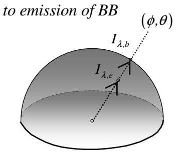
RADIATIVE PROPERTIES OF REAL SURFACES

EMISSIVITY

emission of a real surface is compared to emission of BB



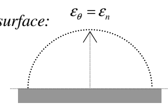
Spectral directional emissivity:

$$\varepsilon_{\lambda\theta} = \frac{I_{\lambda,e}(\phi,\theta,T)}{I_{\lambda,b}(T)} \quad (12.38)$$

Total directional emissivity:

$$\varepsilon_{\theta} = \frac{I_{e}(\phi,\theta,T)}{I_{b}(T)} \quad (12.39)$$

Diffuse surface: $\varepsilon_\theta = \varepsilon_n$



Spectral hemispherical emissivity:

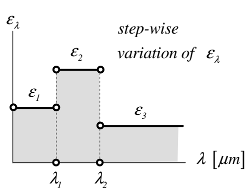
$$\varepsilon_{\lambda} = \frac{E_{\lambda}(T)}{E_{\lambda b}(T)} \quad (12.40)$$

$$= \frac{\int_{2\pi} I_{\lambda,e}\cos\theta d\omega}{\pi I_{\lambda,b}(T)} = \frac{\int_{2\pi} \varepsilon_{\lambda\theta} I_{\lambda b}\cos\theta d\omega}{\pi I_{\lambda,b}(T)} = \frac{1}{\pi}\int_{2\pi}\varepsilon_{\lambda\theta}\cos\theta d\omega$$

Total hemispherical emissivity:

$$\varepsilon = \frac{E(T)}{E_b(T)} = \frac{\int_0^\infty E_\lambda(T)d\lambda}{E_b(T)} \quad (12.36)$$

$$= \frac{\int_0^\infty \varepsilon_\lambda E_{\lambda b}(T)d\lambda}{E_b(T)}$$



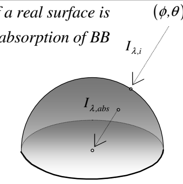
$$= \varepsilon_1 \frac{\int_0^{\lambda_1} E_{\lambda b}(T)d\lambda}{E_b(T)} + \varepsilon_2 \frac{\int_{\lambda_1}^{\lambda_2} E_{\lambda b}(T)d\lambda}{E_b(T)} + \ldots$$

ε depends on surface temperature T

$$\varepsilon = \varepsilon_1 \cdot F_{0\to\lambda_1}(T) + \varepsilon_2 \cdot F_{\lambda_1\to\lambda_2}(T) + \ldots$$

ABSORPTIVITY

absorption of a real surface is compared to absorption of BB



Spectral directional absorptivity:

$$\alpha_{\lambda\theta} = \frac{I_{\lambda,abs}(\phi,\theta)}{I_{\lambda,i}(\phi,\theta)} \quad (12.47)$$

Total directional absorptivity:

$$\alpha_{\theta} = \frac{I_{abs}(\phi,\theta)}{I_{i}(\phi,\theta)}$$

Spectral hemispherical absorptivity:

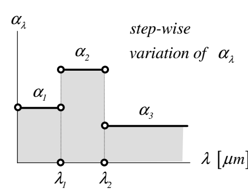
$$\alpha_\lambda = \frac{G_{\lambda,abs}}{G_\lambda} \quad (12.48) \quad = \frac{\int_{2\pi} I_{\lambda,abs}\cos\theta d\omega}{\int_{2\pi} I_{\lambda,i}\cos\theta d\omega} = \frac{\int_{2\pi} \alpha_{\lambda\theta} I_{\lambda,i}\cos\theta d\omega}{\int_{2\pi} I_{\lambda,i}\cos\theta d\omega}$$

Total hemispherical absorptivity:

$$\alpha = \frac{G_{abs}}{G} \quad (12.51)$$

if irradiation is created by emission of a BB at temperature T_b: $G_\lambda = E_{\lambda b}(T_b)$

$$= \frac{\int_0^\infty G_{\lambda,abs}\,d\lambda}{\int_0^\infty G_\lambda\,d\lambda} = \frac{\int_0^\infty \alpha_\lambda G_\lambda\,d\lambda}{\int_0^\infty G_\lambda\,d\lambda} = \frac{\int_0^\infty \alpha_\lambda E_{\lambda b}(T_b)d\lambda}{\int_0^\infty E_{\lambda b}(T_b)d\lambda}$$



$$= \alpha_1 \frac{\int_0^{\lambda_1} E_{\lambda b}(T_b)d\lambda}{E_b(T_b)} + \alpha_2 \frac{\int_{\lambda_1}^{\lambda_2} E_{\lambda b}(T_b)d\lambda}{E_b(T_b)} + \ldots$$

