ELIZADE UNIVERSITY, ILARA-MOKIN, ONDO STATE

FACULTY OF ENGINEERING

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

SEMESTER II EXAMINATION, 2016/2017 ACADEMIC SESSION

COURSE TITLE: ELECTROMAGNETIC WAVES

COURSE CODE: EEE 314

EXAMINATION DATE: 28TH JULY 2017

COURSE LECTURER: DR R. O. Alli-Oke

HOD's SIGNATURE

TIME ALLOWED: 3 HRS

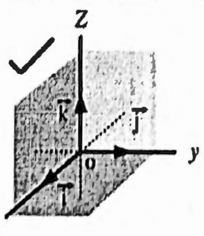
INSTRUCTIONS:

1. ANSWER **QUESTION 1** AND ANY OTHER FOUR QUESTIONS **(TOTAL OF 5 QUESTIONS)**
2. SEVERE PENALTIES APPLY FOR MISCONDUCT, CHEATING, POSSESSION OF UNAUTHORIZED MATERIALS DURING EXAM.
3. YOU ARE **NOT** ALLOWED TO BORROW CALCULATORS AND ANY OTHER WRITING MATERIALS DURING THE EXAMINATION.
4. MAXWELL'S LAWS ARE GIVEN BY:

$$\nabla.\vec{E} = \frac{p}{\varepsilon_0} \qquad \nabla\times\vec{E} = -\frac{\partial\vec{B}}{\partial t}$$

$$\nabla.\vec{B} = 0 \qquad \nabla\times\vec{B} = \mu_0\vec{J} + \mu_0\varepsilon_0\frac{\partial\vec{E}}{\partial t}$$

1. SEPARATION VECTOR $\vec{\xi}$ IS **ALWAYS** FIELD POINT – SOURCE POINT.
2. COULOMB'S LAW: $\vec{\mathrm{E}} = \frac{1}{4\pi\epsilon_0}\frac{q}{\xi^2}\hat{\xi}$ VACUUM PERMITIVITY ϵ_0 : 8.854×10^{-12} Fm^{-1}
3. COLOUMB'S CONSTANT $k_e = \frac{1}{4\pi\epsilon_0} =$ 8.988×10^{9} Nm^{2}C^{-2}
4. USE THE FOLLOWING COORDINATE SYSTEM THROUGHOUT THE EXAM



Include appropriate units in your answers. The speed of light, permittivity and permeability in free space are given by $c = 3\times10^8\ m/s$, $\varepsilon_0 = 8.854\times10^{-12}\ Fm^{-1}$ *and* $\mu_0 = 4\pi\times10^{-7}\ N/A^2$ *respectively. All symbols should be taken as standard. The unit of* $\vec{B}$ *is* Nm^{-1}A^{-1}.

Question #1

a) Show that the integral form of Maxwell's 1st law is given by $\oint \vec{E}.d\vec{A} = \frac{Q}{\varepsilon_0}$. (4 marks). Discuss why your proof would fail if Coulomb's law was a $1/r$ or $1/r^3$ law. (2 marks)

b) Show that $\nabla\times\vec{E} = 0$, where $\vec{E}$ is an electrostatic electric field. *Hint:* $\vec{E} = -\nabla V$, *where V is a scalar function.* (2 marks)

c) Let the separation vector $\vec{\xi}$ between the current-length element and the field-point P be such that $\vec{\xi} = \vec{r}$. Given that the vector $\vec{r} = (x - x')i + (y - y')j + (z - z')k$. Show that $\nabla\times\frac{\hat{r}}{r^2} = 0$. (4 marks)

d) A conductor with total charge of $10\mu C$ has a cavity of radius 2m. Inside the cavity, a spherical charge of radius 1m has a (volume) charge density proportional to the distance from the origin $\rho = \frac{2\mu}{\pi} r$ for some constant k.

(i.) Determine the enclosed charge in the cavity? (2 marks)

(ii.) How much charge is on each surface? (2 marks)

(iii.) Suppose the conductor is a spherical shell, can you find the electric field at $r = 4$m? (4 marks)

Question #2

a) What is electromagnetic induction? Define and differentiate, in no more than 3 sentences, between the two kinds of induced EMF. This should include the nature of the generated electric field and one application where you can find the induced EMF.

