

# Key objectives in Lighting design

- ▶ Visual performance
- ▶ Physiological conditions
- ▶ Visual quality
  - no strong "contrasts"
  - good "color rendering"
  - adequate "light levels"
  - no "disturbing reflections"
  - no direct "glare"

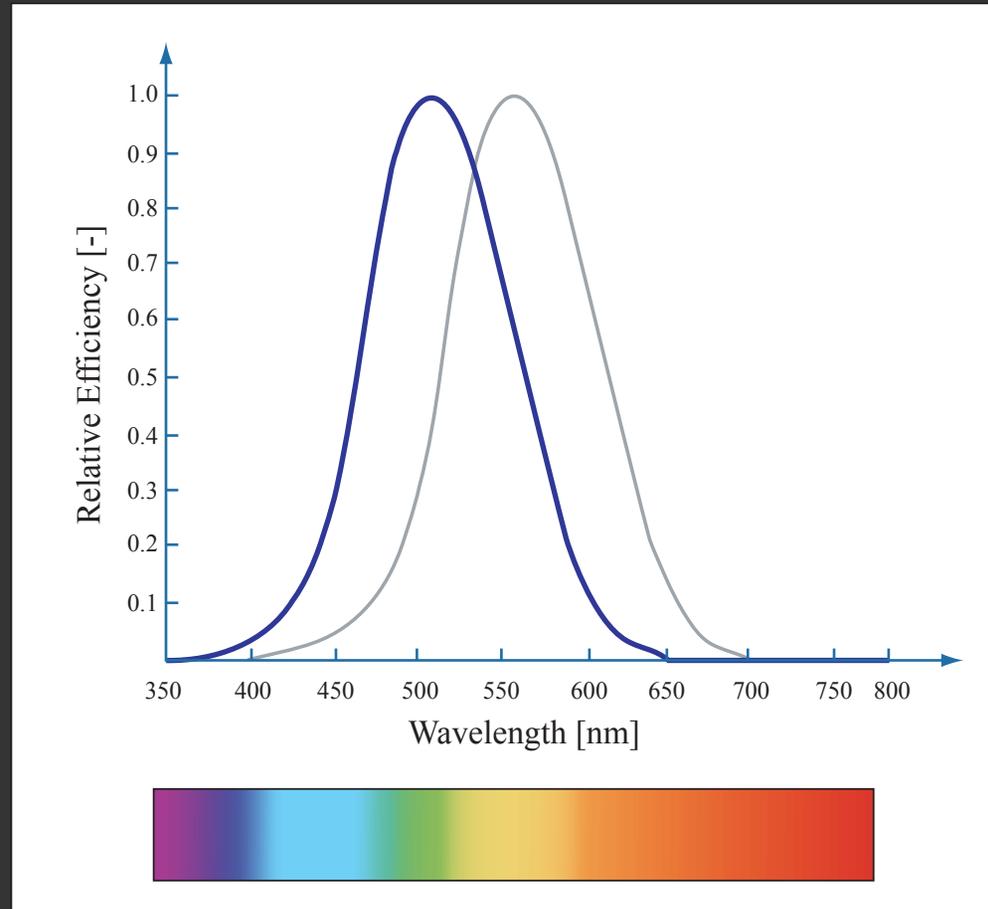
# Radio- and photometric quantities

## ► Radiometry vs. Photometry

- absolute (energy)

vs.

- $V(\lambda)$ -dependent (light)



