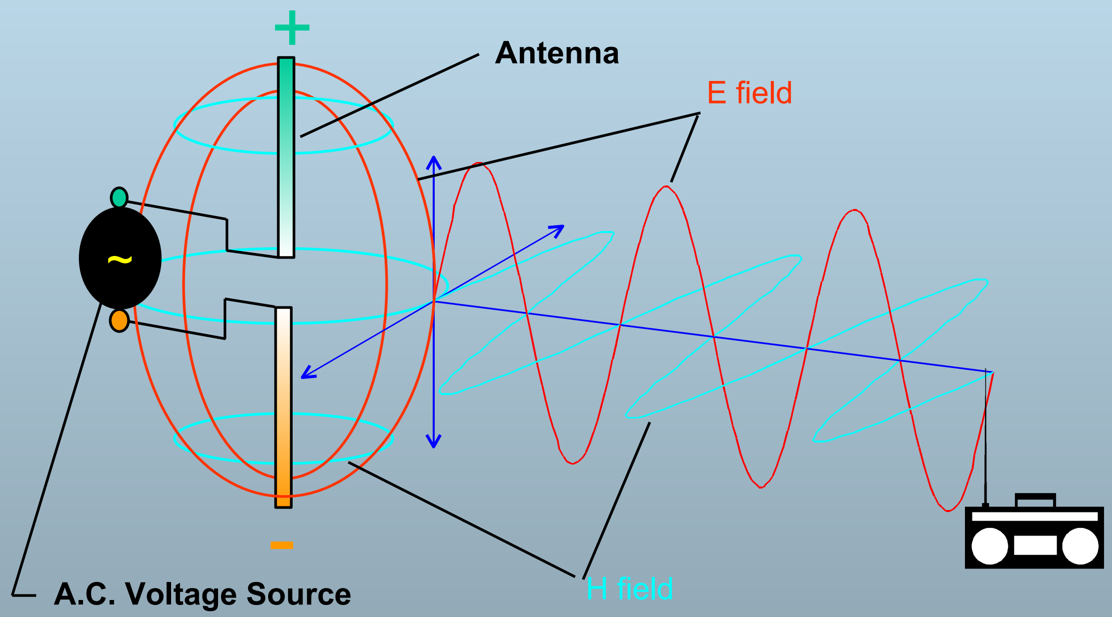
Electricity and Magnetic Fields

- ✓ Generation of EM Waves

Learning Objectives in Electromagnetic Wave Propagation

1. **Appreciate the two components of an electromagnet wave and how they may be generated.**
2. **Appreciate the range of wavelengths and their uses in the electromagnet spectrum.**
3. **Observe the attenuation of the wave due to distance and absorbing medium.**
4. **Observe the mathematical form of the propagating wave equation and the relationship between x, t, λ, η, f and c.**
5. **Learn how to calculate the phase velocity.**
6. **Learn applications to communications.**

Generation of EM Waves



The instantaneous E and H fields correspond to the instantaneous current and electric dipole.
As the charge in the antenna oscillates in time so does the EM wave oscillate and propagate.
The speed of propagation or phase velocity is equal to:

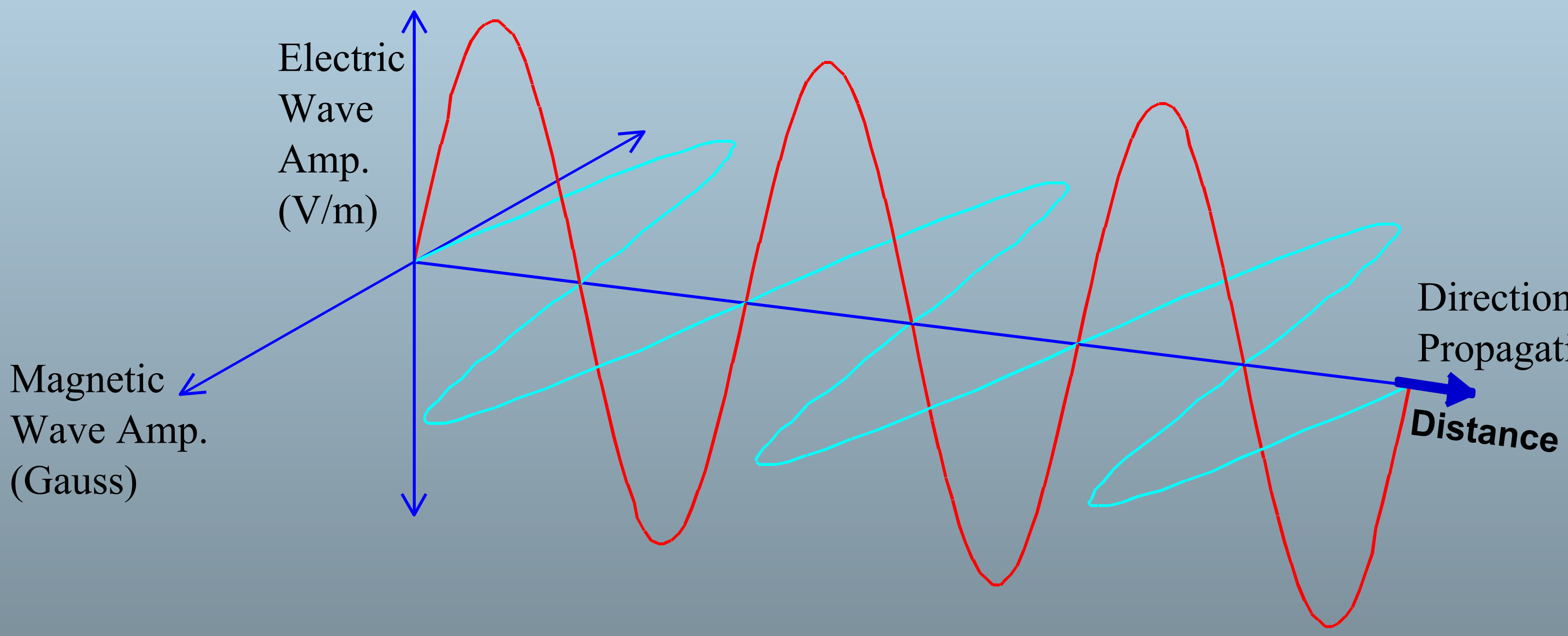
$$\frac{1}{\sqrt{\varepsilon_0 \mu_0}}$$

ε_0 = permittivity of free space

μ_0 = permeability of free space

This is the velocity of light in free space.