(5 marks)

b) Derive the electromagnetic wave equation for electric fields. Make necessary assumptions. *Hint:* $\nabla\times(\nabla\times\vec{P}) = \nabla(\nabla.\vec{P}) - \nabla^2\vec{P}$

$$\nabla^2\vec{E} = \mu_0\varepsilon_0\frac{\partial^2\vec{E}}{\partial t^2}$$

(5 marks)

Question #3

a) What is a Poynting vector? State two important properties of Poynting vectors. A helium-neon laser commonly used for classroom demonstration emits a 2mm diameter laser beam with a power of 2π mW. Calculate the amplitude of oscillating electric field in that laser beam? *Hint:* $I = \frac{E_m^2}{2c\mu_0} = \frac{c\varepsilon_0}{2}E_m^2$.

(5 marks)

b) Derive the electromagnetic wave equation for magnetic fields. Make necessary assumptions. *Hint:* $\nabla\times(\nabla\times\vec{P}) = \nabla(\nabla.\vec{P}) - \nabla^2\vec{P}$

$$\nabla^2\vec{B} = \mu_0\varepsilon_0\frac{\partial^2\vec{B}}{\partial t^2}$$

(5 marks)

Question #4

a) When is a transmission line considered to be electrically long? Suppose a wireless device is transmitting at 8 GHz. Suppose also that a receiver is connected to a microstrip antenna via a microstrip transmission line that is 5 cm long. Is the transmission line electrically long? Should transmission line effects be taken into account?

(4 marks)

b) A 2 m-long lossless transmission line (see Fig. 1) operates at a frequency of 100MHz. The velocity factor is $^1/_3$ and the line

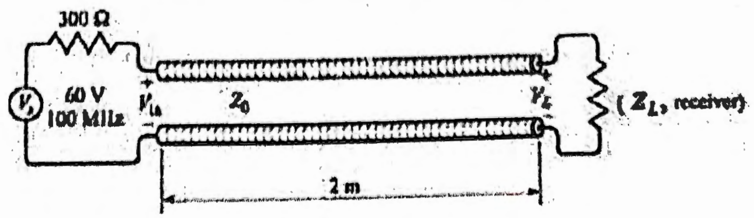


Fig. 1: Lossless transmission line

parameters are $Z_L = 200\ \Omega$, $L = 0.25\ \mu H/m$ and $C = 100\ pF/m$. Find characteristic impedance, velocity of the transmitted electromagnetic wave, and the reflection co-efficient. *Hint: Lossless means that R=0 and G=0.* (6 marks)

Question #5

a) Show that the magnitude of the Poynting vector $\vec{S}$ measures the rate of energy transfer per unit area. *Hint Show that units of the Poynting vector $\vec{S}$ is W/m^2 (Power per unit area)* (3 marks)

b) What is impedance matching? See Figure 1. Suppose characteristic impedance (Z_0) is 50Ω. What value of Z_L is required for impedance matching in Figure 1. The input impedance is given by $Z_{in} = Z_0 \frac{Z_L \cos\beta l + j Z_0 \sin\beta l}{Z_0 \cos\beta l + j Z_L \sin\beta l}$. Using the value of your Z_L, compute the input impedance of your transmission-line design. Also, compute the input current to the transmission line. *Hint:* $V_{in} = 100\cos(2\pi f t)$ V. (7 marks)

Question #6

a) Give 1 implication of Maxwell's 3rd Equation and Maxwell's 4th Equation respectively. (2 marks)

b) The simplest solutions to the electromagnetic wave are simple harmonic plane waves given by:

$$\vec{B}_z(x,t) = B_z(x,t)j = B_m \sin(kx - \omega t)k\ V/m$$

$$\vec{E}_y(x,t) = E_y(x,t)k = 10\sin(kx - 10^8 t)j\ V/m$$

where x is measured in meters and t in seconds. Determine,

(i.) wavelength of the wave (3 marks)

(ii.) angular frequency of the $\vec{B}$ field (2 marks)

(iii.) peak magnitude of the $\vec{B}$ field (3 marks)

Question #7

a) With the aid of diagrams differentiate between a sphere of charge with a cavity and a spherical conducting shell. (2 marks)

b) State 3 properties associated with isolated conductors and illustrate all these properties in a single diagram (2 marks)

c) A transmission line is a device designed to guide electrical energy from one point to another.

(i.) Briefly explain 3 types of losses in transmission lines (3 marks)

(ii.) With the aid of diagrams, state 3 examples of transmission lines (3 marks)