Radiation

Electromagnetic Spectrum

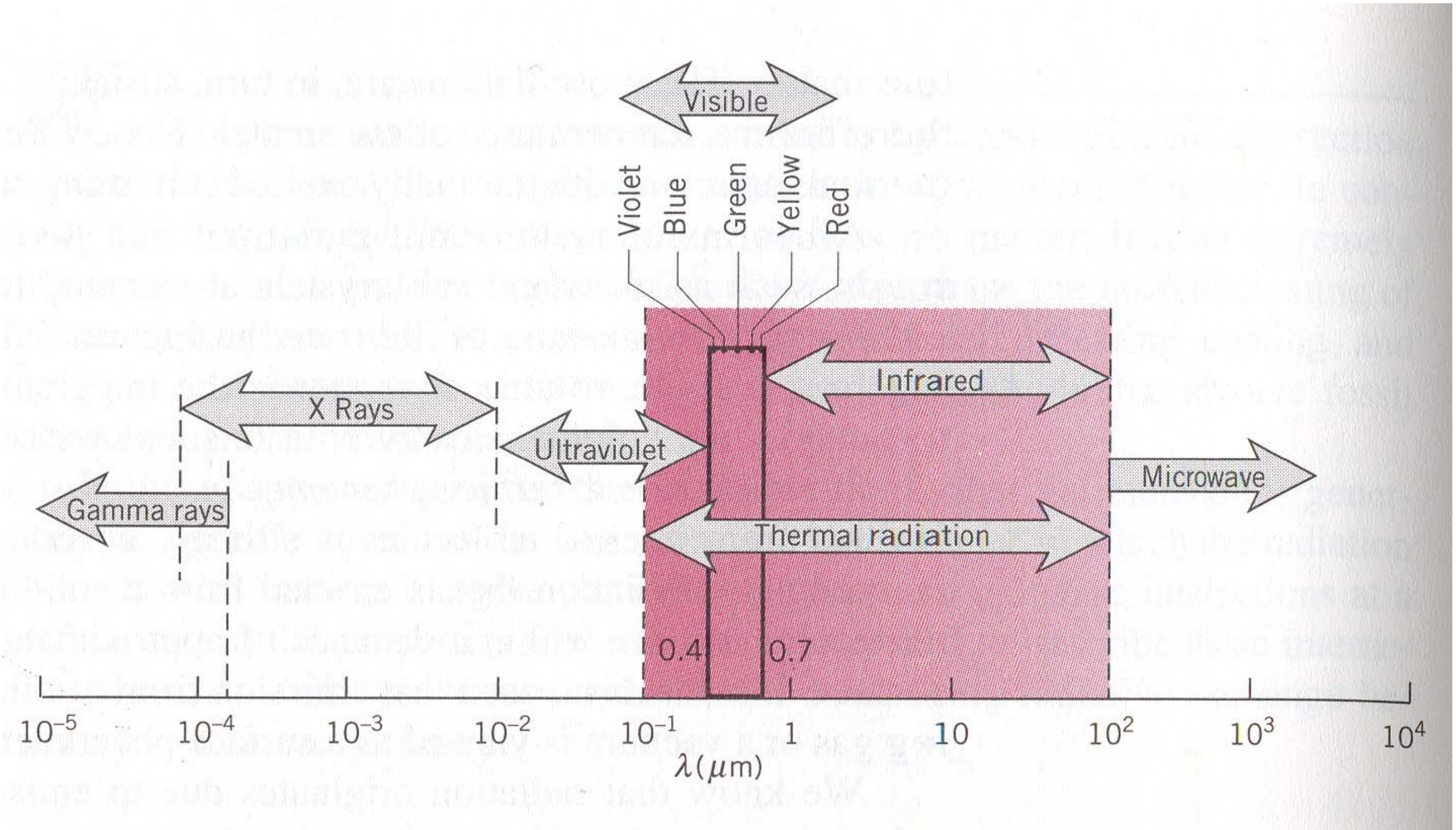


FIGURE 12.3 Spectrum of electromagnetic radiation.

