

3.1 Light and Electromagnetic Radiation

- Maxwell's discovery
- Properties of EM radiation
- Production of EM radiation
- Spectrum of EM radiation



James Clerk Maxwell

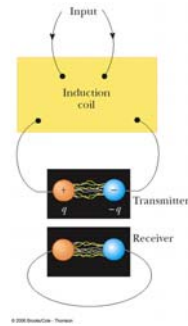
Wave properties of light

- Maxwell discovered that light is a form of electromagnetic radiation.
- Electromagnetic waves are produced that propagate through a vacuum at the speed of light.
- The speed of light is a fundamental constant. $c=2.99792 \text{ m/s}$

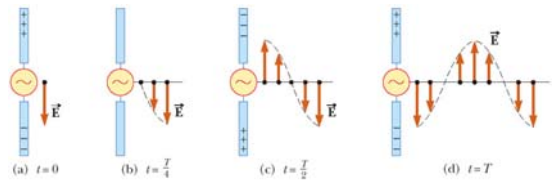
Production of EM waves

- EM waves are produced by oscillations of Electric and Magnetic fields.

Heinrich Hertz
 Showed that electrical oscillation in transmitter produce electromagnetic waves that propagate to the receiver.

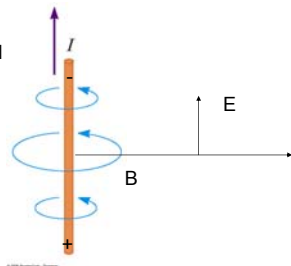


Generation of the E field by an oscillating dipole antenna



The magnetic field associated with the E field

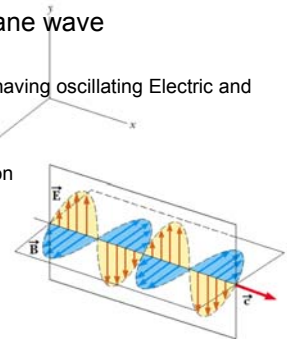
A B field is generated perpendicular to the E field.



Electromagnetic plane wave

Light is a Transverse wave having oscillating Electric and Magnetic fields.

Electric field perpendicular to the direction of propagation
 Magnetic field perpendicular to direction of propagation and to the Electric field.



Speed of Light

Measured values

permeability of free space $\mu_0 = 4\pi \times 10^{-7} \text{ T}\cdot\text{m/A}$

permittivity of free space $\epsilon_0 = 8.85419 \times 10^{-12} \text{ C}^2/\text{N}\cdot\text{m}^2$

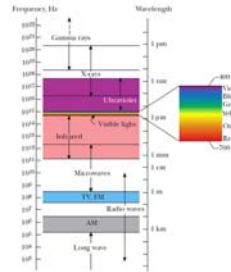
speed of light $c = 2.99792458 \times 10^8 \text{ m/s}$

Predicted value

$$c = \sqrt{\frac{1}{\epsilon_0 \mu_0}} = 2.997924 \times 10^8 \text{ m/s}$$

Perfect agreement!!!!

Spectrum of EM radiation.

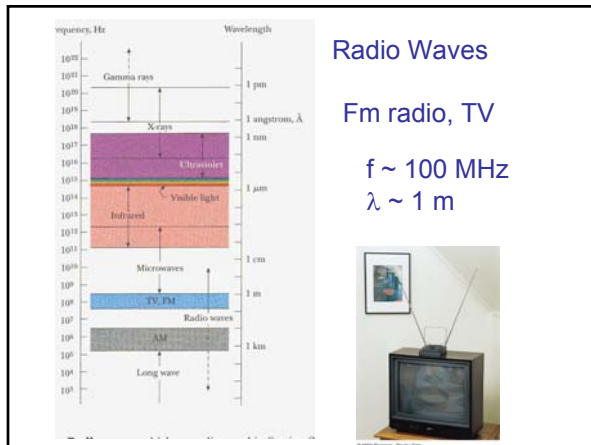


The wavelength of light affects the interaction of EM waves with matter.

An optimal antenna for an EM wave has a size close λ .

EM waves pass easily through holes in a conductor that are larger than λ , but are blocked by holes smaller than λ .

