ELIZADE UNIVERSITY, ILARA-MOKIN, ONDO STATE

FACULTY OF ENGINEERING

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

FIRST SEMESTER EXAMINATION, 2017/2018 ACADEMIC SESSION

COURSE TITLE: ELECTROMAGNETIC FIELDS

COURSE CODE: EEE 313

EXAMINATION DATE: 20TH MARCH, 2018

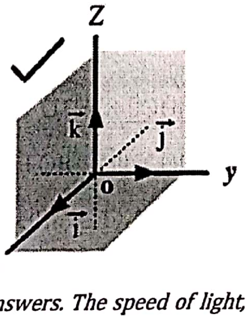
COURSE LECTURER: DR R. O. Alli-Oke

HOD's SIGNATURE

TIME ALLOWED: 3 HOURS

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: $\vec{\mathbf{E}} = \frac{1}{4\pi\epsilon_0}\frac{q}{\xi^2}\xi$ VACUUM PERMITIVITY ϵ_0 : 8.854×10^{-12} Fm^{-1}
6. COLOUMB'S CONSTANT $k_e = \frac{1}{4\pi\epsilon_0} = 8.988 \times 10^9$ Nm^{2}C^{-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* Nm^{-1}A^{-1}.

QUESTION #1

a) An electron travels with a velocity of 4.9×10^6 m/s in the $\hat{\imath}$-direction through a point in space where the magnetic field is 0.111T in the $\hat{\jmath}$-direction. Force of the electron at this point is $F = (9.5 \times 10^{-14})\,\hat{\imath} + (9.5 \times 10^{-14})\hat{k}$ N. Determine the electric field at this point. *Hint: Use Lorentz force law.* **[4 marks]**

b) 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.* **[3 marks]**

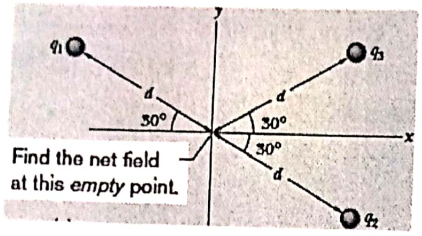


Figure 1: Configuration of Discrete Charges

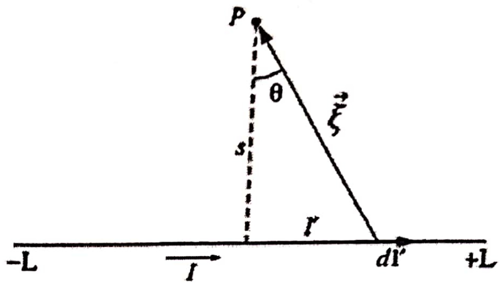


Figure 3: Current-Current Carrying Wire

c) The figure below (Fig. 2a) shows a non-conducting rod with uniformly distributed charge $+Q$. The rod forms a half-circle of radius R and produces an electric field of magnitude E_{arc} at its center of curvature P. If the arc is collapsed in a single point from P (see Fig 2b), by what factor is E_{arc} multiplied? **You must use separation vectors approach.** *Hint: ratio of the electric field at P in Fig 2b to E_{arc} at P in Fig 2a.* **[7 marks]**

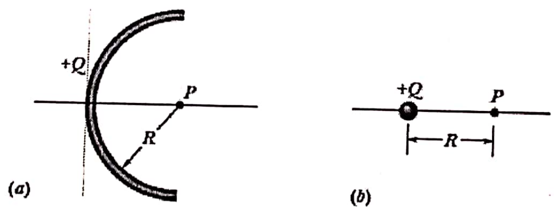


Figure 2: Configuration of Uniformly Distributed Charges

d) A straight wire of length 2L carrying a steady-state current $\vec{I}$ as shown in Figure 3. **You must use separation vectors approach.**

i) Determine the magnetic field $\vec{\mathbf{B}}$ at the mid-point P. **[4 marks]**

ii) Derive the magnetic field $\vec{\mathbf{B}}$ at the mid-point P if the wire shown in Figure 3 is infinite. **[2 marks]**

QUESTION #2

a) Computation of electric field $\vec{\mathbf{E}}$ due to various charge configurations is one of the key goals of this course. In no more than 5 sentences, briefly explain 4 methods of computing $\vec{\mathbf{E}}$. Give one reason why it is important to be able to compute $\vec{\mathbf{E}}$. **[3 marks]**

b) Consider a rod of length l has a uniform charge density of λ and a total charge Q. Calculate the electric field at a point P along the axis of the rod, a distance d from the left end. **[7 marks]**

QUESTION #3

a) A rod of length l has a uniform charge density of λ and a total charge $+Q$. Set the reference point at ∞.

i) Calculate the electric potential V at a point P as shown below in Fig. 4. [4 marks]

ii) Using the grad operator ∇, determine the electric field intensity $\vec{\mathbf{E}}$. [2 marks]

You must use separation vectors approach. *Hint: The infinitesimal electric potential of the differential element* dx *shown in the diagram is given by* $dV = \frac{1}{4\pi\epsilon_0}\frac{dq}{\xi}$, *where* ξ *is your separation vector.*

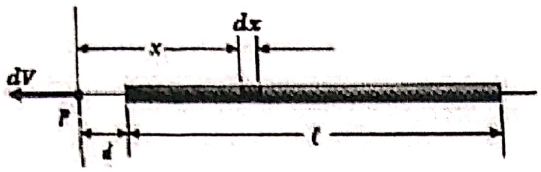


Figure 4: Finite Line of Charge

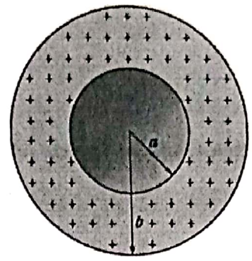


Figure 5: Thick Spherical Shell

b) The electric potential at point P(−4, 3, 6) in free space is given by $V = 2x^2y - 5z$. Compute the numerical values for the :

i) electric potential V [1 mark]

ii) electric field intensity $\vec{\mathbf{E}}$ [2 marks]

iii) electric flux density $\vec{\mathbf{D}}$ [1 mark]

QUESTION #4

a) 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)* [4 marks]

b) Consider an electric field in a region to be $\vec{\mathbf{E}} = 2xzi + (x+2)j + y(z^2-3)k$. Find the total electric flux through a cube of edge-length 2m situated at the origin and placed in that region. [6 marks]

QUESTION #5

a) Show that $\oint \vec{\mathbf{E}}.d\vec{\mathbf{L}} = \mathbf{0}$ for any electric field $\vec{\mathbf{E}}$. [4 marks]

b) Show that any electrostatic field $\vec{\mathbf{E}}$ is a conservative field. *Hint: Show that work done in moving a charge* Q *from a distance* $d\vec{L}$ *in an electric field* $\vec{\mathbf{E}}$ *is independent of path taken.* [6 marks]

QUESTION #6

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 $y = 2$. [5 marks]

b) The figure below shows a thick spherical shell of charge of uniform volume charge density ρ. 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 $b = 20cm$. *Hint: You are to derive* $\vec{\mathbf{E}}$ *for each region and then sketch* $\vec{\mathbf{E}}$ *from 0cm to 30cm.* [5 marks]

QUESTION #7

a) Assume the electric potential V is a function of x only. With the aid of a suitable diagram, show that the capacitor configuration with a potential difference V_0 could serve as boundary conditions to the Laplace's equation. [4 marks]

b) Using the results obtained in (a), derive the capacitance of a capacitor of area S and distance d apart. [6 marks]