Total No. of Printed Pages—4

5 SEM TDC PHYH (CBCS) C 11

2024

(November)

PHYSICS

(Core)

Paper : C–11

(Quantum Mechanics and Applications)

Full Marks : 53

Pass Marks : 21

Time : 3 hours

The figures in the margin indicate full marks for the questions

1. Choose the correct answer from the following : 1×5=5

(a) The de Broglie waves are

(i) electromagnetic waves

(ii) matter waves

(iii) mechanical waves

(iv) standing waves

(b) The solution of Schrodinger equation in three dimensions is expressed as

(i) $\psi(\vec{r}, t) = \psi(\vec{r})e^{-iEt}$

(ii) $\psi(\vec{r}, t) = \psi(\vec{r})e^{-\frac{iE}{\hbar}t}$

(iii) $\psi(\vec{r}, t) = \psi(\vec{r})e^{\frac{iE}{\hbar}t}$

(iv) $\psi(\vec{r}, t) = \psi(\vec{r})e^{-\frac{iE}{\hbar}k}$

(c) The energy of a one-dimensional harmonic oscillator in second excited state is

(i) $\frac{1}{2}\hbar\omega$ (ii) $\frac{3}{2}\hbar\omega$

(iii) $\frac{5}{2}\hbar\omega$ (iv) zero

(d) The angular momentum for an electron in the d-state of the hydrogen atom is

(i) 0 (ii) $\sqrt{2}\hbar$

(iii) $\sqrt{6}\hbar$ (iv) $\sqrt{10}\hbar$

(e) The values of orbital and spin gyromagnetic ratios for electron are

(i) $g_l = 0$ and $g_s = 2$

(ii) $g_l = 1$ and $g_s = 2$

(iii) $g_l = 1$ and $g_s = 1$

(iv) $g_l = 2$ and $g_s = 1$

(Continued)

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

(a) Obtain the commutator relation for position and momentum operator.

(b) Show that probability density of a quantum mechanical particle is independent of time.

(c) How are the zero point energy and uncertainty principle related to each other?

(d) Define and write down the expression for Larmor frequency.

(e) Briefly discuss the spectra of alkali atoms.

3. (a) Find the expectation value of momentum of a particle whose normalized wave function is

$$\psi(x) = \frac{1}{\sqrt{2a}}e^{i(kx-\omega t)}$$

in the interval $(-a, a)$. 3

(b) Distinguish between normal and anomalous Zeeman effect. 3

(c) Briefly discuss the coupling of orbital and spin angular momenta in the vector model of atom. 3

4. (a) Show that the number of final levels is the same for L-S and J-J coupling for an electron in $4p\,4d$ configuration. 6

(Turn Over)

(b) Obtain an expression for the wave function of a Gaussian wave packet. Briefly explain the spread of a Gaussian wave packet. 4+2=6

Or

Show that momentum space wave function is Fourier transform of the position space wave function. 6

(c) Obtain an expression for the energy of a simple harmonic oscillator using Frobenius method. 6

Or

Obtain the energy eigenvalues for a particle confined in a one-dimensional square well potential.

(d) Obtain the Schrodinger equation in spherical polar coordinates from the corresponding equation in Cartesian coordinates. 7

Or

Obtain three independent differential equations from the Schrodinger equation in each of the spherical polar coordinates for the electron of the hydrogen atom.

5. Write short note on any *one* of the following : 4

(a) Stern-Gerlach experiment

(b) Space quantization

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5 SEM TDC PHYH (CBCS) C 12

2024

(November)

PHYSICS

(Core)

Paper : C–12

(Solid-State Physics)

Full Marks : 53

Pass Marks : 21

Time : 3 hours

The figures in the margin indicate full marks for the questions

1. Choose the correct option from the following : 1×5=5

(a) Repeatable entity of a crystal structure is known as

(i) crystal

(ii) lattice

(iii) unit cell

(iv) Miller indices

(b) For solids, the optical and acoustic branches coincide and forbidden band vanishes at

$$k = \pm\frac{\pi}{2a}$$

when (mass of light and heavy atoms are m and M respectively)

(i) $m < M$

(ii) $m > M$

(iii) $m = M$

(iv) $mM = 1$

(c) The paramagnetic susceptibility varies as

(i) T

(ii) T^2

(iii) $\frac{1}{T}$

(iv) $\frac{1}{T^2}$

(d) Ionic polarizability

(i) increases with T

(ii) decreases with T

(iii) is independent of T

(iv) None of the above

(Continued)

(e) Hall effect can be used to measure the

(i) charge carrier density only

(ii) type of semiconductor only

(iii) mobility of charge carrier only

(iv) All of the above

2. Answer any *five* from the following : 2×5=10

(a) Define reciprocal lattice. State the mathematical relation of this lattice with direct lattice.

(b) Define geometrical structure factor. How is it related to atomic scattering factor?

(c) Explain ferrimagnetism. What are ferrites?

(d) What are optical absorption and infrared absorption in a dielectric?

(e) What is piezoelectricity? Give an example of a crystal that is piezoelectric but not ferroelectric.

(f) Define mobility of charge carrier and write its unit.

3. (a) Find the Miller indices of a plane having intercepts of $8a$, $4b$ and $2c$ on the a-, b- and c- axes, respectively. 2

(Turn Over)

(b) Write Bragg's law of crystal diffraction. Give its significance. 1+1=2

4. (a) Derive the vibrational modes of a diatomic lattice. Name the different branches of the dispersion relation curve. 4+2=6

(b) State Dulong and Petit law of specific heat of solid. 2

5. Obtain an expression for diamagnetic susceptibility using the Langevin's theory. What is the significance of negative susceptibility? 5+1=6

Or

Give an account of quantum theory of paramagnetism and derive an expression for susceptibility. 6

6. (a) Obtain an expression for dipolar polarizability at moderate temperature. 4

(b) Classify different groups of ferroelectric materials on the basis of symmetry. Also give one example of each group. 4

7. (a) Discuss the formation of allowed and forbidden energy bands on the basis of the Kronig-Penney model. 4

(*Continued*)

(b) A semiconducting crystal of 1·2 cm length, 5 mm width and 1 mm thick is placed in a magnetic field 0·5 Tesla perpendicularly to its flat surface. When a current of 20 mA flows through its sample along its length, a Hall voltage of 37 micro-Volt is developed across its width. Determine the Hall Coefficient of the specimen. 3

Or

What is an extrinsic semiconductor and how can they be achieved? Draw the energy band diagram of *(a) n*-type semiconductor and *(b) p*-type semiconductor. 2+1=3

8. (a) What is superconductivity? How do magnetic and electrical properties of superconductors differ from those of normal conductor? 1+2=3

(b) What do you mean by flux exclusion and what is Meissner effect? 2

Or

Define isotope effect in superconductor mentioning its importance.