

**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  $2 \times 10^2 \text{ Tm}^{-1}$  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  $\mu_B = 9.27 \times 10^{-24} \text{ JT}^{-1}$  and Boltzman's constant  $k = 1.38 \times 10^{-23} \text{ JK}^{-1}$ . 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  $\sim 13.6 \text{ eV}$ .
  - (d) Minimum energy of a harmonic oscillator is  $E_{min} = \frac{1}{2} \hbar \omega$ .
  
3. Consider a potential barrier,

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

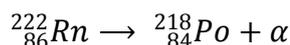
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and a beam of particles of mass  $m$  and energy  $E < V_0$  is incident from left on this barrier.

- (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.

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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  $\alpha$ -particle of energy 5 MeV is scattered through  $180^\circ$  by a fixed Uranium nucleus. Calculate the distance of closest approach.
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5. (a) Write down the Geiger-Nuttal law and discuss its importance.
  - (b) Calculate the kinetic energy of the  $\alpha$ -particle emitted in the following decay.



Given  $M_{\text{Rn}} = 222.017531 \text{ a.m.u.}$ ,  $M_{\text{Po}} = 218.008930 \text{ a.m.u.}$  and  $M_{\alpha} = 4.002603 \text{ a.m.u.}$

- (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.

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### 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 19<sup>th</sup> 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  $1.153 \times 10^{11}$  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. =  $1.66 \times 10^{-27}$  Kg).

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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  $\psi_x = \left(\frac{2}{l}\right)^{1/2} \sin\left(\frac{\pi x}{l}\right)$  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)  ${}^{27}_{13}\text{Al}$  nucleus has a radius of 3.6 Fermi. Find the radius of  ${}^{64}_{29}\text{Cu}$  nucleus.  
 (ii) Calculate the ratio  $\frac{m}{m_0}$  for an electron having kinetic energy of 1 MeV. Symbols have the usual meaning. (Given  $m_0 = 9.1 \times 10^{-31}$  Kg).  
 (b) Find the ground state spin-parity of the nuclei  ${}^{17}_8\text{O}$ . 5