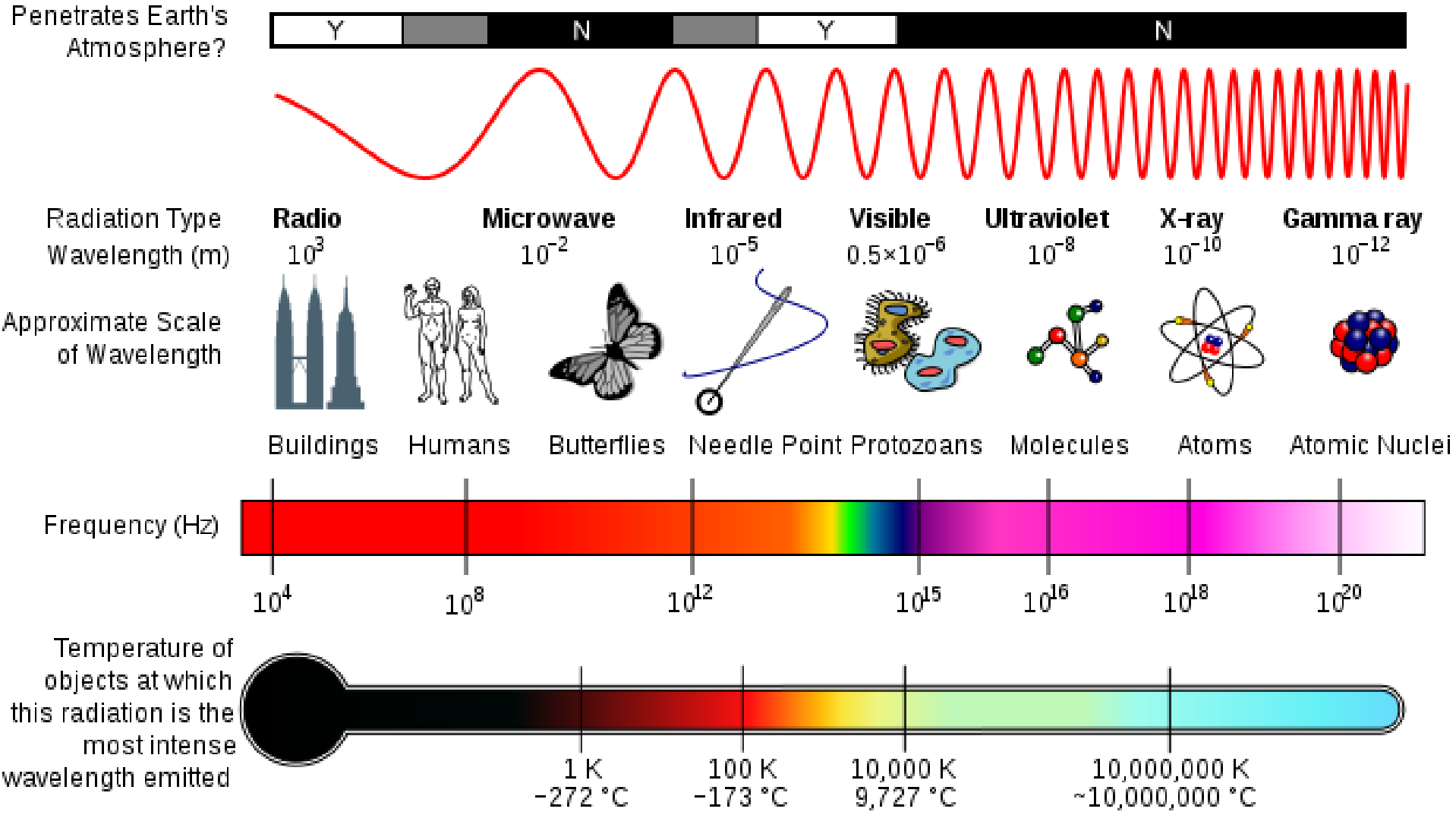
EM Waves

Radio, Microwaves, Infrared,
Visible Light, UV, X-rays,
Gamma Rays


Penetrates Earth's Atmosphere?
Y
N
Y
N
Radiation Type
Wavelength (m)
Radio
10^3
Microwave
10^-2
Infrared
10^-5
Visible
0.5×10^-6
Ultraviolet
10^-8
X-ray
10^-10
Gamma ray
10^-12
Approximate Scale of Wavelength
Buildings
Humans
Butterflies
Needle Point
Protozoans
Molecules
Atoms
Atomic Nuclei
Frequency (Hz)
10^4
10^8
10^12
10^15
10^16
10^18
10^20
Temperature of objects at which this radiation is the most intense wavelength emitted
1 K
−272 °C
100 K
−173 °C
10,000 K
9,727 °C
10,000,000 K
~10,000,000 °C

