

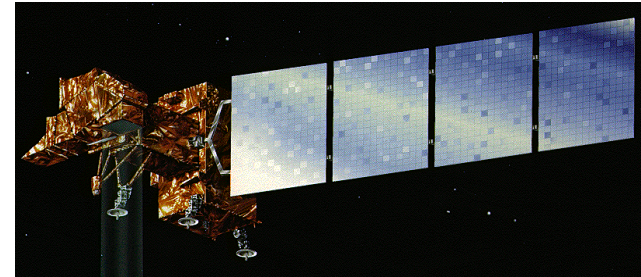
# Basics of remote sensing

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# How to collect scientific data?



**In situ**



**Remotely**

# What is Remote Sensing?

“The science and art of **obtaining information** about an object, area, or phenomenon through the **analysis** of data acquired by a device that is not in contact with the object, area, or phenomenon under investigation”.(L&K,1994)

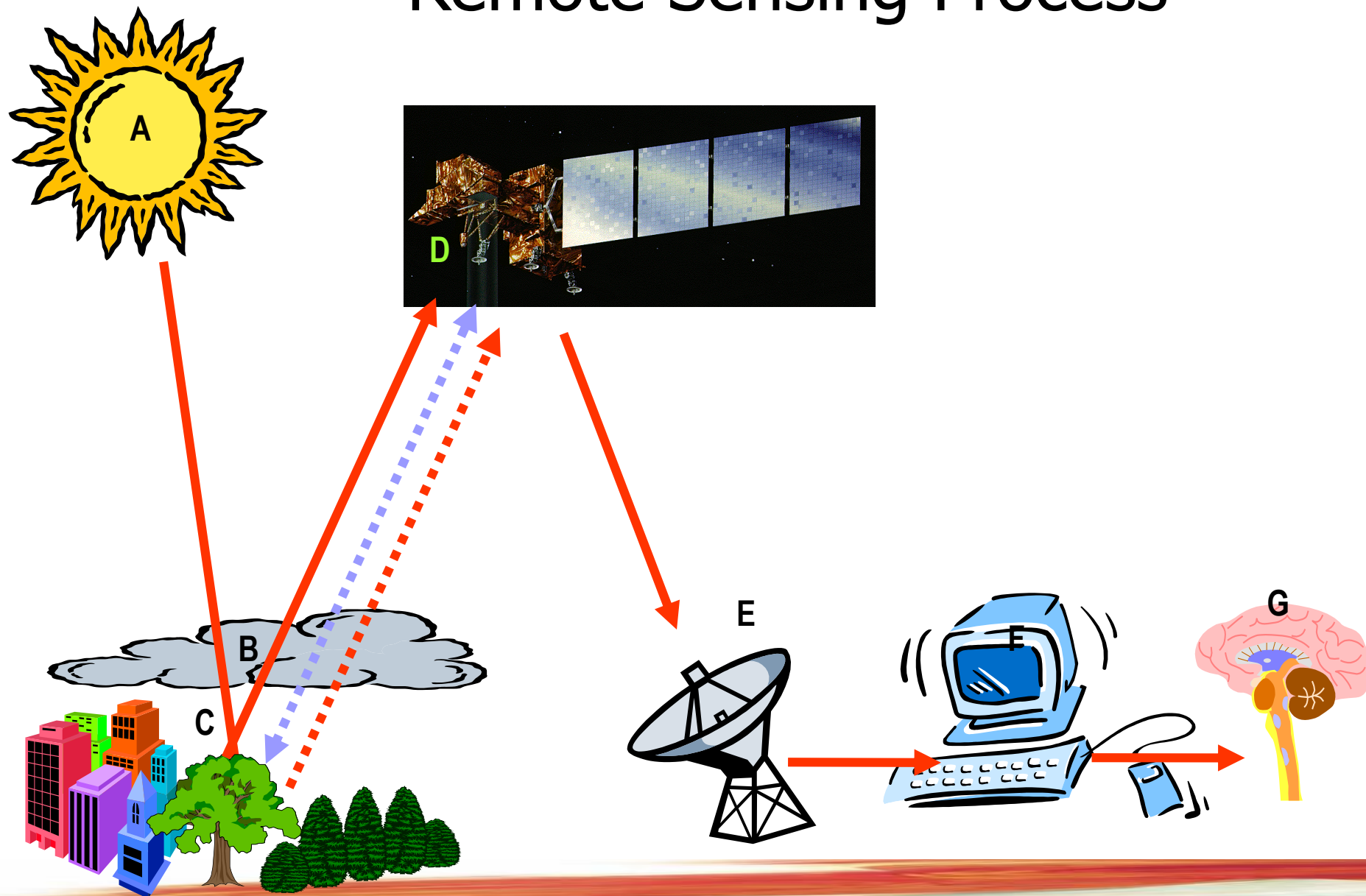
# Why Remote Sensing?

- Systematic data collection
- Information about three dimensions of real objects
- Repeatability
- Global coverage
- The only solution sometimes for the otherwise inaccessible areas
- Multipurpose information

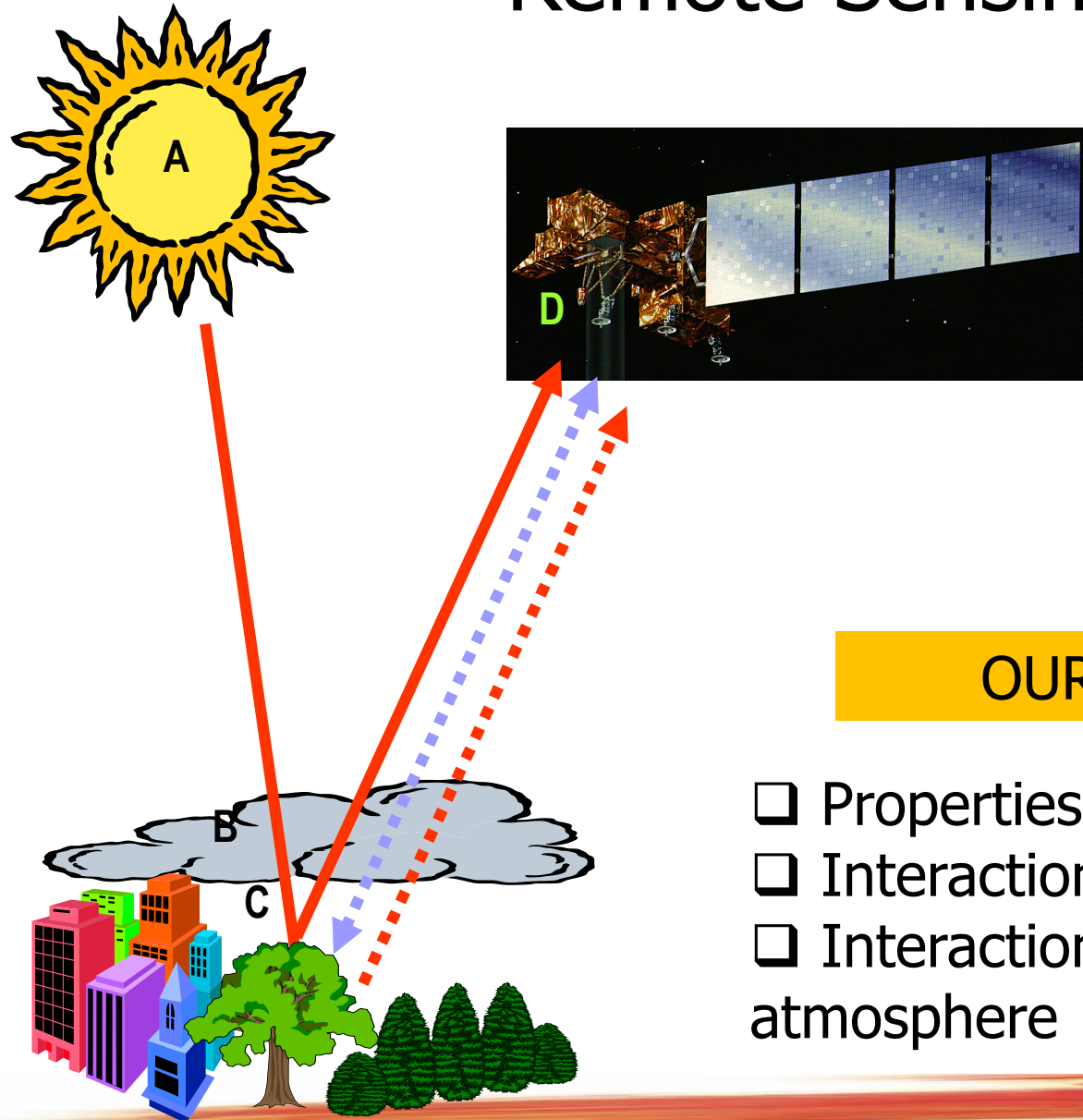
Is it all...???



