D.B.F. Dayanand College of Arts and Science, Solapur

Department of Geology

B.Sc. III

2020-2021

Subject	**GEOLOGY**
Paper No. and Title	**Paper – XVI Applied Geology Part – II**
Module (Flipped classroom) Title	**RS-2**
Module Tag	**DAYA.GEO.VMD2**
Key words	**Remote Sensing**

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Module No. 2

Title – EMR radiations and its interaction with atmosphere and earth.

- **Prerequisites –**
  - ✓ Basic concept and various applications of remote sensing.
  - ✓ Advantages and limitations of remote sensing.
  - ✓ Types of satellite, concept of platforms and sensors
  - ✓ Process of remote sensing and its components.
- **Learning outcome:**
  - Develop critical understanding of physics of electromagnetic radiation and its spectrum.
  - Understand various components of remote sensing.
  - Understand the interaction of EMR with the atmosphere and various objects on the earth surface.

- **Objectives of the Module**

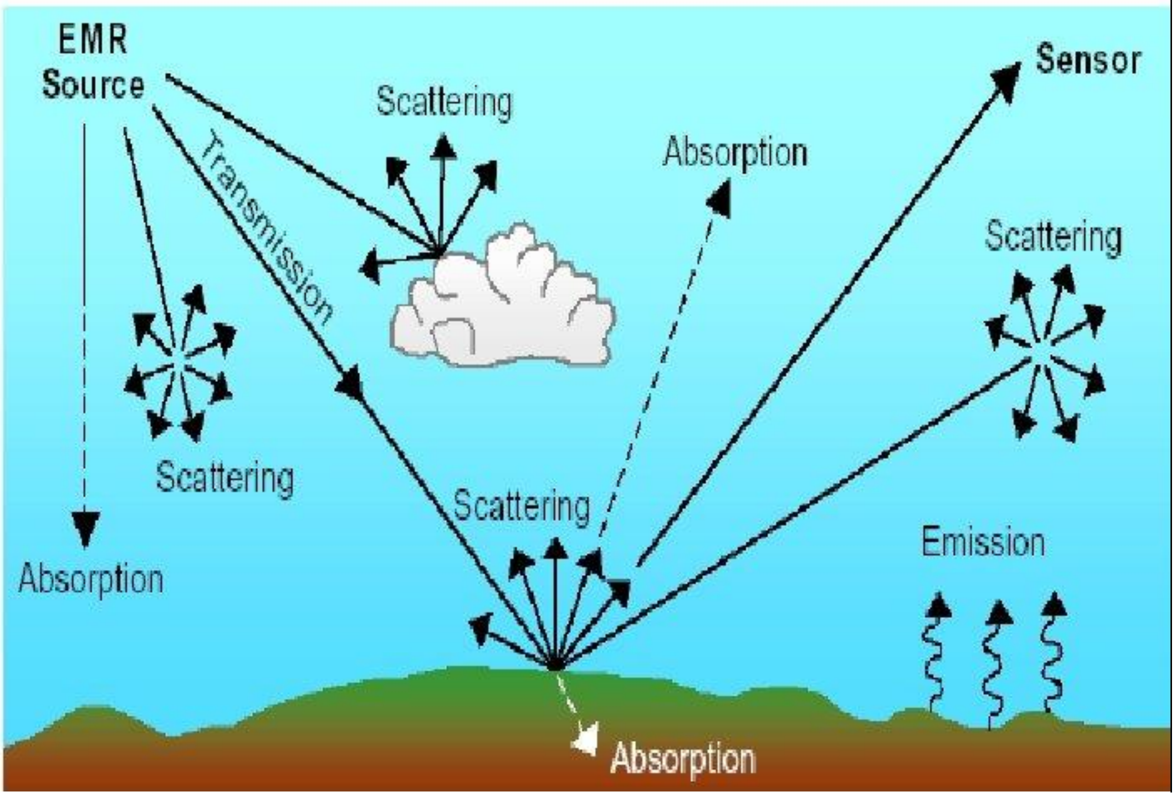
  Students should learn about the details of the meaning and concepts in remote sensing.

Content	Objectives (Learner should be able to)	Cognitive Level
1. Electromagnetic Radiations 2. Interaction of EMR with the atmosphere and various objects on the earth surface.	Electromagnetic spectrum	Remembering
	Components of remote sensing	Remembering
	Atmospheric windows	Remembering
	Visualization method	Applying
	Proper thought process	Understanding
	Asking question and some simple concept	Evaluating

Table of Content:

1. Characteristics of solar radiant energy
The Sun is the only source of radiant energy for passive remote sensing. The energy emitted by the Sun is divided into 40% visible light (VI), 50% IR, 9% UV and 1% x-ray, radio, etc. It is the VI and IR energy, which is used for the remote sensing for getting the information about the earth's surface features.

2. Terrestrial environment



Source: https://slidetodoc.com/basic-concepts-electromagnetic-radiation-two-characteristics-of-electromagnetic/

