



# **SNS COLLEGE OF TECHNOLOGY**

**Coimbatore-35**  
**An Autonomous Institution**



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

## **DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING**

### **19ECT302 – TRANSMISSION LINES AND WAVE GUIDES**

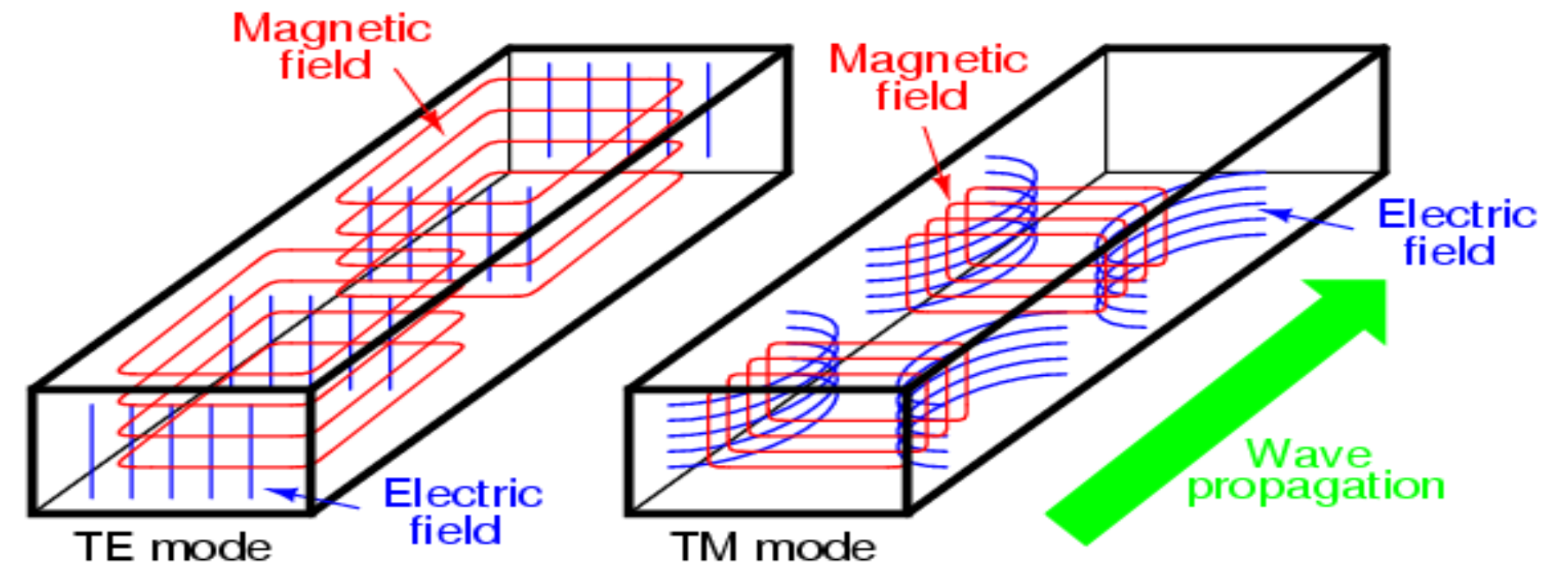
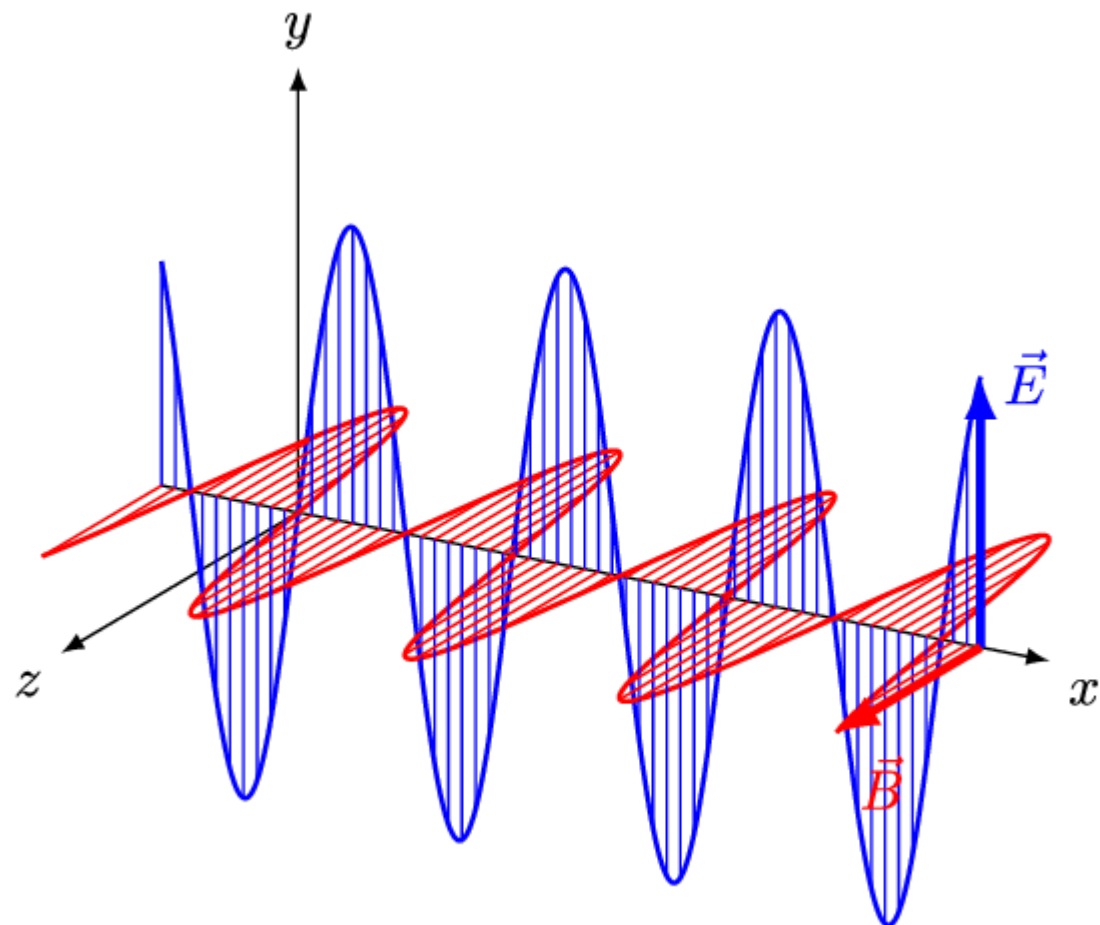
III YEAR/<sub>1</sub> V SEMESTER

