B. Sc. Part-III (Honours) Examination, 2021

Subject: Physics

Paper: X

(New Syllabus)

Time: 2 Hours **Full marks: 50**

The figures in the margin indicate full marks
Candidates are required to give their answers in their own words as far as practicable.

Group-A

Answer *any three (03)* questions: 10×3=30

1. (a) Draw a simple diagram of the Stern-Gerlach experiment showing the splitting of the beam of silver atoms as recorded on the screen. Why is a non-uniform magnetic field used in this experiment? Explain the experimental observation in terms of spin of electron.

   (b) Find the energy levels of a spin $S=\frac{5}{2}$ particle whose Hamiltonian is given by,

   $$\hat{H} = \frac{\epsilon_0}{\hbar^2}\left(\hat{S}_x^2 + \hat{S}_y^2\right) + \frac{\epsilon_0}{\hbar}\hat{S}_z$$

   Where ϵ_0 is a constant having the dimension of energy.

2. Consider the usual set-up of Young's double slit experiment with a source (S), two slits (S_1 and S_2) and a screen (P). The source is that of electrons. Then answer the following questions, regarding the experiment with the electron beam:
   (a) Draw the intensity pattern of P if only S_1 is open,
   (b) Draw the intensity pattern of P if only S_2 is open,
   (c) Draw the intensity pattern of P if both S_1 and S_2 are open,
   (d) If the electron beam is very weak such that the electrons were sent one at time, what will be the intensity pattern created over a sufficiently long time?
   (e) What conclusions can be drawn about the intensity patterns in (c) and (d)?
   (f) How is the intensity pattern in (c) and (d) affected if a strong light source is used to find out the slit through which an electron passes?

3. Obtain the spectrum of energy eigenvalues of the linear harmonic oscillator in the analytic power series method.

4. (i) Draw schematically the experimental arrangement of Rabi's method of determination of magnetic moment of $^{7}_{3}Li$.
   (ii) Elucidate the resonance condition in Rabi's method and the associated observation with the help of the resonance graph.
   (iii) Neutron being an uncharged particle possesses a negative magnetic moment. Why?

5. (a) Draw a schematic diagram of a cyclotron and briefly describe its working principle.
   (b) Obtain the expression for the final energy of a positive ion, accelerated by the cyclotron in terms of the mass of the ion, the frequency of the RF oscillator and the radius of the dees.

Group-B

Answer *any four (04)* questions: 5×4=20

1. Elucidate the Raman effect with reference to the scattering of a photon by a molecule.
   A photon of frequency ν_1 is scattered by a molecule. As a result of this scattering, the rotational angular momentum of the molecule changes from j_i to j_f. Find the frequencies of the scattered photon with the help of appropriate selection rules.

2. Why do the results of the 'normal Zeeman effect' disagree with the experimental observations.
   Show that in the case of strong-field Zeeman effect, the energy shift in the level having quantum numbers n, l, m_l, m_s(the notations have the usual meaning) is $(m_l + 2m_s)B\mu_B$, where B is the uniform magnetic field in the z-direction and μ_B is the Bohr magneton.

3. Show that the eigenvalues of a Hermitian operator are real.
   Show that the product AB of two Hermitian operators A and B is also Hermitian if AB=BA.

4. A particle of mass m is described by the wave function
   $$\Psi(x,t) = \exp\{-a[(mx^2/\hbar) + it]\}$$
   Where a is a positive real constant. Normalize the wave function and calculate the expectation value of x^2.
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5. If a nucleus of mass number *A* undergoes an α-decay, and *Q* is the energy available in the decay, then show that the α particle kinetic energy can be approximately written as $\frac{(A-4)Q}{A}$.
   What is the shape of a nucleus having magic *N* and *Z*? What is the value of the quadrupole moment of such nucleus?
   The quadrupole moment of a nucleus is -0.028 barn. What will be the shape of the nucleus?

6. (a) Write down the quark compositions of K^0meson and Ω^-hyperon.
   (b) Consider the following reaction:
   $$\pi^+ + p \rightarrow K^+ + \overline{K^0} + p$$
   Assuming the target proton initially at rest, find the threshold energy (minimum kinetic energy of the pion) of the reaction.
   [Given Mass of proton= *938 MeV*, Mass of π^+ = *140 MeV*, Mass of K^+= *494 MeV* and Mass of $\overline{K^0}$= *498 MeV*]