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Subject : Introduction to field. waves and antenna.

Module : 8th Semester

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Q1.) Answer the following short questions briefly.

1. 1. What is Electromagnetism?

Explain in brief a long with Gravitational force analogue?

(Ans). Electromagnetism is the force that Causes the interaction between electrically charged Particles.

It is as well one of the four fundamental interactions of nature. The other three are the strong interaction, Weak interaction, Gravitation

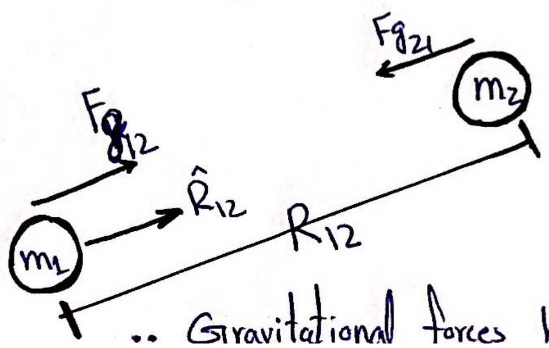
- Gravitational force analogue.

Newton's law of gravity states:

$$F_{g21} = -\hat{R}_{12} \frac{G m_1 m_2}{R_{12}^2} \quad (N)$$

Which expresses the dependence of the gravitational force F acting one mass m_2 due to a mass m_1 at distance R_{12}. (See fig. 1). G is the universal gravitational Constant and $\hat{R}_{12}$ is a unit vector Pointing from m_1 to m_2.

Figure1:



.. Gravitational forces b/w two masses

2. Explain in brief the branches of Electromagnetism along with the table?

(Ans) There are three Branches:

1. Electrostatics :- (Also known as static electricity) is the branch of physics that deals with apparently stationary electric charges...

2. Megnetostatics :- Is the study of magnetic fields in Systems where the Currents are steady (not changing with time)....

3. Dynamics :- Branche of physical Science and Subdivision of mechanics that is Concerned with the motion of material objects in relation of the Physical factors that affect them:

Force, mass, momentum, energy.

Branches of Electromagnetics

Branch	Condition	Field Quantities (Units)
Electrostatics	stationary charges $(\partial q/\partial t = 0)$	Elec. field intensity E (V/m) Elec. flux density D (C/m²) $D = \epsilon E$
Magnetostatics	steady Currents $(\partial I/\partial t = 0)$	Magnetic flux density B (T) Mag. field intensity H (A/m) $B = \mu H$
Dynamics	Time - varying Currents $(\partial I/\partial t \neq 0)$	E, D, B and H (E, D) coupled to (B, H)

3. Explain in detail the Sinusoidal wave in lossless medium with mathematical expressions?

(Ans) Sinusoidal wave in lossless medium:

Lossless medium:

It does not attenuate the amplitude of the wave traveling within it or on its surface. Take water surface waves, where y denotes the height of water relative to unperturbed state, then

$$y(x,t) = A \cos\left(\frac{2\pi t}{T} - \frac{2\pi x}{\lambda} + \phi_0\right)(m),$$

A is amplitude of the wave, T is its time Periode, λ is spatial wavelength, and ϕ_0 is reference phase.

Even simpler form is obtained if the argument of the Cosine term is Called the phase of the wave (not to be Confused with the reference Phase ϕ_0).

$$\phi(x,t) = \left(\frac{2\pi t}{T} - \frac{2\pi x}{\lambda} + \phi_0\right)$$

Which is measured in radians or degrees (rad=? degree?). The quantity $y(x,t)$ Can be written,

$$y(x,t) = \cos\phi(x,t)$$

4. Proof the Euler's formula? Where does it Come from?

(Ans). Euler's Formula : (with real ϕ)

$$e^{j\phi} = \cos\phi + j\sin\phi$$

Where does it Come from?

One way to see this is using Taylor Series.

