MACHAKOS UNIVERSITY

University Examinations for 2018/2019

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

FOURTH YEAR SPECIAL/SUPPLEMENTARY 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 **Compulsory**. Attempt **Any Other Two Questions***

<u>Important Physical Constants</u>

$\mu_0 = 4\pi x 10^{-7} H/m$

$\epsilon_0 = 8.854 x 10^{-12} F/m$

QUESTION ONE (COMPULSORY) (30 MARKS)

a) A harmonic time-dependent vector potential field $\vec{F}$ is defined in a charge-free, current-free region of space filled with homogeneous dielectric medium such that

$$\vec{E} = -\frac{1}{\epsilon}\vec{\nabla} x \vec{F}$$

$$(\nabla^2 + \omega^2 \mu\epsilon)\vec{F} = 0$$

Obtain the expressions of the fields of a Transverse Electric wave (TE) from the axial componentF_z, giving the boundary conditions $\vec{F}$ must satisfy (*Hint: Assume $\vec{F}$ is an axial vector field*) (10 marks)

b) A plane wave is propagating in a lossy media. Beginning from the Maxwell's Equations, show that the complex power (P_s)delivered by the source $\vec{J_s}$ consists of the averages of the complex pointing vector , the conduction losses, dielectric losses and the net reactive energy stored in the fields (10 marks)

c) The current through a gap filled with a gaseous insulating medium can be expressed by

$$I = \frac{I_0 exp\ (\alpha_0 d)}{\{1 - \alpha_s(exp\ (\alpha_0 d) - 1)\}}$$

All the symbols carry their usual meaning

(i) Derive the *Panchen's Law* using *Townsend Breakdown Criterion* (5 marks)

(ii) Given $\alpha_0 d = K$ as the general form of Townsend Criterion, and that

$$\frac{\alpha_0}{p} = A \exp\left(-\frac{Bp}{E}\right)$$

Show that the point of minimum potential V_B can be given by

$$V_B = \left(\frac{E}{p}\right) pd + \sqrt{\frac{K}{C}}\sqrt{pd}$$

A,B,C and E are empirical constants while K defines the relationship between the Townsends and the Panchen's Law (5 marks)

QUESTION TWO (20 MARKS)

a) Beginning from the Maxwell's Equations, show that (3marks)

Show that

$$\nabla^2 E - \gamma^2 E = 0$$

Where

$$\gamma = \alpha + j\beta = j\omega\sqrt{\mu\epsilon}\left[1 + \frac{\sigma}{j\omega\epsilon}\right]^{1/2}$$

All the symbols carry their usual meaning

b) Given that $\epsilon = \epsilon' - j\epsilon''$, show that the propagation and phase properties in Question 2a) above are only dependent on the permittivity and permeability of the medium at a particular frequency (7 marks)

c) A narrow-band signal propagates in a lossy dielectric medium with a loss tangent of 0.2 and 550 kHz is the carrier frequency of the signal. If the dielectric constant of the medium is 2.5, determine the Propagation Constant and its respective components from first principles (10 marks)

QUESTION THREE (20 MARKS)

a) State the three most common structures for guiding the TEM waves (1.5 marks)

b) State any six *Practical Examples of Planar* Transmission Lines (3 marks)

c) Beginning from the modified Curl Maxwell Equations, demonstrate the analogy between wave characteristics on a infinitely long transmission line and uniform plane waves in a *lossy* and unbounded medium. (7 marks)

d) Explain the modifications in 5a) above in case of a *distortionless* line (2.5 marks)

e) The attenuation on a 50Ω distortionless line is $0.01 dB/m$. The line has a capacitance of $0.1 nF/m$. Determine the following

(i) The resistance, inductance and conductance per unit length of the line (3 marks)

(ii) The velocity of the wave propagation and the velocity factor (1.5 marks)

(iii) The percentage to which the amplitude of a voltage travelling wave decreases in 1km and 5km (1.5 marks)

QUESTION FOUR (20 MARKS)

a) For a source –free polarized medium, the Electric Hertzian Potential $\vec{\Pi}_e$ can be defined such that the magnetic field intensity $\vec{H}$ is given by

$$\vec{H} = j\omega\epsilon_0 \vec{\nabla} x \vec{\Pi}_e$$

If $\vec{P}$ is the volume density of polarization in the medium, express the Electric Field Intensity $\vec{E}$ in terms of $\vec{\Pi}_e$ and $\vec{P}$ (4 marks)

b) Show that $\vec{\Pi}_e$ satisfies the Inhomogeneous Helmholtz Equation (7 marks)

$$\nabla^2 \vec{\Pi}_e + k^2 \vec{\Pi}_e = -\frac{\vec{P}}{\epsilon_0}$$

Where $k = \omega\sqrt{\mu_0\epsilon_0}$ and all the other symbols carry their usual meaning.

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

$$\vec{E} = \hat{x}100\cos(\pi x 10^7)V/m$$

Sea water has $\epsilon_r = 72$, $\mu_r = 1$ and $\sigma = 4S/m$.

Determine the expression for $\vec{E}(z,t)$ and $\vec{H}(z,t)$ at $z = 0.8m$ as a function of time (9 marks)

QUESTION 5

a) A parallel polarized wave at an oblique incidence on a dielectric interface is as shown in Figure Q 5a). Derive the expressions for the *Brewster and Transmission Angles*. All symbols carry their usual meaning (7marks)

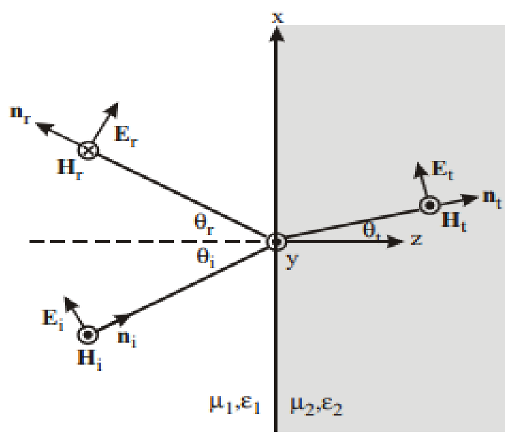

Figure Q 5a)

b) The same wave in Question 5a) is perpendicularly polarized. Derive the expressions for the Fresnel's Coefficients of Reflection and Transmission. All symbols carry their usual meaning (7marks)

c) The dielectric constant of pure water is 80. Determine the following

(i) Brewster Angle and Angle of Transmission for Question 5a) above (3marks)

(ii) Reflection and Transmission coefficients at $\theta_i = \theta_{Bp}$ (3 marks)