UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 3 Examination in Engineering: March 2026

Module Number: EE3304 **Module Name: Engineering Electromagnetism(C-23)**

[3 Hours]

[Answer **all questions,** each question carries 12 marks]

(Permittivity of free space $\varepsilon_0 = 10^{-9}/(36\pi)\ \mathrm{F/m}$ and Permeability of free space $\mu_0 = 4\pi\times10^{-7}\ \mathrm{H/m}$)

Q1. The magnetic field component of a plane wave in a lossless dielectric ($\mu_r = 1$) is $\bar{H} = 30\sin(2\pi\times10^8 t - 5x)\bar{a}_z\ mA/m.$

a) Find relative permittivity (ξ_r) of the medium. [2 Marks]

b) Calculate the wavelength and wave velocity of the signal. [4 Marks]

c) Determine the wave impedance. [2 Marks]

d) Determine the polarization of the wave. [2 Marks]

e) Find the corresponding electric field component. [2 Marks]

Q2. a) i) State the Divergence theorem. [2 Marks]

ii) State the Ampere's circuit law. [2 Marks]

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

c) Find the gradient of the following scalar fields:

i) $V = e^{-z}\sin 2x\cosh y$ [2 Marks]

ii) $U = \rho^2 z\cos 2\phi$ [2 Marks]

iii) $W = 10r\sin^2\theta\cos\phi$ [2 Marks]

Q3. At large observation distances, the electromagnetic field radiated by a satellite antenna communicating with a submerged submarine can be approximated as a locally transverse electromagnetic (TEM) uniform plane wave, as shown in Figure Q3. Assume that the submarine is located directly beneath the satellite. The incident

electric field in air, just before it impinges on the sea surface, has a magnitude of 1 mV/m.
The electromagnetic properties of the media are as follows:
Free space: Permittivity ε_r and permeability μ_o.
Sea water: Relative permittivity - 81, Relative permeability - 1, Conductivity - 1 S/m.
At an operating frequency of 1 MHz, determine the following quantities.

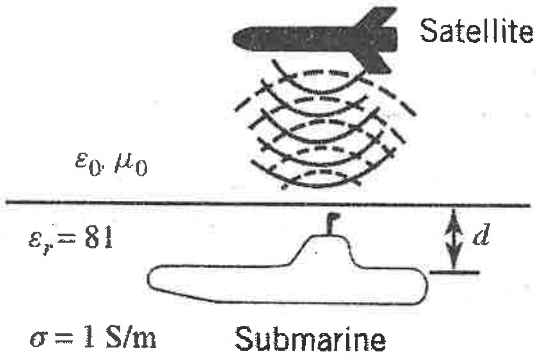

Figure Q3.

a) Intensity of the reflected E field. [2 Marks]

b) SWR created in air. [2 Marks]

c) Intensity of the transmitted E field. [2 Marks]

d) Intensity of the transmitted power density. [2 Marks]

e) Depth (in meters) of the submarine so that the distance from the surface of the ocean to the submarine is 20λ (λ in water). [2 Marks]

f) Time (in seconds) it takes the wave to travel from the surface of the ocean to the submarine at a depth of 100 m. [1 Mark]

g) Ratio of velocity of the wave in water to that in air (V / V_0). [1 Mark]

Q4. "AeroStrike-1" Helicopter "Operational helicopters currently flying in high-conflict zones are experiencing abnormal behavior. Pilots have reported flickering digital cockpit displays and temporary loss of GPS navigation signals whenever they fly near active Missile Defense Systems (MDS) – similar to an Iron Dome battery. These systems use ultra-high-power scanning radars that generate intense electromagnetic fields.