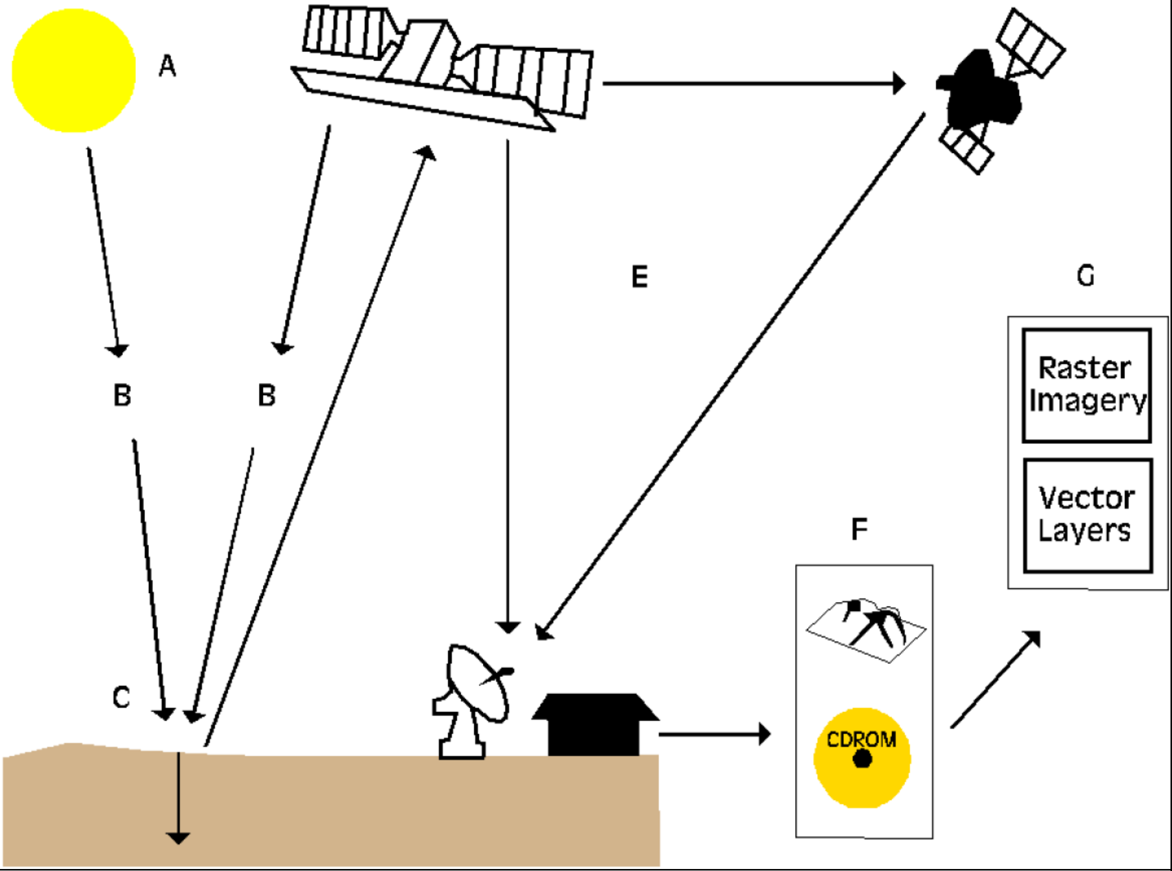
All objects of the earth's surface (at 300 Kelvin) like, soil, rock, vegetation, etc. above absolute zero (-273° Centigrade or 0 Kelvin) emit electromagnetic energy. And so does the Sun (at 6000 Kelvin). Sun is the major source of energy required for passive remote sensing purpose. The energy is transferred by electromagnetic radiation through the vacuum between the Sun and the Earth at the speed of light. It interacts with the atmosphere before coming into contact with the earth's surface. While returning, it interacts with the atmosphere once again and finally reaches the remote sensor. The detectors or photographic film system on-board records this reflected or emitted energy in analogue or digital form (above figure).

3. Components of remote sensing

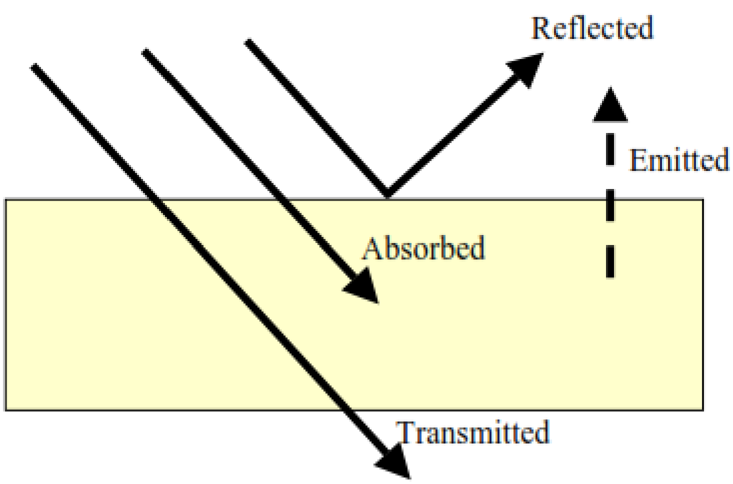
The overall process of remote sensing can be broken down into six components. These components are: 1) Electromagnetic energy source, 2) Interaction with atmosphere, 3) Interaction with target, 4) Recording of energy by sensors, 5) Transmission, Reception and Processing, and 6) Interpretation and analysis. (Figure)

1) **Electromagnetic energy** or radiation is derived from the subatomic vibrations of matter and is measured in a quantity known as wavelength. The units of wavelength are traditionally given as micrometers (µm) or nanometers (nm). Electromagnetic energy travels through space at the speed of light and can be absorbed and reflected by objects. To understand electromagnetic energy, it is necessary to discuss the origin of radiation,

which is related to the temperature of the matter from which it is emitted. The origin of all energy (electromagnetic energy or radiant energy) begins with the vibration of subatomic particles called photons.



2) Interaction with atmosphere: The solar radiation and electromagnetic radiation (EMR) from the sun before reaching the surface of the Earth has to pass through the atmosphere and then strikes the surface of the Earth and then again passes through the atmosphere before a sensor on board a satellite detects it. The interaction of EMR with the atmosphere is important to remote sensing for two main reasons. First, information carried by EMR reflected/emitted by the earth's surface is modified while traversing through the atmosphere. Second, the interaction of EMR with the atmosphere can be used to obtain useful information about the atmosphere itself.



