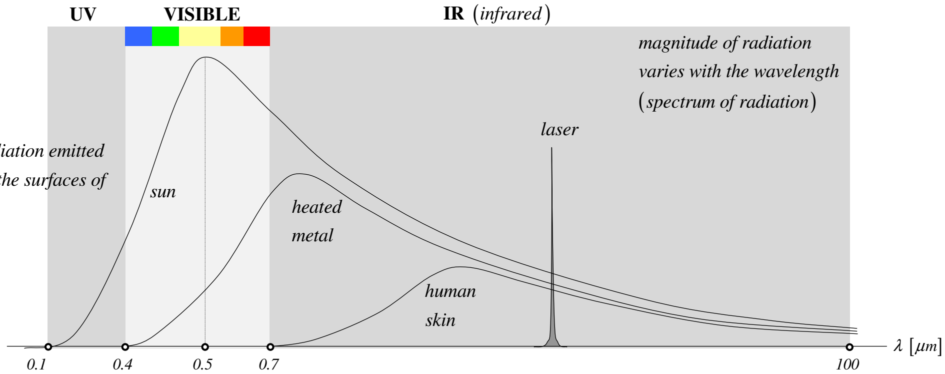
## 12.1 RADIATION – FUNDAMENTAL CONCEPTS

*radiation* = *thermal energy transmitted by electromagnetic vawes (el.-mag.theory)*
*thermal energy transmitted by photons (quantum theory)*

*radiation emitted by the surfaces of*




*Radiation transmits energy with the speed of light:*

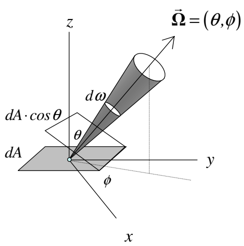
| | | |
|---|---|---|
| $c$ | $\left[\frac{m}{s}\right]$ | *speed of light in the medium* |
| $c_0 = 2.998e8$ | $\left[\frac{m}{s}\right]$ | *speed of light in the vacuum* |
| $\nu$ | $\left[\frac{1}{s}\right]$ | *frequency* |
| $\lambda = \frac{c}{\nu}$ | $[\mu m]$ | *wavelength* $\left[1\mu m = 10^{-6}\,m\right]$ |

### INTENSITY

*Spectral intensity of radiation $I_\lambda$ is the rate of radiation energy transferred through the differential area dA in the differential solid angle $d\omega$ around the direction $\vec{\Omega} = (\theta,\phi)$ in the wavelength $d\lambda$ about $\lambda$*

$$dQ = I_\lambda(\lambda,\theta,\phi)\cdot(dA\cdot\cos\theta)\cdot d\omega\cdot d\lambda\cdot dt \qquad [J]$$

$$dq \equiv \frac{dQ}{dt} = I_\lambda(\lambda,\theta,\phi)\cdot(dA\cdot\cos\theta)\cdot d\omega\cdot d\lambda \qquad [W]$$




***Spectral Intensity***

$$I_\lambda(\lambda,\theta,\phi) = \frac{dq}{(dA\cdot\cos\theta)\cdot d\omega\cdot d\lambda} \qquad \left[\frac{W}{m^2\cdot sr\cdot\mu m}\right] \qquad (12.10)$$

***Total Intensity***

$$I\,(\theta,\phi) = \int_0^\infty I_\lambda(\lambda,\theta,\phi)d\lambda \qquad \left[\frac{W}{m^2\cdot sr}\right]$$

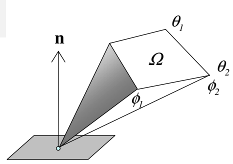
*differential spectral rate of radiation heat transfer*

$$dq_\lambda \equiv \frac{dq}{d\lambda} = I_\lambda(\lambda,\theta,\phi)\cdot(dA\cdot\cos\theta)\cdot d\omega \qquad \left[\frac{W}{\mu m}\right] \qquad (12.11)$$