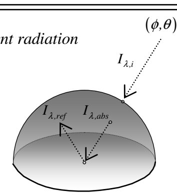
α depends on source temperature T_b

$$\alpha = \alpha_1 \cdot F_{0\to\lambda_1}(T_b) + \alpha_2 \cdot F_{\lambda_1\to\lambda_2}(T_b) + \ldots$$

REFLECTIVITY

12.6.2

the fraction of the incident radiation reflected by a surface



$$I_{\lambda,i}(\phi,\theta) = I_{\lambda,abs}(\phi,\theta) + I_{\lambda,ref}(\phi,\theta)$$

$$1 = \frac{I_{\lambda,abs}(\phi,\theta)}{I_{\lambda,i}(\phi,\theta)} + \frac{I_{\lambda,ref}(\phi,\theta)}{I_{\lambda,i}(\phi,\theta)}$$

$$1 = \alpha_{\lambda\theta} + \rho_{\lambda\theta}$$

$$1 = \alpha_\lambda + \rho_\lambda$$

$$1 = \alpha + \rho$$

$$\rho_{\lambda\theta} = \frac{I_{\lambda,ref}(\phi,\theta)}{I_{\lambda,i}(\phi,\theta)} \quad \textit{spectral directional}$$

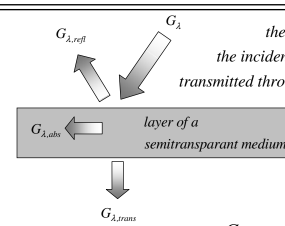
$$\rho_\lambda = \frac{G_{\lambda,ref}}{G_\lambda} \quad \textit{spectral hemispherical}$$

$$\rho = \frac{G_{ref}}{G} \quad \textit{total hemispherical}$$

TRANSMISSIVITY

12.6.3

the fraction of the incident radiation transmitted through a layer



$$1 = \frac{G_{\lambda,abs}}{G_\lambda} + \frac{G_{\lambda,refl}}{G_\lambda} + \frac{G_{\lambda,trans}}{G_\lambda}$$

$$G_\lambda = G_{\lambda,abs} + G_{\lambda,refl} + G_{\lambda,trans}$$

$$1 = \alpha_\lambda + \rho_\lambda + \tau_\lambda$$

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

$$\tau_\lambda = \frac{G_{\lambda,trans}}{G_\lambda} \quad \textit{spectral hemispherical}$$

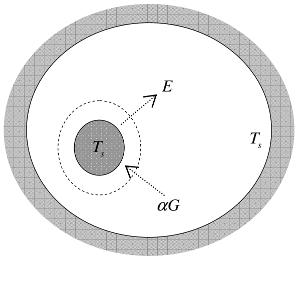
$$\tau = \frac{G_{trans}}{G} \quad \textit{total hemispherical}$$

KIRHHOFF'S LAW

12.7

When emissivity and absorptivity are equal?

surface and surroundings at T_s



surface is in a thermal equilibrium with the surroundings at T_s

$$\alpha G = E$$

$$\alpha G = \varepsilon E_b(T_s)$$

$$\alpha E_b(T_s) = \varepsilon E_b(T_s)$$

$$\alpha = \varepsilon$$

Kirhhoff's Laws:

$$\alpha_{\lambda\theta} = \varepsilon_{\lambda\theta}$$ *always (12.68)*

$$\alpha_\lambda = \varepsilon_\lambda$$ *diffuse surface (12.67)*

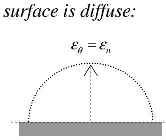
$$\alpha = \varepsilon$$ *thermal equilibrium or gray surface (12.66)*

GRAY SURFACE

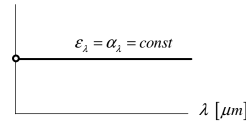
12.8

Surface is called gray if:

1) surface is diffuse:

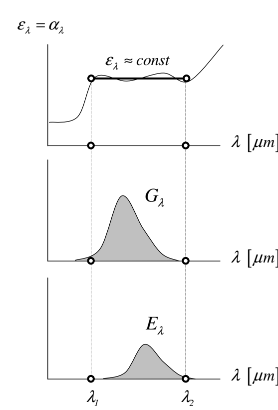


2) and ε & α do not depend on λ:



EFFECTIVELY GRAY

in $[\lambda_1, \lambda_2]$



That is why the Stefan-Boltzmann Law is for gray surfaces: $q''_{rad} = \varepsilon E - \alpha G = \varepsilon\left[\sigma T_s^4 - \sigma T_{sur}^4\right]$