from Fundamentals of Heat and Mass Transfer, 4th Edition, Incorpera and DeWittt, Wiley (1996)

Planck's Law

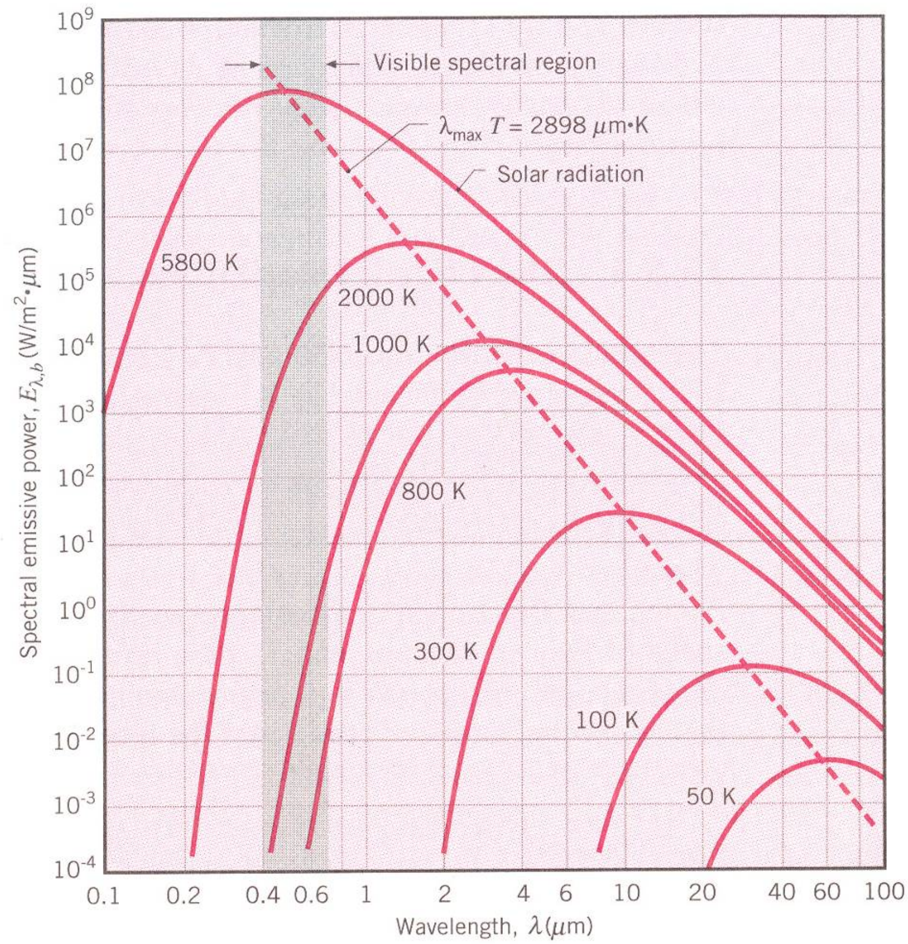
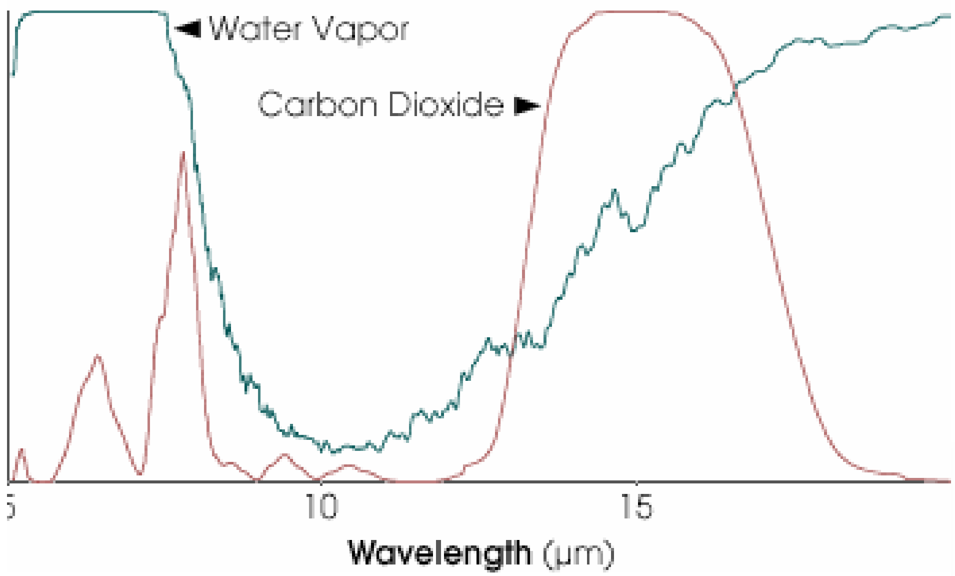


