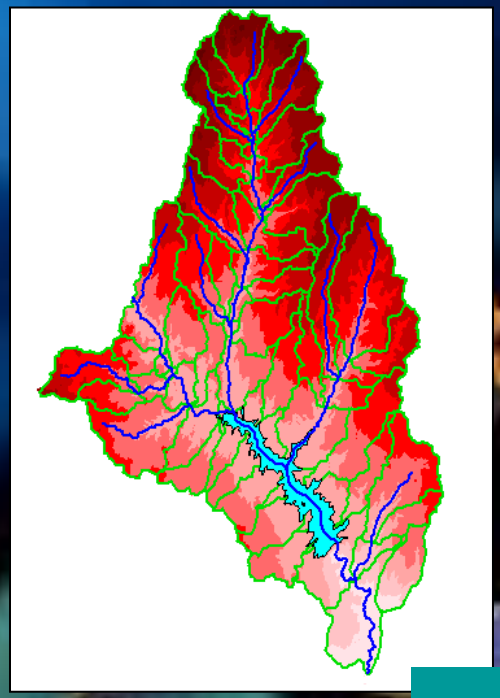
Course Title: Advances in Remote Sensing and GIS

Course Code: ENV-652

Topic: **Introduction to Remote Sensing**



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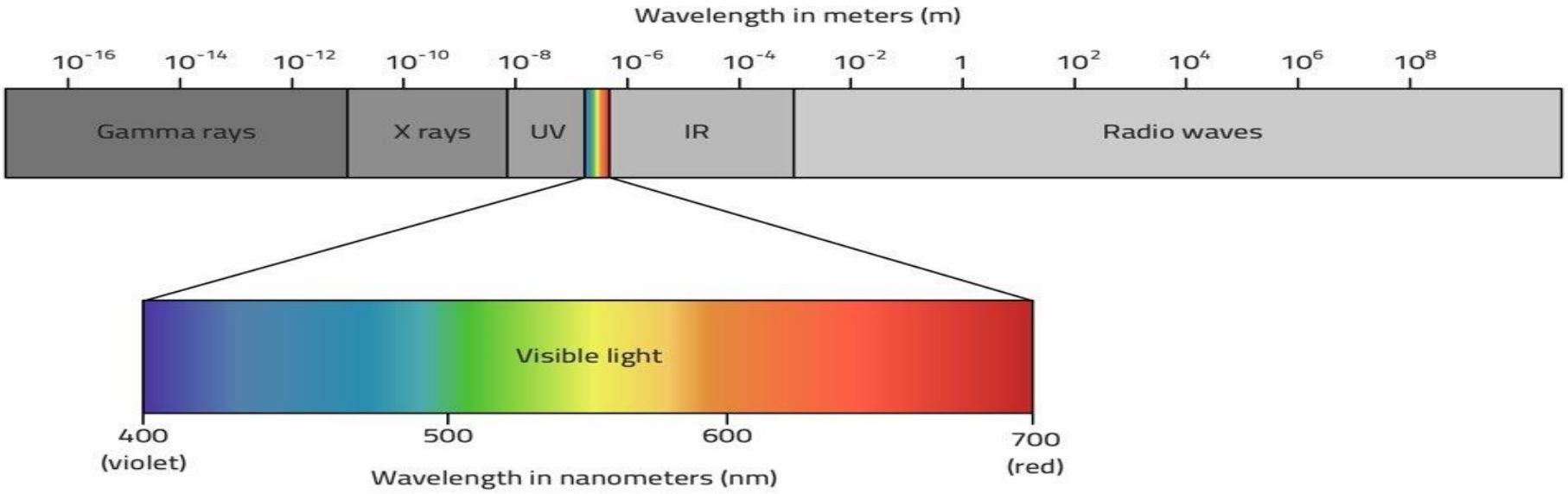
Electromagnetic Radiation

Electromagnetic (EM) spectrum

The electromagnetic spectrum refers to the entire range of electromagnetic radiation, which includes radio waves, microwaves, infrared radiation, visible light, ultraviolet radiation, X-rays, and gamma rays. It encompasses a continuum of frequencies and wavelengths, each associated with different types of energy and behaviors, ranging from the longest wavelengths to the shortest wavelengths.



