GLASGOW COLLEGE UESTC

Exam paper

Electromagnetic Field and Microwave Technology (4002)

Date: 29th June 2021
Time: 14:30-16:30

Attempt all PARTS. Total 100 marks

Use one answer sheet for each of the questions in this exam.
Show all work on the answer sheet.

Make sure that your University of Glasgow and UESTC Student Identification Numbers are on all answer sheets.

An electronic calculator may be used provided that it does not allow text storage or display, or graphical display.

All graphs should be clearly labelled and sufficiently large so that all elements are easy to read.

The numbers in square brackets in the right-hand margin indicate the marks allotted to the part of the question against which the mark is shown. These marks are for guidance only.

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Q1 (a) Differentiate the conducting current and displacement current in terms of power dissipation and physical mechanisms behind them. [4]

(b) State what is the magnetization vector $\vec{M}$; describe the relationship among vectors $\vec{M}$, $\vec{B}$ and $\vec{H}$; how to find the volume magnetized current density and surface magnetized current density by magnetization vector $\vec{M}$. [6]

(c) The interface for two media is xoz plane. The magnetic fields on the interface are $\vec{H}_1 = 5\vec{e}_x + 6\vec{e}_y + 2\vec{e}_z (y = 0_+)$ and $\vec{H}_2 = -5\vec{e}_x + 3\vec{e}_y + 2\vec{e}_z (y = 0_-)$. What is the surface current density $\vec{J}_s$ on the interface. [6]

(d) Illustrate the type of the polarization for the following uniform plane wave, $\vec{E} = \vec{e}_x E_m \sin(\omega t - kz - \frac{\pi}{4}) + \vec{e}_y E_m \cos(\omega t - kz - \frac{\pi}{4})$. [6]

Q2 Annular conductive medium with thickness of h and two radii of r_1 and r_2, has angle of ϕ_0, as shown in ***Figure Q2*** The conductivity of the conductive medium is σ. The two electrodes have electric potential of $\varphi\big|_{\phi=0} = U_0$, $\varphi\big|_{\phi=\phi_0} = 0$.

(a) Find the distribution of electric potential inside the conductive medium. [6]

(b) Find the current density and total current inside the conductive medium. [8]

(c) Find the resistance between the two electrodes along the ϕ direction. [6]

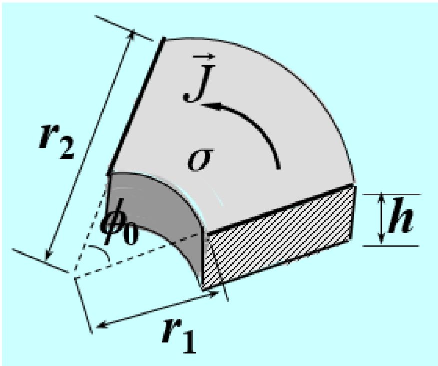

Figure Q2.

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Q3 In time-varying field, the electric field and magnetic field can be induced by each other. The phasor expression of the electric field intensity for plane wave in air is $\vec{E}(\vec{r}) = \vec{e}_z 20e^{j\pi(3x+4y)}$ V/m.

(a) Find the wave vector $\vec{k}$ and propagation direction $\vec{e}_n$ of the plane wave. [8]

(b) Find the wavelength and frequency of the plane wave. [6]

(c) Find the phasor expression for the magnetic field intensity. [6]

(d) Find the average Poynting vector. [8]

Q4 The equal phase surface of a uniform plane wave is a plane, and also the amplitude of a uniform plane wave on the equal phase surface is a constant. A uniform plane wave with frequency of 100MHz is normally incident from media 1 (z < 0, $\varepsilon_{r1} = 4, \mu_{r1} = 1, \sigma_1 = 0$) to media 2 (z > 0, $\varepsilon_{r2} = 9, \mu_{r2} = 4, \sigma_2 = 0$), as shown in ***Figure Q4***. The incident wave is a right-hand circular polarized wave with amplitude of electric field intensity E_{m1}=20V/m.

(a) Find the electric field and magnetic field for incident wave. [10]

(b) Find the electric field and magnetic field for reflected wave and the polarization of the reflected wave. [10]

(c) Find the electric field and magnetic field for transmitted wave. [10]

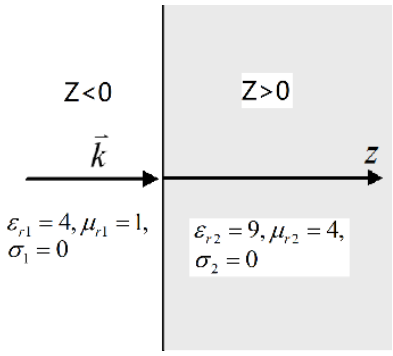

Figure Q4.

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Appendix

Cylindrical coordinate system

$$\nabla \cdot \boldsymbol{A} = \frac{1}{\rho}\frac{\partial}{\partial \rho}(\rho A_\rho) + \frac{1}{\rho}\frac{\partial A_\phi}{\partial \phi} + \frac{\partial A_z}{\partial z}$$

$$\nabla \times \boldsymbol{A} = \frac{1}{\rho}\begin{vmatrix} \boldsymbol{e}_\rho & \rho \boldsymbol{e}_\phi & \boldsymbol{e}_z \\ \frac{\partial}{\partial \rho} & \frac{\partial}{\partial \phi} & \frac{\partial}{\partial z} \\ A_\rho & \rho A_\phi & A_z \end{vmatrix}$$

$$\nabla^2 u = \frac{1}{\rho}\frac{\partial}{\partial \rho}(\rho \frac{\partial u}{\partial \rho}) + \frac{1}{\rho^2}\frac{\partial^2 u}{\partial \phi^2} + \frac{\partial^2 u}{\partial z^2}$$

Spherical coordinate system

$$\nabla \cdot \boldsymbol{A} = \frac{1}{r^2}\frac{\partial}{\partial r}(r^2 A_r) + \frac{1}{r\sin\theta}\frac{\partial}{\partial \theta}(\sin\theta A_\theta) + \frac{1}{r\sin\theta}\frac{\partial A_\phi}{\partial \phi}$$

$$\nabla \times \boldsymbol{A} = \frac{1}{r^2 \sin\theta}\begin{vmatrix} \boldsymbol{e}_r & r\boldsymbol{e}_\theta & r\sin\theta \boldsymbol{e}_\phi \\ \frac{\partial}{\partial r} & \frac{\partial}{\partial \theta} & \frac{\partial}{\partial \phi} \\ A_r & rA_\theta & r\sin\theta A_\phi \end{vmatrix}$$

$$\nabla^2 u = \frac{1}{r^2}\frac{\partial}{\partial r}(r^2 \frac{\partial u}{\partial r}) + \frac{1}{r^2 \sin\theta}\frac{\partial}{\partial \theta}(\sin\theta \frac{\partial u}{\partial \theta}) + \frac{1}{r^2 \sin^2\theta}\frac{\partial^2 u}{\partial \phi^2}$$

End of question paper