MACHAKOS UNIVERSITY

University Examinations for 2019/2020 Academic Year

SCHOOL OF PURE AND APPLIED SCIENCES

DEPARTMENT OF PHYSICAL SCIENCES

DECEMBER SESSION EXAMINATION FOR

BACHELOR OF EDUCATION (SCIENCE)

SPH 204: MODERN PHYSICS

DATE: SCHOOLBASED **TIME:**

INSTRUCTIONS:

- The paper consists of **two** sections.
- Section **A** is **compulsory** (30 marks).
- Answer any **two** questions from section **B** (each 20 marks).

Constants

Electron charge, $e = 1.6 \times 10^{-19}$ C

Electron mass, $m_e = 9.1 \times 10^{-31}$ kg

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

SECTION A (COMPULSORY)

QUESTION ONE (COMPULSORY) (30 MARKS)

a) Briefly explain the following terminologies

(i) Black body (2 marks)

(ii) Photoelectric effect (2 marks)

b) A certain sample of radioactive material decays at a rate of 548 per second at $t = 0$. At $t = 48$ minutes the counting rate has fallen to 213 per second.

i) What is the half-life of the radioactivity? (3 marks)

ii) What is the decay constant? (3 marks)

iii) What will be the decay rate at $t = 125$ minutes? (3 marks)

c) A photoelectric experiment with cesium yields stopping potentials for $\lambda = 435.8\,\text{nm}$ and $\lambda = 546.1\,\text{nm}$ to be 0.95 V and 0.38 V, respectively. Using these data only, find

(i) the threshold frequency for cesium (3 marks)

(ii) work function for cesium and (3 marks)

(iii) the value of Planck's constant h. (3 marks)

d) The length of a spaceship is measured to be exactly half its proper length. What is

(i) the speed of the spaceship relative to the observer on earth? (4 marks)

(ii) the dilation of the spaceship's unit time? (4 marks)

SECTION B: ANSWER ANY OTHER TWO QUESTIONS

QUESTION TWO (20 MARKS)

a) Explain the meaning of the following effects

(i) Thermoelectric effect (2 marks)

(ii) Compton effect (2 marks)

b) Tritium, the hydrogen isotope of mass 3, has a half-life of 12.3 years. What fraction of the tritium atoms remains in a sample after 50 years? (3 marks)

c) The half-life of ^{198}Au is 2.7 days

(i) What is the decay constant of ^{198}Au (3 marks)

(ii) What is the probability that any ^{198}Au nucleus will decay in one second. (3 marks)

Suppose we had a 1.00 μg sample of ^{198}Au.

(iii) What is its activity (3 marks)

(iv) How many decays per second occur when the sample is one week old? (4 marks)

QUESTION THREE (20 MARKS)

a) Why is it extremely difficult to observe Compton Effect using visible light? (3 marks)

b) The threshold frequency of potassium is 588 nm.

(i) What is the work function for potassium? (3 marks)

(ii) What is the stopping potential when light of 400 nm is incident in potassium? (3 marks)

c) How is the result that the maximum photoelectric current is proportional to the intensity explained in the photon model of light? (4 marks)

d) The surface temperature of sun is about 5800 K, and measurement of the Suns spectral distribution show that it radiates very nearly like a black body, deviating mainly at very short wavelengths . Assuming that the sun radiates like an ideal blackbody, at what wavelength does the peak of the solar spectrum occur? (6 marks)

Given: Wiens constant $= 2.898 \times 10^{-3}$ m. K

e) A rod lies parallel to the x axis of reference frame S, moving along this axis at a speed of 0.630c. Its rest length is 1.70 m. What will be its measured length in frame S? (4 marks)

QUESTION FOUR (20 MARKS)

a) Sketch the energy level diagram for the Bohr model of the hydrogen atom. Indicate on the diagram the transitions that correspond to the visible Balmer series of emission lines. (3 marks)

b) An inertial frame *S'* moves with respect to another inertial frame *S* with a uniform velocity 0.6 *c* along the *x-x'* axes. The origins of the two systems coincide when $t = t' = 0$. An event occurs at x_1 = 10 m, $y_1 = 0$, $z_1 = 0$,

$t_1 = 2 \times 10^{-7} s$. Another event occurs at x_2 = 40 m, $y_2 = 0$, $z_2 = 0$, $t_2 = 3 \times 10^{-7}$ s.

In *S'*,

i) What is the time difference? (4 marks)

ii) What is the distance between the events? (4 marks)

c) How fast must an unstable particle move to travel 20 m before it decays? The mean lifetime of the particle at rest = 2.6×10^{-8} s. (3 marks)

d) When light of wavelength 500 nm is incident on a metallic surface, the stopping potential is measured to be 0.45 V.

i) What is the work function for the metal? (3 marks)

ii) If the intensity of the light is doubled, what is the stopping potential? (3 marks)

QUESTION FIVE (20 MARKS)

a) Show that $x^2 + y^2 + z^2 - c^2t^2$ is invariant under Lorentz transformation. (6 marks)

b) A rocket leaves the earth at a speed of 0.6*c*. A second rocket leaves the first at a speed of 0.9*c* with respect to the first. Calculate the speed of the second rocket with respect to earth if:

   i) it is fired in the same direction as the first one; (4 marks)

   ii) it is fired in a direction opposite to the first (4 marks)

c) A spaceship of rest length 130 m races past a timing station at a speed of 0.740c.

   i) What is the length of the spaceship as measured by the timing station? (3 marks)

   ii) What time interval will the station clock record between the passage of the front and back ends of the ship? (3 marks)