



INTI
International College Penang
LAUREATE INTERNATIONAL UNIVERSITIES*

FINAL
Examination Paper

(COVER PAGE)

Session : August 2015

Programme : Diploma in Electrical and Electronic Engineering (DEEI)

Course : EEE2104: Electromagnetic Field Theory

Date of Examination : 10th December 2015 (Thursday)

Time : 2:00pm - 4:00pm Reading Time : Nil

Duration : 2 Hours

Special Instructions :

This paper consists of SIX (6) questions. Answer any FOUR (4) questions in the answer booklet provided. All questions carry equal marks.

IMPORTANT NOTE : THIS PAPER SHOULD NOT BE TAKEN OUT OF THE EXAMINATION HALL

Materials permitted :

Non Programmable Scientific Calculator

Materials provided :

Appendix

Examiner(s) : Mr. Liong Han Wen

Moderator : Dr. Ooi Beng Lee

This paper consists of 5 printed pages, including the cover page.

INTI INTERNATIONAL COLLEGE PENANG

DIPLOMA IN ELECTRICAL AND ELECTRONIC ENGINEERING PROGRAMME
 EEE 2104: ELECTROMAGNETIC FIELD THEORY
 FINAL EXAMINATION: AUGUST 2015 SESSION

Instructions: This paper consists of **SIX (6)** questions. Answer any **FOUR (4)** questions in the answer booklet provided. All questions carry equal marks. The marks allocated to each sub-question are shown in the brackets at the right-hand margin.

Question 1

- a. Two point charges of $-2\mu\text{C}$ (Q_1) and $5\mu\text{C}$ (Q_2) are located at $(4,8,-10)$ and $(2,-8,20)$ respectively.
- Calculate the total electric force acts on a point charge $40\mu\text{C}$ (Q_3) at $(1,5,-25)$. (10 marks)
 - Find electric field strength at $(1,5,-25)$ (5 marks)
- b. Find the potential at point A(0,0,5) with respect to point B(0,0,10) that due to a point charge 500nC at the origin. (7 marks)
- c. Define Gauss's Law. (3 marks)

Question 2

- a. Find the work done in carrying a 5C charge from point A(1,2,-4) to B(3,-5,6) in an electric field $\vec{E} = \vec{a}_x + z^2\vec{a}_y + 2yz\vec{a}_z$ V/m. (10 marks)
- b. A parallel-plate conductor separated by 3mm of air has plate area of 200cm^2 . The charge density of each plate is $1\mu\text{C}/\text{m}^2$. Calculate:
- The capacitance of the capacitor. (3 marks)
 - Voltage between the plates. (4 marks)
 - The attraction force between the plates. (4 marks)
- c. A plane contains an infinite uniform charge distribution of density $\rho_s = 10 \text{ C}/\text{m}^2$ located at $y = 3\text{m}$. Determine \vec{E} at all points. (4 marks)

Question 3

- a. An insulating solid sphere with radius a has a uniform volume charge density ρ_v and carries a total positive charge Q . By using Gauss's Law, prove that: (14 marks)

$$E = \begin{cases} \frac{\rho_v r}{3\epsilon_0} & 0 < r \leq a \\ \frac{a^3}{3\epsilon_0 r^2} \rho_v & r \geq a \end{cases}$$

- b. Two extensive homogeneous and isotropic dielectrics meet on plane $z = 0$. For $z \geq 0$, $\epsilon_{r1} = 4$ and for $z \leq 0$, $\epsilon_{r2} = 3$. A uniform electric field $\vec{E}_1 = 5\vec{a}_x - 2\vec{a}_y + 3\vec{a}_z$ kV/m exists for $z \geq 0$. Find \vec{E}_2 and θ_2 (angle between \vec{E}_2 and normal direction of boundary) for $z \leq 0$. (11 marks)

