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PHE-11

BACHELOR OF SCIENCE (B.Sc.)

Term-End Examination

02982

December, 2014

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) The life-time of muon in its rest frame is 2 μs. How fast is it moving if its life-time appears to be 20 μs in the lab frame ?

(b) Calculate the kinetic energy of an electron ($m_0 = 0{\cdot}5$ MeV/c^2) moving with a speed of 0·8 c.

(c) If an electron is assumed to be confined inside the nucleus of size 10^{-15} m, calculate the uncertainty in its momentum. Take h = $6{\cdot}626 \times 10^{-34}$ Js.

(d) The half-life of a radioactive element is 8 years. How much time will be required for 100 g of the material to disintegrate to 12·5 g ?

(e) Show that for any operator A, $i(A - A^{+})$ is Hermitian.

(f) Which of the following transitions is allowed ? Give reasons.

$$^{1}S_{1/2} \longrightarrow {}^{1}P_{1/2}$$

$$^{1}S_{1/2} \longrightarrow {}^{1}D_{3/2}$$

(g) Give the charge and spin of up and strange quarks.

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

(a) A rocket is fired from the Earth at a speed of 0·6 c and another at a speed of 0·4 c in the same direction. What is the relative speed of the second rocket with respect to the observer in the first rocket ? *5*

(b) Derive the relativistic energy – momentum relation for a free particle. *5*

(c) An event occurs at x = 20 km, y = 5 km, z = 10 km at t = 0 in a frame of reference S. What are the coordinates of the event in another frame S′ moving along the x-axis with a speed 0·8 c ? *5*

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

(a) A particle of mass m is confined in a one-dimensional box of length L such that

$$V(x) = 0 \qquad 0 \le x \le L$$

$$= \infty \qquad x < 0 \text{ and } x > L$$

Solve the Schrödinger equation to obtain the energy eigenvalues

$$E_n = \frac{\hbar^2 \pi^2 n^2}{2\,mL^2}$$

and the normalized wave function

$$\Psi_n(x) = \sqrt{\frac{2}{L}} \sin \frac{n\pi x}{L}$$ *10*

(b) (i) Define parity operator and obtain its eigenvalues.

(ii) Establish the commutator

$$[L_x, L_y] = i\,\hbar\, L_z$$ *5+5*

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

(a) The wave function of hydrogen atom in the second excited state is given by

$$\Psi(r, \theta, \phi) = A\, r\, e^{-r/2a_0} \cos\theta$$

Calculate the normalization constant A and the expectation value of the potential energy

$$V(r) = -\frac{1}{4\pi\varepsilon_0}\frac{e^2}{h}$$ *10*

(b) State the selection rules for X-ray spectra. Explain with the help of a diagram the transitions that give rise to K_α lines. An X-ray tube with a silver anode emits K_α line at 21·99 keV and another K_α line at 15·8 keV due to the presence of an impurity. Atomic number of silver is 47. Calculate the atomic number of the impurity. *2+3+5=10*

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

(a) What do you understand by the term radioactive equilibrium ? Obtain the condition for transient equilibrium in the decay of ^{238}U. *5*

(b) Explain how the synchrocyclotron is used to accelerate particles to a few hundred MeV of energy. *5*

(c) How is energy released in a controlled manner in a nuclear reactor ? Discuss the importance of control rods in a reactor. *5*