16

74

RAJARATA UNIVERSITY OF SRI LANKA
FACULTY OF APPLIED SCIENCES

B.Sc. (General) Degree in Applied Sciences
First Year - Semester II Examination – November/December 2016

PHY 1104 – MODERN PHYSICS

Time: One and half (1 ½) hours

Instructions:

1. Answer **all** the questions
2. Only the calculators provided by the university are allowed to be used.

Values of constants

speed of light in a vacuum	$c = 3.00 \times 10^{8}\ \mathrm{ms}^{-1}$
electron charge	$e = 1.60 \times 10^{-19}\ \mathrm{C}$
the Plank constant	$h = 6.63 \times 10^{-34}\ \mathrm{J\,s}$
mass of electron	$\mathrm{m}_e = 9.11 \times 10^{-31}\ \mathrm{kg}$
mass of proton	$\mathrm{m}_p = 1.67 \times 10^{-27}\ \mathrm{kg}$
acceleration of free fall on the Earth's surface	$g = 9.81\ \mathrm{m\,s}^{-1}$
electron volt	$1\ \mathrm{eV} = 1.60 \times 10^{-19}\ \mathrm{J}$
Rydberg constant	$R_H = 1.097 \times 10^{7}\ \mathrm{m}^{-1}$
Atomic mass unit	$1\ \mathrm{u} = 931.6\ \mathrm{MeV}$
Angstrom	$1\mathrm{Å} = 1 \times 10^{-10}\ \mathrm{m}$

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1. (a) (i) The Bohr theory of the hydrogen atom is based on several assumptions. What are these assumptions? Discuss briefly. **(8 marks)**

(ii) Suppose that the electron in the hydrogen atom obeyed classical mechanics rather than quantum mechanics. Why should such *hypothetical* atom emit a continuous spectrum rather than the observed line spectrum? **(3 marks)**

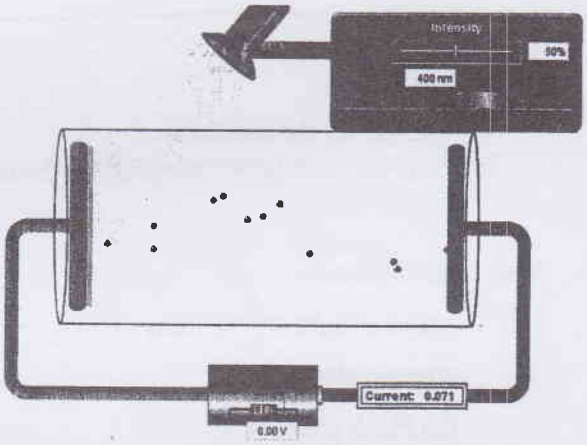
(iii) Find the frequency of the electron's orbital motion, f_e, around a fixed nucleus of charge $+Ze$ by using $m_e vr = n\hbar$ and $f_e = (v/2\pi r)$ to obtain

$$f_e = \frac{m_e k^2 Z^2 e^4}{2\pi\hbar^3}\left(\frac{1}{n^3}\right) \qquad n = 1,2,3, \dots$$

(5 marks)

(b) X-rays are used to take photographs of bones inside the body. X-ray photons typically have frequencies in the range 10^{16} Hz to 10^{19} Hz. An X-ray photon has energy of 191 eV. Calculate the frequency of the photon. **(4 marks)**

2. The diagram shows a simulation of the photoelectric effect. As violet light is shone on the sodium target, electrons leave the sodium and move to the right, causing a small current in the circuit.



(a) When the wavelength of the light is increased, the light becomes red and no electrons leave the sodium. Explain why violet light, but not red light causes electron emission. **(3 marks)**

(b) While violet light shines at the sodium, a student studies the effect of varying the intensity of the light. Describe and explain how this will affect the rate of electron emission, the maximum speed of the emitted electrons and the current in the circuit. **(6 marks)**

(c) With violet of wavelength 4.0×10^{-7} m, shining at the target, the D.C. power supply is changed until there is no current. This stopping potential is 0.80 V.

(i) Calculate the maximum kinetic energy of the electrons leaving the surface of the sodium. **(3 marks)**

E = hf

(ii) Calculate the threshold frequency for sodium. **(3 marks)**

(d) A metal whose work function is 3.0 eV, is illuminated by light of wavelength 3×10^{-7}m.

(i) Calculate the maximum energy of the photoelectrons **(3 marks)**

(ii) Calculate the stopping or retarding potential. **(2 marks)**

76

3. (a) (i) The theory of Special Relativity defines the magnitude of relativistic momentum as $p_{\mathrm{rel}} = \gamma p_{\mathrm{non-rel}}$. Show that the speed of an object with a relativistic momentum p_{rel} and mass m is

$$v = \frac{c}{\sqrt{1 + (mc/p_{rel})^2}}$$

(4 marks)

(ii) An unstable particle at rest breaks into two fragments of unequal mass. The mass of the first fragment is 2.50×10^{-28} kg, and that of the other is 1.67×10^{-27} kg. If the lighter fragment has a speed of $0.893c$ after the breakup, what is the speed of the heavier fragment? (Assume the speeds are measured in a frame at rest with respect to the original particle)

(5 marks)

(b) (i) Show that the energy-momentum relationship, $E_{\mathrm{rel}}^2 = p_{\mathrm{rel}}^2 c^2 + (mc^2)^2$ follows from the expressions $E_{\mathrm{rel}} = \gamma mc^2$ and $p_{\mathrm{rel}} = \gamma mv$. **(4 marks)**

(iii) A proton in a high-energy accelerator is given a **kinetic energy** of 50.0 GeV. Determine its,

(a) Momentum **(4 marks)**

(b) speed **(3 marks)**

-END-

10^3 k
10^6 M
10^9 G