# Remote Sensing Process



# Remote Sensing Process



## OUR FOCUS

- ☐ Properties of EMR
- ☐ Interaction of radiation with target
- ☐ Interaction of radiation with atmosphere

## ❑ **Properties of EMR**

- Wave Nature
- Particle nature
- Wave Particle duality
- EM spectrum
- Radiometry
- Black Body Radiation – Laws, Spectral Emissivity

*Time for some  
Physics*



## ❑ **Interaction of radiation with target**

## ❑ **Interaction of radiation with atmosphere**



# What is Electromagnetic Radiation??

There are 2 theories:

## **Wave theory**

Considers electromagnetic energy as a harmonic, sinusoidal wave

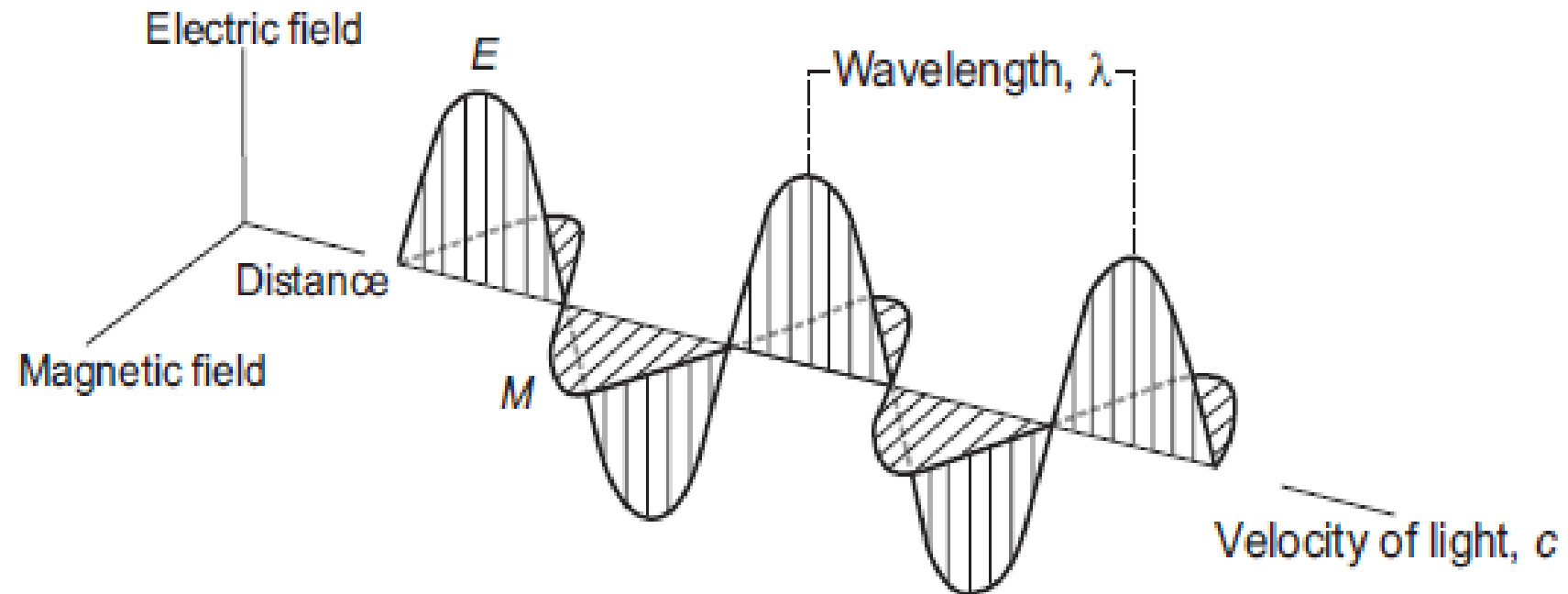
## **Particle theory**

Considers electromagnetic radiation as consisting of many discrete units  
- **photons**



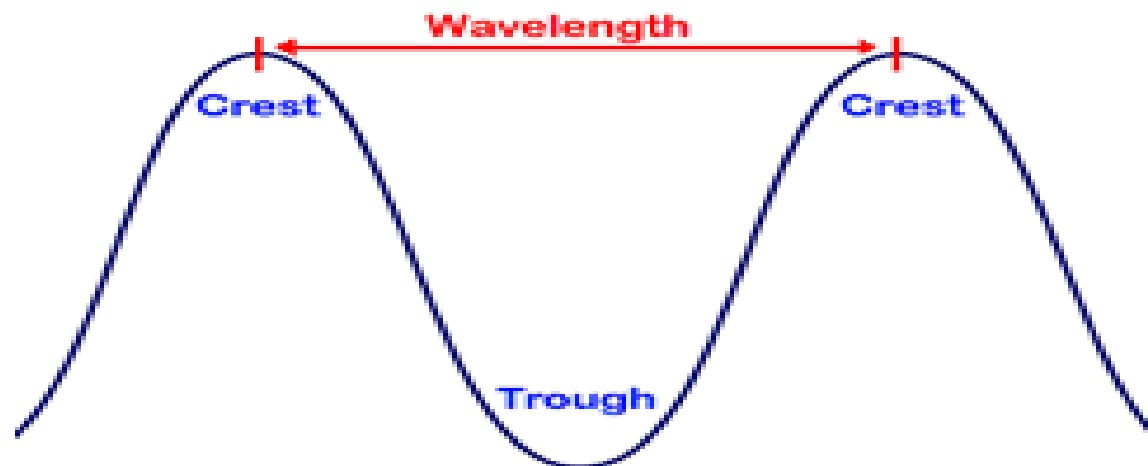
# EMR propagation as wave

An electromagnetic wave is a transverse wave in that the electric field and the magnetic field at any point and time in the wave are perpendicular to each other as well as to the direction of propagation



# Terms associated with wave theory

- Crest : The highest point of the wave.
- Trough : The lowest point of the wave.
- Wavelength : The distance between two identical points on the wave. .
- Frequency : The number of wavelengths that pass a point in a set period of time.



# Speed of light

$$c = \lambda \nu$$

where  $\lambda$  is wavelength (m)

$\nu$  is frequency (cycles per second, Hz)

$c$  is speed of light ( $3 \times 10^8$  m/s)

***Light does not require a material medium for its propagation!!***

## EMR : particle nature

The energy of a photon is given by :

$$E = h\nu$$

$$= hc/\lambda$$

where  $c$ ,  $\nu$  and  $\lambda$  are the velocity, frequency and wavelength respectively and  $h$  is Plank's constant

