INTERNATIONAL UNIVERSITY OF EAST AFRICA
'Learning to Succeed'

FACULTY OF ENGINEERING

END OF SEMESTER EXAMINATIONS - APRIL 2025

PROGRAMME: BACHELOR OF ELECTRICAL AND CONTROL ENGINEERING

YEAR/SEM: YEAR 2/SEMESTER 2

COURSE CODE: ELE2233

NAME: ELECTRICAL AND MAGNETIC FIELDS II

DATE: 2025-04-16

TIME: 9:00AM-12:00PM

<u>INSTRUCTIONS TO CANDIDATES:</u>

1. Read the instructions very carefully
2. The time allowed for this examination is STRICTLY three hours
3. Read each question carefully before you attempt and allocate your time equally between all the Sections
4. Write clearly and legibly. Illegible handwriting cannot be marked
5. Number the questions you have attempted
6. Use of appropriate workplace examples to illustrate your answers will earn you bonus marks
7. Any examination malpractice detected will lead to automatic disqualification.

DO NOT WRITE ANYTHING ON THE QUESTION PAPER

Section A Answer ANY THREE (3) questions in this section.

Question 1:

a) Starting from the expression of the propagation constant, $\gamma = \sqrt{(R + jwL)(G + jwC)}$

Derive expressions for the attenuation constant (α), the phase constant (β) and characteristic impedance (Z_C) for a lossless line. **(5 Marks)**

b) A distortionless line operating at 240 MHz has $Z_o = 80\ \Omega$, $\propto = 0.04\ Np/m$, $\beta = 1.5\ rad/m$. Find the line parameters L, R, G and C. **(6 Marks)**

c) Explain how matching is achieved using a quarter-wave transformer. State the main limitation of the quarter-wave transformer and mention how it can be overcome. **(6 Marks)**

d) Design a quarter-wave transformer to match a 10 Ω load to a 75 Ω system. Assume a design frequency of 200 MHz. **(3 Marks)**

Question 2:

a) Explain clearly the difference between a finite and an infinite transmission line. Hence, distinguish between distributed and lumped parameters. Why are the line parameters called distributed elements? **(5 Marks)**

b) Show that the wave equation for the voltage on the two wire transmission line can be expressed as shown below. Hence or otherwise, derive the expression for the characteristic impendence of the line and give its significance with respect to wave propagation. **(6 Marks)**

$$\frac{\partial^2 V}{\partial z^2} - \gamma^2 V = 0$$ Where γ is the propagation constant.

c) Channel capacity and interference minimization are some of the most critical areas of focus while designing any transmission link. However, without ensuring perfect impedance matching between different components, the performance of the entire system is severely compromised due to multiple reflections and standing waves. With reference to the above statement and limiting the scope to the transmission line- load system;

(i) Briefly discuss the concept of standing waves highlighting how they arise and suggest ways of minimizing them **(4 Marks)**

(ii) State two causes of reflections on a typical transmission line. **(2 Marks)**

(iii)Justify the necessity of impedance matching **(3 Marks)**

Question 3:

a) Discuss why waveguides are preferable to transmission lines when operating at microwave frequencies. Discuss any two modes of wave propagation in waveguide structures. **(6 Marks)**

b) Define Cutoff frequency and hence starting from the general expression of the propagation constant for rectangular waveguide, derive the expression for the cutoff frequency f_c of the waveguide. **(6 Marks)**

c) An air-filled 5-by 2-cm waveguide has $E_z = 12\sin(40\pi x)\sin(50\pi y)e^{-j\beta z}$ V/m at 21 GHz.

Compute

(i) The phase constant β **(5 Marks)**

(ii) The intrinsic impedance η **(3 Marks)**

Question 4:

a) What is the significance of the VSWR on a transmission line? Hence, why are standing waves undesirable in a transmission line? **(4 Marks)**

b) What is a **wave** and why are waves important in daily life? Briefly explain the assertion that a wave typically consists of a progressive and retrogressive component. **(1+2+2 Marks)**

c) The electric field in free space is given by; **(6 Marks)**

$$E = 12\cos(2\text{x}10^6 t - \beta x)\ a_y\ V/m$$

Calculate the wavelength (λ), phase constant (β) and the time it takes to travel a distance $\lambda/6$

d) In a lossless medium for which $\eta = 90\pi$, $\mu_r = 1$, and $H = -0.2\cos(wt - z)\ \mathbf{a_x} + 0.5\sin(wt - z)\ \mathbf{a_y}$ A/m. Calculate ε_r and w **(5 Marks)**

Section B Answer ANY TWO (2) questions in this section.