FIGURE 12.13 Spectral blackbody emissive power.

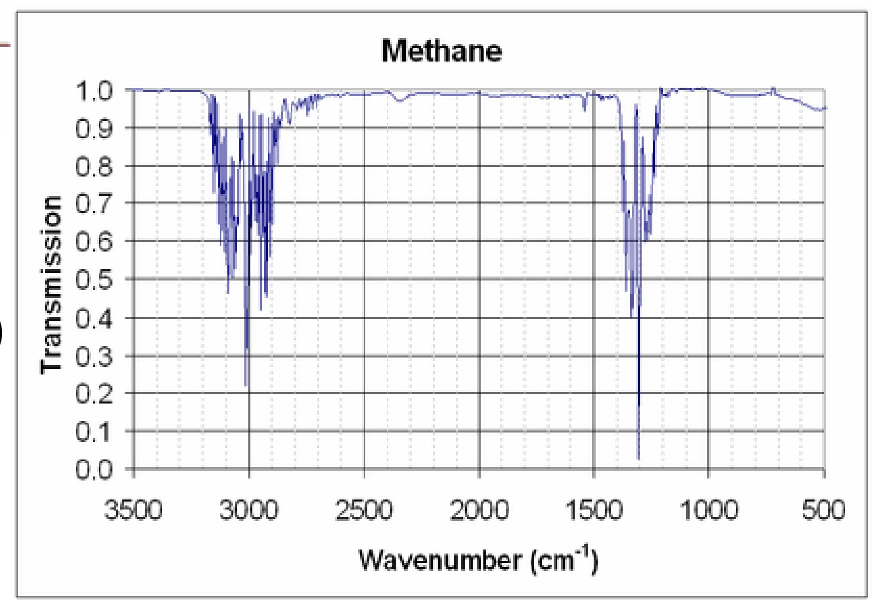
$$e_b(\lambda) = \frac{2\pi C_1}{\lambda^5\left(e^{C_2/\lambda T} - 1\right)}$$

from <u>Fundamentals of Heat and Mass Transfer, 4th Edition</u>, Incorpera and DeWittt, Wiley (1996)

Non-Blackbody Emission

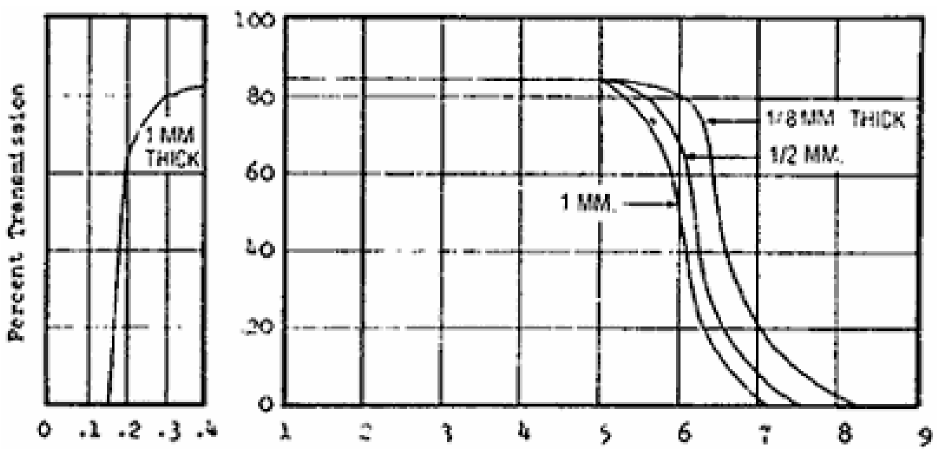


Wavelength (μm) = 1/(Wavenumber/10,000)