Produced by…

• Radio Waves	Accelerating electron
• Microwaves	electronic devices
• Infrared	vibrating molecules
• Visible light	electron transitions
• Ultraviolet	electron transitions
• X-rays	acceleration of high energy electrons bombarding a metal target
• Gamma Rays	Emitted by radioactive nuclei

Cause…

Region of the spectrum	Main interactions with matter
Radio	Collective oscillation of charge carriers in bulk material (plasma oscillation). An example would be the oscillation of the electrons in an antenna.
Microwave through far infrared	Plasma oscillation, molecular rotation
Near infrared	Molecular vibration, plasma oscillation (in metals only)
Visible	Molecular electron excitation (including pigment molecules found in the human retina), plasma oscillations (in metals only)
Ultraviolet	Excitation of molecular and atomic valence electrons, including ejection of the electrons (photoelectric effect)
X-rays	Excitation and ejection of core atomic electrons, Compton scattering (for low atomic numbers)
Gamma rays	Energetic ejection of core electrons in heavy elements, Compton scattering (for all atomic numbers), excitation of atomic nuclei, including dissociation of nuclei
High-energy gamma rays	Creation of particle-antiparticle pairs. At very high energies a single photon can create a shower of high-energy particles and antiparticles upon interaction with matter.

Transverse Plane Wave

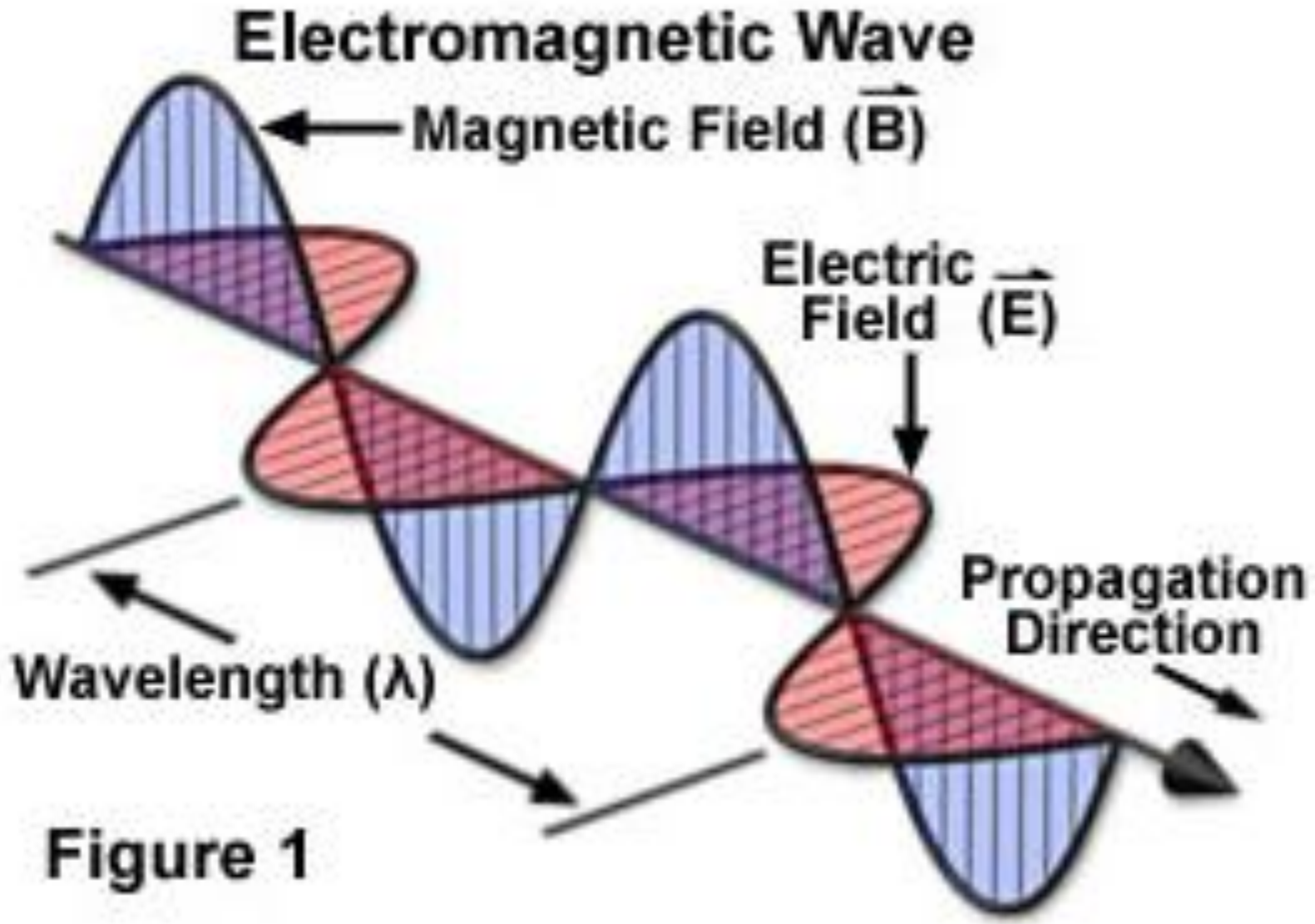
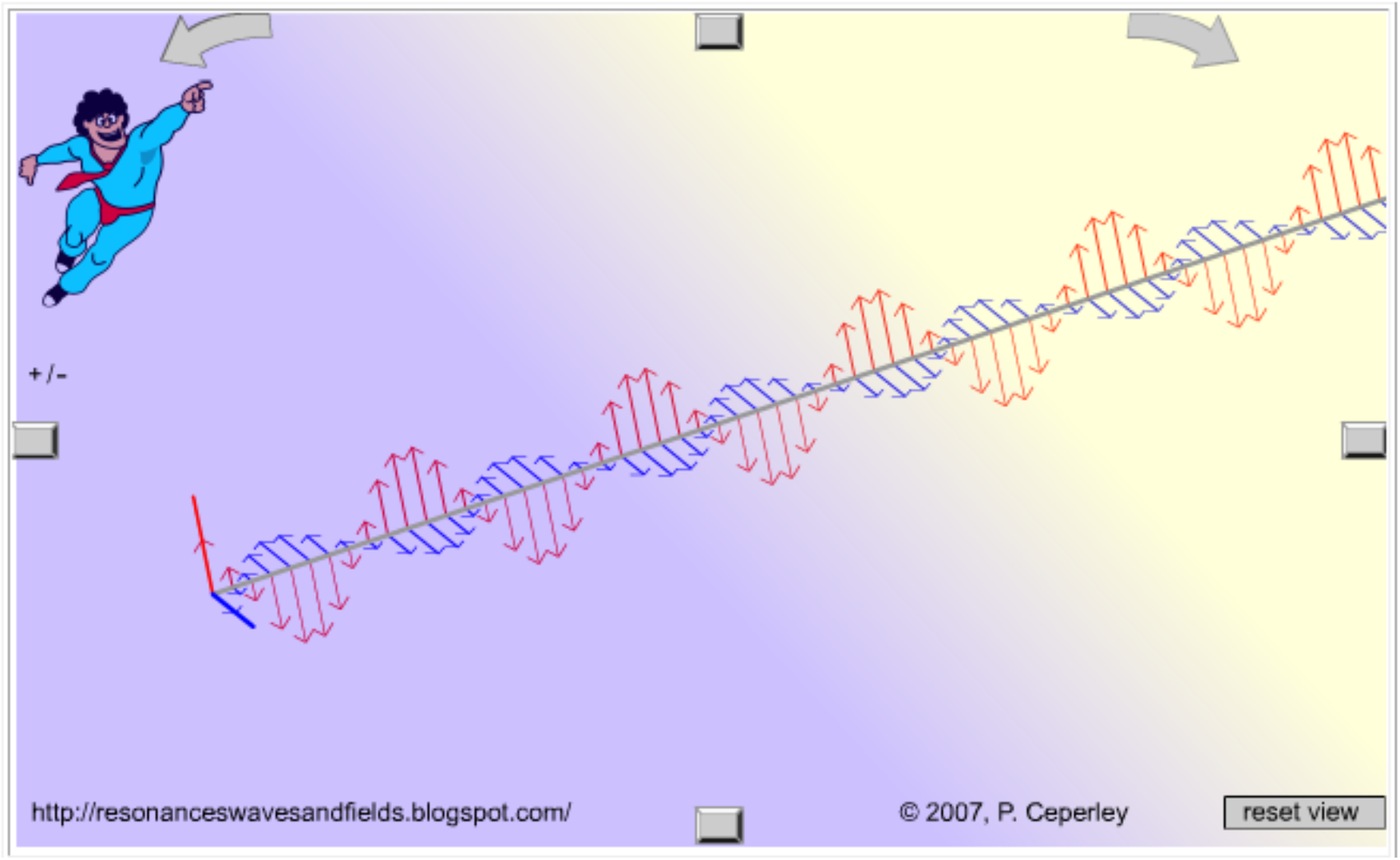