3) **Interaction with target:** Electromagnetic energy that reaches a target will be absorbed, transmitted, and reflected. The proportion of each depends on the composition and texture of the target's surface. Figure 7 illustrates these three interactions. Much of remote sensing is concerned with reflected energy

4) **Recording of energy by sensors:** Data collected at a sensor are converted from a continuous analog to a digital number. This is necessary conversion, as electromagnetic waves arrive at the sensor as a continuous stream of radiation. The incoming radiation is sampled at a regular interval and assigned a value. The value given to the data is based on the use of a 6-, 7-, 8-, 9-, or 10-bit binary computer coding scale. Using this coding allows a computer to store and display the data.
5) Transmission, Reception and Processing: The binary coded data is then transmitted to earth station. On receiving data, it is processed and converted into analog or digital data for further interpretation and analysis by user.
6) **Interpretation and analysis**: Image interpretation and analysis has been done at the user end for strategic planning and decision making.

4. Electromagnetic radiation (EMR)

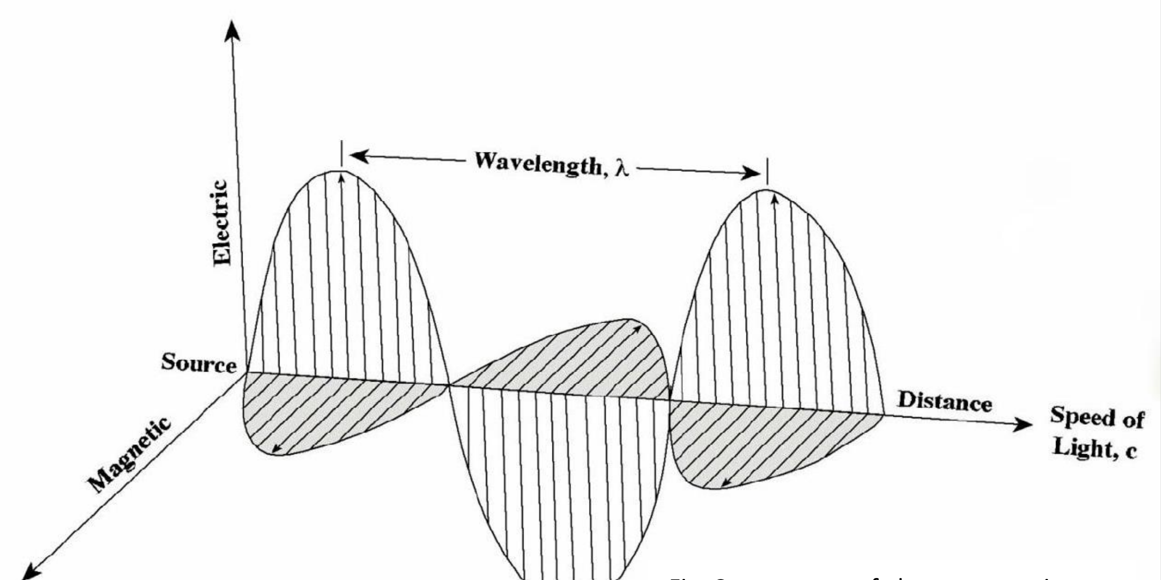
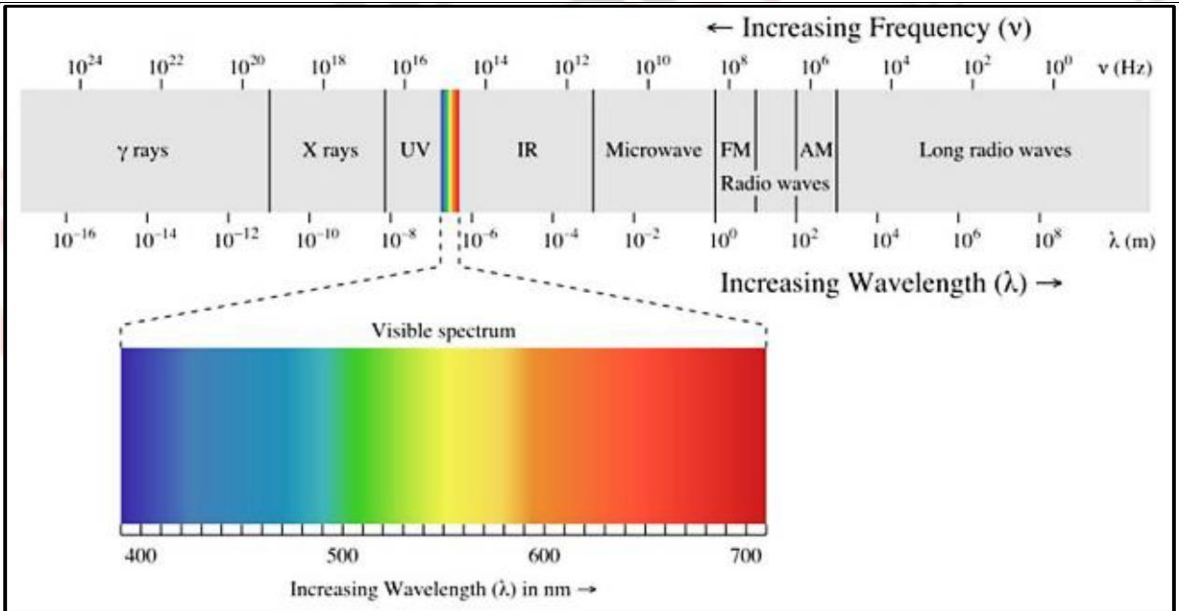
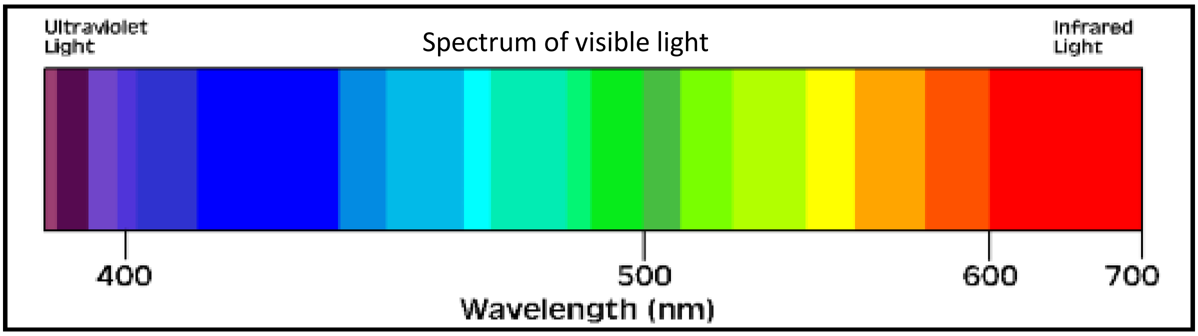