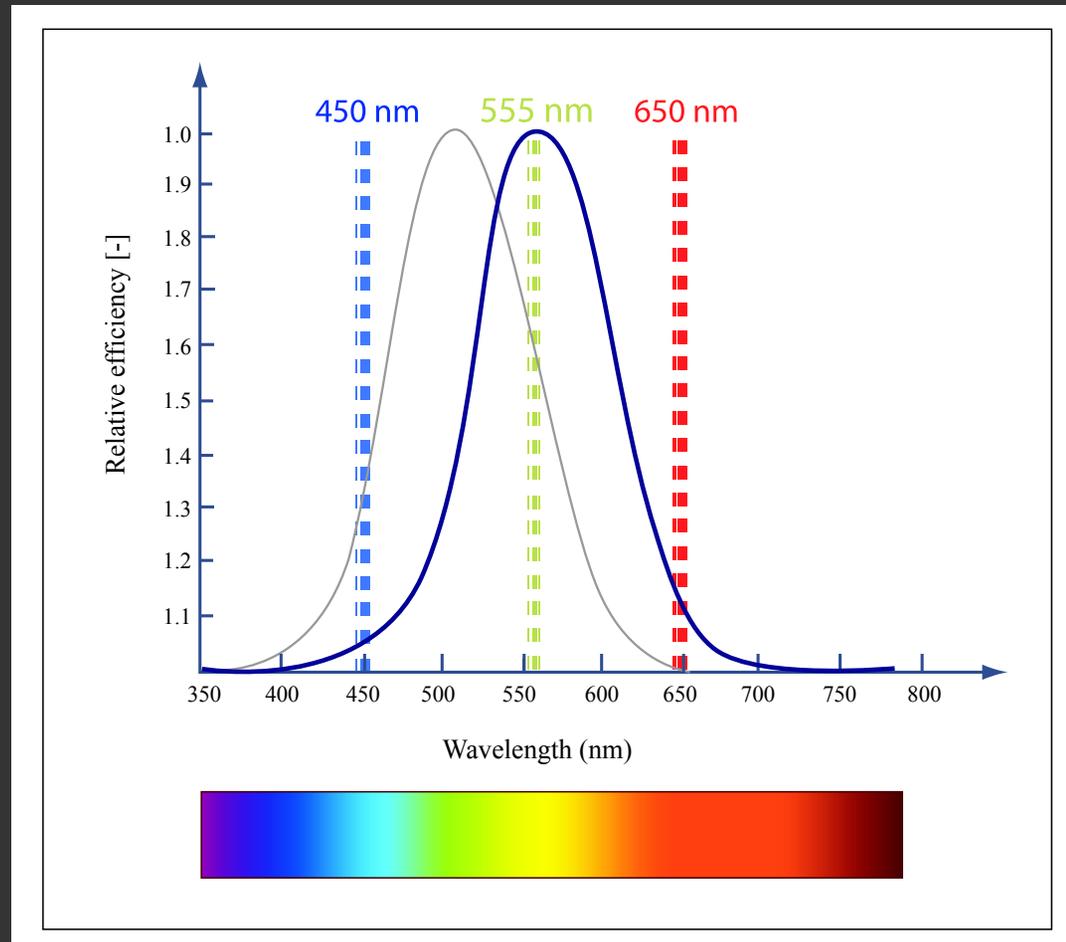
# Radio- and photometric quantities

## ► Radiometry vs. Photometry

- absolute (energy)

VS.

- $V(\lambda)$ -dependent (light)



# Radio- and photometric quantities

## ► Four major quantities

- flux
- illuminance
- intensity
- luminance

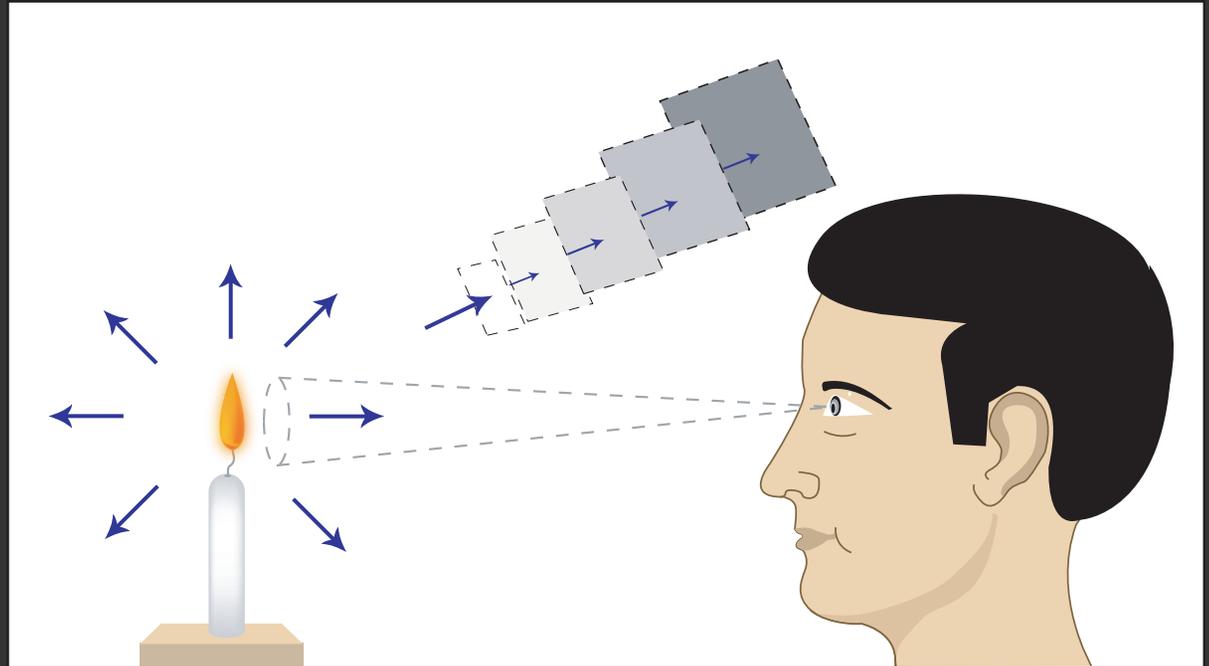


Image by MIT OCW.

# Radio- and photometric quantities

## ► Flux

- energy / unit of time
- $\phi$  in Watts [W] vs. lumen [lm]

