FIJI NATIONAL UNIVERSITY
College of Engineering, Science & Technology

SCHOOL OF ELECTRICAL & ELECTRONICS ENGINEERING

BACHELOR OF ENGINEERING

EEE701 – Fields and Waves

SEMESTER 1, 2017

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. This paper has **Two** sections. Answer **ALL** questions in **both** sections.
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. Some useful mathematical relations are given in page 6

Number of pages including instruction page = 6

PTO

Useful constants: $\varepsilon_o = 8.854 \times 10^{-12}$ Fm^{-1}; $\left|\frac{1}{4\pi\varepsilon_0}\right| = 9 \times 10^9$; $\mu_o = 4\pi \times 10^{-7}$ Hm^{-1}

Useful notation: Into plane of paper⊗. Out from plane of paper ⊙

SECTION A

Answer <u>**ALL**</u> questions

A1. Indicating clearly the axes, draw a Cartesian coordinate system. Indicate points $P(-1, 2, 1)$, $Q(3,-3, 0)$ in the coordinate system:

i) Write the position vector of P

i) <u>**Indicate**</u> and <u>**find**</u> the vector PQ

ii) The distance PQ

(5 marks)

A2. The **total charge** on a metallic spherical shell of radius 1.5m is 12 μC. Using Gauss law or otherwise obtain an expression for:

i) The electric field **E** at a point 2 m away from the centre

ii) The electric field **E**at a point 1 m away from the centre

(5 marks)

A3. Fig. A.3 shows a long thin straight conductor M carrying a current of 5 A. The direction of flow as shown

i) Copy the diagram on your answer sheet. Draw the lines indicating the **direction** of flow of the magnetic induction **B.** Direction of flow ⊗ for the flow **into** and ⊙ for **out** of the plane of the paper

ii) Assume that there are120 turns of closely spaced long thin conductors, all carrying same current (5A) in the same direction. Using Amperes circuital law or otherwise, **obtain** an expression for the magnetic induction **B** at a point 2.2 m away from the conductors. Mark the point on your diagram and indicate the direction of **B**.

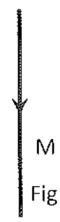

Fig A.3

(5 marks)

A4. Draw the cross sectional view of the **Twin line** transmission line and the **coaxial cable**. Indicate the direction of flow of current by ⊗ for the flow **into** and ⊙ for **out** of the plane of the paper.

i) Draw and indicate the direction of the electric field **E** and the direction of the magnetic field **H**.

ii) Indicate the direction of flow of power.

(5 marks)

SECTION B

Answer ALL questions

Question B1

i) In a Cartesian coordinate system, two charges $Q_1 = 1.2$ C and $Q_2 = 2.5$ C are placed along the y and the z axis respectively as shown in Fig B1.*i*.
A charge Q of 16 nC is now kept at P. The coordinates of Q_1, Q_2, and Q are shown in Fig B1.*i*. Calculate:

a) The forces $\mathbf{F_1}$ on Q due to charge Q_1, and force $\mathbf{F_2}$ on Q due to charge Q_2 and the resultant force.

b) The angle between $\mathbf{F_1}$ and $\mathbf{F_2}$.

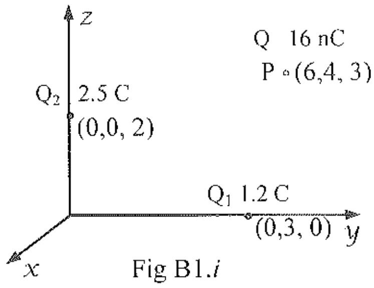

Fig B1.*i*

(7+7 marks)

ii) Express the Gauss law in electrostatics in a mathematical form. Define **all** the quantities used.

(2 marks)

A **long** linear charge distribution of density 4 nC/m is along the z axis in a Cartesian coordinate system as shown in Fig B1.*ii*.
Using the Gauss law or otherwise, **Derive** in cylindrical coordinates, the electric field $\mathbf{E}_\rho$ at P (6,4,3) due to the linear charge distribution..

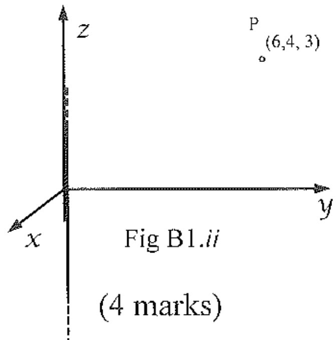

Fig B1.*ii*

(4 marks)

Question B2

i) Using a neatly labeled diagram, express mathematically the Biot-Sarvat's law for the magnetic induction d**B** produced by a current carrying element. All the symbols used must be explained and the direction of d**B** must be indicated.

