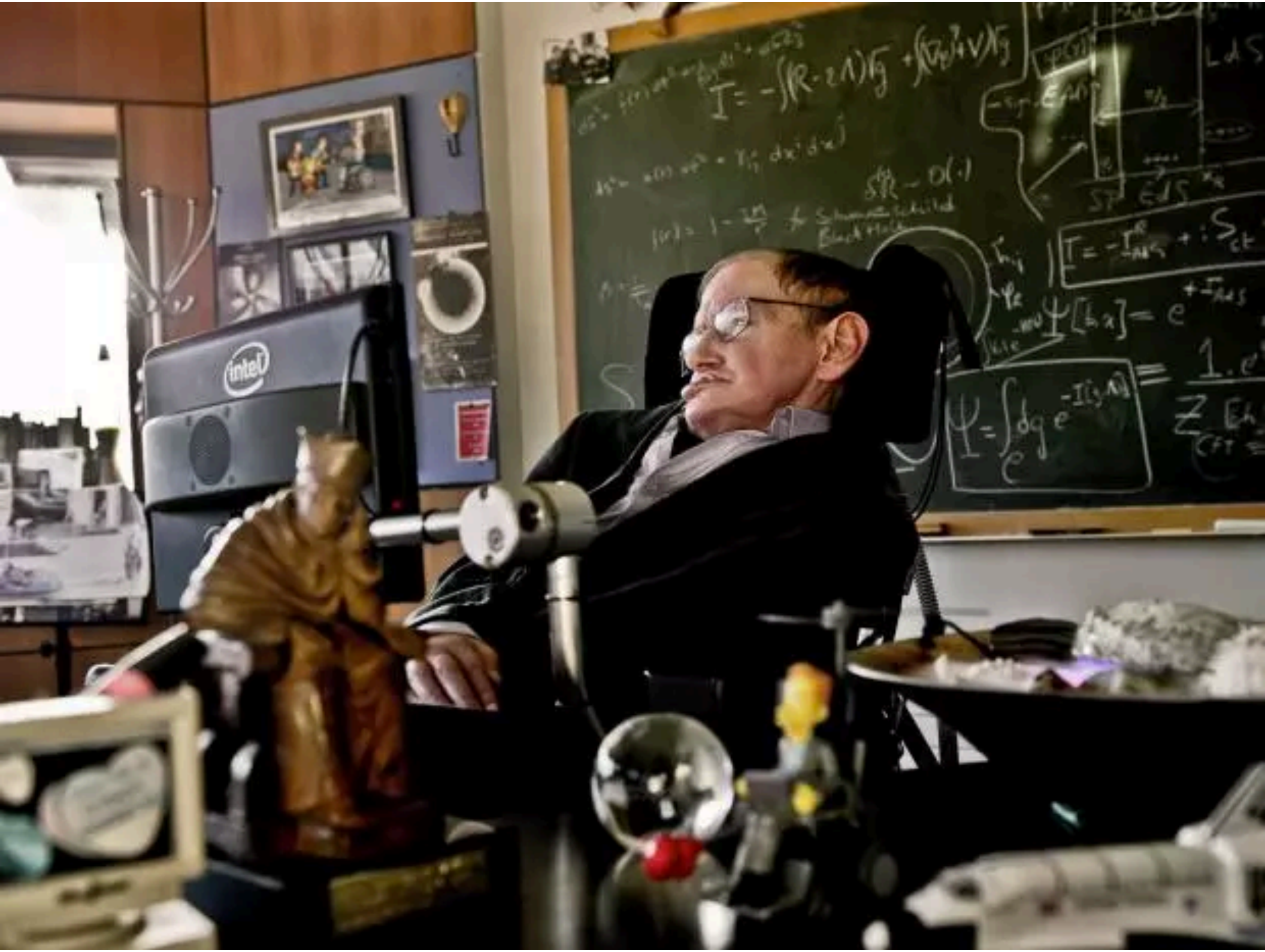
PHY 1120 - Dr. Rowley

Chapter 24 - Electro-Magnetic Waves

Summer 2020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Maxwell's Equations

- James Clerk Maxwell (1831 - 1879)
  - Scottish Theoretical Physicist
  - Lived in Edinburgh, Scotland
  - Newton, Einstein, Maxwell
  - Maxwell's Equations - Unified Electro-Magnetic Theory

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Maxwell's Equations

- Maxwell's Equations

$$\nabla \cdot E = \frac{\rho}{\varepsilon_o}$$ Electric Charge produces Electric Field

$$\nabla \cdot B = 0$$ No magnetic mono-poles (Magnetic Fields)

$$\nabla \times E = -\frac{\Delta B}{\Delta t}$$ Faraday's Law: EMF caused by changing B-Field

$$\nabla \times B = \mu_o \left(I + \varepsilon_o \frac{\Delta E}{\Delta t} \right)$$ Magnetic Field caused by Current AND Changing Electric Field!

