THE OPEN UNIVERSITY OF SRI LANKA

DEPARTMENT OF PHYSICS

BACHELOR OF SCIENCE DEGREE PROGRAMME -2016/2017

LEVEL 04

PYU 2160 – MODERN PHYSICS

FINAL EXAMINATION.

TIME: -TWO HOURS (2 hrs.) **ANSWER FOUR QUESTIONSONLY.**

Date: 19.01.2018 **Time: 9.30 am – 11.30 am**

$c = 3\text{x}10^{8}\text{ms}^{-1}$, $h = 6.63\text{x}10^{-34}$ Js, 1eV = $1.6\text{x}10^{-19}$ J, $\pi = 3.14$, mass of the electron = $9.1\text{x}10^{-31}$ kg, mass of the proton = $1.67\text{x}10^{-27}$kg, $R_H = 1.097\text{x}10^{7}\text{m}^{-1}$, e = $1.6\text{x}10^{-19}$ C

1. (a) An X-ray photon of wavelength λ recoils (Compton scatters) with increased wavelength $\lambda^{/}$ from a stationary electron of mass *m* and at an angle φ with respect to its initial direction. Show that the change in wavelength is $\lambda^{/} - \lambda = \frac{h}{mc}(1 - \cos\phi)$

(10marks)

(b) Show that the direction of recoil electron can be given by $\tan\Phi = \frac{E^{/}\sin\theta}{E - E^{/}\cos\theta}$ (E and $E^{/}$ are the energy of incident and scattered photon.) **(5 marks)**

(c) A beam of radiation of wavelength 0.0242A^{0} is scattered from a target at angle of 90^{0}. Find the energy and direction of recoil electron. **(8 marks)**

(d) Write down two applications for Compton scattering in physics. **(2 marks)**

2. (a) Write down the Bohr postulates for atomic model. **(4 marks)**

(b) In the Bohr model of the hydrogen atom, an electron is moving around the nucleus such that it's non-relativistic velocity ,v and it's radius of orbit , r
(atomic number Z ,charge of the nucleus +Ze, mass of the electron m_e)
Derive the expressions for,

(i) The radius of the nth orbit **(3 marks)**

(ii) The kinetic energy **(3 marks)**

(iii) If an electron is in the first orbit of the hydrogen atom. Determine the speed of the electron and the time it takes to complete one complete revolution.

(7 marks)

(c) Explain what is meant by the Balmer series of Hydrogen and calculate the wavelength of the 8th line of the Balmer series using the Rydberg formula. **(8 marks)**

$$\frac{1}{\lambda} = R_H\left[\frac{1}{n_{lower}^2} - \frac{1}{n_{upper}^2}\right]$$

3. A quantum particle of mass m moves in a potential well of length 2a. Its potential energy is infinite for $x < -a$ and for $x > +a$. Inside the region $-a < x < +a$, its potential energy is given by $U(x) = -\frac{\hbar^2 x^2}{ma^2(a^2-x^2)}$. In addition, the particle is in a stationary state that is described by

the wave function $\psi(x) = A\left(1 - \frac{x^2}{a^2}\right)$ for $-a < x < +a$ and by $\psi(x)=0$ elsewhere.

(a) Write down the 1-D time-independent Schrodinger equation to describe a particle with mass m and energy E subject to a potential $U(x)$. **(7marks)**

(b) Determine the energy E of the particle in terms of $\hbar$, m and a. **(6 marks)**

(c) Using the normalization condition, show that $A = \left(\frac{15}{16a}\right)^{1/2}$ **(6 marks)**

(d) Determine the probability that the particle is located between $x > -\frac{a}{3}$ and $x < +\frac{a}{3}$ **(6 marks)**

4. (a) Write down the Lorentz transformations with usual notation. **(5 marks)**

(b) Show that the Lorentz transformations reduces to Galilean transformation for velocities much smaller than the velocity of light in free space. **(5 marks)**

(c) What is meant by the "simultaneous events"? **(2 marks)**

(d) Show that two simultaneous events at different positions in reference frame S are not in general simultaneous in another frame S' moving with constant velocity relative to frame S. **(5 marks)**

(e) (i) write down the time dilation equation in relativity. **(2 marks)**

(ii) A muon has a lifetime of $2x10^{-6}$s in its rest frame. It is created 100km above the earth and moves towards it at a speed of 2.97x108m/s. At what altitude does it decay? According to the muon, how far did it travel in its brief life? **(6 marks)**

5. (a) Briefly describe the general theory of relativity on the basis of Einstein's principle of equivalence. **(5 marks)**

(b) State two prediction of the general theory of relativity. **(5 marks)**

(c) If an observer directly moving away from a light source of frequency f with a relative velocity, v .Write an expression for the frequency f' measured by the observer. **(5 marks)**

(d) A beam of light of wavelength 5400A° sent from the earth is reflected back by a rocket moving with a uniform velocity directly away from the earth. The reflected light is shifted by 1200A°. Is this shift an increase or a decrease in wavelength? What is the velocity of the rocket?

(10 marks)

6. (a) If a particle of mass m moves with a speed v, write down the relativistic expression for the mass m in terms of its rest mass m_0, its speed v and velocity of light c.

(3 marks)

(b) Using the relativistic expression for mass, show that the kinetic energy of a particle, E_k is given by, $E_k = mc^2(\gamma - 1)$ .Here the symbols have their usual meaning.

(6 marks)

(c) If P and E are the momentum and energy of the particle, show that,

$$E^2 = p^2c^2 + m_o^2c^4$$

(5 marks)

(d) Prove that the particle having rest mass zero always moves with velocity of light.

(5 marks)

(e) A stationary body exploded into two fragments each of mass 1.0kg that move apart at speed of 0.6c relative to the original body. Find the mass of the original body.

(6 marks)