(3 marks)

Starting with the Bio –Savart's law in magnetism, it can be shown that the magnetic induction field **B** at a point P, which is at a distance ρ_0 away from a current carrying straight conductor (Fig B2. *i*) is:

$$\mathbf{B} = \frac{\mu_0 I}{4\pi\rho_0}(\cos\alpha_2 - \cos\alpha_1)$$ where the angles α_1 and α_2 are as shown in Fig. B2.*i*.

a) If ℓ = 4m, the current I = 5 A, the point P is on the perpendicular bisector of ℓ and ρ_0 = 1.5 m , calculate **B** at P. Clearly mark the direction of **B**.

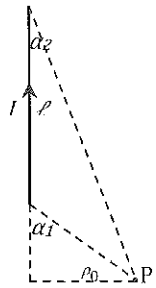

Fig. B2.*i*

B2 continued

PTO

B2 continued

b) A rectangular coil of dimension 4m × 3m of 75 turns of thin wire carry a current of 5 A. calculate the **B** at the centre of the coil.(***Hint:*** *Draw a diagram and mark all the angles*)

(3+6 marks)

ii) Fig. B2.*ii* (*a* & *b*) shows two long thin straight conductors carrying currents, in each figure. The magnitudes of the currents, directions and the separations are different in each figure. Carefully copy the two set ups on your answer sheet and mark them clearly.

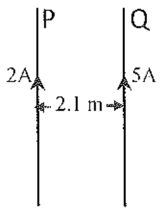

Fig B2*ii*

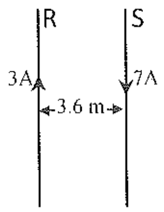

Fig B2*ii*

a) For both cases, draw the **B** lines, both between and outside the two conductors. To distinguish between the **B** lines due to the different currents. (To distinguish between the lines corresponding to different currents, either use different colour pens, pen and pencil or continuous and dashed lines)

b) In each case, calculate the position of the null points from each set of conductors. **Mark the** null points on your diagram.

(3+5 marks)

Question B3

i) Express mathematically, the Ampere's force law on a current element kept in a magnetic induction **B.** Explain **all** the symbols used in the expression. Use a neatly labeled diagram to illustrate the law.

(3 marks)

A side view of a rectangular armature coil ABCD kept in a parallel magnetic induction field is shown in Fig B3. AB = CD= 8 cm; BC = DA = 5cm. The axle of the coil is perpendicular to BC and DA. The number of turns of coil is 2500. In the position shown, the angle between the normal to the coil **N** and **B** is 50°. If **B** = 2 Tesla, and the current flowing through the coil is 800 mA.

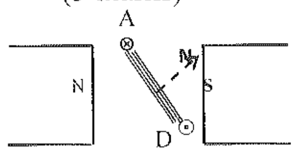

Fig B3

a) Calculate the torque acting on the coil. State the direction of rotation (clock wise or anti clockwise).

b) **Discuss** the motion of this coil.

c) Explain, with suitable diagram, what modification is done in the practical application (motor) and **explain,** with suitable diagram how the modification facilitates the working of the device.

(4+2+4 marks)

ii) Express mathematically the Faradays law of electromagnetic induction. Explain **all** the symbols used in the expression.

(2 marks)

B3 continued

PTO

B3 continued

a) Explain how this law is applied in the operation of a dynamo

b) Write down the Maxwell's equation which illustrates the Faradays law of electromagnetic induction.

(3+2 marks)

Question B4

i) *a*) Draw the representation of a small section of a transmission line which includes the four distributed parameters.

b) Write down the equation for the variation of the voltage and current along the line.

c) Hence obtain the wave equation for the voltage along the line.

(3+5+5 marks)

ii) In the solution to the wave equations the for voltage, let A and B are the amplitudes of the incident and the reflected voltages. For a transmission line of characteristic impedance Z_0 terminated by a load "Z", it can be derived $\frac{Z}{Z_0} = \frac{A+B}{A-B}$.

a) Show that the voltage reflection coefficient $\frac{B}{A} = \frac{Z-Z_0}{Z+Z_0}$

b) For a transmission line $Z_0 = 75\ \Omega$ and the incident voltage = 3 sin ωt. If the load is 25 Ω, calculate the reflected voltage. Draw, to approximate scale, the incident and the reflected waves at the load.

(3+4 marks)

The End

Some useful mathematical relations:

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	$r = \sqrt{x^2 + y^2 + z^2}$ $\theta = \tan^{-1} \frac{\sqrt{x^2 + y^2}}{z}$ $\phi = \tan^{-1} \frac{y}{x}$	$r = \sqrt{\rho^2 + z^2}$ $\theta = \tan^{-1} \frac{\rho}{z}$ $\phi = \phi$	