Heat and Mass Transfer (DI05019071)

Complete Lecture Deck

Milav Dabgar

Lecturer, GP Palanpur

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Radiation Heat Transfer

- Course: Heat and Mass Transfer (DI05019071)
- Unit 3: Radiation
- Lecture 22: Absorptivity, Reflectivity, and Transmissivity

Lecture Agenda

- 1. Introduction to Thermal Radiation
- 2. Electromagnetic Spectrum
- 3. Interaction of Radiation with Matter
- 4. Definitions: Absorptivity, Reflectivity, Transmissivity
- 5. Conservation of Energy Relationship
- 6. Surface Characteristics

What is Thermal Radiation?

- Radiation is energy emitted by matter in the form of electromagnetic waves (or photons).
- Does NOT require an intervening medium (can occur in a vacuum).
- All matter at a temperature above absolute zero (0 K) emits thermal radiation.
- Travels at the speed of light.

The Electromagnetic Spectrum

- Thermal radiation spans a specific portion of the EM spectrum.
- Wavelength range: ~0.1 to 100 micrometers (μm).
- Includes a portion of ultraviolet (UV), all visible light, and infrared (IR).
- Heat transfer is mostly concerned with the infrared region.

Interaction of Radiation with Matter

- When thermal radiation strikes a surface, three things can happen:
- 1. It is absorbed by the material (increases internal energy).
- 2. It is reflected away from the surface.
- 3. It is transmitted through the material.
- Total incident radiation is called Irradiation (G).

Absorptivity (α)

- Absorptivity (α): The fraction of incident radiation absorbed by the surface.
- Mathematical definition: α = G_abs / G
- Where G_abs is absorbed radiation and G is total incident irradiation.
- Range: $0 \leq \alpha \leq 1$
- Depends on the nature of the surface, temperature, and wavelength of incident radiation.

Reflectivity (ρ)

- Reflectivity (ρ): The fraction of incident radiation reflected by the surface.
- Mathematical definition: ρ = G_ref / G
- Where G_ref is reflected radiation.
- Range: $0 \leq \rho \leq 1$
- Types of reflection: Specular (mirror-like) and Diffuse (scattered in all directions).

Transmissivity (τ)

- Transmissivity (τ): The fraction of incident radiation transmitted through the material.
- Mathematical definition: τ = G_tr / G
- Where G_tr is transmitted radiation.
- Range: $0 \leq \tau \leq 1$
- Solid opaque materials generally have $\tau = 0$.

Conservation of Energy

- By the principle of conservation of energy:
- Total Incident Radiation = Absorbed + Reflected + Transmitted
- G = G_abs + G_ref + G_tr
- Dividing by G gives:
- $1 = \alpha + \rho + \tau$

Special Cases: Opaque Surfaces

- For opaque materials (e.g., metals, wood, brick):
- No radiation is transmitted: $\tau = 0$
- The conservation equation simplifies to:
- $\alpha + \rho = 1$
- Therefore, a highly reflective opaque surface must have low absorptivity, and vice versa.

Special Cases: Transparent Gases

- For highly transparent media (e.g., dry air, pure gases):
- Very little radiation is absorbed or reflected.
- $\alpha \approx 0$, $\rho \approx 0$
- Transmissivity approaches 1: $\tau \approx 1$
- Note: Some gases (like CO2 and water vapor) absorb specific wavelengths.

Summary

- Thermal radiation requires no medium and travels as EM waves.
- Irradiation (G) interacts via absorption, reflection, and transmission.
- Properties: α (absorptivity), ρ (reflectivity), τ (transmissivity).
- Conservation law: $\alpha + \rho + \tau = 1$.

Next Lecture Preview

- Topic: Black, white, and grey bodies
- Key questions to ponder:
- - What makes a surface a 'perfect' emitter and absorber?
- - How do real surfaces differ from ideal theoretical surfaces?