Because of these ongoing safety issues, the government has initiated the "Viper-X" helicopter project. Your team is tasked with evaluating AeroStrike-1 failures and designing a new electronic subsystem that can operate reliably even in the presence of high-power radar and communication links. As the lead EMC engineer, you must ensure this new design is fully compatible with its environment."

a) Based on the reports from the AeroStrike-1 pilots:

i) Identify and briefly explain the specific electromagnetic issue occurring in the AeroStrike-1. [1 Mark]

ii) Using your knowledge of EMC, discuss three (03) potential safety or operational impacts that these failures could have on a mission if they are not fixed in the new Viper-X design. [1.5 Marks]

b) In the context of the helicopter projects and the surrounding Missile Defense System (MDS):

i) Define the term Electromagnetic Compatibility (EMC). [1 Mark]

ii) State and briefly describe the two essential components of EMC that the Viper-X must satisfy to operate reliably. [1 Mark]

c) Identify the Source, the Victim, and the Coupling Path in this specific scenario. [1.5 Marks]

d) To protect the digital cockpit from the high-power radar of the MDS, your team decides to implement EMC control mechanisms in new "Viper-X" project. Propose two (02) practical engineering methods to reduce the interference and explain how they work. [2.5 Marks]

e) EMC is not a "one-time" test during design; it must be checked during every phase of manufacturing and while the helicopter is functioning in the field.

i) Why is it necessary to perform EMC testing during every phase of its life cycle even if the individual parts were already tested? [1.5 Marks]

ii) Name three (03) pieces of specialized equipment used in an EMC lab to measure and analyze these interference signals. [1 Mark]

f) Imagine you decide to replace a plastic cover on the Viper-X cockpit with a carbon-fiber or metallic-coated material. From an EMC perspective, explain the primary reason for this change and how it helps the system survive near the Missile Defense System. [1 Mark]

Q5. a) In your own words, briefly explain the role of an antenna as a "Magic Converter" in a communication system and provide the formal definition of an antenna.

[1 Mark]

b) Consider a Hertzian Dipole (a very short current element) of length dl carrying a uniform time-harmonic current $I(t) = I_0 e^{\{j\omega t\}}$.

i) Draw a clearly labeled diagram of the Hertzian dipole placed at the origin and oriented along the z-axis. Show a distant observation point $P(r, \theta, \emptyset)$ and the corresponding unit vectors in a spherical coordinate system. [1 Mark]

ii) The magnetic vector potential A at point *P* is given by:

$$A = \hat{z}[\{\mu_0 I_0 dl\}/\{4\pi r\}]e^{\{j(\omega t - \beta r)\}}$$

Starting with this expression, derive the non-zero electric field (E) and magnetic field (H) components for the Far-Field (Radiation Field) region. Explain why certain terms are neglected in this region. [2 Marks]

c) i) Draw and clearly label the radiation pattern of a typical cell tower antenna. Indicate the primary lobe, secondary lobes, and the relative signal strength in different directions. [1 Mark]

ii) In the same diagram, clearly indicate the main beam (Direction of Maximum Radiation), the directions of the nulls, and the beam width between the first nulls (BWFN). [1 Mark]

iii) Determine the Beam Width Between First Nulls (BWFN) and the Half Power Beam Width (HPBW) in the E-plane (Vertical Plane) for a Hertzian dipole antenna. [1 Mark]

d) A rescue team is setting up a temporary wireless link in a disaster zone. The transmitter (T) is located on a hilltop and operates at a frequency of 3 GHz. It uses an antenna with a power gain of 4 (dimensionless) and transmits a power of 100 W.
A portable receiver (R) is located 5 km from the transmitter. The receiving antenna has an effective aperture area (A_{eff}) of 0.01 m^2.

i) Calculate the wavelength of the transmitted signal and determine the gain of the receiving antenna at this operating frequency. [2 Marks]

ii) Using the Friis Transmission Equation, calculate the power received (P_r) at the portable receiver in Watts. Assume ideal free-space conditions and perfect alignment. [2 Marks]

iii) If the rescue team replaces the receiving antenna with one that has double the gain, but the distance between the antennas also doubles, explain (with a brief calculation) whether the received power will increase, decrease, or remain the same. [1 Mark]