MERU UNIVERSITY OF SCIENCE AND TECHNOLOGY

P.O. Box 972-60200 – Meru-Kenya.
Tel: +254(0) 799 529 958, +254(0) 799 529 959, +254 (0)712 524 293
Website: www.must.ac.ke Email: info@mucst.ac.ke

UNIVERSITY EXAMINATIONS 2024/2025

FOURTH YEAR, FIRST SEMESTER EXAMINATION FOR THE DEGREE OF BACHELOR OF EDUCATION TECHNOLOGY IN ELECTRICAL AND ELECTRONIC ENGINEERING AND BACHELOR OF TECHNOLOGY IN ELECTRICAL AND ELECTRONIC ENGINEERING

EET 3422: ANTENNA THEORY AND PRACTICE

DATE: JANUARY 2025 **TIME: 2 HOURS**

INSTRUCTIONS: Answer Question ONE and any other TWO questions.

QUESTION ONE (30 MARKS)

(a) Define the following terms as they relate to antennas (5 Marks)

i. Directivity
ii. Beam area
iii. Radiation pattern
iv. Beam efficiency
v. Half-Power Beam width

(b) Explain in detail the concept of radiation mechanisms in antennas and briefly describe three conditions under which radiation can occur in antennas. (4 Marks)

(c) Using a suitable illustration, explain the working of an antenna as a transmitting device and as a receiving device. (3 Marks)

(d) Using suitable illustrations, differentiate between dipole and monopole antennas and list two applications of each. (3 Marks)

(e) A transmitter provides 200 W of power to an antenna system with a transmission line of characteristic impedance Z_0=50 Ω. However, the impedance of the antenna is given by Z_A=40+j30 Ω. The antenna has a radiation resistance of Rr=35 Ω and an ohmic resistance Rl=5 Ω (4 Marks)

i. Calculate the reflection coefficient Γ at the antenna.

ii. Find the power delivered to the antenna PA after accounting for reflection.

iii. Determine the antenna's efficiency, η and calculate the radiated power Prad.

iv. Assume an impedance matching network is used to perfectly match the antenna impedance to Z0. Calculate the new reflection coefficient and power delivered to the antenna.

(f) Explain the practical impact of having a lower F/B Ratio in terms of interference and signal clarity, particularly in a communication system operating in a noisy environment. (2 Marks)

(g) Discuss how the beam width affects the antenna's performance in a communication system, particularly in terms of signal coverage and interference. (2 Marks)

(h) An antenna has a Half-Power Beam Width of 30∘ (2 Mark)

i. Calculate the First Null Beam Width.

ii. If the power radiated in the main lobe is described by the equation $P(\theta)=P0\cos^2(\theta)$, where P0=80 W, determine the angles at which the power first reaches 0.

(i) Your team is considering an antenna array for the emergency communication system, but concerns have been raised about potential drawbacks. Identify and discuss at least two disadvantages of using an antenna array in this scenario. How might these disadvantages affect the installation and maintenance of the system? (3 Marks)

(j) Describe the key functions of a feed network in an antenna array. Explain how each function contributes to the overall performance of the antenna system. (2 Marks)

QUESTION TWO (15 MARKS)

(a) A transmission line with a characteristic impedance of Z_0=50 Ω connects a transmitter to an antenna. However, the system suffers from impedance mismatch

i. If the antenna's impedance is measured as ZL=100Ω and a forward power of 150 W, calculate the reflection coefficient (Γ) at the load, the Voltage Standing Wave Ratio (VSWR) and the reflected power.

ii. To improve system efficiency, a matching network is inserted between the transmission line and the antenna. This network brings the antenna impedance to ZL=50Ω. Calculate the new reflection coefficient and VSWR and determine how much reflected power is now observed. (6 Marks)

(b) An antenna designed for a point-to-point communication system has a forward radiation power of 150 W and a backward radiation power of 5 W. The antenna operates at an efficiency of 85%. (9 Marks)

i. Calculate the F/B Ratio of the antenna in decibels (dB).

(c) If the power radiated in the forward direction is reduced to 130 W while maintaining the same backward power of 5 W, calculate the new F/B Ratio and the antenna gain in the forward direction. How does this reduction in forward power affect the overall antenna performance?