Maxwell's Equations

- Implications
  - $E \perp B$
  - E & B $\perp$ to direction of wave travel
  - c = Ratio of E/B
  - c = Universal Constant!

Maxwell's Equations

- Implications
  - c is finite
  - c is derived from Maxwell's Equations
  - Matches Experimental Evidence

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

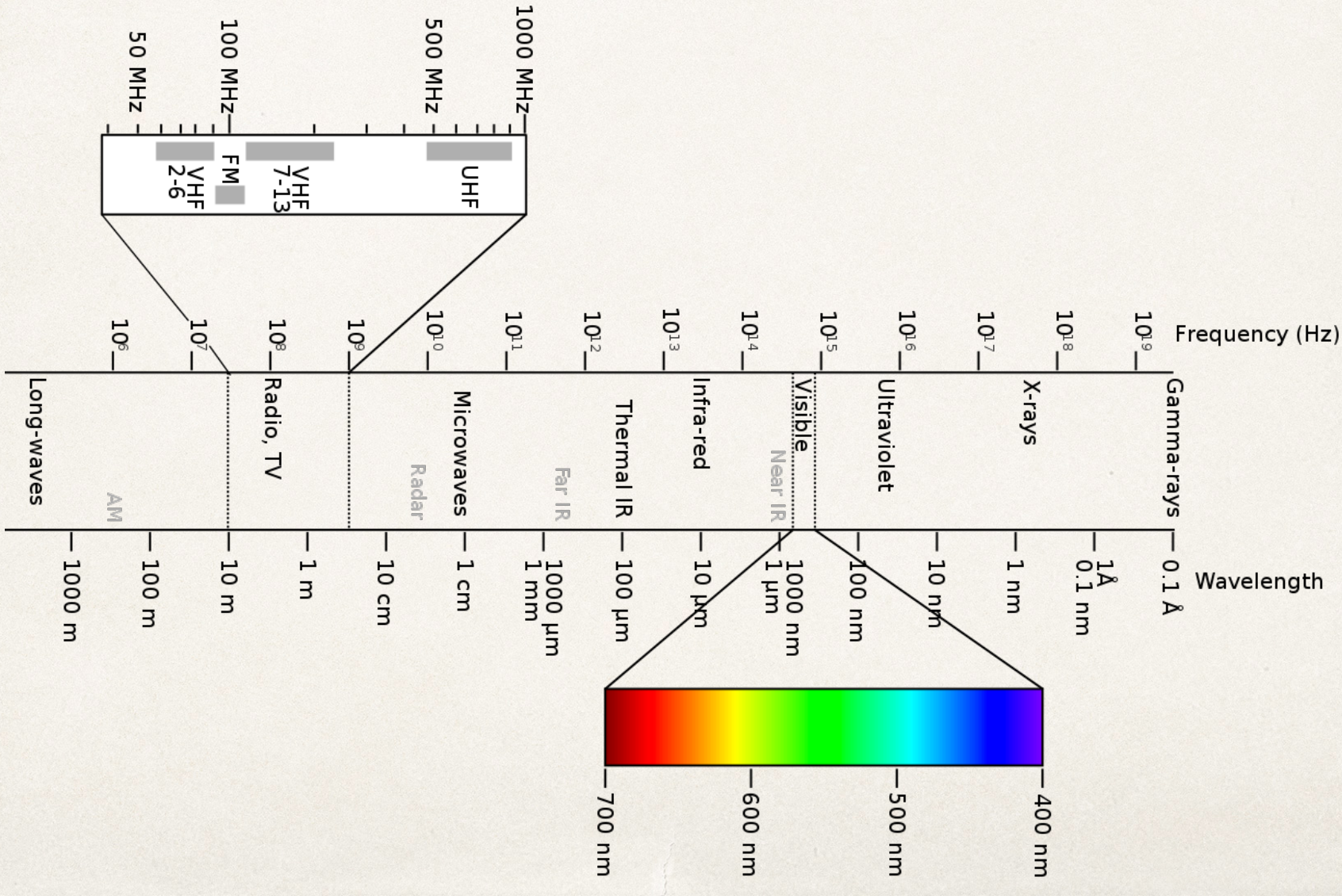
Speed of Light

- $c = 2.997 \times 10^8$ m/s (in a vacuum)
- c is slower in other material (air, water, glass, etc)
- Light is an Electro-Magnetic Wave