1.4 μm 2.5 μm 10 μm

Transmissivity of Synthetic Sapphire



Glossary

Absorption	The process by which a medium attenuates (i.e., absorbs) electromagnetic energy (i.e., radiation) by converting it to thermal energy within the medium.
Absorptivity	Ratio of absorption cross section to geometric cross section of a particle (i.e., the ratio of energy absorbed to energy that could be absorbed based on projected particle surface area).
Albedo	Ratio of the scattering coefficient to the extinction coefficient.
Blackbody	Idealized body that emits the maximum radiation at a given temperature and wavelength (i.e., follows Planck's law). Total emissive power $E_b = \sigma T^4$.
Emission	Conversion of thermal energy to electromagnetic energy (radiation emitted).
Extinction	The process by which a medium attenuates intensity or electromagnetic radiation. Composed of absorption and scattering.
Flux	Energy per area per time.
Intensity	Energy per time per area normal to direction per unit solid angle per wavelength. ($W/m^2/sr/\mu m$) Or flux per unit solid angle per wavelength.
Net Flux	The difference between the flux passing through a plane in one direction minus the flux passing in the other direction.
Scattering	Redirection of electromagnetic energy (intensity) due to electromagnetic wave interaction with surface interfaces of differing index of refraction.
Scattering Phase Function	Ratio of scattered intensity in a given direction to the scattered intensity from isotropic scattering.
Solid Angle	Area on a sphere divided by the square of the sphere radius. Allows for integration over direction. Dimensionless unit of steradian.
Spectral	Radiation or radiative property per unit wavelength.
Total	Integrated over the entire wavelength range of the electromagnetic spectrum.

Spectral and Directional Radiation

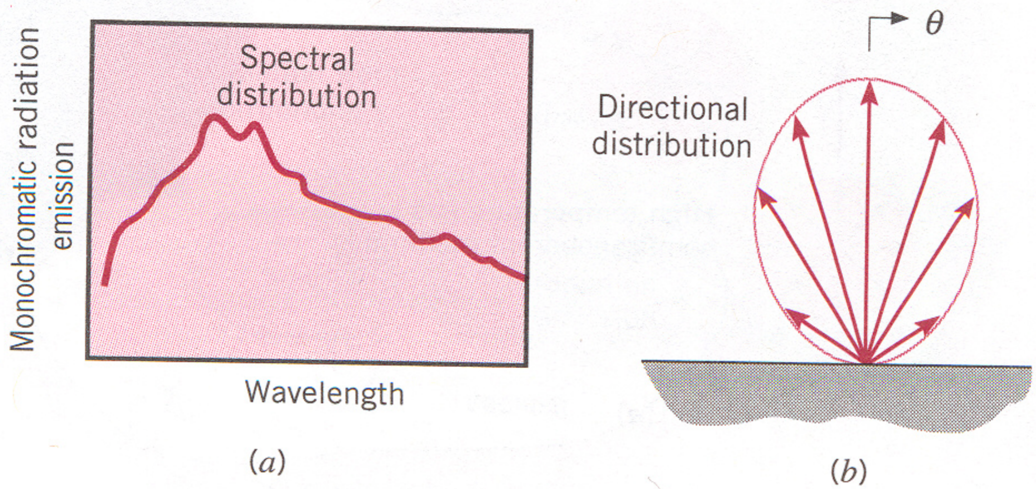


FIGURE 12.4 Radiation emitted by a surface. (*a*) Spectral distribution. (*b*) Directional distribution.

from Fundamentals of Heat and Mass Transfer, 4th Edition, Incorpera and DeWittt, Wiley (1996)