Major Divisions of the Electromagnetic Spectrum

- *Gama rays*
- *X-rays*
- *UV*
- *Visible*
- *Infrared*
- *Microwave*
- *Radio*

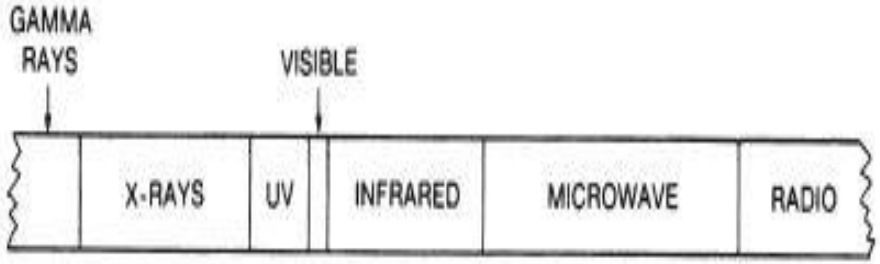
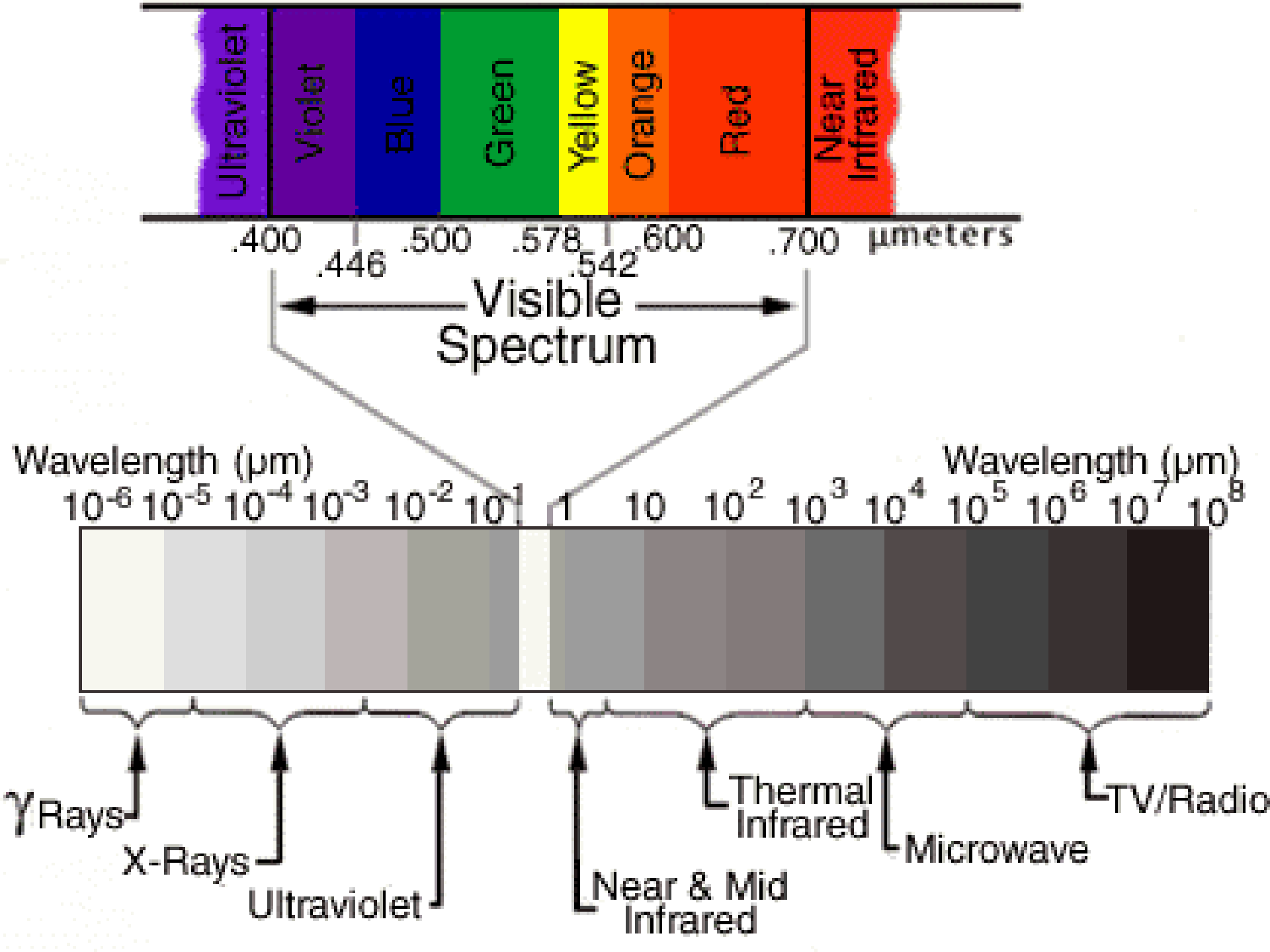


FIGURE 2.3. Major divisions of the electromagnetic spectrum. This diagram gives only a schematic representation—sizes of divisions are not shown in correct proportions. (See Table 2.3.)


