Heat and Mass Transfer (DI05019071)

Complete Lecture Deck

Milav Dabgar

Lecturer, GP Palanpur

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Ideal and Real Surfaces in Radiation

- Course: Heat and Mass Transfer (DI05019071)
- Unit 3: Radiation
- Lecture 23: Black, White, and Grey Bodies

Lecture Agenda

- 1. The Black Body Concept
- 2. Characteristics of a Black Body
- 3. Experimental Realization of a Black Body
- 4. The White Body Concept
- 5. The Opaque Body
- 6. The Grey Body Approximation
- 7. Real Surfaces vs. Grey Bodies

What is a Black Body?

- A black body is an idealized physical body that absorbs all incident electromagnetic radiation.
- Key Property: $\alpha = 1$
- Since it absorbs everything, it reflects and transmits nothing: $\rho = 0$, $\tau = 0$.
- It is a perfect absorber, regardless of wavelength or angle of incidence.

Characteristics of a Black Body

- 1. Perfect Absorber: Absorbs all incident radiation.
- 2. Perfect Emitter: For a prescribed temperature and wavelength, no surface can emit more energy than a black body.
- 3. Diffuse Emitter: Radiation emitted by a black body is independent of direction.
- Serves as a standard against which the radiative properties of real surfaces are compared.

Is a Black Body Actually 'Black'?

- The term 'black body' is a thermodynamic concept.
- Visual appearance depends on its temperature.
- At room temperature, it appears black (absorbs all visible light).
- At high temperatures, it can glow red, yellow, or white (e.g., the Sun, a filament).
- Snow and ice absorb almost all infrared radiation ($\alpha \approx 0.95$), acting nearly as black bodies in the IR spectrum!

Experimental Realization of a Black Body

- A large cavity with a very small opening acts as a near-perfect black body.
- Radiation entering the hole undergoes multiple internal reflections.
- With each reflection, a fraction is absorbed.
- Almost none of the incident radiation escapes back out the hole.
- The hole acts as a black body surface of area equal to the hole's area.

What is a White Body?

- A white body is an idealized surface that reflects all incident radiation.
- Key Property: $\rho = 1$
- Therefore: $\alpha = 0$, $\tau = 0$.
- It absorbs no energy and transmits no energy.
- Like the black body, it is a theoretical extreme.

Opaque Bodies

- As discussed previously, an opaque body transmits no radiation.
- Key Property: $\tau = 0$
- Conservation equation: $\alpha + \rho = 1$
- Most solids we analyze in engineering (metals, walls, machinery) are modeled as opaque bodies.

Real Surfaces vs. Idealizations

- Real surfaces emit and absorb less radiation than a black body.
- Their properties (α, ρ, τ) depend strongly on:
- - The wavelength (λ) of the radiation.
- - The direction (angle) of the radiation.
- This makes analyzing real surfaces mathematically complex.

The Grey Body Concept

- To simplify calculations, we use the Grey Body approximation.
- A Grey Body is defined as a surface whose properties (α, ρ) are independent of wavelength and direction.
- It absorbs a constant fraction of incident radiation across all wavelengths.
- 0 ¡ α_grey ¡ 1 (Constant)

Why Assume a Grey Body?

- Allows use of total (average) properties instead of spectral (wavelength-dependent) properties.
- Most engineering applications involve relatively narrow temperature ranges where the grey body approximation is highly accurate.
- Makes analytical solutions to radiation networks possible.

Summary

- Black Body: $\alpha = 1$ (Perfect absorber and emitter).
- White Body: $\rho = 1$ (Perfect reflector).
- Opaque Body: $\tau = 0$ ($\alpha + \rho = 1$).
- Grey Body: Properties are independent of wavelength (constant α).

Next Lecture Preview

- Topic: Emissive power and emissivity
- Key questions to ponder:
- - How do we quantify the energy emitted by a black body versus a grey body?
- - What is emissivity and how does it relate to absorptivity?