SNS COLLEGE OF TECHNOLOGY

Coimbatore-35
An Autonomous Institution

Accredited by NBA – AICTE and Accredited by NAAC – UGC with 'A++' Grade (3rd Cycle)
Approved by AICTE, New Delhi & Affiliated to Anna University, Chennai

DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

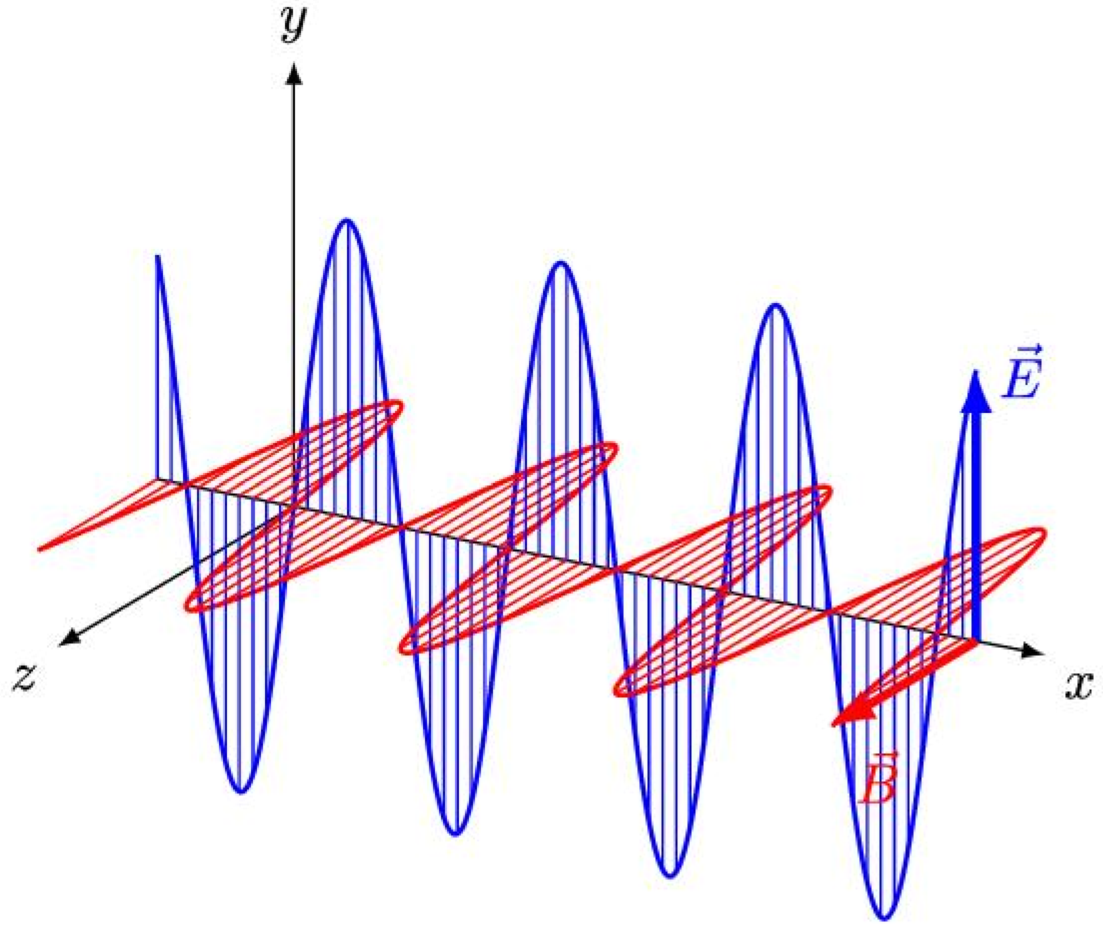
19ECT302 – TRANSMISSION LINES AND ANTENNAS