Ultraviolet
Violet
Blue
Green
Yellow
Orange
Red
Near Infrared
.400
.446
.500
.578
.542
.600
.700
μmeters
Visible Spectrum
Wavelength (μm)
10^{-6} 10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 1 10 10^{2} 10^{3} 10^{4} 10^{5} 10^{6} 10^{7} 10^{8}
Wavelength (μm)
γ Rays
X-Rays
Ultraviolet
Near & Mid Infrared
Thermal Infrared
Microwave
TV/Radio

Visible

- **Violet:** 0.4 - 0.446 μm
- **Blue:** 0.446 - 0.500 μm
- **Green:** 0.500 - 0.578 μm
- **Yellow:** 0.578 - 0.592 μm
- **Orange:** 0.592 - 0.620 μm
- **Red:** 0.620 - 0.7 μm

Electromagnetic (EM) spectrum

Range of Frequencies: The EM encompasses a wide range of frequencies, spanning from extremely low frequencies to extremely high frequencies.

Radio Waves: Radio waves have the longest wavelengths and lowest frequencies in the electromagnetic spectrum. They are used for communication, broadcasting, radar, and navigation systems.

Microwaves: Microwaves have longer wavelengths and are commonly used in satellite communication, radar, and wireless networking.

Electromagnetic (EM) spectrum

Infrared Radiation: Infrared radiation lies between microwaves and visible light in the EM spectrum. It is often used in thermal imaging, remote controls, and infrared photography.

Visible Light: Visible light is the portion of the EM spectrum that is visible to the human eye.

Ultraviolet Radiation: UV radiation has shorter wavelengths and higher frequencies than visible light. It is responsible for causing sunburn and can be used in sterilization processes.

Electromagnetic (EM) spectrum

X-rays: X-rays have very short wavelengths and high frequencies. They are commonly used in medical imaging (X-ray radiography), security screening, and materials analysis.

Gamma Rays: Gamma rays have the shortest wavelengths and highest frequencies in the electromagnetic spectrum. They are emitted by radioactive substances and nuclear reactions and are used in cancer treatment (radiotherapy) and sterilization.

Electromagnetic (EM) spectrum

Electromagnetic energy can be characterized by several properties

1. ***Wavelength***
2. ***Frequency***
3. ***Amplitude***

Electromagnetic (EM) spectrum

1. ***Wavelength*** is the distance from one wave crest to the next. Wavelength can be measured in everyday units of length, although very short wavelengths have such small distances between wave crests that extremely short measurement units are required.

TABLE 2.1. Units of Length Used in Remote Sensing

Unit	Distance	
Kilometer (km)	1,000 m	
Meter (m)	1.0 m	
Centimeter (cm)	0.01 m	$= 10^{-2}$ m
Millimeter (mm)	0.001 m	$= 10^{-3}$ m
Micrometer (μm)[a]	0.000001 m	$= 10^{-6}$ m
Nanometer (nm)		10^{-9} m
Ångstrom unit (Å)		10^{-10} m

[a]Formerly called the "micron" (μ); the term "micrometer" is now used by agreement of the General Conference on Weights and Measures.

Electromagnetic (EM) spectrum

2. Frequency is measured as the number of crests passing a fixed point in a given period. Frequency is often measured in *hertz*.

TABLE 2.2. Frequencies Used in Remote Sensing

Unit	Frequency (cycles per second)
Hertz (Hz)	1
Kilohertz (kHz)	10^3 (= 1,000)
Megahertz (MHz)	10^6 (= 1,000,000)
Gigahertz (GHz)	10^9 (= 1,000,000,000)

Electromagnetic (EM) spectrum

3. Amplitude is equivalent to the height of each peak.

Amplitude is often measured as energy levels expressed as watts per square meter per micrometer (i.e., as energy level per wavelength interval).

