UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 4. Examination in Engineering: September 2024

Module Number: EE4306 **Module Name: Engineering Electromagnetism**

[Three Hours]

[Answer **all questions**, each question carries 10 marks]

(Permittivity of free space $\xi_0 = 10^{-9}/(36\pi)$ F/m and Permeability of free space $\mu_0 = 4\pi \times 10^{-7} H/m$)

Q1. Answer all MCQ given below and each question carries 1 mark.

a) Plane z = 10 m carries charge 20 nC/m². The electric field intensity at the origin is

i) $-10\underset{\sim}{a}_z \; v/m.$

ii) $-18\pi\underset{\sim}{a}_z \; v/m.$

iii) $-72\pi\underset{\sim}{a}_z \; v/m.$

iv) $-360\pi\underset{\sim}{a}_z \; v/m.$

b) If a vector field $\underset{\sim}{q}$ solenoid, which of these is true?

i) $\oint_L \underset{\sim}{q}.d\underset{\sim}{l} = 0$

ii) $\oint_s \underset{\sim}{q}.d\underset{\sim}{s} = 0$

iii) $\Delta \times \underset{\sim}{q} = 0$

iv) $\Delta^2 \underset{\sim}{q} = 0$

c) Stokes theorem is applicable only when a close path exist and the vector field and its derivatives are continuous within the path.

i) True

ii) False

iii) Not necessarily

d) The work done by the force $\overline{F} = 4\underset{\sim}{a}_x - 3\underset{\sim}{a}_y + 2\underset{\sim}{a}_z \; N$ in giving a 1 nC charge a displacement of $10\underset{\sim}{a}_x + 2\underset{\sim}{a}_y - 7\underset{\sim}{a}_z \; m$ is

i) 103 nJ.

ii) 60 nJ.

iii) 64 nJ.

iv) 20 nJ.

e) Which of following is zero?
   i) grad div
   ii) div grad
   iii) curl grad
   iv) curl curl

f) Which of following is mathematically incorrect expression?
   i) grad div
   ii) div curl
   iii) grad curl
   iv) curl grad

g) The relaxation time of mica $(\sigma = 10^{-15}\, S/m,\ \varepsilon_r = 6)$ is
   i) 15 hrs
   ii) 10^{-15} s
   iii) 10^{-6} s
   iv) 10 hrs

h) An antenna located in a city is a source of radio waves. How much time does it take the wave to reach a town 1200 km away?
   i) 36 s
   ii) 20 ms
   iii) 20 μs
   iv) 40 ms

i) Which of the following potentials does not satisfy Laplace's equation?
   i) $V = 2x + 5$
   ii) $V = 10xy$
   iii) $V = r\cos\phi$
   iv) $V = \rho\cos\phi + 10$

j) Two conducting plates are inclined at an angle 30^0 to each other with a point charge between them. The number of image charges is
   i) 11
   ii) 12
   iii) 5
   iv) 6

Q2. a) i) States the Biot-Sarvart's law. [1.5 Marks]

ii) States the Ampere's circuit law. [1.5 Marks]

b) i) States the Divergence theorem. [1.5 Marks]

ii) States the Stokes's theorem. [1.5 Marks]

c) Compute the value of the magnetic field in the airgap of the device shown in Figure Q2 by neglecting both fringing effect in the air-gap and leakage flux. The parameters are given as $I_1 = 2A$, $N_1 = 200$ turns, $h = l_1 = 10$ cm, $l_2 = 5$ cm, $w = 1$ cm, $l_g = 2$ mm $\mu = 2000\mu_0$. [6 Marks]

