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Reg. No. : ....

Name : ....

Fifth Semester B.Sc. Degree Examination, December 2022

First Degree Programme under CBCSS

Physics

Core Course VI

PY 1542 : QUANTUM MECHANICS

(2013 – 2017 Admission)

Time : 3 Hours Max. Marks : 80

SECTION – A

Answer **all** questions, each carries **1** mark.

1. Draw the blackbody radiation spectrum for two different temperatures.

2. Based on Einstein's explanation of photoelectric effect, write equation for the kinetic energy of the emitted electrons and explain the terms.

3. What is Compton effect?

4. Give an experimental evidence for the wave nature of electron.

5. How does the energy of hydrogen atom in Bohr model vary with the quantum number n?

6. If $\Psi(x,t)$ is the wave function of a particle moving along the x-axis, explain the meaning of $\int_a^b |\Psi(x,t)|^2 dx$.

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7. What is meant by the uncertainty ΔA in the measurement of a physical quantity A in a quantum system?

8. Write time-independent Schrodinger equation for a particle moving in a one-dimensional region of potential energy V.

9. Plot the probability density of the first three stationary states of a quantum mechanical linear harmonic oscillator.

10. If f_m and f_n are two functions in the Hilbert space of a quantum system, what is the meaning of the equation, $\langle f_m | f_n \rangle = \delta_{mn}$?

(10 $\times$ 1 = 10 Marks)

SECTION – B

Answer any **eight**, each carries **2** marks.

11. In photoelectric effect experiment, plot the stopping potential of the metal along the y-axis and the frequency of the incident radiation along the x-axis. How do you find the value of the Planck's constant from the graph?

12. Write the expression for the wavelength shift in Compton scattering. What are the factors on which it depends?

13. Briefly discuss Bohr's correspondence principle.

14. Explain the normalization of the wave function of a particle.

15. Explain the expectation value of position of a particle.

16. State the uncertainty principle. Write the uncertainty relation between position and momentum of a particle.

17. Prove the commutation rule $[x, p] = i\hbar$ where x is the position operator and ρ is the momentum operator along the x-direction.

18. Write the expression for the wave packet of a free particle moving along +x-direction. What is the expression for its group velocity?

19. State the boundary conditions on the wave function.

20. What is meant by the completeness of a set of functions in the Hilbert space of a system?

21. Write the eigenvalue equation of an operator and explain each term. Express time-independent Schrodinger equation as an eigenvalue equation.

22. Explain stationary states.

(8×2 = 16 Marks)

SECTION – C

Answer any **six,** each carries **4** marks.

23. A surface of tungsten (work function = 4.52 eV) is illuminated and photoelectrons are observed. What is the largest wavelength that will cause photoelectrons to be emitted?

24. X-rays of wavelength 0.24 nm undergo Compton scattering. The scattered beam is observed at an angle of 60° relative to the incident beam. Find the energy of the scattered X-ray.

25. What is the shortest wavelength present in the Balmer series of spectral lines of hydrogen atom?

26. Obtain the de Broglie wavelength of an electron accelerated through 600 V potential difference.

27. State any four postulates of quantum mechanics.

28. Normalize the wave function $\Psi(x) = Ae^{-\lambda|x|}$.

29. Calculate the expectation value of the position of a particle trapped in a one-dimensional box of infinite potential well when it is in the n^{th} quantum state, $\Psi_n(x) = \sqrt{\frac{2}{L}} \sin\left(\frac{n\pi}{L} x\right)$.

30. The ground state wave function of a linear harmonic oscillator is $\Psi_0(x) = \left(\frac{m\omega}{\pi\hbar}\right)^{1/4} e \frac{-m\omega}{2h} x^2$. Calculate the expectation value of its momentum in this state.

31. Explain Rutherford planetary model.

(6 × 4 = 24 Marks)

SECTION – D

Answer any **two**, each carries **15** marks.

32. Derive an expression for the Compton wavelength shift. Calculate the value of the maximum wavelength shift possible for any incident wavelength.

33. Starting from the three postulates, derive the expressions for the following quantities in the Bohr model of hydrogen atom : (a) Orbital radius (b) Orbital velocity (c) Total energy and (d) Rydberg formula for the wave number of spectral lines. Plot the energy level diagram for the first four energy values.

34. Obtain the time-independent Schrodinger equation from the time-dependent Schrodinger equation by the method of separation of variables. Obtain the expression for the time-dependent part of the total wave function.

35. Derive the energy values and normalized wave functions for a particle in a one-dimensional "box" of infinite potential well. Plot the energy values and wave functions of the first three states.

(2 × 15 = 30 Marks)