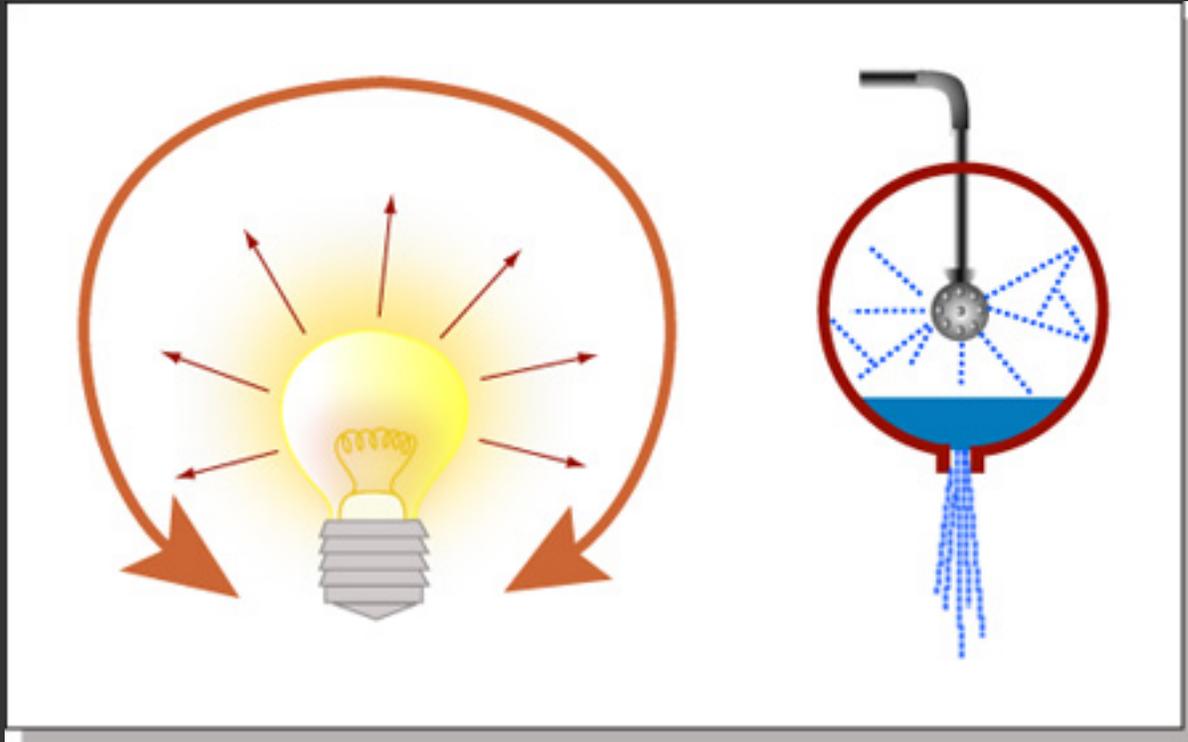


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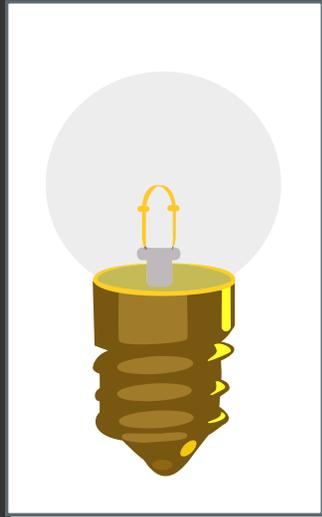
# Radio- and photometric quantities

## ► Flux

- energy / unit of time
- $\phi$  in Watts [W] vs. lumen [lm]
- 683 lumen/Watt at 555 nm :  $\phi_{\text{lum}} [\text{lm}] = 683 \cdot \sum V(\lambda) \cdot \phi_e [\text{W}]$

Incandescence

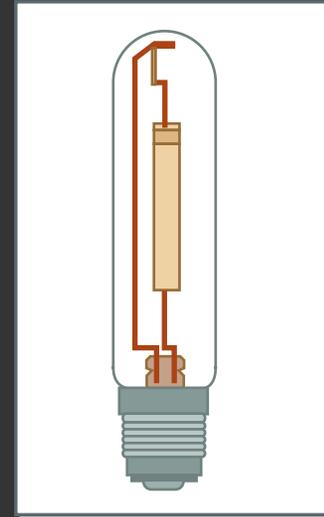
75 watts



1055 lumens

Discharge

70 watts



5600 lumens

Images by MIT OCW.

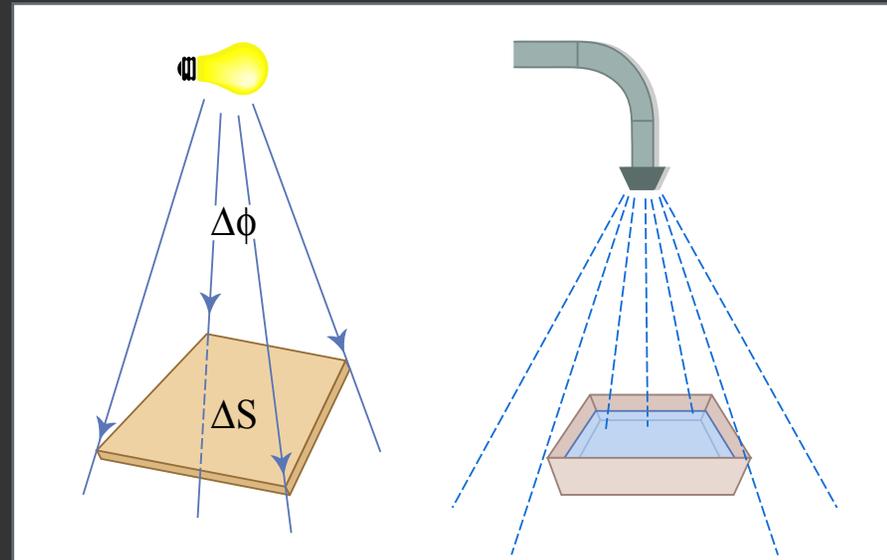
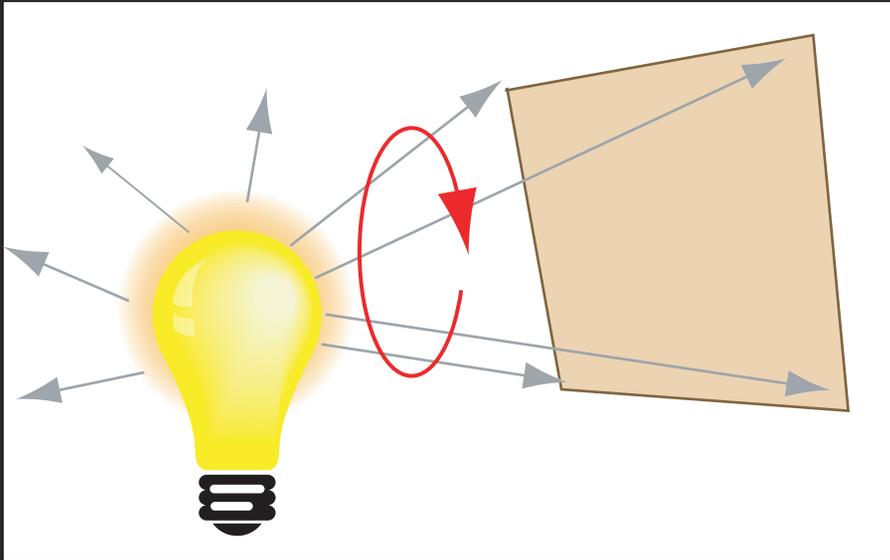
very  
different  
efficacies !

