Write the following information in the first page of Answer Script before starting answer

ODD SEMESTER EXAMINATION: 2020-21

Exam ID Number______________________________

Course____________________________ Semester____________________________

Paper Code _________________Paper Title __________________________________

Type of Exam: ______________________________ (Regular/Back/Improvement)

Important Instruction for students:

1. Student should write objective and descriptive answer on plain white paper.
2. Give page number in each page starting from 1^{st} page.
3. After completion of examination, Scan all pages, convert into a single PDF, rename the file with Class Roll No. **(2019MBA15)** and upload to the Google classroom as attachment.
4. Exam timing from 10am – 1pm (for morning shift).
5. Question Paper will be uploaded before 10 mins from the schedule time.
6. Additional 20 mins time will be given for scanning and uploading the single PDF file.
7. Student will be marked as ABSENT if failed to upload the PDF answer script due to any reason.

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

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

(PART-A : Objective)

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

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

1. A perfect vacuum is a region where all the states of positive energy are:
- **a.** Occupied
- **b.** Unoccupied
- **c.** Both a and b
- **d.** None

2. The electron spin magnetic moment is important in the electron orbit interaction which:
- **a.** Splits atomic energy levels
- **b.** Intrinsic angular momentum
- **c.** Pattern of other momentum
- **d.** None

3. Particles having spins 0 are described by:
- **a.** Klein Gordon equation
- **b.** Dirac equation
- **c.** Pauli equation
- **d.** Proca equation

4. Dirac equation predicts:
- **a.** The spin angular momentum but not the existence of anti particle
- **b.** Both spin angular momentum and existence of anti particle
- **c.** Existence of anti particle but not angular momentum
- **d.** None

5. Pauli exclusion principle is applicable only for:
- **a.** Bosons
- **b.** Fermions
- **c.** Both a and b
- **d.** None

6. According to Dirac theory a positron is:
- **a.** An occupied state of negative energy
- **b.** An unoccupied state of negative energy
- **c.** An occupied state of positive energy
- **d.** None

7. A field is quantity continuously distributed throughout:
- **a.** Space
- **b.** Time
- **c.** Space and Time
- **d.** None

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

9. 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

10. Stark effect occurs in presence of:

a. Electric field **b.** Magnetic field
c. Gravitational field **d.** Weak field

11. 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.** $\mu = \frac{m_1 m_2}{m_1-m_2}$

12. 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

13. 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.** $H' = \vec{p}/\vec{E}$

14. The variational principle gives a/an________ value for ground state energy level.

a. Upper bound **b.** Lower bound
c. Both (a) and (b) **d.** None of these

15. Energy calculated by variation method is________ than the exact energy for ground state energy level.

a. Always smaller **b.** Always larger
c. Equal or larger **d.** None of these

16. Laboratory frame the ground state energy for He atom is precisely calculated as:

a. $-13.6\ eV$ **b.** $-34\ eV$
c. $-79\ eV$ **d.** $-109\ eV$

17. WKB approximation applies to any situations in which potential (as function of position) is:

a. Constant **b.** Fast varying
c. Slowly varying **d.** None of these

18. Identify the correct option for Dirac matrices.

a. They are unity **b.** Their squares are unity
c. They commute with one another **d.** All the above are true

19. Which among the following relations is true for Einstein's A and B coefficient?

a. $\frac{A}{B} = \frac{\hbar\pi^2}{\omega_0^3 c^3}$ **b.** $\frac{A}{B} = \frac{\pi^2 c^3}{\omega_0^3 \hbar}$
c. $\frac{A}{B} = \frac{\pi^2 \omega_0^3}{c^3 \hbar}$ **d.** $\frac{A}{B} = \frac{\omega_0^3 \hbar}{\pi^2 c^3}$

20. 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.** $\frac{\partial\langle E\rangle}{\partial\alpha} = \frac{1}{e}$

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PART-B : Descriptive

Time : 2 hrs. 40 min. 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) Show that there is no first order Stark effect for the ground state of H-atom. 4+6=10

   b) If a system with unperturbed Hamiltonian H_0 is subjected to a perturbation H_p where

$$H_0 = \begin{bmatrix} 15 & 0 & 0 & 0 \\ 0 & 3 & 0 & 0 \\ 0 & 0 & 3 & 0 \\ 0 & 0 & 0 & 3 \end{bmatrix}, \text{ and } H_p = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

   then find the energy Eigen values corrected to the first order.

3. Using variation method, find the lowest upper limit of the ground state energy of He-atom. 5+5=10

4. a) Explain briefly about the WKB approximation. Discuss the turning points and classically allowed region with diagram. 5+5=10

   b) Using WKB approximation, express 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. What are Einstein's A & B coefficients? Establish the relation between these coefficients. 2+8=10

6. a) Define differential scattering cross-section and total scattering cross-section. What is the unit in which they are measured? 4+1+4+1=10

   b) Distinguish between laboratory coordinate system and centre of mass coordinate system. State the relation connecting scattering angles between these two coordinate systems.

7. a) Using Pauli's spin matrices, express Dirac matrices $\vec{\alpha}$ and β. 4+6=10

   b) If $\vec{\alpha}$ represents three Dirac's matrices α_x, α_y and α_z, and $\vec{B}$ and $\vec{C}$ are ususal three dimensional vectors, then show that

$(\vec{\alpha}.\vec{B})(\vec{\alpha}.\vec{C}) = \vec{B}.\vec{C} + i\vec{\sigma}.(\vec{B} \times \vec{C})$, where $\vec{\sigma} = \begin{bmatrix} \vec{\sigma}' & 0 \\ 0 & \vec{\sigma}' \end{bmatrix}$ and $\vec{\sigma}'$ is 4×4 Pauli matrices.

8. Show how Dirac's relativistic wave equation for negative energy state of electrons leads to the theory of positrons. 10

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