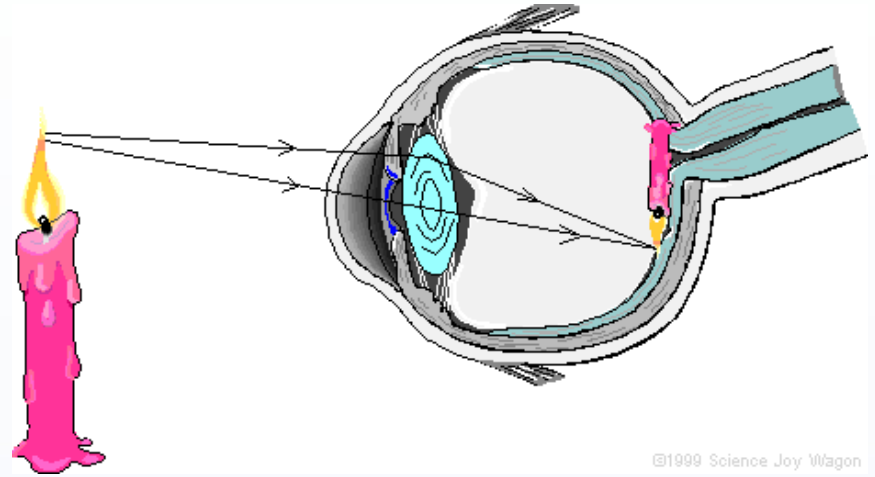


EGM310 – Remote Sensing and GIS



Week 9, Part 2: Electromagnetic Radiation

- Our eyes (and ears! and nose!) are **sensors** that collect information about the world, process it in our brains
 - Normally, our eyes/ears/nose are not in contact with the object they are sensing – they are **remote** sensors
- ⇒ Our eyes use **light** in order to sense the world around us



©1999 Science Joy Wagon

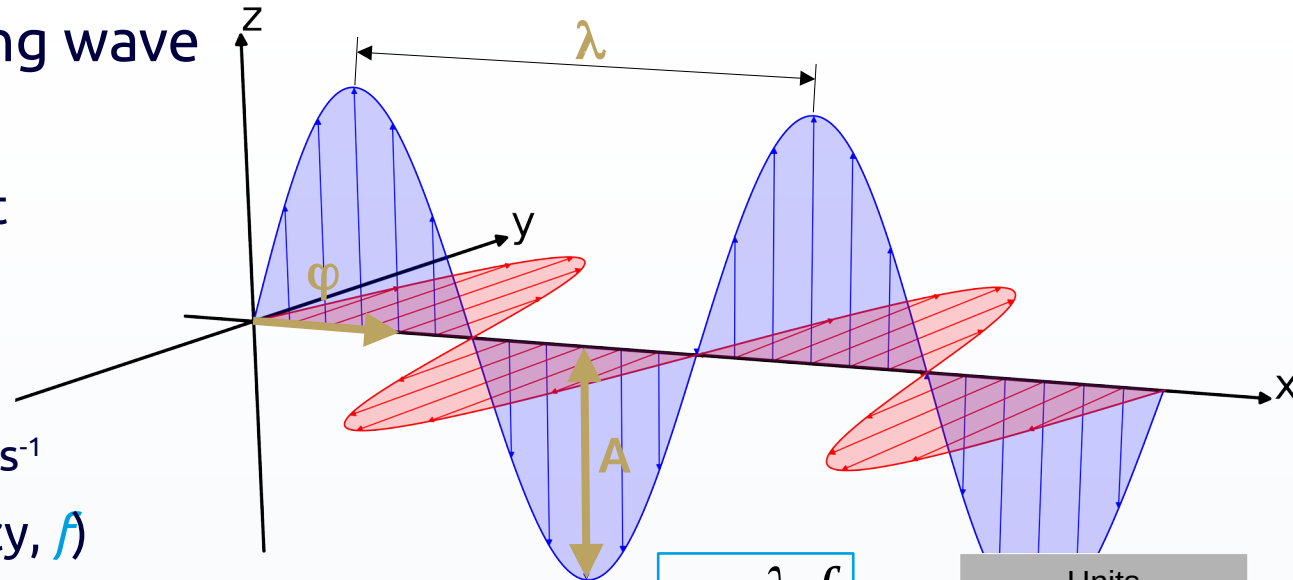
- The light we can see is a form of electromagnetic radiation (EMR)
- For most remote sensing, we use EMR
- Question: is light a particle, or is it a wave?
 - “It depends”

