# MACHAKOS UNIVERSITY

**University Examinations 2022/2023 Academic Year**

**SCHOOL OF PURE AND APPLIED SCIENCES**

**DEPARTMENT OF PHYSICAL SCIENCES**

**SECOND YEAR SECOND SEMESTER EXAMINATION FOR**

**BACHELOR OF SCIENCE (TELECOMMUNICATIONS AND INFORMATION TECHNOLOGY)**

**BACHELOR OF SCIENCE (APPLIED PHYSICS AND TECHNOLOGY)**

**BACHELOR OF EDUCATION (SPECIAL NEEDS)**

**BACHELOR OF SCIENCE (MATHEMATICS)**

**BACHELOR OF EDUCATION (SCIENCE)**

**SPH 202/SPT 207: MODERN PHYSICS**

**DATE: 19/4/2023** **TIME: 2:00 – 4:00 PM**

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**INSTRUCTIONS:**

- The paper consists of **two** sections.
- Section **A** is **compulsory** (30 marks).

Answer question ONE and any other TWO questions

**Useful constants**

| | **Name** | **Value** |
|---|---|---|
| 1 | Plank constant (h) | $6.63\ x\ 10^{-34} m^2 kg/s,$ |
| 2 | Permittivity of free space ($\varepsilon_o$) | $8.854x10^{-12} F.m^{-1}$ |
| 3 | Permeability of free space ($\mu_o$) | $1.2566x10^{-6} NA^{-2}$ |
| 4 | speed of light (c) | $2.998\ \text{x}10^{8} m/s$ |

**SECTION A (COMPULSORY)**

**QUESTION ONE (30 MARKS)**

a) The frequency of a photon of light is given as $v = 5.00x\ 10^{14} Hz$. Calculate Energy E of the photon

i. In joules (j) (3 marks)
ii. In electron volts (eV) (2 marks)

b) Calculate the wavelength of light given off by a hydrogen atom when an electron falls from n=4 to the n =2 orbit in Bohr model (4 marks)

c) The energy (E) of a particle can be determined from its momentum (P). Show that $P = E/c$ , where c is speed of light (3 marks)

d) A moving body moves in certain ways as if it has a wave like nature according to de Broglie in 1924. Find the de Broglie wavelengths of

i. a 200 g golf ball with a velocity of 25 m/s (3 marks)
ii. an electron with a velocity of $2.46x10^8\ m/s$ (4 marks)
iii. comment on your answers in i and ii above (2 marks)

e) Define the following terms

i. black hole (2 marks)
ii. quasar (2 marks)

f) State the Heisenberg uncertainty principle (1 mark)

g) Lightning struck Jesus Christ statue in Brazil and the photo was captured by a stationary observer as shown in figure 1.

i) If the observer was travelling to the right hand side of the statue at speed near that of light. What would the lightning bolt look like. (2 marks)

Figure 1; Lightning strike

ii) The photo in figure 2 was captured by an observer in motion. Which side was she moving (2 marks)

Figure 2. Lightning strike

**SECTION B**

**QUESTION TWO (20 MARKS)**

a) One of the problems faced by scientists in 19$^{th}$ century was how to explain the spectra of electromagnetic radiation emitted by hot objects.

i. Describe the spectra of a black body. (3 marks)
ii. Explain the origin of the spectra (3 marks)

b) Experimental observations of the photoelectric effect were studied using the set up in figure 1 as purported by one book of concepts of modern physics.

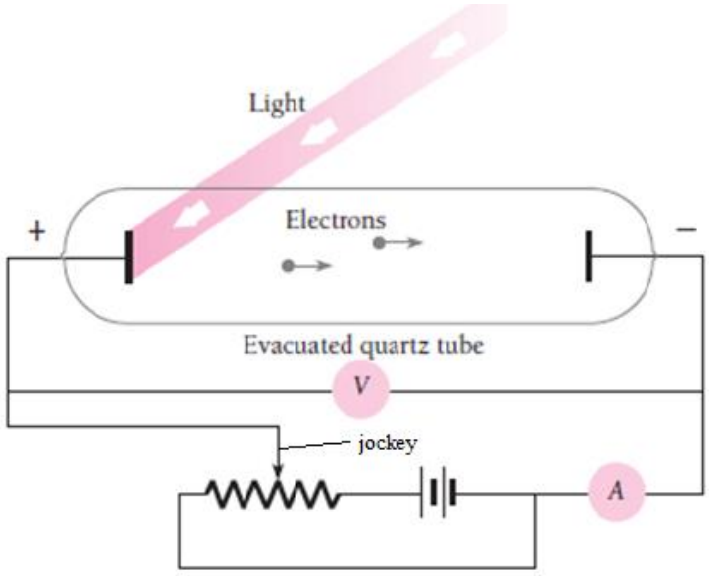


Figure 3

i) Pin point three mistakes in the set-up (3 marks)

ii) Redraw the set-up and label accordingly (3 marks)

iii) What is the effect of moving the jockey pin to the right hand side as per your new drawing? (3 marks)

iv) When the light is blocked, what will the ammeter (A) read a) small current or b) zero current? (1 mark)

c) In 1864 the British physicist James Clerk Maxwell determined the speed of light (c) Verify by calculation that c = 2.998 x$10^8 m/s$ (4 marks)