Fig. Components of electromagnetic



Electromagnetic radiation wavelengths are plotted on a logarithmic scale known as the **electromagnetic spectrum**. The plot typically increases in increments of powers of 10 (Figure). For convenience, regions of the electromagnetic spectrum are categorized based for the most part on methods of sensing their wavelengths. For example, the visible light range is a category spanning 0.4-0.7 µm. The minimum and maximum of this category is based on the ability of the human eye to sense radiation energy within the 0.4- to 0.7 µm wavelength range.

Visible light: Though the spectrum is divided up for convenience, it is truly a continuum of increasing wavelengths with no inherent differences among the radiations of varying wavelengths. For instance, the scale in figure below shows the color blue to be approximately in the range of 435 to 520 nm (on other scales it is divided out at 446 to 520 nm). As the wavelengths proceed in the direction of green they become increasingly less blue and more green; the boundary is somewhat arbitrarily fixed at 520 nm to indicate this



gradual change from blue to green.

Regions of the Electromagnetic Spectrum: Different regions of the electromagnetic spectrum can provide discrete information about an object. The categories of the electromagnetic spectrum represent groups of measured electromagnetic radiation with similar wavelength and frequency. Remote sensors are engineered to detect specific spectrum wavelength and frequency ranges. Most sensors operate in the visible, infrared, and microwave regions of the spectrum. The following paragraphs discuss the electromagnetic spectrum regions and their general characteristics and potential use. The spectrum regions are discussed in order of increasing wavelength and decreasing frequency.

(1) Ultraviolet: The ultraviolet (UV) portion of the spectrum contains radiation just beyond the violet portion of the visible wavelengths. Radiation in this range has short wavelengths (0.300 to 0.446 µm) and high frequency. UV wavelengths are used in geologic and atmospheric science applications. Materials, such as rocks and minerals, fluoresce or emit visible light in the presence of UV radiation. The florescence associated with natural hydrocarbon seeps is useful in monitoring oil fields at sea. In the upper atmosphere, ultraviolet light is greatly absorbed by ozone (0_3) and becomes an important tool in tracking changes in the ozone layer.

(2) Visible Light: The radiation detected by human eyes is in the spectrum range aptly named the visible spectrum. Visible radiation or light is the only portion of the spectrum that can be perceived as colors. These wavelengths span a very short portion of the spectrum, ranging from approximately 0.4 to 0.7 µm. Because of this short range, the visible portion of the spectrum is plotted on a linear scale. This

linear scale allows the individual colors in the visible spectrum to be discretely depicted. The shortest visible wavelength is violet and the longest is red.

Visible light detected by sensors depends greatly on the surface reflection characteristics of objects. Urban feature identification, soil/vegetation discrimination, ocean productivity, cloud cover, precipitation, snow, and ice cover are only a few examples of current applications that use the visible range of the electromagnetic spectrum.

(3) Infrared: The portion of the spectrum adjacent to the visible range is the infrared (IR) region. The infrared region, plotted logarithmically, ranges from approximately 0.7 to 100 μm, which is more than 100 times as wide as the visible portion. The infrared region is divided into two categories, the reflected IR and the emitted or thermal IR; this division is based on their radiation properties.

a. Reflected Infrared: The reflected IR spans the 0.7- to 3.0-μm wavelengths. Reflected IR shares radiation properties exhibited by the visible portion and is thus used for similar purposes. Reflected IR is valuable for delineating healthy verses unhealthy or fallow vegetation, and for distinguishing among vegetation, soil, and rocks.

b. Thermal Infrared: The thermal IR region represents the radiation that is emitted from the Earth's surface in the form of thermal energy. Thermal IR spans the 3.0- to 100 μm range. These wavelengths are useful for monitoring temperature variations in land, water, and ice.

(4) Microwave: Beyond the infrared is the microwave region, ranging on the spectrum from 1 μm to 1 m. Microwave radiation is the longest wavelength used for remote sensing. This region includes a broad range of wavelengths; on the short wavelength end of the range, microwaves exhibit properties similar to the thermal IR radiation, whereas the longer wavelengths maintain properties similar to those used for radio broadcasts.

Microwave remote sensing is used in the studies of meteorology, hydrology, oceans, geology, agriculture, forestry, and ice, and for topographic mapping. Because microwave emission is influenced by moisture content, it is useful for mapping soil moisture, sea ice, currents, and surface winds. Other applications include snow wetness analysis, profile measurements of atmospheric ozone and water vapor, and detection of oil slicks.

