FIJI NATIONAL UNIVERSITY
College of Engineering, Science & Technology

SCHOOL OF ELECTRICAL & ELECTRONICS ENGINEERING

BACHELOR OF ENGINEERING

EEE701 – FIELDS AND WAVES

SEMESTER 1, 2015

DAY/DATE: As timetabled DURATION : Three hours
ROOM: As timetabled

INSTRUCTION TO STUDENTS

1. You are allowed 10 minutes extra reading time during which you are **NOT** to write.
2. Answer ALL questions in Section A and FOUR questions in Section B
3. **Begin the answer to each Question** on a fresh page and use both sides of the sheet.
4. Write clearly the number of the question attempted on the top of each sheet
5. Write your candidate number at the top of each sheet & attach them.
6. Insert all written foolscaps, graph paper etc. in their correct sequence and secure with a string.
7. All sheets of paper on which rough/draft work has been done, cross it through and attach all of them to your answer scripts.
8. Where ever possible, draw clear neat diagrams
9. Data sheet having useful formulae are given in the last page

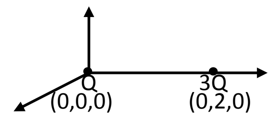
Total number of pages 6

SECTION A (Answer ALL questions)

1. In Cartesian coordinates, points A (3, -2, 4) and B (5,6,9). Write down the unit vector from A to B.

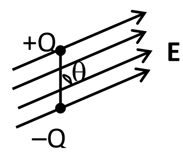
(3 marks)

2. In Cartesian coordinates, two point charges +Q and +3Q are kept as shown. Find the location of the point where the net electric field is zero.



(4 marks)

3. An electric dipole of length d is subjected to an electric field intensity **E** as shown in the figure. What is the torque $\boldsymbol{\tau}$ experienced by the dipole? With respect to the plane of the paper, indicate the direction of this torque.



(3 marks)

4. A **long** straight conductor of radius "*b*" carries a current *I*. Using Amperes circuital Law or otherwise, derive an expression for the magnetic flux density **B** both inside and outside the conductor.

(4 marks)

5. The **total** number of turns of coils on a **thin long** solenoid is *N*. If the length of the solenoid is ℓ, obtain an expression for the magnetic flux density **B** inside the solenoid.

(3 marks)

6. Explain what is meant by TEM mode of propagation of electromagnetic waves in free space. Name the other modes of propagation of guided electromagnetic waves.

(3 marks)

SECTION B (Answer FOUR Questions)

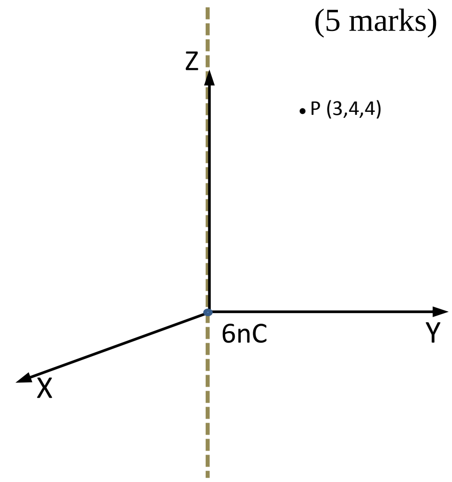
B1. A **long** linear charge distribution ρ_ℓ C m^{-1} kept along the z axis in a Cartesian coordinate system. Using Gauss' law or otherwise obtain an expression for the electric field at a point ρ from the z axis. (5 marks)

The Figure shows a long linear charge distribution of 20 nC m^{-1} kept along the z axis and a point charge of 6 nC is also kept at the origin in a Cartesian coordinate system. Calculate:

a) the field at P due to the line charge, (4 marks)

b) the field at P due to the point charge, (3 marks)

c) the resultant field at the point P. (8 marks)



B2. A metallic sphere of radius " *a* " carries a total charge *Q* on its surface.

i) Derive expressions for the electric field **E** both inside and outside the sphere. Plot the variation of the electric field with the distance from the centre of the sphere. (6 marks)

ii) Derive expressions for the electric potential *V* both inside and outside the sphere. Plot the variation of the *V* with the distance from the centre. (6 marks)

iii) Using ii) above, calculate the capacitance of the sphere. (4 marks)

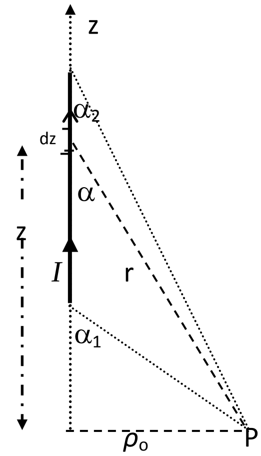
iv) If a = 20 cm and V = 2kV, Calculate the energy stored in the sphere (4 marks)

B3. (i) (*a*) State the Biot-Sarvat's law in magnetism. (2 marks)