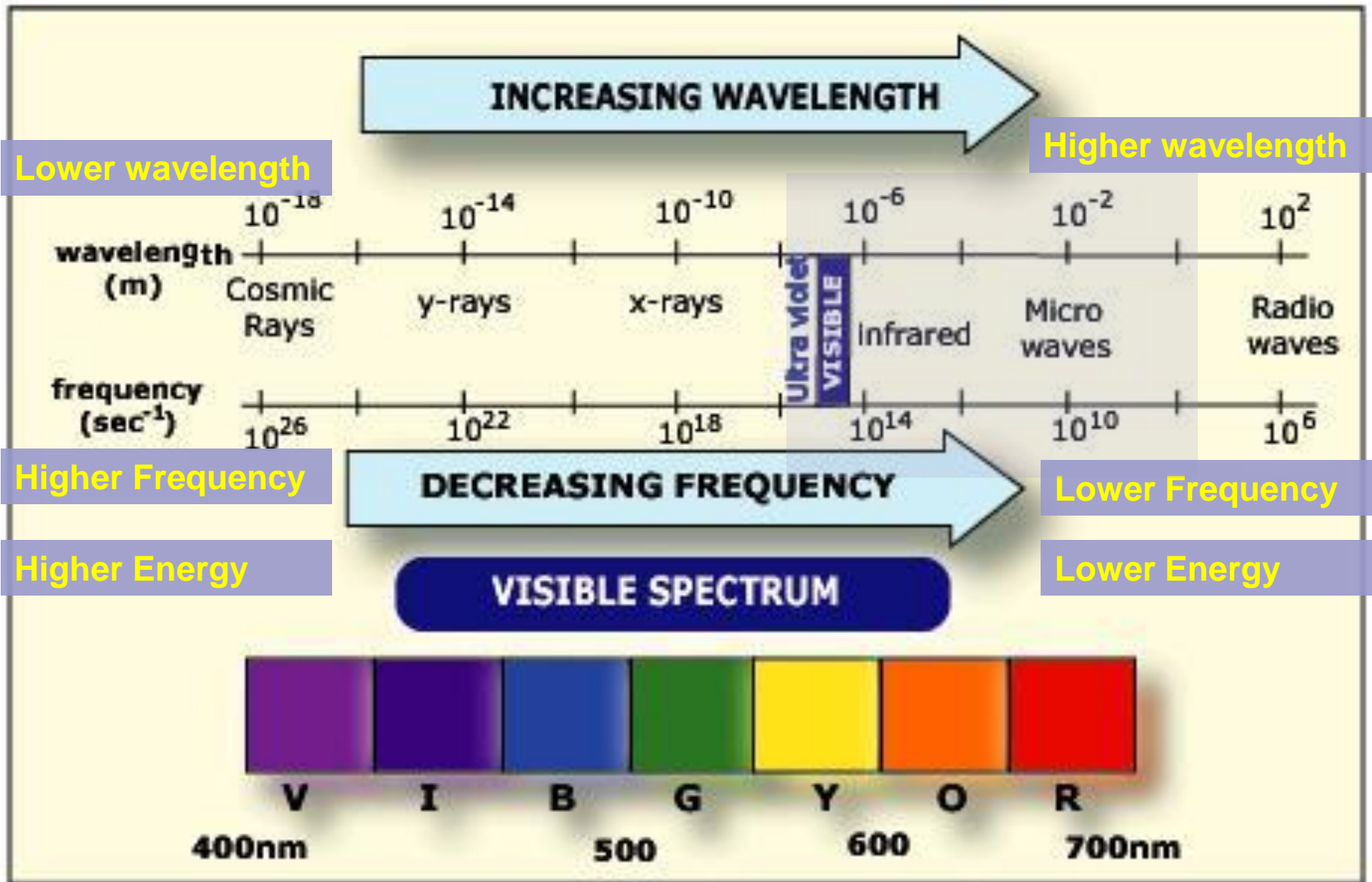
$$h = 6.6260... \times 10^{-34} \text{ Joules-sec}$$

# Wave-particle duality

In 1924, Louis-Victor de Broglie formulated the de Broglie hypothesis, claiming that *a//* matter, not just light, has a wave-like nature; and related wavelength (denoted as  $\lambda$ ), and momentum (denoted as  $p$ ):

$$\lambda = h/p$$

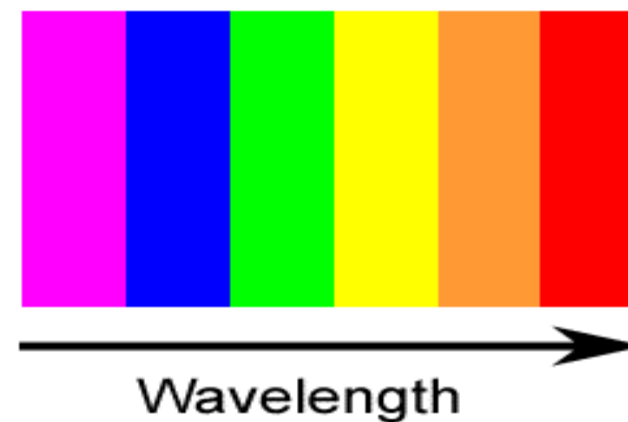
$h$  is Plank's constant



# Visible range

The light which our eyes - our "**remote sensors**" - can detect is part of the visible spectrum.

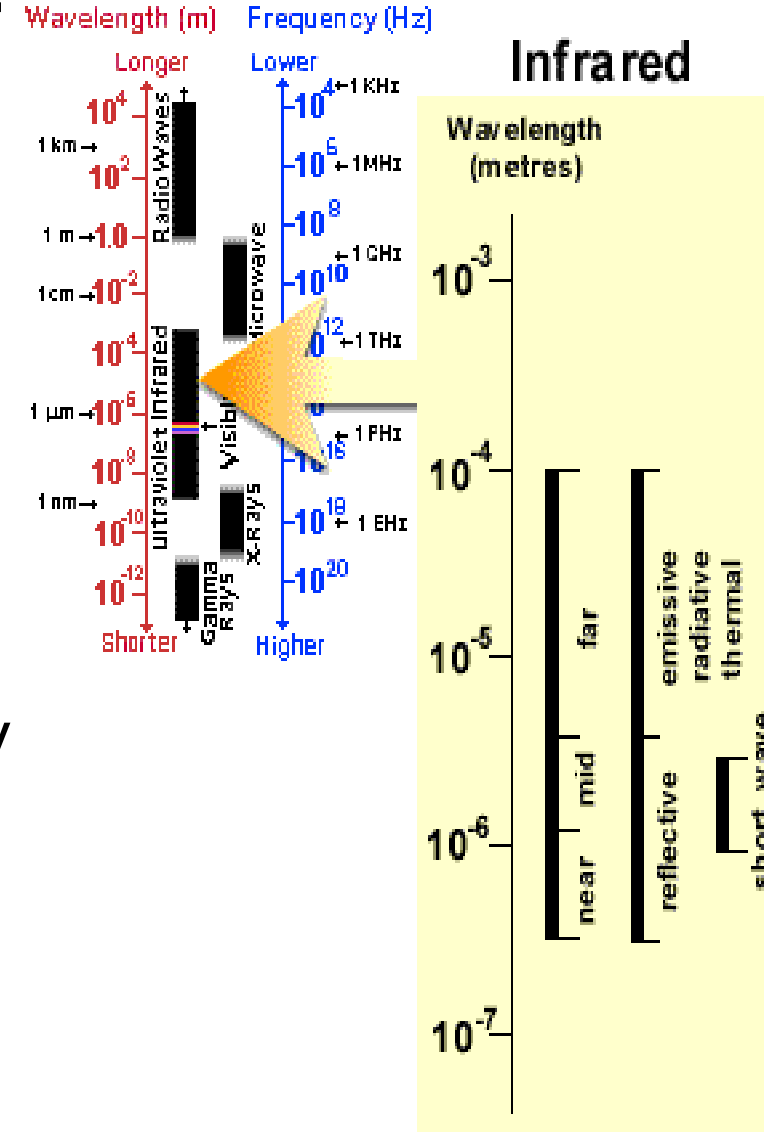
**Violet:** 0.4 - 0.446  $\mu\text{m}$   
**Blue:** 0.446 - 0.500  $\mu\text{m}$   
**Green:** 0.500 - 0.578  $\mu\text{m}$   
**Yellow:** 0.578 - 0.592  $\mu\text{m}$   
**Orange:** 0.592 - 0.620  $\mu\text{m}$   
**Red:** 0.620 - 0.7  $\mu\text{m}$



# Infra-Red range

The infrared region can be divided into two categories based on their radiation properties - the **reflected IR**, and the emitted or **thermal IR**.

