ELIZADE UNIVERSITY, ILARA-MOKIN, ONDO STATE

FACULTY OF ENGINEERING

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

FIRST SEMESTER EXAMINATION, 2019/2020 ACADEMIC SESSION

COURSE TITLE: ELECTROMAGNETIC FIELDS

COURSE CODE: EEE 313

EXAMINATION DATE: 11TH FEBRUARY, 2020

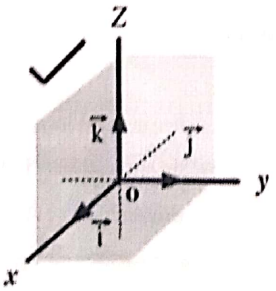
COURSE LECTURER: DR R. Alli-Oke & Dr A. Amusan

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 ξ 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 [20 Marks]

a) Figure Q1a shows a thick spherical shell of charge of uniform volume charge density ρ. Plot $\vec{E}$ due to the shell for distances r from the center of the shell ranging from 0cm to 50cm. Assume that $\rho = 2.0 \times 10^{-6} C/m^3$, $a = 15\ cm$, and $b = 30\ cm$. **[10 marks]**

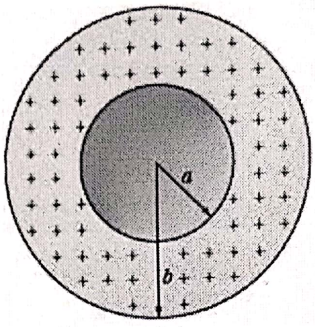


Figure Q1a: Thick Spherical Shell

b)

i.) Five charges each of 1 nC are placed as shown in Figure Q1b. Suppose four of the charges are placed on the four edges of a square of sides 10 nm, while the fifth charge is placed in the center of the square, determine the total energy stored in the configuration of the five charges. (Take $\varepsilon_o = 8.854 \times 10^{-12}$ F/m) **[7 marks]**

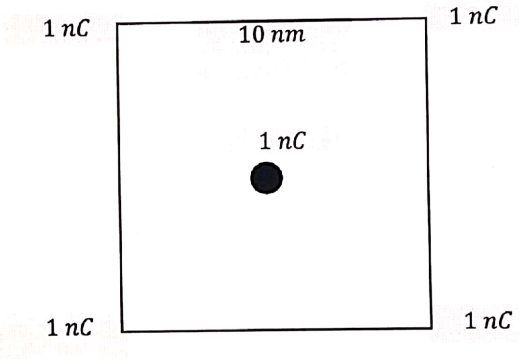


Figure Q1b: Energy Stored in Discrete Configuration

ii.) Calculate the work done in moving an 8-C charge from A (2, 3, 1) to B (0, 0, 1) along the path $y = 2x^2, z = 2$ in the electric field $\mathbf{E} = 10xy\,i + 5yz\,j + 10z\,k$ $^{V}/_{C}$. **[3 marks]**

QUESTION #2 [10 Marks]

a) Space vehicles traveling through Earth's radiation belt can intercept a significant number of electrons. The resulting charge build-up can damage electronic components and disrupt operations. Suppose a 4 m diameter-wide spherical metallic satellite accumulates 40 μC 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. **[4 marks]**

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, $r < \mathrm{R}$ and $r \geq \mathrm{R}$. The charge density is not uniform; you must integrate to get the enclosed charge).* **[6 marks]**

QUESTION #3 [10 Marks]

a) A non-uniform electric field is given by the expression $\vec{\mathbf{E}} = y\,i + 2z\,j + 4z\,k$. 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 diagram in Figure Q3a 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 Q3a is collapsed in a single point-charge $+Q$ at a distance R from P (see Figure Q3b, by what factor is the electric field E_{arc} multiplied? *Hint: label the differential length ds, label the coordinates of ds in terms of θ, obtain the separation vector $\vec{\xi}$, and apply Coulomb's law while noting that $dQ = \lambda\,ds = \lambda\,N\,d\theta$. Compute the ratio* $\frac{\text{electric field at P in Fig 2b}}{E_{arc} \text{ at P in Fig 2a.}}$ **[6 marks]**

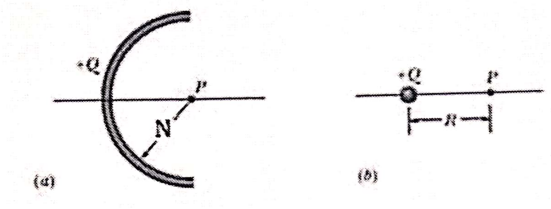


Figure Q3: Configuration of Uniformly Distributed Charges

QUESTION #4 [10 Marks]

a) The diagram in Figure Q4 shows two square arrays of charged particles. The squares, which are centered on point P, are misaligned. The particles are separated by either d or d/2 along the perimeters of the squares. What are the magnitude and direction of the net electric field at P? **[4 marks]**

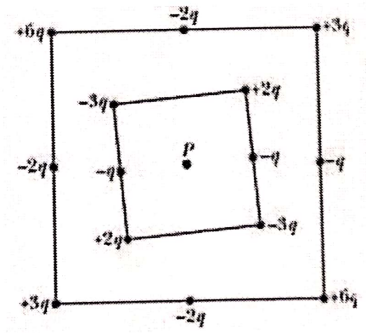


Figure Q4: Configuration of Discrete Charges

b) Consider a rod of length l has a uniform charge density of λ 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 [10 Marks]

(a) State the two boundary conditions for propagation of static electric field in a conductor–free space interface. **[2 marks]**

(b) Given the potential field $V = 200(x^2 - y^2)$ and a point P(2,1,3) that is stipulated to lie on a conductor–free space interface, determine at point P:

(i) Potential V **[1 mark]**

(ii) Equation of the conductor surface **[2 marks]**

(iii) Electric field $\vec{\mathbf{E}}$ **[3 marks]**

(iv) Surface charge ρ_s. Take $\varepsilon_o = 8.854 \times 10^{-12}$ F/m **[2 marks]**

QUESTION #6 [10 Marks]

(a) Derive the Poisson equation and the Laplace equation. State 1-D form of both equations **[4 marks]**

(b) Given the volume charge density in free space as $\rho_v = -2 \times 10^7 \varepsilon_o x \ \ C/m^3$. If the potential $V = 0\ V$ at $x = 0$ and $V = 2\ V$ at $x = 3\ mm$. At $x = 1\ mm$ determine:

(i) Potential V **[3 marks]**

(ii) Electric field E_x **[3 marks]**

QUESTION #7 [10 Marks]

(a)

(i) List two sources of static magnetic field. **[2 marks]**

(ii) State Bio-Savart's Law. **[2 marks]**

(iii) What are the similarities and differences between Bio-Savart's law and Coulomb's law **[2 marks]**

(b) An electron moves with a velocity of 5×10^7 m/s in the j–direction through a point in free space where the magnitude of the applied magnetic field is 2 Telsa in the k–direction. If the force on an electron at this point is given as $\vec{\mathbf{F}} = (9.5 \times 10^{-14})i + (9.5 \times 10^{-14})\ j$, determine the electric field at the point. Note: electron charge $e = 1.602 \times 10^{-19} C$. Use Lorentz force law.

[4 marks]