MACHAKOS UNIVERSITY

University Examinations for 2023/2024 Academic Year

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

FOURTH YEAR FIRST SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (ELECTRICAL AND ELECTRONICS ENGINEERING)

EEE 415: ELECTRODYNAMICS AND INSULATING MATERIALS

DATE: **TIME:**

INSTRUCTIONS

- *This paper consists of **Five** Questions*
- ***Question 1** is **Compulsary**.*
- *Attempt **Any Other Two Questions***

Important Physical Constants

Conductivity of copper $\sigma = 5.8x10^7 S/m$

$\mu_0 = 4\pi x10^{-7} H/m$

$\epsilon_0 = 8.854x10^{-12} F/m$

QUESTION ONE (COMPULSORY) (30 MARKS)

a) Beginning from Ampere's and Faraday's Law, show that (4marks)

i) $\vec{\nabla} x \vec{\mathrm{H}} = \frac{d\vec{\mathrm{D}}}{dt} + \vec{\mathrm{J}}$

ii) $\vec{\nabla} x \vec{\mathrm{E}} = -\frac{d\vec{\mathrm{B}}}{dt}$

All the symbols carry their usual meaning

b) Applying a) above, show that (6marks)

$$\gamma = \alpha + j\beta = [j\omega\mu(\sigma + j\omega\epsilon)]^{1/2}$$

All the symbols carry their usual meaning

c) Given that $\epsilon = \epsilon^{'} - j\epsilon^{''}$, show b) above that (10marks)

$$\alpha = \omega\sqrt{\frac{\mu\epsilon^{'}}{2}}\left[\sqrt{1+\left(\frac{\epsilon^{''}}{\epsilon^{'}}\right)^{2}}-1\right]^{1/2}$$

$$\beta = \omega\sqrt{\frac{\mu\epsilon^{'}}{2}}\left[\sqrt{1+\left(\frac{\epsilon^{''}}{\epsilon^{'}}\right)^{2}}+1\right]^{1/2}$$

All symbols carry their usual meaning

d) A 10-GHz Radar signal may be represented as a uniform plane wave in a sufficiently plane region. Determine the wavelength in cm and the attenuation in nepers per meter if the wave is propagating in a non-magnetic material for which

i) $\epsilon_r^{'} = 1$ and $\epsilon_r^{''} = 0$ (2 marks)

ii) $\epsilon_r^{'} = 1.04$ and $\epsilon_r^{''} = 9.0x10^{-4}$ (4 marks)

iii) $\epsilon_r^{'} = 2.5$ and $\epsilon_r^{''} = 7.2$ (4 marks)

QUESTION TWO (20 MARKS)

a) The Electric Field intensity of a linearly polarized uniform wave propagating in the +z direction in fresh water at the surface $z = 0$ is

$$\vec{E} = \hat{x}0.1\cos(2\pi x 10^6 t)V/m$$

Fresh water has $\epsilon_r = 81$, $\mu_r = 1$ and $\sigma = 4S/m$. Determine the following:

(i) Phase Constant (2 marks)

(ii) Wave length (1 mark)

(iii) Phase Velocity (1 mark)

(iv) Intrinsic Impedance (2 marks)

(v) Expression for $\vec{E}(z,t)$ and $\vec{H}(z,t)$ at as a function of time (4 marks)

b) The propagation in a) above is now is happening in Sea water which has $\sigma = 4S/m$.

(i) Show that Sea water is a good conductor and that radio communication in such a medium is quite impractical (6 marks)

(ii) Determine wave length, phase velocity and propagation constant in such a medium (4 marks)

QUESTION THREE (20 MARKS)

a) Beginning from Gauss Law, show that

$$\nabla . D = \rho$$

All symbols carry their usual meaning (4 marks)

b) Evaluate the divergence of D at the point specified in each of the cases in Table Q3b)

	Table Q 3b)		
Case	D (in various Coordinates)	Point (P)	
(i)	$\frac{1}{z^2}\left[10xyza_x + 5x^2za_y + (2z^3 - 5x^2y)a_z\right]$	(-2,3,5)	(3 marks)
(ii)	$5z^2a_\rho + 10\rho za_z$	$(3, -45°, 5)$	(3 marks)
(iii)	$2r\sin\theta\sin\phi\, a_r + r\cos\theta\sin\phi\, a_\theta + r\cos\phi\, a_\phi$	$(3, 45°, -45°)$	(4 marks)

c) Evaluate both sides of the *Divergence Theorem* for (6 marks)

$$D = 7xya_x + x^2a_y \ c/m^2$$

And the rectangular parallel-piped formed by the planes

$$x = 0 \ and \ x = 2, y = 0 \ and \ y = 2 \ \& z = 0 \ and \ z = 3$$

QUESTION FOUR (20 MARKS)

The phasor magnetic field intensity for a 400-MHz uniform plane wave propagating in a certain lossless material is given by

$$H = \left(2a_y - j5a_z\right)e^{-j25x}A/m$$

Knowing that the maximum amplitude of E is 1500 V/m, Determine the following from *First Principles*

a) Phase Constant (1 mark)

b) Intrinsic Impedance (3 marks)

c) Wavelength (2 marks)

d) Phase Velocity (2 marks)

e) Relative permittivity and relative permeability (8 marks)

f) $H(x, y, z, t)$ (4 marks)

QUESTION FIVE (20 MARKS)

a) A circularly polarized wave at an oblique incidence on a dielectric-dielectric interface is as shown in Figure Q 5a). All symbols carry their usual meaning. Derive the expressions for the *Fresnel's Coefficients* of Reflection and Transmission. All symbols carry their usual meaning (10marks)

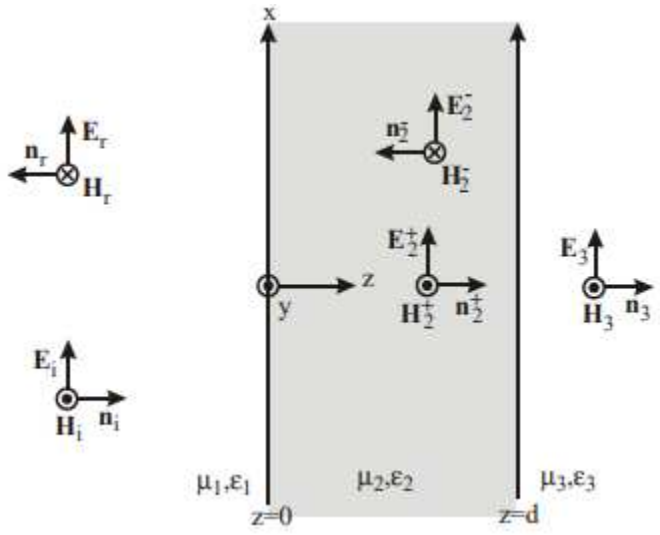

Figure Q 5a)

b) A circularly polarized wave in air is incident at Brewster's Angle onto a semi-infinite slab of plexiglass with $\epsilon_r^{'} = 3.45 \quad \epsilon_r^{''} = 0$ and $\mu = \mu_0$ Determine the following

(i) Brewster Angle and Angle of Refraction (3 marks)

(ii) Reflection and Transmission coefficients (4 marks)

(iii) Fraction of Transmitted Power (3 marks)