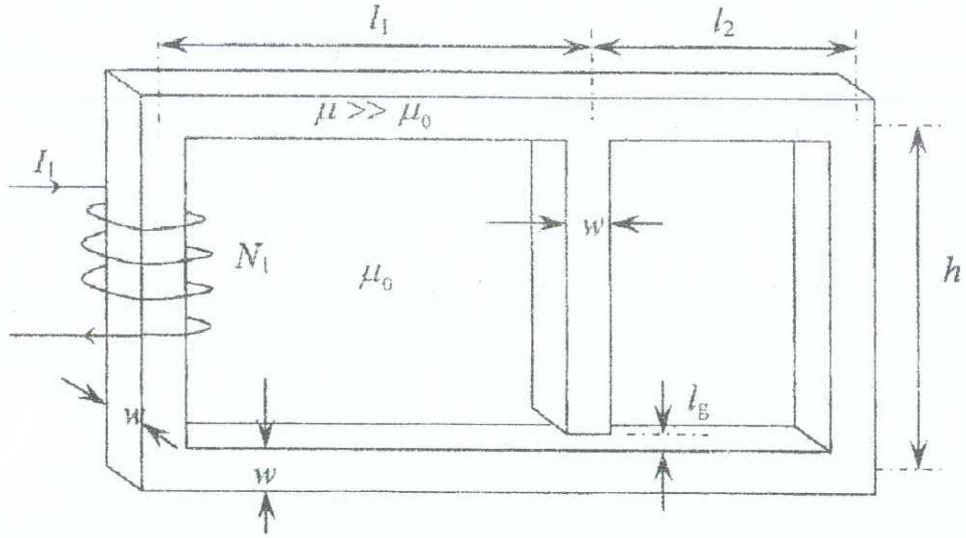

Figure Q2

Q3. The electric field intensity of a linearly polarized uniform plane wave propagating in the +z direction in sea water is $\bar{E} = 100\cos(\pi t \times 10^7)\bar{a}_z\ V/m$ at z = 0. The constitutive parameters of sea water are relative permittivity of $\xi_r = 80$, $\mu_r = 1$, and $\sigma = 4$ S/m

a) Determine the attenuation constant, phase constant, intrinsic impedance, phase velocity wavelength, and skin depth. [6 Marks]

b) Find the distance at which the amplitude of **E** is 1% of its value at z = 0. [2 Marks]

c) Write the expression for $E(z,t)$ and $h(z,t)$ at z = 0.8 m as a function of time(t). [2 Marks]

Q4. a) Describe the four primary types of coupling mechanisms that can result in Electromagnetic Interference (EMI). Provide a distinct example for each type of coupling mechanism. [3 Marks]

b) i) Explain the effect of crosstalk in transmission systems.

[1 Mark]

ii) Suppose a student proposes two strategies to enhance the performance of an electronic system: not bundling the system wires tightly and crossing the wires at a 90-degree angle. How would these measures help in mitigating the crosstalk between two wires?

[2 Marks]

c) Discuss the potential impact of a software upgrade and routine maintenance on the Electromagnetic Compatibility (EMC) of a system. Provide two specific examples illustrating potential issues that might arise due to these activities.

[2 Marks]

d) In a hospital setting with numerous closely situated electronic medical devices such as MRI machines, ECG monitors, infusion pumps, and patient monitoring systems, identify four EMC protection methods that could be implemented to prevent electromagnetic interference. Provide a rationale for each method in relation to the given scenario.

[2 Marks]

Q5. a) You are provided with the following equations derived by a student who is studying the Hertz dipole.

$$H_\phi = \frac{I_0 dl e^{j\omega t}}{4\pi r}\left(j\beta e^{-j\beta r}\sin(\theta) + \frac{e^{-j\beta r}}{r}\sin(\theta)\right)$$

$$E_\theta = \frac{I_0 dl e^{j\omega t} e^{-j\beta r}\sin(\theta)}{4\pi\epsilon}\left(\frac{j\beta^2}{\omega r} + \frac{\beta}{\omega r^2} - \frac{j}{\omega r^3}\right)$$

$$E_r = \frac{I_0 dl e^{j\omega t} e^{-j\beta r}\cos(\theta)}{4\pi\omega\epsilon}\left(\frac{\beta}{r^2} - \frac{j}{r^3}\right)$$

i) What are the quantities represented by these three equations? You must mention the answer with respect to the position of Hertz dipole and the location of the observer.

[1 Mark]

ii) The fields generated by Hertz dipole can be categorized depending upon their variation as a function of distance. Mention these three categories and how they depend on the frequency of operation.

[1.5 Marks]

iii) Obtain a distance from the antenna where the field strengths of the three fields mentioned in part ii) are equal and explain the near field and far field components of a Hertz dipole based on that.

[1.5 Marks]

iv) Considering the far field components of the Hertz dipole. Prove that the ratio between electric and magnetic field at every point in space is equal to the intrinsic impedance.

[1.5 Marks]

v) The student is now assigned a task of simulating the radiation pattern of a dipole antenna where the length $l = \frac{3\lambda}{2}$. The student is planning to use the same equations that was provided earlier. Would you recommend this approach? Explain your answer.

[1.0 Mark]

vi) The power radiated by a Hertz dipole is provided as $40\pi^2 I_0^2 (\frac{dl}{\lambda})^2$. Calculate the radiation resistance of a Hertz dipole with the length, $l = 0.2\lambda$.

[1.5 Marks]

b) A 3dB gain antenna transmits with 20W power and operates with a 10 GHz carrier frequency. The receiver antenna is located across 1km and has a gain of 2dB. Assuming line of sight propagation in free space, what is the received power at the receiving antenna in dBm?

[2.0 Marks]