THE UNIVERSITY OF UTAH

ATMOS 5140

Lecture 2 – Chapter 2

- Properties of Radiation
    - Nature of Electromagnetic Radiation
    - Frequency
    - Polarization
    - Energy
    - Maxwell’s Equations

Frequency

Wavelenth: $\lambda = \frac{c}{\nu}$

Where:

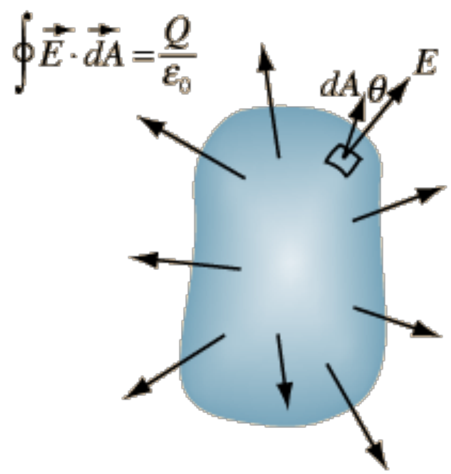
c = speed of light

υ = frequency

For EM radiation – you can track the propagation of each frequency component completely separately from another

Gauss's Law of Electric field

- Relates the distribution of electric charge to the resulting electric field
- The total of the electric flux out of a closed surface is equal to the magnitude of the charge enclosed divided by the permittivity of free space



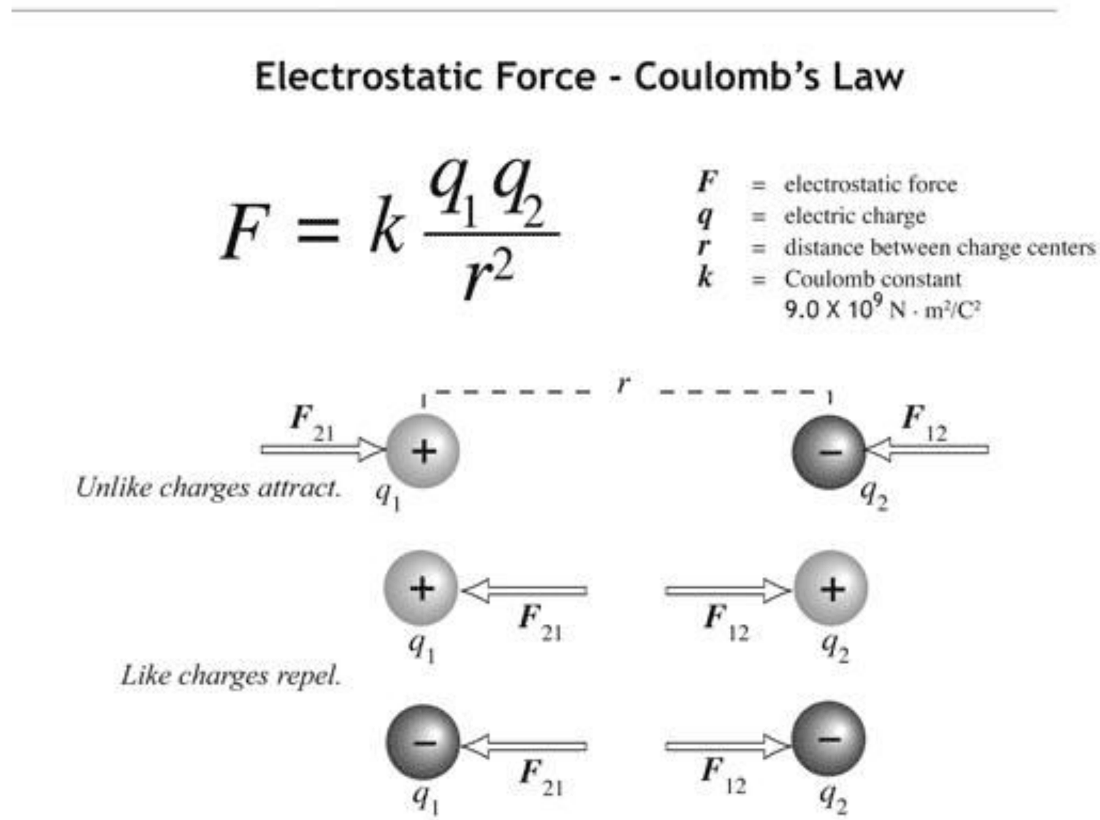
- Used to derive Coulomb's Law

Coulomb’s Law

The magnitude of the electrostatic force of interaction between two point charges is directly proportional to

