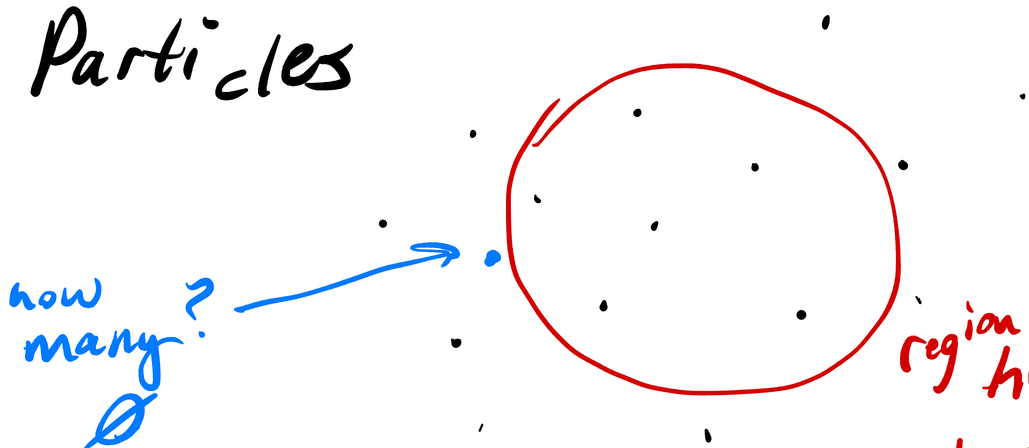
9 – Radiometry

Measuring Light

photon – particle of light, with a position, a direction motion, wavelength (λ)

infinitesimally small

Counting Particles

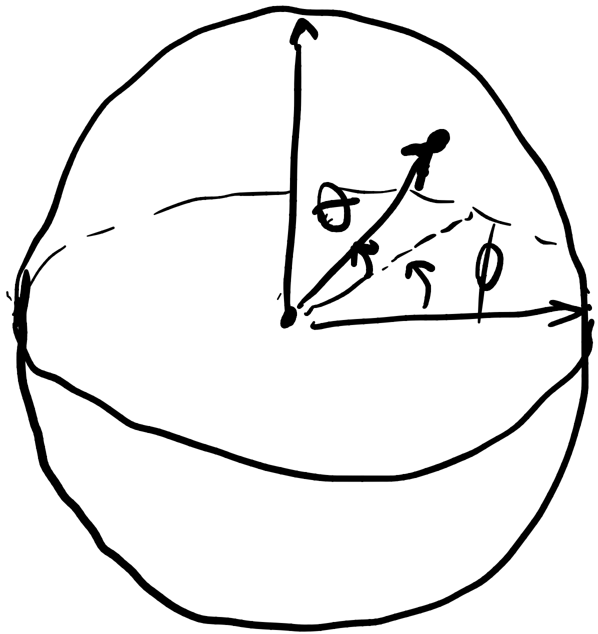


region (A = area)

how many? 6

$$\text{density} = \frac{\#\text{part}}{\text{area}}$$

direction is given by



(x, y, z)

→ unit length

$k = (\theta, \phi)$

$0 \le \phi < 2\pi$

$-\frac{\pi}{2} \le \theta \le \frac{\pi}{2}$

Radiance – fundamental quantity of light

Spectral Radiance ≡ density of photons at some position, travelling in some dir, at a given wavelength