# Radio- and photometric quantities

## ▶ Flux

## ▶ Illuminance

- flux received / unit of surface
- E in  $[\text{W}/\text{m}^2]$  vs.  $[\text{lm}/\text{m}^2]$  or lux  $[\text{lx}]$

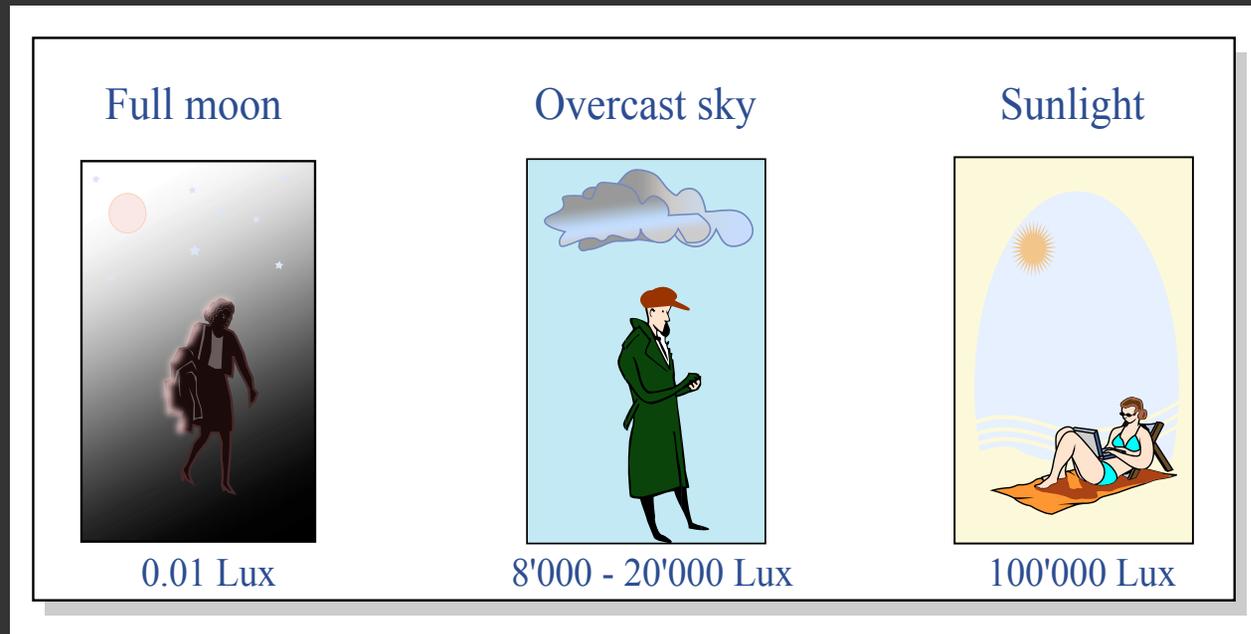


# Radio- and photometric quantities

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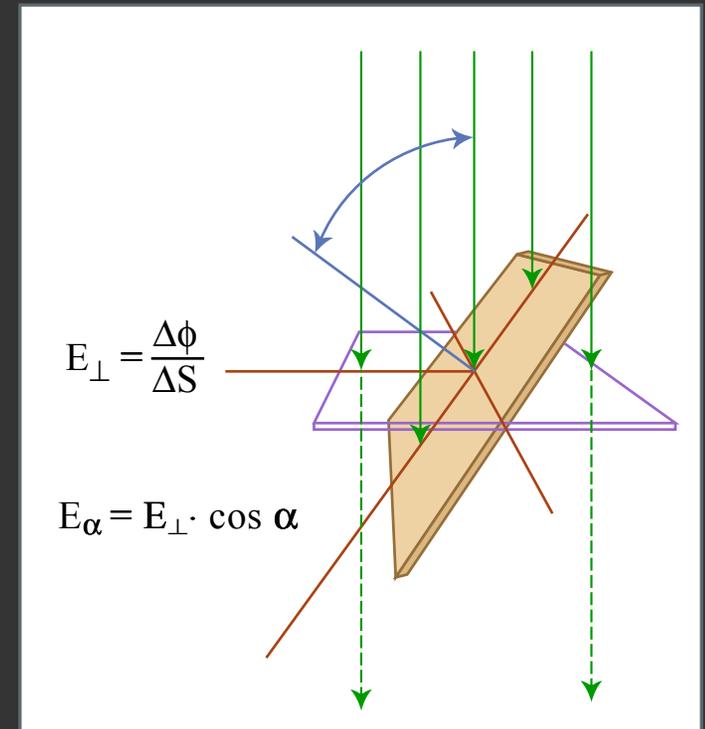


# Radio- and photometric quantities

## ▶ Flux

## ▶ Illuminance

- flux received / unit of apparent surface (cosine ("Lambert") law)
- $E$  in  $[\text{W}/\text{m}^2]$  vs.  $[\text{lm}/\text{m}^2]$  or lux  $[\text{lx}]$



# Radio- and photometric quantities

## ▶ Flux

## ▶ Illuminance

- flux received / unit of apparent surface (cosine ("Lambert") law)
- E in  $[W/m^2]$  vs.  $[lm/m^2]$  or lux  $[lx]$
- measurement with lux-meter (illumance-meter)

Requirements	Lux	Examples
Low	20-70	Circulation, stairs
Moderate	120-185	Entrance, restaurant
Medium	250-375	General tasks
High	500-750	Reading, Writing
Very high	> 1000	Precision tasks