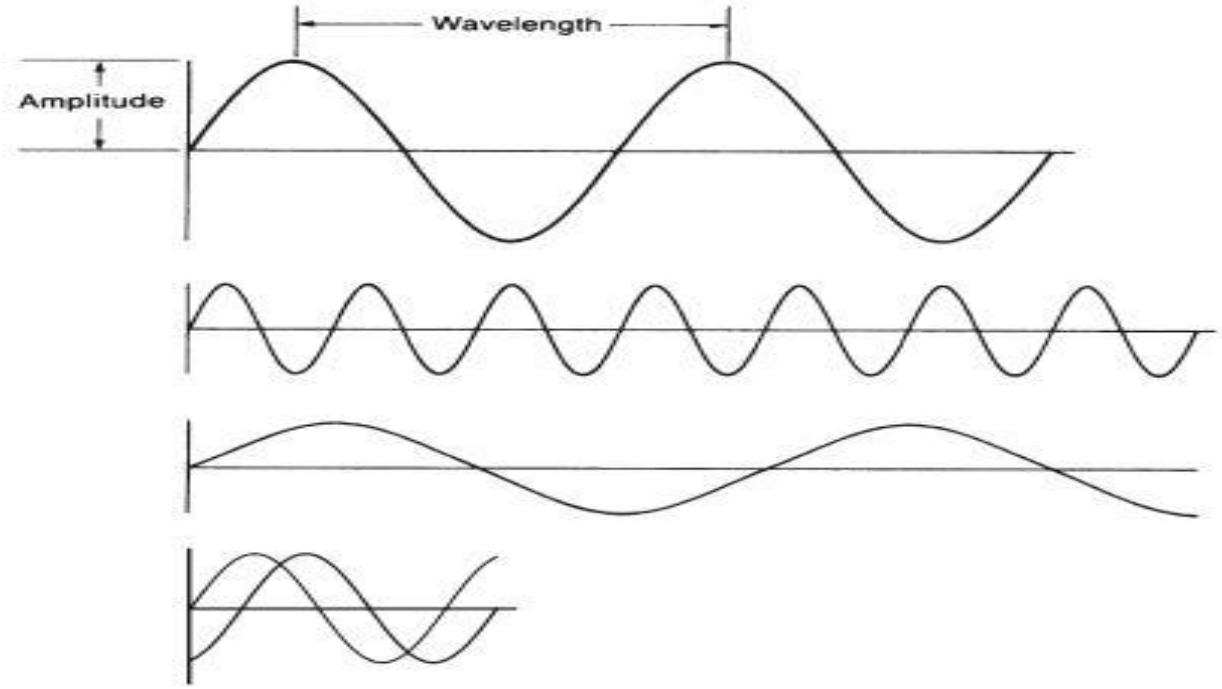


FIGURE 2.2. Amplitude, frequency, and wavelength. The second diagram represents high frequency, short wavelength; the third, low frequency, long wavelength. The bottom diagram illustrates two waveforms that are out of phase.

Electromagnetic (EM) spectrum

- The speed of electromagnetic energy (c) is constant at 299,792 kilometers (km) per second.
- Frequency (ν) and wavelength (λ) are related:

