2014

(6th Semester)

PHYSICS

TWELFTH (A) PAPER

(Solid-State Physics—II)

Full Marks : 55

Time : 2 hours

(PART : B—DESCRIPTIVE)

(*Marks* : 35)

The figures in the margin indicate full marks for the questions

1. Show that the dispersion relation for the lattice waves in a monoatomic linear lattice of mass *m*, spacing *a* and nearest neighbor interactions *f* is equal to $\omega_{max} \sin \frac{ka}{2}$, where $\omega_{max} = \sqrt{\frac{4f}{m}}$, ω = angular frequency and k = wave vector. Discuss the dispersion behavior at *(a)* low frequencies and *(b)* high frequencies. 4+1½+1½=7

(Turn Over)

Or

Write short notes on the following : $3\frac{1}{2} \times 2 = 7$

(a) Phase and group velocities

(b) Acoustic and optical modes of vibrations

2. Obtain an expression for paramagnetic susceptibility using quantum theory. How does it differ from Langevin's classical theory? 6+1=7

Or

Describe the Weiss molecular field theory of ferromagnetism and discuss how the spontaneous magnetization changes with temperature. From Weiss theory, obtain the relation between Curie temperature and Weiss molecular field constant. 3+2+2=7

3. Derive an expression for local field acting at an atom. Using the local field expression, obtain Clausius-Mosotti relation between polarizability and dielectric constant of a solid. 5+2=7

Or

Consider a dielectric placed under an external electric field $\vec{E} = \vec{E}_0 \cos \omega t$. Discuss the condition under which dielectric loss would occur and also obtain the expression for dielectric loss in terms of imaginary part of the dielectric constant. 2+5=7

4. Discuss the Kronig-Penney model for the motion of an electron in a linear lattice. Solve the wave equation for an electron moving in the following potential field :

$$u(x) = 0 \text{ for } 0 < x < a; \; u(x) = V_0 \text{ for } a < x < b$$

Show that for $E < V_0$ it leads to the equation

$$\frac{\beta^2 - \alpha^2}{2\alpha\beta} \sinh(\beta b) \sin(\alpha a) + \cosh(\beta b) \cos(\alpha a) = \cos(a+b)k$$

where $\alpha^2 = \frac{2mE}{\hbar^2}$ and $\beta^2 = 2m(V_0 - E)/\hbar^2$. 2+5=7

Or

Show that the effective mass of an electron in an energy band is given by

$$m^* = \frac{\hbar^2}{\left(\frac{d^2E}{dk^2}\right)}$$

Discuss the variation of effective mass in the first Brillouin zone and also explain the concept of holes. 4+3=7

5. *(a)* What are superconductors? Write down an empirical relation between a critical field and a critical temperature. Explain why it is not possible to construct a high field superconducting magnet. 1+1+2=4

(b) Discuss how the superconducting energy gap changes with temperature. 3

Or

Derive the London equations and also obtain an expression for London penetration depth. 5+2=7

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(PART : A—OBJECTIVE)

(*Marks* : 20)

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SECTION—A

(*Marks* : 5)

Put a Tick (✓) mark against the correct answer in the brackets provided : $1 \times 5 = 5$

1. The effective number of electrons in a completely filled band is

   (a) 1 ( )

   (b) 0 ( )

   (c) infinity ( )

   (d) 100 ( )

2. For a dielectric placed in an alternating electric field, the phase difference between an electric displacement vector $\vec{D} = \vec{D}_0 \cos \omega t$ and displacement current density $\vec{J} = -\omega \vec{D}_0 \sin \omega t$ is

(a) $\pi / 2$ ( )

(b) 0 ( )

(c) π ( )

(d) 2π ( )

3. According to BCS theory, the exchange of virtual phonons between the two electrons forming Cooper pair takes place through

(a) magnetic field ( )

(b) spin-orbit interaction ( )

(c) lattice deformation ( )

(d) electric field ( )

4. In ferromagnetic materials, within a given domain

(a) atomic dipoles aligned randomly ( )

(b) all the atomic dipoles aligned in the same direction ( )

(c) atomic dipoles aligned in such a way that the direction of the consecutive dipole moments are opposite to each other ( )

(d) resultant dipole moment is zero ( )

5. In a linear one-dimensional diatomic lattice, the maximum allowed frequency for an acoustic branch is obtain at

(a) zone boundaries ( )

(b) zone centre ( )

(c) mid-way between zone centre and zone boundaries ( )

(d) infinite distance from zone centre ( )

SECTION—B

(*Marks* : 15)

Answer the following questions briefly : $3 \times 5 = 15$

1. The speed of sound in a linear monoatomic chain is 1×10^4 m/s. The mass of each atom is 6×10^{-26} kg and the equilibrium atomic separation is 4Å. Assuming only nearest neighbour interactions, find the force constant.

3. Explain in brief the physical basis of diamagnetism.

2. Explain in brief the physical basis of diamagnetism.

3. In an atom, if the equation of motion of an electron cloud displaced from its original position around its nucleus is $m\frac{d^2u}{dt^2}+\beta u=0$, where m and β are the mass and force constant respectively, obtain the expression for the characteristic frequency of the oscillating electron cloud.

4. In Kronig-Penney model if we consider a delta function periodic potential, show that for extremely large barrier strength ($P \to \infty$), the electron in the potential field is equivalent to a particle in a constant potential box of atomic dimension.

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8. What are Type I and Type II superconductors? Give one example of each.

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