B. Sc Part-III (Honours) Examination, 2020

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) What do you understand by the terms excitation and ionization potentials of an atom?
(b) An X-ray tube operates at 40 kV. Find the maximum speed of the electrons striking the anticathode and shortest wavelength of X-rays produced.
(c) What was the aim of the Stern-Gerlach experiment? Why was the non-uniform magnetic field used in this experiment?
(d) A beam of silver atoms in a Stern-Gerlach experiment, obtained from an oven heated to a temperature 1500 K passes through an inhomogeneous magnetic field having a field gradient 2×10^{2} Tm^{-1} perpendicular to the beam. The pole pieces are 0.1m long. Find the total separation of the components of the beam just after the pole pieces and on a photographic plate placed at a distance of 0.5m from the pole pieces.
(Given Bohr magneton $\mu_B = 9.27\times10^{-24}\ JT^{-1}$ and Boltzman's constant $k = 1.38\times10^{-23}\ JK^{-1}$. 10

2. Apply Heisenberg's uncertainty principle to explain the following: 10
(a) Non-existence of electron within the nucleus.
(b) Existence of protons and neutrons within the nucleus.
(c) Binding energy of an electron in a hydrogen atom is $\sim 13.6\ eV$.
(d) Minimum energy of a harmonic oscillator is $E_{min} = \frac{1}{2}\hbar\omega$.

3. Consider a potential barrier,

$$\begin{aligned} V(x) &= 0 && \text{for } x < 0 && \textit{(Region I)} \\ &= V_0 && \text{for } 0 \le x \le a && \textit{(Region II)} \\ &= 0 && \text{for } x > a && \textit{(Region III)} \end{aligned}$$

P.T.O.

and a beam of particles of mass m and energy $E < V_0$ is incident from left on this barrier.

(a) Write the solutions of the Schrödinger equation in regions I and II up to two arbitrary constants and in region III up to one arbitrary constant, explaining the notations used.

(b) Calculate the reflection and transmission coefficients by matching the wavefunctions and their first derivatives at the boundaries.

(c) Elucidate the significance of the non-zero transmission co-efficient vis-a vis the classical expectation.

10

4. (a) Give four distinguishing features of nuclear forces.

(b) Using a suitable diagram describe the working principle of a Bainbridge's mass spectrograph.

(c) An α-particle of energy 5 MeV is scattered through 180^0 by a fixed Uranium nucleus. Calculate the distance of closest approach.

10

5. (a) Write down the Geiger-Nuttal law and discuss its importance.

(b) Calculate the kinetic energy of the α-particle emitted in the following decay.

$$^{222}_{86}Rn \longrightarrow \, ^{218}_{84}Po + \alpha$$

Given M_{Rn}= 222.017531 *a.m.u*, M_{Po}= 218.008930 *a.m.u* and M_{α} = 4.002603 *a.m.u.*

(c) Define the Q value of a nuclear reaction. Derive an expression for the Q-value of the reaction X(a,b)Y in terms of masses of various particles and nuclei.

(d) What do you mean by a moderator? Give two examples of a good moderator.

10

Group-B

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

1. (a)(i) Show that no two electrons can have the same quantum state.

(ii) The 19th electron in Potassium atom is in the *4s* subshell instead of *3d* subshell. Explain.

(c) Find the possible values of resultant angular momentum for two electrons; one with $j_1 = \frac{3}{2}$ and other with $j_2 = \frac{5}{2}$.

5

2. (a) Why do all molecules not show rotational spectra?

(b) The *J=0* to *J=1* absorption line in carbon monoxide (CO) occurs at a frequency 1.153×10^{11} Hz. Calculate the moment of inertia, bond length and the lowest energy level of the molecule corresponding to *J=1*. (Given 1 a.m.u. = 1.66×10^{-27} Kg).

5

P.T.O.

3. (a) Explain the terms 'observable' and 'operator'. What is meant by a Hermitian operator?
(b) If $\psi_1(x,t)$ and $\psi_2(x,t)$ are both solutions of Schrödinger's wave equation for a given potential *V(x)*, then show that $\psi = a_1\psi_1 + a_2\psi_2$ is also a solution of the equation where a_1 and a_2 are the arbitrary constants.

5

4. (a) Calculate the expectation value of p^2 (i.e $\langle p^2 \rangle$) for the wavefunction
$\psi_x = \left(2/l\right)^{1/2} \sin\left(\frac{\pi x}{l}\right)$ in the region $0 < x < l$.
(b) Given, the ground state wave function of hydrogen atom as
$\psi = \left(\frac{1}{\pi a_0^{\ 3}}\right)^{1/2} \exp\left(-r/a_0\right)$, the notations have their usual meaning. Obtain the probability of finding the electron between r and r+dr.

5

5. (a) Show that the matrix L_x is Hermitian.
(b) Find the eigen value of the operator $\widehat{L_z}$ for the function $f(\theta) = 5\,cos^3\theta - 3\,cos\theta$.

5

6. (a)(i) ${}^{27}_{13}Al$ nucleus has a radius of 3.6 Fermi. Find the radius of ${}^{64}_{29}Cu$ nucleus.
(ii) Calculate the ratio $\frac{m}{m_0}$ for an electron having kinetic energy of 1 MeV. Symbols have the usual meaning. (Given $m_0 = 9.1\times10^{-31}$ Kg).
(b) Find the ground state spin-parity of the nuclei ${}^{17}_{8}O$.

5