KIBABII UNIVERSITY

UNIVERSITY EXAMINATIONS
2019/2020 ACADEMIC YEAR

SECOND YEAR SECOND SEMESTER
MAIN EXAMINATIONS

FOR THE DEGREE OFBSC (PHYSICS)

COURSE CODE: SPC222

COURSE TITLE: MODERN PHYSICS

DURATION: 2 HOURS

DATE: 5/2/2021 **TIME:8:00-10:00AM**

INSTRUCTIONS TO CANDIDATES

- Answer **QUESTION ONE** (Compulsory) and any other two (2) Questions.
- Indicate **answered questions** on the front cover.

Start every question on a new page and make sure question's number is written on each page
This paper consists of **4** printed pages. Please Turn Over

You may need to use the following constants:

Speed of light	$c = 3.0\times10^{8}$m/s
Planks constant	$h = 6.626\times10^{-34}$J.s
Electron charge	$e = 1.6\times10^{-19}$C
Rest mass of an electron	$M_e = 9.1\times10^{-34}$Kg
Rest mass of a neutron	$M_n = 9.1\times10^{-34}$Kg = 1.0087u = 939.6 Mev/C^2
Rest mass of a proton	$M_p = 9.1\times10^{-34}$Kg = 1.0078u
Mass of deuteron (^2_1H)	= 2.0141u
One atomic mass unit	u=1.66×10^{-27}Kg = 931Mev/C^2

Compton formula	$\lambda' - \lambda = \frac{h}{m_o c}(1 - cos\phi)$
Stefan's constant	σ=5.670 × 10^{-8}w/m^2.k^4
Chemical formula for gold	$^{197}_{79}Au$
Atomic mass of	$^{238}_{92}U$= 238.0508u
Atomic mass of	$^{234}_{90}Th$= 228.0436u
Atomic mass of	$^{4}_{2}He$= 4.0026u
Permittivity of free space	ε_o= 8.854 × 10^{-12}F/m
Paschen series formula	$\frac{1}{\lambda} = R\left[\frac{1}{3^2} - \frac{1}{n^2}\right]$
Half life of carbon	= 5760 years
Atomic spacing	d=$\left\{\frac{M}{k_\rho}(1.66 \times 10^{-27})\right\}^{\frac{1}{3}}$
Bionomial expression $(1 \pm x)^n = 1 \pm nx + \frac{n(n-1)x^2}{2!} \pm \cdots \ldots \ldots \ldots \ldots$	
Wien's constant	ω_c = 2.898 ×10^{-3}m.K

QUESTION ONE[30 Marks]

(a) State the postulates of special relativity [2 marks]

(b) Define the term Lorentz transformation [1 mark]

(c) Two observers, A on earth and B in a spacecraft whose speed is 2x10^8m/s, both set their watches to the same time when the spacecraft is abreast of the earth. How much time must elapse by A's reckoning before the watches differ by 1s? [3 marks]

(d) What is a massless particle? [1 mark]

(e) A meter stick appears only 60cm to an observer. What is its relative speed? How long does it take to pass the observer?[4 marks]

(f) What is a black body? [1 mark]

(g) Deduce Stefan's Law from Planck's Law [3 marks]

(h) In a photoelectric effect, it was observed that for light of wavelength 4000 Å, a stopping potential of 2.0 volts is needed and for light of wavelength 6000 Å, a stopping potential of 1.0 volt. From these data, calculate the work function of the material and the Planck's constant. [3 marks]

(i) Differentiate between nuclear fission and nuclear fussion. [2 marks]

(j) What is the rest mass energy of an electron (me =9.1×10^{-31}kg)? [2 marks]

(k) Find the de Broglie wavelength of (i) electron moving with velocity 1000 m/s (ii) an object of mass 100 gram moving with the same velocity [2, 2 marks]

(l) Experiments show that 13.6eV is required to separate a hydrogen atom into a proton and an electron, that is, its binding energy is -13.6eV. Find the orbital radius and velocity of the electron in a hydrogen atom [3 marks]

QUESTION TWO [20 Marks]

a) In a Compton experiment, an energetic photon is scattered by an electron at rest. Write down the energy and conservation laws. [4Marks]

b) Use the equations in (a) above to prove that; $\Delta\lambda = \lambda' - \lambda = \frac{h}{m_0 c^2}[1 - \cos\phi]$ where ϕ is the angle between the incident and outgoing light rays while λ and λ' are the energies of the incident and emitted photons respectively. [12Marks]

a) A 30 keV x-ray photon strikes the electron initially at rest and the photon is scattered through an angle of 30°, what is the recoil velocity of electron? [4Marks]

QUESTION THREE [20 Marks]

a) Name and describe the process by which the photoelectrons are released from the cathode of a photocell by electromagnetic radiation. [4Marks]

b) The wavelength of the photoelectric threshold for silver is $3{,}250\times10^{-10}$m. Determine the velocity of electron ejected from a silver surface by ultraviolet light of wavelength $2{,}536\times10^{-10}$m. [4Marks]

c) Show that photoelectric effect can not take place with a free electron. [4Marks]

d) When two ultra violet beams of wavelengths $\lambda_1 = 280nm$ and $\lambda_2 = 490nm$ fall on a lead surface they produce photoelectrons with maximum energies 8.57eV and 6.67eV, respectively

i). Estimate the numerical value of the Planck's constant [2Marks]

ii). Calculate the work function of lead [2Marks]

iii). Calculate the cut off frequency of lead [2Marks]

QUESTION FOUR [20 Marks]

a) Define the following terms; Length contraction and Time dilation [4Marks]

b) Starting with the expression of the total energy as $E=E_o+K.E$, derive the expression for the low speed approximation for the Kinetic energy, K.E. [6Marks]

c) Show that for massless particles, the relation between their energy and mass is $E=Pc$, where the symbols have their usual meaning [4Marks]

d) The relation of total energy, E and momentum, P for a relativistic particle is; $E^2 = c^2p^2 + m^2c^2$ where m is the rest mass and c is the velocity of light. Use the relativistic relations $E = \hbar\omega$ and $P = \hbar k$ where ω is the angular frequency and k is the wave number, show that the product of group velocity υ_g and phase velocity υ_p is equal to c^2. [6 Marks]

QUESTION FIVE[20 Marks]

a) Derive the expressions for both the decay law and half-life [4Marks]

b) A sample of 1g of $^{209}_{83}Bi$ with a half life of 2.7 x 10^7yr decays into a stable isotope of thallium by emitting alpha particles. What would be the activity of the sample? [3Marks]

c) Find the mean-life of ^{55}Co radionuclide if its activity is known to decrease 4.0% per hour. The decay product is non-radioactive. [3Marks]

d) What proportion of ^{235}U was present in a rock formed $3{,}000\times10^6$ years ago, given that the present proportion of ^{235}U to ^{238}U is 140? [4Marks]

e) The mass of chlorine $^{35}_{17}$ nucleus is 34.980u. Calculate the mass defect and hence the binding energy per nucleon. Sketch a graph of binding energy per nucleon as a function of mass number indicating the position of the stable nucleus. [6Marks]

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