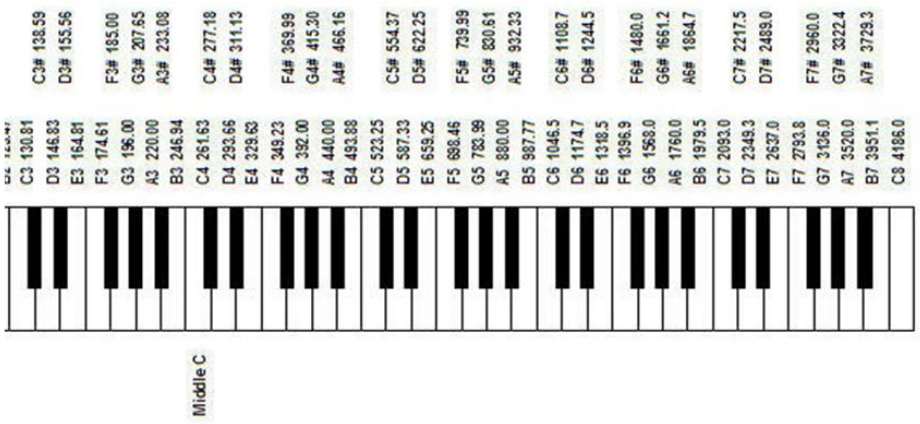
Light and the EM Spectrum

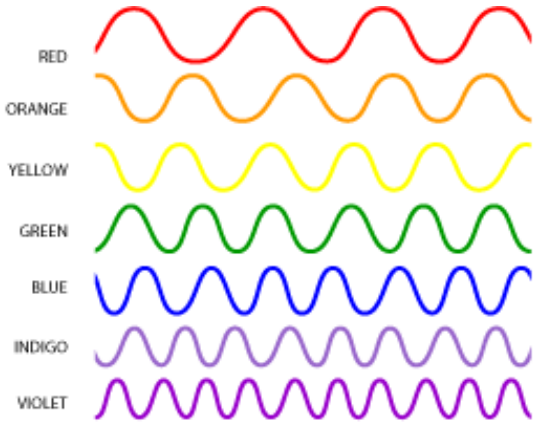
IB PHYSICS | WAVES - LIGHT

Frequency and Light

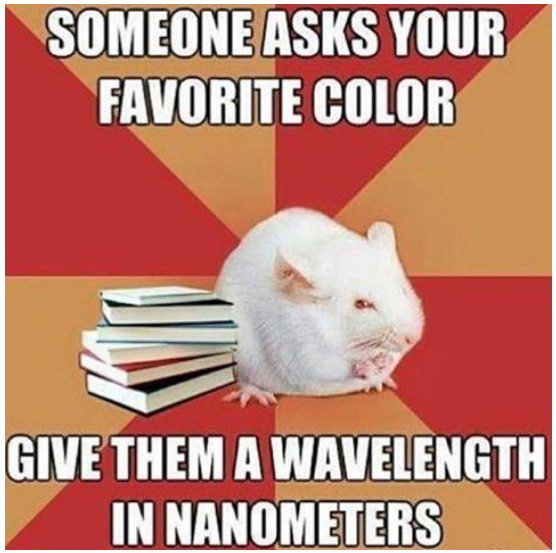
Sound → Change in Frequency → Pitch

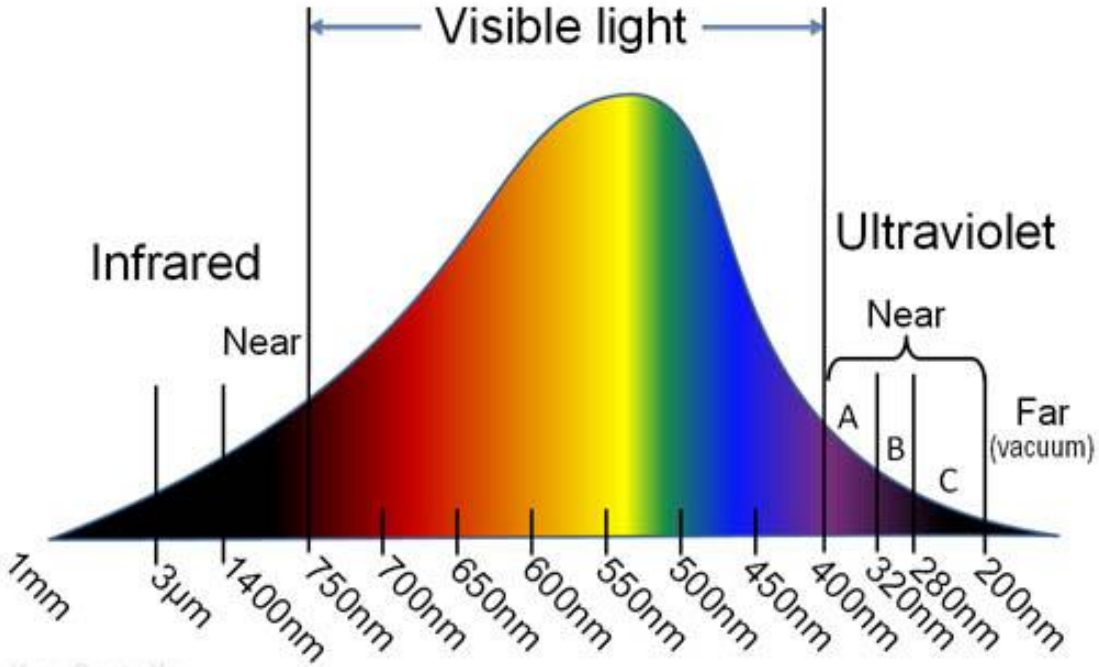
Light → Change in Frequency → Color





Frequency and Light





Speed of Electromagnetic Waves

In a vacuum All electromagnetic waves travel at:

$$c = 299{,}792{,}458 \text{ m s}^{-1}$$

$$c = 3.00 \times 10^{8} \text{ m s}^{-1}$$

Speed of Electromagnetic Waves

Fundamental constants

Quantity	Symbol	Approximate value
Acceleration of free fall (Earth's surface)	g	$9.81\ \mathrm{m\,s^{-2}}$
Gravitational constant	G	$6.67 \times 10^{-11}\ \mathrm{N\,m^2\,kg^{-2}}$
Avogadro's constant	N_A	$6.02 \times 10^{23}\ \mathrm{mol^{-1}}$
Gas constant	R	$8.31\ \mathrm{J\,K^{-1}\,mol^{-1}}$
Boltzmann's constant	k_B	$1.38 \times 10^{-23}\ \mathrm{J\,K^{-1}}$
Stefan–Boltzmann constant	σ	$5.67 \times 10^{-8}\ \mathrm{W\,m^{-2}\,K^{-4}}$
Coulomb constant	k	$8.99 \times 10^{9}\ \mathrm{N\,m^2\,C^{-2}}$
Permittivity of free space	ε_0	$8.85 \times 10^{-12}\ \mathrm{C^2\,N^{-1}\,m^{-2}}$
Permeability of free space	μ_0	$4\pi \times 10^{-7}\ \mathrm{T\,m\,A^{-1}}$
Speed of light in vacuum	c	$3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$
Planck's constant	h	$6.63 \times 10^{-34}\ \mathrm{J\,s}$

Try this…

The sun is roughly 149,600,000 km from Earth, how long has the light from the sun been traveling before it gets here?

$$v = \frac{d}{t} \rightarrow t = \frac{d}{v} = \frac{149{,}600{,}000{,}000\ \text{m}}{3.00 \times 10^8\ \text{m s}^{-1}}$$