#### **UNIT 3 – GUIDED WAVES**

#### **TOPIC 2 – TRANSVERSE ELECTRIC AND TRANSVERSE MAGNETIC WAVES**



# WHAT DO YOU RELATE FROM THIS ?



*Magnetic flux lines appear as continuous loops*  
*Electric flux lines appear with beginning and end points*



## 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  $H_z \neq 0$  [ $\therefore H_y$  &  $E_x = 0$ ]

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

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

The wave equation

$$\frac{\partial^2 E_y}{\partial x^2} + \frac{\partial^2 E_y}{\partial y^2} + \frac{\partial^2 E_y}{\partial z^2} = -\omega^2 \mu \epsilon E_y \quad \text{--- (1)}$$

$$\Delta \frac{\partial^2}{\partial z^2} = \gamma^2$$



# TE WAVES - ANALYSIS



Eq ① becomes ,

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

$$\frac{\partial^2 E_y}{\partial x^2} + h^2 E_y = 0 \quad [ \because h^2 = \bar{\nu}^2 + \omega^2 \mu \epsilon ]$$

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

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

ANALYSIS





# 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

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

$C_1$  &  $C_2$  determined from boundary conditions.

ANALYSIS





# EM WAVE PROPAGATION BETWEEN PARALLEL PLANES - ANALYSIS



Boundary condition

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

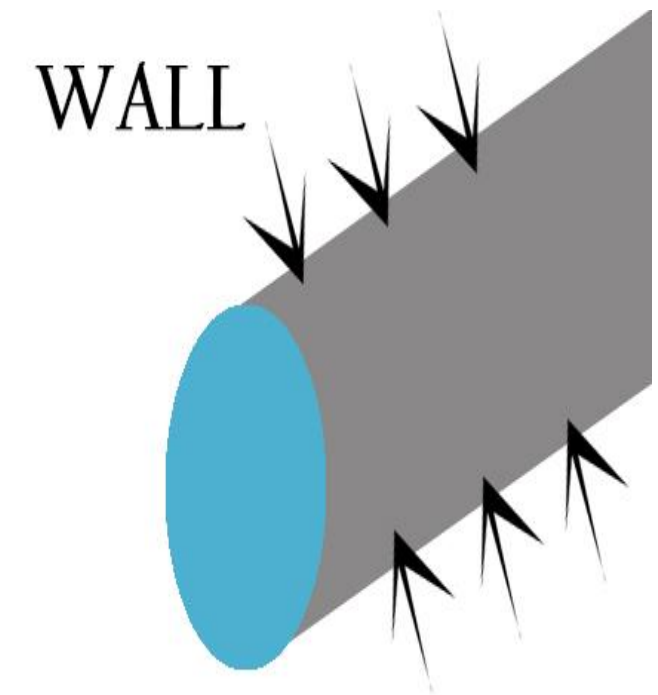
i

$$E_y = 0 \text{ at } x = 0$$

$$E_y = 0 \text{ at } x = a$$

for all values of  $z$ .

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## TE WAVES - ANALYSIS



Applying B.C (i)