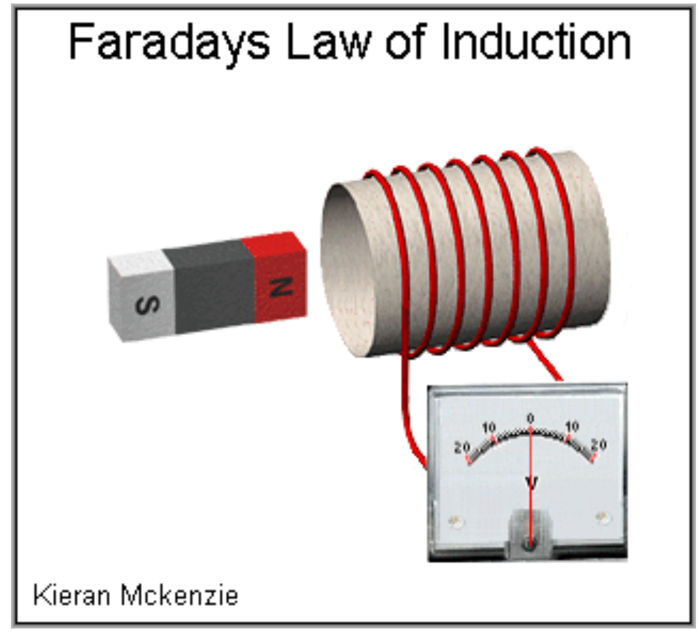
the scalar multiplication of the magnitudes of charges

and inversely proportional to the square of the distance between them



Faraday’s Law

- Magnetic fields are determined by the distribution of electric current
- In other words, changing magnetic fluxes through coiled wires generate electricity (currents and voltage).
- In other words, the induced electricity is proportional to the change in magnetic flux, so the greater the change is the more electricity generated

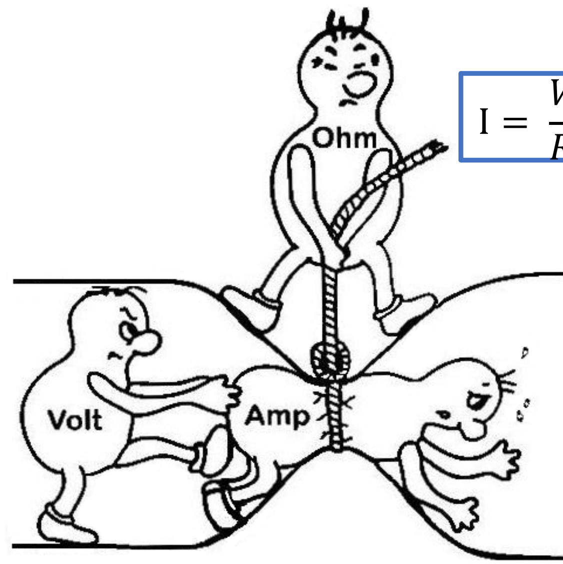


Ohm's Law

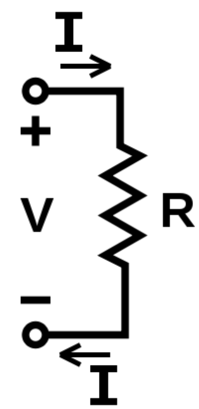
- Current through a conductor between two points is directly proportional to the voltage across the two points.

$$J = \sigma E$$

where J is the current density at a given location in a resistive material, E is the electric field at that location, and σ (Sigma) is a material-dependent parameter called the conductivity.

