(8 pages) Reg. No. : .....

Code No. : 7806 **Sub. Code : WPHM 31**

M.Sc. (CBCS) DEGREE EXAMINATION, NOVEMBER 2024.

Third Semester

Physics – Core

QUANTUM MECHANICS – II

(For those who joined in July 2023 onwards)

Time : Three hours Maximum : 75 marks

PART A — (15 × 1 = 15 marks)

Answer ALL questions.

Choose the correct answer :

1. The first-order Born Approximation assumes that the scattering potential :
   (a) Has no effect on the incoming wave
   (b) Slightly modifies the incoming wave
   (c) Completely alters the incoming wave
   (d) Only affects the outgoing wave

2. In the Born Approximation, the scattering amplitude is proportional to :
   (a) The square of the potential
   (b) The Fourier transform of the potential
   (c) The inverse of the potential
   (d) The derivative of the potential

3. The optical theorem relates the imaginary part of the forward scattering amplitude $f(0)$ to :
   (a) The total cross-section
   (b) The differential cross-section
   (c) The potential energy
   (c)) The phase shift

4. When the perturbation is turned on suddenly, the transition amplitude between states is calculated using :
   (a) The adiabatic theorem
   (b) The sudden approximation
   (c) The Born approximation
   (d) The variational method

5. The interaction picture is often used in time-dependent perturbation theory because :

(a) It simplifies the time evolution of the states

(b) It makes the Hamiltonian time-independent

(c) It is equivalent to the Schrödinger picture

(d) It eliminates the perturbation entirely

6. Which of the following is a limitation of time-dependent perturbation theory?

(a) It cannot handle small perturbations

(b) It is only valid for long times

(c) It assumes the perturbation is weak

(d) It does not apply to time-independent problems

7. Which of the following is a solution type of the Klein-Gordon equation?

(a) Standing waves (b) Traveling waves

(c) Plane waves (d) All of the above

8. The Klein-Gordon equation includes a mass term m^2 which accounts for

(a) The mass of the particle

(b) The spin of the particle

(c) The charge of the particle

(d) The energy of the particle

9. Which of the following best describes the Dirac matrices γ^μ?

(a) 2×2 matrices (b) 3×3 matrices

(c) 4×4 matrices (d) 5×5 matrices

10. In the covariant form, the Dirac equation is said to be Lorentz invariant. What does this mean?

(a) The equation changes under a Lorentz transformation

(b) The equation remains the same under Lorentz transformations

(c) The equation is valid only in flat spacetime

(d) The equation is only valid for massless particles

11. In the covariant Dirac equation, the mass term m is:

(a) A scalar (b) A vector

(c) A tensor (d) A matrix

12. In the context of the Dirac equation, what does the Dirac Lagrangian in covariant form describe?

(a) The dynamics of scalar fields

(b) The dynamics of the Dirac spinor field

(c) The dynamics of vector fields

(d) The dynamics of gravitational fields

13. The Hamiltonian in quantum mechanics is an operator that corresponds to

which classical quantity?

(a) The Lagrangian

(b) The potential energy

(c) The total energy

(d) The kinetic energy

14. The Hamiltonian operator is Hermitian. This implies that:

(a) It has no real eigenvalues

(b) It has complex eigenvalues

(c) Its eigenvalues are real, corresponding to measurable physical quantities

(d) Its eigenvalues are always negative

15. In quantum mechanics, if the Hamiltonian H does not explicitly depend on time, the system is said to be:

(a) Time-independent

(b) Time-dependent

(c) In the ground state

(d) Non-conservative

PART B — ($5 \times 4 = 20$ marks)

Answer ALL questions, choosing either (a) or (b).

16. (a) Deduce an expression for the scattering cross-section of particles by a screened coulomb potential.

Or

(b) Using the Born approximation, calculate the differential cross-section for the scattering by a Yukawa potential defined by $v(r) = -g^2 \frac{e^{-\alpha r}}{r}$.

17. (a) Give an account of sudden approximation.

Or

(b) What do you understand by a selection rule? Explain the selection for dipole radiation.

18. (a) Obtain expressions for current and charge densities in Klein-Gordan equation.

Or

(b) What are negative energy states? What is a hole?

19. (a) Obtain expression for Probability density and Probability current density in the Dirac formalism.

Or

(b) Show that γ_5 is a Constant of motion for a neutrino is massless Dirac particle.

20. (a) Explain quantization of real and complex scalar fields.

Or

(b) Explain the Fock states.

PART C — (5 × 8 = 40 marks)

Answer ALL questions, choosing either (a) or (b)

21. (a) Explain the method of Partial waves to calculate the phase shifts and scattering amplitude.

Or

(b) Discuss scattering by a screened coulomb potential.

22. (a) Derive the Fermi-Golden rule for the transition rate from a given initial state to a final state continuum.

Or

(b) Discuss the Einstein's coefficients of spontaneous and induced emission of radiation. Derive a relationship between A and B coefficients.

23. (a) Establish Dirac equation for an electron and calculate its magnetic moment.

Or

(b) Obtain Dirac equation for a free particle and obtain its solution.

24. (a) Derive relativistic invariance of Dirac equation.

Or

(b) Explain the Feynman's theory of positron.

25. (a) Derive Euler — Lagrange equation using classical field.

Or

(b) State and explain Noether's theorem using classical field.

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