Radiance
↓

$$L(x, k, \lambda) : R^3 \times S^2 \times R \longrightarrow \mathbb{R}^+$$

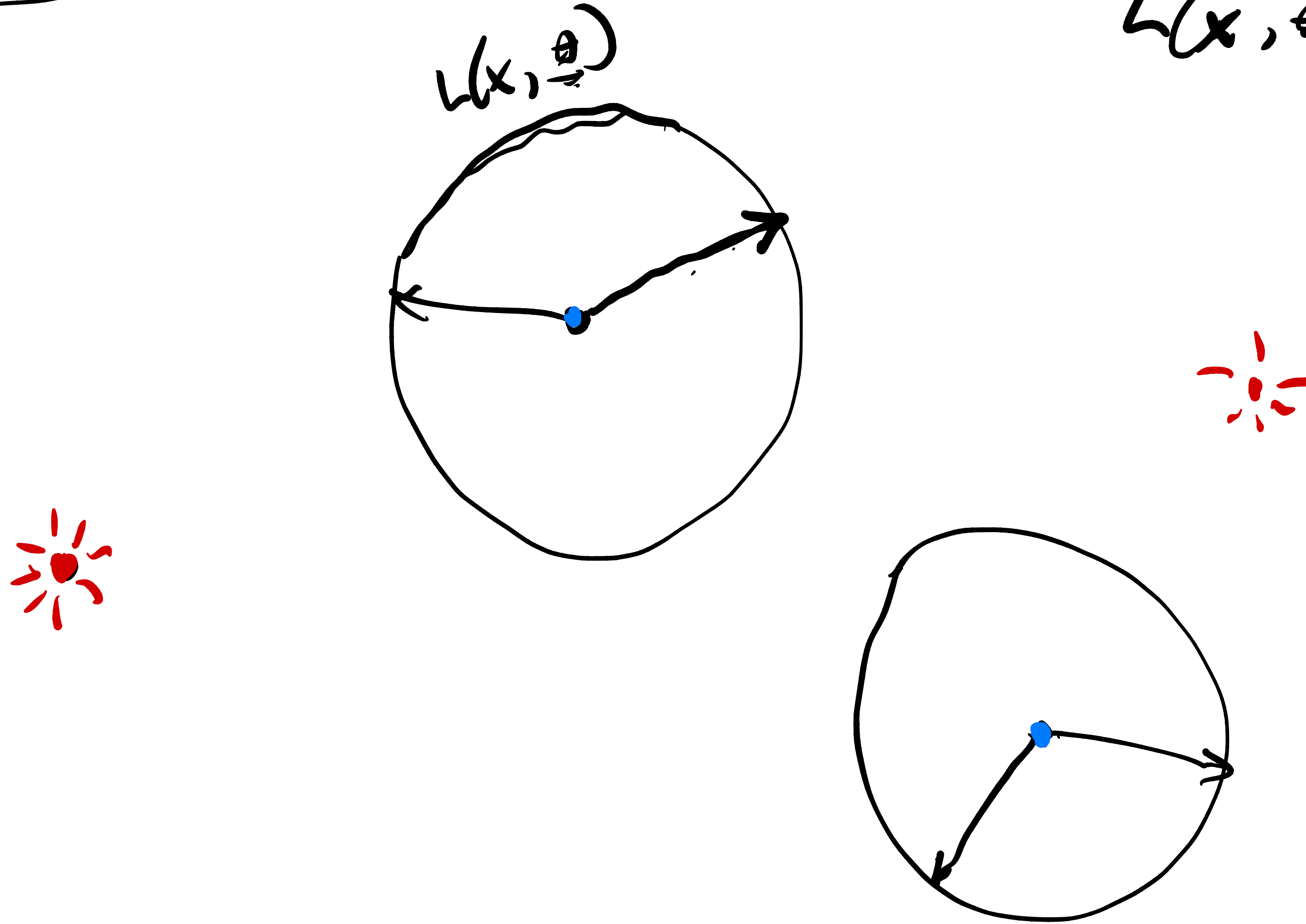
↓ (x, y, z) ↓

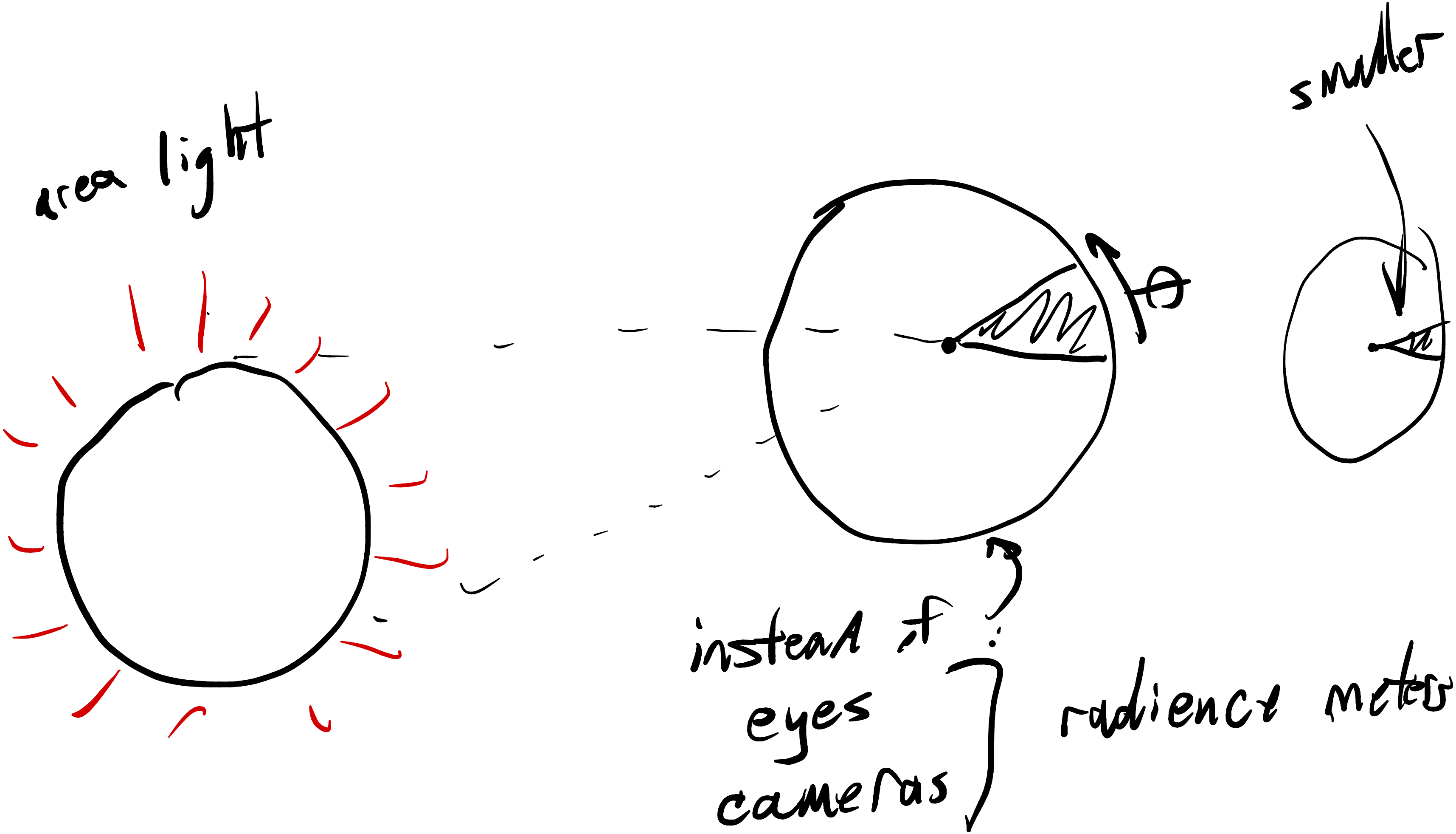
domain

positive real #
range

2D Radiance (not a thing) 2D position + 1 angle

$L(x, \theta)$





area light
θ
smaller
instead of
eyes
cameras
radiance meters

Two properties of radience