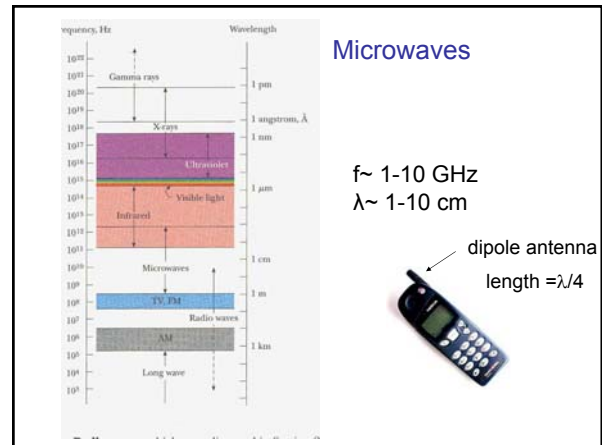
1 micrometer (μm) = 10^{-6} m
 1 millimeter (mm) = 10^{-3} m
 1 angstrom (\AA) = 10^{-10} m



Radio Waves

Fm radio, TV

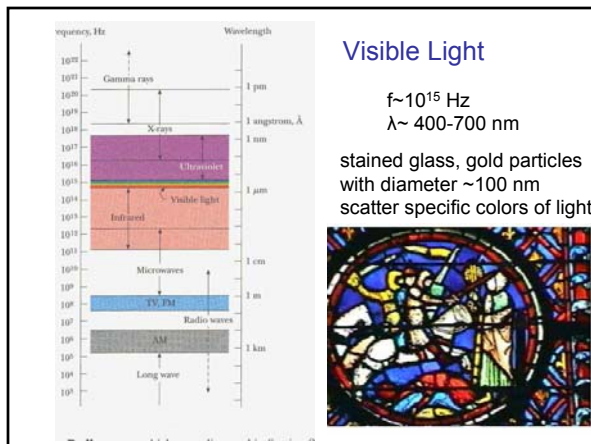
$f \sim 100 \text{ MHz}$
 $\lambda \sim 1 \text{ m}$



Microwaves

$f \sim 1\text{-}10 \text{ GHz}$
 $\lambda \sim 1\text{-}10 \text{ cm}$

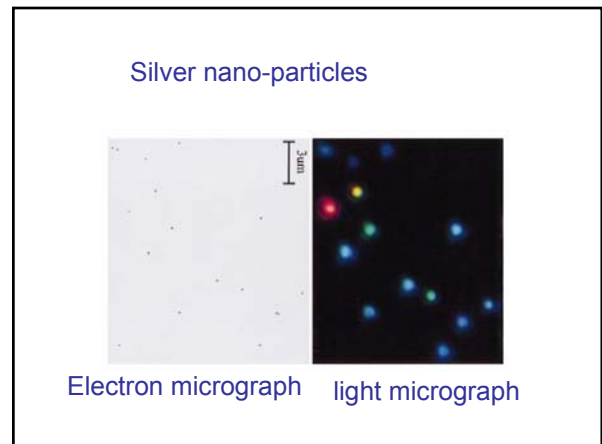
dipole antenna
 length $= \lambda/4$



Visible Light

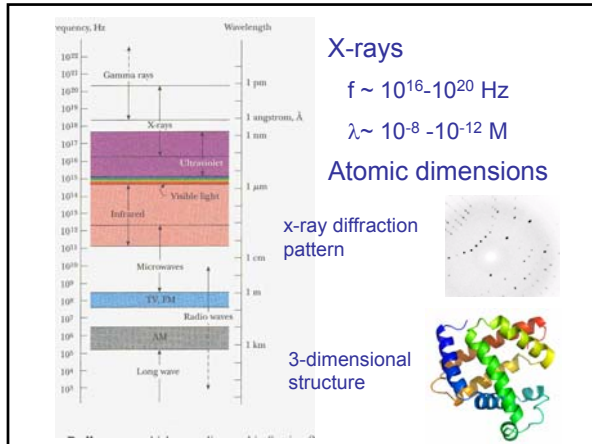
$f \sim 10^{15} \text{ Hz}$
 $\lambda \sim 400\text{-}700 \text{ nm}$

stained glass, gold particles
 with diameter $\sim 100 \text{ nm}$
 scatter specific colors of light



Silver nano-particles

Electron micrograph light micrograph



X-rays

X-rays penetrate soft tissue but are absorbed by heavy atoms, such as Calcium in bones.