Radiometric & Reflectance → To interpret image intensities.

① Radiometric Concept

② Surface Radiance & Image Irradiance

③ BRDF

④ Reflectance Models

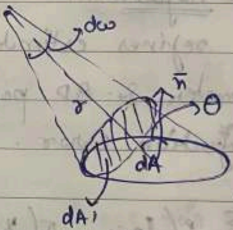
⑤ Dichromatic Model

Solid Angle (3D)

$$d\omega = \frac{dA'}{r^2}$$

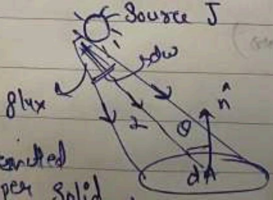
$$\underset{\text{steradian }(sr)}{d\omega} = \frac{dA\cos\theta}{r^2}$$

$d\omega$ is dimensionless.



Light flux → power emitted within a Solid Angle.

$d\Phi$ → watts



Radiant Intensity → flux emitted per Solid angle

$$\boxed{J = \frac{d\Phi}{d\omega}}$$ → Brightness of source

(Illumination of Surface)

Surface Irradiance → flux per unit Area

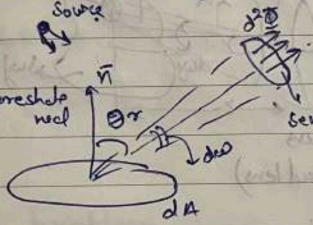
$$E = \frac{d\Phi}{dA} = \frac{J\,d\omega}{dA} = \frac{J\,dA\cos\theta}{r^2\,dA}$$

$$E \propto \frac{J\cos\theta}{r^2} \qquad = \frac{J\cos\theta}{r^2}$$

Surface Radiance (brightness of Surface)

Light flux emitted per unit Area foreshortened

(we use sensor to measure)



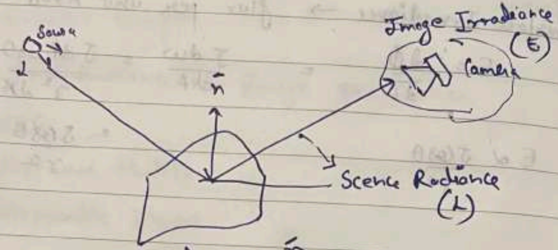
$$L = \frac{d^2\Phi}{(dA\cos\theta_r)\,d\omega}$$ unit: $W m^{-2} sr^{-1}$

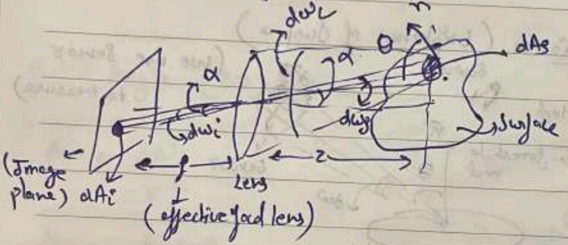
L: depends on reflectance properties of surface

depends on direction θ_r

Surface can radiate into whole hemisphere.

Scene Radiance & Image Irradiance





Solid angle projected on Image plane & on Surface
$d\omega_i$ $d\omega_s$

$d\omega_i = d\omega_s$

$$\frac{dA_i \cos\alpha}{(f/\cos\alpha)^2} = \frac{dA_s \cos\theta}{(z/\cos\alpha)^2} \qquad \frac{dA_s}{dA_i} = \frac{\cos\alpha}{\cos\theta}\left(\frac{z}{f}\right)^2$$

(1)

(2) $$d\omega_L = \frac{\pi d^2}{4} \frac{\cos\alpha}{(z/\cos\alpha)^2}$$

(solid angle subtended by lens from point on scene)

(3) $$d^2\phi = L(dA_s \cos\theta)\, d\omega_L$$

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Image Irradiance $E = \frac{d\Phi}{dA_i}$ → flux recieved by pixel → (4)

using (1) (2) (3) (4)

Scene Radiance

$$\boxed{E = L\left(\frac{\pi}{4}\right)\left(\frac{d}{f}\right)^2 \cos^4\alpha}$$

→ diameter

Image Irradiance

effective focal number

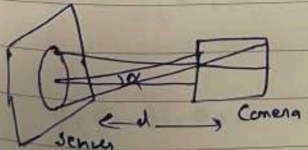
(1) $E \propto L$

(2) Image brightness fall off from Image Center $\cos\alpha$.

