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(Held in 2021)

PHYSICS

(Major)

Paper : 5.3

Full Marks : 42

Time : 2 hours

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

GROUP—A

(*Marks* : 21)

1. Choose the correct answer from the given alternatives : 1×2=2

   (a) Uncertainty principle tells that

   (i) a particle can have only position but no momentum

   (ii) a particle can have only momentum but no position

   (iii) one can determine simultaneously the position and momentum of a particle

   (iv) one cannot determine simultaneously the position and momentum of a particle

(*Turn Over*)

(b) The probability of finding a particle represented by $\psi(\vec{r}, t)$ in unit volume is

   (i) $|\psi(r, t)|$

   (ii) $|\psi(r, t)|^2$

   (iii) $|\psi(r, t)|^3$

   (iv) $\psi(r, t)$

2. Answer the following questions :   2×2=4

(a) What is tunneling? Is there any similar process in classical mechancis analogous to tunneling in quantum mechanics? Discuss.

(b) Define ecliptic. What are vernal equinox and right ascension?

3. Answer any *three* of the following questions :

                                 5×3=15

(a) State and explain the complementarity principle of Niels Bohr. What conclusion can be drawn from the result of γ-ray microscope experiment?   3+2=5

(b) Define phase velocity and group velocity. Deduce the relation between phase and group velocity for the de Broglie's waves. Which of these two is associated with particle velocity?

                                 2+2+1=5

(c) Show with the help of uncertainty principle that protons, neutrons and α-particles can exist within the nucleus.   5

(d) What is a Hermitian operator? Prove that every eigenvalue of a Hermitian operator is real.   1+4=5

(e) Derive the relation between the apparent and absolute magnitudes of a star. What is distance modulus?   4+1=5

GROUP—B

(*Marks* : 21)

4. Answer the following questions :   7×3=21

(a) What is the need for normalization of a wave function? Calculate the normalization constant of a wave function (at $t = 0$) given by

$$\psi(x) = ae^{-(a^2 x^2 / 2)} \cdot e^{ikx}$$

Hence determine the probability current density of the wave function.   2+2+3=7

Or

A particle of mass m is moving in a one-dimensional potential given by

$$V = 0, \quad \text{for} \quad x < 0$$

$$= V_0, \quad \text{for} \quad x \geq 0$$

If the total energy of the incident particle $E > V_0$, then calculate the coefficient of reflection and trans-mission. 7

(b) What is expectation value of a dynamical variable as operator? Calculate $<p>$ and $<p^2>$ for the wave function given as

$$\psi(x) = \begin{cases} \left(\dfrac{2}{L}\right)^{1/2} \sin\dfrac{\pi x}{L}, & 0 < |x| < L \\ 0, & |x| > L \end{cases}$$

where p is a momentum operator.

1+3+3=7

Or

In Davisson and Germer experiment, the produced electron is accelerated through a potential difference of V between the filament and the plate.

(*Continued*)

Show that the de Broglie's wavelength λ and the accelerating potential of the electron are related as

$$\lambda \propto \frac{1}{\sqrt{V}}$$

Find the ratio of the wavelength of deuteron and proton accelerated through the same potential difference.

4+3=7

(c) Write down the sequence of events leading to the formation of a protostar. When does a protostar become a star?

5+2=7

Or

What is Hertzsprung-Russell diagram? Explain all the stellar properties using Hertzsprung-Russell diagram.   2+5=7

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