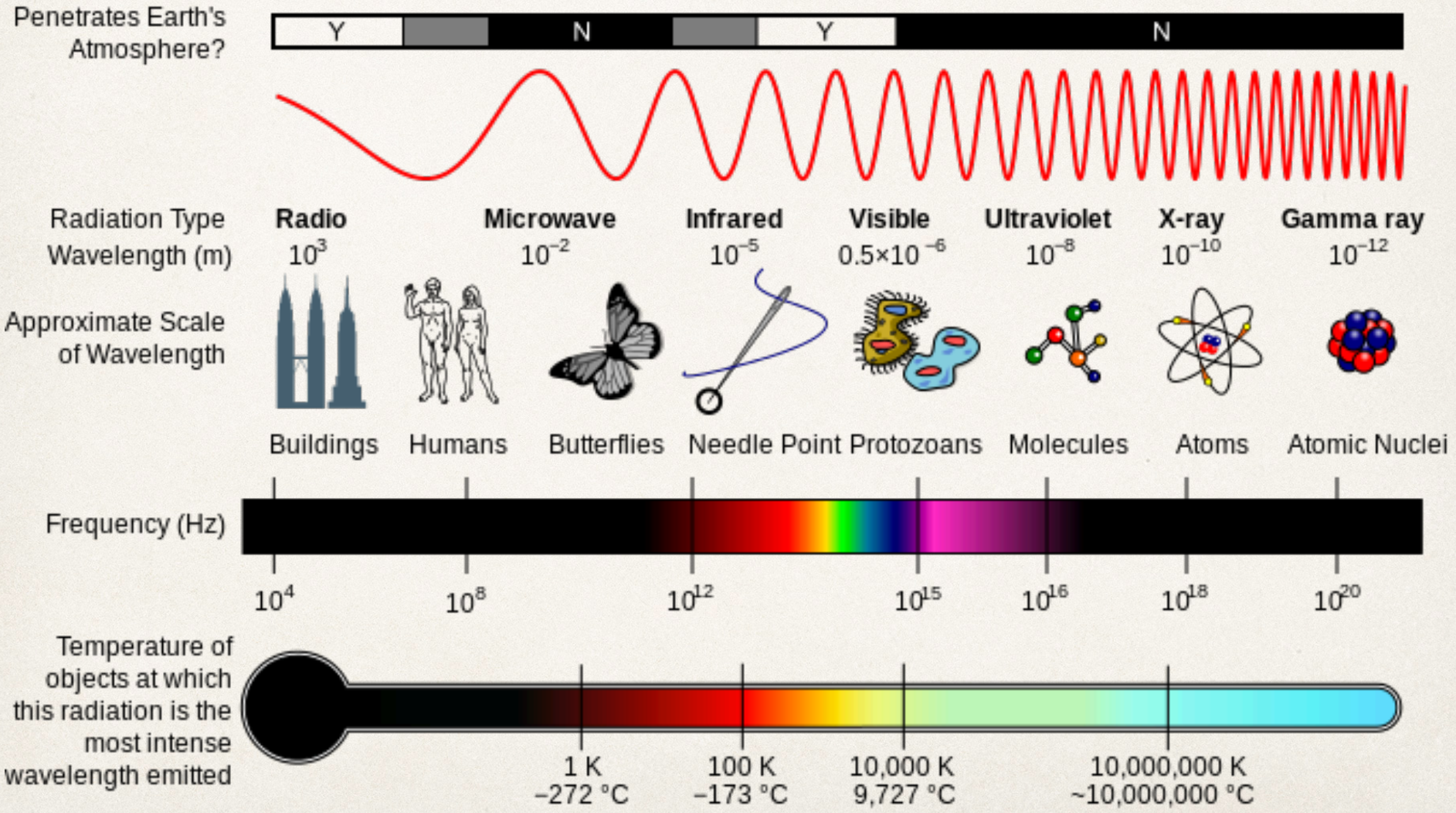
$$c = f \bullet \lambda$$

- No actual limit to size of frequency or wavelength

EM Spectrum*


Frequency (Hz)
Wavelength
Gamma-rays
X-rays
Ultraviolet
Visible
Near IR
Infra-red
Far IR
Thermal IR
Microwaves
Radar
Radio, TV
AM
Long-waves
UHF
VHF 7-13
FM
VHF 2-6
1000 MHz
500 MHz
100 MHz
50 MHz
0.1 Å
1 Å
0.1 nm
1 nm
10 nm
100 nm
1000 nm
1 µm
10 µm
100 µm
1000 µm
1 mm
1 cm
10 cm
1 m
10 m
100 m
1000 m
400 nm
500 nm
600 nm
700 nm

EM Spectrum*


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

Mechanical Waves

- Amplitude, Frequency, Wavelength, Period, Velocity
- Movement of Medium
- Very slow compared to Light

Mechanical Waves

- A ship measures the depth of water below it using SONAR, which travels at 1500 m/s. If the water is 375 m deep, how much time elapses between sending and receiving the SONAR signal?