# Chapter 14. Radiation Heat Transfer

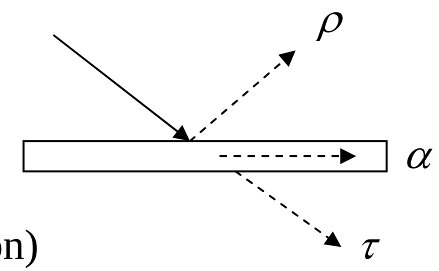
All substances at $T$ above 0 K emit radiation.

“Thermal radiation”

$\rho$ (reflectivity: 반사율) ~ fraction of radiation falling on a body that is reflected.

$\alpha$ (absorptivity: 흡수율) ~ fraction that is absorbed.

$\tau$ (transmissivity: 투과율) ~ fraction that is transmitted.




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

Blackbody (흑체): $\alpha = 1$ (a body that absorbs all incident radiation)

## Emission of radiation

Wavelength of radiation: $10^{-11}$ cm to $10^{3}$ m

“ important in heat flow: 0.1 to 100 μm

(visible light: 0.39 – 0.78 μm)

고온일수록 짧은 파장의 복사열을 방출

(500 $^{o}$C 이상에서는 가시광선보다 큰 파장에 의한 복사도 점차 중요해 짐)

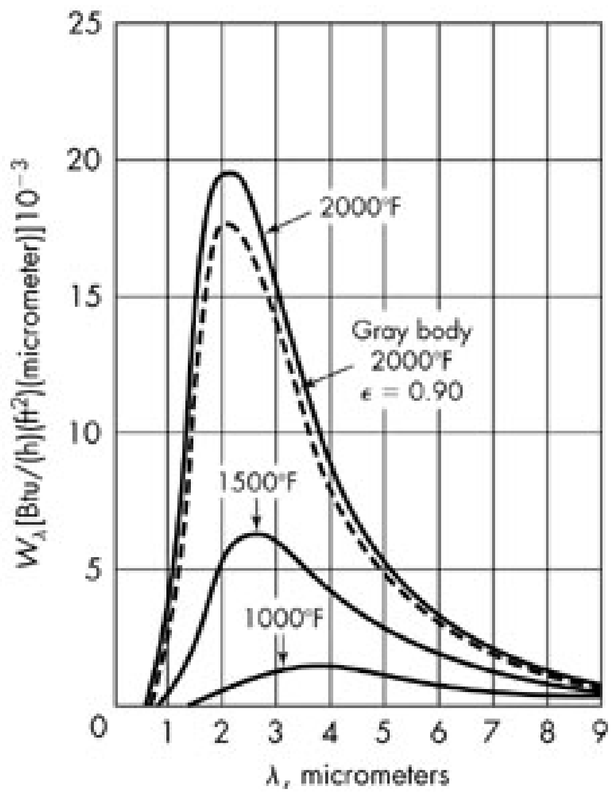



**Fig. 14.1.** Energy distribution in spectra of blackbodies and gray bodies.

$W_{\lambda}$ (***monochromatic radiation power***: 단색광 복사력): Monochromatic radiation emitted from unit area in unit time divided by the wavelength

→ Fig. 14.1의 *y*축 값
(방사에너지는 온도와 파장에 의존)

→ Monochromatic radiation: radiation of a single wavelength

Total radiating power (총 복사력): $W = \int_0^\infty W_\lambda d\lambda$ ⟶ area of Fig. 14.1

$\varepsilon\ (emissivity) \equiv \dfrac{W}{W_b}$ **(방사율)**

$W_b$: emissive power of a blackbody (최대가능 방사력)

$\varepsilon_\lambda\ (monochromatic\ emissivity) \equiv W_\lambda / W_{b,\lambda}$
단색광 방사율

Gray body (회색체): $\varepsilon_\lambda$ of a body is the same for all $\lambda$
(단색광 방사율이 모든 파장에서 동일한 물체)

$\varepsilon$ of solids --- increases with $T$.

- polished metals: 0.03 ~ 0.08
- oxidized metals: 0.6 ~ 0.85
- paper, boards: 0.65 ~ 0.95
- paints (Al계 paints 제외): 0.80 ~ 0.96

*** Laws of blackbody radiation (흑체 복사 법칙)**

***Stefan-Boltzmann law***:

$$W_b = \sigma T^4$$

$\sigma$ → Stefan-Boltzmann constant: $5.672 \times 10^{-8}$ W/m$^2$·K$^4$

***Planck's law*** (distribution of energy in the spectrum of a blackbody):

$$W_{b,\lambda} = \frac{2\pi \mathbf{h} c^2 \lambda^{-5}}{e^{\mathbf{h}c/\mathbf{k}\lambda T} - 1} = \frac{C_1 \lambda^{-5}}{e^{C_2/\lambda T} - 1}$$

--- Eq. (14.6) → Plots (Fig. 14.1)

- $W_{b,\lambda}$ : monochromatic emissive power of blackbody
- $\mathbf{h}$ : Plank's constant
- $c$ : speed of light
- $\lambda$ : wavelength of radiation
- $\mathbf{k}$ : Boltzmann's constant
- $C_1$, $C_2$ : constants

Relationship between Planck's law & Stefan-Boltzmann law:

$$W_b = \int_0^\infty W_{b,\lambda}\, d\lambda$$

$W_b$ → *Stefan-Boltzmann law*

$W_{b,\lambda}$ → *Planck's law*

(즉, Stefan-Boltzmann 식은 Planck 식을 적분한 식)

***Wien's displacement law*** ($\lambda$ that gives the maximum $W_{b,\lambda}$):

$$T\lambda_{\max} = C$$

← Planck 식을 $\lambda$에 대해 미분하고 이를 0으로 두어 구한 식

($T$의 단위를 K, $\lambda_{\max}$의 단위를 μm로 둘 경우 $C$는 2,890을 사용)

# Absorption of Radiation by Opaque Solids

Opaque body (불투명체)

$\rightarrow \quad \tau = 0, \qquad \therefore \ \alpha + \rho = 1$

Reflection (반사)

- specular reflection (정반사 or 거울반사)
  - : 매끄러운 표면에서의 반사
  - 반사각은 입사각에 의존
- diffuse reflection (난반사) or diffuse radiation (난복사)
  - : 거친 표면에서의 반사
  - 일정한 반사각이 없이 모든 방향으로 반사
  - 반사율과 흡수율이 입사각에 무관
  - 보다 일반적인 경우임.

* Absorptivity of a ***gray body*** – the same for all wavelengths, like the emissivity

회색체의 표면이 난복사(난반사)한다면 monochromatic absorptivity도 radiant beam의 입사각에 무관

→ Total absorptivity
- equals the monochromatic absorptivity.
- is independent of the incident angle.

***Kirchhoff's law*** (At $T$ equil., the ratio of the total radiating power $W$ of any body to its absorptivity $\alpha$ depends only on the $T$ of the body):

$$\frac{W_1}{\alpha_1} = \frac{W_2}{\alpha_2}$$

← total radiating powers of 2 bodies

← absorptivities of 2 bodies

If the first body is a blackbody,

$$\alpha = 1 \ \ \& \ \ W_1 = W_b = \frac{W_2}{\alpha_2}$$

$$\therefore \alpha_2 = \frac{W_2}{W_b} = \varepsilon_2$$

*emissivity* 의 정의

→ When any body is at $T$ equilibrium, $\varepsilon = \alpha$

. Total radiation for a unit area of an opaque body:

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