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OFFICE OF THE DEPUTY PRINCIPAL
ACADEMICS, STUDENT AFFAIRS AND RESEARCH

UNIVERSITY EXAMINATIONS
2020/2021 ACADEMIC YEAR

FIRST YEAR SECOND SEMESTER REGULAR EXAMINATION

FOR THE DEGREE OF BACHELOR OF EDUCATION SCIENCE

COURSE CODE: **PHY 122**

COURSE TITLE: **MODERN PHYSICS**

DATE: 19/07/2021 **TIME: 1300 – 1600HRS**

INSTRUCTION TO CANDIDATES

i. **SEE INSIDE**

THIS PAPER CONSISTS OF 4 PRINTED PAGES **PLEASE TURN OVER**

MAIN EXAMINATION

PHY 122: MODERN PHYSICS

STREAM: Bed Sc. **DURATION: 3 Hours**

INSTRUCTIONS TO CANDIDATES

i. *Answer Question **ONE** and **TWO** in **SECTION A** and any other **THREE** questions in **SECTION B**.*

ii. *Where necessary the following constants maybe used:*

- *Velocity of light in vacuum/air (c)* $3.0\times10^{8}\ m/s$
- *Planck constant (h)* $6.6261 \times 10^{-34}\ J\cdot Hz^{-1}$
- *Reduced Planck constant (ħ)* $1.0546 \times 10^{-34}\ J\cdot s$
- *Permittivity* of free space (ε_o) $8.8542 \times 10^{-12}\ F\cdot m^{-1}$
- *Elementary charge (e)* $1.6022 \times 10^{-19} C$
- *Avogadro constant (N_O)* $6.0221 \times 10^{23}\ mol^{-1}$
- *Boltzmann constant* $1.380649\times10^{-23}\ J\cdot K^{-1}$
- *Bohr magneton* $9.274 \times 10^{-24}\ J\cdot T^{-1}$
- *Mass of electron M_e* $9.1094\times10^{-31}\ kg$
- *Mass of proton M_p* $1.67262 \times 10^{-27}\ kg$
- *Stefan–Boltzmann constant* $5.6704 \times 10^{-8}\ W\cdot m^{-2}\cdot K^{-4}$
- *Wien wavelength displacement law constant* $2.8978 \times 10^{-3}\ m\cdot K$
- *Wien frequency displacement law constant* $5.879 \times 10^{10}\ Hz\cdot K^{-1}$

SECTION A (28 MARKS)

Question One (14 Marks)

a. State the postulates of special relativity (2 marks)

b. A certain particle has a lifetime of 10^{-7}s when measured at rest. How far does it go before decaying, if its speed is 0.99c when it was created? (4 Mark)

c. Ultraviolet light of wavelength 350nm and intensity 1w/m^2 is directed at a potassium surface. Find the maximum kinetic energy of the photoelectrons given that the work function of potassium is 2.2eV (4 Marks)

d. Using an illustration, describe Compton scattering. (4 Marks)

Question Two (14 Marks)

a. Define the following terms (2 marks)

i. Emission spectra

ii. Continuous spectra

b. Find the de Broglie wavelength of the following

i. A 46-g golf ball with a velocity of 30m/s. (3 Marks)

ii. An electron with a velocity of 10^7m/s. (3 Marks)

c. State the three quantum numbers that describe an electron in an hydrogen atom (3 Marks)

d. State the Pauli's exclusion principle (2 Marks)

e. Give one example of an elementary particle (1 Mark)

SECTION B (42 MARKS)

Question Three (14 Marks)

a. Deduce the expression $T_{1/2} = \frac{0.693}{\lambda}$ as it applies to radioactivity (5 Marks)

b. How long does it take for 60% of a sample of radon to decay? Given that the half life of radon is 3.8days. (4 Marks)

c. Find the activity of 1μg (10^{-9}kg) of radon (^{222}R). (5 Marks)

Question Four (14 Marks)

a. Show that the photon energy in electron volts (eV) is equivalent to

$E = \frac{1.24\times10^{-6}\, eV.m}{\lambda(m)}$ where the symbols have their usual meaning. (5 Marks)

b. Determine the shortest wavelength and hence the frequency of radiation from an x-ray machine whose accelerating potential is 50,000V. (4 Marks)

c. X-rays of wavelength $10\text{x}10^{-12}$m are scattered from a target, determine the wavelength of x-rays scattered through 45° (4 Marks)

d. State one application of X-ray diffraction (1 Mark)

Question Five (14 Marks)

a. Deduce the hydrogen spectrum equation: $\frac{1}{\lambda} = -\frac{E_1}{ch}\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$ where the terms have their usual meaning. (5 Marks)

b. Write down the expressions for the following spectral series (3 Marks)

i. Paschen series

ii. Bracket series

iii. Pfund series

c. A measurement establishes the position of a proton with an accuracy of $\pm 10^{-11}$m. Find the uncertainty in the proton's position 1 second later. Assume V<<<<c. (4 Marks)

d. Describe the wave-particle duality (2 Marks)

Question Six (14 Marks)

a. Show that $\lambda = \frac{h}{P}$ where the terms have their usual meaning (4 marks)

b. A piece of wood from the ruins of an ancient building was found to have a ${}^{14}_{6}C$ activity of 13 disintegrations per minute per gram. The activity of the living wood is 16 disintegrations per minute per gram. How long ago did the tree from which the wood sample come from, die? (4 Marks)

c. The Polonium isotope ${}^{210}_{84}Po$ is unstable and emits a 5.3MeV alpha particle. The atomic mass of ${}^{210}_{84}Po$ is 209.9829u and that of ${}^{4}_{2}He$ is 4.0026u. Identify the daughter nucleus and find its atomic mass. (4 Marks)

d. Write down the symbols of the following as used in describing the nucleus of an atom, hence explain their physical meaning.

i. Atomic number (1 mark)

ii. Mass number (1 mark)

Question Seven (14 Marks)

a. Deduce the expression for relativistic momentum of a particle (3 marks)

b. A man has a mass of 100kg on the ground. When he is in an aircraft in flight, his mass is 101kg as determined by an observer on the ground. What is the speed of the aircraft? (3 marks)

c. .

i. Using an appropriate graphical illustration, explain the blackbody radiation spectrum (3 marks)

ii. Determine the frequency of electromagnetic radiation of a laser used in fiber optic communication operating at a wavelength of 635nm, power output being 1Mw with a capability of transmitting 2.5GB of data per second. (2 marks)

d. Describe and illustrate with a diagram the Rutherford's atomic model (3 marks)