2016

M.Sc. Part–I Examination

PHYSICS

PAPER—II

Full Marks : 75

Time : 3 Hours

The figures in the margin indicate full marks.

Candidates are required to give their answers in their own words as far as practicable.

Illustrate the answers wherever necessary.

Use separate Answerscripts for Gr. A & Gr. B.

Group—A

[Marks—50]

Answer *Q. No. 1* and *2* and any *two* from the rest.

1. Answer any *six* of the following : 6×2

(a) Can we measure the kinetic and potential energies of

a particle simultaneously with arbitrary precision ?

(b Show that linear momentum is not quantized.

(c) $\hat{A}$ and $\hat{B}$ are Hermitian operators and $[\hat{A}, \hat{B}] = i\hat{c}$.

Prove that $\hat{c}$ is a Hermitian operator.

(d) A beam of 12 eV electrons is incident on a potential barrier of height 30 eV and width 0·05 nm. Calculate the transmission coefficient.

(e) Evaluate the most probable distance of the electron of the hydrogen atom in its 2p state.

Given $R_{21} = \left(\frac{1}{2a_0}\right)^{3/2} \frac{1}{a_0\sqrt{3}} r \exp\left(-\frac{r}{2a_0}\right)$

(f) For a spinless particle moving in a potential V(r), show that the time reversal operator T Commutes with the Hamiltonian.

(g) A real operator $\hat{A}$ satisfies the equation

$A^2 - 5A + 6 = 0$. What are the eigenvalues of A ?

(h) A hydrogen atom in the ground state is placed in an electric field $\vec{E}$ along the z-axis. Calculate the first order correction to the energy.

(i) The invariance of the Hamiltonian $(\hat{H})$ under translation in space requires that linear momentum $(\hat{p})$ must commute with $\hat{H}$.

2. Answer any *three* bits : 3×4

(a) Show that the zero point energy of a linear harmonic oscillator is a manifestation of the uncertainty principle.

(b) Prove that the trace of a matrix is invariant under unitary transformation.

(c) Prove that the parity of spherical harmonics $Y_\ell^m(\theta, \phi)$ is $(-1)^\ell$.

(d) Calculate the second order correction to the energy of the n = 1 state of an oscillator of mass m and angular frequency ω subjected to a potential

$$V(x) = \frac{1}{2}m\omega^2x^2 + bx.$$

3. (a) The Thomas-Reich-Kuhn sum rule connects the complete set of eigen functions and energies of a particle of mass m. Show that

$$\left(\frac{2m}{\hbar^2}\right)\sum_k (E_k - E_s)|x_{sk}|^2 = 1$$

(b) Show that

(i) $\frac{d\langle x\rangle}{dt} = \frac{\langle p_x\rangle}{m}$

(ii) $\frac{d}{dt}\langle p_x\rangle = \left\langle -\frac{\partial v}{\partial x}\right\rangle$

(c) A particle is trapped in an infinite by deep square well of width a. What is the probability that the particle has momentum between p and p+dp ?

5+4+4

4. (a) A simple harmonic oscillator of mass m and angular frequency ω is perturbed by an additional potential $\frac{1}{2}bx^2$. Obtain the first and second order corrections to the ground state energy.

(b) The Schrodinger equation of a particle confined to the positive x-axis is $-\frac{\hbar^2}{2m}\frac{d^2\psi}{dx^2} + mgk\psi = E\psi$.

Use the trial function x exp (– ax) and obtain the best value of the parameter a.

(c) A particle of mass m moves on a ring of radius 'a' on which the potential is constant.

Find the allowed energies and eigenfunctions.

5+4+4

5. (a) Deduce the expression of Fermi's golden rule.

(b) Show that dipolar transition probability for absorption of radiation per unit time is $\omega = \frac{2\pi}{3\hbar^2}|\mu_{kn}|^2 \rho(\omega_{kn})$. 8+5

Group—B

[Marks—25]

Answer *Q. No. 1* and any *two* from the rest.

1. Answer any *three* : 3×3

(a) Explain what is meant by Hot Bond. 3

(b) Clearly distinguish Harmonic and Anharmonic vibration assuming a diatomic molucules. 3

(c) The force constant of the bond in CO molecule is 187 N/m and its reduced mass is $1{\cdot}14 \times 10^{-26}$ kg. Compute the frequency of vibration of CO molucule and the spacing between its vibrational energy levels. 3

(d) The fundamental bond for CO is centered at 2143·3 cm^{-1} and first overtone at 2459·7 cm^{-1}. Calculate w_e. 3

(e) A certain transition involves an energy change of $4{\cdot}005 \times 10^{-22}$ J/molecule. If there are 1000 molecules in the ground state, what is the approximate equilibrium population of the excited state at a temperature 29K. 3

(f) What is the change in the rotational constant B when hydrogen is replaced by deuterium in the hydrogen molecule ? 3

2. Assuming the molecule as a vibrating rotation and ignoring the interaction find the expression for energy levels. Clearly show the transition corresponding to P and R Branch. 6+2

3. Find the rotational fine structure of electronic vibration transition in a molecule. What is Band origin and Band head ? 6+2

4. What is the average period of rotation of HCl molecule if it is in the J = 1 state. The internuclear distance of HCl is 0·1274 nm. Given the mass of hydrogen and chlorine atoms are $1{\cdot}673\times10^{-27}$ kg and $58{\cdot}06\times10^{-27}$ kg respectively.

The first rotational line of $^{12}C^{16}O$ is observed at 3·84235 cm^{-1} and that of $^{13}C^{16}O$ 3·67337 cm^{-1}. Calculate the atomic weight of ^{13}C; assuming the molar mass $^{12}C = 19.93 \times 10^{-27}$kg; $^{16}O = 26{\cdot}56 \times 10^{-27}$kg. The microwave spectrum of CN radical shows a series of lines spaced by a nearly constant amount of 3·798cm^{-1}. What is the bond length of CN ?

Molar Mass of C = 19.92168 × 10^{-27}kg.

N = 23.25 × 10–27kg.

4+2+2
