2.5 Polarization of EM Waves

Tuesday, October 24, 2023 2:15 PM

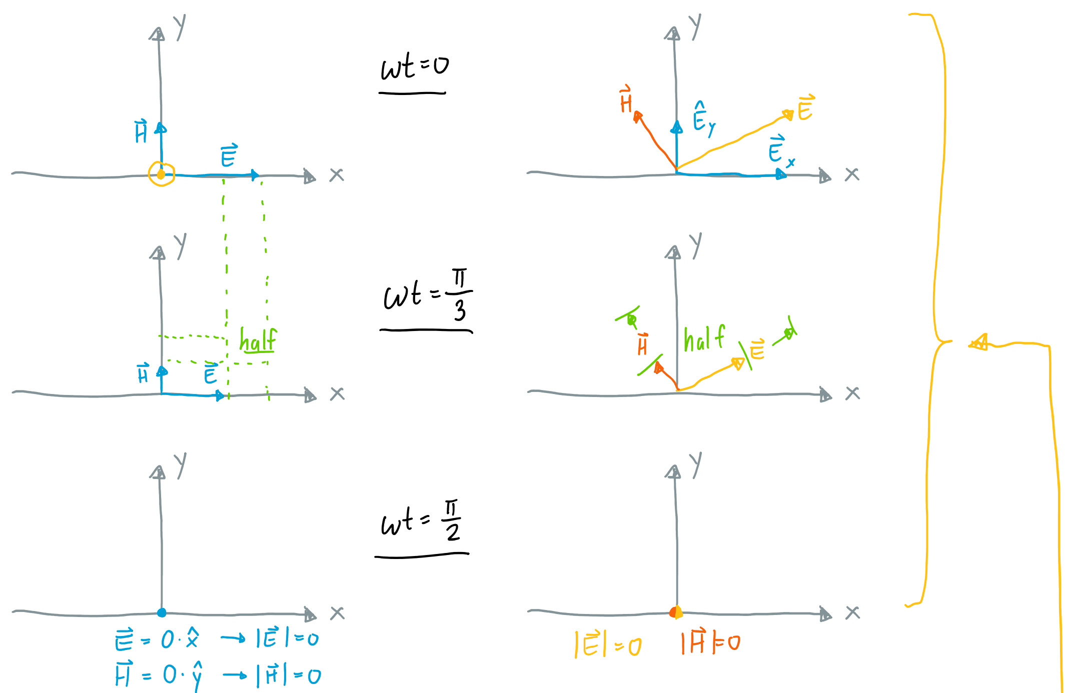
Basic Wave Polarization – Linear Polarization

$$\vec{E}(z,t) = \mathrm{Re}\left(E_x e^{j\omega t} e^{-j\beta z},\ 0,\ 0\right) = E_x \cos(\omega t - \beta z)\,\hat{x}$$

$$\vec{H}(z,t) = \mathrm{Re}\left(0,\ \frac{E_x}{\eta} e^{j\omega t} e^{-j\beta z},\ 0\right) = \frac{E_x}{\eta} \cos(\omega t - \beta z)\,\hat{y}$$

Snapshots In-phase:

- All figures: $z=0$, $\omega t = 0, \frac{\pi}{3}, \frac{\pi}{2}$



$$\vec{E}(z,t) = \mathrm{Re}\left(E_x e^{j\omega t} e^{-j\beta z},\ E_y e^{j\omega t} e^{-j\beta z},\ 0\right) = E_x \cos(\omega t - \beta z)\,\hat{x} + E_y \cos(\omega t - \beta z)\,\hat{y}$$

$$\vec{H}(z,t) = \mathrm{Re}\left(-\frac{E_y}{\eta} e^{j\omega t} e^{-j\beta z},\ \frac{E_x}{\eta} e^{j\omega t} e^{-j\beta z},\ 0\right) = \frac{E_x}{\eta} \cos(\omega t - \beta z)\,\hat{y} + \frac{E_y}{\eta} \cos(\omega t - \beta z)\,\hat{x}$$

Basic Wave Polarization – Circular Polarization

$$\vec{E}(z,t) = E_x \cos(\omega t - \beta_z)\,\hat{x} + E_y \cos(\omega t - \beta_z + \phi)\,\hat{y} \qquad [z=0, E_x = E_y]$$