$$c = \lambda\nu$$

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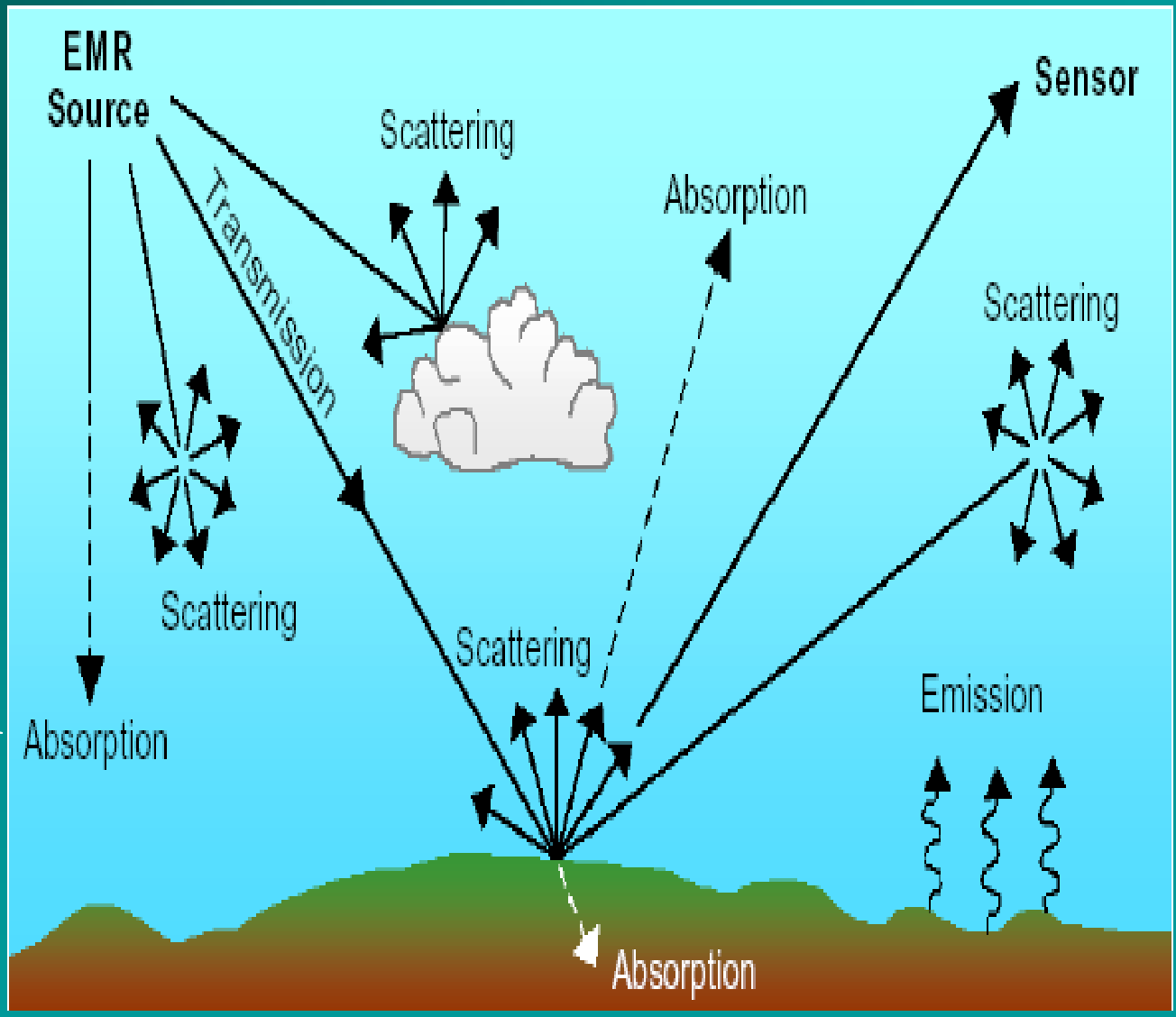
EMR interactions with the atmosphere and at the Earth's surface

1. Scattering
2. Absorption
3. Reflection
4. Transmission



Scattering

- Once electromagnetic radiation is generated, it is propagated through the earth's atmosphere almost at the speed of light in a vacuum.