5. Interaction of EMR with atmosphere

All of the solar EMR passes through space to reach the top of the Earth's atmosphere, but not all reaches the Earth's surface. The atmosphere scatters, absorbs and reflects a portion of the in-coming solar radiation. The Earth scatters, absorbs and reflects the solar radiation that gets transmitted through the atmosphere. Finally, the atmosphere scatters, absorbs and reflects the electromagnetic radiation that is reflected off the Earth's surface back toward the sensor.

The atmospheric constituents scatter and absorb the radiation modulating the radiation reflected from the target by attenuating it, changing its spatial distribution and introducing into field of view radiation from sunlight scattered in the atmosphere and some of the energy reflected from nearby ground area. Both scattering and absorption vary in their effect from one part of the spectrum to the other. The solar energy is subjected to modification by several physical processes as it passes the atmosphere viz. i. Scattering, ii. Absorption, and iii. Refraction

Atmospheric Scattering: Atmospheric scattering is the redirection of EMR by particles suspended in the atmosphere or by large molecules of atmospheric gases. Scattering not only reduces the image contrast but also changes the spectral signature of ground objects as seen by the sensor. The amount of scattering depends upon various factors like i) size of the particles, ii) their abundance, iii) the wavelength of radiation, depth of the atmosphere through which the energy is travelling and iv) the concentration of the particles. The concentration of particulate matter varies in both time, space and season. Thus, the effects of scattering will be uneven spatially and will vary from time to time.

Theoretically scattering can be divided into three categories depending upon the wavelength of radiation being scattered and the size of the particles causing the scattering. The three different types of scattering from particles of different sizes are summarized in the Table 1. Types of scattering:

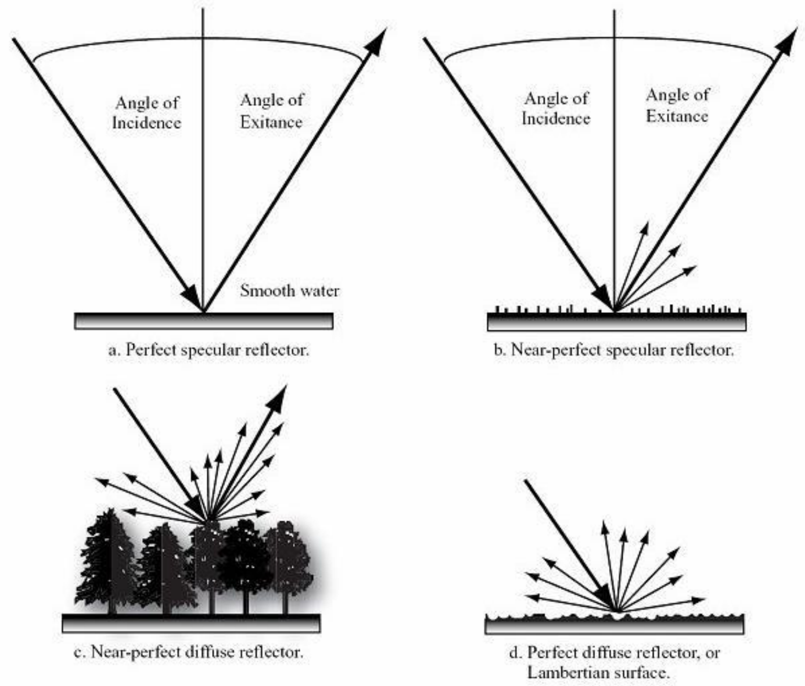
λScattering process	Wavelength	Approximate dependence particle size	Kinds of particles
Selective			
i) Rayleigh	λ^{-4}	< 1 μm	Air molecules
ii) Mie	λ^{0} to λ^{-4}	0.1 to 10 μm	Smoke, haze
Non-selective	λ^{0}	> 10 μm	Dust, fog, clouds

Atmospheric absorption: Atmospheric absorption is another mechanism, which works when electromagnetic radiation (EMR) interacts with the atmosphere. In contrast to scattering, this phenomenon causes molecules in the atmosphere to absorb energy at various wavelengths. Absorption occurs when energy of the same frequency as the resonant frequency of an atom or molecule is absorbed, producing an excited state. If, instead of re-radiating a photon of the same wavelength, the energy is transformed into heat motion and is re-radiated at a longer wavelength, absorption occurs. When dealing with a medium like air, absorption and scattering are frequently combined into an extinction coefficient. Ozone, carbon dioxide, and water vapour are the three main atmospheric constituents, which absorb radiation. Ozone absorbs the high energy, short wavelength portions of the ultraviolet spectrum (μ < 0.24m) thereby preventing the transmission of this radiation to the lower atmosphere. Carbon dioxide is important in remote sensing as it effectively absorbs the radiation in mid and far infrared regions of the spectrum. It strongly absorbs in the region from about 13-17.5 μm, whereas two most important regions of water vapour absorption are in bands 5.5-7.0 μm and above 27 μm. Absorption relatively reduces the amount of light that reaches our eye making the scene look relatively duller. The cumulative effect of the absorption by the various particles/objects can cause the atmosphere to close down in certain regions of the spectrum. This is not good for remote sensing because there will be no energy that can be used for sensing.

