POLARIZATION

16.1 Linearly-polarized and circularly-polarized light
Pattern of electromagnetic radiation from a dipole

AM radio tower

$AM \text{ radio wave} \quad f = 1 \text{MHz}$

$\lambda = \frac{c}{f} = \frac{3 \times 10^8 \text{m/s}}{1 \times 10^6 \text{Hz}} = 300 \text{ m}$

(Works better when the antenna's length $L = \frac{\lambda}{2}$)

Half of the antenna buried in the ground allows building the device $\frac{1}{4} \lambda \sim 75 \text{ m tall}$)
Linearly polarized light

Oscillation of the electric field remains parallel to a fixed line in space.

Three different cases of linearly polarized light:
Description of linearly polarized light

\[ \vec{E} = E_x \hat{x} + E_y \hat{y} \]

Electrified field that exists at a fixed position \( z = z_0 \)

If \( E_x = E_m \cos(\omega t) \)

\[ E_y = E_m \cos(\omega t) \]

Indicate how the orientation and magnitude of the electric field changes as a function of time:

At \( t = 0 \)

\[ E_x \]

\[ E_y \]

\[ E_m \]
Notice, \( E_x \) and \( E_y \) are in phase.

\[ \mathbf{E}(t) = ? \]
Alternative description of linearly polarized light using phasors

\[ E_x = E_m \cos(\omega t) \]

...can be graphically represented as the horizontal component of a phasor.

the rotating radius and its associated angle together constitute a **phasor**
\[ E_x = E_m \cos(\omega t) = E_x(t) \]
\[ E_y = E_m \cos(\omega t) = E_y(t) \]

Notice, the phasors are referenced to two different axes, respectively.
Circularly polarized light

Left-circularly polarized light

Task:

Given

\[
E_x = E_m \cos(\omega t) \quad E_y = E_m \cos(\omega t - \frac{\pi}{2})
\]

indicate how the orientation and magnitude of the electric field vector changes as a function of time
Electric field vector rotates counter-clockwise with angular velocity $\omega$ when looking along the direction in which the wave propagates and into the source. Left circularly polarized light.
Alternative description of left-circularly polarized light using phasors

\[ E_x = E_m \cos(\omega t) \]
\[ E_y = E_m \cos(\omega t - \frac{\pi}{2}) \]

Notice, both phasors and the electric field rotate together counterclockwise.
Right-circularly polarized light

\[ \vec{E} = E_x \hat{x} + E_y \hat{y} \]
Electric field vector at a fixed position \( t = 20 \)

\[
\begin{align*}
E_x &= E_m \cos(\omega t) \\
E_y &= E_m \cos(\omega t + \frac{\pi}{2})
\end{align*}
\]

Given

Task:
Indicate how the orientation and magnitude of the electric field vector \( \vec{E} \) changes as a function of time:

\[ \vec{E} \quad t = 0 \]
Electric field vector rotates clockwise with angular velocity $\omega$ when looking along the direction in which the wave propagates and into the source.

Right circularly polarized light
Alternative description of right-circularly polarized light using phasors

\[ E_x = E_m \cos (\omega t) \]
\[ E_y = E_m \cos (\omega t + \frac{\pi}{2}) \]

we create two phasors

An extra simplification step is possible. Indeed, since COS is a symmetric function, the mathematical expressions for \(E_x\) and \(E_y\) given above can be re-written as:
\[ E_x = E_m \cos(-\omega t) \]
\[ E_y = E_m \cos(-\omega t - \frac{\pi}{2}) \]

we create two phasors

Right circularly polarized light

this time both phasors and the electric field rotate together clockwise
Summary

\[ E_x = E_m \cos(\omega t) \]
\[ E_y = E_m \cos(\omega t - \frac{\pi}{2}) \]

Left circularly polarized

\[ \vec{E} = E_x \hat{x} + E_y \hat{y} \]

\[ E_x = E_m \cos(\omega t) \]
\[ E_y = E_m \cos(\omega t + \frac{\pi}{2}) \]

Right circularly polarized
Observer looks along the direction of wave propagation AND into the light source.