NATIONAL OPEN UNIVERSITY OF NIGERIA
14-16 AHMADU BELLO WAY, VICTORIA ISLAND, LAGOS
SCHOOL OF SCIENCE AND TECHNOLOGY
JANUARY/FEBRUARY 2013 EXAMINATION

COURSE CODE: **PHY 307**

COURSE TITLE: **SOLID STATE PHYSICS I**

CREDIT UNIT: **3**

INSTTRUCTION: **Answer any five questions.**

TIME: **3 Hours**

PHYSICAL CONSTANTS:

Speed of light $c = 2.9979 ms^{-1}$**; mass of electro** $m_e = 0.9110 \times 10^{-31} kg$**;**
Electronic charge $e = 1.6022 \times 10^{-19} C$**; Avogadro's number**
$N_A = 6.0221 \times 10^{26} kmol^{-1}$; **Boltzmann constant** $k = 1.3806 \times 10^{-23} J K^{-1}$**;**
Plank's constant $h = 6.6257 \times 10^{-34} Js$

1. (a) (i) Define the following terms

(i) Unit cell **2 mark**

(ii) Basis **2 mark**

(ii) Show that the perpendicular distance between two adjacent planes of a set

(hkl) **in a cubic lattice of lattice constant *a* is**

$$d_{hkl} = \frac{a}{\left(h^2 + k^2 + l^2\right)^{1/2}}$$

4 marks

(b) (i) Starting from $2\vec{K}.\vec{G} + \vec{G}^2 = 0$, **obtain the diffraction condition** $2d\sin\theta = n\lambda$.
6 marks

(ii)An X-ray beam of energy 0.01 MeV is reflected at the (100) plane of sylvine crystal $(d_{100}=0.314\,nm)$. Calculate the glancing angle θ at which the first order Bragg's spectrum will be observed.
6 marks

2. (a) Explain the terms:

(i) Reciprocal space lattice
3 mark

(ii) First Brillouin zone
3 marks

(b) (i) write down the primitive translation vectors(axis vectors) of the reciprocal lattice

6 marks

(ii) Prove that the reciprocal lattice vectors as defined in equation (5.1) satisfy:

$$A.B\times C=\frac{8\pi^3}{a.b\times c}$$

8 marks

3. (a) Briefly explain the following terms and give an example of each:

(i) Ionic bond
4 marks

(ii) Metallic bond
4 marks

(b) If the potential energy function is expressed as

$$U(r)=\frac{-\alpha}{r^6}+\frac{\beta}{r^{12}}$$

show
(i) that the intermolecular distance r_0 for which the potential energy is minimum is given by

$\left(\frac{2\beta}{\alpha}\right)^{1/6}$

6 marks

(ii) the minimum potential energy is given by

$U_{min} = \frac{\alpha^2}{4\beta}$

6 marks

(a) Define the following terms:

4.

(i) Lattice vibration
4 marks

(ii) Phonons
4 marks

(b)(i) Briefly explain the assumptions made in the harmonic approximation and deduce the dispersion relation for a diatomic lattice.
8 marks

(ii) Sketch the dispersion curve within the first Brillouin zone of a one dimensional diatomic lattice.
4 marks

5. (a) (i) What do you understand by term “Lattice heat capacity” of a crystal? 4 marks

(ii) State the main assumptions of the Debye model of heat capacity of a crystalline solid

4 marks

(b) (i) Use Debye model to obtain an expression for the total phonon energy, hence, obtain an expression for the heat capacity at constant volume at very low temperatures of a crystalline solid.
8 marks

(ii) Write down the expression for Einstein's approximation of the thermal energy and use it to obtain the heat capacity at constant volume of a crystalline solid. 4 marks

6. (a) (i) State the basic assumptions of the free electron model of metals. 5 marks

(ii) Define the term Fermi energy and write down an expression for the Fermi energy of a one-dimensional system of N free electrons each of mass m confined to a length L by finite potential barriers. 5 marks

(b) (i) Write down the Schrödinger's equation and its solution in three dimensions for free electrons confined to a cube of edge L. 6 marks

(ii) Estimate the Fermi energy and velocity for sodium (Na) and comment on the answer you obtain for Fermi velocity.

Hint: Sodium has BCC structure with lattice parameter $a = 4.2\,\text{Å}$**, and one valence electron per atom. 6 marks**

7 (a) At room temperature, $k_B T/e = 26\,mV$**. A sample of cadmium sulfide displays a mobile carrier density of** 10^{16} **cm^{-3} and a mobility coefficient** $\mu = 10^2 cm^2/volt\,sec$

(i) Calculate the electrical conductivity of this sample 5 marks

(ii) If the charge carriers have an effective mass equal to 0.1 times the mass of a free electron, what is the average time between successive scatterings? 5 marks

(b) (i) Briefly discuss the term "superconductivity" and illustrate with a sketch of resistance versus temperature curve. 4 marks

(ii) Mention six regularities in the appearance of superconductivity based on empirical data

6 marks