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OFFICE OF THE DEPUTY PRINCIPAL
ACADEMICS, STUDENT AFFAIRS AND RESEARCH

UNIVERSITY EXAMINATIONS

2020 /2021 ACADEMIC YEAR

FOURTH YEAR FIRST SEMESTER REGULAR EXAMINATION

FOR THE DEGREE OF BACHELOR OF EDUCATION SCIENCE

COURSE CODE: PHY 414

COURSE TITLE: SOLID STATE PHYSICS II

DATE: 10/03/2021 TIME: 1400 – 1700 HRS

INSTRUCTION TO CANDIDATES

- SEE INSIDE

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REGULAR – MAIN EXAM

PHY 411: SOLID STATE PHYSICS II

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*

Boltzmann's constant	$K = 1.38 \times 10^{-23}$ J/K or 8.62×10^{-5} eV/K
Electronic charge	$e = 1.60 \times 10^{-19} C$
Free electron rest mass	$m_o = 9.11 \times 10^{-31}$ Kg
Permeability of free space	$\mu_o = 4\pi \times 10^{-7}$ H/m
Permittivity of free space	$\epsilon_0 = 8.85 \times 10^{-12}$ F/m
Planck's constant	$h = 6.625 \times 10^{-34} J/s$
	$\hbar = \frac{h}{2\pi} = 1.054 \times 10^{-34}$ J/s
Proton rest mass	$M = 1.67 \times 10^{-27}$ Kg

SECTION A (28 MARKS)

Question One (14 Marks)

a) State two results of using the Kronig–Penney model with Schrodinger's wave equation. (2 Marks)

b) Sketch E versus K band diagram of a semiconductor at T=0 K and T > 0 K. (4 Marks)

c) Why does the resistivity of a metal increase with increasing temperature, whereas the resistivity of a semiconductor decreases with increasing temperature? (4 Marks)

a) Sketch the curve of Langevin function ($L(x)$) versus x where $x = \frac{\mu B}{kT}$ for paramagnetic material. For points where $x << 1$, what is the value of $L(x)$. (4 Marks)

Question Two (14 Marks)

a) Explain the meaning of the following forms of magnetism in solids in brief.

i. Diamagnetism (1 Mark)

ii. Paramagnetism (1 Mark)

iii. Ferromagnetism (1 Mark)

iv. Antiferromagnetism (1 Mark)

v. Ferrimagnetism (1 Mark)

b) Define spontaneous magnetization and sketch variation of spontaneous magnetization with temperature in the range $T < T_c$ for ferromagnetic materials. (3 Marks)

c) Briefly describe BCS theory in superconductivity. (2 Marks)

d) Sketch temperature dependence of resistivity of a typical superconducting metal. (2 Marks)

e) How is dielectric constant related to electric susceptibility? (2 Marks)

SECTION B (42 MARKS)

Question Three (14 Marks)

a) Derive an expression of conductivity of an intrinsic semiconductor. (7 Marks)

b) The conductivity of Si is $4.17\times10^{-5}\ (\Omega m)^{-1}$ and $4\times10^{-4}\ (\Omega m)^{-1}$ at $0\,^{\circ}C$ and $27\,^{\circ}C$, respectively. Determine average band gap of Si. (4 Marks)

c) Plot σ versus $1/T$ for Si in the intrinsic range. (3 Marks)

Question Four (14 Marks)

a) If ω_o and ω is the frequency of revolution of an electron around the nucleus in the absence and presence of the field B, respectively. The force equation can be written as $m\omega^2\rho = m\omega_o^2\rho - e\rho\omega B$ where ρ is the radius of orbit. Deduce the expression for diamagnetic susceptibility: $\chi_{dia} = -\dfrac{N\mu_o Ze^2}{6m}\left\langle r^2\right\rangle$ using *Langevin's theory.* (6 Marks)

b) Compare the temperature dependence of diamagnetic and paramagnetic susceptibility. (2 Marks)

c)

i. The ion Dy^{3+} has 9 electrons in the $4f$ shell. Use the Hund rules to show that J, L and S for Dy^{3+} take the values of 15/2, 5 and 5/2 respectively. (3 Marks)

ii. Calculate the paramagnetic susceptibility: $\chi = \dfrac{\mu_o N\mu_B^2}{3kT}g^2J(J+1)$ of a salt containing 1 mole of Dy^{3+} at temperature of 300 K. ($\mu_B = 9.27\times10^{-24}$ and $N = 6.023\times10^{26}$) (3 Marks)

Question Five (14 Marks)

a) Describe piezoelectricity and ferroelectricity. (4 Marks)

b) Derive an expression for electronic polarizability using classical theory. (6 Marks)

c) Determine the percentage of ionic polarizability in the sodium chloride crystal which has optical index of refraction and the dielectric constant as 1.5 and 5.6 respectively. (4 Marks)

Question Six (14 Marks)

a) State two magnetization processes that are attributed to external magnetic field in a ferromagnetic solid. (2 Marks)

b) A ferromagnetic material with $J = 3/2$ and $g = 2$ has a curie temperature of 125 K. Calculate the intrinsic flux density near 0 K. Also calculate the ratio of magnetization at 300 K in the presence of an external field of 1 mT to the spontaneous magnetization at 0 K. (6 Marks)

c) Applying the Weiss model, to an antiferromagnetic substance, derive the Neel formula: $\chi = \frac{C}{T_N + \theta}$ for the susceptibility at high temperature. (6 Marks)

Question Seven (14 Marks)

a) Using well labelled magnetization curves, explain the difference between type I and type II superconductors using the Meissner effect. (6 Marks)

b) Explain the concept of BCS ground state. (4 Marks)

c) Using well labelled plots, describe variation of entropy and specific heat with temperature for a superconductor. (4 Marks)

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