(3) for small fields of view, effects of $\cos^4\alpha$ are small.

Does Image brightness change vary with scene depth?

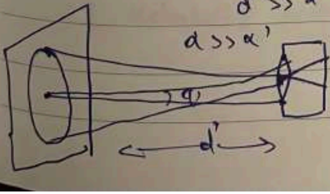
$E = L\frac{\pi}{4}\left(\frac{d}{f}\right)^2 \cos\alpha$ → no z → depth of scene from lens.



- Large the scene depth, larger the area of light accumulation.

$d' >> d$

$\alpha >> \alpha'$



- Larger the scene depth smaller the solid angle, less light from each point.

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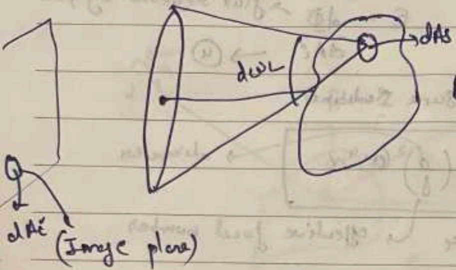


Energy Conservation

flux recieved by lens from dA_s

= flux projected into dA_i

Scene Radiance:

$$L = \frac{d^2\phi}{(dA_s \cos\theta)\, d\omega_L}$$

(flux recieved by Lens)

$$d^2\phi = L(dA_s \cos\theta)\, d\omega_L$$

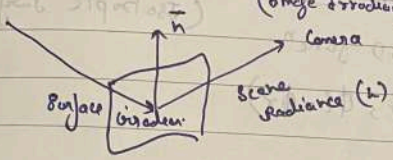
③ eqⁿ

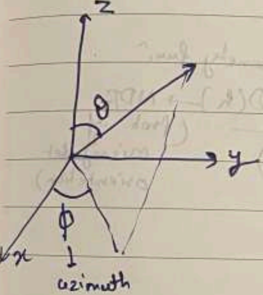
BRDF

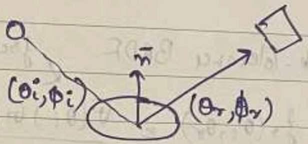
(Bi-directional Reflectance Distribut funcⁿ)

Surface reflect depends upon both viewing & illumination direction

(Image Irradiance)







$E(\theta_i, \phi_i) \rightarrow$ irradiance due to source in dir (θ_i, ϕ_i)

$L(\theta_r, \phi_r)$: Radiance of surface in direc (θ_r, ϕ_r)

BRDF $\quad f(\theta_i, \phi_i, \theta_r, \phi_r) = \dfrac{L(\theta_r, \phi_r)}{E(\theta_i, \phi_i)}$

$f(\theta_i, \phi_i, \theta_r, \phi_r) > 0$ non-negati

& Helmholtz Reciprocity $\rightarrow f(\theta_i, \phi_i, \theta_r, \phi_r)$
$= f(\theta_r, \phi_r, \theta_i, \phi_i)$

BRD4 - 4D funcⁿ

*

For <u>rotationly</u> <u>symmetric</u> reflectance (Isotropic surface)

BRDF is 3D funcⁿ

$f(\theta_i, \theta_r, \phi_i - \phi_r)$

Cook-Tolerance BRDF

① $\underset{\text{BRDF func}^n}{f_r(\theta_i, \theta_r)} = \dfrac{\overset{\text{fresnel effect}}{F(\theta_i)}\,\overset{\text{geometry func}^n}{G(\theta_i, \theta_r)}\,D(h)}{4(\cos\theta_i \cdot \cos\theta_r)}$ $D(h) \rightarrow$ NDF (Prob of Microfacet orientation)

$\underset{\text{Schlich GGX}}{G(\theta_i, \theta_r)} = \dfrac{2(n \cdot v)}{(n \cdot v) + \sqrt{\alpha^2 + (1-\alpha^2)(n \cdot v)^2}}$

$F(\theta_i)$ - defines how light reflectance varies based on incident angles.

$F(\theta_i) = \underset{\text{(refle at normal angle)}}{F_0} + (1 - F_0)(1 - \cos\theta_i)^5$