Components of an Electro-magnetic Plane Polarized, Plane Wave in Free Space

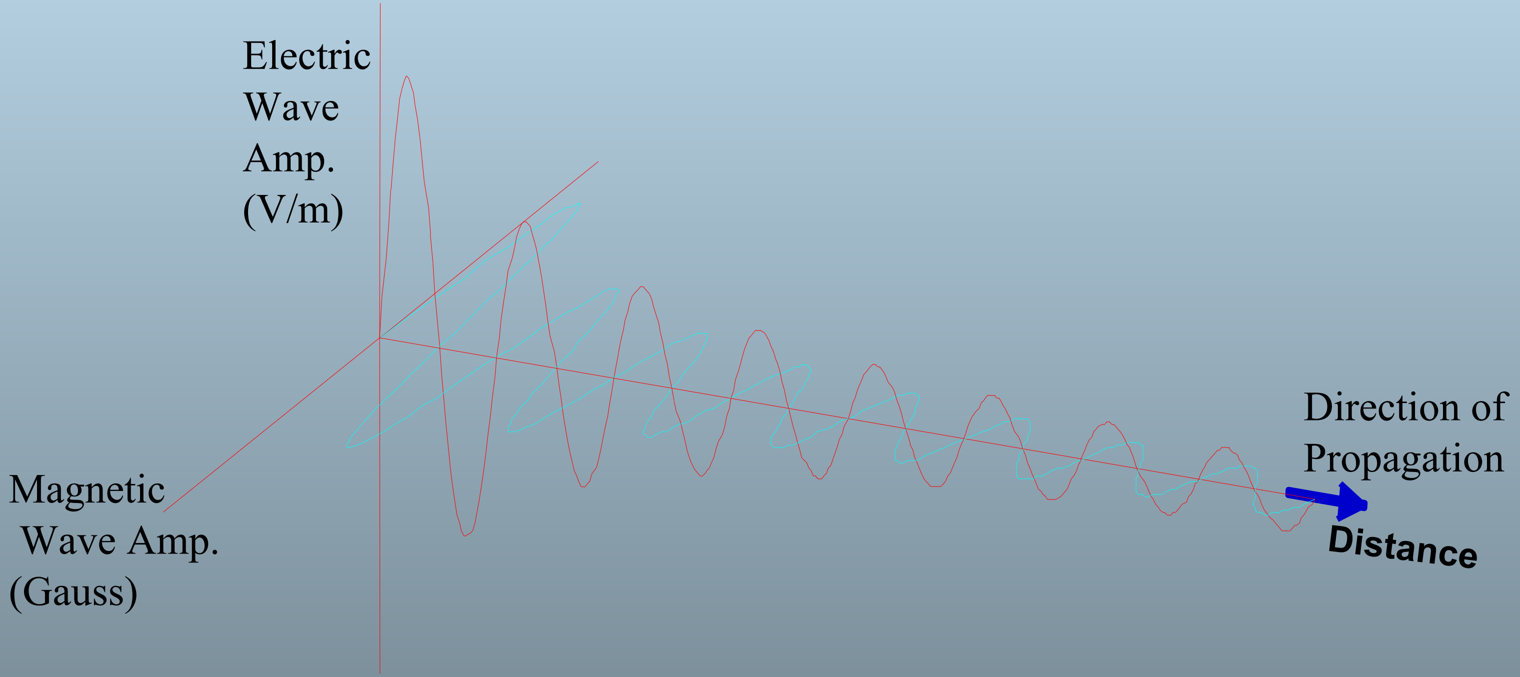


The Electric Wave is responsible for the most pronounced optical effects.

Power = $(1/\mu)\, E * B$

$E_m/B_m = c_m$

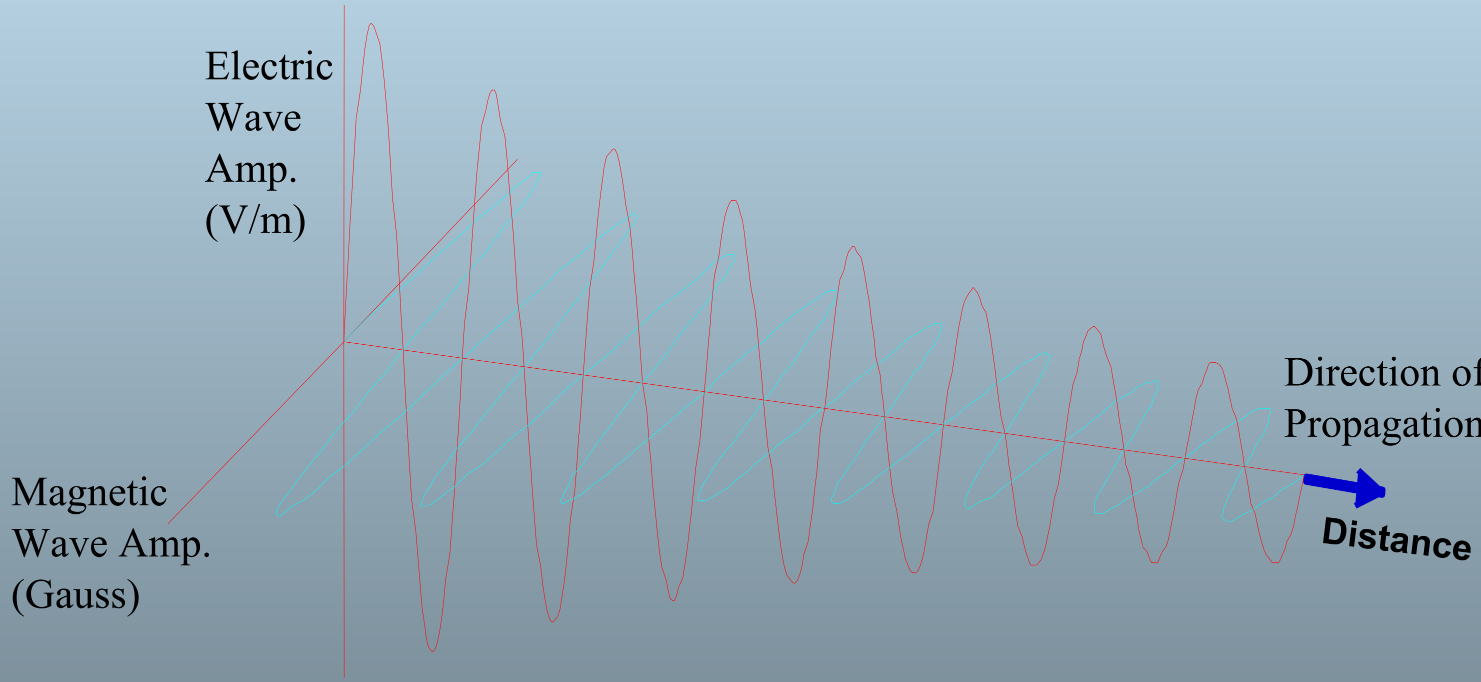
Components of an Electro-magnetic Plane Polarized, Spherical Wave in Free Space



