REV-01
MSP/34/11/14

2022/12

SET A

M.Sc. PHYSICS
THIRD SEMESTER
QUANTUM MECHANICS-II
MSP – 302

[USE OMR SHEET FOR OBJECTIVE PART]

Duration : 3 hrs. **Full Marks : 70**

(Objective)

Time: 30 min. **Marks: 20**

Choose the correct answer from the following: ***1X20=20***

1. The momentum operator is defined by
   a. $\vec{p} = -i\hbar\,\vec{\nabla}$ b. $\vec{p} = i\,\hbar\,\vec{\nabla}$
   c. $\vec{p} = -\frac{i}{\hbar}\vec{\nabla}$ d. $\vec{p} = \frac{i}{\hbar}\vec{\nabla}$

2. The expression $\gamma^{\mu}\gamma^{\nu} + \gamma^{\nu}\gamma^{\mu}$ is equal to
   a. $g^{\mu\nu}$ b. $2\,g^{\mu\nu}$
   c. $\frac{1}{2}g^{\mu\nu}$ d. $-2\,g^{\mu\nu}$

3. The value of Trace (α^k) will be
   a. 0 b. -1
   c. 1 d. ± 1

4. The relativistic wave equations are based on the statement: (i) Einstein's mass energy relation (ii) classical energy relation.
   a. (i) & (ii) are true b. (i) is false and (ii) is true
   c. (i) is true and (ii) is false d. (i) & (ii) are false

5. The determinant of α matrices will be
   a. ± 1 b. -1
   c. 1 d. 0

6. The first order energy correction in time independent perturbation theory is
   a. $E_k^{(1)} = \langle\psi_n^0|H'|\psi_n^0\rangle$ b. $E_k^{(1)} = \frac{\langle\psi_n^0|H'|\psi_n^0\rangle}{E_n^{(0)}}$
   c. $E_k^{(1)} = \frac{\langle\psi_n^0|H'|\psi_n^0\rangle}{E_m^{(0)} - E_n^{(0)}}$ d. none of these

7. If two different unperturbed states of a quantum system share same energy, then the states are
   a. degenerate b. non-degenerate
   c. both (a) and (b) d. none of these

8. In laboratory frame the ground state energy for He atom is precisely calculated as
   a. $-13.6\ eV$ b. $-34\ eV$
   c. $-79\ eV$ d. $-109\ eV$

9. Stark effect occurs in presence of an/a
   a. electric field
   b. magnetic field
   c. gravitational field
   d. strong nuclear

10. Behaviour of H-atom in first excited state ($n = 2$) is like a permanent dipole moment of magnitude (a_0 is the Bohr's radius the options below)
   a. 3
   b. $3e$
   c. $3a_0$
   d. $3ea_0$

11. The first order perturbed Hamiltonian, when an external uniform electric field is E is applied in z-axis of an atom is (p stands for dipole moment, E for external electric field)
   a. $H' = \vec{p}.\vec{E}$
   b. $H' = -\vec{p}.\vec{E}$
   c. $H' = \vec{E}/\vec{p}$
   d. $H' = \vec{p}/\vec{E}$

12. For _____ state of Hydrogen, there is no first order effect
   a. ground
   b. first
   c. second
   d. third

13. Under the Stark effect in H-atom, out of 4-fold degeneracy, ____ -fold degeneracy gets removed.
   a. 1
   b. 2
   c. 3
   d. 4

14. In variational method the constant α appear in trail wave function is evaluated by considering the following relation
   a. $\frac{\partial\langle E\rangle}{\partial\alpha} = 1$
   b. $\frac{\partial\langle E\rangle}{\partial\alpha} = 0$
   c. $\frac{\partial\langle E\rangle}{\partial\alpha} = \infty$
   d. $\frac{\partial\langle E\rangle}{\partial\alpha} = \frac{1}{e}$

15. The ground state energy of a He-atom physically represents the amount of energy it would spend for
   a. strip off an electron
   b. strip off both the electrons,
   c. counter balancing e-e repulsion
   d. avoiding Pauli's exclusion principle

