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(University of Choice)

MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY (MMUST)

UNIVERSITY EXAMINATIONS
2021/2022 ACADEMIC YEAR
FIRST YEAR FIRST SEMESTER
SPECIAL/SUPPLIMENTARY EXAMINATIONS
FOR THE DEGREE
OF
MASTER OF SCIENCE IN PHYSICS

COURSE CODE: SPH 843E

COURSE TITLE: THEORY OF SUPERCONDUCTIVITY

DATE: TUESDAY 2ND AUGUST, 2022 **TIME:** 2 PM - 5 PM

INSTRUCTIONS TO CANDIDATES

TIME: 3 Hours

- **Answer any FIVE questions**
- **Symbols used bear the usual meaning.**

MMUST observes ZERO tolerance to examination cheating

QUESTION ONE (14 MARKS)

(a). Discuss the electrical, thermal, magnetic and mechanical properties of superconductors (7 marks)

(b). Prove that the flux enclosed by a superconducting ring is quantized (7 marks)

QUESTION TWO (14 MARKS)

By constructing a minimum energy wave function, obtain the single particle excitation energy. (14 marks)

QUESTION THREE (14 MARKS)

(a). Use a phase diagram to discuss the change in Gibb's free energy when a superconductor is subjected to an external magnetic field (6 Marks)

(b). By making a wise guess of a trial wave function containing probability pair occupancy, obtain the kinetic and the potential energy of a superconducting system (8 marks)

QUESTION FOUR (14 MARKS)

(a). Why should vortex movement should be restricted in a superconductor (2 mark)

(b). Beginning from Maxwell's fourth equation, show that the magnetic field penetrating a superconducting substance decreases exponentially (14 marks)

QUESTION FIVE (14 MARKS)

(a). Discuss and exemplify the nature of interaction of electrons in a Cooper pair. (4 marks)

(b). Obtain the jump in specific heat at the transition temperature of a superconductor. (10 marks)

QUESTION SIX (14 MARKS)

(a). The Hamiltonian which represents the interaction between two electrons mediated through a phonon exchange is given as;

a. $\boldsymbol{H_I = \sum_q \sum_{k,k'} |B_q|^2 \frac{\hbar\omega_q}{(\varepsilon_k - \varepsilon_{k-q})^2 - \hbar^2\omega_q^2} C^+_{K'+q} C^+_{k-q} C_k C_{K'}}$ where k and k' are the wave vectors of the electrons and q is phonon wavevector.

(i) Write down the electron anti-commutation relations that the operators, Cs obey (3 marks)

(ii) Fully describe the quantity B_q and state the condition for an attractive electron-electron interaction.(5 marks)

(b). Describe any 3 salient features of the BCS theory of superconductivity. (6 marks)