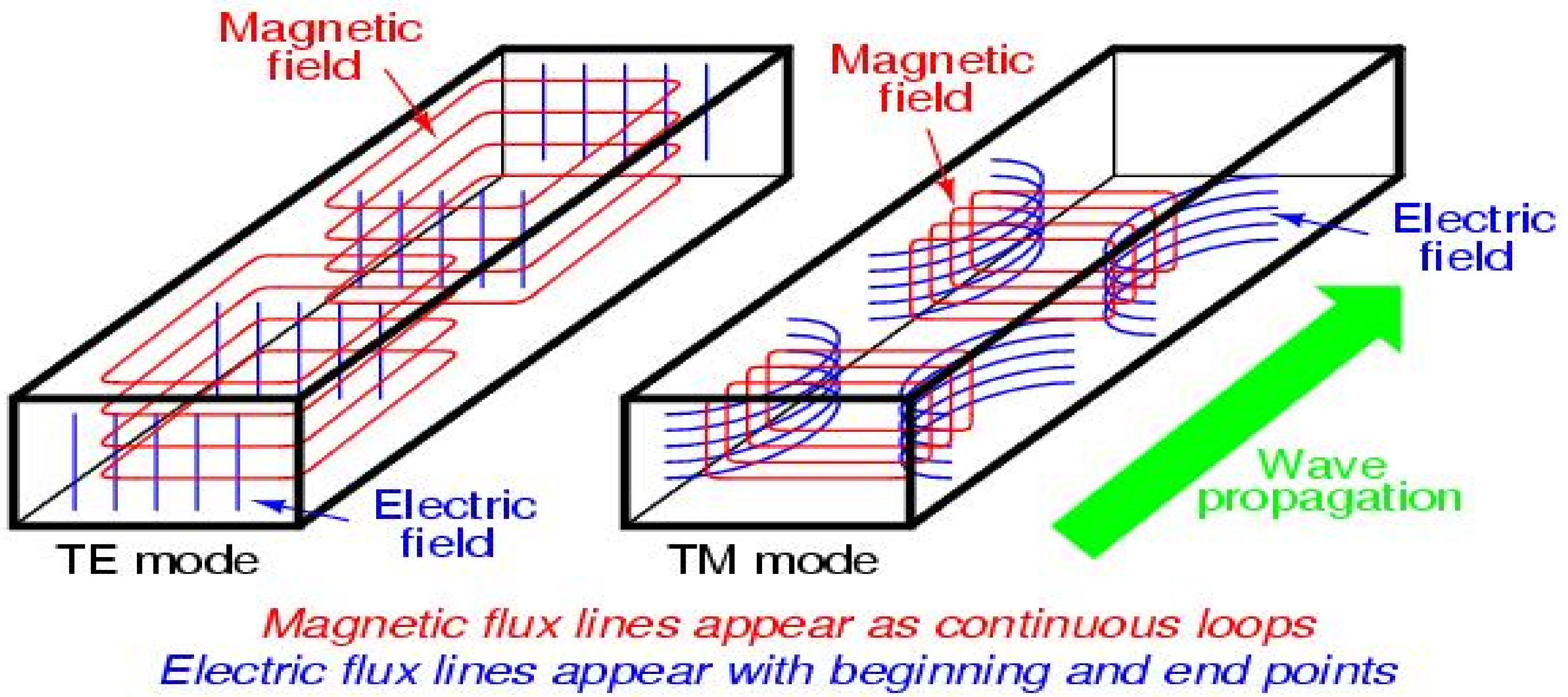
III YEAR/ V SEMESTER

UNIT 2 – GUIDED WAVES

TOPIC 2 – TRANSVERSE ELECTRIC AND TRANSVERSE MAGNETIC WAVES

WHAT DO YOU RELATE FROM THIS ?





EM WAVES - CLASSIFICATION

- EM waves are classified based on the type of field present in the direction of wave propagation

TWO TYPES

1. TE WAVES

2. TM WAVES

TE WAVES

TE WAVES ($E_z = 0$)

If $E_z = 0$, but $H_z \neq 0$ [$\therefore H_y$ & $E_x = 0$]

$$E_y = \frac{j\omega\mu}{h^2} \frac{\partial H_z}{\partial x}$$

$$H_x = \frac{-\gamma}{h^2} \frac{\partial H_z}{\partial x}$$

The wave equation

$$\frac{\partial^2 E_y}{\partial x^2} + \underbrace{\cancel{\frac{\partial^2 E_y}{\partial y^2}}}_{\to 0} + \frac{\partial^2 E_y}{\partial z^2} = -\omega^2 \mu \varepsilon E_y \rightarrow (1)$$

$$\& \quad \frac{\partial^2}{\partial z^2} = \gamma^2$$

TE WAVES - ANALYSIS

Eq ① becomes,

$$\frac{\partial^2 E_y}{\partial x^2} + \bar{\gamma}^2 E_y = -\omega^2 \mu \varepsilon E_y$$

$$\frac{\partial^2 E_y}{\partial x^2} + h^2 E_y = 0 \qquad [\because h^2 = \bar{\gamma}^2 + \omega^2 \mu \varepsilon]$$