The Radiative Transfer Equation (RTE)

$$\frac{1}{c}\frac{\partial I_\lambda}{\partial t} + \vec{\nabla}\bullet\hat{\Omega}\, I_\lambda + \left(\kappa_\lambda + \sigma_\lambda\right) I_\lambda = \kappa_\lambda\, I_{\lambda b}(T) + \frac{\sigma_\lambda}{4\pi}\int_{\Omega' = 4\pi} \Phi_\lambda\left(\Omega',\Omega\right) I_\lambda\left(\Omega'\right) d\Omega'$$

- c = speed of light
- Ω = direction
- I_λ = intensity
- $I_{\lambda b}$ = blackbody emission
- κ_λ = absorption coefficient
- σ_λ = scattering coefficient
- $\Phi_\lambda(\Omega',\Omega)$ = Phase function for light scattered into Ω direction from Ω' direction
- $I_{\lambda'}$ = intensity of light from Ω' direction

The Radiative Transfer Equation (RTE)

Change in intensity In direction Ω-

emission

$$\frac{1}{c}\frac{\partial I_\lambda}{\partial t} + \vec{\nabla}\bullet\hat{\Omega}\, I_\lambda + \left(\kappa_\lambda + \sigma_\lambda\right) I_\lambda = \kappa_\lambda\, I_{\lambda b}(T) + \frac{\sigma_\lambda}{4\pi}\int_{\Omega' = 4\pi} \Phi_\lambda\left(\Omega',\Omega\right) I_\lambda\left(\Omega'\right) d\Omega'$$

transient | absorption | Out-scattering | In-scattering

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- Ω = direction
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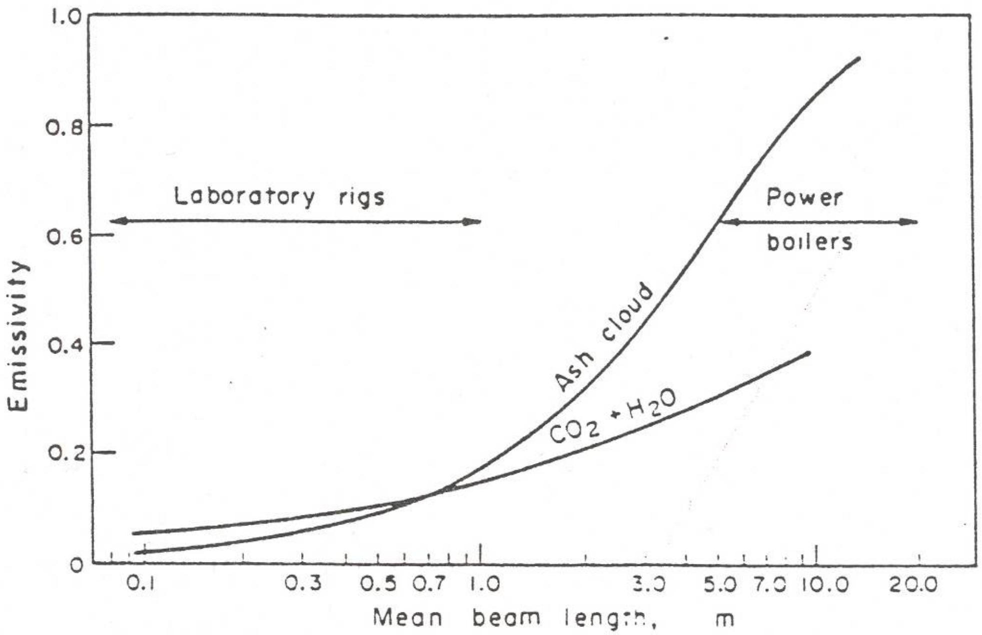
Path-Length Dependence

Mineral matter in coal and the thermal performance of large boilers



25% ash bituminous coal assumed burned in 20% excess air, combustion products at 1500 K

