B. Sc. Physics (Hons.) Examination, 2023

(2nd Year, 2nd Semester)

Elements of Modern Physics

Paper – UG/Sc./Core /Phy/ Th/09

Time : 2 hours | Full Marks : 40

*Answer any **four** questions.*

1. (a) Describe how Planck's radiation law eliminated the ultraviolet catastrophe in Blackbody radiation.

   (b) In a photoelectric effect experiment, the wavelength of the incident light changes from 300 nm to 400 nm. Show that the corresponding change in stopping potential is ~ 1V.

   (b) A photon of wavelength, λ, collides head on with a free electron of rest mass, m_0. Show that the maximum recoil energy of the electron corresponding to $\varphi = 180°$ is given by:

   $E_{max} = \frac{2m_0c^2\lambda_0^2}{\lambda^2+2\lambda\lambda_0}$ where $\lambda_0 = \frac{h}{m_0c}$ is the Compton wavelength of the electron.

   [4+2+4]

2. (a) Establish the interrelation between phase velocity and group velocity for de-Broglie waves and comment on the nature of the medium wherein the phase velocity is lower than the group velocity.

   (b) "In quantum mechanics all the operators are linear"– Explain.

   (c) Evaluate the commutator: $[\hat{p}_x, x^2]$.

   [(4+1)+2+3]

3. (a) What is the physical significance of normalizing a wave function in Quantum Mechanics? Prove that the linear momentum is an Hermitian operator.

   (b) Show that $[\hat{A}, \hat{B}]$ is not Hermitian for two Hermitian operators $\hat{A}$ and $\hat{B}$.

   (c) The normalized energy eigen functions for a particle trapped in an infinite square well potential of width, a, is given by $\psi_n(x) = \sqrt{\frac{2}{a}}\sin\frac{n\pi x}{a}$ and thus show that any two different states are orthogonal to each other.

   [(1+3)+3+3]

4. (a) Explain the origin of electric quadrupole moment of nuclei.

   (b) What do you understand by the binding energy of nucleus? Draw graphically the variation of binding energy per nucleon and explain.

(c) Find the energy release if two ${}_1H^2$ nuclei can fuse together to form ${}_2He^4$ nucleus. The binding energy per nucleon of H^2 and He^4 are 1.1 MeV and 7.0 MeV respectively.

[3+4+3]

5. (a) What do you understand by range of alpha particle?

(b) Explain the origin of line and continuous spectrum of beta rays?

(c) Can a non-radioactive element be changed in to radioactive form?

(d) Given that the period of radon is 3.82 days and that the volume at normal temperature and pressure of the radon in equilibrium with 1 gm of radium is 0.63 mm^3. Deduce the half-life period of radium. (Gram molecular volume = 22.4 lit and atomic weight of radium 226).

[2+3+1+4]

6. (a) What are the Einstein A and B coefficients?

(b) What do you understand by population inversion and how is this achieved?

(c) Describe the working principle of Ruby laser.

[3+3+4]

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