		
Reflection	✓	✓
Refraction	✓	✓
Interference	✗	✓
Diffraction	✗	✓
Polarization	✗	✓
Photoelectric effect	✓	✗

<https://www.youtube.com/watch?v=h1tfIE-L2Dc>

The Wave Model

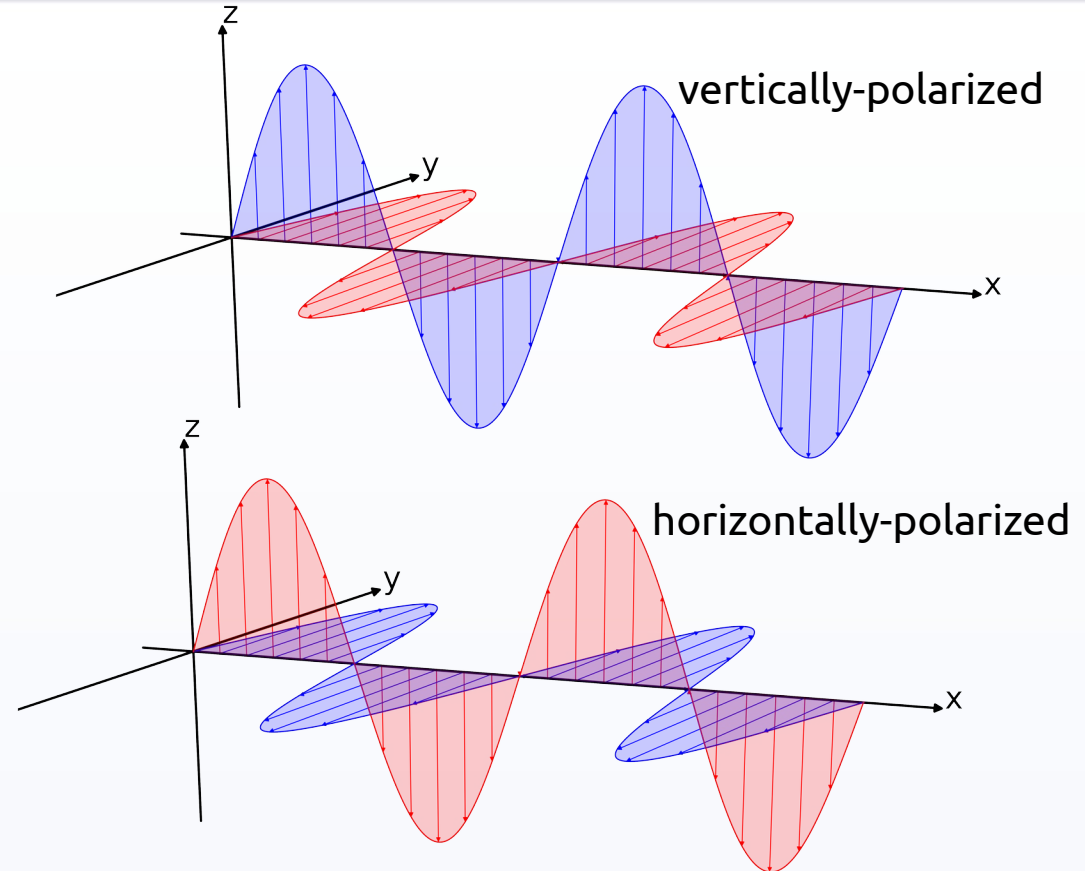
- EMR is a self-propagating wave
 - Electric (**E**) component
 - Magnetic (**B**) component
- Waves have properties:
 - Speed (often **c**)
 - For light, $c_0 \approx 3 \times 10^8 \text{ m s}^{-1}$
 - Wavelength, λ (frequency, f)
 - Phase, φ
 - Amplitude, A