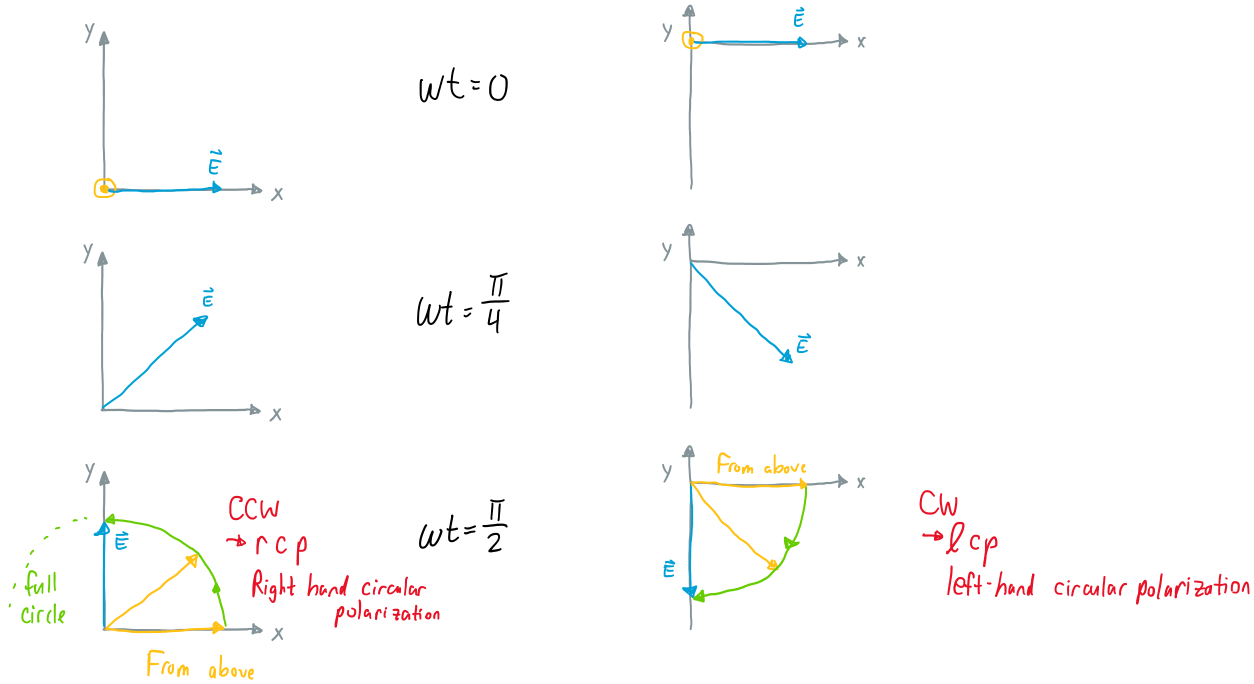
$$= E_x \cos(\omega t)\,\hat{x} + E_x \cos(\omega t + \phi)\,\hat{y}$$

Snapshots:

Snapshots:

- $E_x \cos(\omega t)\,\hat{x} + E_y \sin(\omega t)\,\hat{y}$
- $\phi = -\frac{\pi}{2}$

- $E_x \cos(\omega t)\,\hat{x} - E_y \sin(\omega t)\,\hat{y}$
- $\phi = +\frac{\pi}{2}$



Identify the polarization of the following field descriptions:

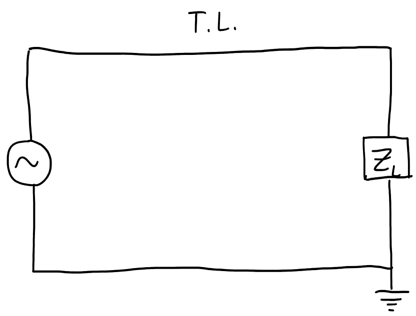
Q1 $\vec{E}(z,t) = E_0\left(\cos(\omega t + \beta z)\,\hat{x} + \sin(\omega t + \beta z)\,\hat{y}\right)$ circular

