VIT

Vellore Institute of Technology

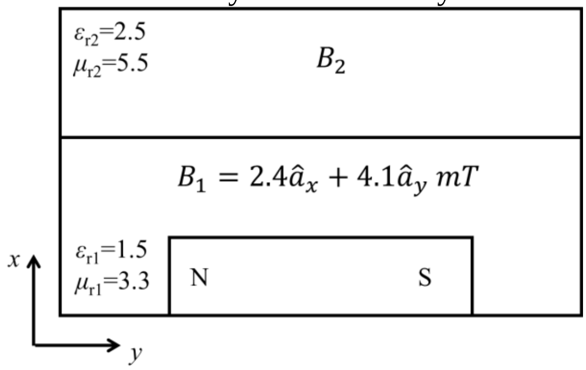
(Deemed to be University under section 3 of UGC Act, 1956)

School of Electronics Engineering

CAT- II, Fall Semester 2022-23

Course Name	: Engineering Electromagnetics	**Duration**	: 90 min.
Course Code	: BECE205L	**Max. Marks**	: 50
Mode	: Open Book	**Slot**	: D2+TD2

Answer all the following Questions

S. No.	**Question**	**Marks**	**CO**	**BL**
1	A permanent magnet is enclosed by two layers of magnetic materials as shown in Figure. Find the magnetic flux density in the layer-2. Assume there is no surface current density in the boundary.  	10	2	5
2	A charge Q = 5 x 10^{-18} Coulomb is moving through a uniform magnetic field **B** = -0.4$\mathbf{a}_x$ + 0.2$\mathbf{a}_y$ - 0.1 $\mathbf{a}_z$ Tesla, with a velocity **v** = (2$\mathbf{a}_x$ – 3$\mathbf{a}_y$ +6$\mathbf{a}_z$) x 10^5 m/s at t = 0. What electric field is present at t = 0 if the net force on the electron is zero?	5	2	5
3	Plane wave travelling in a medium has $\vec{H} = 7e^{-\alpha y}\sin(10^6 t - \beta y)\hat{a}_x$ H/m. The medium is characterized by ε_r=1, μ_r=10 and σ=5 S/m. (i) Identify the type of medium (ii) wave/intrinsic impedance (iii) attenuation constant (iv) phase constant (v) electric field equation.	10	3	5
4	In a lossless medium, if **E** = 80 sin(10^6t – 0.01z) $\mathbf{a}_y$ V/m, find **H** using Maxwell's equation.	5	3	5
5	The following characteristics have been measured on a lossy transmission line at 800 Hz, Zo = 2039.6Ω, α = 0.0019 Np/km, β = 0.0539 rad/km. Determine R, L, G, C, phase velocity and wave length for the line.	10	4	5
6	A 50 Ω transmission line of length 0.3λ is terminated with a load impedance of 100 + j50Ω. Calculate the following using analytical expression or Smith Chart. (i) Reflection co-efficient at the load (ii) Voltage standing wave ratio (iii) Input impedance (iv) Load admittance.	10	4	5

