**ELIZADE UNIVERSITY, ILARA-MOKIN, ONDO STATE**

**FACULTY OF ENGINEERING**

**DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING**

**FIRST SEMESTER EXAMINATION, 2020/2021 ACADEMIC SESSION**

**COURSE TITLE: ELECTROMAGNETIC FIELDS**

**COURSE CODE: EEE 313**

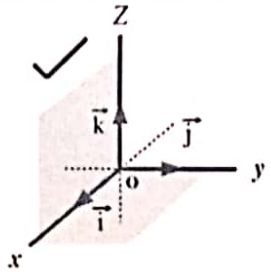
**EXAMINATION DATE: 23RD MARCH, 2021**

**COURSE LECTURER: DR R. Alli-Oke & Dr K. Temikotan** **HOD's SIGNATURE**

**TIME ALLOWED: 3 HRS**

**INSTRUCTIONS:**

1. ANSWER QUESTION 1 AND ANY OTHER FOUR QUESTIONS **(TOTAL OF 5 QUESTIONS)**
2. SEVERE PENALTIES APPLY FOR MISCONDUCT, CHEATING, POSSESSION OF UNAUTHORIZED MATERIALS DURING EXAM.
3. YOU ARE NOT ALLOWED TO BORROW CALCULATORS AND ANY OTHER WRITING MATERIALS DURING THE EXAMINATION.
4. SEPARATION VECTOR $\xi$ IS **ALWAYS** $r - r'$ i.e. FIELD POINT – SOURCE POINT.
5. COULOMB'S LAW: $\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{q}{\xi^2}\hat{\xi}$ VACUUM PERMITIVITY $\epsilon_0 : 8.854 \times 10^{-12}\ \mathrm{Fm^{-1}}$
6. COLOUMB'S CONSTANT $k_e = \frac{1}{4\pi\epsilon_0} = 8.988 \times 10^9\ \mathrm{Nm^2C^{-2}}$
7. USE THE FOLLOWING COORDINATE SYSTEM THROUGHOUT THE EXAM




*Include appropriate units in your answers. The speed of light, permittivity and permeability in free space are given by* $c = 3 \times 10^8\ m/s$, $\varepsilon_0 = 8.854 \times 10^{-12}\ Fm^{-1}$ *and* $\mu_0 = 4\pi \times 10^{-7}\ N/A^2$ *respectively. All symbols should be taken as standard. The unit of* $\vec{B}$ *is* $\mathrm{Nm^{-1}A^{-1}}$.

## QUESTION #1

a) The figure below (Fig. 1) shows a thick spherical shell of charge of uniform volume charge density $\rho$. Plot $\vec{\mathbf{E}}$ due to the shell for distances $r$ from the center of the shell ranging from 0cm to 30cm. Assume that $\rho = 1.0 \times 10^{-6} C/m^3$, $a = 10cm$, and $b = 20cm$

**[10 marks]**

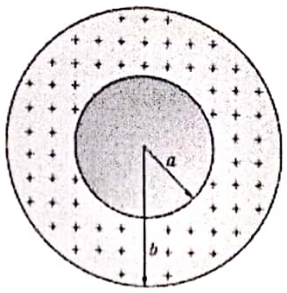



Figure 1: Thick Spherical Shell

b) With the aid of a well-labelled diagram, briefly explain Biot-Savarts law. Your answer should include mathematical expressions.

**[10 marks]**

## QUESTION #2

a) The diagram in Figure (2a) shows a non-conducting rod with uniformly distributed charge $+Q$. The rod forms a half-circle of radius N and produces an electric field $\overrightarrow{E_{arc}}$ at its center of curvature P. If the arc of Figure (2a) is collapsed in a single point-charge $+Q$ at a distance R from P (see Figure 2b), by what factor is the electric field $E_{arc}$ multiplied? *Hint: label the differential length ds, label the coordinates of ds in terms of $\theta$, obtain the separation vector $\vec{\xi}$, and apply Coulomb's law while noting that $dQ = \lambda\, ds = \lambda\, N\, d\theta$. Compute the ratio* $\frac{\text{electric field at P in Fig 2b}}{E_{arc} \text{ at P in Fig 2a.}}$