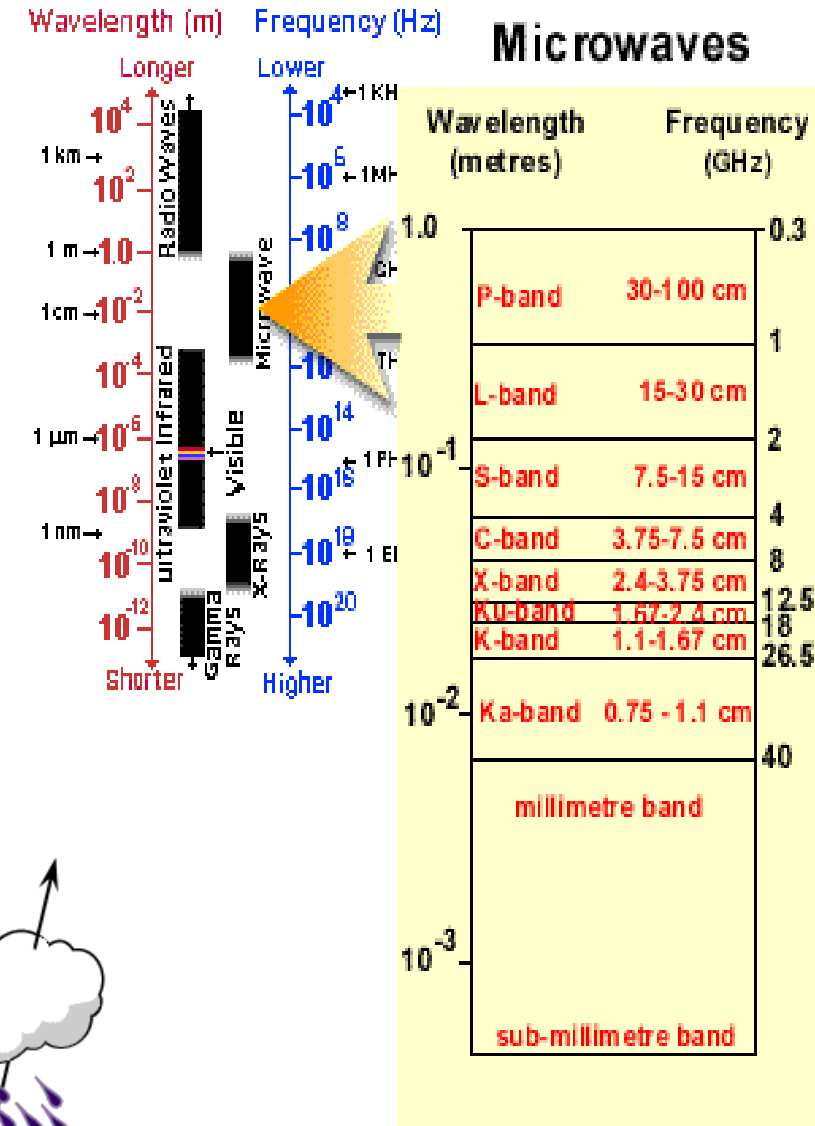
The reflected IR covers wavelengths from approximately  $0.7 \mu\text{m}$  to  $3.0 \mu\text{m}$ . The thermal IR covers wavelengths from approximately  $3.0 \mu\text{m}$  to  $100 \mu\text{m}$ .





# Microwave range

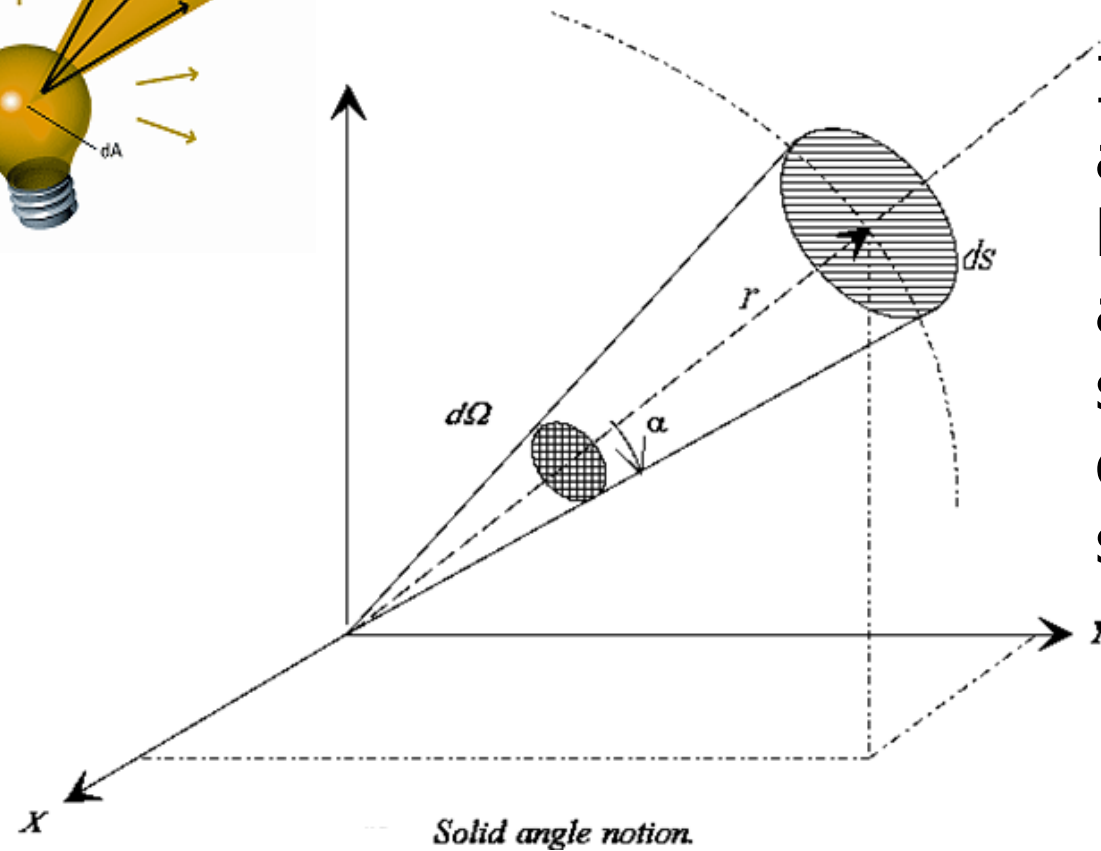
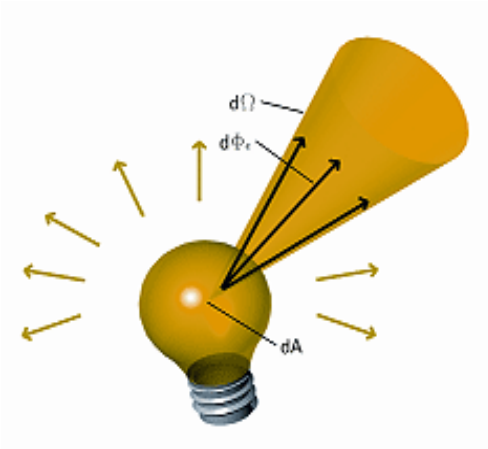
The portion of the spectrum of more recent interest to remote sensing is the microwave region from about 1 mm to 1 m. This covers the longest wavelengths used for remote sensing.



