UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 4. Examination in Engineering: November 2022

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

[Three Hours]

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

(Permittivity of free space $\xi_0 = 10^{-9}/(36\pi)$ F/m and Permeability of free space $\mu_0 = 4\pi\times10^{-7}$ H/m)

Q1. a) States the coulomb's low. [1 Mark]

b) A cylindrical capacitor consists of an inner conductor of radius **a** and an outer conductor whose inner radius is **b**. The space between the conductors is filled with a dielectric of permittivity ξ, and the length of the capacitor is L. Determine the capacitance of this capacitor. [3 Marks]

c) Find the energy required to assemble a uniform sphere of charge of radius **b** and volume charge density ρCm^{-3}. [3 Marks]

d) Assume that N turns of wire are tightly wound on a toroidal frame of a rectangular cross section with dimensions as shown in Figure Q1. Assuming the permeability of the medium to be μ_0, find the self-inductance of the toroidal coil. [3 Marks]

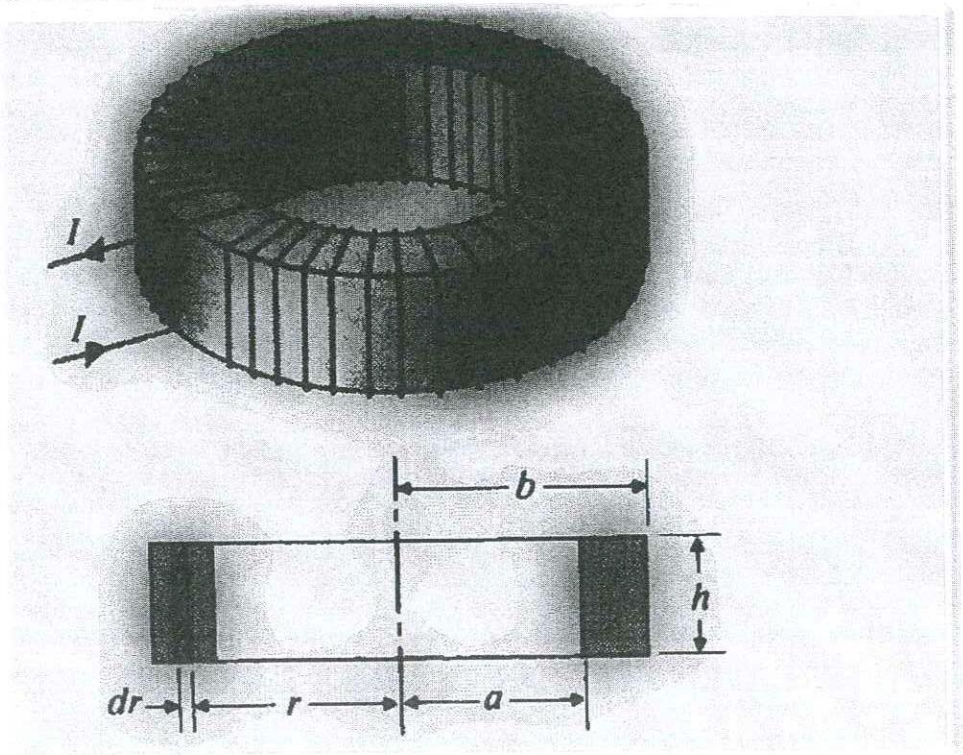

Figure Q1

Q2. a) i) States the Biot-Sarvart's law. [1 Mark]

ii) States the Ampere's circuit law. [1 Mark]

b) i) States the Divergence theorem. [1 Mark]

ii) States the Stokes's theorem. [1 Mark]

