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: 2×5=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: 5×2=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 λ = 5000A. 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: 10×2=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 $E^2 = c^2p^2+m^2c^4$, 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

$$V(x) = 0 \text{ if } x < 0$$
$$= V_b \text{ if } 0 < x < a$$
$$= 0 \text{ if } x > a$$

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) ${}^{27}_{14}Si$ and ${}^{27}_{13}Al$ 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 ${}^{7}_{3}Li$ or ${}^{8}_{3}Li$ and ${}^{9}_{4}Be$ or ${}^{10}_{4}Be$ [given a_c = 0.71MeV and a_n = 22.7 MeV]

2+1+2+3+2

0.9411 0.93233