Amplitude is inversely proportional to distance, therefore:

$$\text{Power} \propto \frac{1}{\text{distance squared}}$$

Components of an Electro-magnetic Plane Polarized, Plane Wave in Absorbing Medium



Beers Law:

$$E = E(0)\, e^{-k(f)*x}$$

$$\text{Power} = P(0)\, e^{-2k(f)*x}$$

The General Linear Wave Equation

$$\frac{\partial^2 y}{\partial x^2} = \frac{1}{v^2} * \frac{\partial^2 y}{\partial t^2}$$

Maxwell developed the theory of electromagnetism which culminated in the following two equation:

$$\frac{\partial^2 E}{\partial x^2} = \mu * \varepsilon * \frac{\partial^2 E}{\partial t^2} \quad \text{and} \quad \frac{\partial^2 B}{\partial x^2} = \mu * \varepsilon * \frac{\partial^2 B}{\partial t^2}$$

These two equations are the same form as the General Wave Equation and can be satisfied by

$$E(x,t) = E_0 \sin\left\{2\pi\left(\frac{x}{\lambda} - ft\right)\right\} \quad \text{and} \quad B(x,t) = B_0 \sin\left\{2\pi\left(\frac{x}{\lambda} - ft\right)\right\}$$

respectively , if $v = \frac{1}{\sqrt{\mu * \varepsilon}}$, **which is the phase velocity of a propagating wave.**

Hence: $v = \frac{c_0}{\eta}$ **and** $c_0 = \frac{1}{\sqrt{\varepsilon_0 * \mu_0}}$

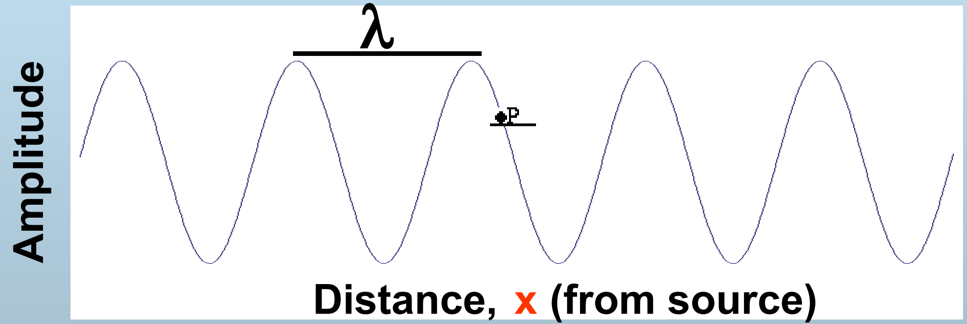
where c_0 is the phase velocity of electromagnetic waves in free space.

Equation for a Propagating Wave

With time, t, fixed:

$$y = A \sin\{ 2\pi x / \lambda \}$$

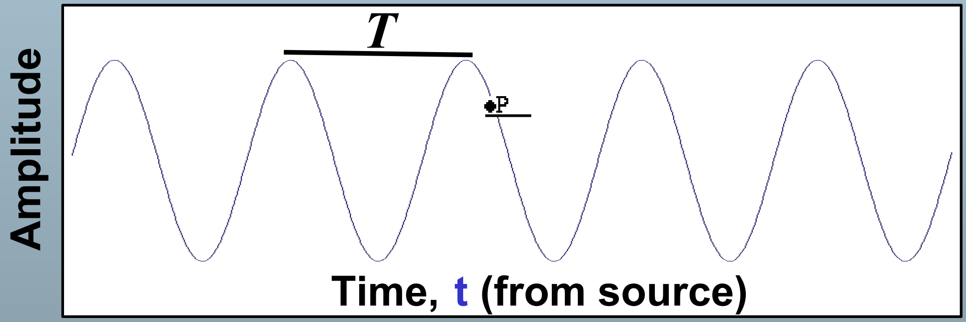
(λ = wavelength)



With distance, x, fixed:

$$y = A \sin\{ 2\pi t / T \}$$

(T = period = 1/ frequency)



The combination of the above two equations is a solution to the wave equation and gives the equation for a propagating wave:

$$y = A \sin\{ 2\pi [x/\lambda - t/T] \} = A \sin\{ 2\pi [x/\lambda - f^*t] \}$$

Phase velocity = λ f = velocity of any point P = c_0/η

Spanish

English

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Show Simulation