**QUESTION THREE (20 MARKS)**

a) Michelson interferometer in figure 2 can be used to measure wavelengths in great precision. Study the figure and answer the following questions

i) how is Michelson interferometer different from Michelson Morley interferometer (2 marks)

ii) In an experiment conducted by Michelson and Morley, show that

I. the round trip time of travel along arm 1 is $t_1 = \frac{2L}{(c^2-v^2)^{\frac{1}{2}}}$ (4 marks)

II. the round trip time of travel along arm 2 is $t_2 = \frac{2Lc}{c}\left(1-\frac{v^2}{c^2}\right)^{-1}$ (4 marks)

III. hence show that (4 marks)

$$\Delta t = t_2 - t_1 \approx \frac{Lv^2}{c^3}$$

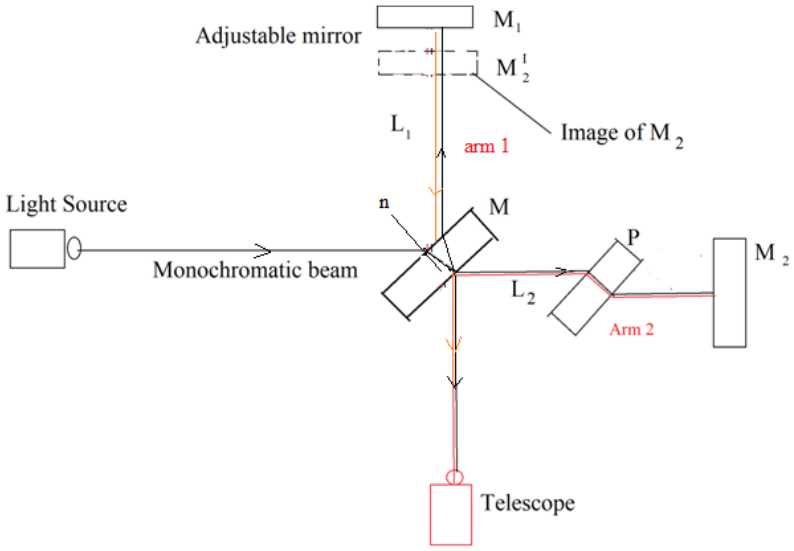


Figure 4. Michelson interferometer

b) An electron of mass ($m$ = 0.622 MeV/$c^2$) and a photon ($m$ = 0) both have momenta of 1.900 MeV/$c$. Find the total energy of each. (6 marks)

**QUESTION FOUR (20 MARKS)**

a) In a hydrogen atom, a single electron of charge (q) and mass (m) orbits the nucleus that has a single positive charge as in figure 5. The radius of the circular orbit is r and the tangential speed of the electron is v

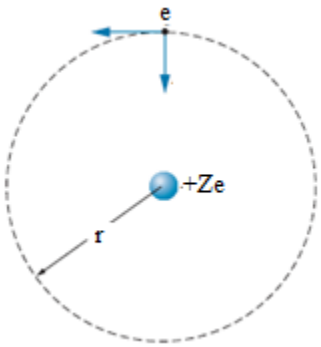


Figure 3; Hydrogen atom

Show that the total mechanical energy of the atom is given by (6 marks)

$$E = \frac{1}{8\pi\varepsilon_o}\frac{q^2}{r}$$

b) A stationary body explodes into three fragments of mass 2.5 kg, 3.5 kg and 1.6 kg that move apart at speeds of 0.6c, 0.5c and 0.8c respectively relative to the original body. Find the mass of the original body. (6 marks)

c) Account why there is a gradual decrease in binding energy of a nucleus, from about 8.8 MeV to 7.6 MeV (4 marks)

d) A radioactive sample containing 31.4 x $10^{18}$ atoms has a half life of 6800 years. What is its activity? (4 marks)

**QUESTION FIVE (20 MARKS)**

a) A photon is an example of a mass-less particle. Show that the energy of a mass-less particle is given by $E = pc$ (6 marks)

b) What is meant by gravitational red shift of spectral lines (3 marks)

c) Calculate the kinetic energy of a proton whose de Broglie wavelength is 9.0 x$10^{-16}$m

(6 marks)

d) Ultra violet light of wavelength 300 nm is directed at a potassium surface. Calculate the maximum kinetic energy of the photo electrons. Take work function of potassium as 2.19 eV (5 marks)