No. of Printed Pages : 2

Seat No.:_____

(37 & A-9)

SARDAR PATEL UNIVERSITY

M. Sc. Physics II[nd] Semester Examination

Saturday, Date: 22-10-2016 Time: 10.00 am to 01.00 pm

CBCS Course No.: PS02CPHY01

Subject: Quantum Mechanics–I

Note: Symbols have their usual meaning. **Total Marks: 70**

Q.1 Write answers of all eight questions in a table form by showing your choice against the question number. **(8)**

(1) According to the method of Dalgarno and Lewis, in order to find matrix element H'_{mn}, one requires to find an operator $\hat{F}$ such that _____.

(a) $[\hat{F}, H'] \neq 0$ (b) $H'|u_m> = [H_0, \hat{F}]|u_m>$

(c) $H'|u_m> = \hat{F}|u_m>$ (d) $H'|u_m> = 0$

(2) For any dynamical operator $\hat{A}$, the expectation value, $\langle \hat{A}^{\dagger}\hat{A} \rangle$ is _____.

(a) ≤ 0 (b) $= \infty$ (c) $= 0$ (d) ≥ 0

(3) The first order perturbation theory of a degenerate level is equivalent of finding a _____ with respect to which the perturbation is diagonal.

(a) orthogonal ket vectors (b) normalized ket vectors

(c) basis vectors (d) null vectors

(4) At the classical turning point; _____.

(a) $E - V(x) = 0$ (b) $E - V(x) < 0$ (c) $E - V(x) > 0$ (d) $E - V(x) = \infty$

(5) If the eigenvalue E_m is non-degenerate, then $|v^{(0)}>$ _____ be defined uniquely.

(a) can (b) cannot (c) may (d) may not

(6) WKB approximation is best suited when _____.

(a) $\hbar \to 0$ (b) $\hbar \to \infty$ (c) $\hbar < 0$ (d) all three conditions are obeyed

(7) The first order stark effect in the first excited state of H-atom is _____.

(a) very large (b) zero (c) dependent on the magnitude of the electric field

(d) dependent on the square of magnitude of the electric field

(8) At large distance from the target, the scattered particles appear *radially outwards*, hence the scattered particles are represented as _____ waves.

(a) spherical (b) cylindrical (c) plane (d) spiral

Q.2 Answer any seven questions. **(14)**

(1) Define projection operator. Mention its use.

(2) State and interpret optical theorem.

(3) How *trial* wave function linear in variational parameters is selected?

(4) Prove that the criterion to estimate the ground state using the variation technique is given by $[\langle \psi|H^2|\psi \rangle - W^2]^{\frac{1}{2}} \geq (W - E_0)$.

(5) Write basic assumptions used in WKB approximation.

(6) Prove that any observable is always diagonal in its own representation.

(P.T.O)

(7) Write advantages of variation technique over the perturbation technique?
(8) With logical argument, prove that the first order stark effect for ground state of H-atom is zero.
(9) Give difference between the partial wave analysis and the Born approximation for scattering phenomena.

Q.3 **(a)** Deduce the relation $(\chi)_A = [F]_A(\psi)_A$ for any linear operator $\hat{F}$. How this representation differs from the Schrödinger representation? **(6)**

(b) What do you mean by Unitary transformation? Prove that the operator $(\frac{\hat{p}_z}{\hbar})$ plays the role of the generator of infinitesimal translation. **(6)**

OR

(b) Prove that for a continuous basis, $\langle x|\hat{p}|x\rangle = -i\hbar\frac{\partial\psi(x)}{\partial x}$. **(6)**

Q.4 **(a)** Write basic assumptions involved in Raylaigh-Schrödinger perturbation theory. Write equations in various orders of perturbation. For non-degenerate case, obtain expressions for energy eigenvalue and eigenfunction corrected up to the first-order in perturbation. **(6)**

(b) Discuss the binding in He-atom applying the perturbation technique. **(6)**

OR

(b) Using the technique due to Dalgarno and Lewis, prove that the *polarizability* (α) of the H-atom in its ground state is equal to $\frac{9}{2}a_0^3$ when it is kept in uniform external electric field. Here, a_0 represents Bohr radius. **(6)**

Q.5 **(a)** Describe the basic procedure involved in the variation technique. For the ground state of two-electron atom, assuming effective charge as a variational parameter, obtain $W_{min} = -\left(Z - \frac{5}{16}\right)\frac{e^2}{a_0}$. Here, a_0 is the Bohr radius. **(6)**

(b) Using WKB approximation, derive the asymptotic solution for one dimensional Schrödinger equation. **(6)**

OR

(b) Apply variation technique to obtain the ground state energy for H_2 molecule. Discuss importance of *overlap* and *exchange* interactions in binding of H_2 molecule. **(6)**

Q.6 **(a)** Define Green's function. Derive formal expression for scattering amplitude in terms of appropriate Green's function. **(6)**

(b) Discuss partial wave analysis, and obtain the expression for phase shift δ_l. **(6)**

OR

(b) Obtain the expression for scattering amplitude within the Born approximation. Comment on its validity. **(6)**

****