# Radio- and photometric quantities

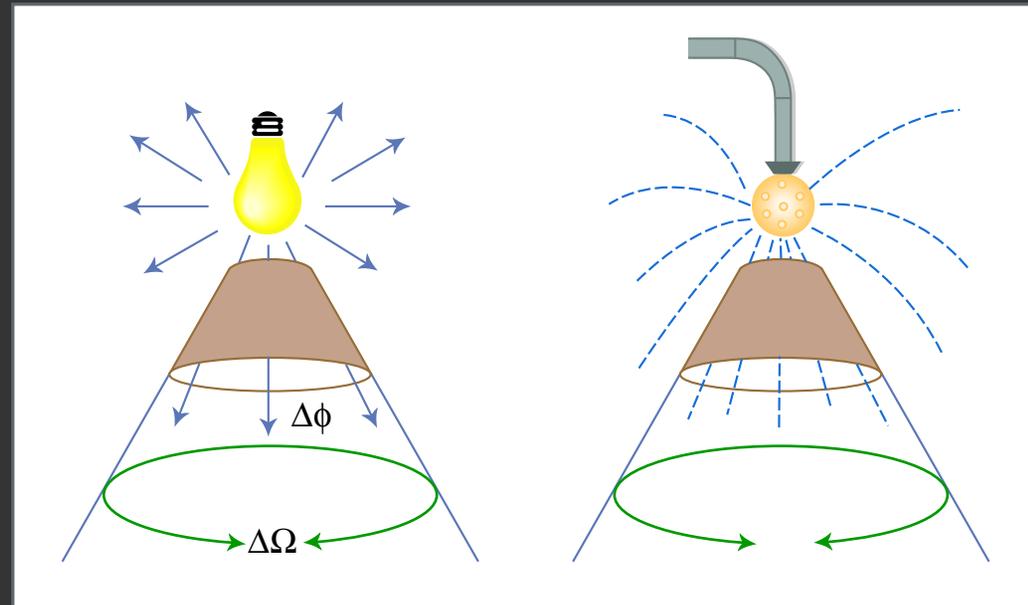
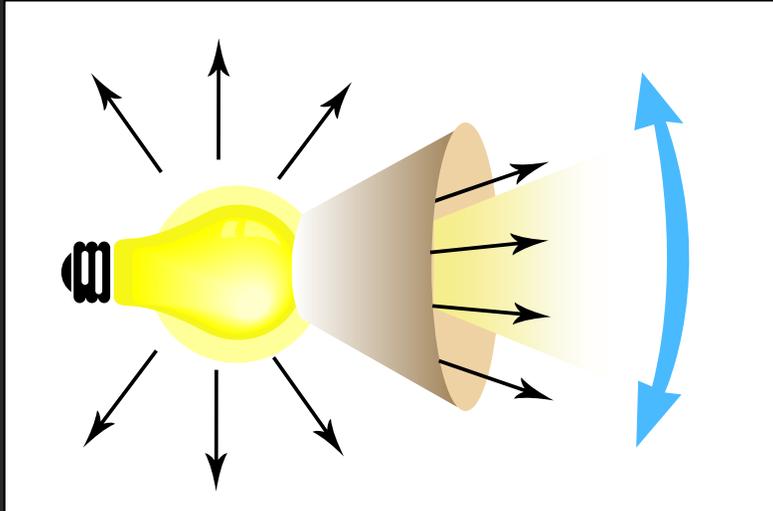
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- measurement with lux-meter (illuminance-meter)
- exitance  $M$  for emitted flux  $[\text{lux}]$

# Radio- and photometric quantities

- ▶ Flux
- ▶ Illuminance
- ▶ Intensity
  - flux emitted "in a certain direction"



Images by MIT OCW.

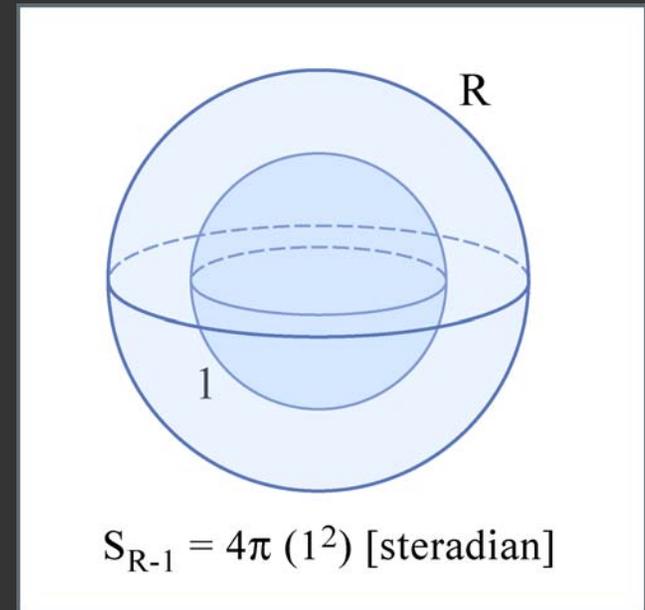
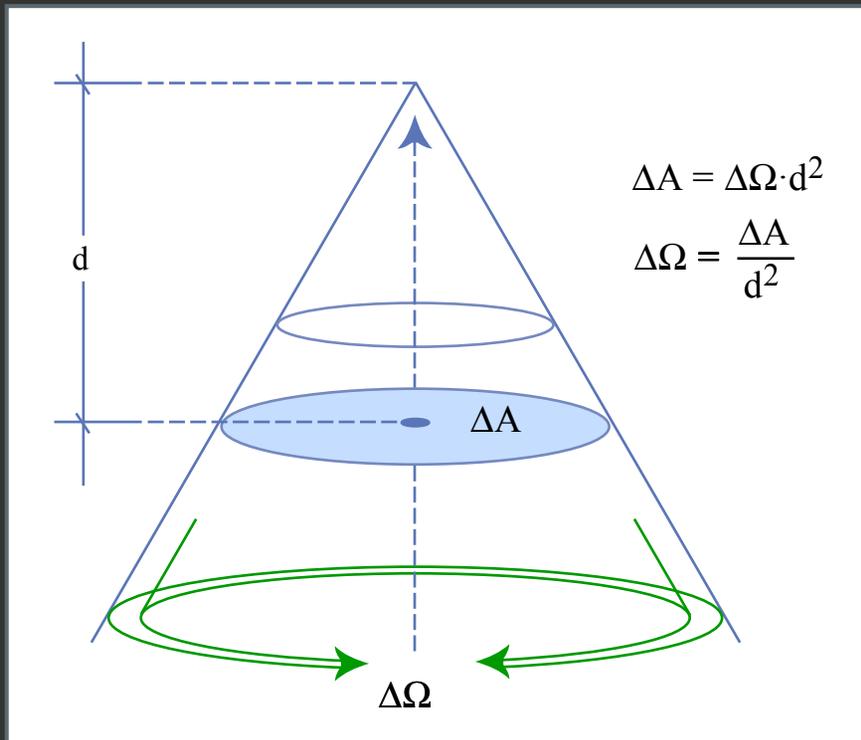
# Radio- and photometric quantities

