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KIBABII UNIVERSITY

**UNIVERSITY EXAMINATIONS
2021/2022 ACADEMIC YEAR**

**SECOND YEAR SECOND SEMESTER
MAIN EXAMINATIONS**

FOR THE DEGREE OF BSC (PHYSICS)

COURSE CODE: SPC 222

COURSE TITLE: MODERN PHYSICS

DATE: 8/10/2021

TIME: 8:00-10:00AM

INSTRUCTIONS TO CANDIDATES

TIME: 2 Hours

Answer question ONE and any TWO of the remaining

KIBU observes ZERO tolerance to examination cheating

QUESTION 1

- a) A meter stick appears only 60cm to an observer. What is its relative speed? How long does it take to pass the observer? (4mks)
- b) Ultraviolet light of wavelength 350nm and intensity 1w/m² is directed at a potassium surface. Find the maximum K.E of the photoelectrons given that the work function of potassium is 2.2eV. (4mks)
- c) Find the atomic spacing for a crystal of rock salt, NaCl, whose formula mass is 58.5u and whose density is $2.16 \times 10^3 \text{ kg/m}^3$. (4 mks)
- d) State the Pauli's exclusion principle. (1mk)
- e) A measurement establishes the position of a proton with an accuracy of $\pm 10^{-11} \text{ m}$. Find the uncertainty in the proton's position 1s later. Assume $V \ll c$. (4mks)
- f) Find the de Broglie wavelength of :
 (i) A 46-g golf ball with a velocity of 30m/s. (3 mks)
 (ii) An electron with a velocity of 107m/s. (3 mks)
- g) A 5MeV alpha particle approaches a gold nucleus with an impact parameter of $2.6 \times 10^{-13} \text{ m}$. Through what angle will it be scattered? (2mks)
 Solution
- h) What is the impact parameter of a 5MeV alpha particle scattered by 10o when it approaches a gold nucleus? Chemical formula for gold is $^{197}_{79}\text{Au}$ (2mks)
 Solution
- i) Define Radioactivity. (1mk)
- j) The Polonium isotope $^{210}_{84}\text{Po}$ is unstable and emits a 5.3MeV alpha particle. The atomic mass of $^{210}_{84}\text{Po}$ is 209.9829u and that of ^4_2He is 4.0026u. Identify the daughter nucleus and find its atomic mass. (4mks)

QUESTION TWO

- a) A reference frame S' moving at a velocity v relative to another frame S. The displacement of each frame after time t is $x' = k(x - vt)$ and $x = k(x' + vt')$ respectively. Show that the Lorentz transformation from S to S' is

$$x' = \frac{x - vt}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$y' = y,$$

$$z' = z,$$

(10mks)

$$\text{and } t' = \frac{x'}{c} = \frac{1}{c} \left(\frac{x - vt}{\sqrt{1 - \frac{v^2}{c^2}}} \right) = \frac{t - \frac{vx}{c^2}}{\sqrt{1 - \frac{v^2}{c^2}}}$$

- 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? (4mks)

- c) If u and u' , are the velocities with reference to the observer at O and O' respectively, such that

$$\left. \begin{aligned} u &= \frac{x_2 - x_1}{t_2 - t_1}, \\ u' &= \frac{x'_2 - x'_1}{t'_2 - t'_1}, \end{aligned} \right\}$$

Show that if $u = c$ then $u' = c$.

(6mks)

QUESTION THREE

- a) Show that for a body moving with acceleration $a = \frac{d}{dt} \left(\frac{v}{\sqrt{1 - \frac{v^2}{c^2}}} \right)$ its kinetic energy is given by $K.E. = \frac{1}{2} m_0 v^2$. (10 mks)
- b) Show that for a massless particle, its momentum and energy are related by $E = Pc$ where c is the speed of light. (10mks)

QUESTION FOUR

Derive the Raleigh-Jeans formula. (20mks)

QUESTION FIVE

- a) A photon of mass m_0 and wavelength λ is scattered through an angle ϕ and changes into a new photon of wavelength λ' . Show that

$$\lambda' - \lambda = \frac{h}{m_0 c} (1 - \cos \phi) \quad (12 \text{ mks})$$

- b) X-rays of wavelength 10×10^{-12} m are scattered from a target.
- Find the wavelength of x-rays scattered through 45° (3mks)
 - Find the maximum wavelength present in the scattered x-rays. (2mks)
 - Find the maximum K.E of the recoil electrons. (λ_c of an electron is 2.424pm) (3mks)