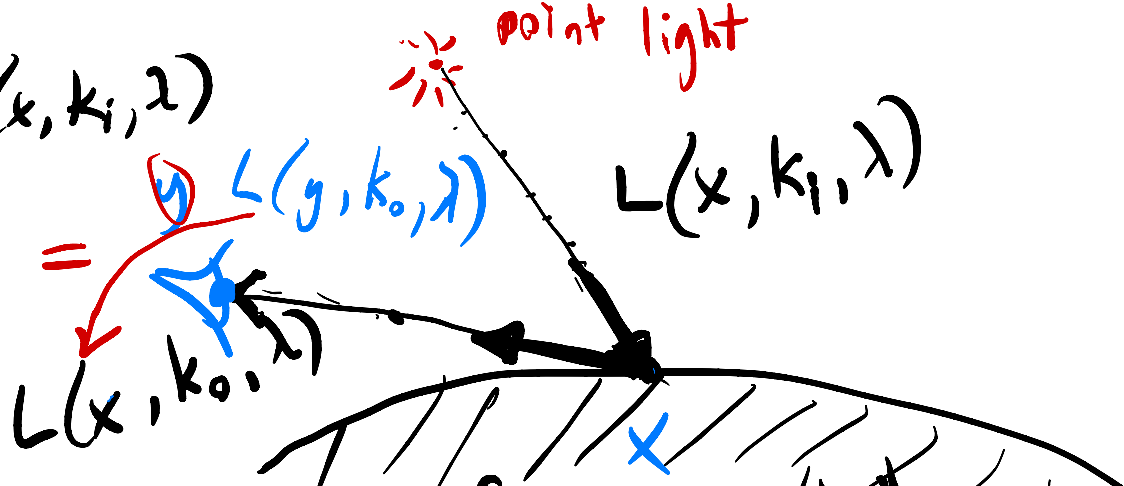
1) Response of senser is proportional to <u>radience</u> of visible surface

2) radiance along a ray is <u>constant</u>

Q:

2x light $L(x, k_i, \lambda)$

$L(x, k_o, \lambda)$ approx doubles



"light in × surface properties"

$$L(x, k_o, \lambda) \propto L(x, k_i, \lambda)$$