Question 4

- a. An infinite current carrying current of I_o is placed along z-axis. By using Ampere's Law, prove that H at any point of (ρ, ϕ, z) is (5 marks)

$$H = \frac{I_o}{2\pi \rho}$$

- b. A current carrying wire conducting 2A is located close to an infinitely long, straight conductor with a current of 5A, as shown in Figure Q4(b) below. Calculate the total force react on the 2A current line. (17 marks)

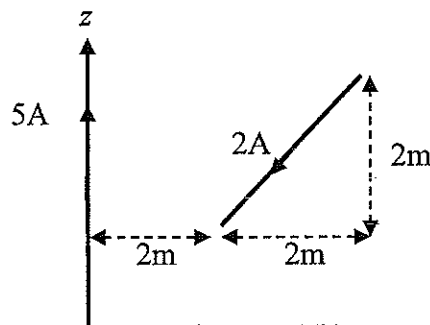


Figure Q4(b)

- c. Define Biot Savart Law. (3 marks)

Question 5

- a. Refer to Figure Q5(a), find the total flux crossing the portion of the plane at $\phi = \pi/4$ defined by $0.01 \leq \rho \leq 0.05$ m and $0 \leq z \leq 2$ m due to current filament of 2.5A along the z-axis in the \vec{a}_z direction. Assume that the medium is free space. (4 marks)

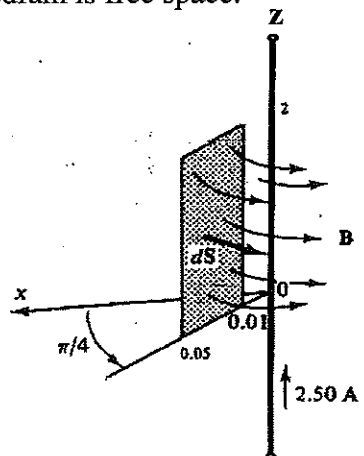


Figure Q5(a)

- b. In the magnetic circuit of Figure Q5(b), calculate the current in the coil that will produce a magnetic flux density of 1.5 Wb/m^2 in the air gap assuming that $\mu = 50\mu_0$ and that all branches have the same cross-sectional area of 10 cm^2 . (12 marks)

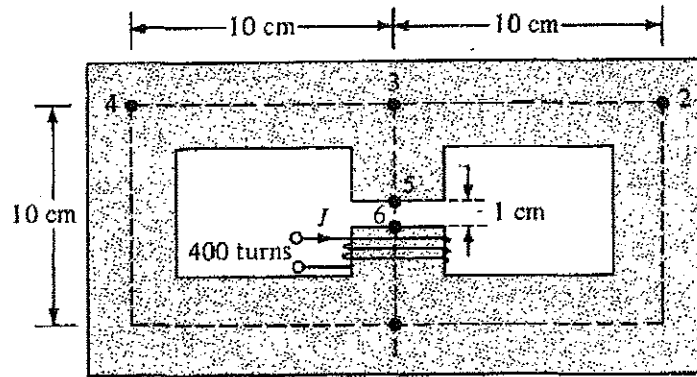


Figure Q5(b)

- c. A conductor loop of area 10 cm^2 with 10Ω resistance located in a region with $\vec{B} = 50 \cos 10^3 t \vec{a}_z \text{ mWb/m}^2$ as shown in Figure Q5(c). Find:

- the induced emf. (5 marks)
- the induced current in the loop. (2 marks)

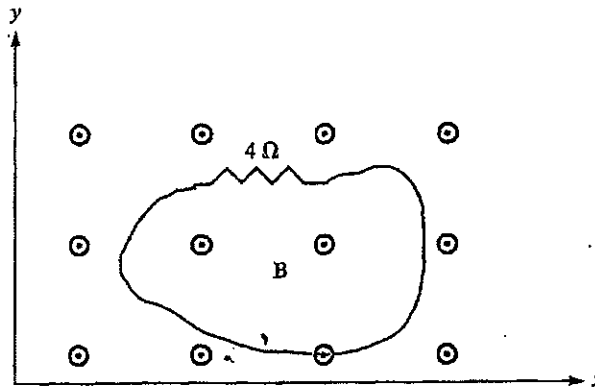


Figure Q5(c)

