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B.Sc./4th Sem (H)/PHYS/23(CBCS)

2023

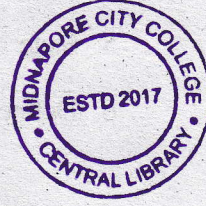
4th Semester Examination

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 :  $2 \times 5 = 10$

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  $(\hat{\alpha} + \hat{\alpha}^\dagger)$  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  $t = 0$ )  $\psi(x) = A \exp(-\sigma^2 x^2 / 2) \exp(ikx)$ . 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  $(M_p / 4m_e)(\lambda_p / 2\pi)$ , where  $\lambda_p$  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

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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  $\psi(x, 0) = Ax(a - x)$ , ( $0 \leq x \leq a$ ), for some constant  $A$ . Outside the well the wave function is zero. Find  $\psi(x, t)$ . 5

12. Define the decay constant  $\lambda$  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**

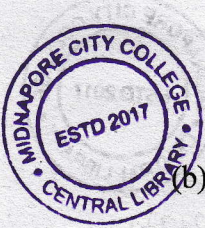
Answer any *one* of the following : 10×1=10

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.





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- (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  $^{16}\text{O}$  nucleus.
- (c) What do you mean by nuclear fission and chain reaction? 5+(1.5+1.5)+(1+1)
16. (a) Explain Geiger-Nuttall law relating to the ranges of  $\alpha$ -particles in  $\alpha$ -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  $\psi_n = u_n(\mathbf{r})\exp(-iE_n t/\hbar)$  is certainly  $E_n$ , where  $u_n(\mathbf{r})$  is normalized. 5+3+2
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