U.G. 4th Semester Examination - 2021

PHYSICS

[HONOURS]

Course Code : PHY-H-CC-T-9

(Elements of Modern Physics)

Full Marks : 20 Time : 1 Hour

The figures in the right-hand margin indicate marks.

Candidates are required to give their answers in their own words as far as practicable.

GROUP-A

1. Answer any **five** questions: 1×5=5

   a) What is the expectation value of p_x the linear momentum of a particle trapped in a one-dimensional box (infinite well)?

   b) Show, from Heisenberg's uncertainty relation, that the electron cannot be a constituent of the atomic nucleus.

   c) Describe with energy level diagrams the phenomena of stimulated emission, and stimulated absorption in a two-level system.

   d) What is the group velocity of a wave packet? Show that $v_g = v_p - \lambda \frac{dv_g}{d\lambda}$ here v_g and v_p are the group and phase velocity respectively.

   e) Consider black body radiation at absolute temperature T. Show that the number of photons per unit volume is proportional to T^3.

   f) Show from the semi-empirical mass formula, that $Z = \frac{A}{2}$ for light nuclei.

   g) Distinguish between nuclear fission and nuclear fusion.

   h) In what way is the neutron/proton ratio changed when a radioactive nucleus emits (i) an electron (ii) a positron? Which of the following refer to the same thing? (i) α-particle (ii) β-particle (iii) X-rays (iv) Photoelectrons (v) Cathode rays?

GROUP-B

2. Answer any **one** question : 5×1=5

   a) Calculate the normalization constant for a wave function (at t=0) given by $\psi(x) = Ae^{-\frac{\alpha x^2}{2}} e^{ikx}$. Determine the probability density and probability current density of the wave packet. 2+1+2

b) Define the binding energy of a nucleus. How does the binding energy per nucleon vary with the mass number? Given the following isotope masses: $_3Li^7$ = 7.016004 u, $_3Li^6$ = 6.015125 u and $_0n^1$=1.008665 u. Calculate the binding energy of a neutron in the $_3Li^7$ nucleus in MeV. 1.5+1.5+2

c) What is a neutrino? How does the neutrino hypothesis solve the apparent breakdown of conservation momentum and energy in β-decay? What is Ultraviolet catastrophe? Show that Planck's constant has the dimension of angular momentum. 1+2+1+1

GROUP-C

3. Answer any **one** question: 10×1=10

a) Show that the de Broglie wavelength in Angstrom unit for an electron accelerated from rest through a potential difference of V volt is given relativistically by

$$\lambda = \frac{h}{\sqrt{2m_0eV}}\left(1+\frac{eV}{2m_0c^2}\right)^{-\frac{1}{2}}$$

What is quantum dot? Derive relations between Einstein's A and B coefficients. What is the

population inversion in laser action? 3+2+4+1

b) A particle of mass m is moving in a square well the potential of infinite depth such that

V(x) = ∞ for x = 0 and x = a.

V(x) = ∞ for x = 0 < x < a

Solving time-independent Schrodinger equation, find out the normalized eigen function and eigen values. Show that (i) $\left[\hat{x},\hat{p}_x^n\right]=i\hbar n\hat{p}_x^{n-1}$ (ii)$\left[\hat{L}_x,\hat{L}_y\right]=i\hbar\hat{L}_z$ here symbols have their usual meaning. Show that the eigenvalues of a Hermitian operator are real. 5+2+2+1

c) What is photoelectric effect? Discuss how Einstein's photoelectric equation explains the essential features of photoelectric emission. Derive an expression for the kinetic energy of the recoiling electron in the Compton effect. Why the Compton effect cannot be observed with visible light? 1+3+5+1

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