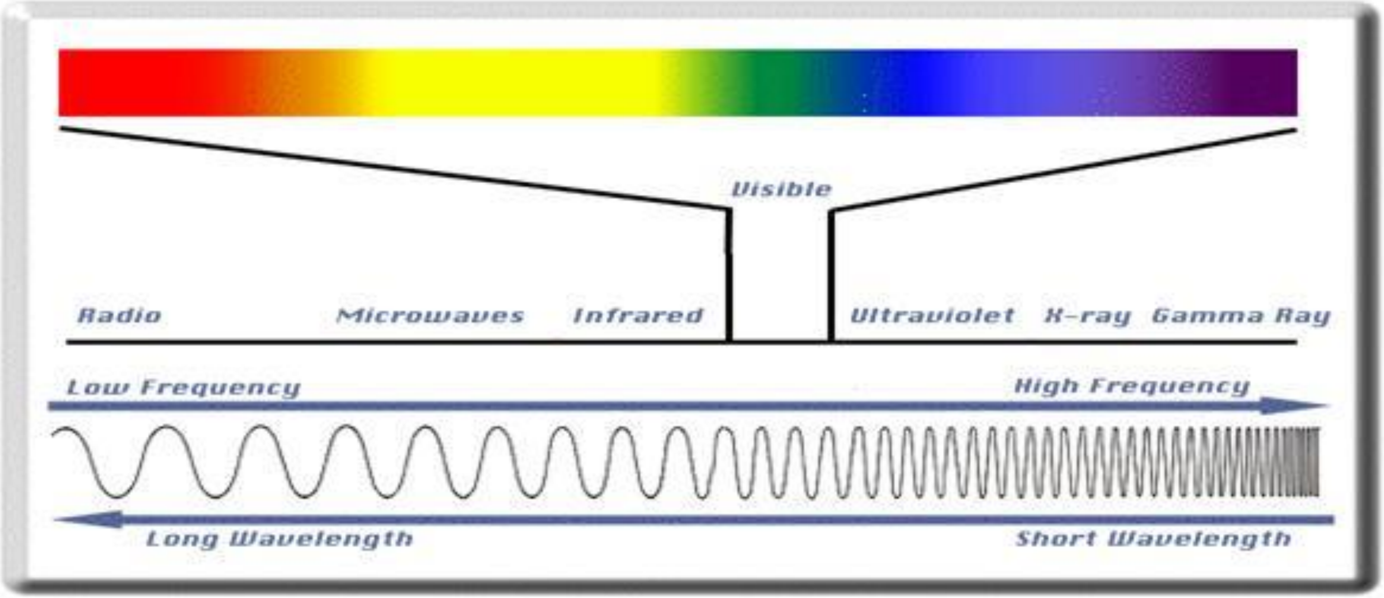
Paper No. : 04
Paper Title: Unit Operations in Food processing
Module –7: Heat Radiation

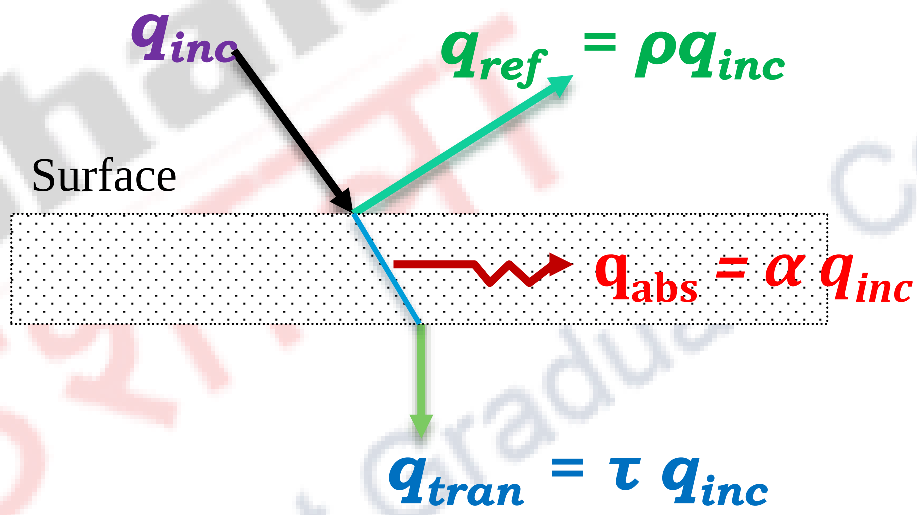
Introduction



- Emission of energy in the form of electromagnetic waves
- Depends on body temperature
- Can travel in complete vacuum
- Rate of heat transfer is faster
- Example: Baking, sunshine, Boiler

