Lecture 31: Electromagnetic Waves

Electromagnetic Waves

Changing magnetic filed causes induced electric field, even without charges present.

Maxwell:
Changing electric field causes induced magnetic field, even without currents present

Electric and magnetic fields can exist in the absence of charges and currents:
Electromagnetic waves

- Transverse wave: electric and magnetic fields are perpendicular to direction of wave travel
- In vacuum, electromagnetic waves travel with speed of light $c = 3 \times 10^8 m/s$
- $c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}}$
- $c = \lambda f$
- Long wavelength – low frequency (radio, micro)
- Short wavelength – high frequency (UV, X-Ray)
- Intensity $I = \frac{Power}{Area} = \frac{1}{2} c \varepsilon_0 {E_0}^2 = \frac{1}{2} \frac{c}{\mu_0} {B_0}^2$

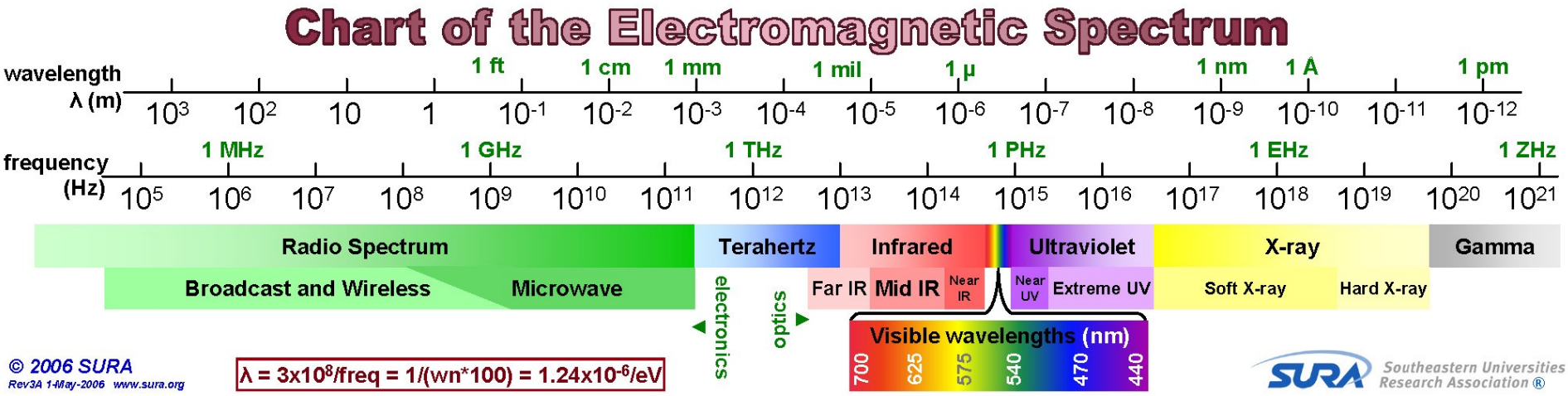
For a wave traveling in the x-direction (thumb):

$$E_y = E_{0y} \sin\left(2\pi\left(\frac{x}{\lambda} - ft\right)\right)$$ Index finger

$$B_z = B_{0z} \sin\left(2\pi\left(\frac{x}{\lambda} - ft\right)\right)$$ Middle finger