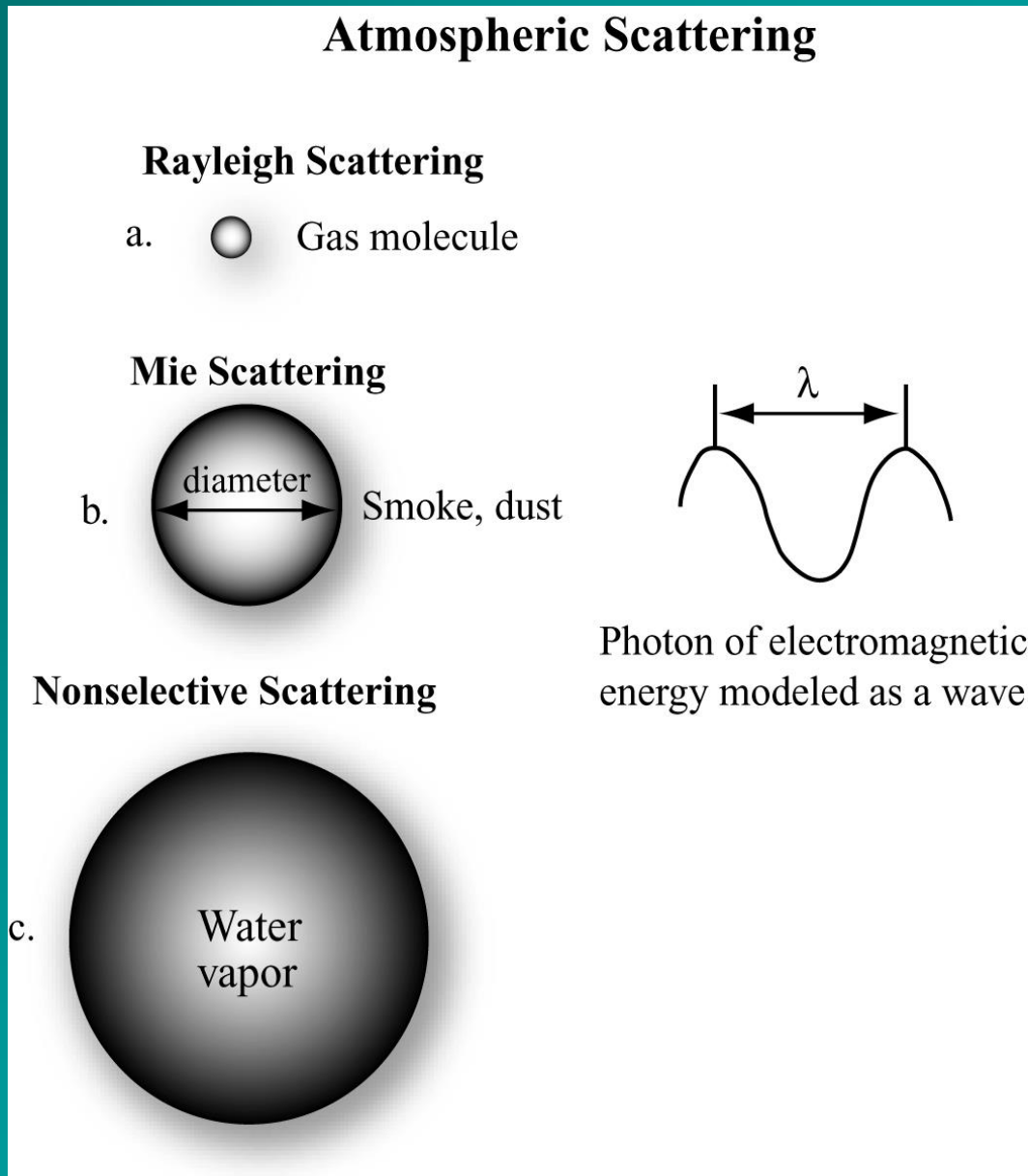
  There are essentially three types of scattering:

  - Rayleigh,
  - Mie, and
  - Non-selective.

Atmospheric Scattering

Type of scattering is a function of:

- the *wavelength* of the incident radiant energy, and the *size* of the gas molecule, dust particle, and/or water vapor droplet encountered.



Rayleigh scattering

- Rayleigh scattering occurs when the diameter of the matter (usually air molecules) are many times smaller than the wavelength of the incident electromagnetic radiation.
- *Rayleigh scattering* is responsible for the ***blue sky.***
- *Rayleigh scattering is responsible for red sunsets*.

