Total number of printed pages–7

63/2 (SEM–4) PHY 404

2024

PHYSICS

Paper : PHY 404

(Advanced Condensed Matter Physics–II)

Full Marks : 80

Pass Marks : 32

Time : Three hours

The figures in the margin indicate full marks for the questions.

1. Answer the following questions : 1×5=5

   (a) In diatomic molecule like H_2 atom, the Hamiltonian H for singlet state is

   (i) $-J/2$

   (ii) $3J/2$

   (iii) $3J/4$

   (iv) $J/2$

Contd.

(b) An intrinsically conducting polymer has

(i) delocalized n electrons in the polymer backbone

(ii) delocalized sigma electrons in the polymer backbone

(iii) localized pi electrons in the polymer backbone

(iv) delocalized pi electrons in the polymer backbone

(c) The frequency of the AC current produced when a DC voltage of 5 μV is applied across the Josephson junction is

(i) $2{\cdot}41\times10^{8}$ *Hz*

(ii) $2{\cdot}41\times10^{9}$ *Hz*

(iii) $2{\cdot}41\times10^{10}$ *Hz*

(iv) $2{\cdot}41\times10^{11}$ *Hz*

(d) What role does the Ginzburg-Landau parameter (κ) play in the Ginzburg-Landau equation ?

(i) It represents the critical temperature of the superconductor

(ii) It quantifies the strength of the magnetic field applied to the superconductor

(iii) It characterizes the type of superconductor (Type I or Type II)

(iv) It measures the ratio of the penetration depth to the coherence length

(e) The factors that determine the magnetic behavior of small clusters is

(i) atomic arrangement

(ii) nearest neighbour distance

(iii) Both (i) and (ii)

(iv) None of the above

2. Answer the following questions : 2×5=10

(a) Discuss the indirect exchange and super exchange interaction with examples.

(b) Discuss the limitations and challenges associated with the observation of De Hass-van Alphen oscillations in experimental studies.

(c) Define high-temperature superconductors (HTS) and briefly discuss the distinctions between HTS and conventional superconductors.

(d) Discuss the vortex state in Type II superconductors and its relevance to their behavior in magnetic fields.

(e) Explain how spin-dependent scattering contributes to the phenomenon of GMR in magnetic multilayer structures.

3. Answer the following questions : ***(any five)*** 5×5=25

(a) What is cyclotron resonance ? Obtain the expression for resonant frequencies of an electron in magnetic field. 1+4=5

(b) Deduce the Heisenberg's Hamiltonian for H_2 molecule and explain whether H_2 is ferromagnetic or antiferromagnetic based on exchange criteria. 4+1=5

(c) Define colloidal dispersion and describe the different types of colloids, including sols, gels and emulsions.

(d) Discuss the distinctions in entropy and specific heat between the normal state and the superconducting state.

(e) Show that the AC Josephson current exhibits oscillatory behaviour characterized by a frequency $\omega = \frac{2eV}{\hbar}$.

(f) Explain the phenomenon of superparamagnetism in small ferromagnetic materials. What are the key characteristics of superparamagnetic behavior and how does it differ from typical ferromagnetic behavior ? What is blocking temperature ? 3+1+1=5

(g) What does spin diffusion length refer to ? Explain spin polarization and spin accumulation at interfaces between ferromagnetic and nonmagnetic materials. 1+4=5

4. Answer the following questions : ***(any four)*** 10×4=40

(a) (i) Explain the terms 'ferromagnetic spin wave' and 'magnon'. 3

(ii) Obtain the dispersion relation of ferromagnetic spin waves detailing the mathematical steps involved. 7

(b) (i) Explain the concept of magneto-conductivity and its significance in understanding the electrical properties of materials. 4

(ii) Discuss the key factors influencing the magnetoconductivity in the material and obtain the expression for magnetoconductivity when considering an applied magnetic field aligned along the z-axis. 6

(c) (i) Discuss the influence of polymer molecular structure on mechanical properties. Explain how factors such as chain length, branching and cross-linking affect polymer stiffness, strength, and ductility. 5

(ii) What are intrinsic conducting polymers? Describe the different types and highlight their advantages. 5

(d) Derive the London equations for superconductors. Explain the physical significance of the London equations in describing the behaviour of superconductors. 8+2=10

(e) What is a superconducting quantum interference device (SQUID) and what are its core components? Discuss the output voltage with respect to applied magnetics flux of a SQUID. Derive the mathematical expressions governing the total current in a DC SQUID. 2+3+5=10