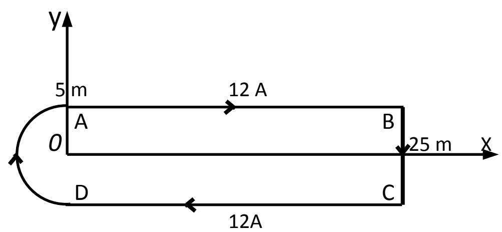
(*b*) The ends of a straight conductor carrying a current *I* subtends angles α_1 and α_2 at a point P as shown in the figure. Show that the magnetic induction **B** at P is:

$$\mathbf{B} = \frac{\mu_0 I}{4\pi \rho_0} \left(\cos\alpha_2 - \cos\alpha_1\right) \boldsymbol{\phi}$$

(6 marks)



(ii)



For the filamentary loop ABCD shown in the diagram, find the total magnetic field **B** at the origin *O*.

(12 marks)

B4. (a) (i) State Ampere's circuital law in magnetism. (2 marks)

(ii) Applying the Amperes law or otherwise, derive an expression for the magnetic induction **B** at a point at a distance ρ away from a long straight conductor carrying a current *I*. (2 mark)

(b) In a coaxial cable, the diameters of the inner conductor and outer conductors are *a* and *b* respectively.

(i) Considering a unit length of the cable, show that the magnetic flux ϕ linked between the conductors for this unit length is $\phi = \frac{\mu_0}{2\pi} \ln \frac{b}{a}$ (12 marks)

(ii) If a = 1 mm and b = 12 mm, calculate the inductance per unit length of the cable.

(4 marks)

B5. (a) Write down the Four Maxwell's equations in the differential form.

(4 marks)

(b) Starting with the above equations, **derive** the wave equation for the electric field propagating in a charge free nonmagnetic dielectric medium.

(6 marks)

(c) Show that the electric and magnetic fields are perpendicular to each other

(4 marks)

(c) Write down the expression for the phase velocity of the waves in the medium.

(2 marks)

(d) If the dielectric constant of the medium is 1.69, calculate the phase velocity. What is the refractive index of the medium? (4 marks)

THE END

DATA SHEET

1. **Some useful constants**:

$\varepsilon_0 = 8.854 \times 10^{-9}$ F/m; $1/(4\pi\varepsilon_0) = 9 \times 10^9$

$\mu_0 = 4\pi \times 10^{-7}$ H/m

2. **Relationship between different sets of coordinates:**

	Cartesian x, y, z	Cylindrical ρ, ϕ, z	Spherical r, θ, ϕ
Cartesian x, y, z		$x = \rho\cos\phi$ $y = \rho\sin\phi$ $z = z$	$x = r\sin\theta\cos\phi$ $y = r\sin\theta\sin\phi$ $z = r\cos\theta$
Cylindrical ρ, ϕ, z	$\rho = \sqrt{x^2 + y^2}$ $\phi = \tan^{-1}\frac{y}{x}$ $z = z$		$\rho = r\sin\theta$ $\phi = \phi$ $z = r\cos\theta$
Spherical r, θ, ϕ	$r = \sqrt{x^2 + y^2 + z^2}$ $\theta = \tan^{-1}\frac{\sqrt{x^2 + y^2}}{z}$ $\phi = \tan^{-1}\frac{y}{x}$	$r = \sqrt{\rho^2 + z^2}$ $\theta = \tan^{-1}\frac{\rho}{z}$ $\phi = \phi$	

3. **Vector transformations**

$$\begin{bmatrix} \mathbf{A}_x \\ \mathbf{A}_y \\ \mathbf{A}_z \end{bmatrix} = \begin{bmatrix} \cos\phi & -\sin\phi & 0 \\ \sin\phi & \cos\phi & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \mathbf{A}_\rho \\ \mathbf{A}_\phi \\ \mathbf{A}_z \end{bmatrix}$$

$$\begin{bmatrix} \mathbf{A}_\mathbf{x} \\ \mathbf{A}_\mathbf{y} \\ \mathbf{A}_\mathbf{z} \end{bmatrix} = \begin{bmatrix} \sin\theta\cos\phi & \cos\theta\cos\phi & -\sin\phi \\ \sin\theta\sin\phi & \cos\theta\sin\phi & \cos\phi \\ \cos\theta & -\sin\theta & 0 \end{bmatrix} \begin{bmatrix} \mathbf{A}_\mathbf{r} \\ \mathbf{A}_\theta \\ \mathbf{A}_\phi \end{bmatrix}$$

4. **Vector Identity**

$$\nabla \wedge (\nabla \wedge \mathbf{A}) = \nabla(\nabla \cdot \mathbf{A}) - \nabla^2\mathbf{A}.$$

5. **Curl operation of a vector in Cartesian coordinates**

$$\nabla \wedge \mathbf{A} = \begin{vmatrix} \mathbf{i} & \mathbf{j} & \mathbf{k} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ A_x & A_y & A_z \end{vmatrix}$$