16. For elastic scattering case, the relation between the scattering cross-section $D(\theta)$ and scattering amplitude $f(\theta)$ is
   a. $D(\theta) = f(\theta)$
   b. $D(\theta) = \frac{f(\theta)}{\hbar}$
   c. $D(\theta) = |f(\theta)|^2$
   d. $D(\theta) = \hbar f(\theta)$

17. Which among the following relations is true for Einstein's A and B coefficient
   a. $\frac{A}{B} = \frac{\hbar\pi^2}{\omega_0^2 c^3}$
   b. $\frac{A}{B} = \frac{\pi^2 c^3}{\omega_0^2 \hbar}$
   c. $\frac{A}{B} = \frac{\pi^2\omega_0^2}{c^3\hbar}$
   d. $\frac{A}{B} = \frac{\omega_0^3\hbar}{\pi^2 c^3}$

18. In 'centre of mass' system, the reduced mass of two particles of masses m_1 and m_2 is

a. $\mu = \frac{m_1 m_2}{m_1 + m_2}$ b. $\mu = \frac{m_1 - m_2}{m_1 m_2}$

c. $\mu = \frac{m_1 + m_2}{m_1 m_2}$ d. $\mu = \frac{m_1 m_2}{m_1 - m_2}$

19. In WKB approximation the motion of a particle gets slowdown when

a. $V \cong E$ b. $V > E$

c. $V < E$ d. None of these

20. Classical action can be expressed as

a. $L = \int_{t_1}^{t_2} (KE - PE)$ b. $L = \int_{t_1}^{t_2} (KE + PE)$

c. $L = \hbar \int_{t_1}^{t_2} (KE - PE)$ d. $L = \frac{1}{i\hbar} \int_{t_1}^{t_2} (KE + PE)$

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Descriptive

Time : 2 hrs. 30mins. Marks : 50

[Answer question no.1 & any four (4) from the rest]

1. a. What you understand by perturbation in quantum systems? Write the first order perturbation correction to energy for a non-degenerate system. **2+1+7 =10**

   b. If the unperturbed wave function of an infinite square well is given by $\psi_n^0(x) = \sqrt{\frac{2}{a}}\sin\left(\frac{n\pi x}{a}\right)$, and if the system is perturbed simply by raising the floor half way across the wall by a constant amount V_0. Calculate the first order correction to the energy of the system.

2. a. If one wants to write the relativistic energy E of a free particle as $E^2 = c^2(\alpha \cdot p + \beta\, m\, c)^2$. Show that α's and β are Hermitian matrices. **6+2+2 =10**

   b. Express the Dirac equation in covariant form.

   c. Show that $(\vec{\sigma}\cdot\vec{A})(\vec{\sigma}\cdot\vec{B}) = (\vec{A}\cdot\vec{B}) + i\,\sigma\cdot(\vec{A}\times\vec{B})$.

3. a. State the theorem of variational principle and prove that it gives an upper limit for the ground state energy of a system. **6+4=10**

   b. Write down the steps to calculate the ground state energy through variational method.

4. a. Explain briefly about the WKB approximation. Discuss the turning points and classically allowed region with diagram. **2+2+6 =10**

   b. Using WKB approximation, deduce the energy Eigen value for a particle confined in an infinite square well potential with the following potential

   $V(x) = 0$ for $0 < x < a$

   $V(x) = \infty$ otherwise

5. a. What is the Hamilton operator used in the Schrodinger equation? **3+4+3 =10**

   b. Using the Schrodinger wave equation, derive the following continuity relation $\frac{\partial\,\rho\,(r,t)}{\partial t} + \vec{\nabla}\cdot\vec{j} = 0$.

   c. Find the probability and current density for the wave function $\Psi(x) = e^{2\,i\,k\,x}$ in Schrodinger picture.

6. What are Einstein's A & B coefficients? Establish the relation between these coefficients. **2+8=10**

7. a. Define Laboratory and Centre of mass frames of references. **2+8=10**

   b. Establish the relation between the scattering angles in Laboratory and Centre of mass frames.

8. a. Derive the Klein-Gordon equation using the relation $E^2 = p^2c^2 + M^2c^4$. **4+3+3 =10**

   b. Express the Klein-Gordon equation in covariant form.

   c. Write down the Klein-Gordon equation in spherical coordinates

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