KISII UNIVERSITY

UNIVERSITY EXAMINATIONS

SPECIAL EXAMINATION

SECOND YEAR EXAMINATION FOR THE AWARD OF THE DEGREE OF BACHELOR OF EDUCATION (SCIENCE), BACHELOR OF SCIENCE

FIRST SEMESTER 2021/2022

(JULY, 2022)

PHYS 212/PHRE 218: MODERN PHYSICS/EMERGING PHYSICS

STREAM: Y2 S1 **TIME: 2 HOURS**

DAY: WEDNESDAY, 8:00 AM – 10:00 AM **DATE: 27/07/2022**

INSTRUCTIONS:

1. ***Do not write anything on this question paper.***
2. ***Answer Question ONE (Compulsory) and any other TWO questions.***
3. **Make use of the following constants;**

Speed of light in air, $c = 3.0 \times 10^{8}\ ms^{-1}$

Mass of an electron, $m_e = 9.11 \times 10^{-31}\ kg = 0.511\ MeV/c^2$

Mass of a proton or neutron, $m_p = 1.67 \times 10^{-27}\ kg$

Planck constant, $h = 6.63 \times 10^{-34}\ Js = 4.1357 \times 10^{-15}\ eVs$

ħ (hbar), $\hbar = 1.0546 \times 10^{-34}\ Js = 6.5821 \times 10^{-16}\ eVs$

Boltzmann constant, $k_B = 1.38 \times 10^{-23}\ J/K$

Charge of electron, $e = 1.60 \times 10^{-19}\ C$

$1/4\pi\varepsilon_0 = 9 \times 10^{9} \times Fm^{-1}$

$\pi = 3.14$

QUESTION ONE (COMPULSORY - 30 MARKS)?

a) If a rod travels with a speed $v = 0.8\ c$ along its length, how much does it shrink (1 mark)

b) The mean life-time of muons at rest is found to be about 2.2×10^{-6} s, while the mean life time in a burst of cosmic rays is found to be 1.5×10^{-5} s. What is the speed of these cosmic ray muons? (4 marks)

c) Explain why it is possible to cause photoelectric emission with blue light and not red light. (2 marks)

d) Describe the ultraviolet catastrophe. (2 marks

e) An Electron in a hydrogen atom jumps from the n = 6 to n = 2 level

i) Is a photon absorbed or emitted in this process? (2 marks)

ii) Calculate the energy of the photon. State whether it is in the visible region. (2 marks)

f) What potential difference is required to accelerate an electron from rest to velocity 0.6 *c*? (3 marks)

g) Find the effective mass of a photon for

(i) λ = 5,000°A (visible region)

(ii) λ = 1°A (X-ray region) (4 marks)

h) Show that 1 amu = 931.5MeV/c^2. (3 marks)

QUESTION TWO (20 MARKS)

a) A 100MeV electron moves along the axis of an evacuated tube of length 4m fixed to the laboratory frame. What length of the tube would be measured by the observer moving with the electron? (4 marks)

b) A woman has a mass of 100 kg on the earth. When she is in the space-craft, an observer from the earth registers her mass as 101 kg. Determine the speed of the space-craft. (3 marks)

c) A spaceship is moving away from earth with speed $v = 0.6\ c$. When the ship is at a distance $d = 5 \times 10^8$ km from earth. A radio signal is sent to the ship by the observers on earth. How long does the signal take to reach the ship as measured by the scientist on earth? (6 marks)

d) A physicist was arrested for going over the railway level crossing on a motorcycle when the lights were red. When he was produced before the magistrate the physicist declared that he was not guilty as red lights (λ =

670 nm) appeared green (λ = 525 nm) due to Doppler Effect. At what speed he was travelling for the explanation to be valid? Do you think such a speed is feasible? (7 marks)

QUESTION THREE (20 MARKS)

(a) In the photoelectric effect experiment a photon of wavelength imparts all its energy to a stationary electron in a metal. Assume an incident photon has a wavelength of 440 nm.

(i) Calculate the energy in the photon (3 marks)

(ii) Find the wavelength of an electron after absorbing the photon. (5 marks)

(b) Assume ^{236}U undergoes symmetric fission into two uniformly charged spheres, each of radius R=5 fm.

(i) Calculate the Coulomb energy in MeV when they are just touching.(7 marks)

(ii) Explain why ^{235}U+ n fissions whereas ^{238}U+ ndoes not. (5 marks)

QUESTION FOUR (20 MARKS)

(a) The Lorentz velocity transformation is $v' = \frac{v - u}{1 - uv/c^2}$ where v' and v are the velocities of an object parallel to u as measured in two inertial frames with relative velocity u. Show that a photon moving at c, the speed of light will have the same speed in all frames of reference. (4 marks)

b) The mean life-time of muons at rest is 2.2×10^{-6} s. The observed mean lifetime of muons as measured in the laboratory is 6.6×10^{-6} s. Find

(i) The effective mass of a muon at this speed when its rest mass is $207m_e$ (3 marks)

(ii) its kinetic energy (3 marks)

(iii) its momentum (2 marks)

(c) (i) Calculate the energy needed to break up the 12C nucleus into its constituents.The rest masses in amu are:

12C = 12.000000; p = 1.007825; n = 1.008665; a = 4.002603 (3 marks)

(ii) If 12C nucleus is to break up into 3 alphas. Calculate the energy that isreleased (2 marks)

(iii) If the alphas are to further break into neutrons and protons, then show that the overall energy needed is identical with the results in (b) (i) above. (3 marks)

QUESTION FIVE (20 MARKS)

(a) Cosmic ray photons from space are bombarding your laboratory and smashing massive objects to pieces! Your detectors indicate that two fragments, each of mass m_0, depart such a collision moving at 0.6c at 60^0 to the photon's original direction of motion.

(i) In terms of m_0 and c, what is the energy of the cosmic ray photon? (6 marks)

(ii) In terms of m_0, what is the mass m of the particle being struck (assumed initially stationary) (3 marks)

(b) (i) The solar spectrum has the approximate shape of a black body. The peak intensity is found at a wavelength of $4700A^0$. Calculate the surface temperature of the sun (3 marks)

(ii) Show that the energy of an electron is given by $E = \frac{Z^2 m e^4}{8n^2h^2e_0^2}$

where n = 1, 2, 3,..... and the rest of the symbols have their usual meanings. (8 marks)