$$t = 499\ \text{s} = \mathbf{8.31\ min}$$

Light Equation

You already know the wave speed equation

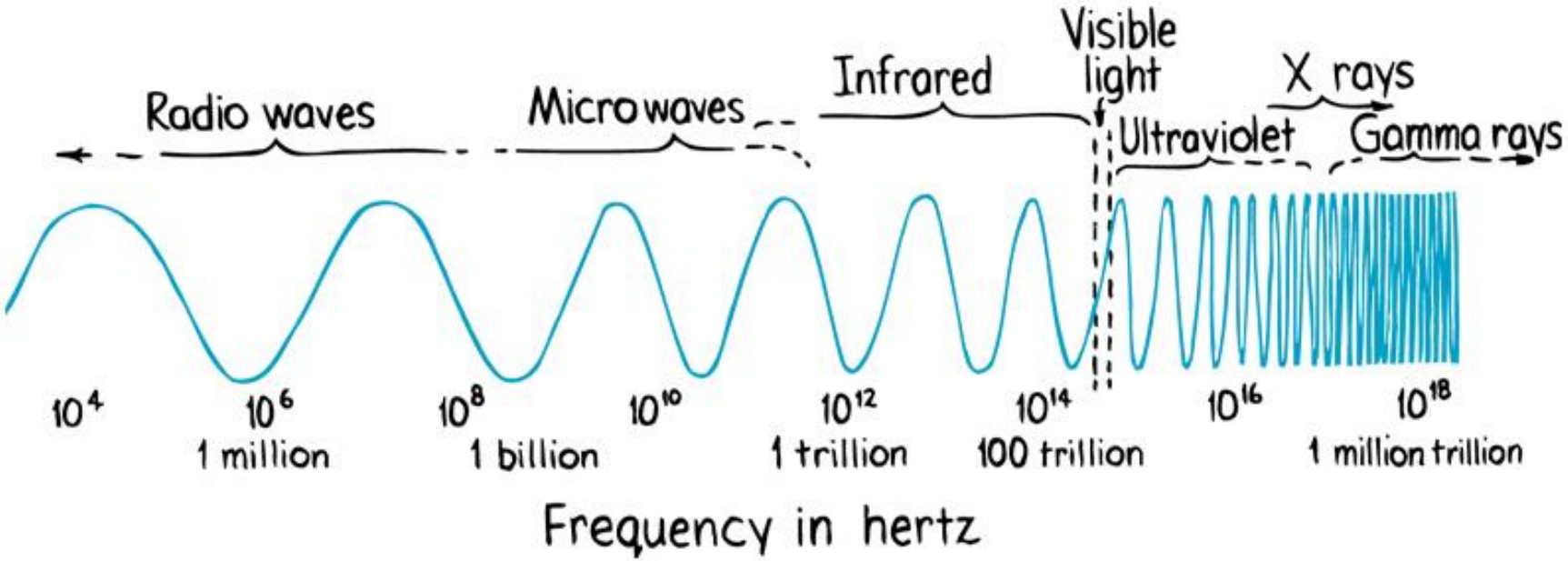
$$v = f\lambda$$

Works the same for electromagnetic waves

$$c = f\lambda$$

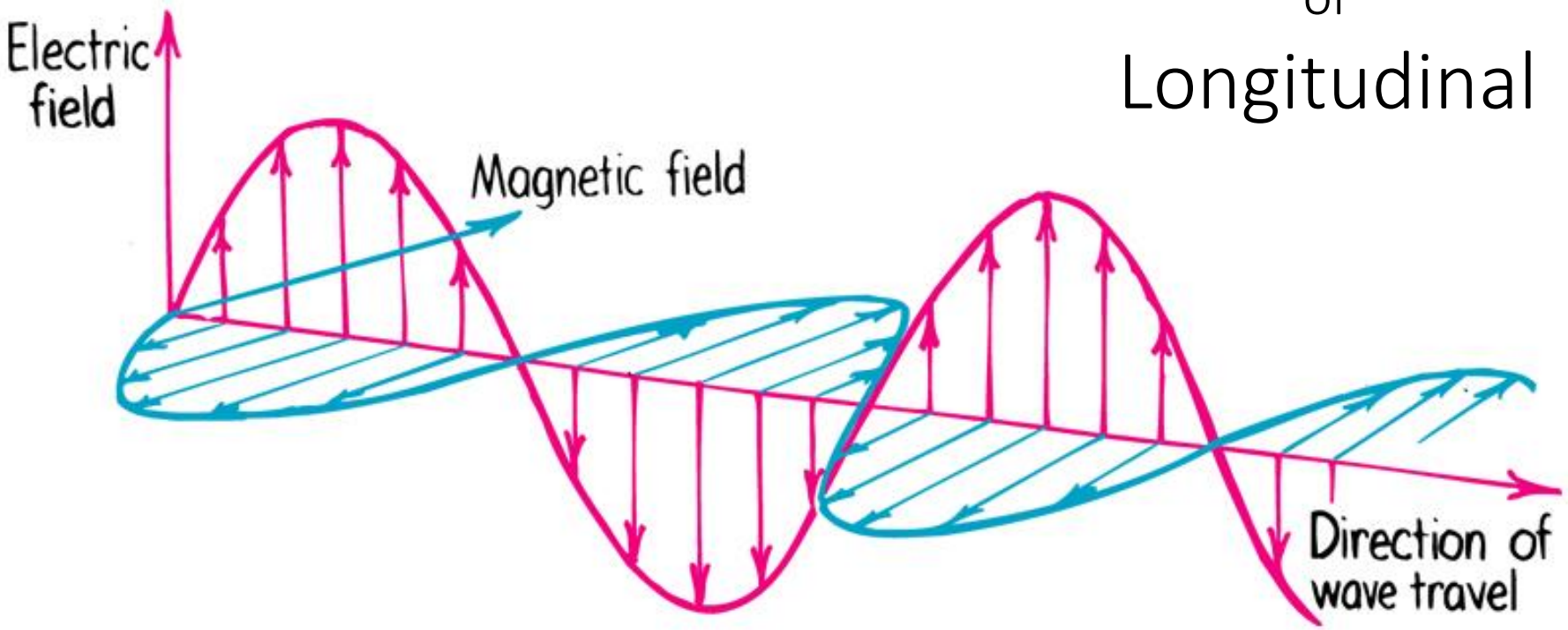
Electromagnetic Spectrum

Visible light is just part of the picture…



Electromagnetic Waves

? Transverse or Longitudinal ?

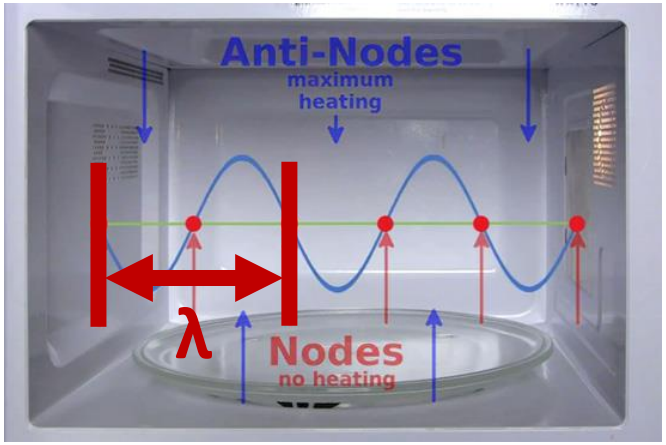


Standing Waves in a Microwave

How far between antinodes of a 2450 MHz standing wave in a microwave?