Mie scattering

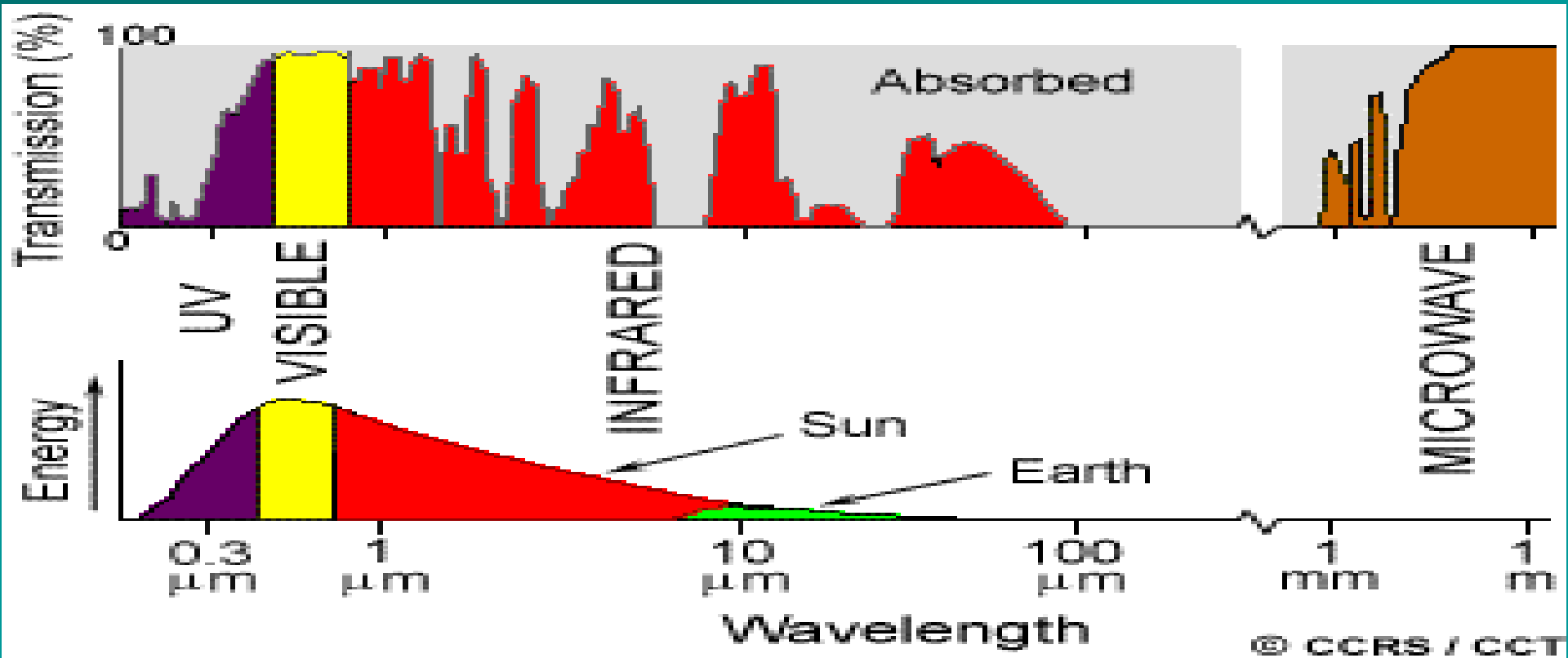
- *Mie scattering* takes place when there are essentially *spherical* particles present in the atmosphere *with diameters approximately equal to the wavelength of radiation being considered.*

Non-selective scattering

- Non-selective scattering is produced when there are particles in the atmosphere several times the diameter of the radiation being transmitted.

Atmospheric windows

- Those areas of the spectrum which are not severely influenced by atmospheric absorption and thus, are useful to remote sensors, are called **atmospheric windows**.



RADIATION - TARGET INTERACTIONS

Incident radiation

- Incident energy (I) from the source
- Absorption (A) occurs when radiation (energy) is absorbed into the target
- Transmission (T) occurs when radiation passes through a target
- Reflection (R) occurs when radiation "bounces" off the target and is redirected.

Absorption

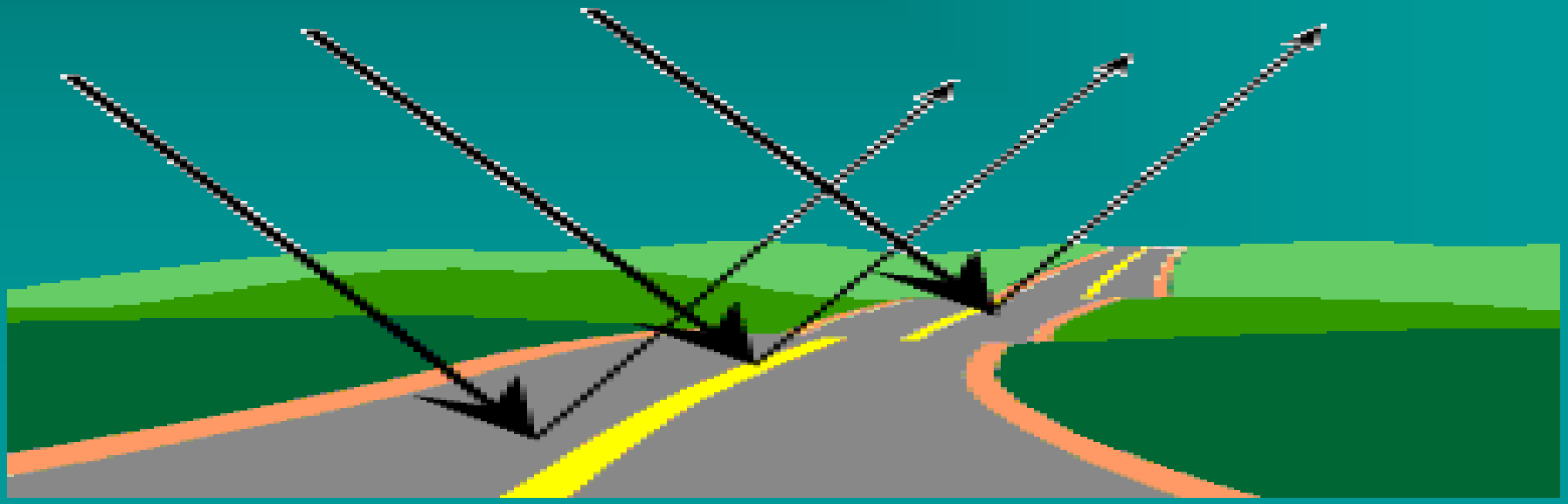
- *Absorption* is the process by which radiant energy is absorbed and converted into other forms of energy.
- the atmosphere does not absorb all of the incident energy but transmits it effectively. Parts of the spectrum that transmit energy effectively are called “atmospheric windows”.