Surface characteristics

Absorptivity, $\alpha = \dfrac{q_{abs}}{q_{inc}}$



Reflectivity, $\rho = \dfrac{q_{ref}}{q_{inc}}$

Transmissivity, $\tau = \dfrac{q_{tran}}{q_{inc}}$

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

- **The radiation energy is presented as energy flux (*W/m²*)**
- **Polished surface reflects all the incident radiation** $\rho = 1$
- **Black body absorbs all the incident radiation, So,** $\alpha = 1$

Types of Body

Black Body

A body is said to be perfectly black if it absorbs all the incident radiation to it.

$$absorptivity,\ \alpha = 1$$
$$emissivity,\ \varepsilon = 1$$
$$So,\quad \alpha = \varepsilon = 1$$

Gray Body

A body is said to be gray if the monochromatic properties are constant at all wavelengths.

$$absorptivity,\ \alpha < 1$$
$$emissivity,\quad \varepsilon < 1$$

Opaque Body

A body is said to be opaque if no incident radiation gets transmitted through the body.

$$\alpha + \rho = 1$$

Emissivity

- Emissivity is the ratio of radiant heat flux of a real body to that of a perfect black body
- Black body is a perfect emitter
- Energy emitted by a real surface is always less than energy emitted by a black surface at same temperature

Radiation of a body

$$\text{Emissivity,} \quad \varepsilon = \frac{E}{E_0}$$

Radiation of a blackbody

Kirchhoff's Law

Emissivity, $\varepsilon = \dfrac{E}{E_0}$

Absorptivity, $\alpha = \dfrac{E}{E_0}$

At thermal equilibrium, $\varepsilon = \alpha$

So, Kirchhoff's law states that a body at constant temperature which is in equilibrium with its surroundings, the amount of energy absorbed by radiation is exactly same as that emitted.

Stefan-Boltzmann Law

It states that the total emissive power is the total radiation energy per unit area leaving a surface with temperature *T* over all wavelengths.

$$\frac{q}{A} = \sigma \varepsilon T^4$$

Radiation power (Watt)

emissivity

Absolute temperature (K)

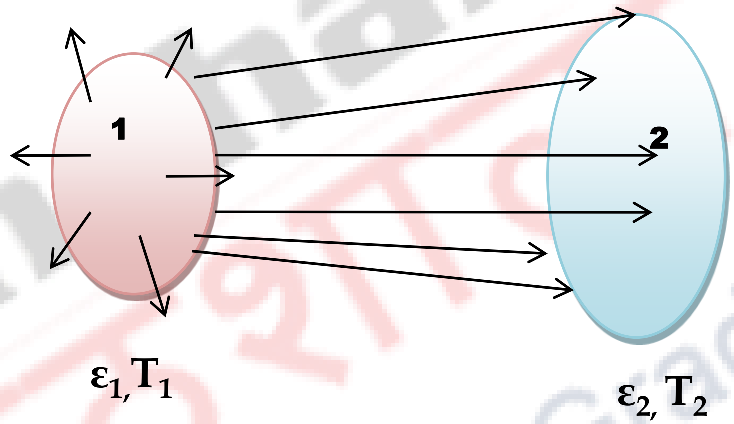
Surface Area (m^2)

Stefan-Boltzmann constant (5.669×10^{-8} W/m^2K^4)

For a perfectly black body,

$$\frac{q}{A} = \sigma T^4$$

Radiation between two surfaces



$$q_{1\to 2} = \begin{bmatrix} radiation\ \ leaving\ surface\, 1 \\ that\ strikes\ surface\, 2 \end{bmatrix} - \begin{bmatrix} radiation\ \ leaving\ surface\, 2 \\ that\ strikes\ surface\, 1 \end{bmatrix}$$

$$q_{12} = \sigma AK \left[T_1^{\ 4} - T_2^{\ 4} \right]$$

$$\frac{1}{K} = \frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1$$

Radiation from the surrounding

Example: Heat transfer from the surrounding to the bread loaf inside a baking oven

$$q_r = h_r A(T_1 - T_2)$$

$$q_{12} = \sigma A(T_1^4 - T_2^4)$$

$$h_r = \sigma \frac{(T_1^4 - T_2^4)}{T_1 - T_2}$$

$$q_{total} = q_r + q_c$$

Radiating heat transfer medium

1. Gases with high concentration
2. Asymmetric molecules like H_2O, CO_2, CO, SO_2 etc.
3. Absoption and emission depends on the gas concentration

THANK YOU