

U.G. 4th Semester Examination - 2024**PHYSICS****[HONOURS]****Course Code : PHY-H-CC-T-9****(Elements of Modern Physics)****Full Marks : 40****Time : $2\frac{1}{2}$ Hours***The figures in the right-hand margin indicate marks.**Candidates are required to give their answers in their own words as far as practicable.***1. Answer any five questions:** **$2 \times 5 = 10$**

- a) Define Bohr Radius and estimate numerical value for it.
- b) Explain what was learned about the quantization of radiation from Franck-Hertz experiment. Indicate which of the measured effects were non-classical and why, and explain how they can be understood as quantum phenomena.
- c) A photon has of energy 4.2×10^{-19} J. What is its wavelength?

[Turn over]

- d) An electron of energy 200 eV is passed through a circular hole of radius 10^{-4} cm. What is the uncertainty introduced in the angle of emergence?
- e) Why do the stable medium nuclei contain excess neutrons?
- f) Determine the activity of 1 gm sample of ^{90}Sr whose half life against β decay is 28 years.
- g) What are magic numbers in the context of shell structures of nucleons inside nuclei?
- h) What do you understand by spectral line width of a Laser?

2. Answer any two questions: $5 \times 2 = 10$

- a) State and explain radio-active decay law. Radium being a member of the uranium series occurs in uranium ores. If the half-lives of uranium and radium are respectively 4.5×10^9 and 1,620 years, calculate the relative proportions of these elements in a uranium ore, which has attained equilibrium and from which none of the radioactive products have escaped. $2+3$
- b) Illustrate basic differences between spontaneous emission and stimulated emission of radiation. At what temperature the rates of spontaneous and stimulated emissions are equal? Assume $\lambda = 5000\text{\AA}$. $3+2$

- c) Calculate the uncertainty in the momentum of a proton which is confined to a nucleus of radius equal to 10^{-13} cm. From this result, estimate the kinetic energy of the proton inside the nucleus. What would be the kinetic energy for an electron if it had to be confined within a similar nucleus?

$3+2$

- d) What is photo-electric effect? Explain Einstein's photo electric equation.

A light source of wavelength λ illuminates a metal and ejects photoelectrons with a maximum kinetic energy of 1.00 eV. A second light source with half the wavelength of the first ejects photoelectrons with a maximum kinetic energy of 4.00 eV. Determine the work function of the metal.

$1+1+3$

Answer any two questions: $10 \times 2 = 20$

- 3. a) Write one-dimensional time-independent Schrodinger equation and explain the meanings of the symbols in that equation.
- b) An electron is trapped in an infinitely deep potential well of width $L = 10^6$ fm. Solve the Schrodinger equation and hence find the normalized wave function and energy for n th. state where n is an integer ($n > 0$).

- c) Calculate the wavelength of photon emitted from the transition $E_4 \rightarrow E_3$. (1+2)+(3+2)+2
4. a) The relation for total energy (E) and momentum (p) for a relativistic particle is $E^2 = c^2 p^2 + m^2 c^4$, where m is the rest mass and c is the velocity of light. Using the relativistic relations $E = \hbar \omega$ and $p = \hbar k$, where ω is the angular frequency and k is the wave number, show that the product of group velocity and the phase velocity is equal to c^2 .
- b) Consider a stream of particles with energy E travelling in one dimension from $x = -\infty$ to ∞ . The particles have an average spacing of distance L . The particle stream encounters a potential barrier at $x = 0$. The potential can be written as
- $$V(x) = 0 \text{ if } x < 0$$
- $$= V_0 \text{ if } 0 < x < a$$
- $$= 0 \text{ if } x > a$$

Suppose the particle energy is smaller than the potential barrier. For each of the three regions, write down Schrodinger's equation and calculate the wave-function ψ and its derivative $d\psi/dx$. Derive the expression for the transmission amplitude. 2+(2+2)+4

5. a) Derive the kinetic energy of α -particle in terms of Q value of the decay process.
- b) Draw a typical β -ray spectrum for (β^-) decay. Why Pauli's postulate of neutrino was necessary to explain this spectrum?
- c) Discuss briefly the phenomenon of pair production by gamma photon.
- d) What are the prompt and delayed neutrons in a Fission process? 2+(1+2)+3+2
6. a) What are the Coulomb and asymmetric terms of the semi-empirical mass-formula?
- b) How is the radius of a nucleus related to its mass number?
- c) $^{27}_{14}\text{Si}$ and $^{27}_{13}\text{Al}$ are mirror nuclei with mass difference 6 MeV. Estimate their radius?
- d) Using the semi empirical mass formula, find the atomic number of the most stable nucleus for a given mass number A . Hence explain which nuclei would expect to be the most stable among ^7_3Li or ^8_3Li and ^9_4Be or $^{10}_4\text{Be}$ [given $a_c = 0.71\text{MeV}$ and $a_n = 22.7\text{MeV}$] 2+1+2+3+2