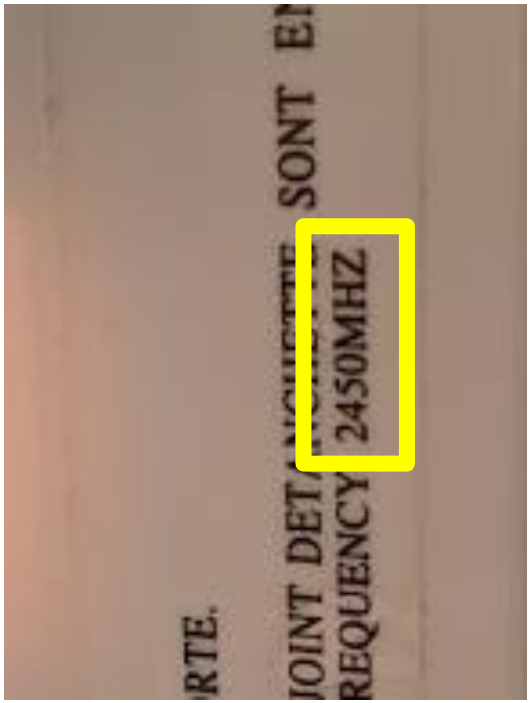
$$v = f\lambda$$

$$\lambda = \frac{v}{f} = \frac{3.00 \times 10^8}{2450 \times 10^6} = 0.12 \text{ m}$$



$$\frac{0.12 \text{ m}}{2} = 0.06 \text{ m}$$

$$= \mathbf{6 \text{ cm}}$$



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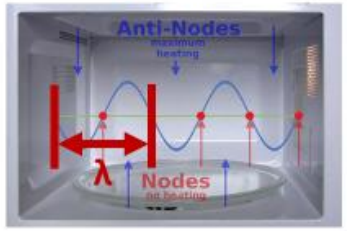