6. Interaction of EMR with earth surface

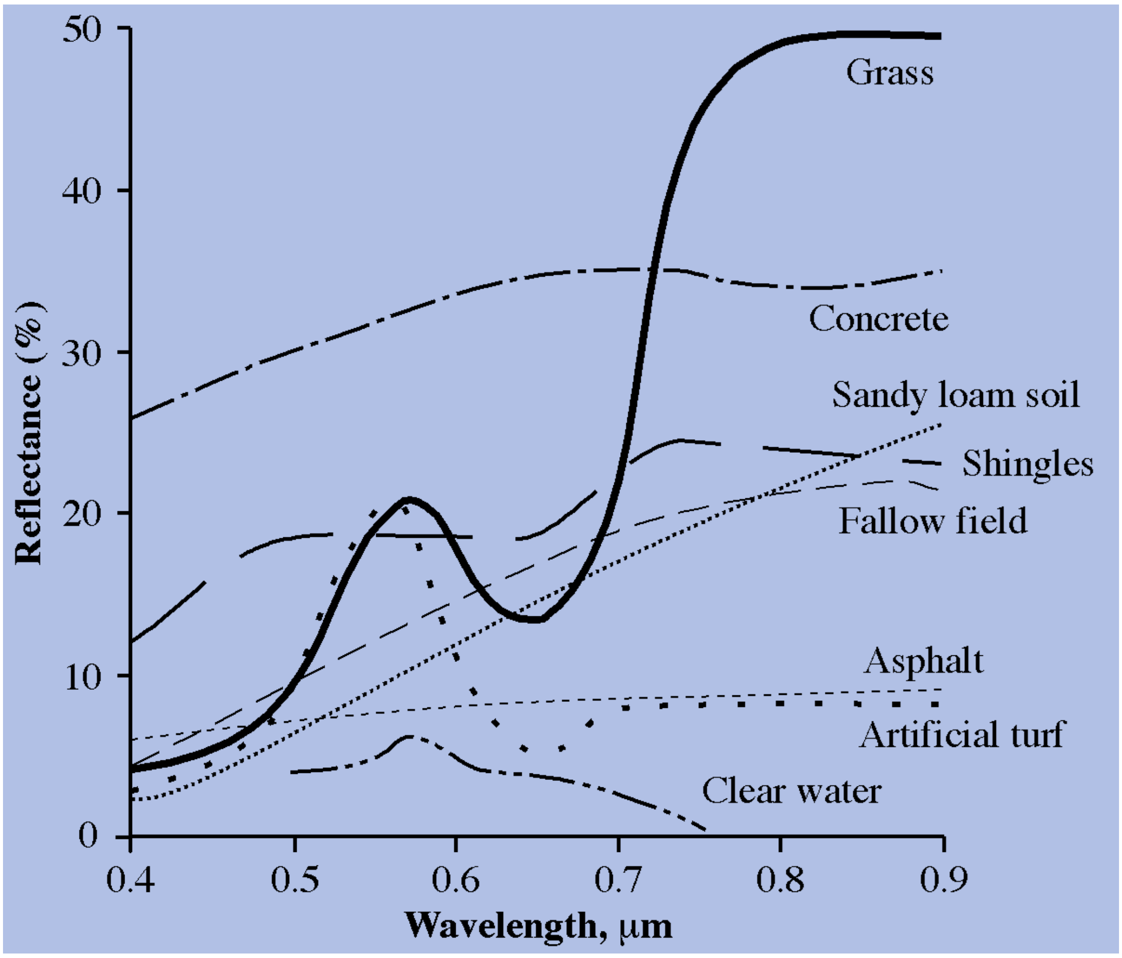
The radiant energy from the Sun, after passing through the atmosphere when reaches the Earth's surface, three things happen i) some portion energy is reflected by the earth surface, ii) some portion of energy is transmitted into the surface iii) and some portion of it is absorbed and emitted by the earth's surface later on. The EMR, on interaction with earth's surface, experiences a number of changes in the magnitude, direction, wavelength, polarization and phase etc. The remote sensor detects these changes and that enable the interpreter to obtain useful information about the object or features of a particular interest. Let us examine each one of the above-mentioned features one by one in detail.

1. Reflectance: It is the process whereby radiation reflects back from earth/terrain. This process involves re-radiation of photons in unison by atoms or molecules in a layer one-half wavelength deep. Reflection exhibits fundamental characteristics that are important in remote sensing. The incident radiation, the reflected radiation, and a vertical to the surface from which the angles of incidence and reflection are measured all lie in the same plane. The reflection intensity depends on the surface refractive index, absorption coefficient and the angles of incidence and reflection. Depending upon whether the surface is smooth or rough, the reflection can be either specular or diffuse. Surface roughness is a function of the wavelength of incident radiation. As per the Rayleigh criterion, if surface height variations are less than μ/8, then the surface can be called as smooth surface, otherwise, rough surface. Therefore, it is the wavelength of the incident EMR which determines the surface roughness. There are four types of reflecting surfaces as shown below in figure below:



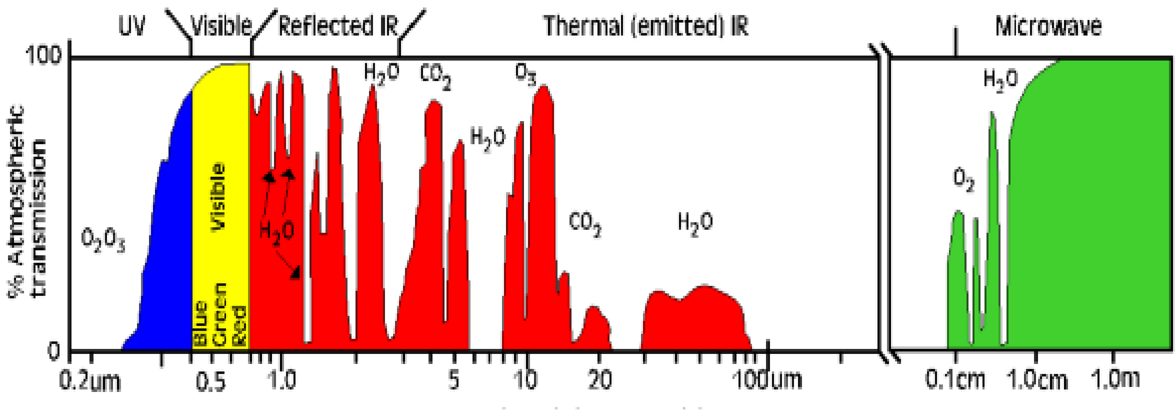
2. Transmission: Transmission of radiation takes place when radiation passes through an object without significant attenuation. For a given thickness, or depth of an object, the ability of a medium to transmit energy can be measured as transmittance, which is represented by tou (τ)