$$E_y = 0 \text{ at } x = 0$$

$$E_y' = c_1 \sin 0 + c_2 \cos 0$$

$$E_y = c_2$$

$\therefore c_2$  must be zero to make  $E_y = 0$  at  $x = 0$

Then Eqn. (3) becomes,

$$E_y' = c_1 \sin hx \rightarrow (4)$$

ANALYSIS



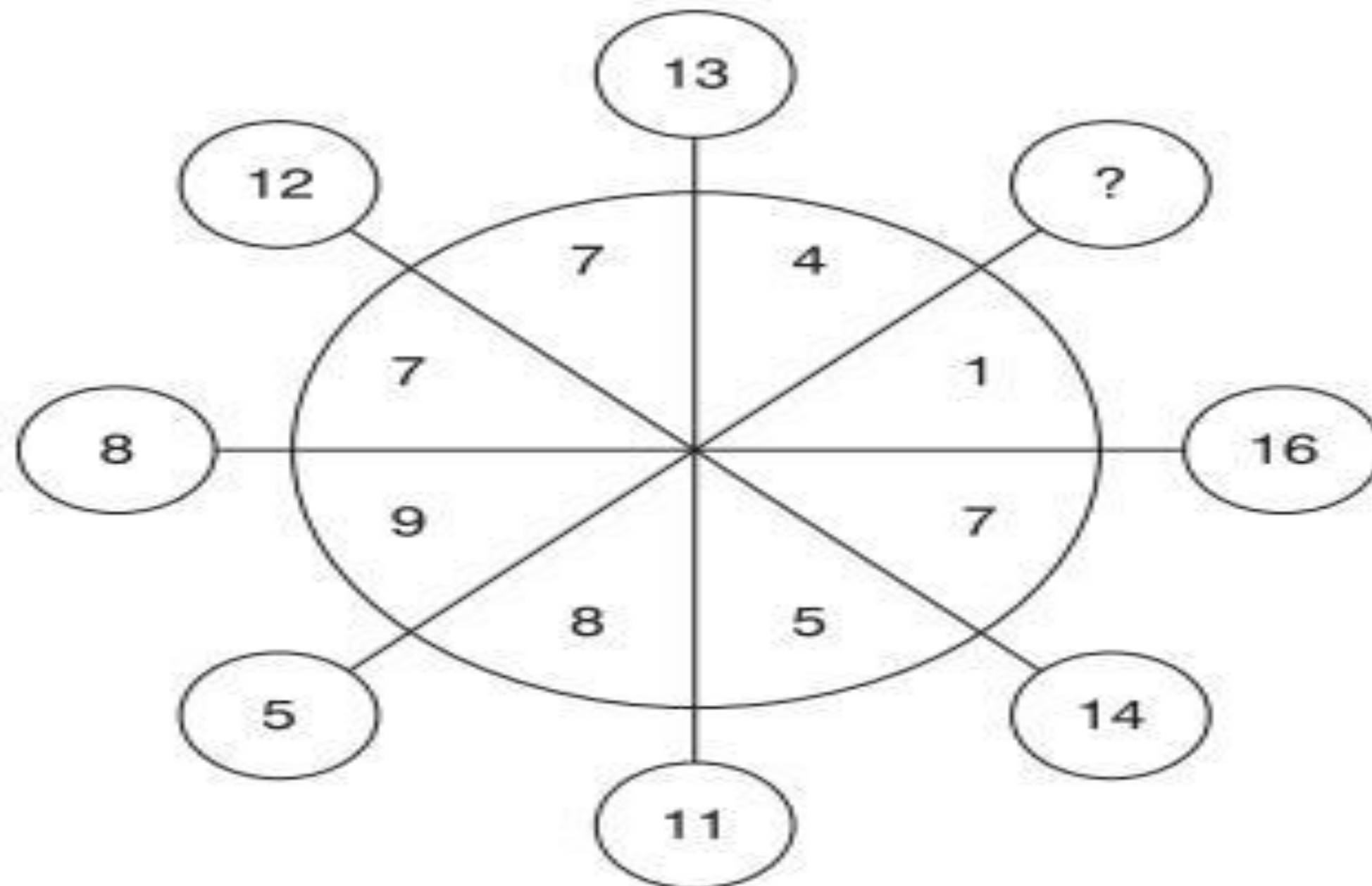




# ACTIVITY



Find the number replaces the question mark





# TE WAVES - ANALYSIS



Applying B.C (ii)

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

$$E_y^o = C_1 \sin h x$$

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

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

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

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

ANALYSIS





# TE WAVES - ANALYSIS



Other fields determination

$$\vec{\nabla} E_y = -j\omega\mu H_x$$

$$H_x = \frac{-\vec{\nabla}}{j\omega\mu} c_1 \sin\left(\frac{m\pi}{a}x\right) e^{-\vec{\nabla}z} \rightarrow \textcircled{b}$$

ANALYSIS





# TE WAVES - ANALYSIS



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

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

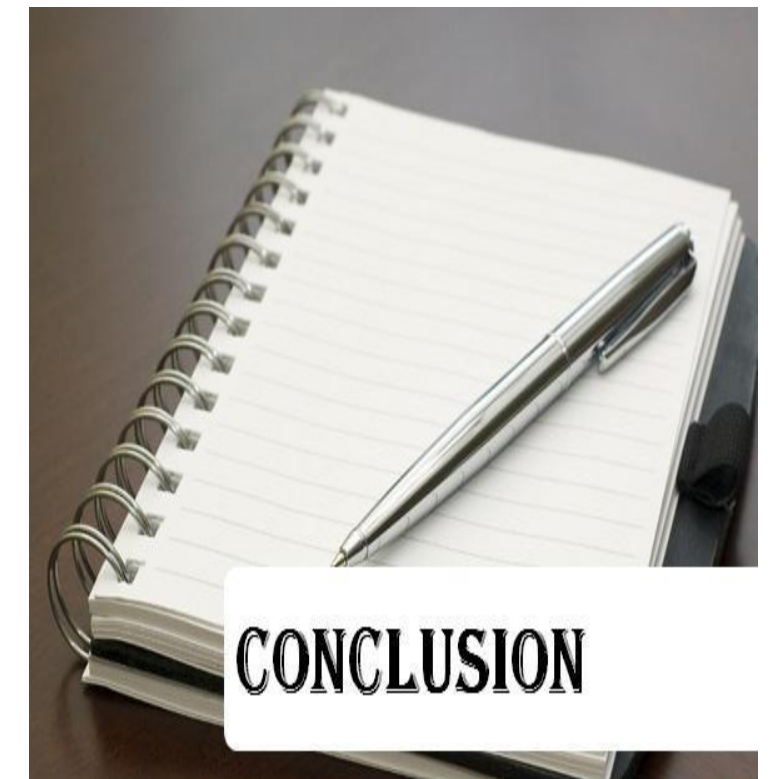
TE<sub>m0</sub> wave (or) mode

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

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

→ The associated wave is known as TE<sub>m0</sub> wave (or) TE<sub>m0</sub> mode.

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## TE<sub>m0</sub> MODE



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

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

TE<sub>m0</sub> wave (or) mode.

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

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

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## 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

$$H_y = (C_3 \sinh x + C_4 \cosh x)$$

- 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  
 $E_z=0$  at  $x=0$  and  $x=a$   
 $E_z=0$  at  $y=0$  and  $y=b$
- After applying the B.C as for TE waves, we get  
 $C_3=0$  &  $h=m\pi/a$



# TM WAVES - FIELDS



## TM WAVE FIELDS

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

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

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

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