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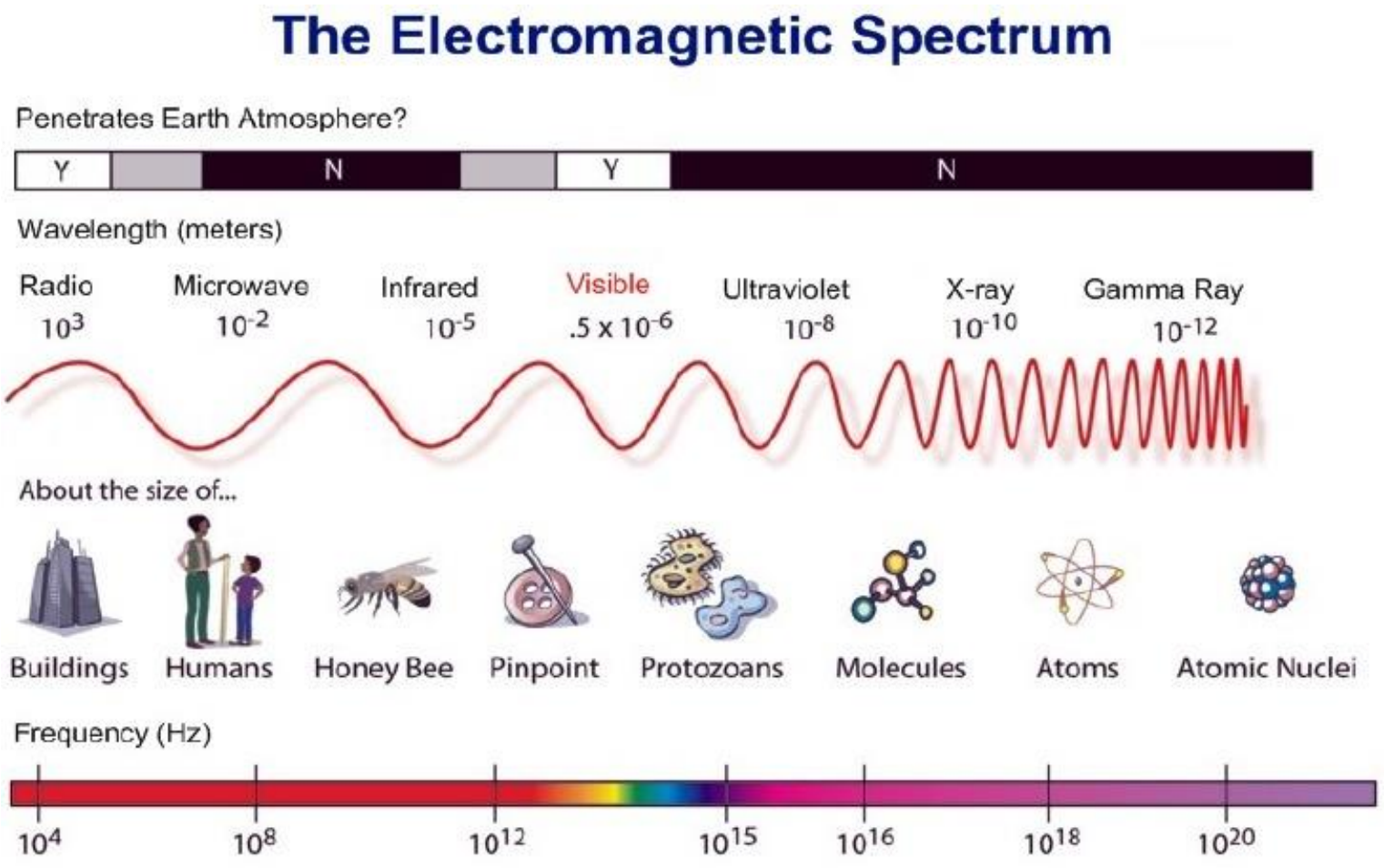
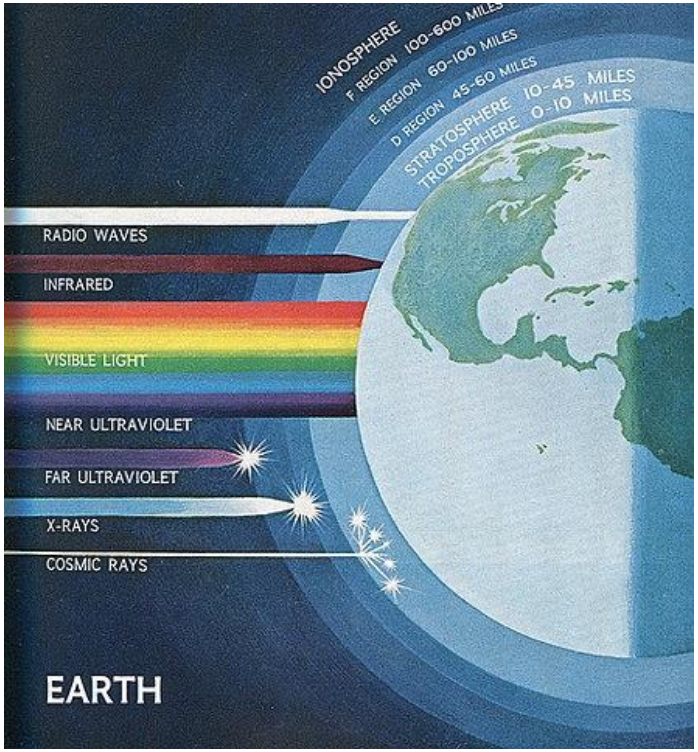
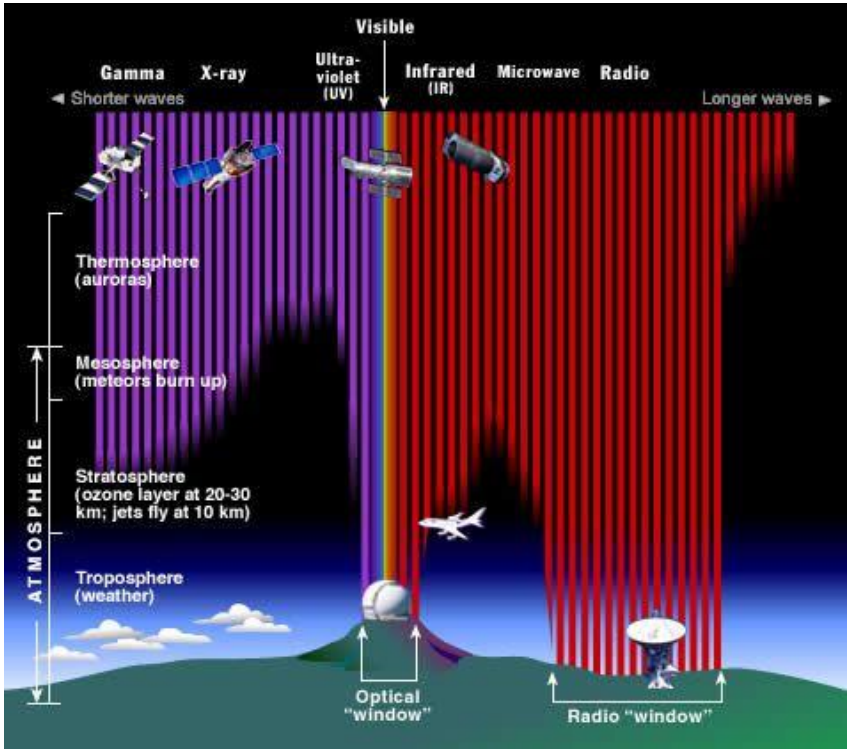
Electromagnetic Spectrum