Since $E_y = E_y^0 e^{-\bar{\gamma} z}$ the above eqn, becomes

$$\frac{\partial^2 E_y^0}{\partial x^2} + h^2 E_y^0 = 0 \rightarrow ②$$

EM WAVE PROPAGATION BETWEEN PARALLEL PLANES - ANALYSIS

Eq ② is a differential Eqn, & the solution is

$$E_y^0 = C_1 \sin hx + C_2 \cos hx \rightarrow (3)$$

where C_1, C_2 are arbitrary constants.

Showing the variation in z direction

$$E_y = E_y^0 e^{-\bar{\gamma} z} = (C_1 \sin hx + C_2 \cos hx) e^{-\bar{\gamma} z}.$$

C_1 & C_2 determined from boundary conditions.

EM WAVE PROPAGATION BETWEEN PARALLEL PLANES - ANALYSIS

<u>Boundary condition</u>

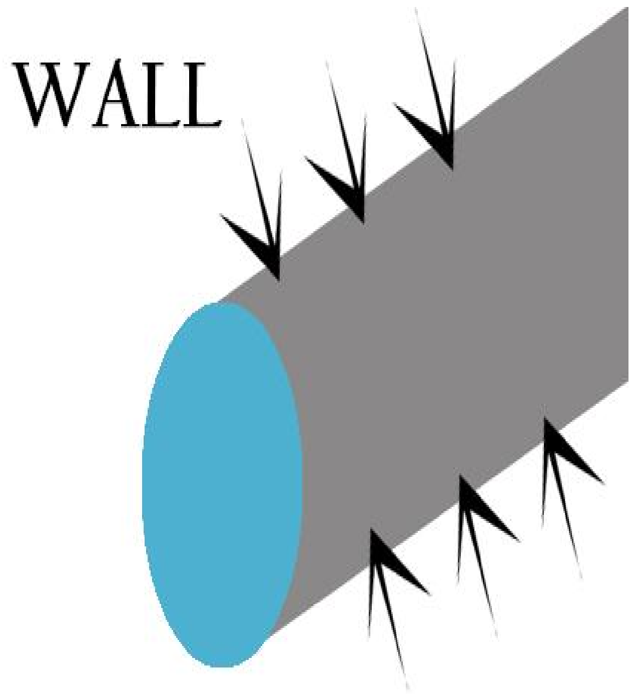
$E_{tan} = 0$ at the surface of the perfect conductors for all values of z and time.

i.e.

$E_y = 0$ at $x = 0$

$E_y = 0$ at $x = a$

for all values of z.



TE WAVES - ANALYSIS

Applying B.C (i)