Reflectance

- *Reflectance* is the process whereby radiation "bounces off" an object like a cloud or the terrain.
- The angle of incidence and the angle of reflection are equal.

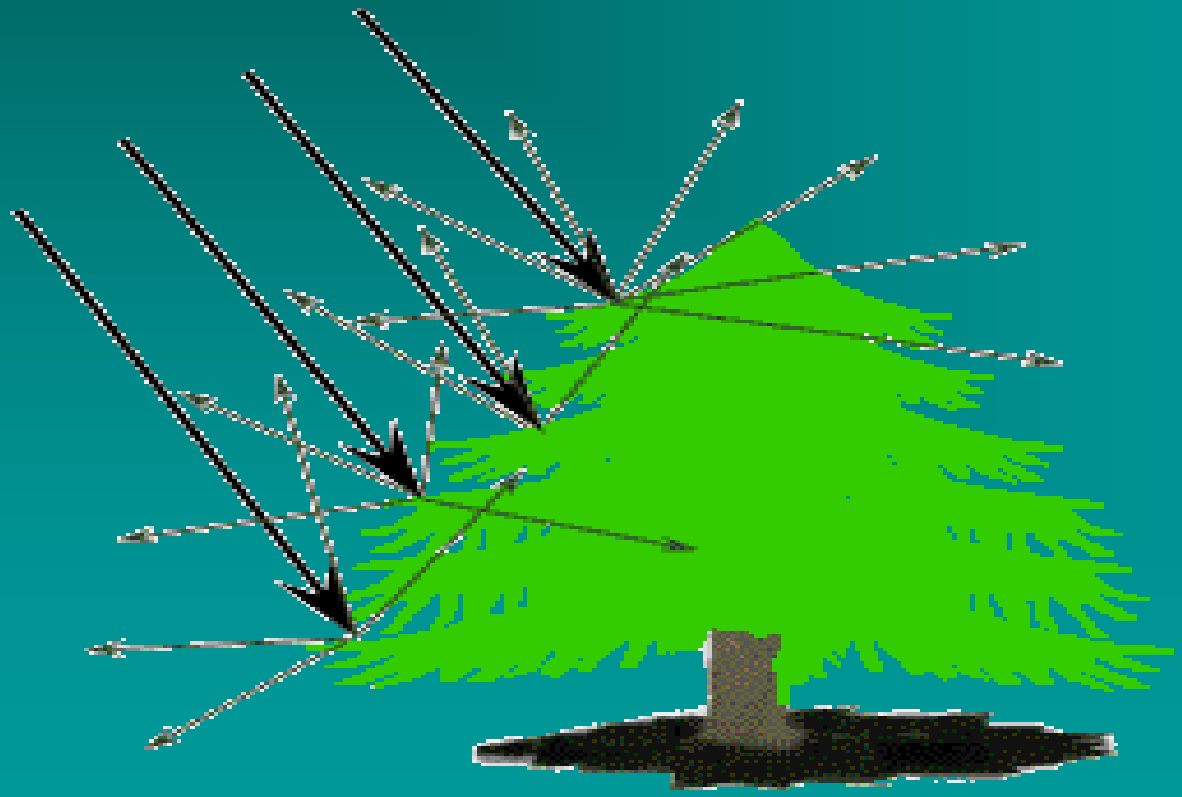
SPECULAR REFLECTION

- When a surface is smooth we get **specular** or mirror-like reflection where all (or almost all) of the energy is directed away from the surface in a single direction



DIFFUSE REFLECTION

- When the surface is rough and the energy is reflected almost uniformly in all directions.



Reflectance Curve