outgoing light — proportional — incoming light proportionality of a surface ⇒ BRDF

Bidirectional Reflectance Distribution Function

$$\rho(k_i, k_o) = \frac{\text{outgoing light towards } k_o}{\text{incoming light from } k_i}$$

in ↗ (k_i) out ↘ (k_o)

$\mathbb{R}^4$

BRDF's

Function of 4 variable. $\rho(k_i, k_o)$

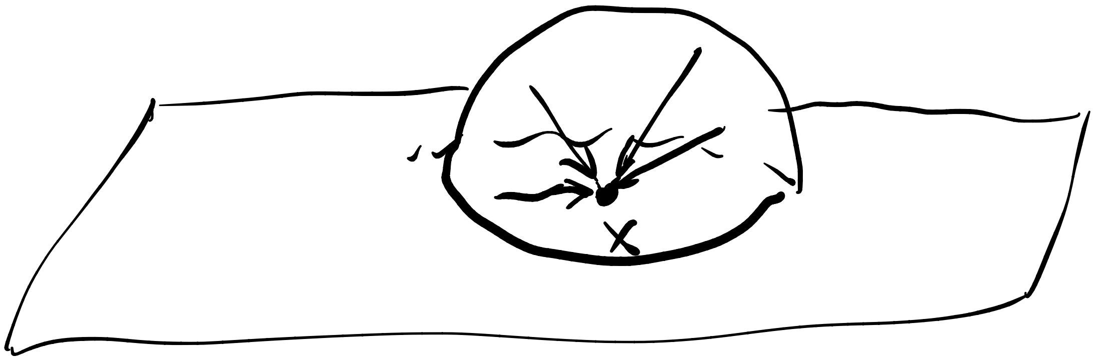
$(\theta_i, \phi_i) \quad (\theta_o, \phi_o)$