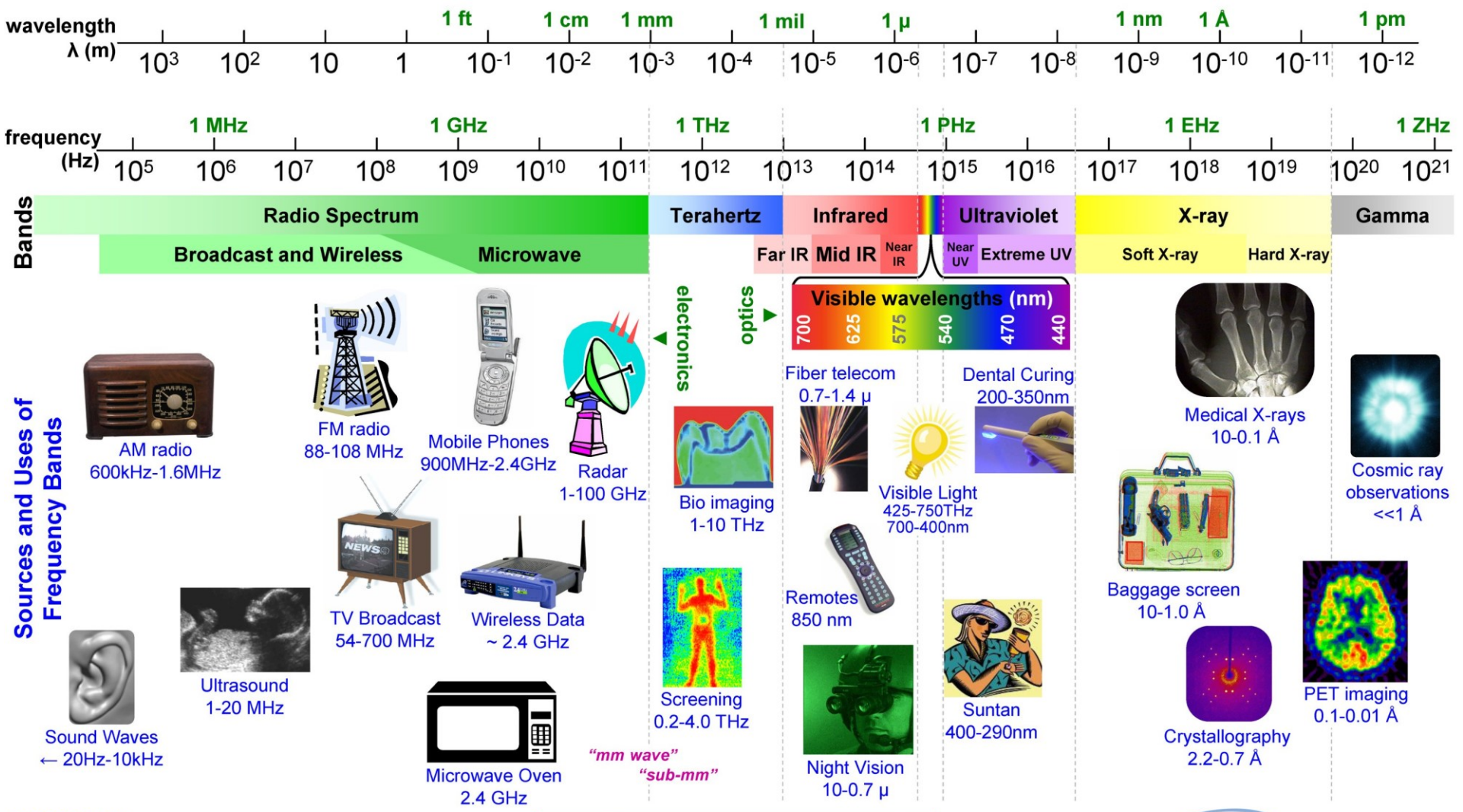
At any point: $E = cB$

Types of electromagnetic waves



- enormous range of wave lengths and frequencies
- spans more than 15 orders of magnitude

Applications of electromagnetic waves



$\lambda = 3\times10^{8}/\text{freq} = 1/(\text{wn}*100) = 1.24\times10^{-6}/\text{eV}$

Photon model of electromagnetic wave

- Electromagnetic waves have a particle like nature
- Discrete massless photons
- Photons travel in vacuum at speed of light $c = 3 \times 10^8 \text{ m/s}$
- Each photon has energy $E_{ph} = hf$
- $h = 6.63 \times 10^{-34} Js$ Planck's constant
- Electromagnetic waves come in discrete chunks of energy
- The higher the frequency, the higher the energy
- Large number of photons act together as a wave