# RADIOMETRY

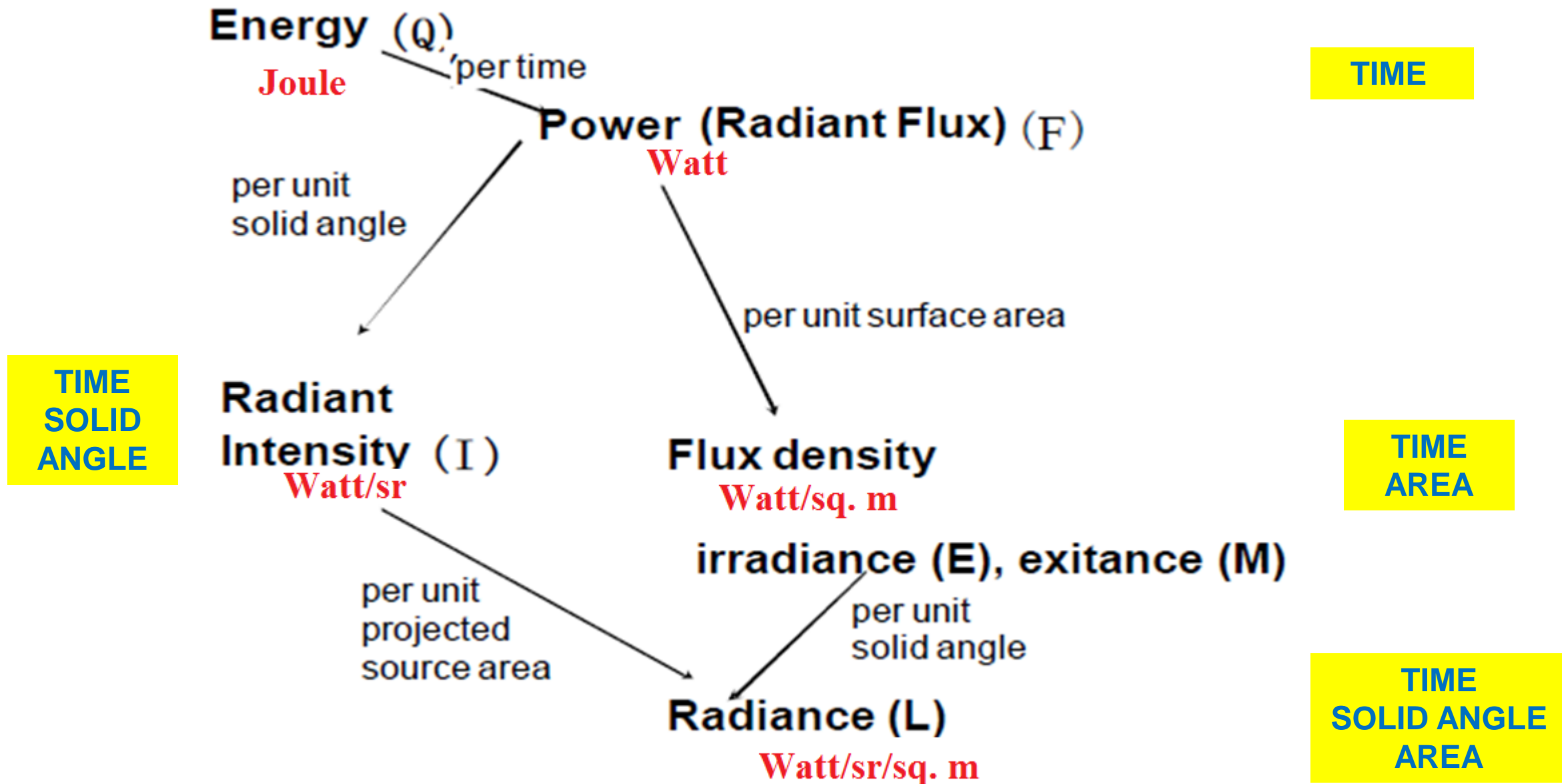


# Solid angle

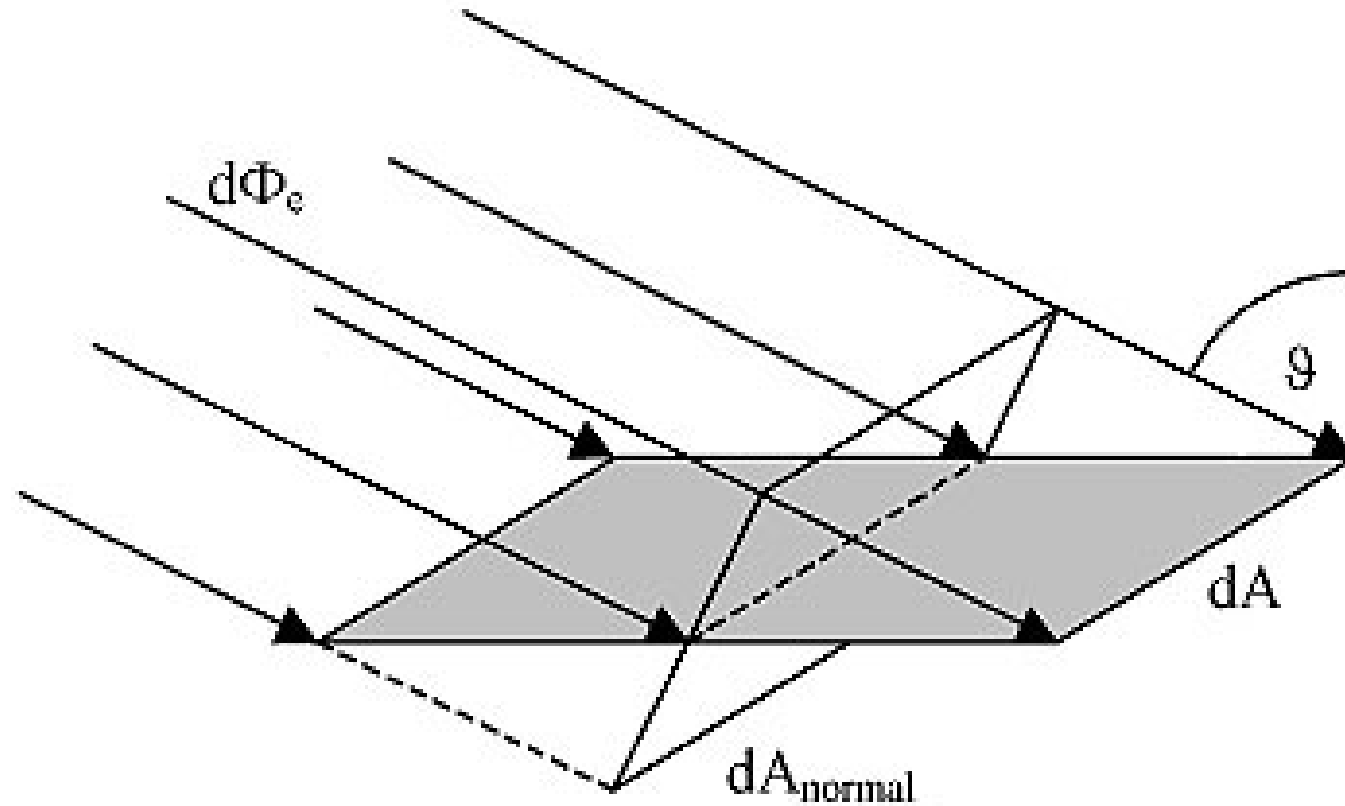


It is the cone angle subtended by the portion of a spherical surface at the center of the sphere.

$$d\Omega = dS / r^2 \text{ (in steradian, Sr)}$$



# Projected area



सभी प्रतिभागियों से अनुरोध है कि प्रश्नोत्तरी में भाग लेने हेतु वे ई-क्लास में लॉगिन करें:

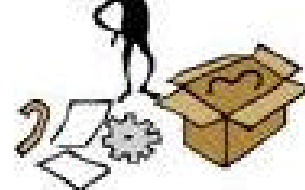
**URL :** <https://eclass.iirs.gov.in/login>

**नोट:** प्रतिभागी जो पहले से ही ई-क्लास में लॉगइन हैं , प्रश्नोत्तरी में भाग लेने हेतु कृपया अपने वेब पेज को रिफ्रेश करें ।

All the Participants are requested to login in E-CLASS :

**URL :** <https://eclass.iirs.gov.in/login>

**Note :** Participants who are already logged in, please refresh your Web Page to Participate in the quiz.

1. Is our eye a remote sensor?  
A) YES B) NO
2. What are the units of spectral radiance ?  
A) W/m sq. B) W/m sq./Sr C) W/m sq/Sr/micron
3. Which radiometric quantity would be most suitable to measure for sun's incoming energy ?  
A) Irradiance B) Exitance C) Radiance
4. A radiation of wavelength 4 micron falls in which portion of EM spectrum ?  
A) Visible B) IR C) Microwave
- 





# Black Body

Blackbodies absorb and re-emit radiation in a characteristic, continuous spectrum. However, a black body emits a temperature-dependent spectrum of light. This thermal radiation from a black body is termed **black-body radiation**.

