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The Open University of Sri Lanka
Faculty of Engineering Technology
Department of Electrical and Computer Engineering

Study Programme	: Bachelor of Technology Honours in Engineering
Name of the Examination	: Final Examination
Course Code and Title	**: EEX7333 Microwave Devices and Antennas**
Academic Year	: 2021/2022
Date	: 07th Tuesday, March 2023
Time	: 0930 - 1230 hrs
Duration	: **3 hours**

General Instructions

1. Read all the instructions carefully before answering the questions.
2. This is a Closed Book Test (CBT).
3. This question paper consists of **Eight (08)** questions in **Four (04)** pages.
4. Answer **only Five (05) questions.**
5. All questions carry equal marks.
6. The answer for each question should commence from a new page.
7. Answers should be in clear handwriting.
8. Do not use Red color pen.
9. All the notations have their usual meaning.
10. Assume any missing parameters with suitable values.

Q1.

(a) Write the Maxwell's equations in differential form. [4 Marks]

(b) Modify the equations written in part (a) when the medium of propagation is source-free. [3 Marks]

(c) Using the vector identity $\nabla \times (\nabla \times A) = \nabla(\nabla \cdot A) - \nabla^2 A$, derive wave equation $\nabla^2 E = -\frac{1}{C^2}\frac{\partial^2 E}{\partial t^2}$ for the electric field of propagating wave in a source-free medium, where C is a constant. [8 Marks]

(d) If the permeability and permittivity of free space are $\mu_0 = 4\pi \times 10^{-7}$ H/m and $\varepsilon_0 = 8.854 \times 10^{-12}$ F/m respectively, find the value of C. Hence, determine the speed of electromagnetic wave propagation in free space. [5 Marks]

Q2. Using the Maxwell's equations, the time and space derivatives of electric field E can be related by

$$\nabla^2 \boldsymbol{E} = \mu\left(\sigma\frac{\partial E}{\partial t} + \varepsilon\frac{\partial^2 E}{\partial t^2}\right).$$

(a) Define the parameters μ, σ and ε. [3 Marks]

(b) If the electric field variation is sinusoidal $\left(\boldsymbol{E} = \boldsymbol{E}_0 e^{j\omega t}\right)$, show that the equation given in part (a) reduces to the standard form $\nabla^2 \boldsymbol{E} = \gamma^2 \boldsymbol{E}$. Determine the value of γ. [6 Marks]

(c) Assume that the medium of propagation is a perfect dielectric.

i. Determine the value of γ. [3 Marks]

ii. Show that the wave propagates without having any attenuation. [4 Marks]

Assume sinusoidal variation for field components.

(d) If the wave propagates in free space, simplify equations obtained in part (c). [4 Marks]

Q3.

(a) What should the conditions be satisfied for an E-field at a metallic boundary? [3 Marks]

(b) A rectangular waveguide with a cross section of $a \times b$ ($< a$) lies on z-axis such that one corner is on origin and other is on xy-plane. For TM waves, electric field component along the propagation direction of waveguide, $\boldsymbol{E}_z$ is given by $A\sin(k_x x)\sin(k_y y)$, where A is a constant. Applying boundary conditions for the E-field mentioned in part (a), show that $k_x = \frac{m\pi}{a}$ and $k_y = \frac{n\pi}{b}$, where m and n are integers. [6 Marks]

(c) Cut-off wave number of a waveguide is given by $k_c = \sqrt{k_x^2 + k_y^2}$. An air-filled rectangular waveguide operates at 6 GHz frequency in TM_{11} mode. The internal dimensions of the waveguide are 7.6 cm and 3.8 cm. Determine the following.

i. Cut-off wave number [3 Marks]

ii. Cut-off frequency [4 Marks]

iii. Guided wavelength [4 Marks]

Q4.

(a) Draw an E-plane tee and an H-plane tee. [3 Marks]

(b) Indicate the directions of E-field and the H-field at the port 1 of each tee mentioned in part (a). [3 Marks]

(c) A Signal is fed to the side arm (port 3) of the E-plane tee.

i. Mark the direction of field at port 2 and port 3. [1 Marks]

ii. Write the scattering matrix (S matrix) for E-plane tee by using minimum number of parameters. Assume that the medium inside the tee is isotropic. [3 Marks]

iii. In the S matrix given in part ii), some elements of the matrix are duplicated, and some have negative values. Give reasons for this. [4 Marks]

iv. Modify the S matrix given in part(ii) when the ports 1 and 2 are matched. [6 Marks]

Q5.

(a) What are the three major losses associated with waveguides? [6 Marks]

(b) Briefly explain two methods used to minimize the losses mentioned in part (a). [4 Marks]

(c) Describe the principle of operation in a directional coupler. [5 Marks]

(d) The insertion loss of a directional coupler is 0 dB. What is the amount of power coupled to the auxiliary arm of the directional coupler? Determine the coupling factor. [5 Marks]

Q6.

(a) Explain the mechanism of radiation of an antenna with a single wire. [6 Marks]

(b) Draw the three-dimensional radiation pattern of an infinitesimal dipole. [4 Marks]

(c) A hypothetical isotropic antenna is radiating in free space. At a distance of 200 m from the antenna, the total electric field E_θ is measured to be 2.5 $^{V}/_{m}$. Determine the following.

i. Power density of the antenna, W_{rad} [5 Marks]

ii. Total radiated power by the antenna, P_{rad} [5 Marks]

Q7.

(a) A horizontal infinitesimal electric dipole having a constant current I_0, is placed symmetrically about the origin and directed along the x-axis. Derive the equations for

i. far-zone fields radiated by the dipole, and [6 Marks]

ii. directivity of the antenna. [6 Marks]

(b) Determine the directivity of an antenna having a normalized radiation intensity.

$$U(\theta,\phi) = \begin{cases} \sin\theta & 0 \le \theta \le \frac{\pi}{2}, 0 \le \phi \le 2\pi \\ 0 & \text{otherwise} \end{cases}$$

[8 Marks]

Q8.

(a) "A widely used type of microwave antennas is the circular aperture." Justify this statement. [5 Marks]

(b) Discuss the salient features of a horn antenna. [5 Marks]

(c) Briefly explain the merits of a parabolic reflector antenna. [5 Marks]

(d) What is the need of an antenna array? [5 Marks]

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