3 Spectral Signature Curve: Spectral reflectance $\rho(\lambda)$, cab be defined as the ratio of reflected energy to incident energy as a function of wavelength. Various earth's surface features weather natural or manmade have different spectral reflectance characteristics. Spectral reflectance is responsible for the color or tone in an image of an object. Trees appear green because they reflect more of the green wavelength. The values of the spectral reflectance of objects averaged over different, well-defined wavelength intervals comprise the spectral signature of the objects or features by which it can be identified or distinguished. A typical reflectance curve of surface features, like vegetation, concrete, sandy loamy soil and clear lake water etc. is shown in figure below.



7. Atmospheric windows and bands

The Regions in the electromagnetic spectrum (EMS) that pass Sun's energy and allow sensing the earth surface features are called *atmospheric windows* is remote sensing. In other words, the spectral bands for which the atmosphere is relatively transparent are known as atmospheric windows (figure below). There are certain regions of EMS, which does not allow to pass the sun's light to pass rather that regions are opaque/blocked by e.g. water vapor (H_2O), carbon dioxide (CO_2), and ozone (O_3) cannot be used for remote sensing.



Definition: *spectrum that are not severely influenced by atmospheric absorption are the most useful regions, and are called atmospheric windows.* Absorption of electromagnetic radiation is another mechanism at work in the atmosphere. This phenomenon occurs as molecules absorb radiant energy at various wavelengths. Ozone (O_3), carbon dioxide (CO_2), and water vapour (H_2O) are the three main atmospheric compounds that absorb radiation. Each gas absorbs radiation at a particular wavelength. To a lesser extent, oxygen (O_2) and nitrogen dioxide (NO_2) also absorb radiation (Figure 6). Below is a summary of these three major atmospheric constituents and their significance in remote sensing.

1. *Ozone.* Ozone (O_3) absorbs harmful ultraviolet radiation from the sun. Without this protective layer in the atmosphere, our skin would burn when exposed to sunlight.
2. *Carbon Dioxide.* Carbon dioxide (CO_2) is called a greenhouse gas because it greatly absorbs thermal infrared radiation. Carbon dioxide thus serves to trap heat in the atmosphere from radiation emitted from both the Sun and the Earth.
3. *Water vapour.* Water vapour (H_2O) in the atmosphere absorbs incoming long-wave infrared and shortwave microwave radiation (22 to 1 µm). Water vapour in the lower atmosphere varies annually from location to location. For example, the air mass above a desert would have very little water vapour to absorb energy, while the tropics would have high *concentrations of water vapour (i.e., high humidity).*
4. *Summary. Because these molecules absorb radiation in very specific regions of the spectrum, the engineering and design of spectral sensors are developed to collect wavelength data not influenced by atmospheric absorption. The areas of the spectrum that are not severely influenced by atmospheric absorption are the most useful regions, and are called* ***atmospheric windows****.*

Spectrum Bands: By comparing the characteristics of the radiation in atmospheric windows (Figure above; areas where reflectance on the y-axis is high), groups or bands of wavelengths have been shown to effectively delineate objects at or near the Earth's surface. The visible portion of the spectrum coincides with an atmospheric window, and the maximum emitted energy from the Sun. Thermal infrared energy emitted by the Earth corresponds to an atmospheric window around 10 μm, while the large window at wavelengths larger than 1 mm is associated with the microwave region (Figure above). Following table 2 shows the spectral bands of LANDSAT ETM+ sensor.

Table – 2

Landsat 7 (ETM+ sensor)	Wavelength μm (micrometers)	Bands Name	Resolution (meters)
Band 1	0.45 - 0.515	Blue	30
Band 2	0.525 - 0.605	Green	30
Band 3	0.63 - 0.69	Red	30
Band 4	0.75 - 0.90	NIR	30
Band 5	1.55 - 1.75	SWIR	30
Band 6	10.40 - 12.5	TIR	60
Band 7	2.09 - 2.35	SWIR – 2	30
Pan Band	.52 - .90	PAN	15

NIR - near-infrared, **SWIR** - short wave infrared and **TIR** – Thermal infrared

Band 1 (0.45 - 0.52μm): provides increased penetration of water bodies and also capable of differentiating soil and rock surfaces from vegetation and for detecting cultural features.

Band 2 (0.52 - 0.60μm): it is sensitive to water turbidity differences; it highlights the turbid water within a water body. Because it covers the green reflectance peak from leaf surfaces, it has separated vegetation (forest, croplands with standing crops) from soil. In this band barren lands urban areas and roads and highways have appeared as brighter (lighter) tone, but forest, vegetation, bare croplands, croplands with standing crops have appeared as dark (black) tone.

Band 3 (0.63 - 0.69μm): senses in a strong chlorophyll absorption region and strong reflectance region for most soils. It has discriminated vegetation and soil. But it couldn't separated water and forest. Forest land and water both have appeared as dark tone. This band has highlighted barren lands, urban areas, street pattern in the urban area and highways. It has also separated croplands with standing crops from bare croplands with stubble.

