 2017/12

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

Duration: 3 Hrs. **Marks: 70**

PART : A (OBJECTIVE) = 20
PART : B (DESCRIPTIVE) = 50

[PART-B : Descriptive]

Duration: 2 Hrs. 40 Mins. **Marks: 50**

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

1. What do you mean by perturbation theory? Obtain the expression of the first order perturbation energy correction for a non degenerate system. (2+8=10)

2. a) The unperturbed wave function for the infinite square well is given by $\psi_n^0(x) = \sqrt{\frac{2}{a}} sin\left(\frac{n\pi x}{a}\right)$. If the system is perturbed simply by raising the floor of the wall by a constant amount only halfway across the wall. Calculate the energy of the nth state correcting to the first order. (5+5=10)
   b) For a perturbation $H' = ax$, (where a is a constant) is added to an infinite square well potential expressed as
   $V(x) = 0$ for $0 < x < \pi$
   $= \infty$ otherwise,
   then find the first order correction to the ground state energy.

3. a) Applying stationary degenerate perturbation theory show that there is no first order Stark effect for ground state of H-atom. (5+5=10)
   b) On the basis of variation method, prove that $\langle E \rangle \geq E_0$, where E_0 is the lowest energy state.

4. a) The first order probability in time dependent perturbation theory expressed as $\left|a_k^{(1)}(t)\right|^2 = \frac{4|\langle k|H'|m\rangle|^2}{\hbar^2 \omega_{km}^2} sin^2\left(\frac{\omega_{km} t}{2}\right)$. Discuss its physical significance. (5+5=10)
   b) Derive the Fermi-Golden rule from transition probability per unit time.

5. Define 'laboratory' and 'centre of mass' systems. Establish the relation between the laboratory and centre of mass system of scattering angles. (2+8=10)

6. a) State Born approximation for scattering theory. When does it applied? Write the validity condition of Born approximation. (2+1+1+6=10)
   b) Apply the Born approximation method to calculate the scattering cross-section from a screened Coulomb field.

7. Establish Dirac's relativistic equation for free particle. (6+2+2=10)
Using Pauli's spin matrices, find the Dirac's matrices for $\vec{\alpha}$ and β.
Prove that $\alpha_x\alpha_y\alpha_z = \frac{1}{2}[\alpha_x\alpha_y\alpha_z\beta, \beta]$.

8. Show that Dirac electron has a magnetic moment $\mu = \frac{e\hbar\vec{\sigma}}{2mc}$. (10)

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[PART-A : Objective]

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

1. Stark effect occurs in presence of:
   a. electric field
   b. magnetic field
   c. gravitational field
   d. weak field

2. The behaviour of H-atom in first excited state $(n = 2)$ is like a permanent dipole moment of magnitude. (for a_0 being Bohr's radius)
   a. $3e$
   b. $3ea_0$
   c. 3
   d. $3a_0$

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

4. 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

5. A system is called degenerate system if a number of orthogonal Eigen function corresponds to ______ Eigen value. (Select the correct option)
   a. same
   b. different
   c. zero
   d. none of these

6. The transition probability per unit time in time dependent perturbation theory is:
   a. $\omega = \frac{1}{t}\int \left|a_k^{(1)}(t)\right|^2 dE_k$
   b. $\omega = \int \left|a_k^{(1)}(t)\right|^2 \rho(k) dE_k$
   c. $\omega = \frac{1}{t}\int \left|a_k^{(1)}(t)\right|^2 \rho(k) dE_k$
   d. constant in time

7. The value of time dependent constants in perturbation theory is:
   a. $\dot{a}_k = i\hbar \sum a_n \langle k|H'|m\rangle e^{i\omega_{km}t}$
   b. $\dot{a}_k = (i\hbar)^{-1} \sum a_n \langle k|H'|m\rangle e^{i\omega_{km}t}$
   c. $\dot{a}_k = i\hbar^{-1} \sum a_n \langle k|H'|m\rangle e^{i\omega_{km}t}$
   d. $\dot{a}_k = i\hbar^{-2} \sum a_n \langle k|H'|m\rangle e^{i\omega_{km}t}$

8. 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. $\mu = \frac{m_1 m_2}{m_1 - m_2}$

