2023/TDC(CBCS)/EVEN/SEM/
PHSHCC-402T/005

TDC (CBCS) Even Semester Exam., 2023

PHYSICS

(Honours)

(4th Semester)

Course No. : PHSHCC-402T

(Elements of Modern Physics)

Full Marks : 50
Pass Marks : 20

Time : 3 hours

The figures in the margin indicate full marks for the questions

SECTION—A

Answer any *ten* questions from the following : 2×10=20

1. What do you mean by Quantum theory of light?

2. What is wave-particle duality? Define wave function.

3. Find the de Broglie wavelength of an electron travelling with the velocity of 0·6c.

4. Write down the uncertainty relation between two pairs of conjugate variables.

5. Explain the significance of uncertainty principle.

6. What is energy-time uncertainty principle?

7. Discuss the origin of quantum mechanics.

8. Explain the physical significance of wave function.

9. Define orthogonal and normalized wave function.

10. Define Hermitian operator. Why are only Hermitian operators associated with physical quantities?

11. Define eigenvalues and eigenfunctions.

12. What do you mean by tunnelling through a barrier?

13. Define activity of a radioactive sample. What are its different units?

14. What do you mean by spontaneous and stimulated emission?

15. What is optical pumping? How is population inversion achieved by this method?

SECTION—B

Answer any *five* questions from the following : 6×5=30

16. Distinguish between wave and group velocities. Show that de Broglie wave group associated with a moving particle travels with the same velocity as the particle. 2+4=6

17. Describe experimental verification of de Broglie's matter waves by two-slit interference pattern with electrons.

18. *(a)* State and explain Heisenberg's uncertainty principle. 1+3=4

    (b) An electron has a speed of 300 ms^{-1} accurate to 0·01%. With what fundamental accuracy can we locate the position of the electron? 2

19. How does the concept of Bohr orbit violate the principle of uncertainty? Why the principle does not reveal itself if we work with an object of 1 gram? 4+2=6

20. Deduce the time independent form of the Schrödinger's wave equation.

21. *(a)* Define probability current density. Normalize the wave function

$$\phi(x) = e^{-|x|} \sin \alpha x \qquad 1+3=4$$

(b) The normalized state of a free particle is represented by a wave function

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

Calculate the factor N. 2

22. *(a)* Show that the operators $i\frac{d}{dx}$ and $\frac{d^2}{dx^2}$ are Hermitian. 3

(b) If the wave function for a system is eigenfunction of the operator associated with the observable A, show that

$$\langle A^n \rangle = \langle A \rangle^n \qquad 3$$

23. A particle travelling with energy E along x-axis, has a potential barrier defined as

$$V(x) = \begin{cases} 0 & \text{for} \quad x < 0 \\ V_0 & \text{for} \quad 0 < x < a \\ 0 & \text{for} \quad x > a \end{cases}$$

Derive the expression for the equation and transmission coefficients of the particle.

24. State the law of radioactive decay. Define half life and mean life of a radioelement. Show that the mean life of a radioactive element is the reciprocal of the decay constant. 1+2+3=6

25. Give the construction of an He-Ne laser. With the help of a simple energy level diagram, describe the operation of an He-Ne laser. 3+3=6

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