Band 4 (0.76 - 0.90μm): operates in the best spectral region to distinguish vegetation varieties and conditions. Because water is a strong absorber of near IR, this band has delineated water bodies (lakes and sinkholes), distinguished between dry and moist soils (barren land and croplands). In this band croplands and grasslands have showed higher reflectance (brighter tone) than the forest. This band has also separated croplands from bare croplands. Since standing crops (vegetation) has higher reflectance in the near IR region, they have appeared as brighter tone and due to presence of moisture content in the bare croplands, they have appeared as darker tone. In the band 4 barren lands, urban areas and highways have not been highlighted and they appeared as dark tone. Band 4 is useful for crop identification and emphasizes soil-crop and land-water contrast.

Band 5 (1.55 - 1.75μm): is sensitive to the turgidity or amount of water in plants. Band 5 has separated forest lands, croplands, water body distinctly. Forests have appeared as comparatively darker tone than the croplands (light gray).Band 5 has separated water body (dark tone) from barren lands, croplands, and grass lands (lighter tone). Since urban area and croplands have responded almost in same spectral reflectance band 5 could not be able to separate these areas.

Band 7 (2.08 -2.35μm): has separated land and water sharply. Band 7 has strong water absorption region and strong reflectance region for soil and rock. Urban area, croplands, highways, bare croplands have appeared as bright tone and water body, forest have appeared as dark tone.

Learning resources:

1. **Books:**

1. Sabins, Flyod F. (1986), Remote Sensing: Principles and Interpretation, 2nd Edn., W H Freeman & Co, New York.
2. Jensen, John R. (2006), Remote Sensing of the Environment: An Earth Resource Perspective, 2nd Edn., Pearson Prentice Hall. ISBN: 0131889508, 978-0131889507.
3. Gupta, Ravi P. (2003), Remote Sensing Geology, 2nd Edn., Springer Publications. ISBN: 354043185, 978-3540431855.
4. Lillesand Thomas, Keifer Ralph W. and Chipman Jonathan (2015). Remote sensing and Image Interpretation, 7th Edn. John Wiley & Sons, New York.
5. Mather, Paul M. and Koch, Magaly (2010), Computer Processing of Remotely-Sensed Images : An Introduction, 4th Edn., Wiley-Blackwell Publications. ISBN: 978-0-470-74239-6.
6. Warner, Timothy A., Nellis, M. Duane and Foody, Giles M. (Eds.) (2009), The SAGE Handbook of Remote Sensing, 1st Edn., SAGE Publications Ltd. ISBN: 141293616, 978-1412936163.
7. Jensen, John R. and Jensen, Ryan R. (2012), Introductory Geographic Information Systems, 1st Edn., Pearson Prentice Hall. ISBN: 013614776, 978-0136147763.

2. **Syllabus of B. Sc. III Geology**

   https://drive.google.com/file/d/120EHc9HiM6KicNhnx6IYn_PEHqL47zf8/view?usp=sharing

3. **Material OER/URL/Instructor-made/**

   A. Lecture notes

   https://drive.google.com/file/d/1NLcO1fTBix7_BlHQESfvYuFtPbFMt4tT/view?usp=sharing

   B. Online book:

   https://drive.google.com/file/d/1ZYtYwAeSLe74HfjyEOwC-xTC4DCMDEfM/view?usp=sharing

4. **Instructor-made -**

   A. Power Point Presentation:

   https://drive.google.com/file/d/1ZgUCSqUjRUY2y0y5BKlSVlk3CSL94tzo/view?usp=sharing

   B. Video -

   https://www.youtube.com/watch?v=PG8NkuZnDdc&t=1s

   C. Question Bank:

https://drive.google.com/file/d/1cjwQMidZxKzbTfliz-JMVUfraT_99LH3/view?usp=sharing

   D. Quizzes / Practice tests:

https://forms.gle/aCzAoR7TLRMJU5a58
https://forms.gle/DTSrpujovoz52CET6
https://forms.gle/uvmJsRygp8upeDxw9
https://forms.gle/Bj2hdw3rQxfRXrqo8

Detailed Plan of Out-of-class and In-class activities

Sub Unit 2 - **EMR radiations and its interaction with atmosphere and earth.**

Objectives –

- Process and components of remote sensing
- Understanding of electromagnetic spectrum and its characteristics.
- Understand the interaction of EMR with atmosphere and earth surface.
- Knowledge of atmospheric windows and its importance in selecting image bands.
- Students can select particular band combination for specific purpose.

Sub Unit 2 - **EMR radiations and its interaction with atmosphere and earth.**

Content	**Objectives (Learner should be able to)**	**Cognitive Level**
Components of remote sensing Electromagnetic radiations and their interactions with atmosphere and earth objects Various bands of satellite images	Understand components of remote sensing	Remembering
	Understand interaction of electromagnetic radiations with the atmosphere and earth objects	Remembering
	Know about atmospheric windows and bands of imageries	Remembering
	Visualization of satellite images and identification of features. Select bands for a particular purpose.	Applying
	Proper thought process	Understanding
	Asking question and some simple concept	Evaluating

Units	**Out-of-class activity** **Details of Activity**	**In-class activity** **Details of Activity**	**Assessment**
1.1	Students should read out the topic from a book Students should see the PPTs	Discussion on the topic Check the level of understanding through Question – answer session	Question – answer session
1.2	Students should read out the topic from a book Students should watch video on given links	Discussion on the topic Various topics of remote sensing. Application of remote sensing knowledge to identify earth's features.	Question to write in detail On-line quiz