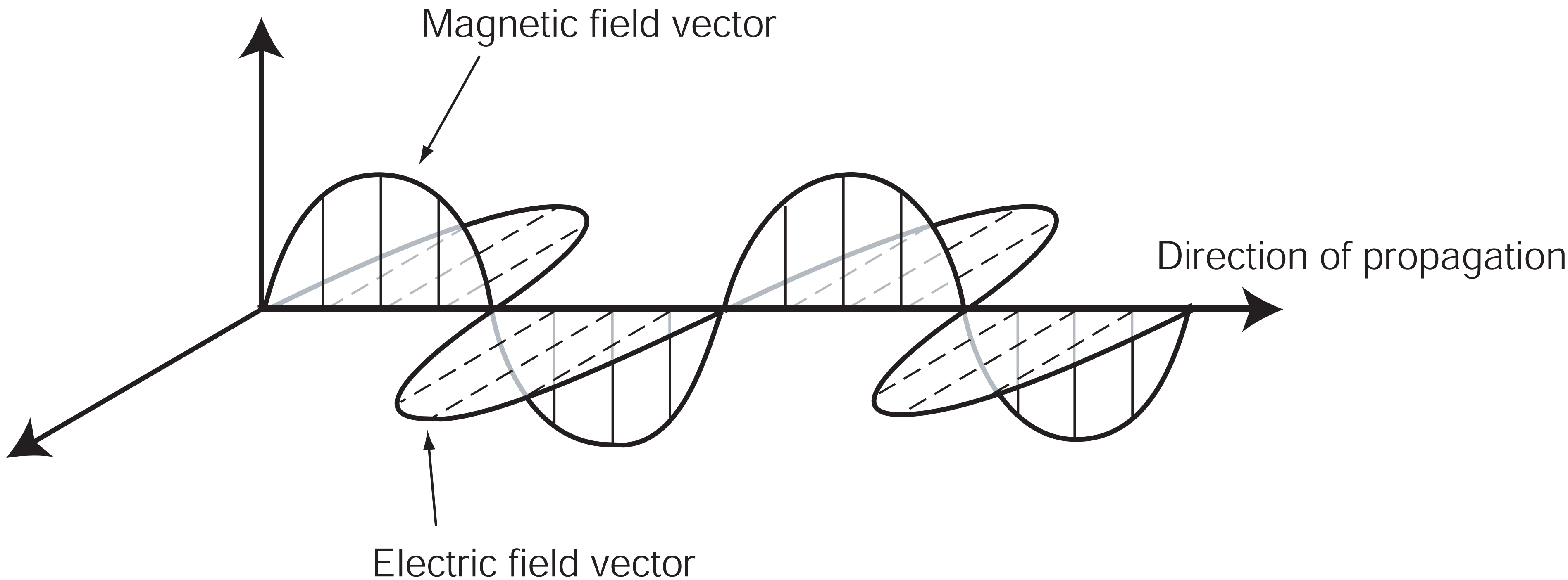


$$I = \frac{V}{R}$$



Maxwell’s Equations

- Changing electric field induces a magnetic field
- Changing magnetic field induces an electric field
- Does not need material medium (vacuum works)
- Quantitative Interplay described by Maxwell’s Equations


Magnetic field vector
Direction of propagation
Electric field vector

Maxwell's Equations

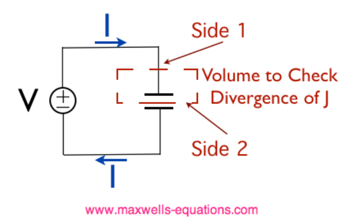
D = Electric displacement
E = Electric field
B = Magnetic induction
H = Magnetic field
J = Electric Current
ρ_V = density of electric charge

1. $\nabla \cdot \mathbf{D} = \rho_V$ — Gauss's Law of Electric Field

2. $\nabla \cdot \mathbf{B} = 0$ — Gauss's Law of Electric Field

3. $\nabla \times \mathbf{E} = -\dfrac{\partial \mathbf{B}}{\partial t}$ — Faraday's Law

4. $\nabla \times \mathbf{H} = \dfrac{\partial \mathbf{D}}{\partial t} + \mathbf{J}$ — Ampere's Law and Maxwell's addition of displacement current density



Maxwell's Equations

D = Electric displacement
E = Electric field
B = Magnetic induction
H = Magnetic field
J = Electric Current

$$\mathbf{D} = \varepsilon \mathbf{E} \qquad \mathbf{B} = \mu \mathbf{H} \qquad \mathbf{J} = \sigma \mathbf{E}$$

$\varepsilon = permittivity\ of\ space$
$\mu = magnetic\ permeability\ of\ the\ medium$
$\sigma = conductivity\ of\ medium$

Maxwell's Equations

D = Electric displacement
E = Electric field
B = Magnetic induction
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J = Electric Current
ρ_V = density of electric charge

