Plane Electromagnetic Wave

Electromagnetic Waves

- Mechanical waves require the presence of a medium.
- Electromagnetic waves can propagate through empty space.
- Maxwell's equations form the theoretical basis of all electromagnetic waves that propagate through space at the speed of light.
- Hertz confirmed Maxwell's prediction when he generated and detected electromagnetic waves in 1887.
- Electromagnetic waves are generated by oscillating electric charges.
  - The waves radiated from the oscillating charges can be detected at great distances.
- Electromagnetic waves carry energy and momentum.
- Electromagnetic waves cover many frequencies.

Plane Electromagnetic Waves

We will assume that the vectors for the electric and magnetic fields in an electromagnetic wave have a specific space-time behavior that is consistent with Maxwell's equations.

Assume an electromagnetic wave that travels in the x direction with $\vec{\mathbf{E}}$ and $\vec{\mathbf{B}}$ as shown.

The x-direction is the *direction of propagation.*

The electric field is assumed to be in the y direction and the magnetic field in the z direction.
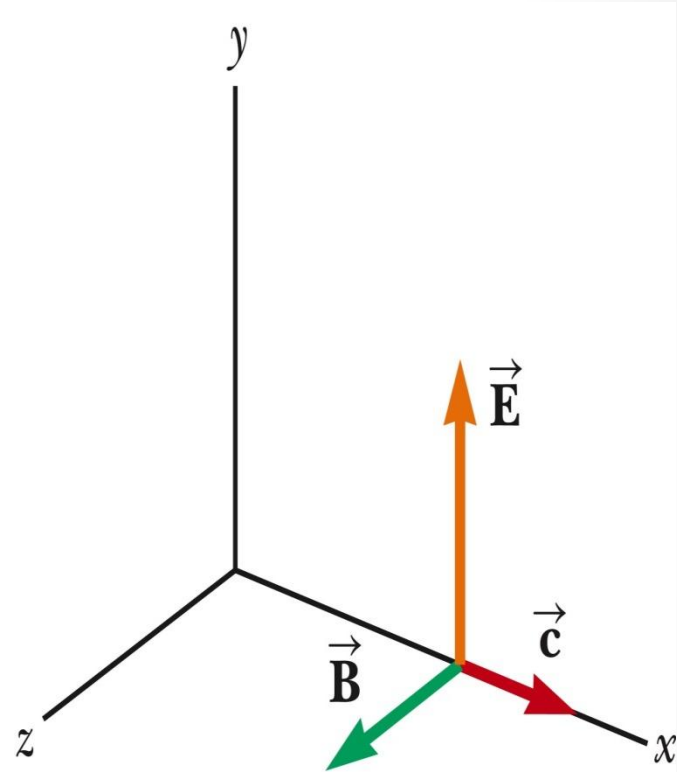
Plane Electromagnetic Waves, cont.

Waves in which the electric and magnetic fields are restricted to being parallel to a pair of perpendicular axes are said to be *linearly polarized waves.*
We also assume that at any point in space, the magnitudes E and B of the fields depend upon x and t only.

Properties of em Waves

The solutions of Maxwell's third and fourth equations are wave-like, with both *E* and *B* satisfying a wave equation.
Electromagnetic waves travel at the speed of light:

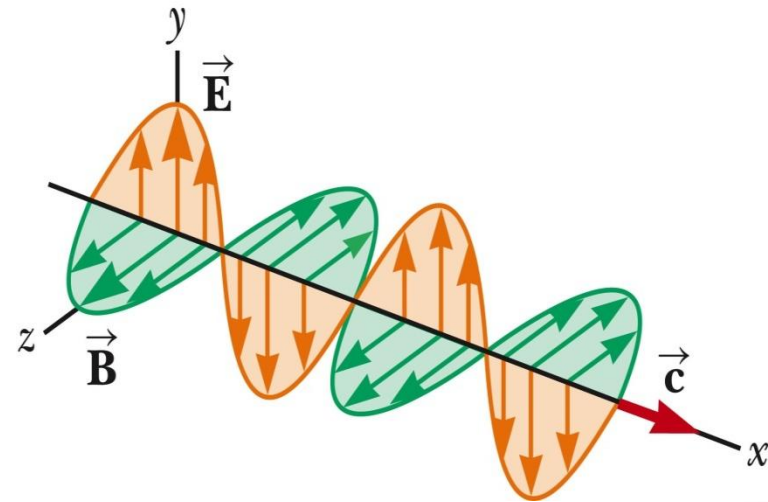$$c = \frac{1}{\sqrt{\mu_o \varepsilon_o}}$$

This comes from the solution of Maxwell's equations.

Properties of em Waves

The components of the electric and magnetic fields of plane electromagnetic waves are perpendicular to each other and perpendicular to the direction of propagation.

This can be summarized by saying that electromagnetic waves are transverse waves.

The figure represents a sinusoidal em wave moving in the x direction with a speed c.

Properties of em Waves

The magnitudes of the electric and magnetic fields in empty space are related by the expression:

$$c = \frac{E}{B}$$

This comes from the solution of the partial differentials obtained from Maxwell's equations.

Electromagnetic waves obey the superposition principle.