- d. Define Lenz's Law. (2 marks)

Question 6

- a. Compute the electromotive force and the current for the circuit in Figure Q6(a) if the conducting rod, $l = 0.1\text{m}$ move with a constant speed, $v = 2\text{m/s}$. Given $B = 2\text{T}$ and the resistance of the conducting rod, $R = 2\Omega$. Also find the power required in order to move the conducting rod with the given constant speed. (10 marks)

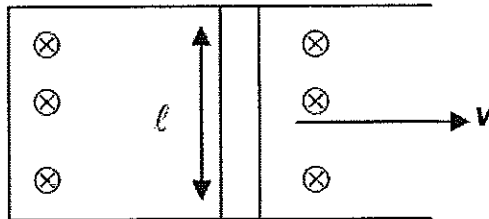


Figure Q6(a)

- b. A parallel plate capacitor with plate area of 4 cm^2 and plate separation of 3mm has an electric field $\vec{E} = 25 \sin 10^{10} t \vec{a}_z$ V/m applied to its plates. Calculate the magnitude of the displacement current in between the plates assuming $\epsilon = 2\epsilon_0$. (4 marks)
- c. State three type of magnetic materials. (3 marks)
- d. Region 1 for which $\mu_{r1}=4$ is defined by $x < 0$ and region 2, $x > 0$ has $\mu_{r2} = 5$. Given $\vec{H}_1 = 4\vec{a}_x + 3\vec{a}_y - 6\vec{a}_z$ A/m. Find $|\vec{H}_2|$. (8 marks)

--THE END--

(EEE 2104/(F)/August 2015/Liong Han Wen /29-8-2015)

MATHEMATICAL FORMULAS AND PHYSICAL CONSTANT

Appendix A: Physical Constant

Permittivity of free space, $\epsilon_0 = 8.854 \times 10^{-12} \text{ F/m} \cong \frac{10^{-9}}{36\pi} \text{ F/m}$

Permeability of free space, $\mu_0 = 12.6 \times 10^{-7} \text{ H/m} \cong 4\pi \times 10^{-7} \text{ H/m}$

Appendix B: Trigonometry Identities

Sum or difference of two angles:

$$\sin(a \pm b) = \sin a \cos b \pm \cos a \sin b$$

$$\cos(a \pm b) = \cos a \cos b \mp \sin a \sin b$$

$$\tan(a \pm b) = \frac{\tan a \pm \tan b}{1 \mp \tan a \tan b}$$

Double angle formulas:

$$\sin 2\theta = 2 \sin \theta \cos \theta$$

$$\cos 2\theta = 1 - 2 \sin^2 \theta$$

$$\tan 2\theta = \frac{2 \tan \theta}{1 - \tan^2 \theta}$$

$$\cos 2\theta = 2 \cos^2 \theta - 1$$

$$\cos 2\theta = \cos^2 \theta - \sin^2 \theta$$

Pythagorean Identities:

$$\tan^2 \theta + 1 = \sec^2 \theta$$

$$\sin^2 \theta + \cos^2 \theta = 1$$

$$\cot^2 \theta + 1 = \csc^2 \theta$$

Half angle formulas:

$$\sin^2 \theta = \frac{1}{2}(1 - \cos 2\theta)$$

$$\cos^2 \theta = \frac{1}{2}(1 + \cos 2\theta)$$

$$\sin \frac{\theta}{2} = \pm \sqrt{\frac{1 - \cos \theta}{2}}$$

$$\cos \frac{\theta}{2} = \pm \sqrt{\frac{1 + \cos \theta}{2}}$$

$$\tan \frac{\theta}{2} = \pm \sqrt{\frac{1 - \cos \theta}{1 + \cos \theta}} = \frac{\sin \theta}{1 + \cos \theta} = \frac{1 - \cos \theta}{\sin \theta}$$

Appendix C: Differential Length, Area and Volume

Cartesian System :

