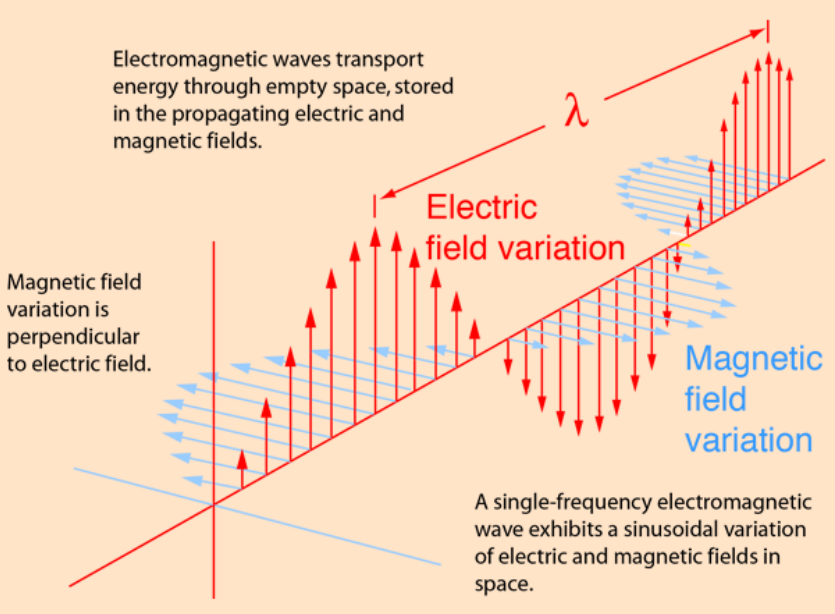
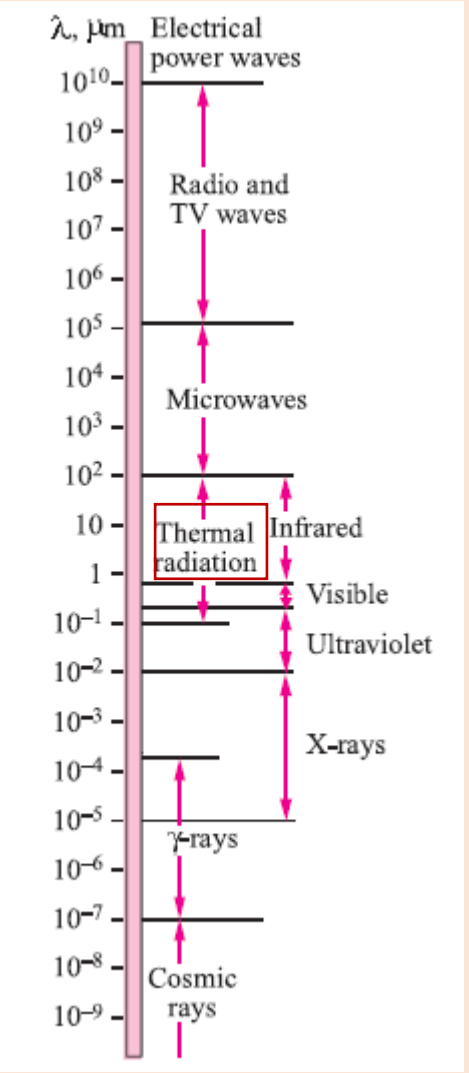
Radiation

- Radiation heat transfer is the *transfer of heat (or energy) by electromagnetic radiation*
- Thermal radiation is an *electromagnetic radiation emitted by a body as a result of its temperature* - any matter with temperature above absolute zero (0 K) emits electromagnetic radiation
- In radiation heat transfer, the *medium through which the heat is transferred is not usually heated*