Q2 $\vec{H}(z,t) = H_x \sin(\omega t - \beta z)\,\hat{x} + H_y \sin(\omega t - \beta z)\,\hat{y}$ linear

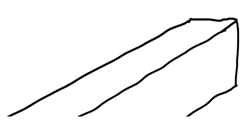
Q3 $\vec{E}(z,t) = E_0\left(\cos(\omega t + \beta z)\,\hat{x} - \cos(\omega t + \beta z + \frac{\pi}{2})\,\hat{y}\right)$ circular

In-class 10/27/23

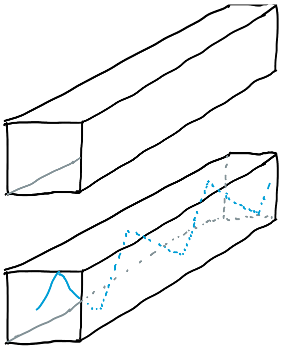
Why can't a (closed) rectangular waveguide (with perfect conductivity) accept TEM waves.
(Also can't for circular waveguides)



The T.L. has 2 conductors.



This waveguide has 1 conductor



This waveguide has 1 conductor

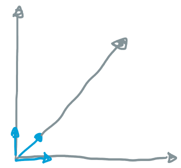
No potential difference at the ends

TEM cannot exist here.

Only either TE or TM waves

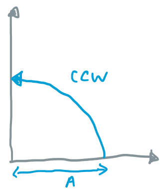
Polarization

$$E_x = A_x e^{j\omega t}$$
$$E_y = A_y e^{j\omega t}$$
$\longrightarrow$



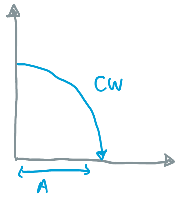
90° out of phase:

$$E_x = A \cos \omega t$$
$$E_y = A \sin \omega t$$
$$\vec{E} = A \cos \omega t \, \hat{x} + A \sin \omega t \, \hat{y}$$
$$= A(\cos \omega t \, \hat{x} + \sin \omega t \, \hat{y})$$



−90° out of phase

$$\vec{E} = A \cos \omega t \, \hat{x} - A \sin \omega t \, \hat{y}$$
$$= A(\cos \omega t \, \hat{x} - \sin \omega t \, \hat{y})$$



In-class 11/01/2023

> In IMAX, they use two projectors, one vertical & one horizontally polarized. Each goes to a different eye, letting you see in 3D.

> When you tilt your head 45°, the images get distorted as images from both projectors get into your eyes. How do you adjust to reduce this sensitivity to still see in 3D?

> Use the concept of rotation & circular polarization

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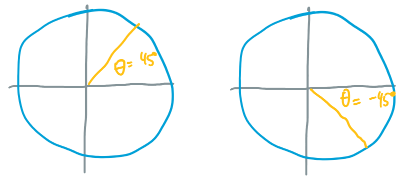
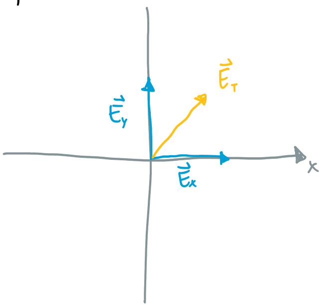
> 4 projectors — vertical, horizontal, 45°, −45°

Circular Circular



- Elliptical Polarization



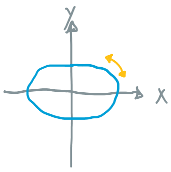
$\vec{E}_T = \vec{E}_x + \vec{E}_y$

$\vec{E}_x + \vec{E}_y$ equal magnitude, in-phase

→ Linear

equal magnitude, out of phase 90°

→ Circular



unequal magnitude, out of phase 90°

→ Rectangular Ellipse (L or R - handed)

$$\vec{E} = A(\cos \omega t \ \hat{i} + \sin \omega t \ \hat{j}) \qquad \text{circular}$$

$$= A_1 \cos \omega t \ \hat{i} + A_2 \sin \omega t \ \hat{j} \qquad \text{rectangular ellipse}$$

$$= A \cos \omega t \ \hat{i} + A \sin(\omega t + \phi) \ \hat{j} \qquad \text{skewed-angle ellipse}$$