# Plank's Law of radiation

$$M_{\lambda} = C_1 \lambda^{-5} [\exp.(C_2/\lambda T) - 1]^{-1}$$

***Manifestation of quantization of energy !***

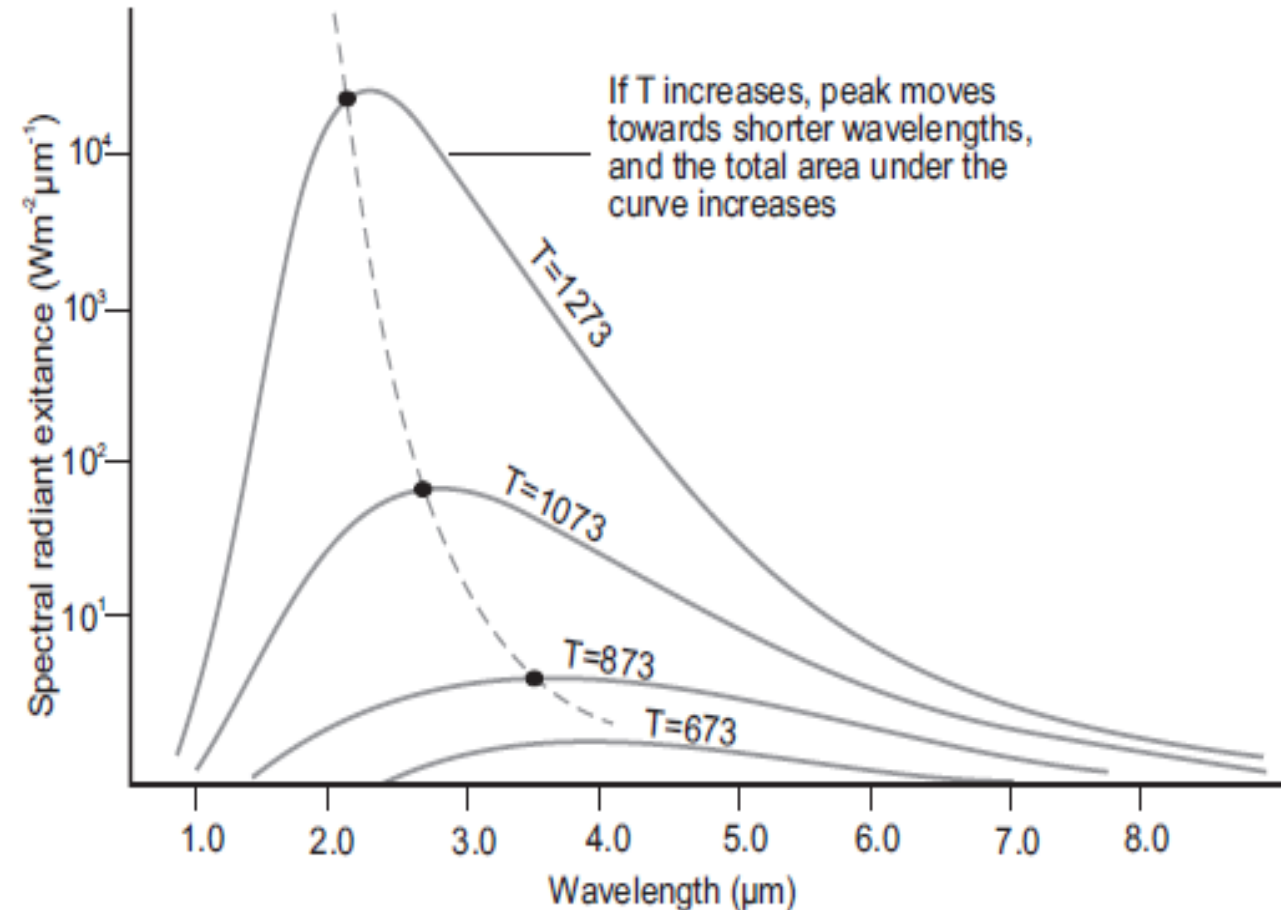
$M_{\lambda}$  is spectral exitance

$C_1 = 3.74 \times 10^{-16} \text{ Wm}^2$

$C_2 = 1.44 \times 10^{-2} \text{ m}^{\circ}\text{K}$

$\lambda$  is the wavelength

T is the absolute temperature



# Plank's Law of radiation

INTEGRATE

DIFFERENTIATE

Stefan Boltzmann  
Law

Wien's Displacement law

$$M = \int M(\lambda) d\lambda = \sigma T^4$$

$M(\lambda)$  = spectral radiant exitance

$T$  = temperature ( $^{\circ}\text{K}$ ),

$$\sigma = 5.67 \times 10^{-8} \text{ W/m}^2\text{K}^4$$

$$\lambda_{\max} (\mu\text{m}) \cong \frac{2898}{T(^{\circ}\text{K})}$$

How close a real body is to a Black  
Body ??

# Spectral Emissivity

The efficiency with which real materials emit thermal radiation at different wavelengths is determined by their emissivity ' $\epsilon$ '

$$\epsilon(\lambda) = M_{\lambda}(\text{material}, ^{\circ}\text{K}) / M_{\lambda}(\text{blackbody}, ^{\circ}\text{K})$$

*$\epsilon(\lambda)$  varies between 0 and 1*

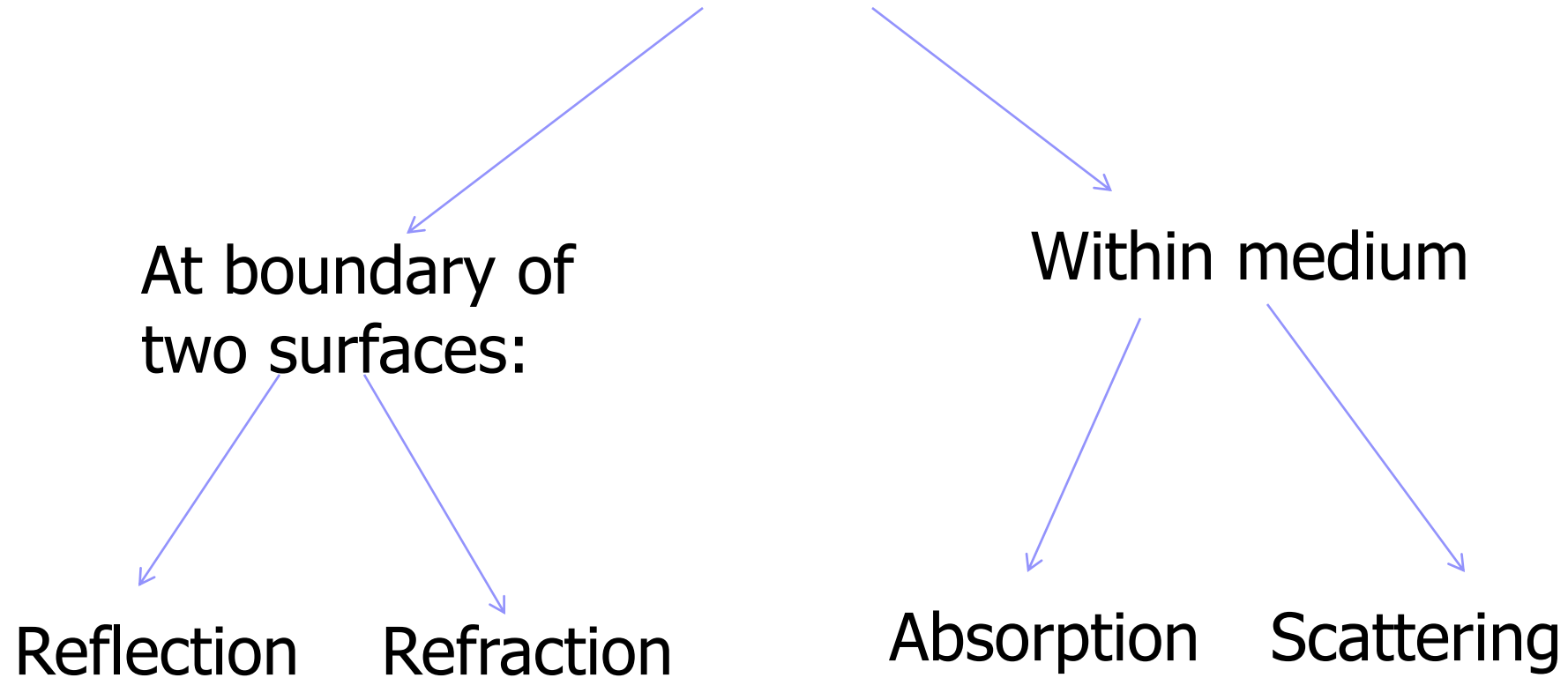
Blackbody :  $\epsilon = 1$  at all wavelengths.

Gray body :  $0 < \epsilon < 1$  (does not depend upon wavelength)