1. $\nabla \cdot \mathbf{D} = \rho_V$
2. $\nabla \cdot \mathbf{B} = 0$
3. $\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$
4. $\nabla \times \mathbf{H} = \frac{\partial \mathbf{D}}{\partial t} + \mathbf{J}$

1. $\nabla \cdot \mathbf{E} = \frac{\rho_V}{\varepsilon}$
2. $\nabla \cdot \mathbf{H} = 0$
3. $\nabla \times \mathbf{E} = -\mu \frac{\partial \mathbf{H}}{\partial t}$
4. $\nabla \times \mathbf{H} = \varepsilon \frac{\partial \mathbf{E}}{\partial t} + \sigma \mathbf{E}$

Maxwell's Equations

- https://www.youtube.com/watch?v=kGia0ngFq0o

Maxwell's Equations for plane waves

The fundamental equations that describe electromagnetic radiation are Maxwell's equations. The solutions to the equations are sinusoidal of form

$$\vec{E} = \vec{E}_0 \exp\left(i\vec{k}\cdot\vec{x} - i\omega t\right) \qquad (1.1)$$

$$\vec{H} = \vec{H}_0 \exp\left(i\vec{k}\cdot\vec{x} - i\omega t\right) \qquad (1.2)$$

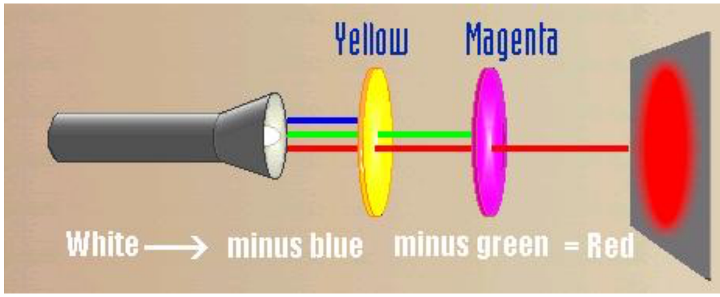
where E is the electric field and H is the magnetic field, the real component of $\vec{k}$ is the wavenumber $2\pi/\lambda$, $\vec{x}$ is the direction of wave propagation and ω is the angular frequency of the radiation $2\pi\nu$.

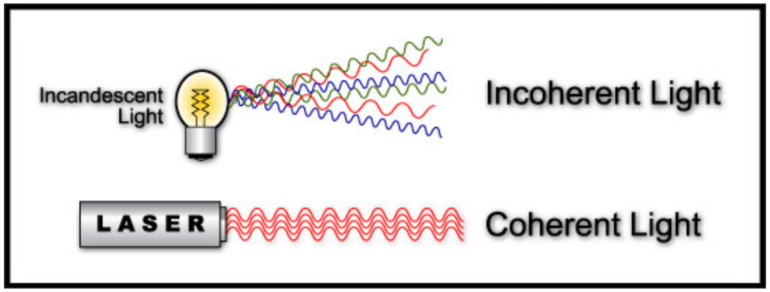
Maxwell's Equations for plane waves

- Index of refraction - N
- Flux – F (W/m^2)
- Absorption coefficient – $\beta_a = 4\pi n_i/\lambda$
- $\frac{1}{\beta_a}$= distance required for the wave's energy to be attenuated to e^{-1} (about 37%)