▶ Flux

▶ Illuminance

▶ Intensity

- flux emitted within a certain solid angle



# Radio- and photometric quantities

▶ Flux

▶ Illuminance

▶ Intensity

- flux emitted within a certain solid angle
- $I$  in  $[\text{W}/\text{sr}]$  vs.  $[\text{lm}/\text{sr}]$  or Candela  $[\text{Cd}]$



1 Candela = intensity of one candle

# Radio- and photometric quantities

## ▶ Flux

## ▶ Illuminance

## ▶ Intensity

- flux emitted within a certain solid angle
- I in [W/sr] vs. [lm/sr] or Candela [Cd]
- inverse square law for point source

$$E = I \cos(\theta) / d^2$$

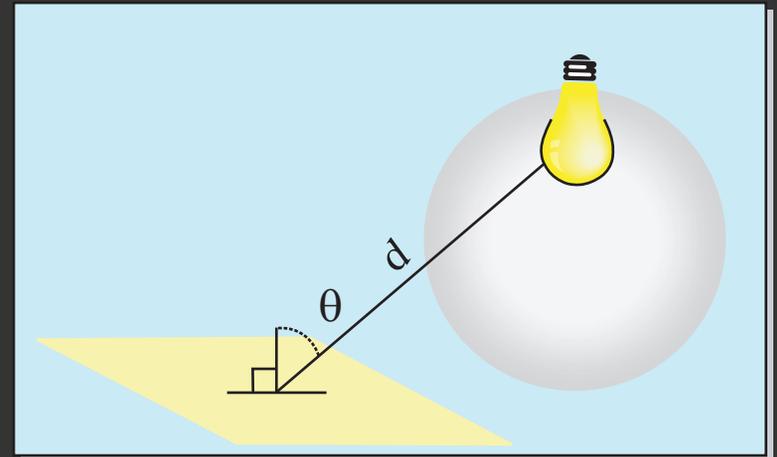


Image by MIT OCW.

# Radio- and photometric quantities

## ▶ Flux

## ▶ Illuminance

## ▶ Intensity

- flux emitted within a certain solid angle
- $I$  in  $[W/sr]$  vs.  $[lm/sr]$  or Candela  $[Cd]$
- inverse square law for point source
- intensity distribution

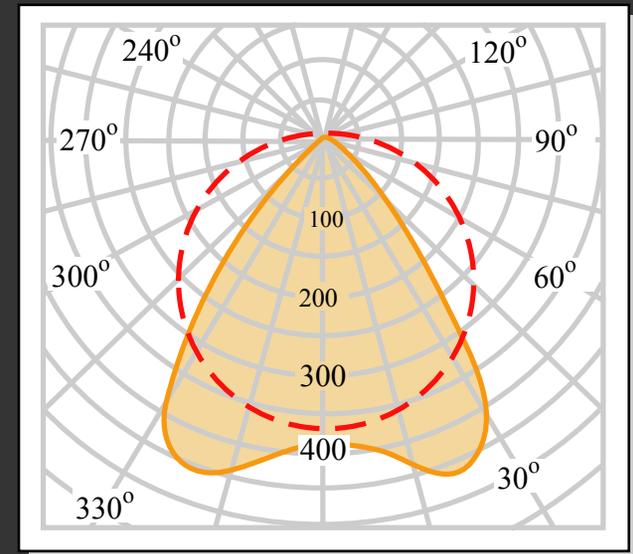


Image by MIT OCW.

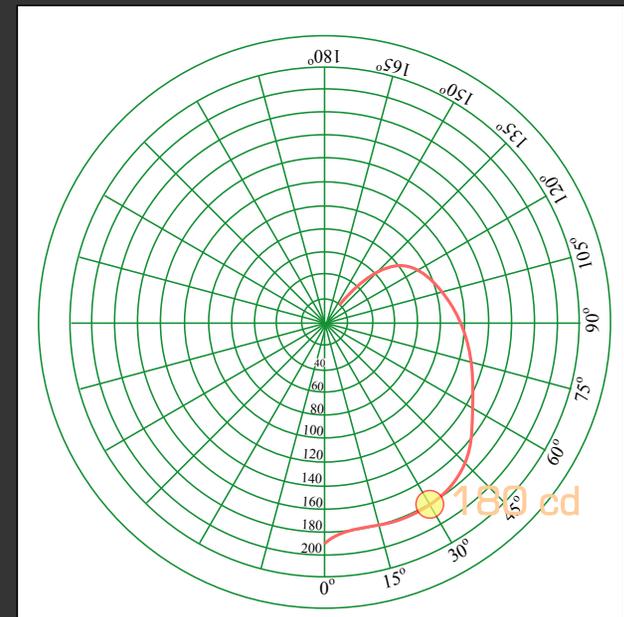
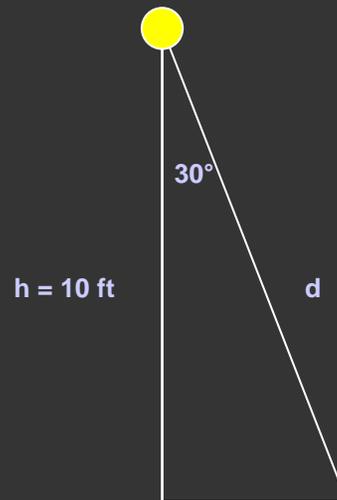
# Radio- and photometric quantities

