UNIVERSITY OF BOLTON

WESTERN INTERNATIONAL COLLEGE FZE

BENG (HONS) ELECTRICAL AND ELECTRONIC ENGINEERING

SEMESTER ONE EXAMINATION 2018/2019

ENGINEERING ELECTROMAGNETISM

MODULE NO: EEE6012

Date: Wednesday 9th January 2019 **Time: 10:00am - 12:30pm**

INSTRUCTIONS TO CANDIDATES:

There are 5 questions.

Answer any 4 questions.

All questions carry equal marks.

Marks for parts of questions are shown in brackets.

Western International College FZE
BEng (Hons) Electrical & Electronic Engineering
Semester 1 Examination 2018/19
ENGINEERING ELECTROMAGNETISM
Module No. EEE6012

Q1

(a) Magnetic field vector B is expressed in spherical co-ordinates as:

$B = 10/r\ a_r + r\cos\theta\ a_\theta + a_\phi$ Wb/m^2

Express the vector in cylindrical co-ordinates to determine B (5, □/2, -2).

(8 marks)

(b) *Figure 1* shows conductors with di-electric interface half way between. Analyse the voltage drop across each dielectric in given figure, where $\varepsilon_{r1} = 2.0$ and $\varepsilon_{r2} = 5.0$. The inner conductor is at $r_1 = 0.02$ m and the outer at $r_2 = 0.025$ m with dielectric interface half way between. (7 marks)

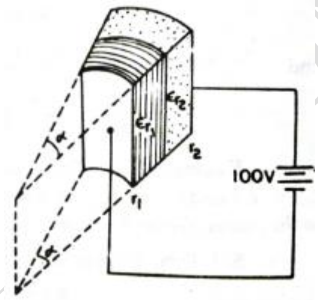

Figure 1

(c) Two extensive homogenous isotropic dielectrics meet on a plane z=0. For z>0, $\varepsilon_{r1} = 4.0$ and for z<0, $\varepsilon_{r2} = 3.0$. A uniform electric field E_1 exists for z>=0, where $E_1 = 5a_x - 2a_y + 3a_z$ KV/m. Determine:

(i) E_2 for z<=0. (4 marks)

(ii) The angles E_1 and E_2 make with the interface. (2 marks)

(iii) The energy densities (in J/m^3) in both dielectrics. (2 marks)

(iv) The energy within a cube of side 2m centred at (3,4,-5). (2 marks)

Total 25 marks

Please turn the page

Q2

(a) A circular loop located on $x^2 + y^2 = 9$, $z = 0$ carries a direct current of 10 A along a_ϕ. Determine magnetic field intensity H at (0, 0, 4) and (0, 0,-4).

(8 marks)

(b) Determine the self-inductance of a coaxial cable of length 'ℓ' with inner radius 'a' and outer radius 'b' when inner conductor is a solid. (10 marks)

(c) Given magnetic field intensity $H_1 = (-2a_x + 6a_y + 4a_z)$ A/m in region y-x-2 <= 0, where $\mu_1 = 5\mu_0$. Calculate:

(i) Magnetization M_1 and magnetic field B_1. (2 marks)

Magnetic field intensity H_2 and magnetic field B_2 in region y-x-2 >= 0, where $\mu_2 = 2\mu_0$. (5 marks)

Total 25 marks

Q3

(a) The electric field (E) and magnetic field (H) in free space are given by the following expressions:

$$E = \frac{50}{\rho} cos(10^6 t + \beta z) a_\phi V/m \qquad H = \frac{H_0}{\rho} cos(10^6 t + \beta z) a_\rho A/m$$

By expressing them in phasor form, determine and analyse:

i) Value of constant β such that the fields satsify Maxwell's equations.

(8 marks)

ii) Value of constant H_0 in the given field H to satisfy Maxwell's equations.

(7 marks)

Q3 continued over the page

Please turn the page

Q3 continued

(b) Electric flux density **D** for a cylindrical coordinate system is shown.

$$\vec{D} = (20r + \frac{r^2}{3})\vec{a_r} \;\; for\ r < 2\ and\ \vec{D} = (\frac{5r}{138})\vec{a_r}\ for\ r > 2$$

Evaluate charge density in both regions r<2 and r>2. (5 marks)

(c) For a homogenous medium where relative permeability $\mu_r = 1$ and relative permittivity $\varepsilon_r = 50$, it is given that Electric field E = 20 □ $e^{j(\omega t - \beta z)} a_x$ V/m and magnetic field $B = \mu_0 H_0 e^{j(\omega t - \beta z)} a_y$ Wb/m^2. Calculate angular frequency ω and constant H_0 if wavelength is 1.78 m. (5 marks)