Differential displacement, $d\vec{l} = dx\vec{a}_x + dy\vec{a}_y + dz\vec{a}_z$

$$d\vec{s}_x = dydz\vec{a}_x$$

Differential normal area, $d\vec{s}_y = dx dz\vec{a}_y$

$$d\vec{s}_z = dx dy\vec{a}_z$$

Differential volume, $dv = dx dy dz$

Cylindrical System :

Differential displacement, $d\vec{l} = d\rho\vec{a}_\rho + \rho d\phi\vec{a}_\phi + dz\vec{a}_z$

Differential normal area, $d\vec{S} = \rho d\phi dz \vec{a}_\rho$

$$= d\rho dz \vec{a}_\phi$$

$$= \rho d\phi d\rho \vec{a}_z$$

Differential volume, $dv = \rho d\rho d\phi dz$

Spherical System :

Differential displacement, $d\vec{l} = dr\vec{a}_r + r d\theta\vec{a}_\theta + r \sin\theta d\phi\vec{a}_\phi$

Differential normal area, $d\vec{S} = r^2 \sin\theta d\theta d\phi \vec{a}_r$

$$= r \sin\theta dr d\phi \vec{a}_\theta$$

$$= r dr d\theta \vec{a}_\phi$$

Differential volume, $dv = r^2 \sin\theta dr d\theta d\phi$

Appendix D: Gradient of scalar

$$\text{Cartesian System} : \nabla V = \frac{\partial V}{\partial x} \bar{a}_x + \frac{\partial V}{\partial y} \bar{a}_y + \frac{\partial V}{\partial z} \bar{a}_z$$

$$\text{Cylindrical System} : \nabla V = \frac{\partial V}{\partial \rho} \bar{a}_\rho + \frac{1}{\rho} \frac{\partial V}{\partial \phi} \bar{a}_\phi + \frac{\partial V}{\partial z} \bar{a}_z$$

$$\text{Spherical System} : \nabla V = \frac{\partial V}{\partial r} \bar{a}_r + \frac{1}{r} \frac{\partial V}{\partial \theta} \bar{a}_\theta + \frac{1}{r \sin \theta} \frac{\partial V}{\partial \phi} \bar{a}_\phi$$

Appendix E: Curl of a Vector

$$\text{Cartesian System} : \nabla \times \bar{A} = \begin{vmatrix} \bar{a}_x & \bar{a}_y & \bar{a}_z \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ A_x & A_y & A_z \end{vmatrix}$$

$$\text{Cylindrical System} : \nabla \times \bar{A} = \frac{1}{\rho} \begin{vmatrix} \bar{a}_\rho & \rho \bar{a}_\phi & \bar{a}_z \\ \frac{\partial}{\partial \rho} & \frac{\partial}{\partial \phi} & \frac{\partial}{\partial z} \\ A_\rho & \rho A_\phi & A_z \end{vmatrix}$$

$$\text{Spherical System} : \nabla \times \bar{A} = \frac{1}{r^2 \sin \theta} \begin{vmatrix} \bar{a}_r & r \bar{a}_\theta & r \sin \theta \bar{a}_\phi \\ \frac{\partial}{\partial r} & \frac{\partial}{\partial \theta} & \frac{\partial}{\partial \phi} \\ A_r & r A_\theta & r \sin \theta A_\phi \end{vmatrix}$$

Appendix F: Divergence of a vector

$$\text{Cartesian System} : \nabla \cdot \bar{A} = \frac{\partial A_x}{\partial x} + \frac{\partial A_y}{\partial y} + \frac{\partial A_z}{\partial z}$$

$$\text{Cylindrical System} : \nabla \cdot \bar{A} = \frac{1}{\rho} \frac{\partial}{\partial \rho} (\rho A_\rho) + \frac{1}{\rho} \frac{\partial}{\partial \phi} (A_\phi) + \frac{\partial}{\partial z} (A_z)$$

$$\text{Spherical System} : \nabla \cdot \bar{A} = \frac{1}{r^2} \frac{\partial}{\partial r} (r^2 A_r) + \frac{1}{r \sin \theta} \frac{\partial}{\partial \theta} (A_\theta \sin \theta) + \frac{1}{r \sin \theta} \frac{\partial}{\partial \phi} (A_\phi)$$