Even if you don't prove it, you Can Convince yourself that these Series hold. Take the Taylor Series representition for Sin and Cos :

$$\cos\phi = 1 - \frac{\phi^2}{2!} + \frac{\phi^4}{4!} - \frac{\phi^6}{6!} + \frac{\phi^8}{8!} - \cdots$$

$$\sin\phi = \phi - \frac{\phi^3}{3!} + \frac{\phi^5}{5!} - \frac{\phi^7}{7!} + \frac{\phi^9}{9!} - \cdots$$

What about for the exponential function?

$$e^z = 1 + \frac{z^2}{2!} - \frac{z^3}{3!} + \frac{z^4}{4!} + \frac{z^5}{5!} + \frac{z^6}{6!} + \frac{z^7}{7!} \cdots$$

We write as z since this Can be a Complex number

What about if we take z to be $j\phi$?

$$e^z = 1 + z + \frac{z^2}{2!} + \frac{z^3}{3!} + \frac{z^4}{4!} + \frac{z^5}{5!} + \frac{z^6}{6!} + \frac{z^7}{7!} \cdots$$

$$e^{j\phi} = 1 + j\phi - \frac{\phi^2}{2!} - \frac{j\phi^3}{3!} + \frac{\phi^4}{4!} + \frac{j\phi^5}{5!} - \frac{\phi^6}{6!} - \frac{j\phi^7}{7!} \cdots$$

Q2.

PART a). An airline is a transmission line in which air separates the two conductors, which renders in addition, ---------- Following quantities are given as :

(Ans). Solution : The following quatities are given :

$$Z_0 = 50\ \Omega, \quad \beta = 20 \text{ rad/m}$$

$$f = 700\,MHz = 7 \times 10^8\ Hz$$

With $R' = G' = 0$, Eqs. (2.25b) and (2.29) reduce to :

$$\beta = \mathfrak{Im}\left[\sqrt{(j\omega L')(j\omega C')}\right]$$

$$= \mathfrak{Im}\left(j\omega\sqrt{L'C'}\right) = \omega\sqrt{L'\cdot C'},$$

$$Z_0 = \sqrt{\frac{j\omega L'}{j\omega C'}} = \sqrt{\frac{L'}{C'}}$$

The ratio of β to Z_0 is :

$$\frac{\beta}{Z_0} = \omega C',$$

or

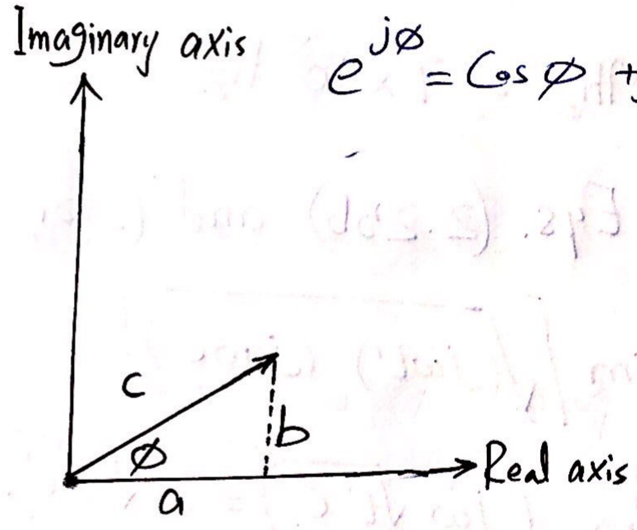
$$\cos\phi = 1 - \frac{\phi^2}{2!} + \frac{\phi^4}{4!} - \frac{\phi^6}{6!} + \frac{\phi^8}{8!} \cdots\cdots$$

$$j\sin\phi = j\phi - \frac{j\phi^3}{3!} + \frac{j\phi^5}{5!} - \frac{j\phi^7}{7!} + \frac{j\phi^9}{9!} \cdots\cdots$$

So we have:

$$e^{j\phi} = \cos\phi + j\sin\phi$$

Euler's Formula: (with real ϕ)



$$e^{j\phi} = \cos\phi + j\sin\phi$$

In general, when magnitude is not 1:

$$|c| = \sqrt{a^2 + b^2}$$

$$C = |c|\, e^{j\phi} = \underbrace{|c|\cos\phi}_{\text{Real}} + j\underbrace{|c|\sin\phi}_{\text{Imaginary}}$$

Polar to rectangular phasor form

$$C' = \frac{\beta}{\omega Z_0}$$

$$= \frac{20}{2\pi \times 7 \times 10^8 \times 50}$$

$$= 9.09 \times 10^{-11}\ (F/m) = 90.9\ (pF/m).$$

From $Z_0 = \sqrt{L'/C'}$, it follows that

$$L' = Z_0^2\, C'$$

$$= (50)^2 \times 90.9 \times 10^{-12}$$

$$= 2.27 \times 10^{-7}\ (H/m)$$

$$= 227\ (nH/m)$$

Q_2

PART b). A 50 microstrip line uses a 0.5 mm-thick Sapphire substrate with What is the width of its Copper strip?

