Instructions:

1. All questions carry equal marks
2. Attempt any **THREE (ONLY)** out of four questions

Assume the following data for free-space:

Permittivity: $\epsilon_0 = \frac{1}{36\pi} \times 10^{-9}\ [f/m]$
Permeability: $\mu_0 = 4\pi \times 10^{-7}\ [H/m]$
Speed of electromagnetic wave: $v_0 = 3 \times 10^8\ [m/s]$

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Question 1

a) Explain 4 Maxwell's equations for time-varying electromagnetic fields in any form and explain their physical significance. **(4 marks)**

b) You are to design a link budget for a telecomms company under clear-air weather conditions. In free space, the electric field at a point is known to be $\vec{E}(z,t) = A\sin(wt - \beta z)\vec{a}_y$ [V/m]. Firstly, obtain the magnetic field intensity. Secondly, determine the propagation constant γ at a frequency $f = 27[MHz]$ and $f = 8[GHz]$. **(6 marks)**

c) From Maxwell's two curl equations, for free space, obtain a three dimensional wave equation in either $\vec{H}$ or $\vec{E}$, and derive the velocity of a wave in free-space medium. **(4 marks)**

d) i) Given that the magnetic field intensity is described as $\vec{H} = 5\vec{i} + y\vec{j} - 3x\vec{k}$, find the current density due to this field.
ii) Given that the electric field density for an EM wave in free-space is expressed as $\vec{D} = D_0 \sin(\omega t + \beta z)\vec{a}_x$, use Maxwell's equations to deduce the corresponding magnetic field density of the field. **(6 marks)**

Question 2

a) State or define the following terms as used in EMF fields: **(6 marks)**
i) Skin depth
ii) polarization direction
iii) Faraday's law

b) In a static field, a straight conductor, $9[cm]$ long moves perpendicularly to its axis in a uniform B-field, where the flux density is given as $1.4[T]$. If the velocity is $12.7[m/s]$, evaluate the electromotive force (e.m.f.) induced in the conductor if the direction of motion is at an angle of 30 degrees to the orientation of the field. Comment on the orientation.
(4 marks)

c) i) Define Loss Tangent for an electromagnetic wave.
ii) A plane wave is travelling through a medium with $\mu_r = 1.24$, where the electric field is expressed as $\vec{E} = E_0 e^{-z/2}\sin(10^8 t - \beta z)\vec{a}_x$ $[V/m]$. If $\epsilon_r = 3.4$, determine the propagation constant, wave impedance and expression for H-field **(4 marks)**

d) Let a medium be non-magnetic with $\vec{E} = 2\sin(2\pi \times 10^7 t - 0.63x)\vec{a}_z$.
Determine:
i) Intrinsic impedance
ii) Relative permittivity
iii) Average power transported by the wave
iv) Total power that crosses an area of 4 $[cm^2]$ of plane $2x + y = 5$
(6 marks)

Question 3

a) Describe the following terms as used in wave propagation. **(4 marks)**

i) Skin depth

ii) VSWR

b) A uniform plane wave with $\mathbf{E}_i = A\cos(\omega t - \beta z)\mathbf{a}_x$ in air encounters a perfectly conducting plane normal to the z axis at $z = 0$.

i) Find $\mathbf{H}_i, \mathbf{E}_r, \mathbf{H}_r$, and sketch the waves. Also show their directions on a Cartesian plot.

ii) Find the total fields in the region $z \leq 0$.

iii) Calculate the time average Poynting vectors for $z \leq 0$ and $z \geq 0$. **(6 marks)**

c.) The electric field of an EM wave in free-space is given as $\vec{E}_s = 10e^{j(0.866y+0.5z)}\vec{a}_x[V/m]$.

Find:

i) $\omega, \lambda, \vec{H}$

ii) Time-average power **(4 marks)**

d) A uniform plane wave in air with $\vec{E} = A\cos(\omega t - 3x - 4z)\vec{a}_y[V/m]$ is incident on a dielectric slab ($z \geq 0$) with $\mu_r = 1, \epsilon_r = 2.34, \sigma = 0$.

Find:

i) Polarization of the wave

ii) The angle of incidence

iii) $\vec{E}_r, \vec{H}_t$ **(6 marks)**

Question 4

a) Sketch and describe any FOUR types of transmission lines. **(4 marks)**

b) i) Define characteristic impedance.

ii) Use circuit theory to derive the input impedance Z_{in} of an l-long line terminated by a load, where a wave propagates with a propagation constant γ. **(6 marks)**

c) Use equation to define and describe the following properties of transmission lines. **(4 marks)**

i) Distortionless

ii) Lossless

d) A transmission line operating at $800[MHz]$ has $z_0 = 70[\Omega], \alpha = 0.034[Np/m], \beta = 3.4[rad/m]$. Find the line parameters R, L, G, C. **(6 marks)**