Total 25 marks

Q4

(a) In a nonmagnetic medium E = 4 sin(2□ x 10^7t – 0.8*x*)a_z V/m. Find:

(i) Relative permittivity (ε_r) and Intrinsic impedance (η) and time average power carried by the wave. (6 marks)

(ii) Total power crossing 0.01 m^2 of plane 2x + y = 5. (2 marks)

(b) A certain transmission line 2 m long operating at $\omega = 10^6$ rad/s has α = 8 dB/m, β = 1 rad/m, and Z_0 = 60 + j40 Ω. If the line is connected to a source of 10 < 0^0 V, Z_g = 40 Ω and terminated by a load of 20 + j50 Ω. Determine:

(i) The input impedance. (4 marks)

(ii) The sending-end current. (2 marks)

(iii) The current at the middle of the line. (5 marks)

Q4 continued over the page

Please turn the page

Q4 continued

(c) The Electric field associated with a plane wave travelling in a perfect dielectric medium having $\mu = \mu_0$ is given by

$$E = 10 \text{ Cos } (6\square \; x \; 10^7 t - 0.4\square z) \text{ i V/m}$$

Evaluate phase velocity, permittivity of the medium and associated magnetic field H assuming velocity in free space is $3 \; x \; 10^8$ m/s. (6 marks)

Total 25 marks

Q5.

(a) Assume that a rectangular waveguide is operating in an isotropic, homogeneous dielectric with negligible magnetic properties in-- TM_{13} mode for which a=0.015 m, b= 0.008 m, $\sigma = 0$, $\mu = \mu_0$ and $\varepsilon = 4\varepsilon_0$, $H_x = 2 \text{ Sin}(\pi x/a) \text{ Cos}(3\pi y/b) \text{ Sin}(10^{11}\pi t - \beta z)$ A/m. Determine:

(i) Cut off frequency and phase constant, β. (5 marks)

(ii) Propagation constant γ and intrinsic wave impedance η. (3 marks)

(b) A copper plate waveguide ($\sigma_c = 5.8\text{x}10^7$ S/m) operating at 4.8 GHz is supposed to deliver a minimum power of 1.2 kW to an antenna. If the guide is filled with polystyrene ($\sigma = 10^{-17}$ S/m, $\varepsilon = 2.55\,\varepsilon_0$) and its dimensions are a = 0.042 m, b = 0.026 m, Analyse:

(i) Attenuation constants α_d and R_s termed as real part of intrinsic impedance. (8 marks)

(ii) Attenuation constant α_c and Power dissipated in a length 60 cm of the guide in TE_{10} mode.

(3 marks)

Q5 continued over the page

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Q5 continued

(c) A fibre serves as an optical link between two cities. The step index fibre has a core diameter of 80 μm, a core refractive index of 1.62 and a numerical aperture of 0.21. Calculate:

(i) Acceptance angle, refractive index and number of modes that the fibre can propagate at a wavelength of 0.8 μm.

(2 marks)

(ii) If light pulses propagate with an attenuation of 0.25 dB/km, determine distance through which the power of pulses is reduced by 40%. Evaluate percentage of input power received at distance of 10 km.

(4 marks)

Total 25 marks

END OF QUESTIONS

Please turn the page for the Equation Sheet

EQUATION SHEET

Co-ordinate systems:

$r = \sqrt{(\rho 2 + z^2)}$

$\theta = \tan^{-1}(\rho/z)$

$\text{Sin } \theta = \rho / \sqrt{(\rho 2 + z^2)}$

$\text{Cos } \theta = z / \sqrt{(\rho 2 + z^2)}$

$$\begin{bmatrix} A_\rho \\ A_\phi \\ A_z \end{bmatrix} = \begin{bmatrix} \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \\ \cos\theta & -\sin\theta & 0 \end{bmatrix} \begin{bmatrix} A_r \\ A_\theta \\ A_\phi \end{bmatrix}$$

Capacitors:

$C_1 = \alpha\varepsilon_0\varepsilon_{r1} l / 2.303 \log_{10} (r/r_1)$

$C_2 = \alpha\varepsilon_0\varepsilon_{r2} l / 2.303 \log_{10} (r_2/r)$

$V_1 = VC_2 / (C_1 + C_2)$

$V_2 = VC_1 / (C_1 + C_2)$

Electrostatics:

Boundary conditions:

$E_{1t} = E_{2t}$

$D_{1n} = D_{2n}$

$\text{Tan } \theta_1 = E_{1t} / E_{1n}$

$\text{Tan } \theta_2 = E_{2t} / E_{2n}$

Energy density, $W = (1/2)\, \varepsilon\, |E|^2$

Magnetostatics

$dH = I\, dl \times R / (4\pi R^3)$

Ampere circuital law : $B_1 = \mu\, I\, \rho / 2\pi a^2$ (for $0 <= \rho <= a$)

$B_2 = \mu\, I / 2\pi\, \rho$ (for $a <= \rho <= b$)

Magnetic Energy, $W_m = LI^2/2$

Magnetisation, $M = X_{m1} H_1$

Boundary Conditions: $B = \mu H$

$H_{1n} = (H_1.a_n)a_n$

$H_{1t} = H_{2t}$, $B_{1n} = B_{2n}$

Maxwell's Equations

$\nabla .E_s = 0$

$\nabla .H_s = 0$

$\nabla \times H_s = j\omega\varepsilon_0 E_s$

$\nabla \times E_s = -j\omega\mu_0 H_s$

$\omega/\beta = C/\sqrt{(\mu_r \varepsilon_r)}$

$E_0/H_0 = \sqrt{(\mu_0\mu_r/\varepsilon_0\varepsilon_r)}$

$$\text{charge density}, \rho = \nabla \cdot \mathbf{D} = \frac{1}{r}\frac{\partial}{\partial r}(r\mathbf{D}_r) + \frac{1}{r}\frac{\partial \mathbf{D}_\theta}{\partial \theta} + \frac{\partial \mathbf{D}_z}{\partial z}.$$

Equation Sheet continued over the page

Please turn the page

EM wave propagation and Transmission lines

$\varepsilon_r = \beta^2 / (\omega^2 \mu_0 \mu_r \varepsilon_0)$

$\eta = \sqrt{(\mu/\varepsilon)}$

$P_{avg} = E \times H$

$P_{total} = \int P_{avg} .dS$

$\gamma = \alpha + j\beta$

$$Z_{in} = Z_o \left(\frac{Z_L + Z_o \tanh \gamma \ell}{Z_o + Z_L \tanh \gamma \ell} \right)$$

$$I(z = 0) = \frac{V_g}{Z_{in} + Z_g}$$

$$V_o = Z_{in} I_o$$

$$V_o^+ = \frac{1}{2}(V_o + Z_o I_o)$$

$$V_o^- = \frac{1}{2}(V_o - Z_o I_o)$$

$$I_s(z = \ell/2) = \frac{V_o^+}{Z_o} e^{-\gamma z} - \frac{V_o^-}{Z_o} e^{\gamma z}$$

phase velocity, $v = \frac{\omega}{\beta} = \frac{1}{\sqrt{\mu\varepsilon}}$

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t} = -\mu_0 \frac{\partial \vec{H}}{\partial t}$$

Waveguides and Optical Fibres:

$$f_{c_{mn}} = \frac{u'}{2} \sqrt{\frac{m^2}{a^2} + \frac{n^2}{b^2}}$$

$$u' = \frac{1}{\sqrt{\mu\varepsilon}}$$

$$\beta = \omega \sqrt{\mu\varepsilon} \sqrt{1 - \left[\frac{f_c}{f}\right]^2}$$

$$\gamma = j\beta$$

$$\eta_{TM_{mn}} = \eta' \sqrt{1 - \left[\frac{f_c}{f}\right]^2}$$

For the TE_{10} mode

$$\alpha_d = \frac{\sigma \eta'}{2\sqrt{1 - \left[\frac{f_c}{f}\right]^2}}$$

$$f_c = \frac{u'}{2a}$$

$$\eta' \simeq \sqrt{\frac{\mu}{\varepsilon}}$$

$$R_s = \frac{1}{\sigma_c \delta} = \sqrt{\frac{\pi f \mu}{\sigma_c}}$$

For the TE_{10} mode

$$\alpha_c = \frac{2R_s}{b\eta' \sqrt{1 - \left[\frac{f_c}{f}\right]^2}} \left(0.5 + \frac{b}{a}\left[\frac{f_c}{f}\right]^2 \right)$$

$$\alpha = \alpha_d + \alpha_c$$

$$P_a = (P_d + P_a)\, e^{-2\alpha z}$$

Numerical aperture, NA = Sin $\theta_a = \sqrt{(n_1^2 - n_2^2)}$

V = □d $\sqrt{(n_1^2 - n_2^2)}/\lambda$

No: of modes, N = $V^2/2$

$\alpha\ell = 10 \log_{10}[P(0)/P(\ell)]$

END OF PAPER