(Ans). Solution: Since $Z_0 = 50 > 44 - 18 = 32$,

we should use:

$$P = \sqrt{\frac{\varepsilon_r + 1}{2} \times \frac{Z_0}{60}} + \left(\frac{\varepsilon_r - 1}{\varepsilon_r + 1}\right)\left(0.23 + \frac{0.12}{\varepsilon_r}\right)$$

$$= \sqrt{\frac{9+1}{2} \times \frac{50}{60}} + \left(\frac{9-1}{9+1}\right)\left(0.23 + \frac{0.12}{9}\right)$$

$$= 2.06,$$

$$S = \frac{w}{h}$$

$$= \frac{8e^{P}}{e^{2P} - 2}$$

$$= \frac{8e^{2.06}}{e^{4.12} - 2}$$

$$\boxed{= 1.056.}$$

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Hence,

$$\omega = sh$$

$$= 1.056 \times 0.5 \text{ mm}$$

$$= 0.53 \text{ mm}$$

To check our Calculations, we will use $s = 1.056$ to Calculate Z_o to verify that the value we obtained is indeed equal or Close to $50\,\Omega$. With $\varepsilon_r = 9$,

$$X = 0.55,$$

$$y = 0.99,$$

$$t = 12.51,$$

$$\vartheta_{eff} = 6.11,$$

$$\boxed{Z_o = 49.93\,\Omega}$$

The Calculated value of Z_o is, for all Practical Purposes, equal to the value Specified in the Problem statement.

Q_3

PART a). Transform the vector $(x+yz)a_y$ to cylindrical?

$$\begin{bmatrix} A_\rho \\ A_\phi \\ A_z \end{bmatrix} = \begin{bmatrix} \cos\phi & \sin\phi & 0 \\ -\sin\phi & \cos\phi & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0 \\ x+z \\ 0 \end{bmatrix}$$

(Ans). Solution:

$A_\rho = 0 * \cos\phi + (x+z)\sin\phi + 0$

$A_\rho = (x+z)\sin\phi$

$A_\phi = 0 * (-\sin\phi) + (x+z)\cos\phi + 0$

$A_\phi = (x+z)\cos\phi$

$A_\phi = (\rho\cos\phi + z)\cos\phi$

$A_z = 0$

$x = \rho\cos\phi$

$y = \rho\sin\phi$

$z = r\cos\phi$

$\rho = r\sin\phi$

$\rho = \sqrt{x^2+y^2}$

$r = \sqrt{x^2+y^2+z^2}$

Convert the vector F to Cylindrical:

$$F = \frac{x a_x + y a_y + 4 a_z}{\sqrt{x^2+y^2+z^2}}$$

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

$$A_\rho = \frac{x * \cos\phi + y * \sin\phi + 0}{\sqrt{x^2+y^2+z^2}} = \cancel{\rho\cos\phi * \cos\phi}$$

$$= \frac{\rho\cos\phi * \cos\phi + \rho\sin\phi * \sin\phi}{\sqrt{\rho^2+z^2}} = \frac{\rho}{\sqrt{\rho^2+z^2}}$$

$$A_\phi = \frac{x * (-\sin\phi) + y * \cos\phi + 0}{\sqrt{x^2+y^2+z^2}} = \frac{\rho\cos\phi * -\sin\phi + \rho\sin\phi * \cos\phi}{\sqrt{\rho^2+z^2}} = 0$$

$$A_z = \frac{4}{\sqrt{x^2+y^2+z^2}} = \frac{4}{\sqrt{\rho^2+z^2}}$$

$$A_{cyl.} = \frac{\rho}{\sqrt{\rho^2+z^2}} a_\rho + \frac{4}{\sqrt{\rho^2+z^2}} a_z$$

Q3

PART b). Explain the difference between the two points with help of figures -- .... A at points (3, -4,0) given below?