Appendix G: Laplacian of a vector

Cartesian System:

$$\nabla^2 \vec{A} = \left(\frac{\partial^2 A_x}{\partial x^2} + \frac{\partial^2 A_x}{\partial y^2} + \frac{\partial^2 A_x}{\partial z^2} \right) \vec{a}_x + \left(\frac{\partial^2 A_y}{\partial x^2} + \frac{\partial^2 A_y}{\partial y^2} + \frac{\partial^2 A_y}{\partial z^2} \right) \vec{a}_y + \left(\frac{\partial^2 A_z}{\partial x^2} + \frac{\partial^2 A_z}{\partial y^2} + \frac{\partial^2 A_z}{\partial z^2} \right) \vec{a}_z$$

Appendix H: Relationship between Cartesian and Cylindrical System

$$\rho = \sqrt{x^2 + y^2}, \quad \tan \phi = \frac{y}{x}, \quad z = z$$

or

$$x = \rho \cos \phi, \quad y = \rho \sin \phi, \quad z = z$$

$$\begin{aligned} \vec{a}_x &= \cos \phi \vec{a}_\rho - \sin \phi \vec{a}_\phi & \vec{a}_\rho &= \cos \phi \vec{a}_x + \sin \phi \vec{a}_y \\ \vec{a}_y &= \sin \phi \vec{a}_\rho + \cos \phi \vec{a}_\phi & \vec{a}_\phi &= -\sin \phi \vec{a}_x + \cos \phi \vec{a}_y \\ \vec{a}_z &= \vec{a}_z & \vec{a}_z &= \vec{a}_z \end{aligned}$$

Appendix I: Vector relationship between Cartesian and Spherical System

$$r = \sqrt{x^2 + y^2 + z^2}, \quad \tan \theta = \frac{\sqrt{x^2 + y^2}}{z}, \quad \tan \phi = \frac{y}{x}$$

or

$$x = r \sin \theta \cos \phi, \quad y = r \sin \theta \sin \phi, \quad z = r \cos \theta$$

$$\begin{aligned} \vec{a}_x &= \sin \theta \cos \phi \vec{a}_r + \cos \theta \cos \phi \vec{a}_\theta - \sin \phi \vec{a}_\phi & \vec{a}_r &= \sin \theta \cos \phi \vec{a}_x + \sin \theta \sin \phi \vec{a}_y + \cos \theta \vec{a}_z \\ \vec{a}_y &= \sin \theta \sin \phi \vec{a}_r + \cos \theta \sin \phi \vec{a}_\theta + \cos \phi \vec{a}_\phi & \vec{a}_\theta &= \cos \theta \cos \phi \vec{a}_x + \cos \theta \sin \phi \vec{a}_y - \sin \theta \vec{a}_z \\ \vec{a}_z &= \cos \theta \vec{a}_r - \sin \theta \vec{a}_\theta & \vec{a}_\phi &= -\sin \phi \vec{a}_x + \cos \phi \vec{a}_y \end{aligned}$$

Appendix J: Derivatives of Trigonometric Functions

$$\frac{d}{dx} \sin(x) = \cos(x)$$

$$\frac{d}{dx} \cos(x) = -\sin(x)$$

$$\frac{d}{dx} \tan(x) = \sec^2(x)$$

$$\frac{d}{dx} \cot(x) = -\csc^2(x)$$

$$\frac{d}{dx} \sec(x) = \sec(x) \tan(x)$$

$$\frac{d}{dx} \csc(x) = -\csc(x) \cot(x)$$

Appendix K: Table of Integrals

$$\int \frac{1}{(a^2 + u^2)^{3/2}} du = \frac{u}{a^2 \sqrt{a^2 + u^2}} + C$$

$$\int \frac{u}{(a^2 + u^2)^{3/2}} du = -\frac{1}{\sqrt{a^2 + u^2}} + C$$

$$\int \frac{1}{a^2 + u^2} du = \frac{1}{a} \tan^{-1} \frac{u}{a}$$

$$\int \frac{1}{\sqrt{a^2 + u^2}} du = \ln \left(u + \sqrt{a^2 + u^2} \right) + C$$