- *Electromagnetic radiation* can be visualized as *waves traveling at the speed of light* (c)
- The two prominent characters of the wave are the wavelength (λ) and frequency (ν)
- The wavelength is the distance between crest to crest on the wave
- The frequency is related to wavelength by the following: $\nu = \frac{c}{\lambda}$
- Emission of radiation is not continuous, but occurs in the form of discrete quanta and each quantum has an energy of $E = h\nu$
- Thermal radiation is a form of electromagnetic radiation similar to x-rays, light waves, gamma rays and so on, differing only in their wavelength



- The *amount of radiation emitted by a body depends on its temperature*, and is proportional to T^4
- This relation shows that as the temperature of the object increases, the amount of radiation emitted increases very rapidly
- The emitted radiation will travel at the speed of light until it is absorbed by another body
- The absorbing medium can be gas, liquid, or solid



- Thermal radiation obeys the same laws as light –
  - *travels in a straight line,*
  - *can be transmitted through space and vacuum*
- The electromagnetic radiation (shown in figure) covers a wide range of wavelengths, from less than 10^{-10} μm for cosmic rays to more than 10^{10} μm for electrical power waves
- Energy of an electromagnetic wave is inversely proportional to wavelength – radiation of shorter wavelength have higher energy
- **Thermal radiation** (type of electromagnetic radiation pertinent to heat transfer) **lies in the range from about 0.1 to 100 μm**
- Visible portion of the spectrum lies between 0.35 to 0.75 μm
- Thermal radiation includes the entire range of visible and infra-red (IR) radiation, as well as a portion of the ultra-violet (UV) radiation

- Heat transfer by radiation plays an important role in many heating and cooling operations such as *combustion of fossil fuels, operation of a furnace, thermal cracking, different types of kilns, heating stills in petroleum refineries*

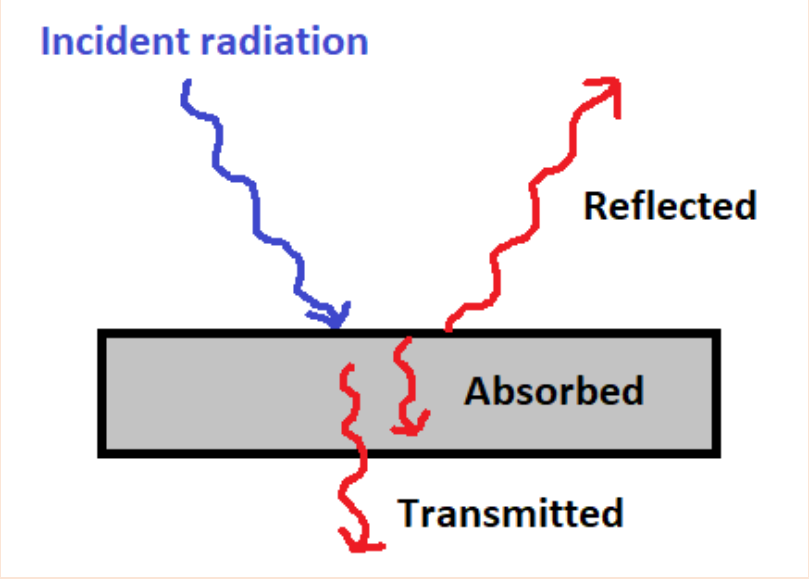
- The mechanism of radiation heat transfer is composed of three distinct steps:
  (a) the thermal energy of a hot body (T_1) is converted into the energy of electromagnetic radiation waves
  (b) these waves travel through the intervening space in straight lines and strike a cold object (T_2)
  (c) the electromagnetic waves are absorbed by the body and converted back into thermal energy or heat

Properties of radiation

- When ***radiant energy strikes a material surface***, part of the radiation is ***reflected***, part is ***absorbed*** and part is ***transmitted***
- The fraction of incident radiation absorbed by a body is called ***absorptivity*** $(\boldsymbol{\alpha})$, the fraction reflected is ***reflectivity*** $(\boldsymbol{\rho})$ and the fraction transmitted through the body is the ***transmissivity*** $(\boldsymbol{\tau})$