## ▶ Flux

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## ▶ Intensity

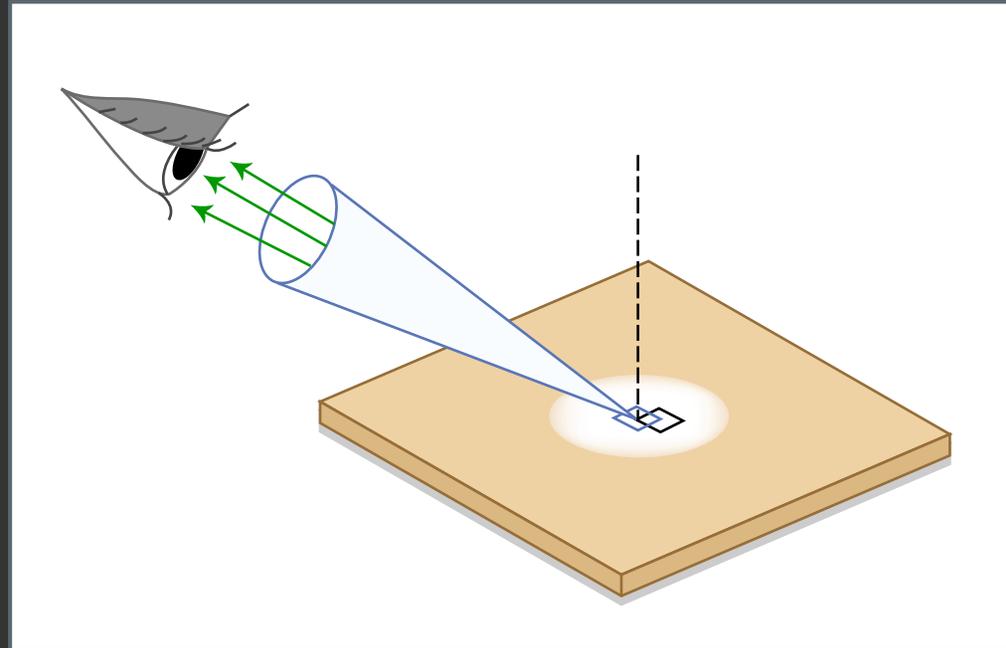
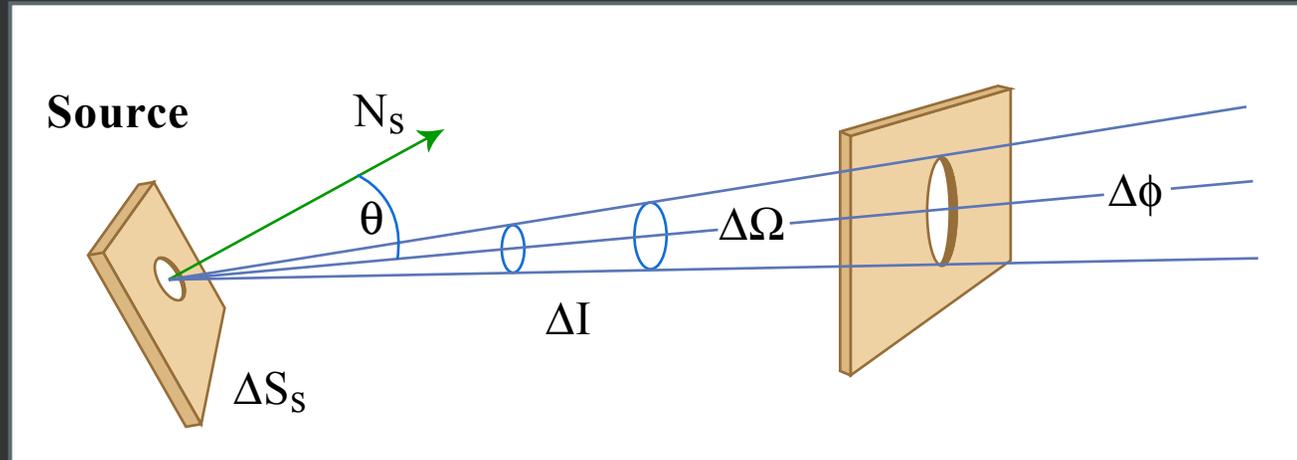
- flux emitted within a certain solid angle
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- inverse square law for point source
- intensity distribution



# Radio- and photometric quantities

- ▶ Flux
- ▶ Illuminance
- ▶ Intensity
- ▶ Luminance

- flux emitted by apparent surface in a given direction
- $\approx I/m^2$  (or  $M/sr$ )
- $L$  in  $[Cd/m^2]$



# Radio- and photometric quantities

- ▶ Flux
- ▶ Illuminance
- ▶ Intensity
- ▶ Luminance
  - flux emitted by apparent surface in a given direction
  - $\approx I/m^2$  (or  $M/sr$ )
  - $L$  in  $[Cd/m^2]$

$$L = I / S_a$$

$$L = I / (S \cdot \cos \theta)$$



# Radio- and photometric quantities

## ▶ Flux

## ▶ Illuminance

## ▶ Intensity

## ▶ Luminance

- flux emitted by apparent surface in a given direction

- $\approx I/m^2$  (or  $M/sr$ )