(Ans) The distance between two Points:

$d = |r_2 - r_1|$

Cartesian $\Rightarrow d^2 = (x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2$

Cylindrical $\Rightarrow d^2 = P_2^2 + P_1^2 - 2P_2 P_1 \cos(\phi_2 - \phi_1) + (z_2 - z_1)^2$

Spherical $\Rightarrow d^2 = r_2^2 + r_1^2 - 2r_2 r_1 \cos\phi_2 \cos\phi_1 - 2r_2 r_1 \sin\phi_2 \ldots \sin\phi_1 \cos(\phi_2 - \phi_1)$

a). $P_1 = (2,1,5)$ and $P_2 = (6,-1,2)$

$P_1 P_2 = P_2 - P_1 = 4a_x - 2a_y - 3a_z$

$|P_1 P_2| = \sqrt{16+4+9} = 5.38$

b). $P_1 = (3, P\frac{1}{2}, -1)$ and $P_2 = (5, 3P\frac{1}{2}, 5)$

$d^2 = P_2^2 + P_1^2 - 2P_1 - 2P_2 P_1 \cos(\phi_2 - \phi_1) + (z_2 - z_1)^2$

$d_{st}^2 = 5^2 + 3^2 - 2(5)(3)\cos(\pi) + (6)^2 = 100$

$d = 10$

or Convert all Points to Cartesian Coordinates:

$(3, pi/2, -1) \Rightarrow (0, 3, -1)$

$(5, 3i/2, 5) \Rightarrow (0, -5, 5)$

$d = \sqrt{0 + 64 + 36} = 10$

$\Rightarrow$ $H = \rho z \cos\phi \; a\rho + \sin\frac{\phi}{2} a_\phi + \rho^2 a z^1$

At Point $(1, \pi/3, 0)$ find:

a) $H.ax$: first we must Convert [H to Cartesian] or [A to cylindrical

$$\begin{bmatrix} H_x \\ H_y \\ H_z \end{bmatrix} = \begin{bmatrix} \cos\phi & -\sin\phi & 0 \\ \sin\phi & \cos\phi & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \rho z \cos\phi \\ \sin\frac{\phi}{2} \\ \rho^2 \end{bmatrix}$$

$H = \rho z \cos\phi \; a\rho + \sin\frac{\phi}{2} a_\phi + \rho^2 a z$

At Point $(1, \pi/3, 0)$ find:

(a) $H x a_\theta$

first we must Convert [H to sph] or [A to cyl]

$A_\rho = \cos\phi$

$A_\rho = 0$

$A_z = -\sin\phi$

$\theta = \tan^{-1}\left(\frac{\rho}{z}\right) = \tan^{-1}\left(\frac{1}{0}\right) = \pi/2$

$A_\rho = \cos 90 = 0$

$A_\rho = 0$

$A_z = -\sin 90 - 1$

$H_\downarrow\ (1, \pi/3, 0) = 0.5 a_\phi + a_z$

$H \times A = H \times a_z = (0.5 a_\phi + a_z) \times (a_z)$

$$\Rightarrow \begin{vmatrix} a_\rho & a_\phi & a_z \\ 0 & 0.5 & 1 \\ 0 & 0 & -1 \end{vmatrix} = -0.5 a_\rho$$

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Transform A to spherical and Find the value of A at Point (3, -4, 0)

$$A = \rho \cos\phi \, a_\rho + \rho z^2 \sin\phi \, a_z$$

$$\begin{bmatrix} A_r \\ A_\theta \\ A_\phi \end{bmatrix} = \begin{bmatrix} \sin\theta & 0 & \cos\theta \\ \cos\theta & 0 & -\sin\theta \\ 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} \rho\cos\phi \\ 0 \\ \rho z^2 \sin\phi \end{bmatrix}$$

$$A_r = \rho \cos\phi \sin\theta + \rho z^2 \sin\phi \cos\theta$$

$$= (r\sin\theta)\cos\phi\sin\theta + (r\sin\theta)(r\cos\theta)^2 \sin\phi\cos\theta$$

$$= r\sin^2\theta\cos\phi + r^3 \sin\theta \cos^3\theta \sin\theta$$

$$A_\theta = r\sin\theta\cos\theta\cos\phi - r^3 \sin^2 \cos^2\theta \sin\theta$$

$$A_\theta = 0$$

$$\Rightarrow A = A_r a_r + A_\theta a_\theta + A_\phi a_\phi$$

$$(x, y, z) = (3, -4, 0) \Rightarrow (r, \theta, \phi) = (5, \pi/2, -53.13^\circ)$$

$$A_r (5, \pi/2, -53.13^\circ) = 3 a_r$$

$$|A| = 3 \text{ as in Part (a)}$$