**[10 marks]**

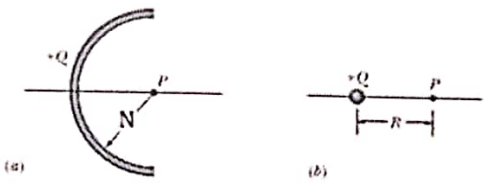



Figure 2: Configuration of Uniformly Distributed Charges

## QUESTION #3

a) Space vehicles traveling through Earth's radiation belt can intercept a significant number of electrons. The resulting charge buildup can damage electronic components and disrupt operations. Suppose a 2 $m$ diameter-wide spherical metallic satellite accumulates 20 $\mu$C in one orbital revolution. (i) Find the resulting surface charge density. (ii) Calculate the magnitude of the electric field just outside the surface of the satellite due to surface charge.

**[10 marks]**

## QUESTION #4

a) The charges below shows particles with charges $q_1 = +2Q$ , $q_2 = +2Q$ , and $q_3 = -4Q$ each at a distance $d$ from the origin. What is the net electric field at the origin? *Hint:* ***Separation vectors approach is a must.*** *Note that the origin is already specified.*

**[4 marks]**

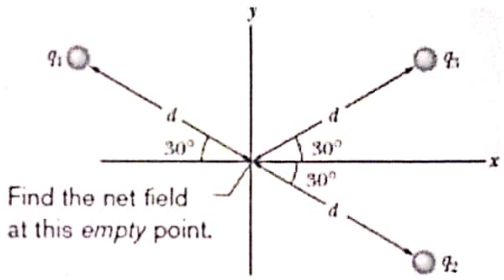



Figure 3: Configuration of Discrete Charges

b) Consider a rod of length $l$ has a uniform charge density of $\lambda$ and a total charge $Q$. Compute the electric field at a point P along the axis of the rod, a distance $d$ from the left end. **[6 marks]**

## QUESTION #5

a) A sphere of radius R has a total charge Q with a uniform (volume) charge density $\rho$. Find the electric field everywhere inside the sphere. *(Hint: There is only one region, $r \leq$ R. Use direct proportion to obtain the enclosed charge).* **[4 marks]**

b) Show that the field $\vec{E} = (x + 5)\, a_z$ is electrostatic. **[6 marks]**

## QUESTION #6

a) A rectangular loop carrying 10 A of current is placed on z = 0 plane as shown in Figure 4. Evaluate **H** at (2, 2, 0). **[4 marks]**

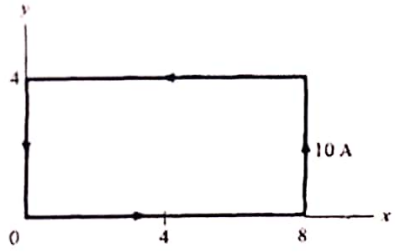



Figure 4

b) A sphere of radius R has a (volume) charge density proportional to the distance from the origin, $\rho = kr$, for some constant $k$. Find the electric field everywhere inside and outside the sphere. *(Hint: There are two regions, $r <$ R and $r \geq$ R. The charge density is not uniform; you must integrate to get the enclosed charge).* **[6 marks]**

## QUESTION #7

a) A non-uniform electric field is given by the expression $\vec{E} = y\, i + 2z\, j + 4z\, k$. With the aid of a diagram, determine the electric flux through a rectangular surface in the $zy$ plane extending from $z = 0$ to $z = 1$ and from $y = 0$ to $y = 4$. **[4 marks]**

b) The potential field $V = 2x^2yz - y^3z$ exists in a dielectric medium having $\varepsilon = 2\varepsilon_o$ **[6 marks]**

i) Does V satisfy Laplace's equation?

ii) Calculate the total charge within the unit cube $0 < x, y, z < 1$ m.