PAM1014
Introduction to Radiation Physics

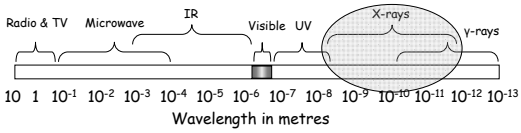
"Electromagnetic Radiation"

Objectives

- Electromagnetic Radiation
- Electromagnetic Waves
- Properties of Electromagnetic Radiation
- Electromagnetic Spectrum
- Inverse Square Law

What are X-rays?

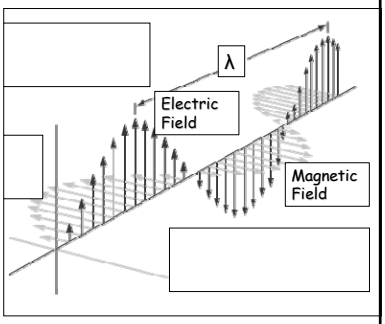
- Electromagnetic Radiation



- Useful Characteristics
  - Penetrate Matter
  - Interact with Matter
  - Cause Certain Materials to Fluoresce
  - Cause Certain Material to Produce Electric Charge

Electromagnetic Radiation

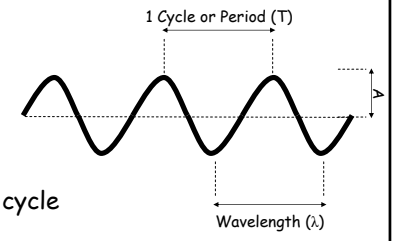
- A single-frequency EM wave exhibits a sinusoidal variation of electric and magnetic fields in space
- Magnetic variation is perpendicular to electric field



Electromagnetic Waves

Sinusoidal Model

- Amplitude, A
  - Electric field
- Wavelength
  - Length of one cycle
- Frequency
  - Hz = cycles per second



Electromagnetic Radiation

- Transport energy through space
- Energy is stored in the propagating electric and magnetic fields

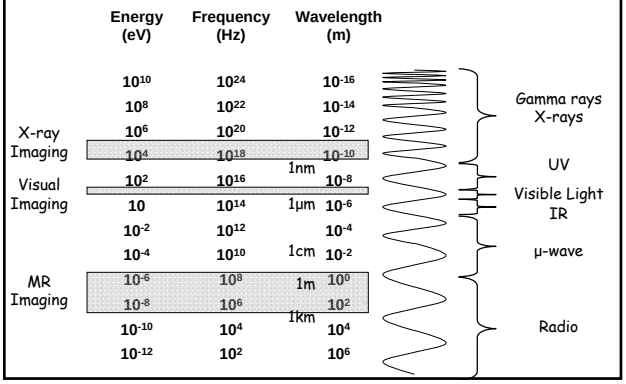
Photons

- A *photon* is the smallest quantity of ANY type of electromagnetic radiation
- Energy disturbances moving through space at the speed of light
- $c = 3 \times 10^8\ ms^{-1}$

Electromagnetic Spectrum

- Frequency Range: $10 - 10^{24}$ Hz
- Wavelength Range: $10^6 - 10^{-16}$ m
- Regions relevant to medical imaging?

Electromagnetic Spectrum

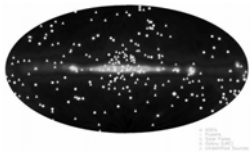


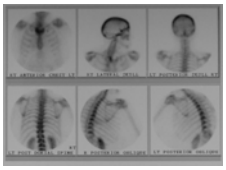
Electromagnetic Radiation

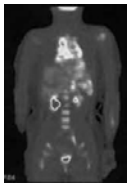
- Electromagnetic Radiation can interact with matter
- Interacts with particles matter of length scale of the same order as the radiation wavelength

