UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 4 Examination in Engineering: September 2023

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

[3 Hours]

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

(Permittivity of free space $\varepsilon_0 = 10^{-9}/(36\pi)\ F/m$ and Permeability of free space $\mu_0 = 4\pi \times 10^{-7}\ H/m$)

Q1 a) An electromagnetic plane wave in free space with power density of 3 W/m^2 impinges normally on a lossless dielectric boundary with a reflection coefficient of 0.375.

i. What is the intrinsic impedance of the dielectric medium? [1 Mark]

ii. What is the power density of the wave transmitted into dielectric? [2 Marks]

b) i. State Biot-Savart Law. [1 Mark]

ii. Compare the usefulness of Ampere's circuit law and Biot-Savart law in determining magnetic flux density (**B**) of a current-carrying circuit. [2 Marks]

iii. Determine the self-induction of a toroidal coil of N turn of wire wound on air frame with mean radius **r** and a circular cross section of radius **b**. Obtain an approximate expression assuming **b<<r**. [4 Marks]

Q2 a) i. State the Stokes's theorem. [2 Marks]

ii. State the Gauss's Law. [1 Mark]

b) What do you mean by boundary condition analyze in electrostatic and electromagnetic field? [2 Marks]

c) Asymmetric core of steel shown in Figure Q2 has the permeability of 1000 μ_0 has a uniform cross section of 4 cm^2 except in the central leg with cross section of 6 cm^2 . The other dimensions of the core have been indicated in the Figure Q2. The left leg has a coil with 300 turns carrying a 10 A of current and the right leg has a coil with 200 turns carrying a 5 A of current. Determine the flux density in each leg. [5 Marks]

Q3 a) What do you mean by skin depth? [1 Mark]

b) The electrical field intensity of a linear polarized uniform plane wave propagating in the +z direction in seawater is $E = a_x 100\cos(10^7 \pi t) V/m$ at $z=0$. The constitutive parameters of seawater are $\varepsilon_r = 72$, $\mu_r = 1$ and $\sigma = 4 S/m$.

i. Determine the attenuation constant, phase constant, intrinsic impedance, phase velocity, wave length and skin depth. [6 Marks]

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

iii. Write the expression for $E(z,t)$ and $H(z,t)$ at $z=0.8m$ as a function of t(time). [1 Mark]

Q4 a) Explain what is EMC and why it is a vital consideration in engineering design today than it was a few decades back. [2 Marks]

b) You are designing a new medical device that includes both analog and digital circuits. The device will be used in a hospital environment where there are many other electronic devices present. During the initial testing phase, you notice that the device is not functioning as expected. You suspect that electromagnetic interference (EMI) from other devices in the environment might be affecting your device's performance.

i) What steps would you take to confirm if EMI is indeed causing the issue? [1 Mark]

ii) If EMI is confirmed to be the issue, what design modifications would you consider to improve the Electromagnetic Compatibility (EMC) of your device? [1 Mark]

iii) How would you ensure that your modifications are effective and that the device now meets the necessary EMC standards for medical devices? [1 Mark]

c) You are an engineer working as an EMC consultant for a company that has recently released a new line of wireless devices. After the product has been released to the market, you discover a significant EMC issue that could potentially interfere with other devices and violate EMC standards. However, you are bound by a non-disclosure agreement (NDA) with the company that prohibits you from releasing this information.

i) As an engineer, what steps would you take upon discovering this EMC issue in the already released product? [1.5 Marks]

ii) What would be the potential implications for the public and the company if this information is not released and the product continues to be sold? [1.5 Marks]

d) Explain two potential issues in grounding that can cause EMI and mention how to overcome them with respect to EMC control mechanisms. [2 Marks]

Q5 a) i) The fields generated by a Hertz dipole can be divided into three categories depending upon their variation as a function of distance. Explain how electric fields generated by a Hertz dipole varies with the distance and how they are influenced by the frequency of operation. [1.5 Marks]

ii) The average pointing vector P_{av} of a hertz dipole is provided as follows. $P_{av} = \frac{1}{2}\left(\frac{I_0 dl \sin\theta}{4\pi r}\right)^2 \frac{\beta^3}{\omega\varepsilon}\hat{r}$. Show that the toal power radiated by a Hertz dipole is equal to $W = 40\pi^2 I_0^2 \left(\frac{dl}{\lambda}\right)$. [3 Marks]

iii) A Hertzian dipole is excited by a current of $5A$ in amplitude. If the length of the dipole is $l = 0.001\lambda$, determine the average power radiated by the antenna and the radiation resistance of the Hertz dipole. [2 Marks]

b) i) A transmitting antenna (*T*) that operates with a $1.2\,GHz$ carrier frequncy has a gain of two. A receiver antenna (**R**) with a gain of three is located at a distanec of $150\,m$ from **T**. If the tranmit power of **T** is given as $50\,W$, calculate the received power at **R** assuming line of sight propagation in the free space. [2.5 Marks]

ii) What is the received power of **R** if it was located at $2000\,m$ from **T**. [1 Mark]

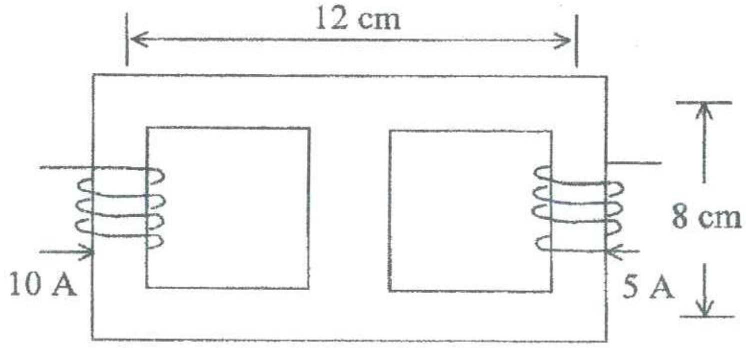

Figure Q2