$E_y = 0$ at $x = 0$

$$E_y^\circ = C_1 \sin 0 + C_2 \cos 0$$

$$E_y = C_2$$

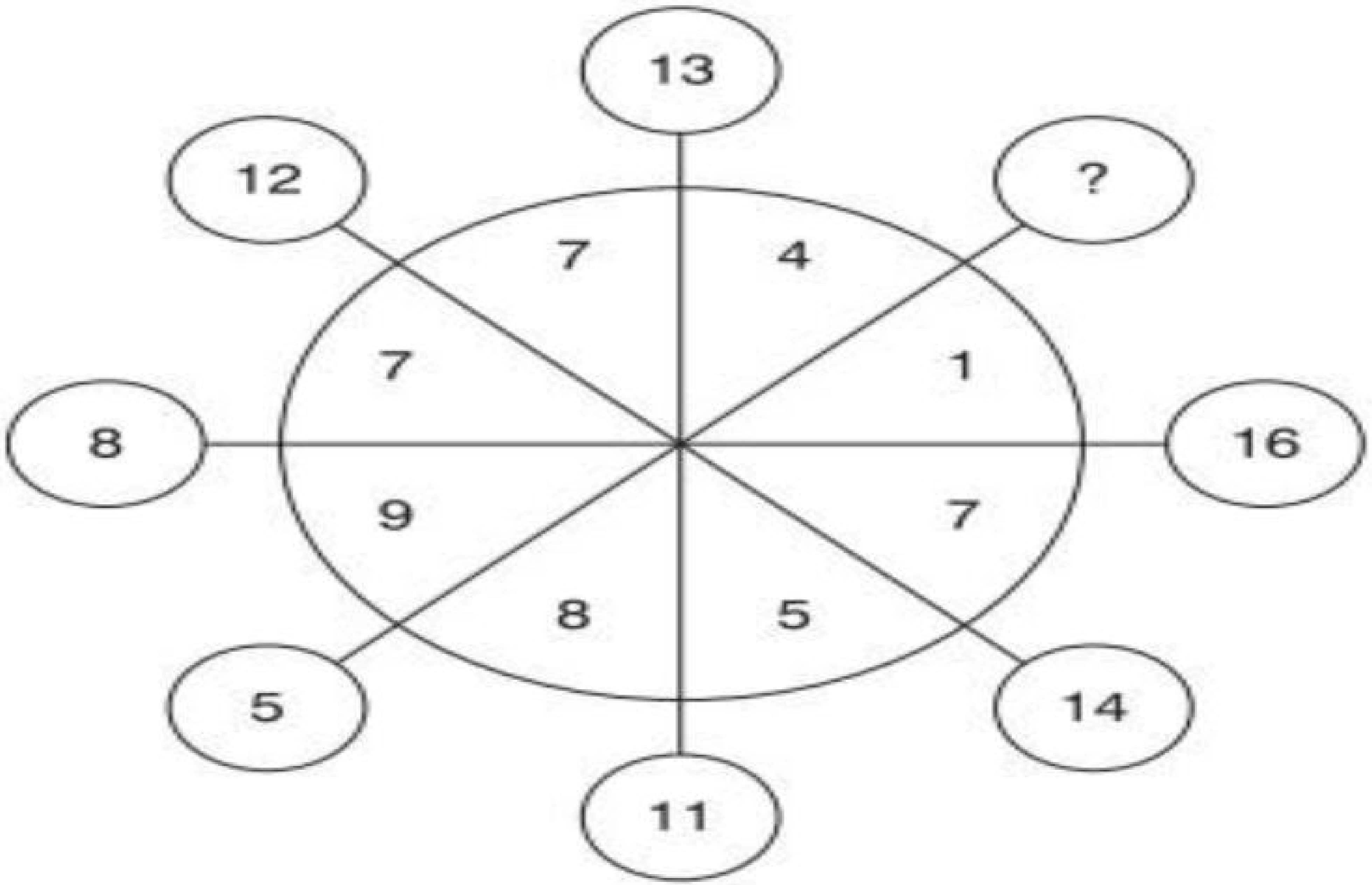
$\therefore$ C_2 must be zero to make $E_y = 0$ at $x = 0$

Then Eqn. (3) becomes,

$$E_y^\circ = C_1 \sin hx \rightarrow (4)$$

ACTIVITY

Find the number replaces the question mark



TE WAVES - ANALYSIS

Applying B.C (ii)

subs $E_y = 0$ at $x = a$ in eq (4)

$$E_y^{0} = C_1 \sin h x$$

To make $E_y = 0$, h must be equal to $\frac{m\pi}{a}$

$$\therefore h = \frac{m\pi}{a} \quad \text{for } m = 1, 2, 3 \ldots$$

$$\therefore E_y^{0} = C_1 \sin h \left(\frac{m\pi}{a}\right)$$

$$E_y = C_1 \sin h \left(\frac{m\pi}{a}\right) x \, e^{-\bar{\gamma} z} \longrightarrow (5)$$

TE WAVES - ANALYSIS

Other Fields Determination

$$\gamma E_y = -j\omega\mu H_x$$

$$H_x = \frac{-\gamma}{j\omega\mu} C_1 \sin\left(\frac{m\pi}{a}\right)x \, e^{-\gamma z} \rightarrow (b)$$

TE WAVES - ANALYSIS

$$H_z = -\frac{1}{j\omega\mu}\frac{\partial E_y}{\partial x}$$

$$H_z = \frac{-m\pi}{j\omega\mu a} C_1 \cos\left(\frac{m\pi}{a}\right) x\, e^{-\gamma z} \rightarrow (7)$$

TEmo wave (or) mode

In eqn (5), (6) & (7)

→ Each value of m specifies a particular field configuration (or) mode.