Figure 1

Transverse Plane Wave



Transverse Plane Wave

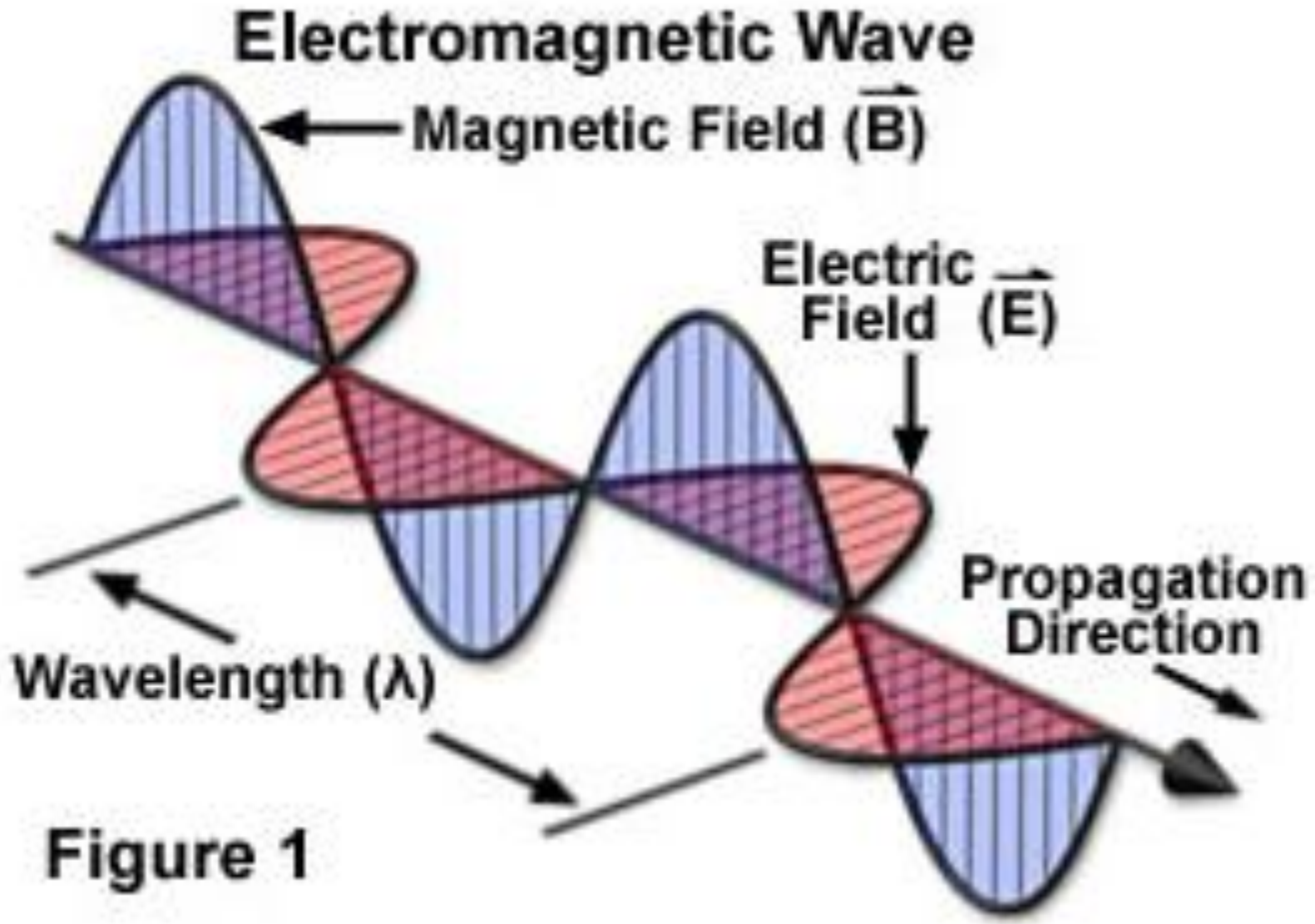


Figure 1

Properties of EM Waves

- Travel at the speed of light

$$c = 2.998 \times 10^8 \text{ m/s}$$

- Transverse waves because E & B are $\perp$ to propagation (v)
- Ratio of Electric field to Magnetic field is the speed of light

$$E/B = c$$

- EM waves carry both energy and momentum, which can be delivered to a surface.

Wave or a particle?

- Waves have wave fronts that expand out
  - Results in apparent “bending” of light
  - Causes interference of waves
  - Nickel experiment
- Particle Nature
  - Photoelectric effect