



TOM MBOYA UNIVERSITY

2022/2023 ACADEMIC YEAR

FOURTH YEAR FIRST SEMESTER EXAMINATION FOR THE DEGREE OF BACHELOR OF EDUCATION (SCIENCE)

SPH 410: ELECTRODYNAMICS

DATE: 13/12/2022

TIME: 3 HOURS

DURATION OF THE EXAMINATION

INSTRUCTIONS TO CANDIDATE

ANSWER QUESTION ONE (**COMPULSORY**) AND ANY OTHER **TWO** QUESTIONS

CONSTANTS

Elementary charge (e) = $1.6 \times 10^{-19}C$

Permittivity constant (ϵ_0) = $8.85 \times 10^{-12}F/m$

Permeability constant (μ_0) = $1.26 \times 10^{-6}H/m$

Speed of light in a vacuum (c) = $2.998 \times 10^8m/s$

EXAMINATION CHEATING IS A CRIME

QUESTION ONE (30 MARKS)

- a) Determine the differential form of Gauss's law (4 marks)
- b) Find the electric potential V at the center of a square in Fig. 1 of side 1.0 m and having charges $q, 2q, -3q, 4q$ at its corners. (4 marks)

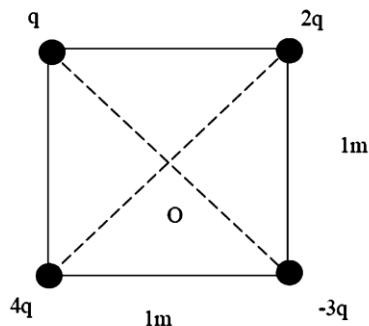


Fig.1

- c) Three charges $q, -2q$ and $4q$ are placed at the corners of an equilateral triangle having length of each side $a = 1.0\text{ m}$ as shown in Fig.2. Determine the potential energy U of the structure. (3 marks)

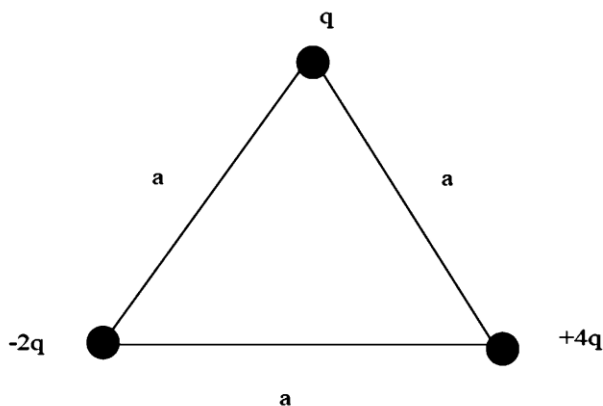


Fig.2

- d) A long cylinder carries a charge density given by $\rho(r) = kr$, where r is the distance from the axis of the cylinder and k is some constant. Find the electric intensity at a point inside the cylinder. (4 marks)
- e) Two long parallel wires separated by 1 cm in air carry current of 1 A . Find the force on 1 m length of wire. (3 marks)
- f) Show that another point form of Faraday's law is

$$\vec{E} = -\frac{\partial}{\partial t} \vec{A},$$

where $\vec{A}$ is the magnetic vector potential. (3 marks)

- g) The average energy per second reaching the earth from the sun is about $1350 \text{ J/m}^2 \text{ s}$. Assume this is a single electromagnetic (EM) wave, determine the maximum values of E and B fields for sunlight on earth. (3 marks)
- h) Write the expression for the magnetic scalar and vector potentials, from which the following magnetic field can be derived (3 marks)
- $$\vec{B} = K(y\hat{i} + x\hat{j}).$$
- i) Show $\vec{E} \cdot \frac{\partial \vec{D}}{\partial t}$ denotes the rate of change of energy density stored in electric field. (3 marks)

QUESTION TWO (20 MARKS)

- a) State limitations of Coulomb's Law. (2 marks)
- b) Find the electric field $\vec{E}$ a distance z above the midpoint between two equal charges, q , a distance d apart in Fig. 3. (10 marks)

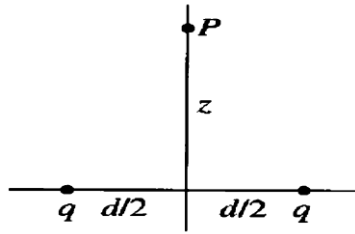


Fig. 3

- c) Show that the charge-free non-conducting medium, Maxwell's equations lead to

$$\nabla^2 \vec{E} - \frac{1}{c^2} \frac{\partial^2 \vec{E}}{\partial t^2} = 0. \quad (8 \text{ marks})$$

QUESTION THREE (20 MARKS)

- a) Find the magnitude of polarization $\vec{P}$ in a dielectric material with a dielectric constant $k = 2.8$, if the Electric displacement $D = 3.5 \times 10^{-7} \text{ C/m}^2$. (5 marks)
- b) Show that the energy density in a magnetic field is given by (10 marks)
- $$U = \frac{1}{2} \vec{B} \cdot \vec{H}.$$
- c) Find the magnetic field associated with $\vec{E} = E_0 \cos(\beta x) \cos(\omega t) \hat{k}$. (5 marks)

QUESTION FOUR (20 MARKS)

- a) Show that the Maxwell Equation $\vec{\nabla} \cdot \vec{D} = \rho$ is contained in (or implicit in) (6 marks)
- $$\vec{\nabla} \times \vec{H} = \vec{J} + \frac{\partial \vec{D}}{\partial t}.$$
- b) Find the potential between anode and grounded cathode of a working vacuum diode. (7 marks)
- c) A plane monochromatic plane polarized em-wave is travelling eastwards. The wave is polarized with E directed vertically up and down alternately. Determine S , provided that the amplitude of the electric field strength is 0.05 V/m and the frequency is 6 MHz . (7 marks)