Question 1:

a) Show that for a transmission line characterized with no distortion, the phase constant β and characteristic impedance Zc are given as below; **(6 Marks)**

$$\beta = \alpha(\frac{\omega C}{G}) \qquad Z_C = \sqrt{\frac{R}{G}}$$

Where α is the attenuation constant of the line, C, G and R are distributed Capacitance, Conductance and Resistance of the line respectively.

b) A lossless transmission line is 60cm long and operates at 600 MHz. The line parameters are L= 0.25 μH/m and C=100pF/m. Find the characteristic impedance, the phase constant, the velocity on the line, and the input impedance for Z_L=100 Ω. **(6 Marks)**

c) With the aid of illustrations, briefly describe the principle of matching transmission lines using stub tuners. Discuss any two (2) advantages and disadvantages of single stub tuners in impedance matching, and hence how can these disadvantages be rectified? **(8 Marks)**

Question 2:

a) Basing on the knowledge you've acquired, differentiate between an Ideal and Practical model as used in transmission lines. **(4 Marks)**

b) Briefly explain any two key differences between waveguides and transmission lines. **(4 Marks)**

c) An air-filled rectangular waveguide having the dimensions a = 2.5 cm and b = 1.25 cm carries the dominant TE_{21} mode at 100 GHz. Find for this mode the:

(i) The cutoff frequency **(3 Marks)**

(ii) Guide wavelength **(3 Marks)**

(iii) Phase constant β **(3 Marks)**

(iv) Intrinsic wave impedance η **(3 Marks)**

Question 3:

a) With reference to transmission media, distinguish between guided and unguided media. Hence state any two advantages and disadvantages of unguided media. **(6 Marks)**

b) Uganda Broadcasting Television (**UBC**) wants to setup a transmission link between the headquarters in Kampala and their transmission center in Kololo. Basing on the knowledge you've acquired, discuss any two parameters that should be considered when selecting any transmission media. **(4 Marks)**

c) An air-filled rectangular waveguide has inner dimensions of 4 cm x 2 cm. Find the intrinsic wave impedance of the TE_{10} mode of operation in the waveguide at a frequency of 30 GHz. **(5 Marks)**

d) Explain what you understand by the term "**skin depth**" in the context of an electromagnetic wave incident on a good conductor, hence describe the relationship between the penetration of a wave and the conductivity of the material. How can skin effect be reduced in transmission lines? **(5 Marks)**

Question 4:

a) A transmission line has characteristic impedance Z_0 and is terminated with load of impedance Z_L. By expressing load impedance in terms of the forward and reflected travelling waves, show that the reflection coefficient is given by; $\Gamma_L = \frac{Z_L - Z_0}{Z_L + Z_0}$ **(5 Marks)**

b) Briefly discuss what is meant by a steady magnetic field. **(3 Marks)**

c) Stating any valid assumptions made, show that the magnetic field intensity H at the point P due to a filamentary conductor shown in **figure 1** below given as: **(6 Marks)**

$$H = \frac{I}{4\pi\rho}(\cos\alpha_2 - \cos\alpha_1)a_\phi$$

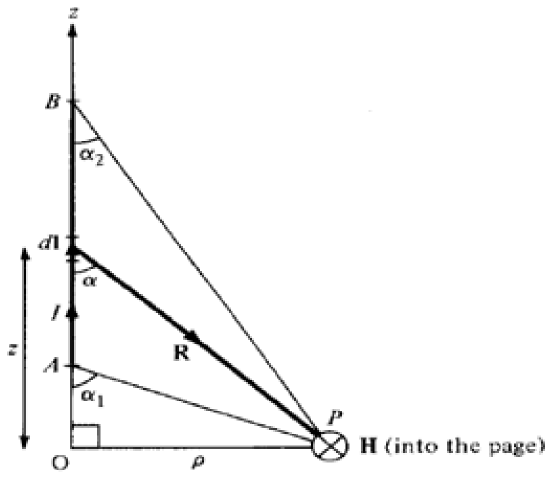

Figure 1

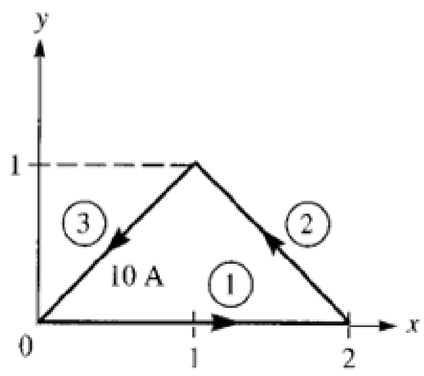

Figure 2

d) A current filament carrying 2.5 A is arranged into a triangular loop in the xy plane as shown in **figure 2**. Determine H at the point P(0,0,5) due to side 1 of the loop. **(6 Marks)**