

2018

PHYSICS

( Major )

Paper : 5.3

Full Marks : 60

Time : 3 hours

*The figures in the margin indicate full marks  
for the questions*

GROUP—A

**( Quantum Mechanics )**

( Marks : 40 )

1. Answer any *four* questions as directed :  $1 \times 4 = 4$

(a) Select the correct answer :

All the radiation laws can be shown to be special case of

(i) Wien's law

(ii) Rayleigh-Jeans law

(iii) Planck's law

(iv) Stefan-Boltzmann law

- (b) Which statement is correct?
- (i) Phase velocity ( $v_p$ ) of light wave is independent of  $\lambda$  in vacuum.
  - (ii) Phase velocity of matter depends on  $\lambda$  in vacuum.
  - (iii) Phase velocity of matter wave is independent on  $\lambda$  in vacuum.
  - (iv) Phase velocity of light wave is dependent on  $\lambda$  in vacuum.

(c) What is the ground-state energy of a linear harmonic oscillator?

(d) Show that

$$\left[ x, \frac{\delta^2}{\delta x^2} \right] = -2 \frac{\delta}{\delta x}$$

(e) What is the total number of energy level (or degeneracy) for  $n$ th state of hydrogen atom?

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

(a) A radio station operates at frequency of 103.7 Hz with a power output of 200 kW. Determine the rate of emission of quanta from the station.

- (b) What is the physical significance of the wave function  $\psi(x, t)$ ?
- (c) Assume the uncertainty in the location of a particle is equal to its de Broglie wavelength. Show that the uncertainty in the velocity is equal to its velocity.
- (d) What is quantum mechanical tunnelling? Under what condition, the transmission coefficient  $T = 1$ ?
- (e) Draw the wave function of a particle in a box of infinite depth.

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

- (a) The energy distribution of blackbody radiation is given by Planck's law :

$$\rho(\lambda T) = 8\pi hc / \lambda^5 \frac{1}{\exp\left(\frac{hc}{\lambda kT}\right) - 1}$$

Show that for long wavelength

$$\rho(\lambda, T) \rightarrow 8\pi kT / \lambda^4$$

and for short wavelength

$$\rho(\lambda T) \rightarrow 8\pi hc / \lambda^5 \exp\left(\frac{-hc}{\lambda kT}\right)$$

What is Planck's quantum hypothesis?  
Mention one experiment for determining  
Planck's constant  $h$ .

3+1+1=5

- (b) An  $\alpha$ -particle is accelerated through a potential difference of 2000 volts. What is the wavelength of the associated de Broglie wave?

Given, mass of the proton =

$$1.67 \times 10^{-27} \text{ gms}$$

Planck's constant

$$h = 6.62 \times 10^{-27} \text{ erg sec} \quad 5$$

- (c) (i) State and explain Heisenberg uncertainty principle.
- (ii) Give an account of the  $\gamma$  ray microscope experiment.  $2+3=5$
- (d) Explain the need for differential wave equation. Starting from the wave equation and introducing energy and momentum of the particle, obtain three-dimensional Schrödinger equation in time-dependent form.  $2+3=5$
- (e) (i) What is one-dimensional potential step?  $1$
- (ii) A particle of mass  $m$  is moving in one-dimensional potential given by

$$V = \begin{cases} 0 & \text{for } x < 0 \\ \nu_0 & \text{for } x > 0 \end{cases}$$

If energy  $E$  of the incident particle is greater than  $\nu_0$ , then calculate the coefficients of refraction and transmission.  $2+2=4$

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

(a) (i) What is an observable corresponding to a quantum mechanical system?

(ii) Establish the relation

$$[L_x, L_y] = i\hbar L_z; [L^2, L_z] = 0$$

where the notations have their usual meanings. What conclusion about the eigenfunction of the operators involved can be shown from those relation? 1+4=5

(b) Discuss the wave mechanics of the electron in a hydrogen atom in a spherically symmetric potential and derive the energy state and energy function. 2+3=5

(c) Briefly discuss G. P. Thomson's experiment of electron diffraction, and its significance for quantum theory. 5

## GROUP—B

## ( Astrophysics )

( Marks : 20 )

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

- (a) Draw a neat diagram of the celestial sphere showing a star in northern hemisphere, the celestial equator hour angle and the right ascension of the star. 2
- (b) If one P-P chain transform  $4.8 \times 10^{-29}$  kg, then how many reaction cycles must produce the total transformed mass per second? 2
- (c) What is universal time? Express 2165 sidereal days in terms of mean solar days. 2
- (d) What do you mean by color index? What is the declination ( $\delta$ ) at celestial pole and celestial equator?  $1+1=2$
- (e) Calculate the temperature of Sun from the following data : 2

$$\lambda_m T = 0.287, \lambda_m = 4753 \text{ \AA}$$

6. Answer any *two* of the following :  $4 \times 2 = 8$

(a) How are the spectra classified? What are the various spectral classes? Show that the colour of a star defines a spectral class.  $1+1+2=4$

(b) What is the main process that creates energy in solar system? Discuss P-P cycle. What is the end product of CNO cycle reaction under equilibrium condition?  $1+2+1=4$

(c) A star has a proper motion of 10 arc second per year. It is about 2 per sec away. The star radial velocity is measured to be 100 km/sec, i.e. it is moving towards the earth. Calculate star's space velocity. 4

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

(a) Sidereal time

(b) Pulsars

(c) H-R diagram

(d) Black hole

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