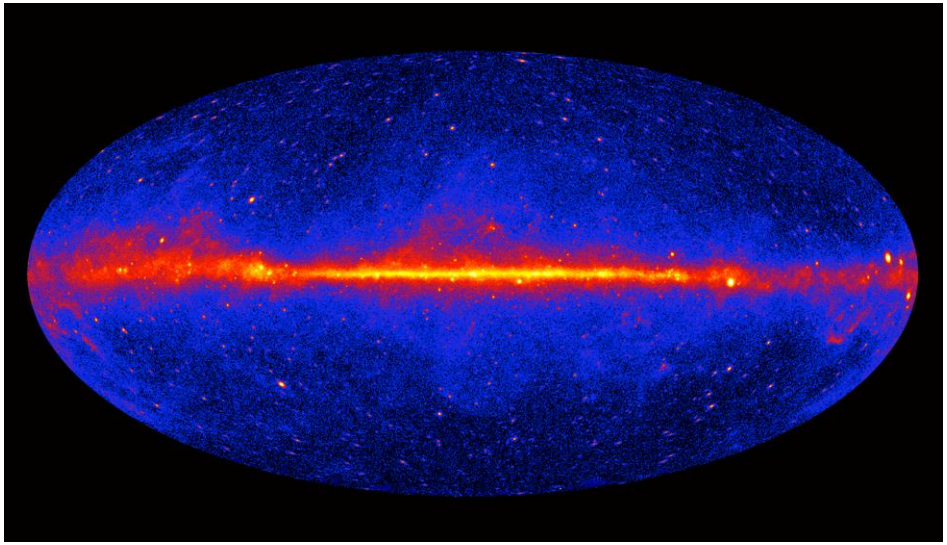


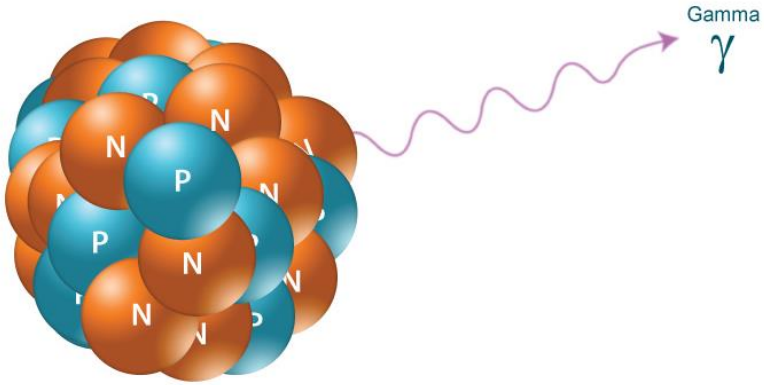
Not everything makes it to Earth





Gamma Ray



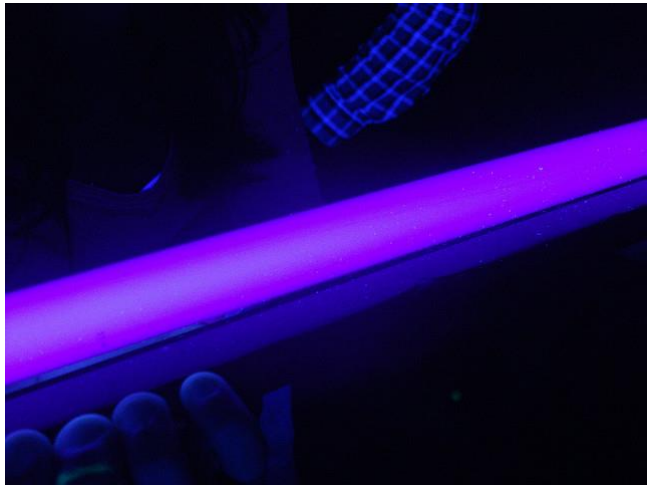


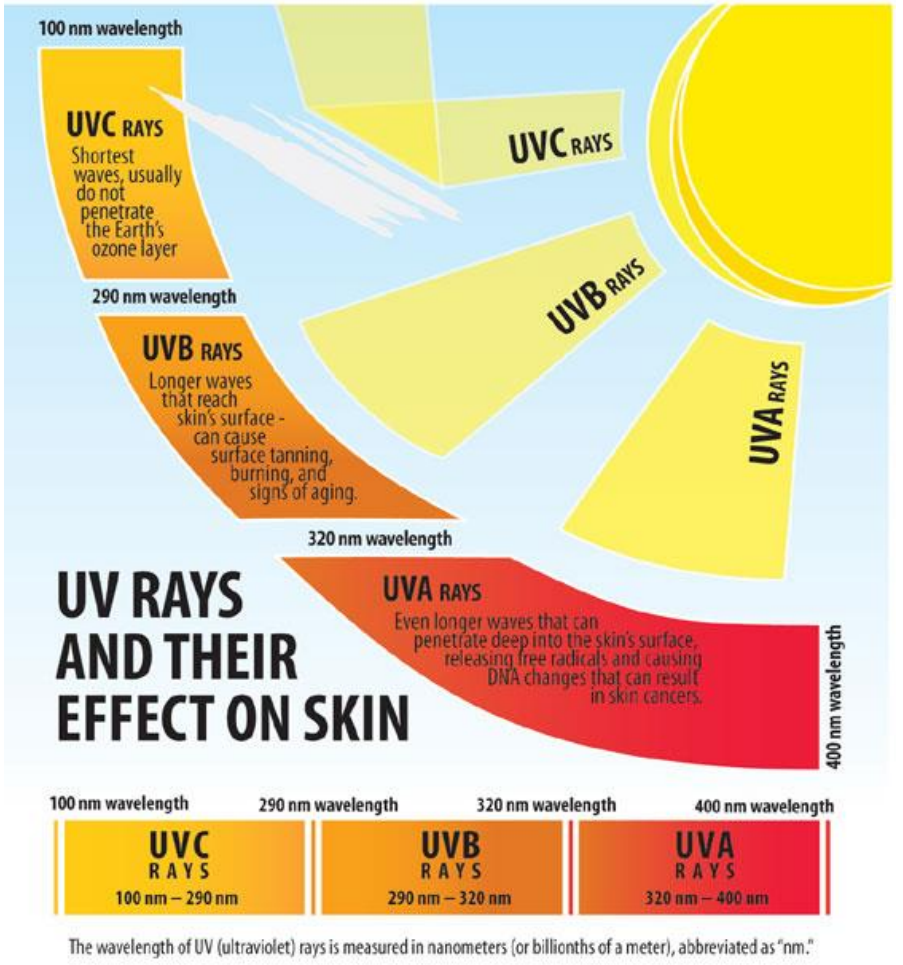
Wavelength: 10^{-12} m | 1 pm

X-Rays

Wavelength: 10^{-10} m | 10 nm

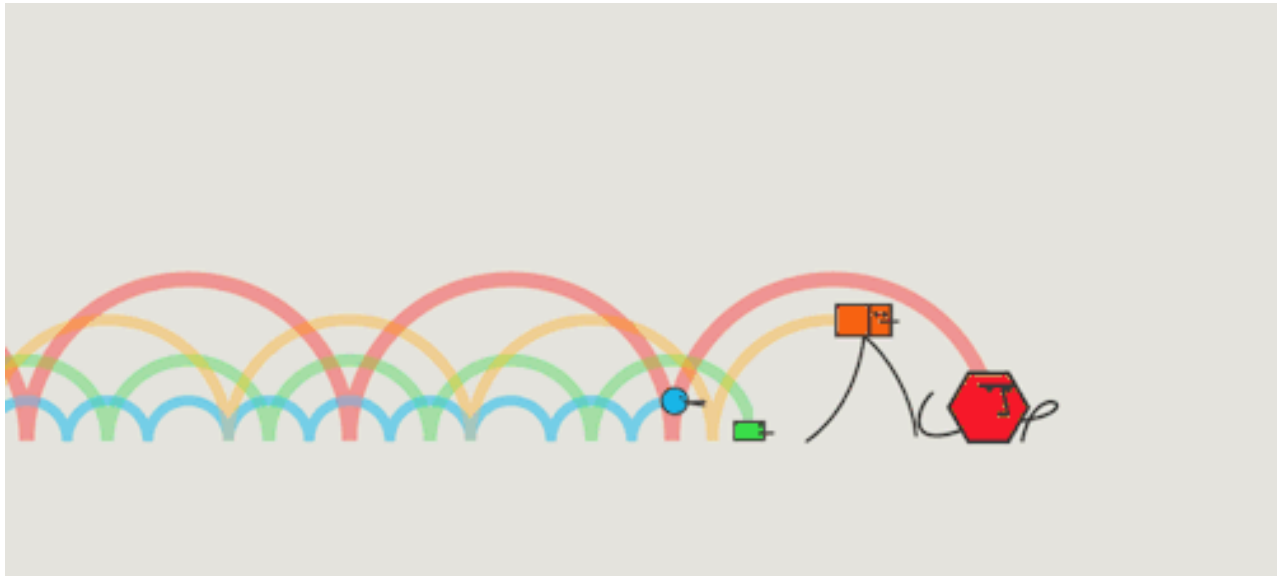
Ultraviolet

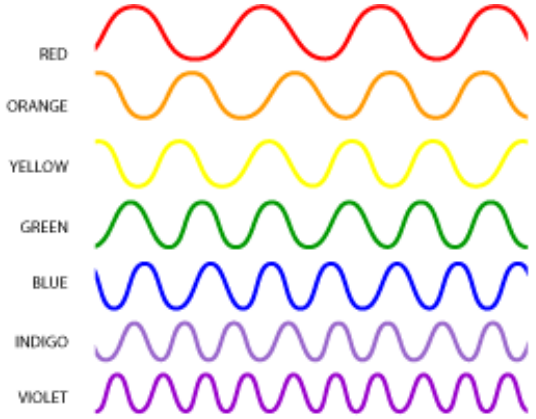