9. The interaction Hamiltonian for a charged particle in an electromagnetic field is given by:
   a. $H_{int} = -\frac{e}{mc} \boldsymbol{A}.\boldsymbol{p}$
   b. $H_{int} = \frac{e}{mc} \boldsymbol{A}.\boldsymbol{p}$
   c. $H_{int} = \boldsymbol{A}.\boldsymbol{p}$
   d. $H_{int} = \frac{h}{2\pi} \boldsymbol{A}.\boldsymbol{p}$

10. The scattering process, in which energy of the incident particle alters, is a/an __________ scattering process. (Select correct option)
    a. elastic
    b. inelastic
    c. plastic
    d. none of these

11. The scattering cross-section $(\sum \omega)$ of the incident particles (as presented by $n = \sum \omega \, J \, d\omega$) has the dimension of:
    a. length
    b. surface area
    c. volume
    d. no dimension

12. Condition for validity of classical theory of scattering is derived from:
    a. Lagrange's equation
    b. Hamilton's principle
    c. Heisenberg's uncertainty principle
    d. Compton scattering

13. The D'Alembertian operator is given by:

a. $\square = \nabla - \frac{\partial}{\partial t}$

b. $\square^2 = \nabla^2 + \frac{2mE}{\hbar^2}$

c. $\square = \nabla^2 - \frac{1}{c^2}\frac{\partial^2}{\partial t^2}$

d. $\square^2 = \nabla^2 + \frac{1}{c^2}\frac{\partial^2}{\partial t^2}$

14. The differential scattering cross-section is given by:

a. $\frac{d\sigma}{d\Omega} = |f(\theta)|$ b. $\frac{d\sigma}{d\Omega} = |f(\theta)|^2$

c. $\frac{d\sigma}{d\Omega} = \frac{|f(\theta)|}{r}$ d. $\frac{d\sigma}{d\Omega} = \frac{1}{|f(\theta)|}$

15. Hamiltonian for free particle is:

a. $H = -\frac{\hbar^2}{2m}\nabla^2$ b. $H = -\frac{2m}{\hbar^2}\nabla^2$

c. $H = \frac{2m}{\hbar^2}\frac{\partial}{\partial t}$ d. $H = \frac{\hbar^2}{2m}\frac{\partial}{\partial t}$

16. Klein-Gordon equation can describe particles of:

a. integral spin b. half integral spin

c. zero spin d. all of these

17. Dirac's matrices for $\vec{\alpha}$ and β are:

a. commutative b. associative

c. anti-commute d. none of these

18. For the Dirac electrons (at rest) the negative and the positive energy states are separated by a gap equal to:

a. $\frac{1}{2}mv^2$ b. mc^2 c. $2mc^2$ d. ∞

19. In Feynman's path integral method the classical "action" is expressed as:

a. $S = H\{x(t)\}$

b. $S = L\{x(t)\}$

c. $S = \int_0^t L\{x(t)\}\,dt$

d. $S = \sum H\{x(t)\}$

20. The total wave function of all possible paths of a particle can be given by:

a. $\psi = N\sum_{all\ path} e^{iS[x(t)]/\hbar}$

b. $\psi = -N\sum_{all\ path} e^{iE/\hbar}$

c. $\psi = N\sum_{all\ path} e^{i\hbar/S[x(t)]}$

d. $\psi = N\sum_{all\ path} e^{-i\hbar/S[x(t)]}$

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UNIVERSITY OF SCIENCE & TECHNOLOGY, MEGHALAYA

[PART (A) : OBJECTIVE]

Duration : 20 Minutes

Serial no. of the main Answer sheet

Course : ....

Semester : .... Roll No : ....

Enrollment No : .... Course code : ....

Course Title : ....

Session : 2017-18 Date : ....

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Instructions / Guidelines

- ➢ The paper contains twenty (20) / ten (10) questions.
- ➢ Students shall tick (✓) the correct answer.
- ➢ No marks shall be given for overwrite / erasing.
- ➢ Students have to submit the Objective Part (Part-A) to the invigilator just after completion of the allotted time from the starting of examination.

Full Marks	Marks Obtained
20	

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Scrutinizer's Signature *Examiner's Signature* *Invigilator's Signature*