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5 SEM TDC PHYH (CBCS) C 11

2023

(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 momentum of a photon of energy E is

(i) Ec *(ii)* E/c

(iii) E^2c *(iv)* E/c^2

(b) The Hamiltonian operator is expressed as

(i) $\hat{H} = \frac{\hbar^2}{2m}\nabla^2 + V(\vec{r})$

(ii) $\hat{H} = -\frac{\hbar^2}{2m}\nabla^2 + V(\vec{r})$

(iii) $\hat{H} = -\frac{\hbar^2}{2m}\nabla^2 - V(\vec{r})$

(iv) $\hat{H} = \frac{\hbar^2}{2m}\nabla^2 - V(\vec{r})$

(c) The zero point energy of a harmonic oscillator is

(i) $\frac{5}{2}\hbar\omega$ (ii) $\frac{3}{2}\hbar\omega$

(iii) $\frac{1}{2}\hbar\omega$ (iv) zero

(d) The number of values of magnetic quantum numbers (m_l) for a given l is

(i) $2l-1$ (ii) $2l+1$

(iii) $2l$ (iv) infinite

(e) One Bohr magneton is defined as

(i) $\mu_B = \frac{e\hbar}{2m}$ (ii) $\mu_B = \frac{\hbar}{2m}$

(iii) $\mu_B = \frac{2e\hbar}{m}$ (iv) $\mu_B = \frac{e\hbar}{2m}$

2. Answer the following questions : $2\times5=10$

(a) Briefly discuss the principle of linear superposition of quantum states.

(Continued)

(b) How does a Gaussian wave packet spread with time?

(c) What are the boundary conditions which should be satisfied by a wave function and its derivative at the boundary of a potential?

(d) What do you mean by gyromagnetic ratio? What are the values of orbital and spin gyromagnetic ratios of an electron?

(e) What is total angular momentum of an electron? Calculate its value for an electron in the d orbital.

3. (a) Calculate the expectation value of $\hat{p}$ for the wave function

$$\psi(x) = \left(\frac{2}{L}\right)^{1/2} \sin\frac{\pi x}{L}$$

in the region $0 < x < L$. 3

(b) Briefly explain the concept of space quantization. 3

(c) What are identical particles? How can Pauli's exclusion principle be proved using the concept of symmetric and anti-symmetric wave functions? 1+3=4

(d) Show the ordering of various possible terms for the $3p\,3d$ configuration using Hund's rule. 5

(Turn Over)

4. *(a)* Obtain an expression for the general solution of the time-dependent Schrödinger equation in terms of linear combinations of stationary states. 6

Or

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

(b) Obtain an expression for the energy eigenfunction of a simple harmonic oscillator and hence express the ground state eigenfunction using the concept of Hermite polynomials. 6

(c) Obtain the Schrödinger equation in spherical polar coordinates from the corresponding equation in Cartesian coordinates. 7

Or

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

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

(a) Normal Zeeman effect

(b) Paschen-Back effect

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