RAJARATA UNIVERSITY OF SRI LANKA
FACULTY OF APPLIED SCIENCES

B.Sc. (General) Degree
Second Year – Semester II Examination – March/ April 2014

PHY 2106- ATOMIC AND NUCLEAR PHYSICS

Answer any two questions — Time: One hour

electron mass, m_e	$= 9.1 \times 10^{-31}$ kg
Planck constant, h	$= 6.624 \times 10^{-34}$ J s
elementary charge, e	$= 1.6 \times 10^{-19}$ C
permittivity of free space, ε_0	$= 8.85 \times 10^{-12}$ C^2 N^{-1} m^{-2}
1 electron volt, eV	$= 1.6 \times 10^{-19}$ J
speed of light in free space, c	$= 3.0 \times 10^{8}$ m s^{-1}

Use of a non-programmable calculator is permitted.

Unless otherwise specified, symbols have their usual meaning.

1. (a) Explain how Rutherford's experiment on alpha particle scattering led to the concept of nuclear model of atom. [20 marks]

   (b) What are the major deficiencies of Rutherford's nuclear model? How were they overcome by Bohr? [20 marks]

   (c) Considering Bohr theory of hydrogen atom, derive an expression for the frequency of a photon released in the transition between n_2 to n_1. [30 marks]

   (d) The lowest two excited states of a hydrogen atom are 10.2 eV and 12 eV above the ground state. Calculate the wavelengths of radiation that could be produced by transition between these states and the ground state. [30 marks]

2. (a) i. Explain the underline words in the following section.

Bohr theory could not explain the multiple structure of spectral lines in the simplest hydrogen atom. And also older theories would not able to explain the new discoveries like Zeeman Effect. Therefore, in order to explain the complex spectra of atoms, the vector model was introduced in which each of the electrons in the given atom associated with a set of quantum numbers. The two distinct features of the vector model are spatial quantization and spinning electron. [18 marks]

ii. In an atom having two or more electrons, coupling schemes are used in order to obtain the total orbital and spin angular momenta. What do you mean by coupling?

Write down the two types of coupling schemes and explain briefly. [18 marks]

iii. Find S, L and J values that correspond to each of following states.

$^2S_{1/2}$, $^3P_2$, $^2D_{3/2}$ and $^2P_{3/2}$ [24 marks]

(b) Define "mass defect" and "binding energy per nucleon".

Sketch the variation of binding energy per nucleon with the atomic mass number. Explain briefly how it accounts for nuclear fission and fussion. [24 marks]

Calculate the binding energy per nucleon of Helium.

Atomic mass of Helium	= 4.00260 a.m.u.	
Mass of proton	= 1.007895 a.m.u.	
Mass of neutron	= 1.008665 a.m.u.	[16 marks]

3. (a) i. Explain the terms "decay constant" and "half life" as applied to a radioactive substance. Find the relationship between them. [25 marks]

ii. The half life of Radon is 3.8 days. After how many days will only 1/20 of a radon sample be left over? [20 marks]

(b) i. What is nuclear fission? Give an application of nuclear fission. [15 marks]

ii. A railway engine develops an average power of 1200 kW during a 10 hour run from one station to another. If the engine is driven by an atomic power plant of 20% efficiency, how much ^{235}U would be consumed on the run? Each atom of ^{235}U on fission releases 180 MeV of energy.

[40 marks]