→ The associated wave is known as TEmo wave (or) TEmo mode.

TEmo MODE

$$H_z = -\frac{1}{j\omega\mu}\frac{\partial E_y}{\partial x}$$

$$H_z = \frac{-m\pi}{j\omega\mu a} C_1 \cos\left(\frac{m\pi}{a}\right)x\, e^{-\gamma z} \rightarrow (7)$$

<u>TEmo</u> wave (or) mode

In eqns (5), (6) & (7)

→ Each value of m specifies a particular field configuration (or) mode.

→ The associated wave is known as TEmo wave (or) TEmo mode.

TM WAVES - ANALYSIS

- For TM waves $H_z=0$
- Therefore H_x & $E_y = 0$ in the basic field equations
- E_z, E_x & H_y will have value

$$H_y = (C_3 \sin hx + C_4 \cos hx)$$

- The boundary condition can not be applied directly to H_y to evaluate C_3 & C_4
- Because H_{tan} is not equal to zero at the perfect conductor surface
- Therefore E_z is obtained in terms of H_y and then the boundary condition is applied to E_z

TM WAVES - ANALYSIS

- Boundary conditions are

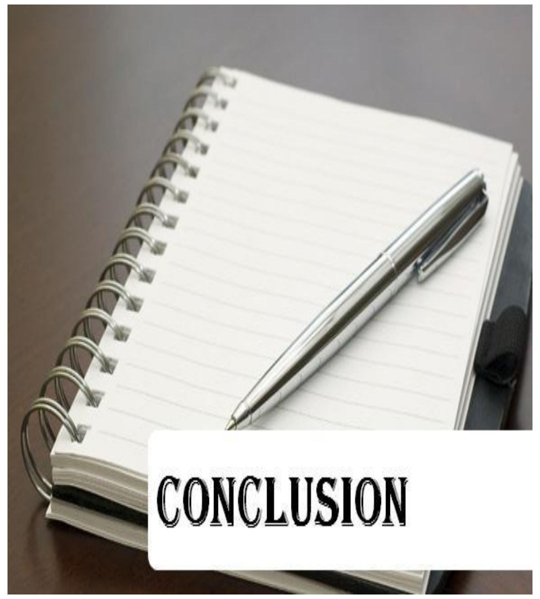
  Ez=0 at x=0 and x=a

  Ez=0 at y=0 and y=b

- After applying the B.C as for TE waves, we get

  C3=0 & h=mπ/a

TM WAVES - FIELDS



TM WAVE FIELDS

$$E_z = -\frac{m\pi}{a} \frac{C_4}{j\omega\varepsilon} \sin\left(\frac{m\pi}{a}\right) x \; e^{-\bar{\gamma} z}$$

$$H_y = C_4 \cos\left(\frac{m\pi}{a}\right) x \; e^{-\bar{\gamma} z}$$

$$E_x = \frac{\bar{\gamma}}{j\omega\varepsilon} C_4 \cos\left(\frac{m\pi}{a}\right) x \; e^{-\bar{\gamma} z}$$

subs $\bar{\gamma} = j\bar{\beta}$ for wave propagation.

ASSESSMENT

1. The wave in which the component of electric field is absent in the direction of propagation is known as -------
2. The wave in which the component of magnetic field is absent in the direction of propagation is known as -------
3. For waveguide propagation the value of the propagation constant is equal to -----------.
4. When the value of propagation constant is equal to attenuation constant, then it refers to ---------- wave propagation.
5. What is the boundary condition for a perfect conductor?

REFERENCES

- E.C. Jordan and K.G.Balmain "Electro Magnetic Waves and Radiating System, PHI,New Delhi, 2003
- John D Kraus and Daniel A Fleisch, "Electromagnetics with Applications", Mc Graw Hill Book Co, 2005.

THANK YOU