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

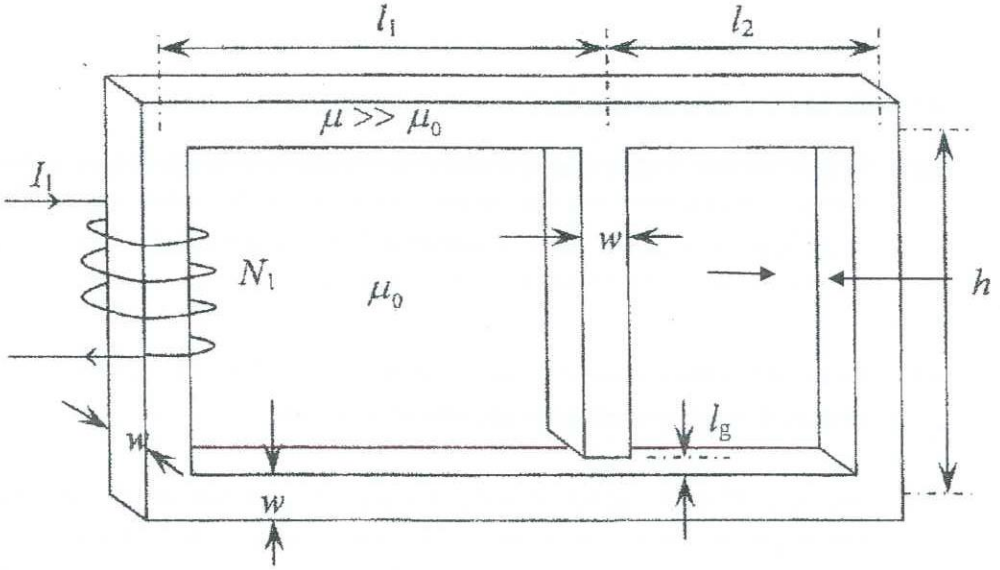

Figure Q2

Q3. a) What do you mean by "uniform plane wave"? [2 Marks]

b) What do you mean by lossy medium and lossless medium for electromagnetics wave? [2 Marks]

c) A uniform sinusoidal plane wave in air with the following phasor expression for electric intensity $E_i(x,z) = \underset{\sim}{u}_y 10e^{-j(6x+8z)}\ V/m$ is incident on a perfectly conducting plane at z =0.

i) Find the wavelength of the wave. [1 Mark]

ii) Find the frequency of the wave. [1 Mark]

iii) Write the instantaneous expression for $E_i(x,z;t)$ and $H_i(x,z;t)$, using a cosine reference. [2 Marks]

iv) Determine the angle of incidence wave. [2 Marks]

Q4. a) The total average power (P_{rad}) radiated by a Hertzian dipole consisting of an infinitesimal current element of length dl, carrying a rms current I_{rms} given by $P_{rad} = 80\pi^2 \left(\frac{dl}{\lambda_0}\right)^2 I_{rms}^2$, where λ_0 denotes the wavelength.

i) Obtain an expression for the value of a radiation resistance (R_{rad}), which dissipates the same amount of power radiated by a Hertzian dipole when both carries the same rms current. [1 Mark]

ii) Calculate the rms current required in a 1 cm long Hertzian dipole antenna to radiate 1 W of power at the frequency of 300 MHz. [2 Marks]

iii) What is the rms current required in part a) ii), if the frequency is set to 3MHz? What conclusions you can make about the antenna from this result? [1 Mark]

iv) How can you design a Hertz dipole for a given frequency and current so that it increases the total average power radiated? Mention any constraints in your solution. [1 Mark]

v) Suppose that an observer is located at a far field point 100 m away from a Hertz dipole antenna and measures the magnitude of the electric field as 1 V/m. Determine the magnitudes of the electric and magnetic fields at a distance of 1000 m along the same radial line. [2 Marks]

b) Assume a receiver is located at 10 km away from a 50 W transmitter. The carrier frequency is 900 MHz. Free space propagation is assumed between the transmitter and the receiver. The transmitter and the receiver antenna gains are provided as $G_t = 1$ and $G_r = 2$ respectively.

i) Find the received power at the receiver antenna in dBW. [2 Marks]

ii) Find the effective aperture at the receiver antenna. [1 Mark]

Q5 a) Discuss the importance of achieving electromagnetic compatibility (EMC) with examples under the following considerations.

i) Proper functioning of devices

ii) Safety of users

iii) Legal consequences [1.5 Marks]

b) Assume you are developing an electronic device to be implemented in an environment with other operating electrical and electronic devices. What are the considerations you would take to make sure that the device has electromagnetic compatibility? [2 Marks]

c) *"Apart from the initial designing phase, it is important to make sure the electromagnetic compatibility of devices at each phase after installation, maintenance, modification, upgrade, and refurbishment"*. Discuss and justify the above statement providing one example each for the importance of EMC in maintenance and upgrade phases. [2 Marks]

d) Lack of electromagnetic interference related threat data is often a major concern for proper assessment of electromagnetic threats. Discuss the causes for a lack of data and its impact on electromagnetic threat assessment. [1.5 Marks]

e) i) Minimizing the loop area in circuits is one method of improving EMC. With the help of a figure, explain what is loop area in a circuit and why having a larger loop area could degrade the EMC. [2 Marks]

ii) Filtering solutions are often used in pair with shielding as control techniques for EMC. Explain the reason for this paring. [1 Mark]