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PHE-11

BACHELOR OF SCIENCE (B.Sc.)

Term-End Examination

December, 2015

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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 non-programmable calculators or log tables. The values of physical constants are given at the end.*

1. Answer any ***five*** parts : *5×4=20*

(a) Calculate the kinetic energy of an electron moving with a velocity of 0·999 c in the laboratory system where c is the velocity of light.

(b) Calculate the de Broglie wavelength of a 100 MeV electron.

(c) Calculate the minimum uncertainty in the momentum of a proton confined to a nucleus of radius 10^{-14} m. Also calculate the minimum kinetic energy of the proton.

(d) Obtain the most probable value of r for the ground state of a hydrogen atom for which the wave function is

$$\psi(r) = \frac{2}{(a_0^3)^{1/2}} e^{-r/a_0} .$$

(e) List all the spectral terms of a hydrogen-like atom in n = 3 state.

(f) The half-life of a radioactive element is 26 days. Calculate the time required for 25% of the element to decay.

(g) Explain whether the following reactions are possible :

(i) $\lambda^0 + \Sigma^+ \rightarrow p + n + e^- + \bar{\nu}_e$

(ii) $h = p + e + \bar{\nu}_e$

2. Answer any ***one*** part :

(a) An electron is moving with a speed of 0·85 c in a direction opposite to that of a photon. Calculate the relative velocity of the photon with respect to the electron. *5*

(b) A pion at rest decays into a muon and a neutrino (zero rest mass). Using the relativistic law of conservation of energy and momentum obtain the momentum of muon in terms of m_π and m_μ. *5*

3. Answer any ***one*** part :

(a) (i) Write the time-dependent Schrödinger equation and deduce the time-independent Schrödinger equation. *5*

(ii) Obtain the value of the commutator $[L_x, L_y]$. *5*

(b) (i) State the properties of wave function. *5*

(ii) The wave function of a particle confined in a length $0 < x < L$ is

$$\psi(x) = A \sin \frac{n \pi x}{L}.$$

Obtain the normalisation constant. *5*

4. Answer any ***one*** part :

(a) Give the selection rules for atomic transitions that yield a characteristic X-ray spectrum. Draw the approximate energy levels for the L and M shells and show all the allowed transitions. Use Moseley's law to obtain the frequency of an X-ray line when an L to K transition takes place in an Ag atom for $\sigma = 3$. *10*

(b) Write down the time-independent Schrödinger equation for a one-dimensional harmonic oscillator which has an angular frequency ω. Also calculate the mean kinetic energy and potential energy of the oscillator in the ground state given by the wave function

$$\psi(x) = \left(\frac{a}{\pi}\right)^{1/2} \exp\left(\frac{-a^2x^2}{2}\right),$$

where $a = \frac{m\omega}{\hbar}$. *10*

5. Answer any ***one*** part :

(a) Define mass defect and binding energy. The energy released when two ^2_1H nuclei fuse together to form ^4_2He nucleus is 23·6 MeV. Given that the binding energy per nucleon in ^2_1H is 1·1 MeV, calculate the binding energy per nucleon for ^4_2He. *5*

(b) Explain the working of Wilson cloud chamber. *5*

Physical Constants

$h = 6{\cdot}6 \times 10^{-34}$ Js

$m_e = 9{\cdot}1 \times 10^{-31}$ kg

$m_p = 1{\cdot}67 \times 10^{-27}$ kg