4 SEM TDC PHY M 2

2017

(May)

PHYSICS

(Major)

Course : 402

(Quantum Mechanics)

Full Marks : 60
Pass Marks : 24/18

Time : 3 hours

The figures in the margin indicate full marks for the questions

1. Choose the correct answer : 1×6=6

(a) In the Heisenberg's gamma ray microscope experiment, gamma ray was used because

(i) gamma ray source is easily available

(ii) it is easily detectable

(iii) it increases the resolving power of the microscope

(iv) it decreases the resolving power of the microscope

(b) The wavelength λ of matter wave associated with a particle of mass m moving with a kinetic energy E is equal to

(i) $\sqrt{2mE}$

(ii) $2mE$

(iii) $\frac{h}{\sqrt{2mE}}$

(iv) $\frac{h}{\sqrt{mE}}$

(c) The minimum uncertainty in the simultaneous determination of position (Δx) and momentum (ΔP) is related by

(i) $\Delta x \Delta P = \frac{\hbar}{2}$

(ii) $\Delta x \Delta P = \frac{h}{2}$

(iii) $\Delta x \Delta P = 2\hbar$

(iv) $\Delta x \Delta P = \frac{\hbar}{\sqrt{2}}$

(Continued)

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(d) Schrödinger's one-dimensional wave equation is

(i) first order in x and second order in t

(ii) first order in t and second order in x

(iii) second order in both x and t

(iv) first order in both x and t

(e) A free particle has

(i) definite energy but indefinite momentum

(ii) indefinite energy but definite momentum

(iii) definite energy and definite momentum

(iv) indefinite energy and indefinite momentum

(Turn Over)

(f) The momentum operator corresponds to

(i) $\frac{h}{i}\nabla$

(ii) $\frac{\hbar^2}{i}\nabla$

(iii) $\frac{\hbar}{i}\nabla$

(iv) $i\hbar\nabla^2$

2. (a) State and explain Planck's quantum theory of radiation. 1+2=3

(b) Express linear momentum of a photon in terms of wave vector $\vec{k}$. 2

(c) An incident X-ray photon of frequency ν_0 is scattered by a free electron at rest through an angle ϕ. Show that the change in wavelength of the photon is

$$\Delta\lambda = \frac{h}{m_0 c}(1-\cos\phi)$$

where m_0 is the rest mass of the electron. 5

(Continued)

3. (a) State and explain Bohr's complementary principle. 1+1=2

(b) Prove mathematically Heisenberg's uncertainty principle for one-dimensional wave packet. 5

Or

Describe Young's double-slit experiment.

(c) An electron is confined to a box of length $1{\cdot}1\times10^{-8}$ m. Calculate the minimum uncertainty in its velocity. 3

4. (a) Derive Schrödinger's three-dimensional time-independent wave equation. Why is this equation not valid for relativistic particles? 4+1=5

(b) What is the physical significance of wave function ψ? Show that the probability density ρ and probability current density $\vec{j}$ satisfy the continuity equation

$$\frac{d\rho}{dt} + \vec{\nabla}\cdot\vec{j} = 0$$ 1+4=5

(Turn Over)

5. *(a)* Calculate the transmission coefficient of electrons of energy E through one-dimensional rectangular potential barrier. 5

(b) What is meant by stationary state? Find the stationary state solution independent of time by making use of probability distribution function. 1+4=5

6. *(a)* Define Hermitian operator. Show that—

(i) Hermitian operators have real eigenvalues;

(ii) if two Hermitian operators commute, then their product is also a Hermitian operator. 1+2+3=6

(b) State and prove Ehrenfest's theorem. 1+5=6

(Continued)

(c) Show that the operator

$$\frac{xp + px}{2}$$

is a linear operator. 2

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