. At $t = 0$ the atom starts its journey from the site at $X = 0$. The probabilities of transiting to a nearest-neighbor site on right and left sides are p and q, respectively. The atom makes total of N transitions.



(a) Write down an expression for the probability of making n transitions to right side in total of N transitions. .... (05)

(b) Calculate the mean number of transitions $\bar{n}$ to right side. ..... (08)

(c) If $p = 2/3$ and $q = 1/3$, what is the probability that this atom will be at $X = 0$ after completing 20 total transitions? ......(08)

(d) What is the probability that this atom will be at $X = 0$ after completing N total transitions when N is an odd number? .... (04) (Note: $np^n = p\dfrac{\partial p^n}{\partial p}$ and $\sum_{n=0}^{N} \dfrac{N!}{n!(N-n)!} p^n q^{N-n} = (p+q)^N$)

4. (a) Write down the canonical distribution. Further, show that the mean energy $\overline{E}$ of a system in thermal equilibrium at absolute temperature T is given by $-\dfrac{1}{Z}\dfrac{\partial Z}{\partial \beta}$. .... (07)

(b) Consider a system with only two accessible energy levels ε_1 and ε_2 in thermal equilibrium with a reservoir at absolute temperature T. The lower energy level (ε_1) is not degenerated, while the degeneracy of the upper energy level (ε_2) is two.

(i) Calculate the probability of finding the system, in lower energy level. .....(04)

(ii) Find the mean energy of the system. .....(04)

(iii) Calculate the Helmholtz free energy (F) for the system. .....(04)

(iv) Consider the very high temperature limits where $T \to \infty$. Now find the probability that the lower energy level is occupied by the system. .....(03)

(v) Find the mean energy of the system at this very high temperature limits. .....(03)

PART C

5. State Heisenberg uncertainty principle in mathematical form. .....(04)

(a) A particle is free to move in one dimension. Show that the uncertainty principle can be written as $(\Delta\lambda)(\Delta x) \geq \frac{\lambda^2}{4\pi}$ where (Δx) and $(\Delta\lambda)$ are the uncertainties of position and wavelength of the particle, respectively. ..... (05)

(b) A biologist needs to image a virus of linear size d using an electron microscope. If the wavelength of electrons is λ, what should be the maximum value of λ in order to produce the image? Show that the electrons must be accelerated to a voltage, V, that must satisfy $V \geq \frac{2\pi^2\hbar^2}{med^2}$ to image the virus. .....(08)

(m and e are mass and charge of an electron, respectively)

(c) (i) $\hat{A}$, $\hat{B}$ and $\hat{C}$ are three Hermitian operators. Obtain following commutator relationships,

$[\hat{A},\hat{B}+\hat{C}] = [\hat{A},\hat{B}] + [\hat{A},\hat{C}]$ and $[\hat{A}\hat{B},\hat{C}] = \hat{A}[\hat{B},\hat{C}] + [\hat{A},\hat{C}]\hat{B}$ .....(04)

(ii) Show that $[\hat{x},\hat{p}] = i\hbar$ where $\hat{x}$ and $\hat{p}$ are position and momentum in x direction, respectively. .....(04)

6. A particle is confined to a 1- D potential well with infinite walls at $x = 0$ and $x = L$.

(a) Find possible eigenfunctions and energy eigenvalues of the particle. (take normalization constant of eigenfunctions as $\sqrt{2/L}$). .....(14)

(b) A small ball having mass of 1g is constrained to roll inside a tube of closed ends with length $L = 1$ cm. Assuming that this macroscopic system can be modelled as 1 – D potential well, determine the value of quantum number n if ball has energy 1 mJ. .....(05)

(c) Calculate the energy required for the ball to go the next higher excited state. Discuss your answer, briefly. .....(06)

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