

B.Sc. 4th Semester (Honours) Examination, 2023 (CBCS)**Subject : Physics****Course : CC-IX****(Elements of Modern Physics)****Time: 2 Hours****Full Marks: 40***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****1. Answer any five questions:****2×5=10**

- (a) What is meant by a wave packet? Why do we need it? 1+1
- (b) The life-time of an excited state of an atom is 10^{-8} s. Calculate the minimum uncertainty in the determination of the energy of that excited state. (Given $\hbar = 6.6 \times 10^{-34}$ J.s)
- (c) In one dimension the wave function of a particle is represented by $\psi(x) = \sqrt{a}e^{-ax}$. What is the probability of finding the particle in the region between $x = \frac{1}{a}$ and $x = \frac{2}{a}$? 1+1
- (d) What do you understand by quantum tunnelling? Mention one of its application. 1+1
- (e) State the basic assumptions related to the single particle shell model of nucleus.
- (f) Mention the different types of nuclear reactors. Why do we use a moderator in a nuclear reactor? 1+1
- (g) What do you mean by 'induced or artificial radioactivity'?
- (h) What does the acronym 'LASER' stand for? What are the 'metastable states'? 1+1

Group-B**2. Answer any two questions:****5×2=10**

- (a) (i) Find the probability current density associated with a plane wave Ae^{ikx} in one dimension and verify that it satisfies the equation of continuity in one dimension.
(ii) Find the probability current density for a real wave function. (2+2)+1
- (b) (i) Define the terms 'stopping potential (V_0)' and 'threshold frequency (v_0)' in the case of photo-electric effect.
(ii) Show that Planck's constant (\hbar) has the dimension of angular momentum. 3+2

- (c) (i) Give the definition of 'binding energy (E_b)' of a nucleus.
(ii) ${}^2\text{He}^4$ nucleus has no magnetic moment. Explain.
(iii) A reactor is producing energy at the rate of 32×10^6 watts. How many atoms of U-235 do undergo fission per second?
(Assume that on an average 200 MeV is released per fission.) 2+1+2
- (d) What are Einstein coefficients? Derive the relation between them.

Group-C

3. Answer *any two* questions:

10×2=20

- (a) (i) Deduce Planck's law of radiation.
(ii) A proton is confined to a nucleus of radius 5×10^{-5} m. Calculate the minimum uncertainty in its momentum and also calculate the minimum kinetic energy the proton should have. The proton mass is 1.67×10^{-27} Kg. 6+4
- (b) (i) Establish the Geiger law $R \propto v^3$ for mono-energetic α -particles (the symbols have their usual meanings).
(ii) What is Geiger-Nuttal law? State the importance of this law.
(iii) Using semi-empirical binding energy formula, calculate the binding energy of ${}_{20}\text{Ca}^{40}$. 4+(1+1)+4
- (c) (i) A betatron working on an operating frequency of 60 Hz has a stable orbit of diameter 1.6 m. Find the energy gained per turn and also the final energy if the magnetic field at the orbit is 0.5 Telsa.
(ii) What is a nuclear reactor? What are the essential elements of a nuclear reactor?
(iii) Write down all possible conservation laws of nuclear reactions. 2+(1+3)+4
- (d) (i) Discuss the significance of the results of Davisson-Germer experiment.
(ii) What are the different natural radioactive series?
(iii) Explain, in brief, the construction and working principle of (Pulsed) Ruby laser. 2+2+(3+3)