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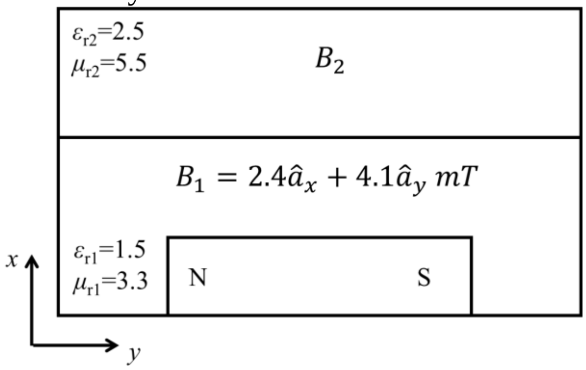
1	A permanent magnet is enclosed by two layers of magnetic materials as shown in Figure. Find the magnetic flux density in the layer-2. Assume there is no surface current density in the boundary.  Given – Medium 1: μ_{r1}=3.3 Medium 2: μ_{r2}=5.5 $B_1 = 2.4\hat{a}_x + 4.1\hat{a}_y\ mT$ Magnetostatic boundary conditions: $\boxed{B_{1n} = B_{2n}}$ $\boxed{\frac{B_{1t}}{\mu_1} - \frac{B_{2t}}{\mu_2} = K}$ Here, normal component is a_x Hence $B_{1n} = (B_n \cdot \hat{a}_n)\hat{a}_n = 2.4\hat{a}_x\ mT$ $B_{1t} = 4.1\hat{a}_y\ mT$ Therefore $B_{2n} = B_{1n} = 2.4\hat{a}_x\ mT$ $B_{2t} = -K + \frac{\mu_2 B_{1t}}{\mu_1} = \frac{\mu_2 B_{1t}}{\mu_1}$ $B_{2t} = \frac{5.5 \times (4.1\hat{a}_y)}{3.3} = 6.83\hat{a}_y\ mT$ $\boxed{B_2 = 2.4\hat{a}_x + 6.83\hat{a}_y\ mT}$	10

2a

A charge Q = 5 x 10^{-18} Coulomb is moving through a uniform magnetic field $\mathbf{B} = -0.4\mathbf{a}_x + 0.2\mathbf{a}_y - 0.1\ \mathbf{a}_z$ Tesla, with a velocity $\mathbf{v} = (2\mathbf{a}_x - 3\mathbf{a}_y + 6\mathbf{a}_z) \times 10^5$ m/s at t = 0. What electric field is present at t = 0 if the net force on the electron is zero?

$Q = 5 \times 10^{-18}$ C

$\vec{v} = (2\hat{a}_x - 3\hat{a}_y + 6\hat{a}_z) 10^5$ m/s

$\vec{B} = -0.4\hat{a}_x + 0.2\hat{a}_y - 0.1\hat{a}_z$ Tesla.

$$\vec{F} = Q\,\vec{v} \times \vec{B}$$

$$= 5 \times 10^{-18} \times 10^5 \times \begin{vmatrix} \hat{a}_x & \hat{a}_y & \hat{a}_z \\ 2 & -3 & 6 \\ -0.4 & 0.2 & -0.1 \end{vmatrix}$$

$$\vec{F} = 5 \times 10^{-13}\left[(0.3 - 1.2)\hat{a}_x + (-2.4 + 0.2)\hat{a}_y + (0.4 - 1.2)\hat{a}_z\right]$$

$$= 5 \times 10^{-13}(-0.9\hat{a}_x - 2.2\hat{a}_y - 0.8\hat{a}_z) \text{ Newton.}$$

$$\vec{E} = \frac{\vec{F}}{Q} = \frac{5 \times 10^{-13}(+0.9\hat{a}_x + 2.2\hat{a}_y + 0.8\hat{a}_z)}{5 \times 10^{-18}}$$

$$\vec{E} = (0.9\hat{a}_x + 2.2\hat{a}_y + 0.8 a_z) \times 10^5 \text{ V/m}$$

This is the required electric field intensity

5+5

2b

In a lossless medium, if $\mathbf{E} = 80 \sin(10^8 t - 0.1z)\ \mathbf{a_y}$ V/m, find $\mathbf{H}$ using Maxwell's equation.