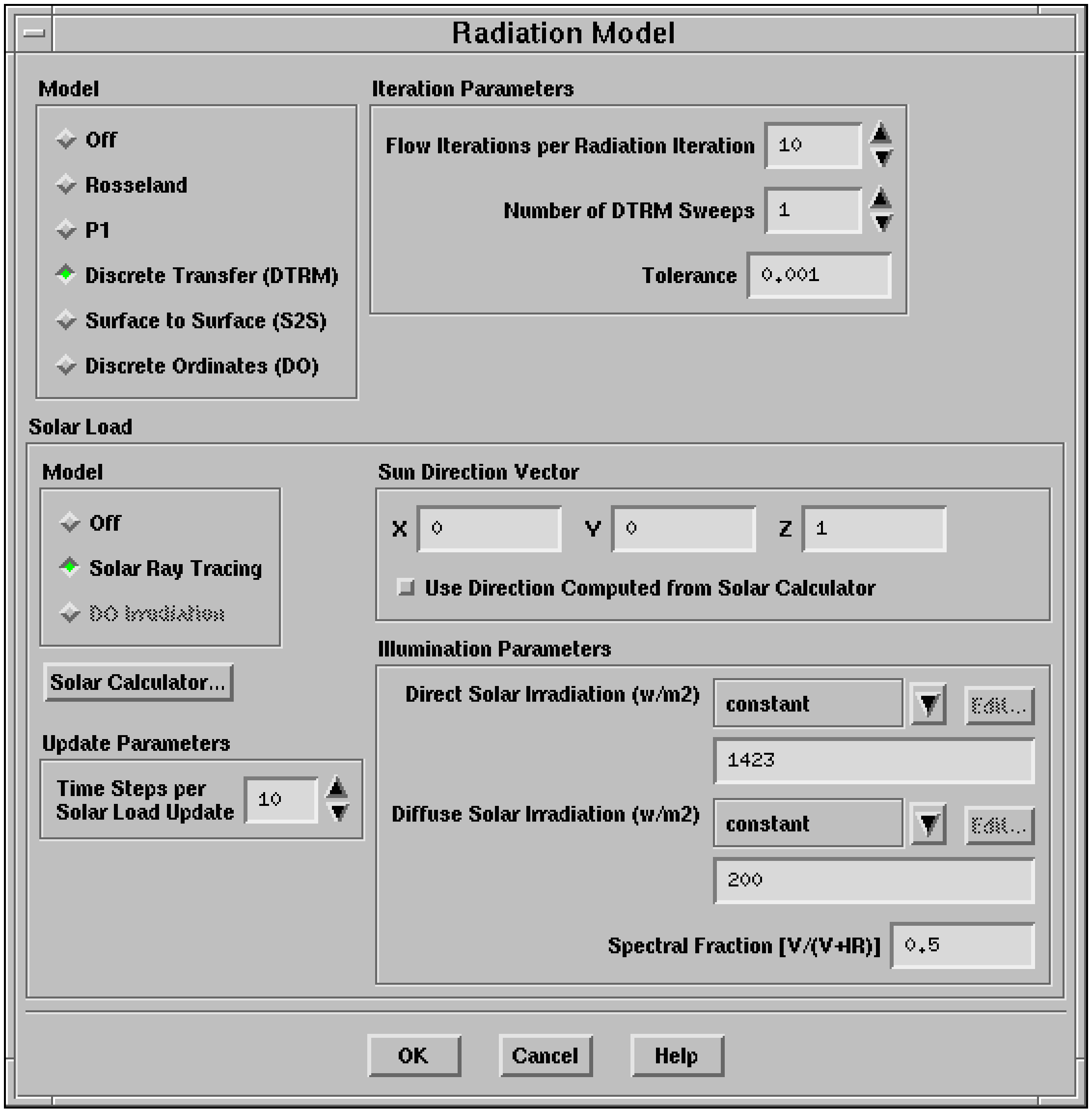
FIG. 3. Emissivity of p.f. combustion product components.

TABLE 11. Effect of ash absorption area on heat absorbed in furnace[66]

Ash cloud absorption area (m^2/kg)	Mean particle absorption efficiency	Heat absorbed in furnace (MW)
58.4	0.7	362.5
41.7	0.5	338.9
10.4	0.125	271.8

from Wall et al., *PECS*, **5**, 1-29 (1979)

Fluent Radiation Options



Fluent Terms