*differential spectral flux of radiation heat transfer*

$$dq''_\lambda \equiv \frac{dq_\lambda}{dA} = I_\lambda(\lambda,\theta,\phi)\cdot\cos\theta\cdot d\omega \qquad \left[\frac{W}{m^2\cdot\mu m}\right] \qquad (12.12)$$

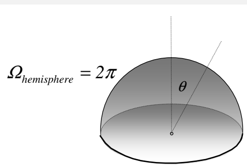
### FLUX




*spectral flux of radiation heat transfer through with the plane defined by the normal vector* **n** *into the solid angle Ω: $\phi_1 \le \phi \le \phi_2,\ \theta_1 \le \theta \le \theta_2$*

$$q''_\lambda = \int_\Omega I_\lambda(\lambda,\theta,\phi)\cdot\cos\theta\cdot d\omega = \int_{\theta_1}^{\theta_2}\int_{\phi_1}^{\phi_2} I_\lambda(\lambda,\theta,\phi)\cdot\cos\theta\cdot\sin\theta\, d\phi\, d\theta$$

### HEMISPHERICAL FLUX




*hemispherical spectral flux into the solid angle Ω: $0 \le \phi \le 2\pi,\ 0 \le \theta \le \pi/2$*

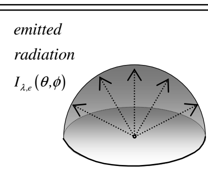
$$q''_\lambda = \int_{\Omega=2\pi} I_\lambda(\lambda,\theta,\phi)\cdot\cos\theta\cdot d\omega = \int_0^{\pi/2}\int_0^{2\pi} I_\lambda(\lambda,\theta,\phi)\cdot\cos\theta\cdot\sin\theta\, d\phi\, d\theta$$

*total hemispherical flux*

$$q'' = \int_0^\infty q''_\lambda\, d\lambda$$

### EMISSION

*radiation flux of emission into hemisphere*




*spectral emissive power*

$$E_\lambda = \int_{\Omega=2\pi} I_{\lambda,e}(\theta,\phi)\cdot\cos\theta\cdot d\omega \qquad \left[\frac{W}{m^2\cdot\mu m}\right]$$

*total emissive power*

$$E = \int_0^\infty E_\lambda\, d\lambda \qquad \left[\frac{W}{m^2}\right]$$

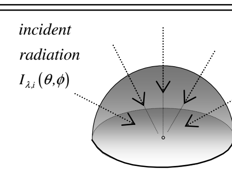
*diffuse surface:* $I_{\lambda,e}(\phi,\theta) = I_{\lambda,e}$

$E_\lambda = \pi I_{\lambda,e}$ *spectral*

$E = \pi I_e$ *total*

### IRRADIATION

*flux of radiation incident from all directions of hemisphere*




*spectral irradiation*

$$G_\lambda = \int_{\Omega=2\pi} I_{\lambda,i}(\theta,\phi)\cdot\cos\theta\cdot d\omega \qquad \left[\frac{W}{m^2\cdot\mu m}\right]$$

*total irradiation*

$$G = \int_0^\infty G_\lambda\, d\lambda \qquad \left[\frac{W}{m^2}\right]$$

*diffuse irradiation:* $I_{\lambda,i}(\phi,\theta) = I_{\lambda,i}$

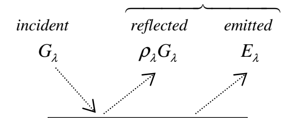
$G_\lambda = \pi I_{\lambda,i}$ *spectral*

$G = \pi I_i$ *total*

### RADIOSITY

*radiosity is a flux of all radiation leaving the surface*

$$J_\lambda = \rho_\lambda G_\lambda + E_\lambda$$




$$J_\lambda = \rho_\lambda G_\lambda + E_\lambda \qquad \left[\frac{W}{m^2\cdot\mu m}\right]$$

$$J = \int_0^\infty J_\lambda\, d\lambda \qquad \left[\frac{W}{m^2}\right]$$

### NET RADIATIVE FLUX

$$q''_{rad} = J - G$$