

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 : $1 \times 4 = 4$

(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
 $h = 6.62 \times 10^{-34}$ Js, mass of the electron
 $m = 1.67 \times 10^{-27}$ kg and Boltzmann
constant $k = 1.38 \times 10^{-23}$ J/K.

- (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 : $h = 6.63 \times 10^{-34}$ Js, $c = 3 \times 10^8$ m/s, $1 \text{ eV} = 1.6 \times 10^{-19}$ J and $1 \text{ Å} = 10^{-8}$ 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

(6)

GROUP—B

(**Astrophysics**)

(Marks : 20)

5. Answer any *three* from the following : $2 \times 3 = 6$

- (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 $B_1 = 5.2$ m and $B_2 = 6.7$ 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 : $4 \times 2 = 8$

(a) Draw a neat HR diagram showing the main sequence, red giant, red supergiant 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 : $3 \times 2 = 6$

(a) Mass-luminosity relation

(b) Chandrasekhar limit

(c) Protostar

(d) Supernova

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