



KIBABII UNIVERSITY

UNIVERSITY EXAMINATIONS
2021/2022 ACADEMIC YEAR

FIRST YEAR SECOND SEMESTER
MAIN EXAMINATIONS

FOR THE DEGREE OF B. ED (SCIENCE)

COURSE CODE: SPH 122

COURSE TITLE: INTRODUCTION TO QUANTUM PHYSICS

DATE: 09/05/2022

TIME: 9:00AM-11:00AM

INSTRUCTIONS TO CANDIDATES

- Answer question one (**Compulsory**) and any other **Two** questions.
- Attempted questions must be indicated on front cover of answer booklet.
- Every question should be started on new page and question indicated respectively.

List of constants

Speed of light, $c=3.0 \times 10^8$ m/s

Mass of electron, $M_e = 9.1 \times 10^{-31}$ kg

Planck's constant, $h=6.6 \times 10^{-34}$ J

KIBU observes ZERO tolerance to examination cheating

Question one (30 Marks)

- a. Define gravitational red shift (2mks)
- b. With reference to quantum mechanics, discuss the meaning of a standard inertial frame of reference. (2mks)
- c. Discuss wave-particle duality of matter in reference to light (3mks)
- d. Find the wavelength of an electron moving with a speed of $2 \times 10^6 \text{ ms}^{-1}$ (3mks)
- e. X-rays with an energy of 300 KeV undergo Compton scattering with a target. If the scattered X-rays are detected at 30° relative to the incident X-rays, determine the Compton shift at this angle, the energy of the scattered X-ray, and the energy of the recoiling electron. (4mks)
- f. Discuss the Heisenberg Uncertainty (3mks)
- g. An FM radio transmitter has a power output of 100 kW and operates at a frequency of 94 MHz. How many photons per second does the transmitter emit? (3mks)
- h. Light source of wavelength 600nm illuminates a metal and ejects photoelectrons with a maximum kinetic energy of 1.00 eV. A second light source with half the wavelength of the first ejects photoelectrons with a maximum kinetic energy of 4.00 eV. Determine the work function of the metal. (3mks)
- i. The earth and sun are 8.3 light-minutes apart. Ignore their relative motion for this problem and assume they live in a single inertial frame, the Earth-Sun frame. Events *A* and *B* occur at $t = 0$ on the earth and at $t = 2$ minutes on the sun respectively. Find the time difference between the events according to an observer moving at $u = 0.8c$ from Earth to Sun. Repeat if observer is moving in the opposite direction at $u = 0.8c$. (4mks)
- j. Discuss the birth and development of the special relativity. (3mks)

Question Two (20 Marks)

- a. Show that the low-frequency limit of Planck's Law reduces to the Rayleigh-Jeans Law and in the high-frequency limit reduces to Wien's Law. (6mks)
- b. Discuss the Wien's Displacement Law as outlined in quantum mechanics. (6mks)
- c. Suppose in the Michelson-Morley experiment, it is given that $\Delta L = L_1 - L_2 \neq 0$ and that there is a contraction by a factor of $\sqrt{1 - \frac{v^2}{c^2}}$ in the direction of the ether wind. Then show that

$$\Delta t = \frac{2}{c} \Delta L \left(1 + \frac{v^2}{2c^2}\right) \quad (8\text{mks})$$

Question Three (20 Marks)

- Derive the Einstein photoelectric equation and discuss it basing on Einstein's explanation on existence of threshold frequency, effect of intensity of the incident light and possible maximum energy. (6mks)
- Derive the Stefan Boltzmann Law for the energy density of black-body radiation. (6mks)
- Derive the Compton equation the proofs the existence of quantum mechanics. (8mks)

Question Four (20 Marks)

- Show that the standard space and time Lorentz transformation equation is given respectively by the equation below. (8mks)

$$x' = \frac{x-vt}{\sqrt{1-\frac{v^2}{c^2}}}, \quad t' = \frac{\frac{vx}{c^2} + t}{\sqrt{1-\frac{v^2}{c^2}}}$$

- Show that De Broglie formular is given by $\lambda = \frac{h}{mv}$ where m is the mass, v the velocity and λ is the wavelength. (6mks)
- Discuss the Davison-Gerner experiment stating how the finding relate with Bragg's law, de Broglie law and the acceleration through a given voltage V . (6mks)