Perfect reflector:  $\epsilon = 0$

All other bodies  $\epsilon = \epsilon(\lambda)$  is a function of wavelength

# EMR interaction with matter

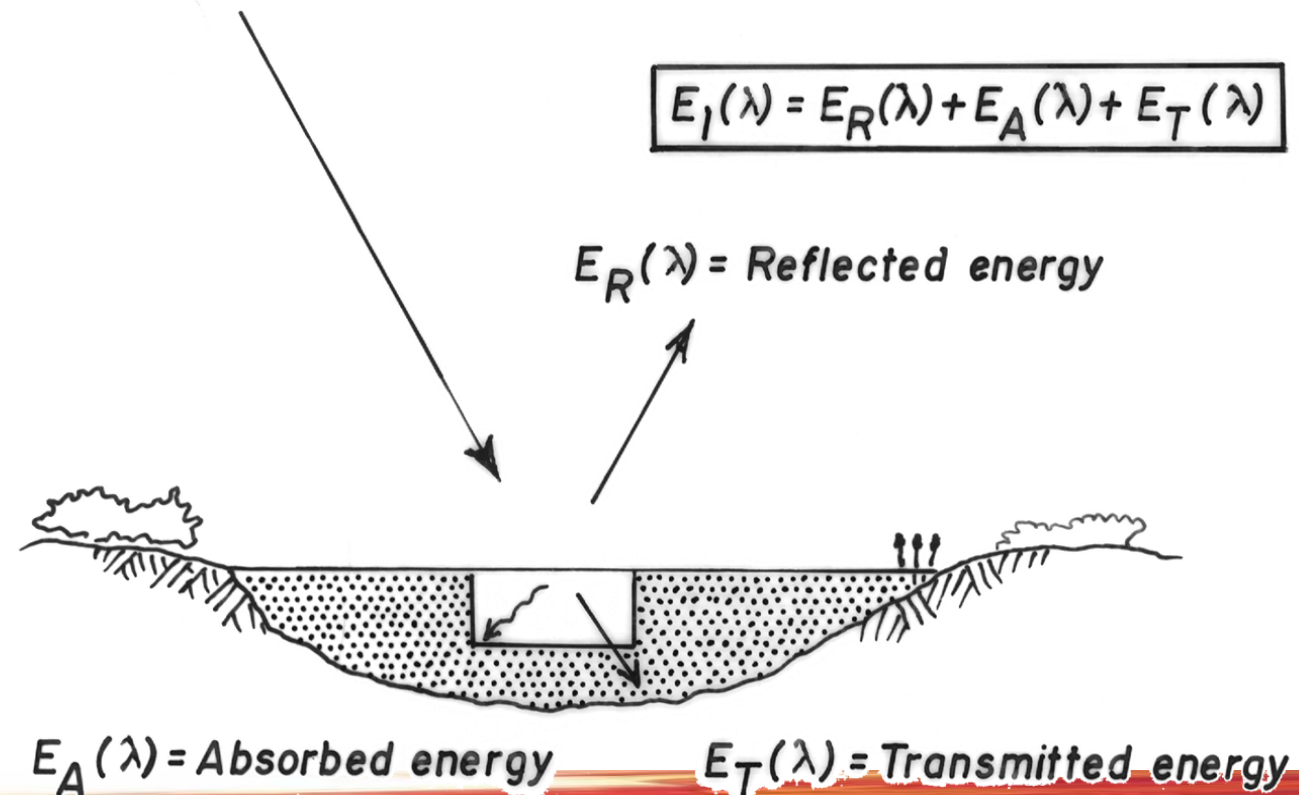


# Interaction of EMR with Earth's surface

## ***Kirchoff's law of Radiation***

$$\alpha(\lambda) + \rho(\lambda) + \tau(\lambda) = 1$$

where  $\alpha(\lambda)$  is absorptivity,  $\rho(\lambda)$  is reflectance and  $\tau(\lambda)$  is transmittance  $E_I(\lambda) = \text{Incident energy}$





# Interaction Processes

## 1. Reflection

***Specular** : Snell's law*

***Diffused***

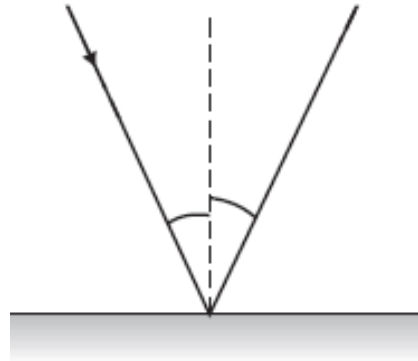
*Lambertian : Lambert Cosine law*

## 2. Transmission

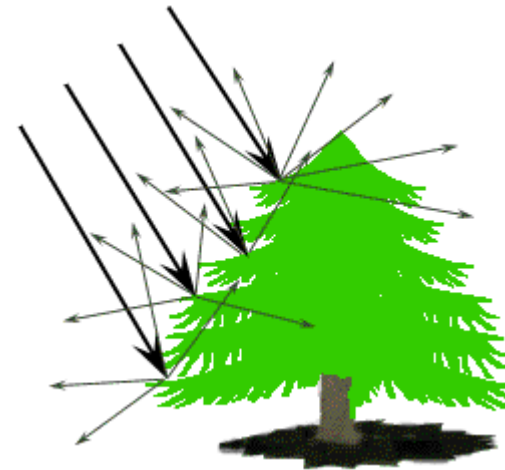
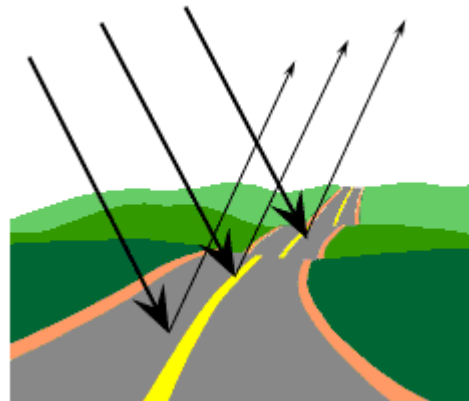
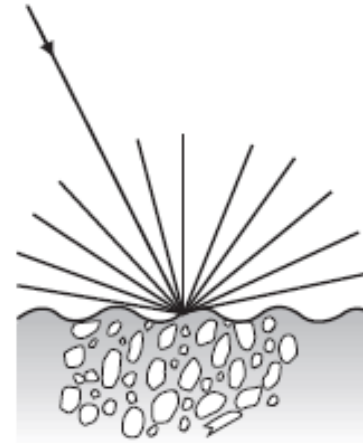
## 3. Absorption

# Reflection

***Specular***



***Diffused***



# Rayleigh Criteria for smooth surface

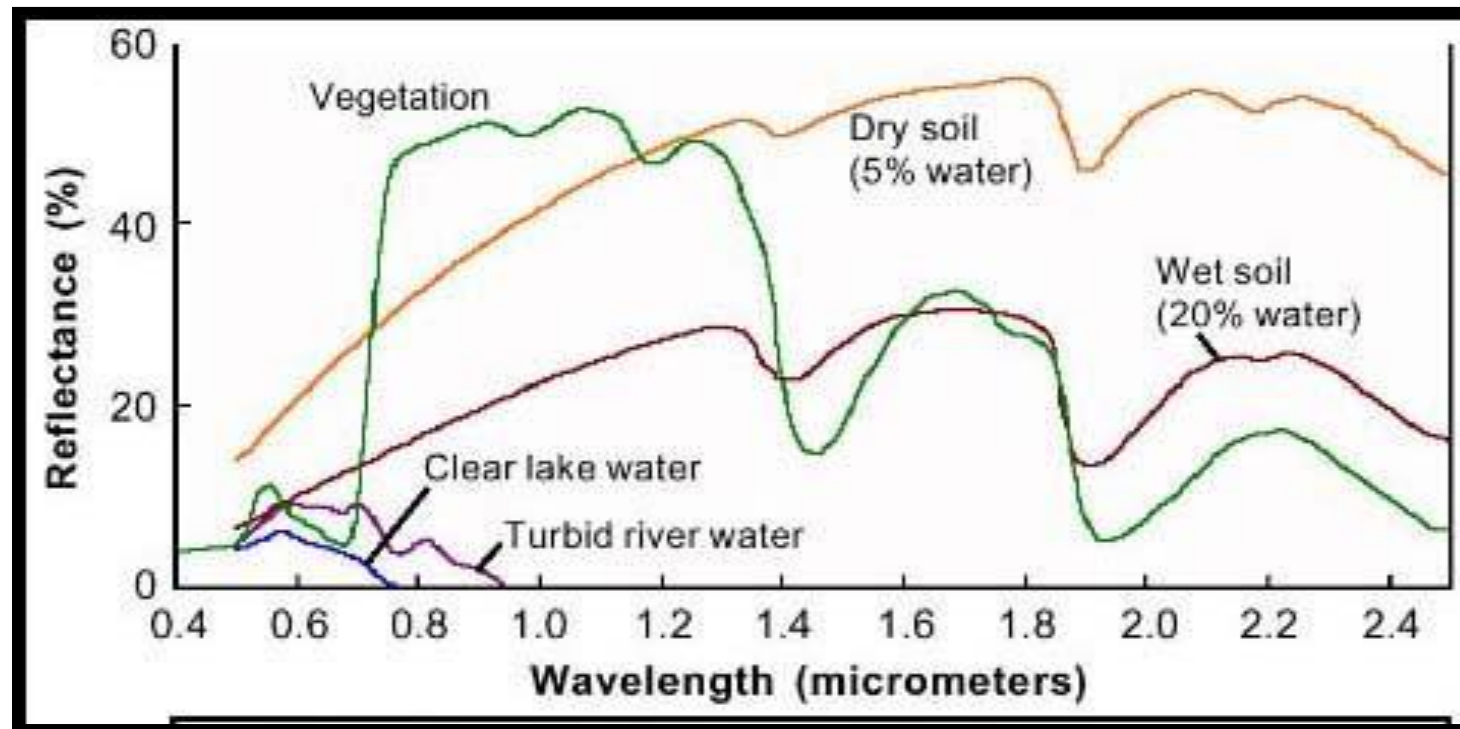
Rayleigh's criteria for a rough surface is :

$$h > \lambda / 8 \cos \theta$$

where  $h$  = rms height variation above a reference plane in units of  $\lambda$   
 $\lambda$  is the wavelength and  $\theta$  is the angle of incidence

