Department of Physics, Indian Institute of Tech, Delhi

EPL206, SOLID STATE PHYSICS, MAJOR EXAMINATION April 29, 2008

II SEMESTER 2007-08 DURATION: 2 hrs.

MAX. MARKS : 50

NOTE : 1. All questions are to be attempted.

2. State/define all the symbols used in your answers.

3. Symbols used in the question paper have their usual meanings. However, you need to define in your answers.

1 (a) Calculate the maximum radius of a sphere which fits an octahedral void in a octahedron (formed by hard spherical atoms touching along the edges). Assume R = radius of the hard sphere.

(b) In a fcc unit cell of lattice parameter 'a', draw [121] and (212). Also, estimate the linear/planar density of atoms along the given direction/in the given plane. (2+4=6)

2 (a) With the help of neat diagrams show that the position of atoms in a unit cell affects the intensities but not the direction of the diffracted (x-ray) beams.

(b) State the reasons/characteristics of low energy electrons which make these suitable for LEED. (5+2=7)

3 (a) A net polarization P is induced in a linear isotropic dielectric material of relative permittivity, ϵ_r, when it is subjected to an external field, E. Starting from an expression for the Lorentz field, derive the Clausius - Mossoti equation.

(b) An ionic crystal (AB) has one $A^+ B^-$ pair per unit cell, and has a lattice parameter of 0.4 nm. The electronic polarizability of A^+ and B^- ions is 3×10^{-40} and 3.1×10^{-40} Fm^2, respectively; and the mean ionic polarizability per ion pair is 6×10^{-40} Fm^2. Calculate the dielectric constant of the crystal at optical frequencies. (4+4=8)

4 (a) In a neat diagram show $\vec{\mu}_{spin}$, μ_z and $\vec{S}$. (i) State the relation between $\vec{\mu}_{spin}$ and $\vec{S}$.

(ii) Derive an expression for the precession frequency of $\vec{S}$.

(iii) Calculate the average magnetic moment of an isolated sodium atom.

(iv) How are the above answer, μ_z and β related with each other?

4(b)(i). Explain Pauli's theory of paramagnetism, and derive an expression for χ_{para}.

(ii) Using the above expression, and that $g(E_F)$ of a paramagnetic material is $7.54 \times 10^{46}\ J^{-1} m^{-3}$, calculate its χ_{para}.

(7+5=12)

5.(a) A bar magnet of length l has L-shaped ferromagnetic pieces, of length l each, attached to its ends, with an air gap of $l/10$. Assume the cross-sectional area of the bar magnet and of yokes as A each and of air gap as $A/4$. Also assume that the magnetic flux through the magnet, the two yokes and in the air gap is same.

(i) Obtain an expression for B_m / H_m, and hence

(ii) What do you infer about the mag. properties of the magnets

(iii) Calculate H_g/H_y, assuming $\mu_{ry} = 1000$.

(b) (i) With the help of neat diagrams explain the phenomenon of giant magnetoresistance (GMR).

(ii) State an application of GMR.

(iii) How is GMR different from CMR. (5+4=9)

6. (a) Describe a method to distinguish an ideal conductor from a superconductor.

(b) With the help of neat diagrams briefly discuss the variation of B and ρ with temperature of a type II superconductor.

(c) (i) What is an "$\bar{e}$-pair wave."

(ii) Write an expression for the phase-difference across two points X, Y in a current carrying superconductor placed in a magnetic field.

(iii) Define a 'fluxoid' and a 'fluxon'.

(iv) Calculate the value of a fluxon. (2+2+4=8)

USEFUL DATA: $N_A = 6.02 \times 10^{23}\ mol^{-1}$

$k = 1.38 \times 10^{-23}\ J K^{-1}$

$m_e = 9.1 \times 10^{-31}\ kg$; $e = 1.6 \times 10^{-19}\ C$,

$\mu_0 = 4\pi \times 10^{-7}\ H m^{-1}$; $\epsilon_0 = 8.85 \times 10^{-12}\ F m^{-1}$.

$h = 6.626 \times 10^{-34}\ Js$; $\hbar = 1.055 \times 10^{-34}\ Js$

$\beta = 9.27 \times 10^{-24}\ J T^{-1}$