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PHE-11

BACHELOR OF SCIENCE (B.Sc.)

Term-End Examination

June, 2015

00388

PHYSICS

PHE-11 : MODERN PHYSICS

Time : 2 hours *Maximum Marks : 50*

Note : *Attempt **all** questions. The marks for each question are indicated against it. Symbols have their usual meanings. You may use log table or a calculator.*

1. Attempt any ***five*** parts : *5×2=10*

(a) Calculate the energy of an electron that has de-Broglie wavelength of 1·8 Å. ($h = 6{\cdot}63 \times 10^{-34}$ Js; $m_e = 9{\cdot}1 \times 10^{-31}$ kg)

(b) What is the uncertainty in the energy of an atom in an excited state having a lifetime 10^{-9} s ? ($\hbar = 1{\cdot}055 \times 10^{-34}$ Js)

(c) List any four applications of radioisotopes.

(d) For a hydrogen-like atom in n = 2 state, give all possible values of L and J.

(e) Is the following wave function physically permissible ? Give reasons.

$$\psi(x) = A\frac{e^{-x^2}}{x^2 - a^2}, \quad -\infty < x < \infty$$

(f) Which of the following reactions are allowed ? Give reasons.

(i) $n \rightarrow p + e + \gamma$

(ii) $\mu \rightarrow e + \nu_e + \bar{\nu}_\mu$

(g) Calculate the binding energy for $^{9}_{4}Be$ given $M(^{9}_{4}Be) = 9{\cdot}0122$ u, $M_p = 1{\cdot}0073$ u, $M_n = 1{\cdot}0087$ u, $M_e = 0{\cdot}0005$ u and u = 931 MeV

2. Attempt any ***two*** parts : *2×5=10*

(a) A particle at rest decays into two particles one of which is massless. Using relativistic laws of conservation of energy and momentum, obtain the momentum of the decayed particles. *5*

(b) Two events occurring at the same place in a certain inertial frame of reference are separated by a time interval of 6 μs. In another inertial frame, they appear to be separated by 18 μs. What is the velocity of the second frame relative to the first frame and what is their spatial separation in the second frame ? *5*

(c) Derive the relativistic velocity addition formula. *5*

3. Attempt any ***one*** part : *1×10=10*

(a) Wave function of a particle of mass m in the following one-dimensional square well

$$V(x) = 0 \qquad -a \le x \le a$$

$$= \infty \qquad x < -a;\ x > a$$

is given by

$$\psi(x) = A \sin \frac{2\pi x}{a} + B \cos \frac{2\pi x}{a}$$

Calculate A and B and the energy eigenvalue corresponding to the above wave function. Explain how the existence of zero point energy for an infinite potential well is consistent with the uncertainty principle. *7+3=10*

(b) For the following function

$$f(p_x) = \sum_{n=0}^{\infty} p_x^n$$

show that

$$[x, f(p_x)] = i\hbar \frac{\partial f(p_x)}{\partial p_x}.$$ *10*

4. Attempt any ***one*** part : *1×10=10*

(a) Calculate the average potential energy of a one-dimensional harmonic oscillator in the 1^{st} excited state

$$\psi_1(x) = \left(\frac{a}{2\sqrt{\pi}}\right)^{1/2} 2 a x e^{-a^2x^2/2}$$ *10*

(b) Obtain the average value of $< r >$ and of potential energy $V(r) = -\frac{e^2}{r}$ of a hydrogen atom in the ground state $\psi_{100}(r) = \frac{1}{\sqrt{\pi a_0^3}} e^{-r/2a_o}$.

Show that for n = 2, there are 4 degenerate eigenfunctions for the hydrogen atom. *7+3=10*

5. Attempt any ***two*** parts : *2×5=10*

(a) Due to a nuclear accident, a radioactive substance leaked into the surrounding area and the level of radiation became 100 times the permissible level. If the half-life of the radioactive substance is 50 days, after how many days would the area be safe for occupation ? *5*

(b) Describe the general features of a nuclear reactor with the help of a schematic diagram. *5*

(c) Name the different models of the atomic nucleus. Discuss briefly the shell model. *2+3=5*