



NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF APPLIED SCIENCES

DEPARTMENT OF APPLIED PHYSICS

BSc HONOURS IN EARTH SCIENCE PART II

SPH2105 – ELECTROMAGNETISM

First Semester Examination Paper

December 2024

This examination paper consists of 4 pages

Time Allowed: 3 hours

Total Marks: 100

Special Requirements: Calculator

Examiner's Name: Mr. E. Jonathan

INSTRUCTIONS

ANSWER ALL QUESTIONS IN SECTION A AND ANY THREE QUESTIONS FROM SECTION B. SECTION A CARRIES 40 MARKS AND SECTION B CARRIES 60 MARKS

MARK ALLOCATION

QUESTION	MARKS
1.	40
2.	20
3.	20
4.	20
5.	20
6.	20
Maximum possible marks	100

Permittivity of Free Space	ϵ_0	=	$8.85 \times 10^{-12} \text{ Fm}^{-1}$
Permeability of Free Space	μ_0	=	$4\pi \times 10^{-7} \text{ Hm}^{-1}$
Mass of an Electron	m_e	=	$9.1 \times 10^{-31} \text{ kg}$
Charge of an Electron	e	=	$1.6 \times 10^{-19} \text{ C}$
Mass of proton	m_p	=	$1.67 \times 10^{-27} \text{ kg}$
Speed of light in vacuum	c	=	$3 \times 10^8 \text{ ms}^{-1}$

Some useful formulas

$$\begin{aligned}\nabla \times (\nabla S) &= \mathbf{0} \\ \nabla \cdot (\nabla \times \mathbf{a}) &= \mathbf{0} \\ \mathbf{a} \times (\mathbf{b} \times \mathbf{c}) &= \mathbf{b}(\mathbf{a} \cdot \mathbf{c}) - \mathbf{c}(\mathbf{a} \cdot \mathbf{b}) \\ \nabla \times (\nabla \times \mathbf{a}) &= -\nabla^2 \mathbf{a} + \nabla(\nabla \cdot \mathbf{a}) \\ \nabla \cdot (\mathbf{a} \times \mathbf{b}) &= \mathbf{b} \cdot (\nabla \times \mathbf{a}) - \mathbf{a} \cdot (\nabla \times \mathbf{b})\end{aligned}$$

SECTION A

Question 1

- (a) The electrostatic force on a small sphere of charge is $0.5\mu\text{C}$ due to another small sphere of charge $-0.8\mu\text{C}$ in the air is 0.2N
- (i) What is the distance between the two spheres? [4]
- (ii) What is the force on the second sphere due to the first one? [2]
- (b) Given that the relative permeability and relative permittivity of the medium is 1.5 and 2.2 respectively.
- (i) Find the speed of the electromagnetic wave in this medium. [4]
- (ii) Define permeability and permittivity. [4]
- (c) If three point charges, $q_1 = 50\text{nC}$, $q_2 = 100\text{nC}$ and $q_3 = -50\text{nC}$ are enclosed by surface S . What is the net flux that crosses S ? [3]
- (d) What is the significance of the modified Ampere's Law? [3]
- (e) The propagation constant γ for electromagnetic waves is given by [6]

$$\gamma = \alpha + j\beta$$

Explain the terms α and β .

- (f) A proton moves with velocity of $\mathbf{v} = (\mathbf{i} - 3\mathbf{j} + \mathbf{k})$ m/s in a region in which the magnetic field is $\mathbf{B} = (\mathbf{i} + 3\mathbf{j} - 2\mathbf{k})\text{T}$. Determine the magnitude of the magnetic force experienced by this proton. [5]
- (g) Explain the pointing vector and its significance. [6]
- (h) Explain the basic principle of radiation from a single wire carrying a time-varying current. [3]

SECTION B

Question 2

- (a) For a long solenoid of length l and radius R consisting of N turns of wire,
- (i) Neglecting the end effects, find the self-inductance. [4]
 - (ii) Find the energy stored in the system when current I is passed through the coil. [3]
 - (iii) Compute the self-inductance given that $l = 20\text{cm}$, $R = 4\text{cm}$ and $N = 700$ turns. [3]
- (b) Using Maxwell's equations obtain the expressions and values for \mathbf{B} , \mathbf{D} , \mathbf{E} and β given the following parameters, $\mu = 4 \times 10^{-5}\text{H/m}$, $\epsilon = 1.2 \times 10^{-10}\text{F/m}$ and $H = 3 \cos(10^{10}t - \beta x)\text{A/m}$, $\sigma = 0$ everywhere. [10]

Question 3

- (a) From Maxwell's equations derive the continuity equation. [10]
- (b) A nonmagnetic wire of radius R and length l carries a current I which is uniformly distributed over its cross-section. Determine the magnetic energy per unit length inside the wire? [10]

Question 4

- (a) A charge of 1C is at $(2,0,0)$. What charge must be placed at $(-2,0,0)$ which will make the y component of total \mathbf{E} zero at the point $(1,2,2)$? [10]
- (b) Given that there is a point charge Q at the origin. Show that $\text{div } \mathbf{D}$ is zero everywhere except at the origin. [10]

Question 5

- (a) Use Maxwell's equations in free space to show that \mathbf{E} satisfies the following wave equation [10]

$$\nabla^2 \mathbf{B} - \frac{1}{c^2} \frac{\partial^2 \mathbf{B}}{\partial t^2} = \mathbf{0}$$

- (b) Given a parallel-plate capacitor filled with a non-uniform dielectric characterised by $\epsilon_r = 2 + 3 \times 10^6 x^3$ where x is the distance from [10]

one plate to the other in metres. If $S = 0.03m^2$ and $d = 1mm$ find C .

Question 6

- (a) For a rectangular waveguide explain the following terms;
- (i) Cut-off frequency. [2]
 - (ii) Waveguide modes. [2]
 - (iii) Dominant mode. [2]
 - (iv) Given the following dimensions for the rectangular waveguide $1cm \times 0.5cm$. Calculate the cut-off frequency. [4]
- (b) Given the following dimensions for the rectangular waveguide $1cm \times 0.5cm$. Calculate the cut-off frequency. [10]

END OF EXAMINATION PAPER