Introduction to Physical Science

Electromagnetic Spectrum

Presented by Robert Wagner

The Electromagnetic Spectrum

- Electromagnetic waves are grouped according to wavelength/ frequency

Type of EM wave	Production	Applications	Life sciences aspect	Issues
Radio & TV	Accelerating charges	Communications Remote controls	MRI	Requires controls for band use
Microwaves	Accelerating charges & thermal agitation	Communications Ovens Radar	Deep heating	Cell phone use
Infrared	Thermal agitations & electronic transitions	Thermal imaging Heating	Absorbed by atmosphere	Greenhouse effect
Visible light	Thermal agitations & electronic transitions	All pervasive	Photosynthesis Human vision	
Ultraviolet	Thermal agitations & electronic transitions	Sterilization Cancer control	Vitamin D production	Ozone depletion Cancer causing
X-rays	Inner electronic transitions and fast collisions	Medical Security	Medical diagnosis Cancer therapy	Cancer causing
Gamma rays	Nuclear decay	Nuclear medicineSecurity	Medical diagnosis Cancer therapy	Cancer causing Radiation damage

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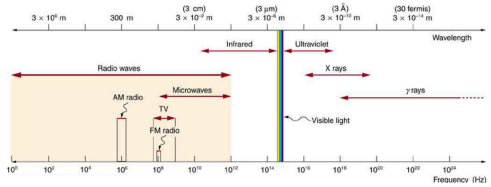
Electromagnetic Waves

- For electromagnetic waves, , the speed of light
  -
  - Higher frequency = smaller wavelength



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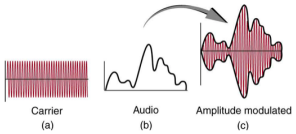
General Rules

- High frequency electromagnetic waves are more energetic and more penetrating than low frequency waves
- High frequency electromagnetic waves carry more information pr unit time than low frequency waves
- The shorter the wavelength of the electromagnetic radiation probing a material - the smaller detail it is able to resolve

Radio Waves

- Longest wavelength
- Often used as carriers of radio waves
  - AM - Amplitude modulation on carrier wave
  - FM - Frequency modulation on carrier wave
  - Television - uses VHF and UHF of much wider ranges since they carry more information



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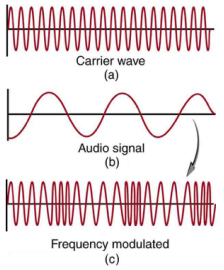

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Example

- Calculate the wavelengths of a 1530 kHz Am radio signal, a 105.1 MHz FM radio signal and a 1.90 GHz cell phone signal.
  - Draw a sketch (if applicable)
  - Identify known values
  - Identify equation
  - Enter values in the equation and solve

$$f_1 = 1530\ kHz = 1530x10^3\ cycles/sec$$
$$f_2 = 105.1\ MHz = 105.1x10^6\ cycles/sec$$
$$f_3 = 1.90\ GHz = 1.90x10^9\ cycles/sec$$

$$\lambda = \frac{c}{f}$$

$$\lambda_1 = \frac{c}{f_1} = \frac{3.00x10^8\ m/s}{1530x10^3\ cycles/sec} = 196\ m$$

$$\lambda_2 = \frac{c}{f_2} = \frac{3.00x10^8\ m/s}{105.1x10^6\ cycles/sec} = 2.85\ m$$

$$\lambda_3 = \frac{c}{f_3} = \frac{3.00x10^8\ m/s}{1.90x10^9\ cycles/sec} = 0.158\ m$$

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Microwaves

- Shorter wavelengths than radio
- Carry more information per unit time => better for communications
- Radar - application of microwaves
  - Used by spacecraft to map the surface of Venus
- Microwave ovens - used to heat food
  - Frequencies are selected so polar molecules (like water) absorb the energy increasing the temperatures

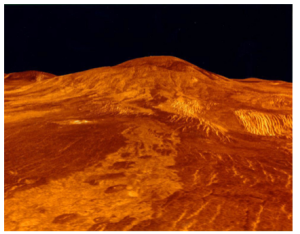


Image Credit: OpenStax College Physics - Figure 24.15 - Public Domain NASA

Infrared

- Longer wavelengths than visible - below red
- Produced by thermal motions
- Night vision goggles
  - Detect radiation emitted by warm objects
- Earth heated by our Sun
  - Earth is cooler - emits infrared
  - Infrared absorbed by
  - Greenhouse effect

Visible Light

- Produced by vibrations of atoms and molecules
- Radiation from our Sun peaks in the visible portion of the spectrum
  - Photosynthesis - Use of sunlight to produce food in plants

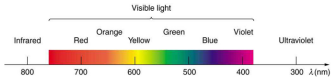
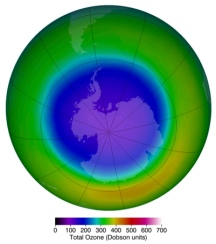


Figure 24.16 A small part of the electromagnetic spectrum that includes its visible components. The divisions between infrared, visible, and ultraviolet are not perfectly distinct, nor are those between the seven rainbow colors.

Image Credit: OpenStax College Physics - Figure 24.16 CC BY 4.0

Ultraviolet Radiation

- Ultraviolet - above violet
- Divided into UV-A, UV-B and UV-C
  - Most UV-B and all UV-C are absorbed by ozone ( ) in Earth's atmosphere
- UV-B - causes skin cancer
  - Tanning - body adapts to have more energy absorbed in upper skin layers
- Ozone Hole - Depletion of ozone due to CFCs in Earth's atmosphere
- Some UV-B needed - helps vitamin D production, treat jaundice and kill germs



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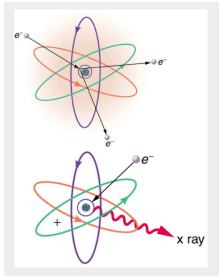
X-Rays

- High energy - much more penetrating
- Can be produced by high voltage discharge - ionization of atoms
- X-ray images - medical uses
  - More sophisticated - CT scan can show 3-dimensional information



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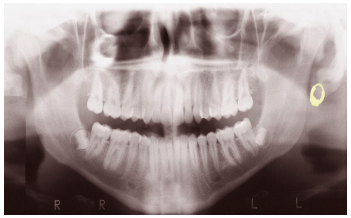

Gamma Rays

- Highest energy electromagnetic radiation
- Radiation emitted by atomic nucleus
- Sometimes used in cancer therapy
  - High energy can kill cancer cells

Electromagnetic Waves from Space

- Astronomers now use the entire electromagnetic spectrum
- Visible light and radio waves are visible from Earth's surface
- Infrared can be viewed from high mountains, planes or satellites
- UV, X-Ray and Gamma Rays must be studied from space telescopes.

Summary

- The electromagnetic spectrum is divided into parts by wavelength/ frequency
- All electromagnetic waves travel at the speed of light and have their wavelength and frequency related by:
- Different parts of the electromagnetic spectrum have different uses because of the wavelength and energy of the radiation