1) Helmholtz reciprocity: $\rho(k_i, k_o) = \rho(k_o, k_i)$

2) Conservation of Energy

Hemisphere

Ω

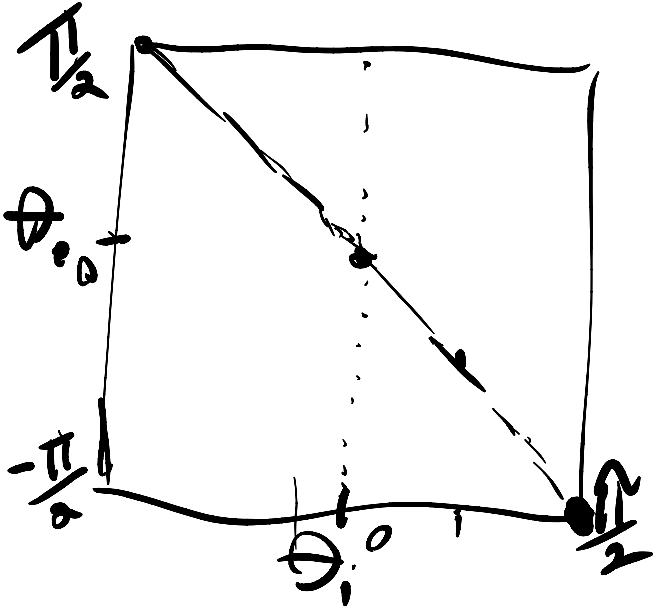


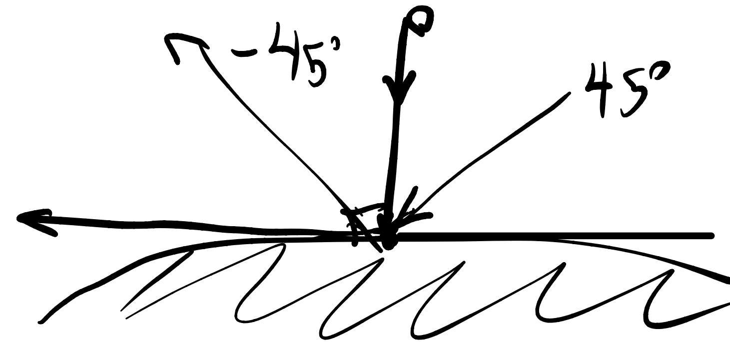
For some ray k_o want all of contribution of all k_i