Wavelength: 10^{-8} m | 10 nm

Visible Light





Wavelength: 0.5×10^{-12} m | 500 nm

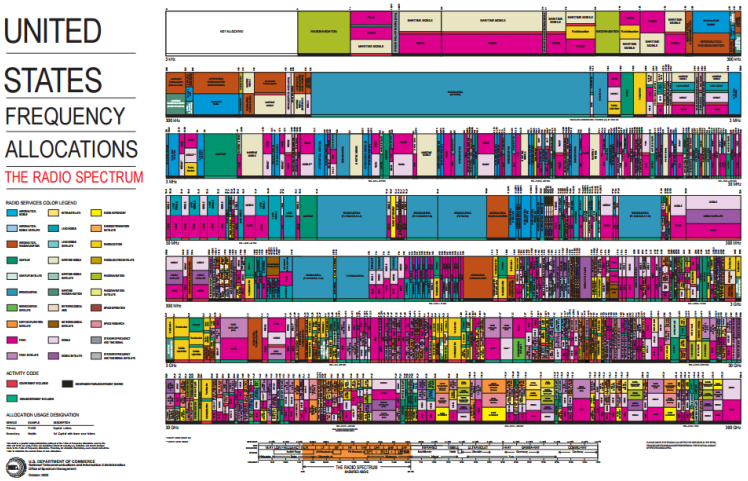
Infrared

Wavelength: 10^{-5} m | 0.01 mm

Microwaves

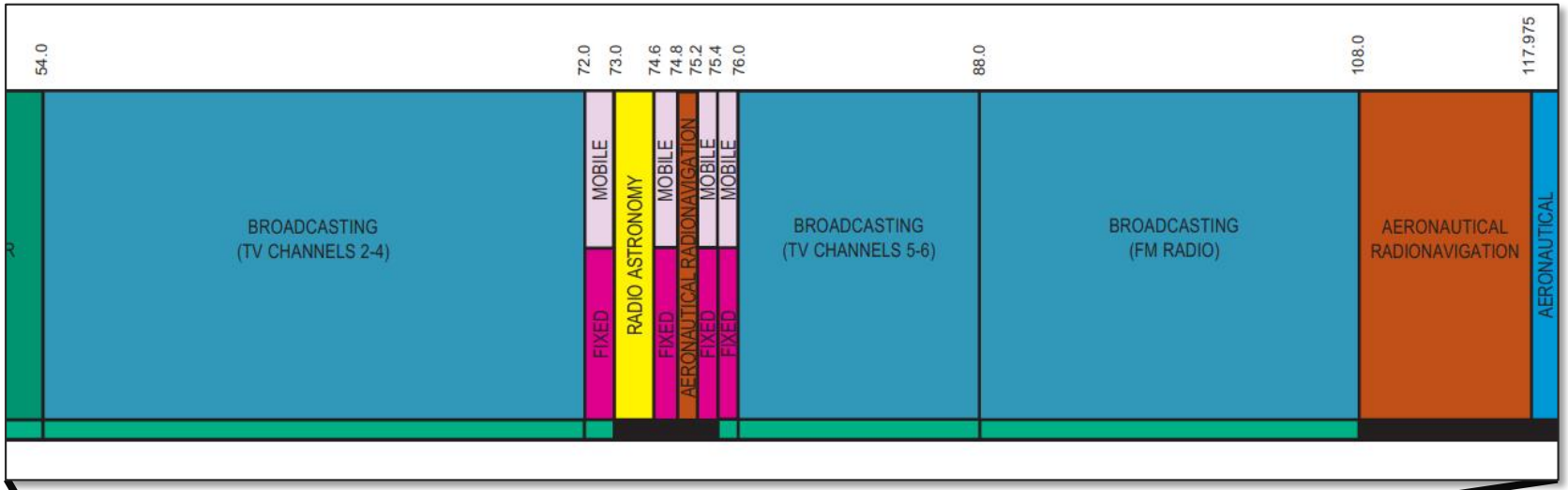
Wavelength: 10^{-2} m | 1 cm

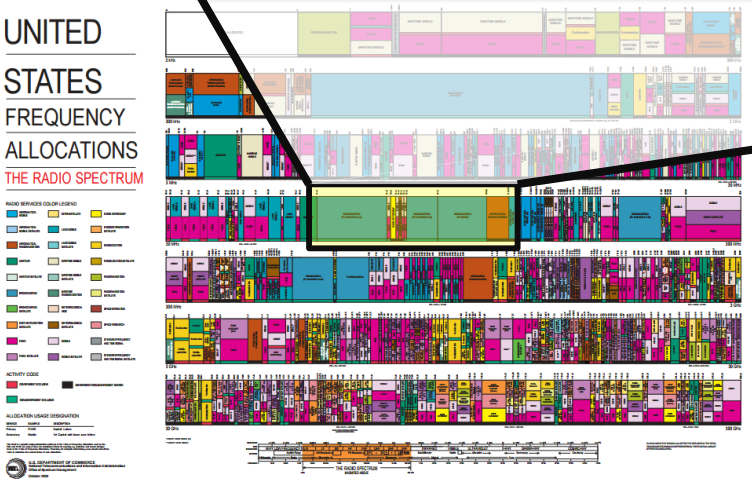
Radiowaves



Wavelength: 10^3 m | 1 km

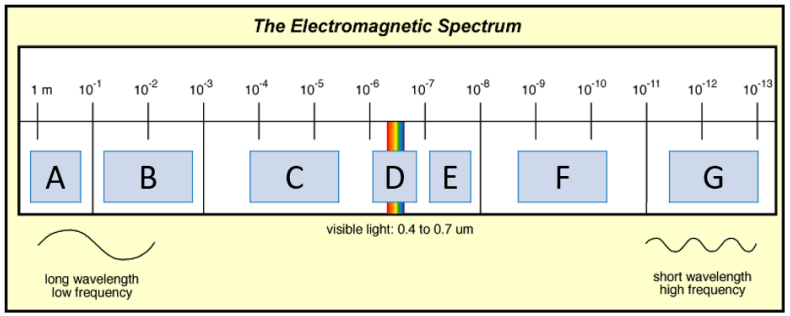
Wireless Data Transfer





Can you name them? You should.

A	Radio
B	Microwaves
C	Infrared
D	Visible
E	Ultraviolet
F	X-Rays
G	Gamma



Higher Frequency

More Energy

Lesson Takeaways

- ❑ I can identify and use the speed of light to solve wave problems with the wave equations
- ❑ I can estimate the wavelength magnitude for the different EM waves
- ❑ I can provide real world examples for each of the electromagnetic waves