Thus,

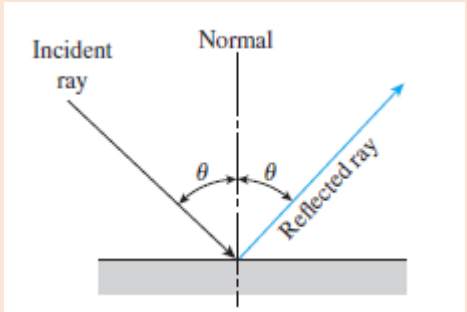
$$\alpha + \rho + \tau = 1$$



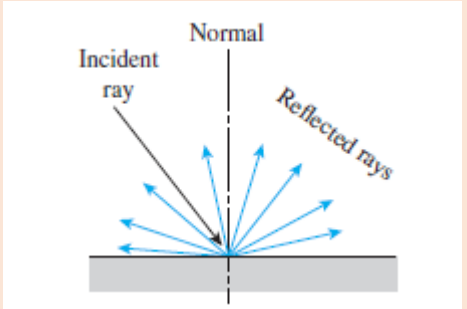
- Absorption and refection of light on a surface are responsible for the perception of colour
- The colour of a body is determined by the wavelength of radiation it reflects
- A surface which absorbs light of all wavelengths in the visible range is ‘black’ and a surface that reflects the light of all wavelengths and does not absorb any appears ‘white’
- For an opaque black surface, $\rho = 0\ and\ \tau = 0$. Therefore, $\alpha = 1$
- For an opaque white surface, $\alpha = 0\ and\ \tau = 0$. Therefore, $\rho = 1$

Types of reflection:

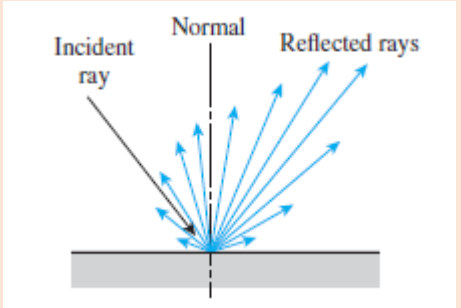
- When radiation strikes a surface, two types of reflection phenomenon may be observed
- If the angle of incidence is equal to the angle of reflection, the reflection is called ***specular***
- If the incident beam is reflected in all possible directions , the reflection is called ***diffuse***
- Real surfaces have reflective properties in between the two extremes



Specular



Diffuse



Actual reflection

- Another important property of a surface is its ability to ***emit radiation*** – this is different from reflection
- *Reflection occurs when a surface receives radiation whereas emission occurs if the temperature of the surface is above absolute zero*
- ***Emissivity*** $(\boldsymbol{\varepsilon})$ of a surface is a measure of how good it is as an emitter

Black body

- The laws and relations for radiation have been developed on the basis of the concept of an idealized body called the ***black body***
- The ***black body*** is a surface that has the following properties:

  (i) It absorbs all the incident radiation irrespective of its wavelength, and reflects none

  (ii) It is a perfect emitter

  No other surface can emit more radiation than a blackbody provided they are at the same temperature

  Emissivity of a black body is taken as $\varepsilon = 1$

  (iii) Emission occurs in all possible directions

  A black body is a perfectly diffuse emitter

- The ***black body*** is a standard with which a real surface can be compared, as it is an ***ideal absorber*** $(\boldsymbol{\alpha = 1})$ and an ***ideal emitter*** $(\boldsymbol{\varepsilon = 1})$ of radiation
- Milk absorbs long range thermal radiation, hence it is a blackbody

- The concept of a ***black body*** is an idealization – a perfect black body does not exist
- A close approximation of a blackbody is a hollow body with a small hole
- The inside of the body is blackened by charcoal
- The radiation enters the hole and impinges on the rear wall, part is absorbed and part reflected
- The reflected rays impinge again on the wall, part absorbed and part reflected and the process continues
- After several repetitions, almost all the incident radiation is absorbed