$$\int_{k_i \in \Omega} \rho(k_i, k_o) \cos\theta_i \, dk_i \leq 1$$

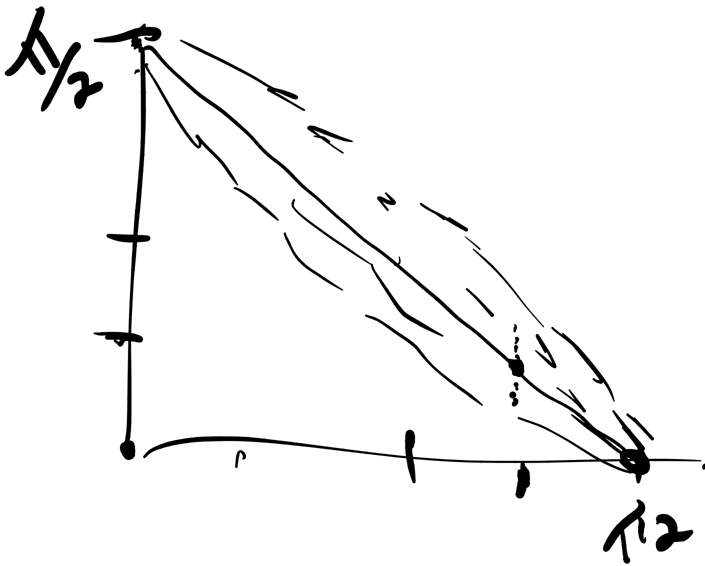
2D BRDF's

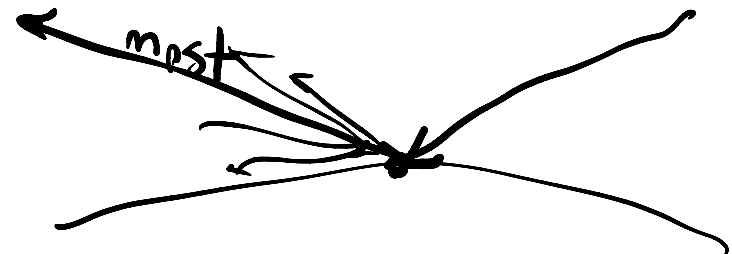
perfect mirror



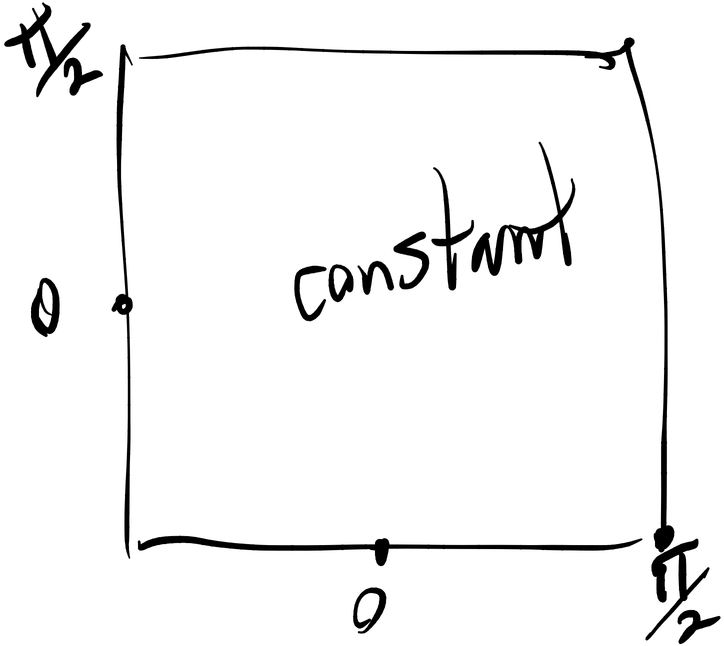


fairly shiny



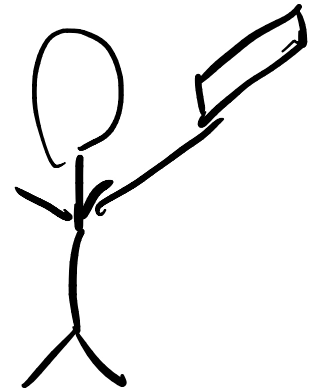


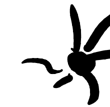
diffuse / matte / Lambertian



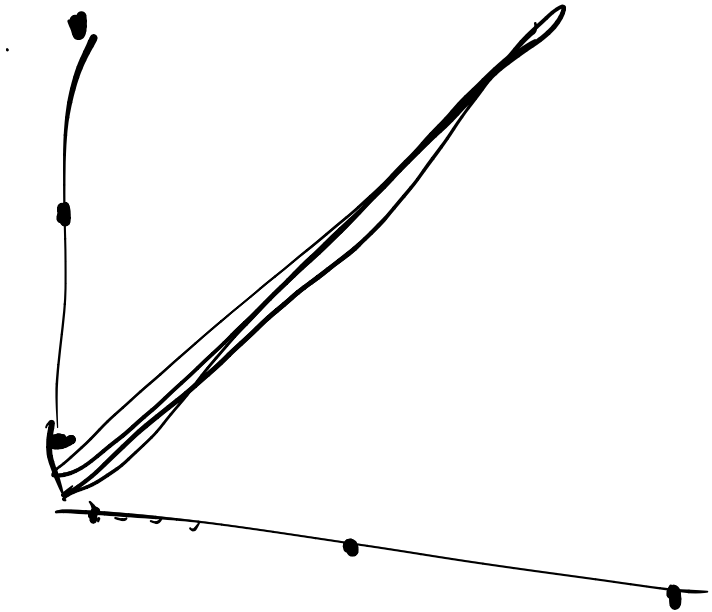
defined ∀ λ

Paper

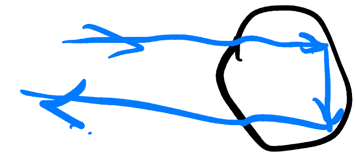


