2023

4th Semester Examination

PHYSICS (Honours)

Paper : C 9-T

[Elements of Modern Physics]

[CBCS]

Full Marks : 40 Time : Two Hours

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 ***five*** of the following : 2×5=10

1. Write the expression for the de Broglie wavelength associated with a charged particle having charge 'q' and mass 'm', when it is accelerated by a potential V. 2

2. How does the light from a torch differ from that of a LASER, although both can be equally intense and of same colour. 2

3. An X-ray tube operates at 30 kV. Calculate the shortest wavelength of the emitted X-rays. 2

P.T.O.

4. If $\hat{\alpha}$ is a non-Hermitian operator then show that $\left(\hat{\alpha}+\hat{\alpha}^{\dagger}\right)$ is Hermitian. 2

5. State and explain Ehrenfest's theorem. 2

6. Define binding energy and packing fraction of nuclei. 1+1

7. The half-life of UX_1 is 24.1 days. After the isolation of UX_1, how many days are required for 90% of it to be converted to UX_2? 2

8. Calculate the normalization constant for a wave function given by (at $t=0$) $\psi(x)=A\exp\left(-\sigma^2x^2/2\right)\exp(ikx)$. 2

Group - B

Answer any ***four*** of the following : 5×4=20

9. An electron is observed by scattering a beam of protons from it in a so-called proton microscope. If the electron is initially at rest, show that the smallest distance within which it can be localized is equal to $\left(M_p/4m_e\right)\left(\lambda_p/2\pi\right)$, where λ_p is the de Broglie wavelength of the proton. 5

10. Explain the need for a wave equation to describe the behaviour of a quantum system. Starting from de Broglie's hypothesis, set up one-dimensional Schrödinger wave equation for a free particle. How is

it modified if the particle is under the influence of a potential field? 2+2+1

11. A particle in the infinite square well has the initial wave function $\psi(x, 0) = Ax(a-x)$, $(0 \le x \le a)$, for some constant A. Outside the well the wave function is zero. Find $\psi(x, t)$. 5

12. Define the decay constant λ of a radioactive material. Hence obtain an expression for the number of radioactive atoms at time t, given that their initial number was N_0. Explain half-life and mean life of radioactive material. 1+2+2

13. Obtain an expression for the binding energy and mass of a nucleus in the ground state on the basis of semi-empirical mass formula of Weizsacker. 3+2

14. Describe briefly the working of a ruby laser and state how population inversion has been achieved in this device. 2+3

Group - C

Answer any ***one*** of the following : 10×1=10

15. (a) Prove that the expression for the one-dimensional probability current density is

$$j_x = \frac{i\hbar}{2m}\left(\psi \frac{\partial \psi^*}{\partial x} - \psi^* \frac{\partial \psi}{\partial x}\right).$$

P.T.O.

(b) The mass of the hydrogen atom and of neutron are 1.008142 and 1.008982 amu respectively. Calculate the packing fraction and binding energy per nucleon of ^{16}O nucleus.

(c) What do you mean by nuclear fission and chain reaction? 5+(1.5+1.5)+(1+1)

16. (a) Explain Geiger-Nuttal law relating to the ranges of α-particles in α-ray disintegrations and the value of half-life.

(b) A free neutron decays into a proton, an electron and an antineutrino. If $M(n) = 1.00898\ u$, $M(p) = 1.00759\ u$ and $M(e) = 0.00055\ u$, find the kinetic energy shared by the electron and the antineutrino.

(c) Prove that the expectation value of energy in the eigenstate $\psi_n = u_n(\boldsymbol{r})\exp(-iE_nt/\hbar)$ is certainly E_n, where $u_n(\boldsymbol{r})$ is normalized. 5+3+2