# Spectral Signatures

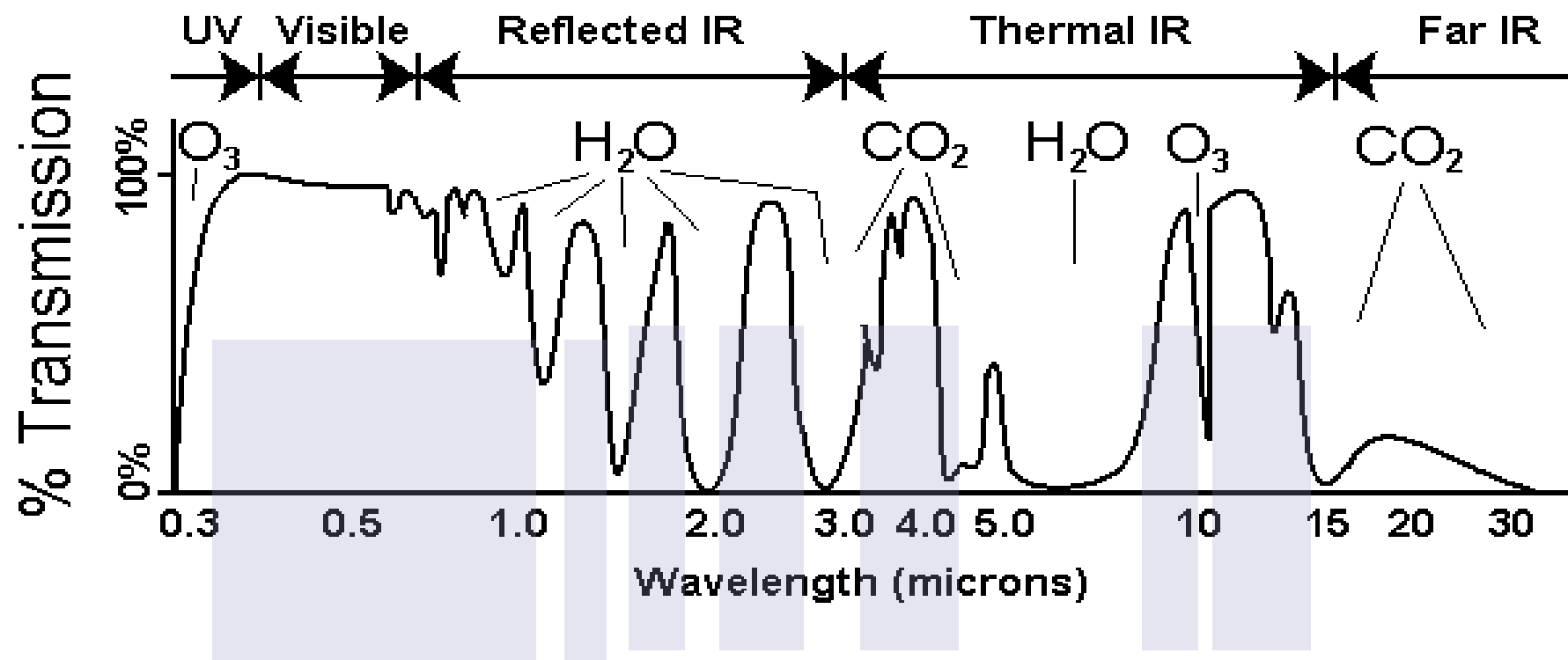
Why the name signature ??



# Physical processes in atmosphere

- Absorption
- Scattering
- Refraction

# Atmospheric Windows

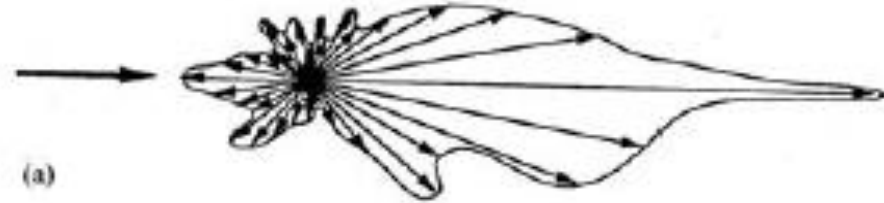


Atmospheric windows : Spectral regions where the EMR is passed through without much attenuation.

# Scattering : Redirection of light

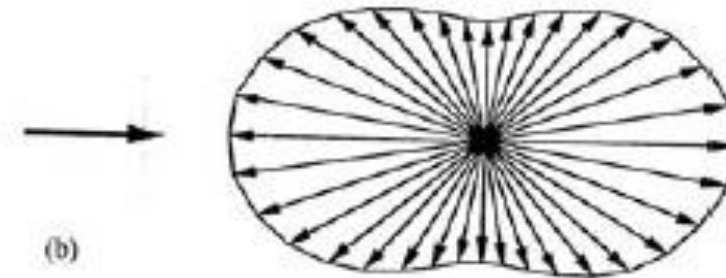
**Mie**

Atmospheric Dust  
Smoke



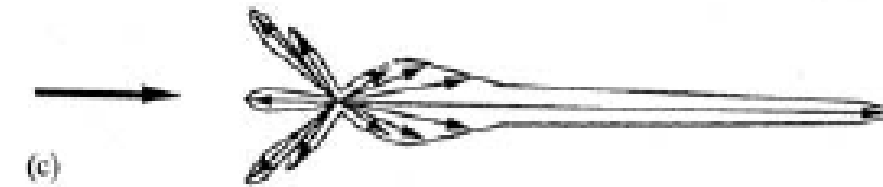
**Rayleigh**

Atmospheric  
Molecules



**Non-selective**

Large Water  
Droplets





# Scattering

Scattering process	Wavelength dependency	Approximate dependence on particle size	Kinds of particles
<b>Selective</b>			
Rayleigh	$\lambda^{-4}$	$< 1 \text{ } \mu\text{m}$	Air molecules
Mie	$\lambda^0$ to $\lambda^{-4}$	$0.1 \text{ to } 10 \text{ } \mu\text{m}$	Smoke, haze
<b>Non-selective</b>	$\lambda^0$	$> 10 \text{ } \mu\text{m}$	Dust, fog, clouds

# Effect of Atmosphere on Remote sensing

- Absorption

Only Atmospheric windows available !

- Scattering

Modification of spatial/spectral distribution of incoming and outgoing radiation !

Atmospheric turbulence limits resolution !

# What have we learnt ??

- Definition and Overview of Remote Sensing History and Evolution of Remote Sensing and Remote Sensing Systems.
- Electromagnetic Radiation, Terms and Definitions, Laws of Radiation, EM Spectrum
- Interaction between EM Radiation and matter, Reflection, Absorption and Transmission.
- Interactions between EM Radiation and Atmosphere, Atmospheric windows

# THANKS

**For further queries and doubts :  
[manu@iirs.gov.in](mailto:manu@iirs.gov.in)**

*PS : The material used in the presentation has been compiled from various sources : book by Dr. George Joseph, RS tutorials by ccrs, NASA, ITC, other books, lecture notes, tutorials and online resources*

# Suggested readings

- George J. (2005) : Fundamentals of remote Sensing; Universities press (India) Pvt Ltd, Hyderabad, india.
- Lillesand T.M., Keifer R.W. and Chipman J. (2008) : remote Sensing and Image Interpretation, 6<sup>th</sup> Edition, John Wiley.
- Sabins F.F. (1996) : Remote Sensing and Interpretation , Waveland Pr. Inc.
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- Remote Sensing III Edition : American Society of photogrammetry and Remote Sensing.
- Jenson, J. R., (2000) : Remote Sensing of the Environment : An Earth Resource Perspective, New Jersey : Prentice Hall.