$$c = \lambda \cdot f$$

Units	
c	m s^{-1}
λ	m
f	$\text{s}^{-1} (\text{Hz})$
φ	rad

- Light is a **transverse** wave
 - Oscillation perpendicular to direction of travel
- Polarization: the orientation of the wave
 - Normally defined using **E** (electric component)
 - Used frequently in microwave/radar remote sensing
- Can use as a filter (ex.: polarized sunglasses)



The particle model

- Light is a particle called a **photon**, which has energy Q
- Objects (i.e., atoms) **absorb** and **emit** energy (photons) in discrete units (*quanta*)
- The size of the unit is directly related to f .

$$Q = h \cdot f$$

Planck's constant

- Or, using what we know from the wave model:

$$Q = \frac{hc}{\lambda}$$

Units	
Q	J
h	J·s
f	s ⁻¹

- For light:
 - Longer wavelength \rightarrow lower frequency \rightarrow lower energy
 - Shorter wavelength \rightarrow higher frequency \rightarrow higher energy
- For remote sensing:
 - Longer wavelengths are harder to detect

Blackbody radiation

- All matter at a temperature T above 0 K (-273.15°C) emits EMR
- How much is emitted (the **radiant emittance**, M) depends on the temperature
- For a (hypothetical) object that perfectly absorbs and re-emits all energy that falls on it (a **blackbody**):

$$M = \sigma T^4$$

← Stefan-Boltzmann constant

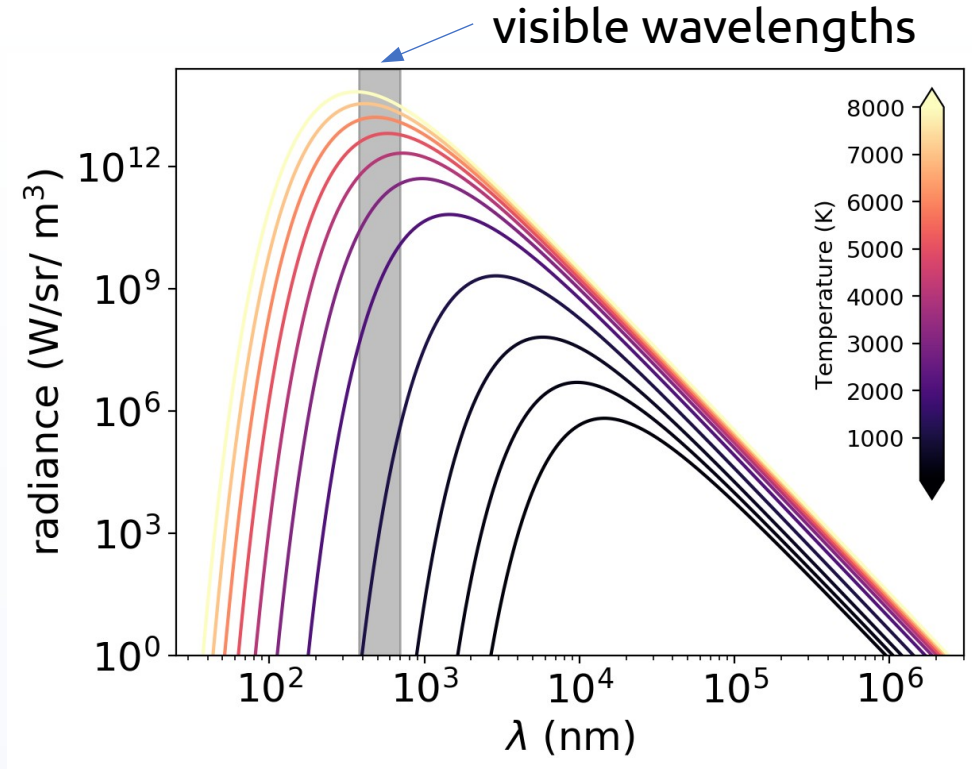
- Can define **emissivity** ε for a non-perfect object:

$$\varepsilon = \frac{M}{M_b}$$

Units	
M	W m^{-2}
σ	$\text{W m}^{-2} \text{K}^{-4}$
T	K

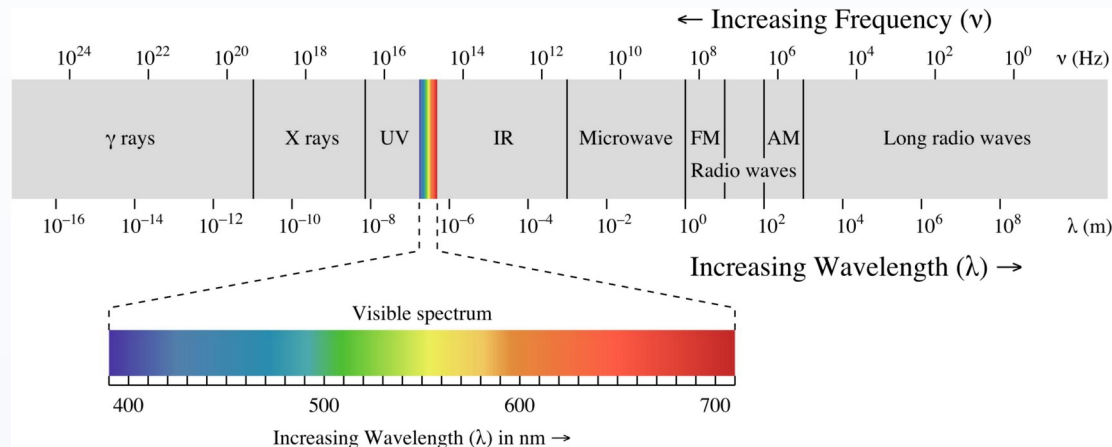
Blackbody radiation

- Higher temperature \rightarrow higher energy \rightarrow shorter wavelengths
- The *colour* of EMR an object emits changes as well:
 - Sun (~ 6000 K) appears white*
 - Wood fire (~ 1500 K) appears reddish-orange
 - Human body (~ 300 K) doesn't emit in visible wavelengths
- *Wien's displacement law* tells us the **dominant wavelength** (max. radiance)



The Electromagnetic spectrum

- Electromagnetic spectrum: the range of wavelengths and frequencies of EMR
- Arbitrarily divided into regions of wavelengths with “similar enough” properties:



Divisions of the EM spectrum

- Different users may have different definitions
- Different 'preferred' units (e.g., Hz, nm, μm)
- These are what are typically used for remote sensing
 - Why nothing 'below' visible?

Region	Limits
Visible light	380 – 720 nm
Blue	400 – 500 nm
Green	500 – 600 nm
Red	600 – 700 nm
Infrared radiation	700 – 10^6 nm (1mm)
Near-infrared	700 – 1000 nm
Shortwave infrared	1000 – 3000 nm
Mid infrared	3000 – 8000 nm
Longwave infrared	8000 – 14000 nm
Far infrared	14000 – 10^6 nm
Microwave	1 mm – 1 m

- Electromagnetic radiation (EMR) has properties of both a wave and a particle
- Energy of EMR depends on wavelength/frequency:
 - Higher wavelength/lower frequency → less energy
- All objects (above 0 K) emit EMR, dependent on temperature
- EMR can be divided into different regions of a spectrum, depending on properties

- Lillesand, Kiefer & Chipman – Chapter 1
- Campbell & Wynne – Chapter 2
- Natural Resources Canada [Remote Sensing Tutorials](#)
- Tour of the Electromagnetic Spectrum [[NASA](#)]
- EM waves and the EM spectrum [[Khan Academy](#)]
- The photoelectric effect [[National STEM Centre](#)]
- The Ultraviolet Catastrophe [[Physics Girl](#)]