EGM703 – Advanced Active and Passive Remote Sensing

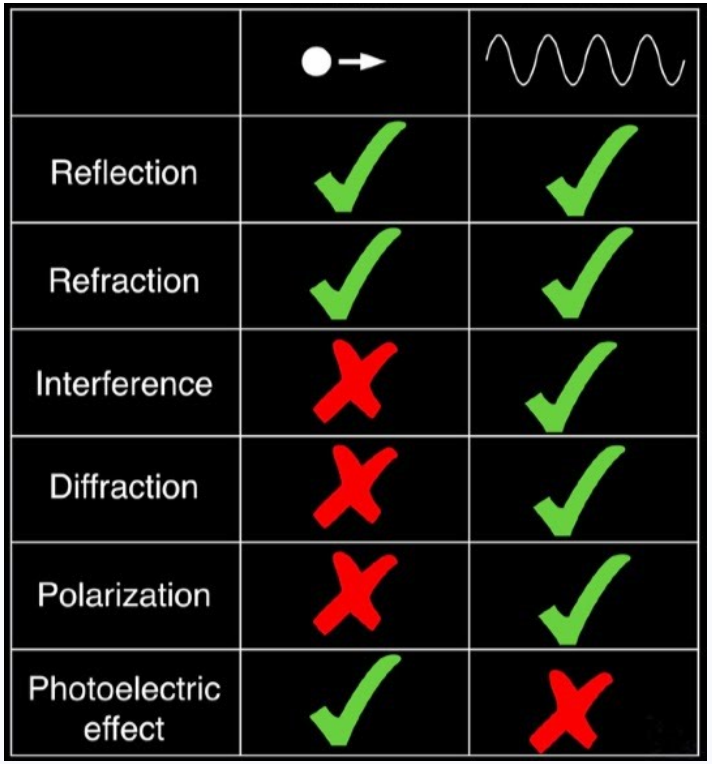
Week 1, Part 1: Principles of Thermal Remote Sensing

Week 1 Outline

1. Principles of Thermal Remote Sensing
2. Principles of Thermal Remote Sensing (part 2)
3. Thermal properties of objects
4. Radiance to Temperature
5. Atmospheric Correction
6. Applications of Thermal Remote Sensing

Recap: Light (Electromagnetic Radiation)

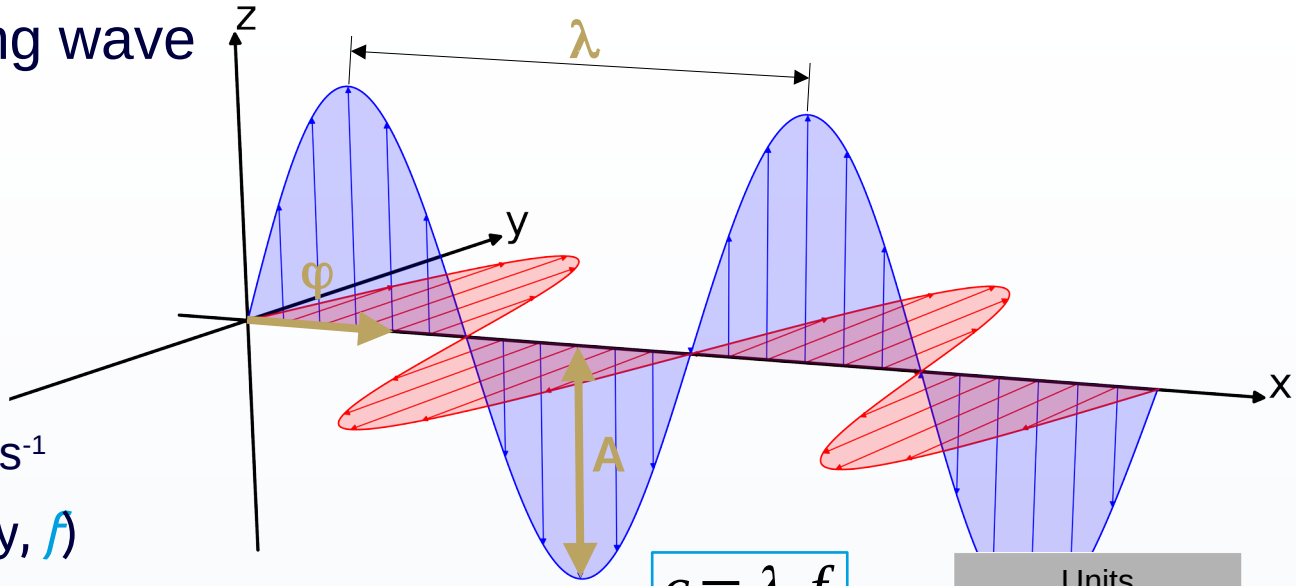
- The light we can see is a form of electromagnetic radiation (EMR)
- For most remote sensing, we use EMR
- Question: is light a particle, or is it a wave?
  - "It depends"



