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OFFICE OF THE DEPUTY PRINCIPAL
ACADEMICS, STUDENT AFFAIRS AND RESEARCH

UNIVERSITY EXAMINATIONS

2021/2022 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: 2ND FEBRUARY, 2022 **TIME: 0900 – 1200 HRS**

INSTRUCTION TO CANDIDATES

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REGULAR – MAIN EXAMINATION

PHY 414: 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) Distinguish between donor impurity and acceptor impurity in extrinsic semiconductor. (2 Marks)

b) State the Bloch theorem. (2 Marks)

c) Draw energy level diagram for p-type semiconductor and label it. (3 Marks)

d) A rod of intrinsic silicon is 1 cm long and has diameter of 1 mm. At room temperature, the intrinsic concentration in silicon is $n_i = 1.5 \times 10^{16}$ per m^3. The electron and hole mobilities are $\mu_n = 0.13 m^2 V^{-1} s^{-1}$ and $\mu_p = 0.05 m^2 V^{-1} s^{-1}$. Calculate the conductivity σ of silicon and the resistance R of the rod. (4 Marks)

e) State Lamor theorem. (1 Marks)

f) Give the Curie theory of paramagnetism. What is Curie temperature? (2 Marks)

Question Two (14 Marks)

a) Using well labelled ordered arrangement of electron spins, distinguish between ferromagnetism, antiferromagnetism and ferrimagnetism in solids. (3 Marks)

b) State the Curie-Weiss law and explain its meaning in ferromagnetic materials. (2 Marks)

c) What is the difference between ferroelectric materials and piezoelectric materials? (4 Marks)

d) State three main characteristics of superconductors (3 Marks)

e) Describe isotope effect in superconductors. (2 Marks)

SECTION B (42 MARKS)

Question Three (14 Marks)

a) Explain why carriers reach an average drift velocity in the presence of an applied electric field. (2 Marks)

b) Given that $n = N_C \exp\left[-\left(\frac{E_C - E_F}{kT}\right)\right]$ and $p = N_v \exp\left[-\left(\frac{E_F - E_v}{kT}\right)\right]$, where the symbols have their usual meanings. Obtain an expression of the position of the Fermi-level in an intrinsic semiconductor. (5 Marks)

c) The electron concentration in silicon at T = 300 K is $n = 5 \times 10^4 cm^{-3}$.

i) Determine hole concentration, p (1 Mark)

ii) Determine the position of the Fermi level with respect to the intrinsic level. (2 Marks)

d) A particular intrinsic semiconductor has resistivity of $50\,\Omega$cm at T = 300 K and 5Ωcm at T = 330K. Neglecting the change in mobility with temperature, determine the band gap energy of the semiconductor. (4 Marks)

Question Four (14 Marks)

a) Describe the following three main contributions to polarization of dielectric material.

i) Electronic polarization (2 Marks)
ii) Ionic polarization (2 Marks)
iii) Oriental polarization (2 Marks)

b) Derive the Clausius-Mossotti relation expressing the relationship between dielectric constant and atomic polarisability. (6 Marks)

c) Why do piezoelectric crystals having centre inversion show no piezoelectricity? (2 Marks)

Question Five (14 Marks)

a) State three contributions of permanent magnetic moments that generate paramagnetism. (3 Marks)

b) Using Langevin's theory of paramagnetism, deduce an expression of paramagnetic susceptibility. (7 Marks)

c) Dy^{3+} has outer electronic configuration of $4f^9 6s^0$. Using Hund's rules, determine the Lande's g-factor from the expression $g = 1 + \frac{J(J+1) + S(S+1) - L(L+1)}{2J(J+1)}$. (4 Marks)

Question Six (14 Marks)

a) Explain the following physical arguments and ideas underlying BCS theory of superconductivity.

i) Electron-Phonon interaction (2 Marks)
ii) Cooper pair (2 Marks)
iii) Existence of energy gap (2 Marks)

b) Show that when a super conductor is placed in an external magnetic field, the field must penetrate up to a certain depth inside the superconductor. (3 Marks)

c) Compare the main properties of high-T_c with those of conventional superconductors. (3 Marks)

d) Lead in the superconducting state has critical temperature of 6.2 K at zero magnetic field and a critical field of 0.064 MAm^{-1} at 0 K. Determine the critical field at 4 K.

(2 Marks)

Question Seven (14 Marks)

a) Explain how and why magnetic domains are formed. (4 Marks)

b) Draw a typical B-H loop and describe the different magnetization processes, which lead to formation of B-H loop. (6 Marks)

c) Given that $M = Ng\mu_B(J+1)x/3$ and $x = \frac{gJ\mu_B(B+\lambda M}{kT}$. Derive Curie-Weiss law of antiferromagnetic material in the region $T > T_C$. (4 Marks)

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