QUESTION THREE (15 MARKS)

(a) A directional antenna radiates a total power of 100 W with 70% of that power concentrated in the main lobe. The maximum radiation intensity U(θ,ϕ) in the main lobe is 30 W/sr.

i. Calculate the beam efficiency ηB of the antenna.

ii. Calculate the directivity D of the antenna.

iii. If the antenna's radiation efficiency η=90%, calculate the antenna gain G in linear terms and in decibels (dB).

iv. Suppose the antenna's main lobe beam area decreases to ΩA=0.5sr, what would the new directivity and antenna gain be? Would this lead to more or less focused radiation?

(b) An antenna's radiation pattern exhibits a maximum power of 100 W at its peak. The power levels at different angles are measured, and it is found that the power drops to 50 W at two angles, which are −25° and +25° from the peak. (9 Marks)

i. Calculate the HPBW in degrees and radians.

ii. Calculate the FNBW in degrees and radians.

iii. If the field pattern at the maximum power is represented as $E(\theta)=E0\cos^2(\theta)$, where E0 is the peak electric field, derive the expression for the angle θ at which the power drops to 50 W. (6 Marks)

QUESTION FOUR (15 MARKS)

a) With the help of a suitable illustration, discuss the antenna field zones. (5 Marks)

b) You are designing a communication system for a remote area requiring reliable connectivity for emergency services. Explain at least three key advantages of using an antenna array over a single high-gain antenna in this context. (3 Marks)

c) Given the electromagnetic wave described by the equations:

$$E = 10sin(4\pi x - 2\pi \times 10^8 t)V/m$$

$$B = 0.0333\sin(4\pi y - 2\pi \times 10^8 t)\,T$$

i. Determine the direction of the EM wave and the angular wave number.

ii. Determine the wavelength of the wave.

iii. Calculate the energy densities of the magnetic and electric fields, and then find the total energy density. (7 Marks)

QUESTION FIVE (15 MARKS)

(a) In an array consisting of identical elements, several parameters can be adjusted to shape the overall radiation pattern of the antenna. Briefly describe four such Control Parameters. (4 Marks)

(b) A parabolic reflector antenna has a diameter of 3 meters and operates at a wavelength of 0.1 meters.

i. Calculate the gain (G) of the antenna if the efficiency factor (η) is 0.65.

ii. Determine the half-power beamwidth (HPBW) of the antenna and explain how changing the diameter of the reflector affects the beamwidth. (3 Marks)

(c) Figure Q5 (c) shows two point sources are separated by a distance d and fed with currents of equal magnitude and phase.

i. Derive the expressions for the path difference and the phase difference between the waves from two point sources.

ii. Show that the total electric field (ET) at a distant point P is given by the expression provided.

$$E_T = 2E_0 cos\left(\frac{kdcos\phi}{2}\right)$$

iii. Calculate the angles at which the maximum and minimum radiation occurs.

iv. Sketch the field pattern for the two point sources. (8 Marks)

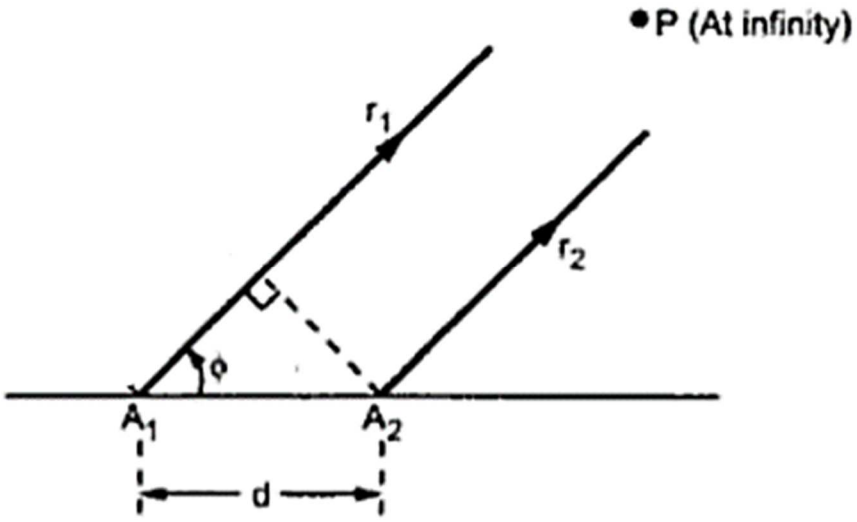

Fig Q5(c)