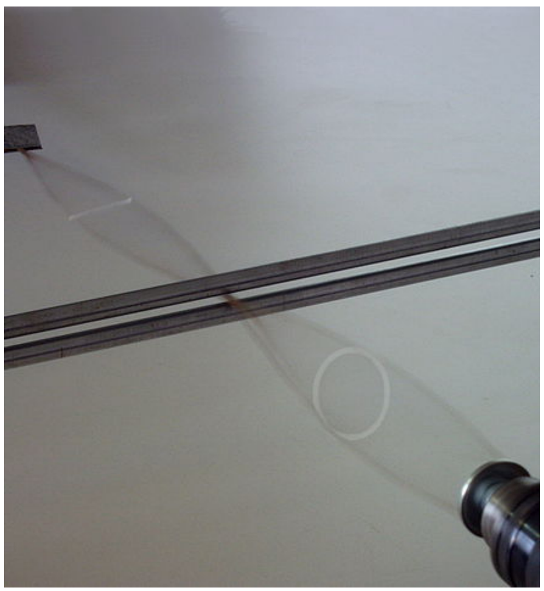
Will be discuss further next lecture

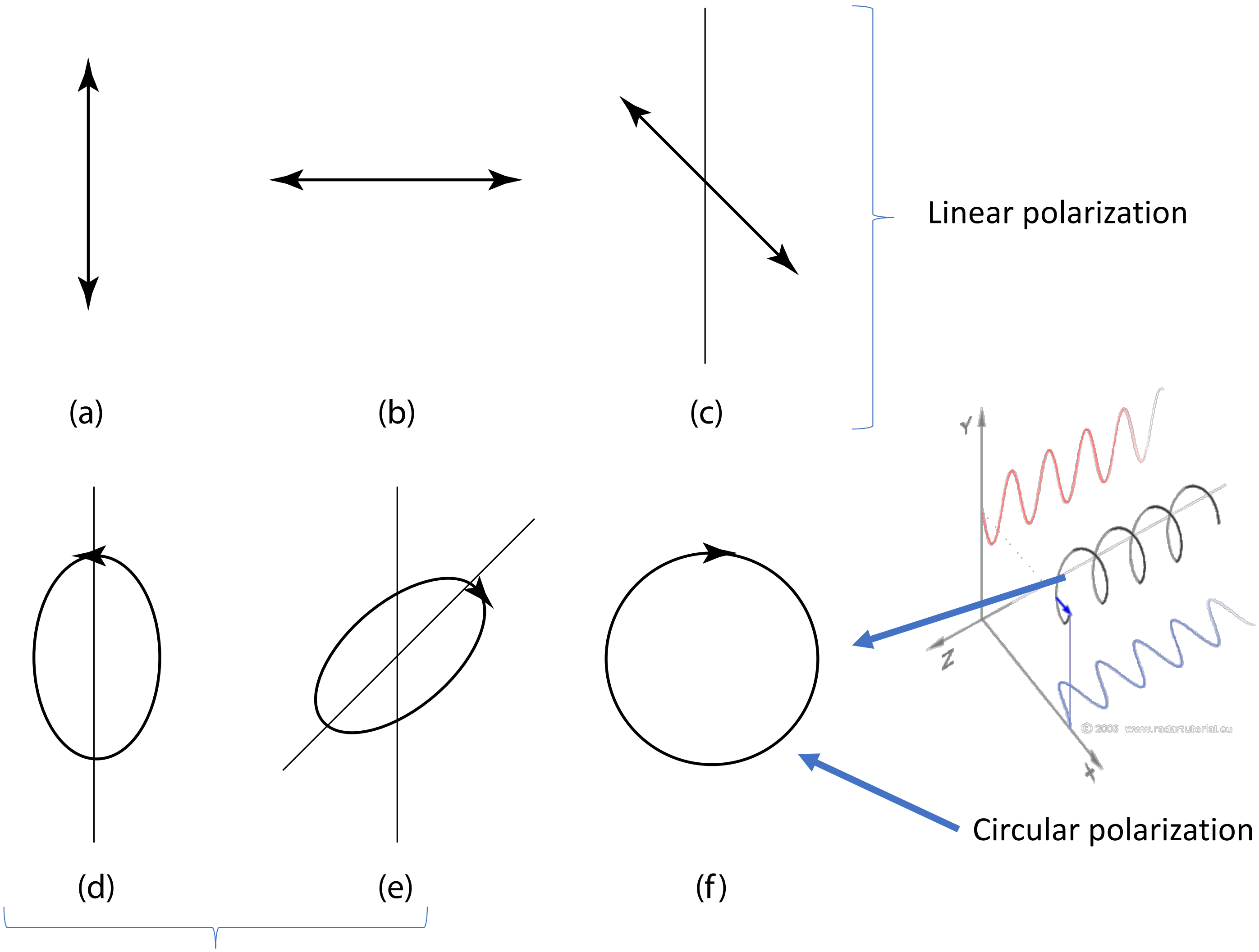
- Broadband Radiation
  - Wide range of frequencies
- Monochromatic Radiation Radiation
  - Single frequency (one color)
  - More commonly use: quasi monochromatic (range of frequencies)
- Coherent
  - Perfect synchronization
  - Artificial Source – radar, lidar, microwave
- Incoherent Radiation
  - Not phase locked
  - No synchronization
  - Natural radiation in the lower atmosphere





Polarization





Elliptical polarization (Hybrid of Linear and Circular)