Appendix L: Vector Identities

Gradient

1. $\vec{\nabla}(f + g) = \vec{\nabla}f + \vec{\nabla}g$
2. $\vec{\nabla}(cf) = c\vec{\nabla}f$, for any constant c
3. $\vec{\nabla}(fg) = f\vec{\nabla}g + g\vec{\nabla}f$
4. $\vec{\nabla}(f/g) = (g\vec{\nabla}f - f\vec{\nabla}g)/g^2$ at points \vec{x} where $g(\vec{x}) \neq 0$.
5. $\vec{\nabla}(\vec{F} \cdot \vec{G}) = \vec{F} \times (\vec{\nabla} \times \vec{G}) - (\vec{\nabla} \times \vec{F}) \times \vec{G} + (\vec{G} \cdot \vec{\nabla})\vec{F} + (\vec{F} \cdot \vec{\nabla})\vec{G}$

Divergence

6. $\vec{\nabla} \cdot (\vec{F} + \vec{G}) = \vec{\nabla} \cdot \vec{F} + \vec{\nabla} \cdot \vec{G}$
7. $\vec{\nabla} \cdot (c\vec{F}) = c\vec{\nabla} \cdot \vec{F}$, for any constant c
8. $\vec{\nabla} \cdot (f\vec{F}) = f\vec{\nabla} \cdot \vec{F} + \vec{F} \cdot \vec{\nabla}f$
9. $\vec{\nabla} \cdot (\vec{F} \times \vec{G}) = \vec{G} \cdot (\vec{\nabla} \times \vec{F}) - \vec{F} \cdot (\vec{\nabla} \times \vec{G})$

Curl

10. $\vec{\nabla} \times (\vec{F} + \vec{G}) = \vec{\nabla} \times \vec{F} + \vec{\nabla} \times \vec{G}$
11. $\vec{\nabla} \times (c\vec{F}) = c\vec{\nabla} \times \vec{F}$, for any constant c
12. $\vec{\nabla} \times (f\vec{F}) = f\vec{\nabla} \times \vec{F} + \vec{\nabla}f \times \vec{F}$
13. $\vec{\nabla} \times (\vec{F} \times \vec{G}) = \vec{F}(\vec{\nabla} \cdot \vec{G}) - (\vec{\nabla} \cdot \vec{F})\vec{G} + (\vec{G} \cdot \vec{\nabla})\vec{F} - (\vec{F} \cdot \vec{\nabla})\vec{G}$

Laplacian

14. $\vec{\nabla}^2(f + g) = \vec{\nabla}^2f + \vec{\nabla}^2g$
15. $\vec{\nabla}^2(cf) = c\vec{\nabla}^2f$, for any constant c
16. $\vec{\nabla}^2(fg) = f\vec{\nabla}^2g + 2\vec{\nabla}f \cdot \vec{\nabla}g + g\vec{\nabla}^2f$

Degree Two

17. $\vec{\nabla} \cdot (\vec{\nabla} \times \vec{F}) = 0$
18. $\vec{\nabla} \times (\vec{\nabla}f) = 0$
19. $\vec{\nabla} \cdot (\vec{\nabla}f \times \vec{\nabla}g) = 0$
20. $\vec{\nabla} \cdot (f\vec{\nabla}g - g\vec{\nabla}f) = f\vec{\nabla}^2g - g\vec{\nabla}^2f$
21. $\vec{\nabla} \times (\vec{\nabla} \times \vec{F}) = \vec{\nabla}(\vec{\nabla} \cdot \vec{F}) - \vec{\nabla}^2\vec{F}$

