KIBABII UNIVERSITY

UNIVERSITY EXAMINATIONS
2022/2023 ACADEMIC YEAR

FOURTH YEAR FIRST SEMESTER
MAIN EXAMINATIONS

FOR THE DEGREE IN BSC (PHYSICS)

COURSE CODE: SPC 412

COURSE TITLE: SOLID STATE PHYSICS II

DATE: 20/04/2023 **TIME:** 2:00-4:00PM

INSTRUCTIONS TO CANDIDATES

TIME: 2 HOURS

Answer question ONE and any TWO of the remaining

QUESTION ONE [30 MARKS]

(a) Give the difference in meaning between superconductivity and Superfluidity. [2 marks]

(b) To what temperature must lead be cooled in a magnetic field of $2000Am^{-1}$for it to become a superconductor $(B_c(0) = 0.0803T \; and \; T_c = 7.19K)$ [3 marks]

(c) What contributes mainly to heat capacity of solids [1 mark)]

(d) Aluminium has heat capacity of 0.81Jmol-1 at constant volume at 30K and Debye temperature is 375K. Estimate specific heat at 100K and 400K [R = 8.314J/mol.K] [4 marks]

(e) Calculate Bragg's angle if (111) planes of a cube (a = 3.57Å) crystal is exposed to x-rays of wavelength, $\lambda = 1.54Å$. (Assume its first order diffraction) [4 marks]

(f) Calculate the saturation magnetization of a certain metal of density$8.9g/cm^3$. [3 marks]
$[\mu_B = 9.27x10^{-24}A - m^2, A = 58.71g/mol, N_A = 6.023x10^{23}atoms/mol]$

(g) Differentiate between thermal stress and thermal shock. [2 marks]

(h) Calculate the number of free electrons in a copper conductor at 300K and hence find its conductivity if the collision time for electron scattering is $2x10^{-14}s$, [$atomic\ wt = 63.54amu$, $N_A = 6.023x10^{23}atoms/mol$, $e = 1.602x10^{-19}C, m_e = 9.11x10^{-31}kg$] [3 marks]

(i) Differentiate between Curie and Neel temperatures. [2 marks]

(j) A glass window pane has area of $3.0m^2$ and thickness of 0.6cm. $10000J$of thermal energy is conducted through the window per second when the temperature difference between the two faces is 25°C.calculate the thermal conductivity of glass. [3 marks]

(k) Calculate the relative dielectric constant of barium titanate crystal when inserted between a condenser of area $10mmx10mm$, plate separation of $2mm$ and capacitance of $1nF$. [3 marks]

QUESTION TWO [20 MARKS]

(a) Consider an electron of mass m bound to move in a one-dimensional crystal of length $0 \leq L \leq x$ .The electron is prevented from leaving the crystal by presence of large potential energy barrier at its surface defined by: - [10 marks]

$$V(x) = \begin{cases} 0 & for\ 0 < L < x \\ \infty\ for\ x \leq 0 and\ x \geq L \end{cases}$$

Basing on quantum mechanical free electron gas theory, show that the energy of an electron in state n is given by: - $E_n = \frac{h^2}{8mL^2}n^2$.Obtain also an expression for energy in a three dimensional case.

(b) Account for Ohm's law on the basis of free electron theory. [10 marks]

QUESTION THREE[20 MARKS]

(a) In some detail explain the following phenomena; paramagnetism, diamagnetism and ferromagnetism. [15 marks]

(b) Consider the Shockley equation of a diode $I = I_0 exp[(eV/kT) - 1]$show that the slope resistance r_e of I-V characteristic curve at a particular dc bias is given to a good approximation at room temperature $(300K)$ by expression:- $r_e = \frac{26}{I}$ for forward bias and $r_e \rightarrow \infty$ for reverse bias where I is in milliamps. [5 marks]

QUESTION FOUR [20 MARKS]

(a) From London's first equation of superconductivity $\nabla X J_s = \frac{-n_s e^2}{mc}\boldsymbol{B}$ and using Maxwell's equations $\nabla X \boldsymbol{B} = \mu_0 J_s$ and $\nabla X \boldsymbol{B} = 0$. Obtain an expression for London's penetration depth (λ_L). [$\nabla X \nabla X \mathbf{A} = \nabla(\nabla . \mathbf{A}) - \nabla^2 \boldsymbol{A}$] [10 marks]

(b) Explain the band theory of solids. [10 marks]

QUESTION FIVE [20 MARKS]

(a) Give important properties of metals [10 marks]

(b) Debye model of solids gives the expression for specific is given by:-

$c_V = 9N_0 k \frac{1}{x^3} \int_0^x \frac{\xi^4 e^\xi}{(e^\xi - 1)^2} d\xi$ where $N_0 k = R$, $\xi = \frac{h\upsilon}{kT}$, $x = \frac{h\upsilon_m}{kT}$ and $\theta_D = \frac{h\upsilon_m}{k}$. [10 marks]

Show that the Debye model produces the Dulong-Petit law at high temperatures and $c_V \propto T^3$.