Paper 1

TECHNICAL UNIVERSITY OF MOMBASA

School of Engineering and Technology

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

UNIVERSITY EXAMINATION FOR:

BACHELOR OF TECHNOLOGY IN ELECTRICAL AND ELECTRONIC ENGINEERING

TEE 4209 ELECTROMAGNETIC FIELDS AND WAVES

END OF SEMESTER EXAMINATION

SERIES: AUGUST 2024

TIME: 2 HOURS

DATE: August 2024

Instructions to Candidates

You should have the following for this examination

Answer Booklet, examination pass and student ID

This paper consists of **FIVE** questions. Attempt **Question ONE and ANY other TWO questions.**

Do not write on the question paper.

Question ONE

(a) In free space $\overline{D} = D_m \sin(\omega t + \beta z)\hat{a}_x$

Using Faraday's law show that $B = \frac{-\omega \mu_0 D_m}{\beta} \sin(\omega t + \beta z)\hat{a}_y$

(10 marks)

(b) Using appropriate sketches show that the energy contained in an electric field is given by $\frac{1}{2}\varepsilon_0 \frac{\partial |\overline{E}|^2}{\partial t}$ Motivate all steps taken indicating assumptions made. (10 marks)

(c) Using appropriate sketches describe the operation of a capacitor. (5 marks)

(d) A $100\,\mu C$ point charge is located at $(1,2,0)m$ and another point charge of $50\,\mu C$ is located at $(5,2,0)m$. Determine the vector force on the first charge.

(5 marks)

Question TWO

(a) State mathematically and explain the practical significance of the following set of Maxwell's equations:

(i) Faraday's law in point form (ii) Ampere's law in integral form

(iii) Gauss' electric law in point form (iv) Gauss' magnetic law in integral form (8 marks)

(b) If $\overline{A}=(3,2,1)$; $\overline{B}=(3,4,5)$ Find (i) $\overline{A}\,X\,\overline{B}$(ii) The angle between $\overline{A}$ and $\overline{B}$ (6 marks)

(c) A plane electromagnetic wave having a frequency of $500\,MHz$ has an average Poynting vector of $1\,W/m^2$. If the medium is lossless with $\varepsilon_r=3$ and $\mu_r=2$ determine:

(i) The velocity of propagation (ii) Wavelength (iii) Impedance of the medium

(iv) rms value of the electric field (6 marks)

Question THREE

(a) Determine for the following applications, the conditions for which lumped-circuit models are valid:

(i) Satellite systems ($12\,GHz$) (ii) Radar systems ($20\,GHz$) (6 marks)

(b) With reference to Fig. Qu.3(b) and given that medium 1 is air and medium 2 ($\mu_{r2}=1\,;\varepsilon_{r2}=3.6$), determine the time domain expressions for ALL the fields in these two media if the transmitted electric field is given by

(14 marks)

$$E^i=10\cos\left(wt-\left(\frac{8\pi}{3}\right)z\right)a_x$$

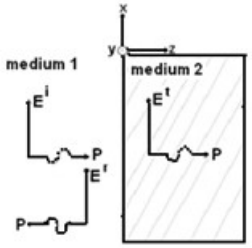

Fig. Qu.3(b)

Question FOUR

(a) Determine the voltage V in the circuit of Fig. Qu.4(a). Show all your workings clearly and motivating all the steps taken. (14 marks)

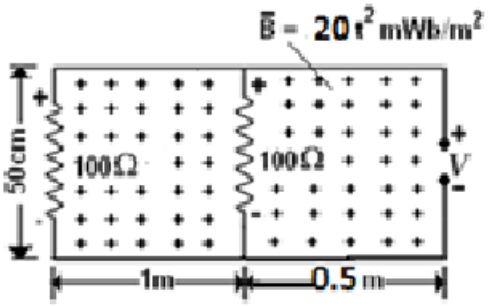

Fig. Qu.4(a)

(b) Assuming that sea water has a conductivity of $20\,S/m$ and $\varepsilon_r = 81$ determine the frequency at which the conduction current is equal to the displacement current. (6 marks)

Question FIVE

Given the Maxwell's equations $\nabla X \hat{E} = -jw\mu\hat{H}$ and $\nabla X \hat{H} = jw\varepsilon_0\hat{E}$

Motivating all your steps prove that $\hat{E}_x = E_m^{+¿} e^{-j\beta z} + E_m^{-¿} e^{+j\beta z} ¿$

$$\hat{H}_y = \frac{E_m^{+¿}}{\eta} e^{-j\beta z} - \frac{E_m^{-¿}}{\eta} e^{+j\beta z} ¿¿$$

(20 marks)