Gamma-Ray

- Gamma-Ray Imaging

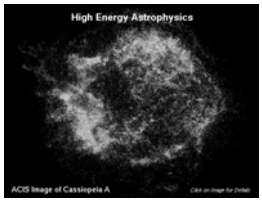






X-ray

Astronomy

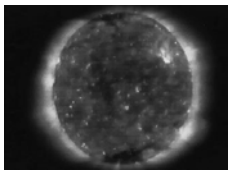


Security

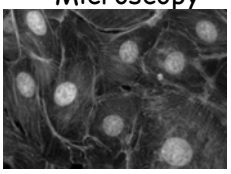
Medical

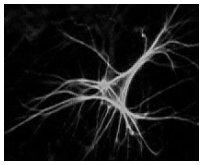
Ultraviolet

Astronomy



Microscopy



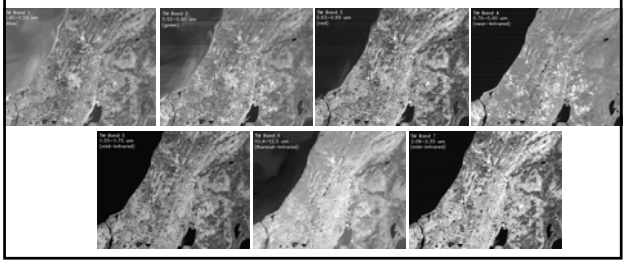


Fluorescence Microscopy: Endothelial Cells, Astrocyte

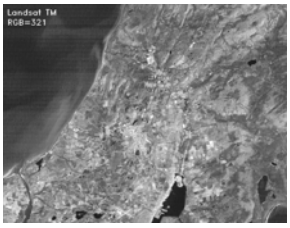
Optical

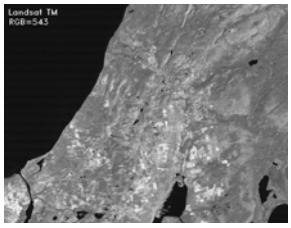
Band	Name	λ (μm)	uses
1	Vis blue	0.45-0.52	Max water penetration
2	Vis green	0.52-0.60	Measuring planet vigour
3	Vis red	0.63-0.69	Vegetation
4	NIR	0.76-0.90	Biomas & shoreline mapping
5	Middle IR	1.55-1.75	Moisture content
6	Thermal IR	10.4-12.5	Soil moisture & thermal mapping
7	Middle IR	2.08-2.35	Mineral mapping

NASA's LANDSAT satellite



Optical

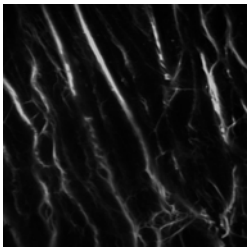




True color image; the red satellite data (band3) is displayed in red, the green satellite data (band 2) is displayed in green, and the blue satellite data (band 1) is displayed in blue

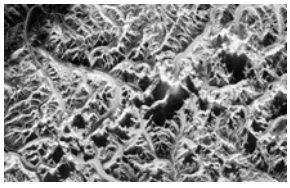
False color image; any of the bands can be put in a single color. The band combination which is used can be changed to highlight the desired feature or phenomena.

Infrared

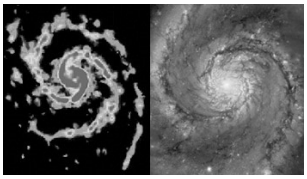


Microwave

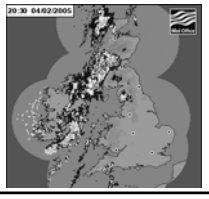
Spaceborne Radar



Astronomy



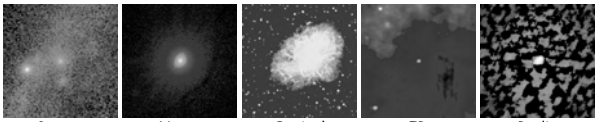
Weather Radar



Radio Imaging

Medical - MRI

Astronomy – Radiotelescope



Gamma X-ray Optical IR Radio

Electromagnetic Waves

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  - Electric field
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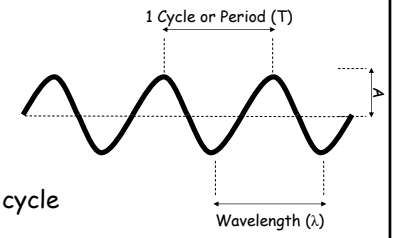
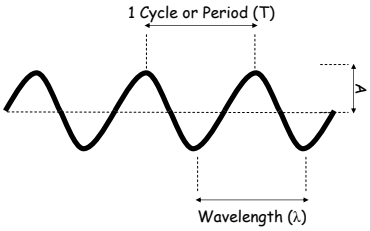


Electromagnetic Waves

- Frequency is the number of wavelength passing a point per second



$$velocity = \frac{dis\tan ce}{time}$$

$$velocity = frequency \times wavelength$$

$$= [s^{-1}][m] = [ms^{-1}]$$

$$c = f\lambda$$

Energy of Electromagnetic Radiation

- Energy is proportional to frequency
- Energy = constant x frequency

OR

$$E = hf$$

- Where h is Plank's constant
- h = 6.626 x 10^{-34} Js

Measurement of EM Radiation

Frequency, Wavelength & Energy

- Different regions of the electromagnetic spectrum are measured in different ways

Measurement of EM Radiation

- Visible light:
- Early experiments describe light as a wave
  - Quoted in meters

Example

- Calculate the energy of a 400 nm photon

Measurement of EM Radiation

- Radio waves:
- Measured via oscillations of electrons in conductors
  - Quoted in Hz

Example

- Calculate the wavelength of 97.7 MHz

Measurement of EM Radiation

- X-rays:
- Produced using electric potential
  - Quoted in keV
- eV = the energy of one electron accelerate by one volt
- E = hf

Example

- Calculate the frequency of a 50 keV x-ray photon

Ionizing Radiation

- Radiation with sufficient energy to cause ionization
- Binding energy of outermost electron to atoms ~10-100 ev

Summary

- Electromagnetic Radiation
- Electromagnetic Waves
- Properties of Electromagnetic Radiation
- Electromagnetic Spectrum
- Inverse Square Law