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OFFICE OF THE DEPUTY PRINCIPAL
ACADEMICS, STUDENT AFFAIRS AND RESEARCH

UNIVERSITY EXAMINATIONS

2019 /2020 ACADEMIC YEAR

THIRD YEAR FIRST SEMESTER REGULAR EXAMINATION

FOR THE DEGREE OF BACHELOR OF EDUCATION SCIENCE

COURSE CODE: **PHY 311**

COURSE TITLE: **SOLID STATE PHYSICS**

DATE: 9th DECEMBER 2019 **TIME: 9AM-12NOON**

INSTRUCTION TO CANDIDATES

- **SEE INSIDE**

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PHY 311: SOLID STATE PHYSICS I

STREAM: BED (Scie) **DURATION: 3 Hours**

INSTRUCTIONS TO CANDIDATES

i. *Answer the **TWO** question in **SECTION A** and any other **THREE** questions in **SECTION B.***

ii. *The following constants maybe useful*

Electron mass	m_e	$= 9.10\times10^{-31}\,kg$
Electron charge	e	$= 1.60\times10^{-19}\,C$
Boltzmann constant	k_B	$= 1.381\times10^{-23}\,JK^{-1}$
Plank constant	h	$= 6.60\times10^{-34}\,JS$
Avogadro's number	N_A	$= 6.022\times10^{23}\,mole^{-1}$
Speed of light in a vacuum c		$= 3.0\times10^{8}\,m/s$
Permittivity constant	μ_0	$= 4\pi\times10^{-7}$
Permeability constant	ε_0	$= 8.85\times10^{-12}$
1 eV		$= 1.60\times10^{-19}\,J$

SECTION A (28 MARKS)

Question One (14 Marks)

a) Discuss metallic and covalent bonding (4 Marks)

b) Define the following terms commonly used in the study of the crystal structure of materials.

i) Basis (1 Mark)

ii) Lattice (1 Mark)

iii) Primitive unit cell (1 Mark)

c) Copper has fcc lattice of 3.61 Å. The first order Bragg reflection from (111) appears at an angle of $21.7°$. Determine the wavelength of the x-rays. (3 Marks)

d) Write Bragg's law in vector form and state the meaning of each term. (2 Marks)

e) Distinguish between atomic scattering factor and geometric structure factor in the study of the crystals. (2 Marks)

Question Two (14 Marks)

a) Sketch the dispersion relations for lattice vibrations in a monoatomic and diatomic solid. (4 Marks)

b) i) What is meant by electron density of states. (1 Mark)

ii) Sketch the electron density of states for free electron system at a temperature above 0 K. (2 Marks)

c) Show that electrical conductivity in metals is $\sigma = \frac{ne^2\tau}{m}$ where τ is the electron relaxation time, m is the mass, e is the electron charge and n is the electron concentration. (3 Marks)

d) i)Differentiate between a reciprocal lattice and direct lattice. (2 Mark)

ii) What is the meaning of the term Brillouin zone (1 Mark)

SECTION B (42 MARKS)

Question Three (14 Marks)

a) Consider a Na^+ and Cl^- ion brought from infinite separation to close proximity. Sketch on the following axes the following variables

i) The attractive forces (1 Mark)

iii) $T_2 > T_1$

d) What is meant by the Fermi level and Fermi energy? (2 Marks)

e) A copper wire of radius 1mm and length 10 meters carries a direct current of 5 ampere. Calculate the drift velocity of electron in copper if $n=5\times10^{28}/m^3$. (3 Marks)

f) List two failures of free electron theory. (2 Marks)

Question Seven (14 Marks)

a) i) What salient feature of Einstein's theory of lattice heat capacity makes it different from classical theory? (1 Mark)

ii) Show that the average energy of a solid according to Einstein's model is

$$\langle E\rangle = \frac{\hbar\omega}{e^{\frac{\hbar\omega}{KT}}-1}.$$ (3 Marks)

iii) The Einstein's model at high temperature shows that average energy $\langle E\rangle$ approaches classical limit, but it fails at low temperature. Explain? (2 Marks)

b) Using the Dybe approximation whose expression for energy shown below

$E = 9NK_BT\left(\frac{T}{\theta_D}\right)^3\int_0^{\theta_D/T}\frac{x^3dx}{e^x-1}$. Show that the heat capacity at high temperature ($T >> \theta_D$) and ($e^x - 1 \approx x$), $C_V = 3NK_B$. (4 Marks)

c) What are the assumptions of the Dybe model of the lattice specific heat? (4 Marks)

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