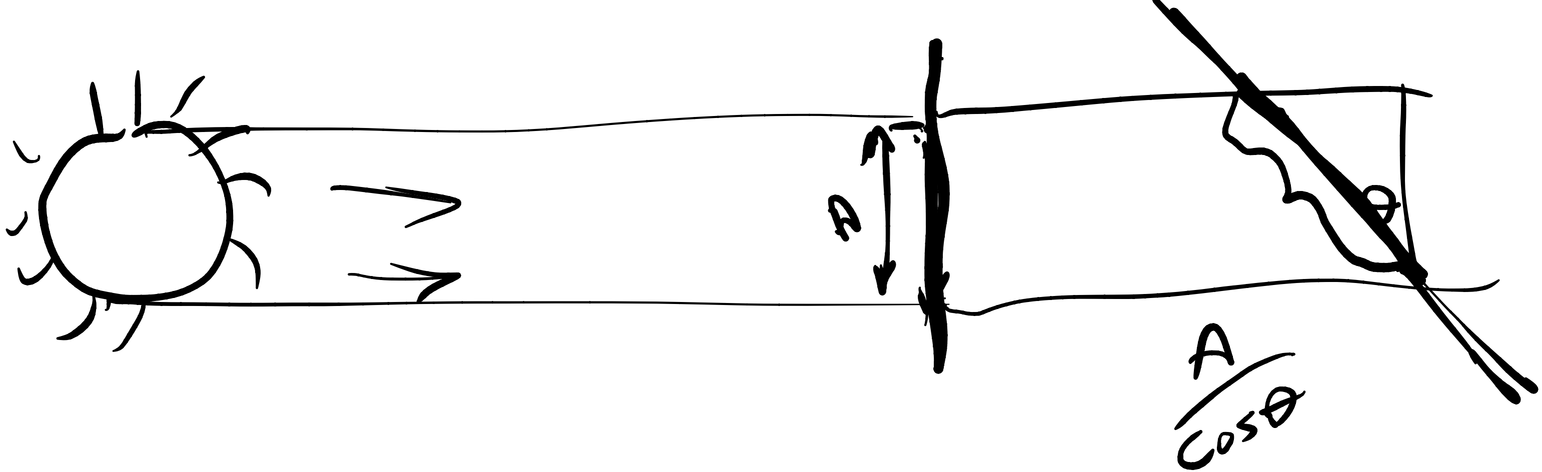


Retro reflector



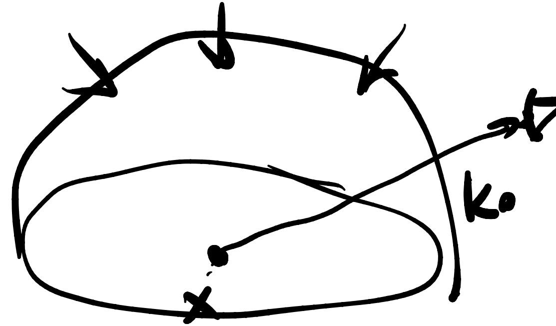
material




A
θ
A / cos θ

Reflectance Equation

gives us theoretical basis



$$L(x, k_o, \lambda) = \int_{k_i \in \Omega} L(x, k_i, \lambda)\, \rho(k_i, k_o) \cos\theta_i \, dk_i$$

- $L(x, k_o, \lambda)$: outgoing rad (to eye)
- $k_i \in \Omega$: over hemisphere
- $\rho(k_i, k_o)$: proportion
- $\cos\theta_i$: angle