https://www.youtube.com/watch?v=h1tflE-L2Dc

Recap: The Wave Model

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



$$c = \lambda \cdot f$$

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

Recap: 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*:

Planck's constant

$$Q = h \cdot f$$

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

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

Units	
Q	J
h	J·s
f	s^{-1}

Recap: Implications

- For light:
  - Longer wavelength → lower frequency → lower energy
  - Shorter wavelength → higher frequency → higher energy

- For remote sensing:
  - Longer wavelengths are harder to detect

Recap: 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

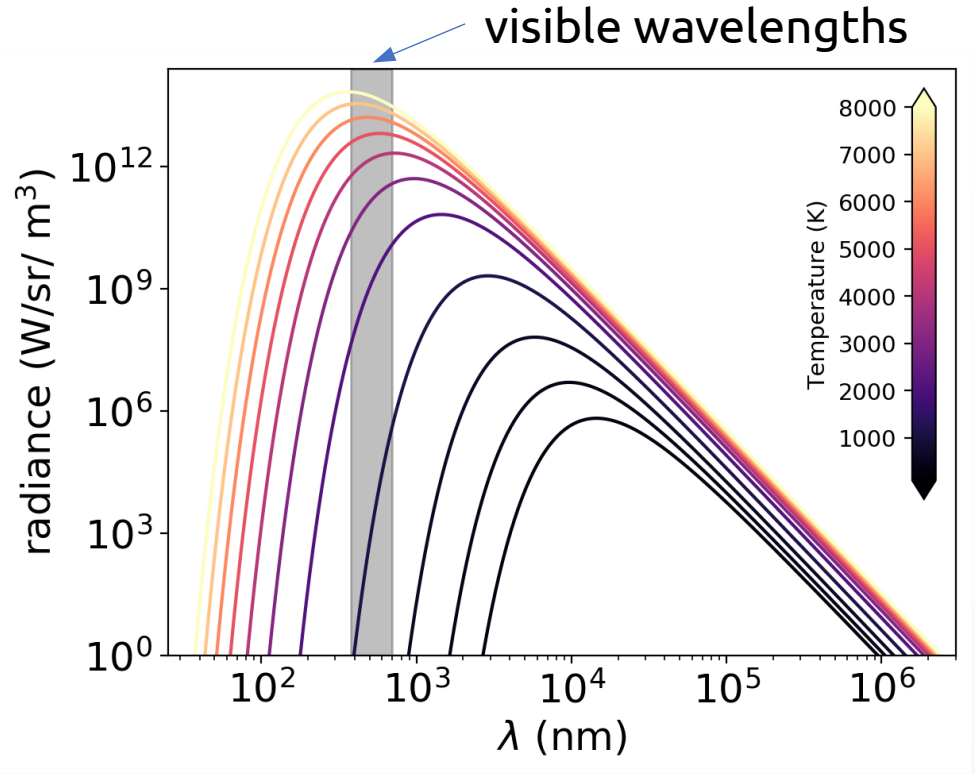
- Can define emissivity ε for a non-perfect object:

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

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

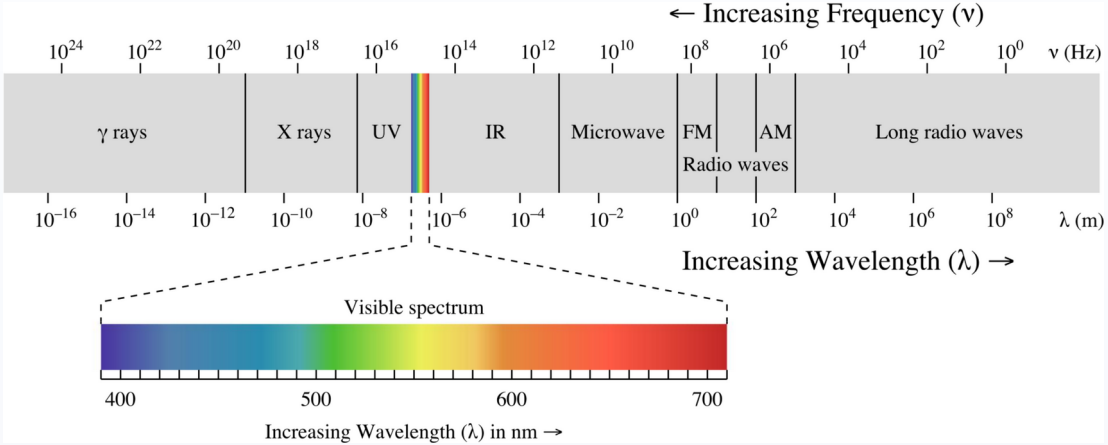
Recap: Blackbody radiation

- Higher temperature → higher energy → 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)



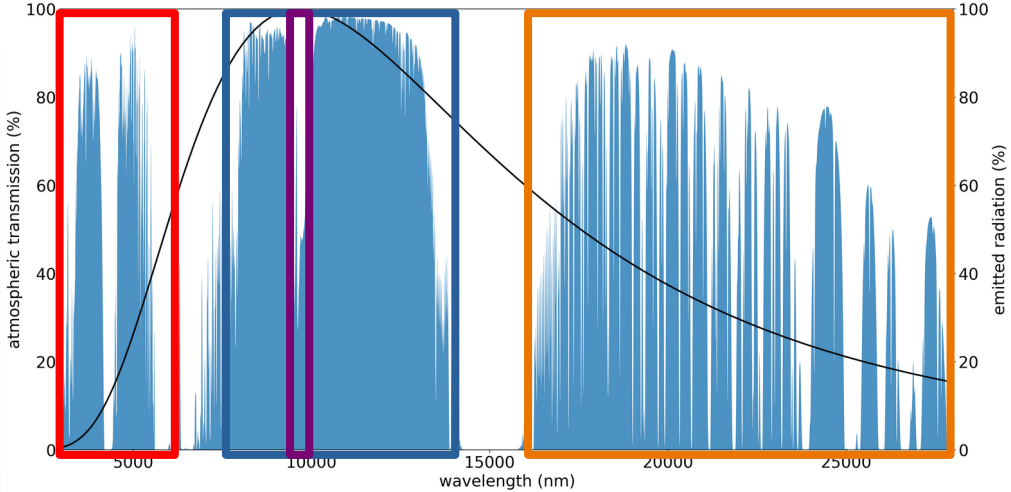
Recap: The Electromagnetic spectrum

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



Thermal Infrared

- Within 3000-35000 nm region, three “atmospheric windows”
- 3000 – 5000 nm
  - Overlaps with solar reflection
- 17000 – 25000 nm
  - Not typically used
- 8000 – 14000 nm
  - O_3 absorption ~9600 nm
  - Overlaps with peak of Earth’s emitted radiation (!)



Summary

- 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
  - Thermal Infrared: 3000 – 35000 nm*
- For (satellite) Thermal remote sensing: typically 8000 – 14000 nm
  - Atmospheric window *and* peak of Earth's emitted radiation

Additional resources

- Lillesand, Kiefer & Chipman – Chapter 1, 4.8 – 4.11
- Campbell & Wynne – Chapter 2, 9
- 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]