Soln: $E_y : 80 \sin(10^8 t - 0.1z)$. (5 mark)

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

$$\vec{H} = \frac{-1}{\mu}\int \nabla \times \vec{E}\ dt.$$

(3)

$$\therefore \nabla \times \vec{E} : \begin{vmatrix} \hat{x} & \hat{y} & \hat{z} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ 0 & E_y & 0 \end{vmatrix} = -\hat{x}\cdot\frac{\partial E_y}{\partial z} + \cancel{\hat{z}\cdot\frac{\partial E_y}{\partial x}} = 0$$

$$= -\frac{\partial}{\partial z}\left(80 \sin(10^8 t - 0.1z)\right)\hat{x}$$

$$\nabla \times \vec{E} = +8 \cos(10^8 t - 0.1z)\ \hat{x}.$$

(2)

$$\therefore \vec{H} = \frac{-1}{\mu}\int +8 \cos(10^8 t - 0.1z)\hat{x}$$

$$= -\frac{8}{\mu_0}\frac{\sin(10^8 t - 0.1z)}{10^8}\hat{x} = \frac{-8 \times 10^{-8}}{4\pi \times 10^{-7}} \cdot \sin(10^8 t - 0.1z)\hat{x}$$

$$\vec{H} = -0.628 \sin(10^8 t - 0.1z)\ \hat{x}.$$

<table>
<tr><td>3</td><td>Plane wave travelling in a medium has $\vec{H}$ = 7e-$^{\alpha y}$ sin(10^6t - βy)$\hat{a}_x$ H/m. The medium is characterized by ε_r=1, μ_r=10 and σ=5 S/m. Determine
(i) the type of medium (ii) wave/intrinsic impedance (iii) attenuation constant (α)
(iv) phase constant (β) (v) electric field equation.

$\bar{H} = 7e^{-\alpha y} \sin[10^6 t - \beta y]\,\hat{a}_x$ V/m
$\sigma = 5$ S/m ; $\omega = 10^6$; $\mu_r = 10$
(i) Medium
$\frac{\sigma}{\omega\epsilon} = \frac{5}{10^6 \times 8.854\times10^{-12}} = \frac{5}{8.854\times10^{-6}}$
$\boxed{\sigma >> \omega\epsilon}$ Conducting medium
(ii) $\alpha = \beta = \sqrt{\frac{\omega\mu\sigma}{2}} = \sqrt{\frac{10^6 \times 4\pi\times10^{-7}\times10\times5}{2}}$
$\boxed{\alpha = \beta = 5.6}$
(iii) $|\eta| = \sqrt{\frac{\mu\omega}{\sigma}} = \sqrt{\frac{10\times4\pi\times10^{-7}\times10^6}{5}} = 1.585$
$\boxed{\angle\theta_\eta = 45^\circ}$
(iv) $\frac{E_0}{H_0} = \eta$; $E_0 = 7\times1.585\angle45^\circ = 11.095\angle^{\pi/4}$
$\hat{P}_y = \bar{E}_z \times \bar{H}_x$
$\therefore \boxed{\bar{E} = 11.095\, e^{-\alpha y} \sin[10^6 t - \beta y]\,\hat{a}_z}$</td><td>10</td></tr>
<tr><td>4</td><td>The following characteristics have been measured on a lossy transmission line at 800 Hz, Z_o = 600 Ω, α = 0.0019 Np/km, β = 0.0539 rad/km. Determine R, L, G, C, phase velocity and wave length for the line.

(2) $f = 800$ Hz $Z_0 = 2039.6\,\Omega$ $\alpha = 0.0019$ np/km
$\beta = 0.0539$ rad/km
$\omega = 5.026\times10^3$
$\gamma = \alpha + j\beta = 0.0019 + j\,0.0539 = 0.0539\angle 87.981$
$Z_0 \times \gamma = R + j\omega L = 2039.6 \times 0.0539 \angle 87.981$
$R = 3.872\ \Omega$/m $L = 0.02185$ H/m
$\frac{\gamma}{Z_0} = G + j\omega C = 9.308\times10^{-7} + 2.64\times10^{-5}$
$G = 9.308\times10^{-7}$ S/m $C = 5.253\times10^{-9}$ F/m
$\lambda = \frac{2\pi}{\beta} = 116.57$m $v_p = \frac{\omega}{\beta} = 93.256\times10^3$ m/s</td><td>10</td></tr>
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