2017

PHYSICS

(Major)

Paper : 5.3

(Quantum Mechanics and Astrophysics)

Full Marks : 60

Time : 3 hours

The figures in the margin indicate full marks for the questions

Write the answers to the two Groups in separate books

GROUP—A

(Quantum Mechanics)

(*Marks* : 40)

1. Answer any *four* questions as directed : 1×4=4

(a) Select the correct answer :

Quantum nature of light emerged in an attempt to explain

(i) radioactivity

(ii) interference

(iii) blackbody radiation

(iv) pair production

(b) What is the relation between group velocity and phase velocity?

(c) What is the probability of finding a particle represented by $\psi(r, t)$ in unit volume?

(d) Select the correct answer :

In view of uncertainty principle, the radiation emitted by an atom can have

(i) a definite frequency

(ii) a band of frequencies

(iii) a definite phase

(iv) a definite wavelength

(e) Show that expectation value of H is the total energy E of the system.

(f) What is the expectation value of momentum $\langle p \rangle$ of a particle trapped in a one-dimensional box of length a?

2. Answer any *three* questions : 2×3=6

(a) A beam of monoenergetic neutrons corresponding to 27 °C is allowed to fall on a crystal. A first-order reflection is observed at a glancing angle 30°. Calculate the interplanar spacing of the crystal.

Given, Planck's constant $h = 6 \cdot 62 \times 10^{-34}$ Js, mass of the electron $m = 1 \cdot 67 \times 10^{-27}$ kg and Boltzmann constant $k = 1 \cdot 38 \times 10^{-23}$ J/K.

(Continued)

(b) On the average, an excited state of a system remains in that for 10^{-11} s. What is minimum uncertainty in the energy of an excited state?

(c) Distinguish between classical and quantum harmonic oscillators.

(d) What do you mean by reflection coefficient and transmission of a particle incident at the surface of a step potential?

(e) The lowest energy of a particle entrapped in a box is 40 eV. What are the next three higher energies the particle can have?

3. Answer any *four* questions : 5×4=20

(a) The work function of aluminium is 4·2 eV. Calculate the kinetic energy of the fastest and slowest photoelectrons, the stopping potential and cut-off wavelength when light of wavelength 2000 Å falls on a clean aluminium surface. [Given : $h = 6 \cdot 63 \times 10^{-34}$ Js, $c = 3 \times 10^{8}$ m/s, 1 eV = $1 \cdot 6 \times 10^{-19}$ J and 1 Å = 10^{-8} m] 5

(b) An incident X-ray photon of frequency ν_0 is scattered by a free electron at rest through an angle ϕ. Using relativistic expression of electron energy, show that the change in the wavelength of the photon is given by

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

where m_0 = rest mass of electron, h is the Planck's constant and c is the velocity of light. 5

(c) Using uncertainty relation, show that an electron cannot reside inside a nucleus.

The maximum uncertainty in the position of an electron in a nucleus is 2×10^{-14} m. Find the minimum uncertainty in its momentum. 2+3=5

(d) In what respect does the Schrödinger equation differ from classical wave equation? Explain the term 'stationary state of a quantum mechanics' system. In a stationary state E, what is the form of time-dependent part of the wave function? 2+1+2=5

(e) What are the properties satisfied by a physical wave function? Normalise the wave function $\psi(x) = Ae^{-(\frac{\alpha}{2})x^2}$ to unity in domain $x \in [-\alpha, \alpha]$, here α is constant, $\Gamma\frac{1}{2} = \sqrt{\pi}$. 2+3=5

Or

State and prove Ehrenfest's theorem. 5

(f) Describe briefly Davisson-Germer experiment. What inference may you draw from this experiment? 3+2=5

4. Answer any *two* questions : 5×2=10

(a) Write down the Schrödinger equation for a linear harmonic oscillator. What are the eigenvalues and eigenfunctions of the Hamiltonian of a linear harmonic oscillator? Explain the significance of zero-point energy of the oscillator. 1+2+2=5

(b) Derive the continuity equation from the time dependent Schrödinger equation of a particle moving in a real potential. Give the physical interpretation of the continuity equation you derive. 4+1=5

(c) What are the conjugate variables in quantum mechanics? Give any one pair of conjugate variables and obtain their commutation relation. 1+1+3=5

GROUP—B

(Astrophysics)

(*Marks* : 20)

5. Answer any *three* from the following : 2×3=6

(a) What is the difference between solar time and sidereal time? What is the right ascension (α) and the declination (δ) of the point of vernal equinox? 1+1=2

(b) What is zodiac? State the relation among right ascension, local sidereal time and hour angle. 1+1=2

(c) The blue magnitudes of star 1 and star 2 are $B_1 = 5 \cdot 2$ m and $B_2 = 6 \cdot 7$ m respectively. The visual magnitude v for both the stars is observed as 5 m. Derive the colour index (CI) of each star. 2

(d) Luminosity of Regal Star in Orion constellation is 17000 that of our Sun. If the surface temperature of the Sun is 6000 K, calculate the temperature of the Regal Star. 2

(e) What is the apparent and absolute magnitude of a star? The sun has an apparent magnitude 26·5 m, calculate its absolute magnitude. 1+1=2

6. Answer any *two* of the following : 4×2=8

   (a) Draw a neat HR diagram showing the main sequence, red giant, red super-giant and the white dwarf stars. Show the evolutionary track of Sun like stars in the HR diagram. 2+2=4

   (b) What is the energy generation mechanism inside the main sequence stars? Which reaction cycle dominates in the Sun like stars? Discuss carbon-nitrogen-oxygen (CNO) cycle. 1+1+2=4

   (c) Show how the parallax method is used for determination of stellar distances. Why is it not possible to measure very distant object by this method? 3+1=4

7. Write short notes on any *two* of the following : 3×2=6

   (a) Mass-luminosity relation

   (b) Chandrasekhar limit

   (c) Protostar

   (d) Supernova

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