- $L$  in  $[Cd/m^2]$

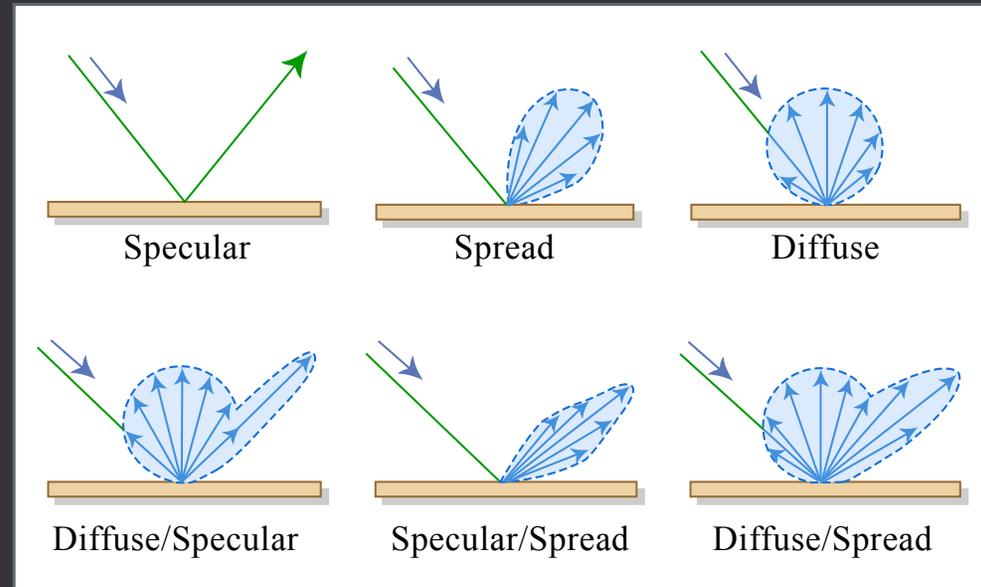
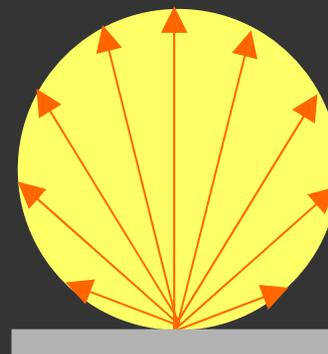


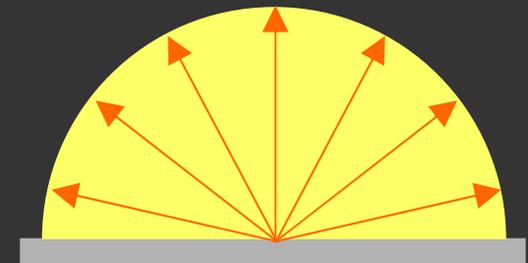
Image by MIT OCW.

Intensity variation



lambertian surface

Luminance variation



lambertian surface

# Radio- and photometric quantities

## ▶ Flux

## ▶ Illuminance

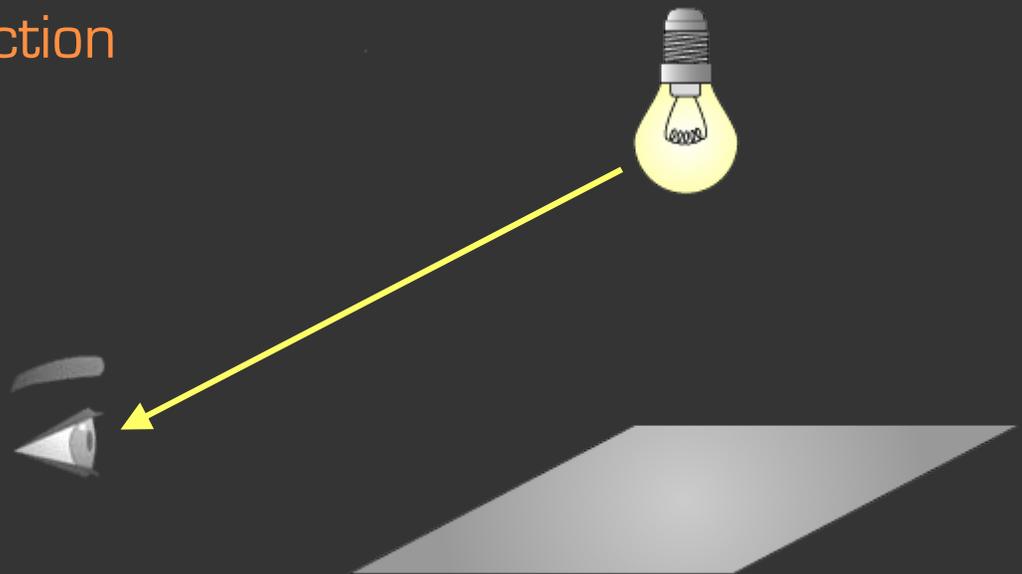
## ▶ Intensity

## ▶ Luminance

- flux emitted by apparent surface in a given direction
- $\approx I/m^2$  (or  $M/sr$ )
- $L$  in  $[Cd/m^2]$

### Primary sources

• Sun	1 650 000 000
• Incandescent lamp (100 W, bright)	6 000 000
• Incandescent lamp (100 W, frosted)	125 000
• Fluorescent tube (40 W, 38 mm)	5000 - 8000
• Candle	5000
• Computer screen	100-200



# Radio- and photometric quantities

## ▶ Flux

## ▶ Illuminance

## ▶ Intensity

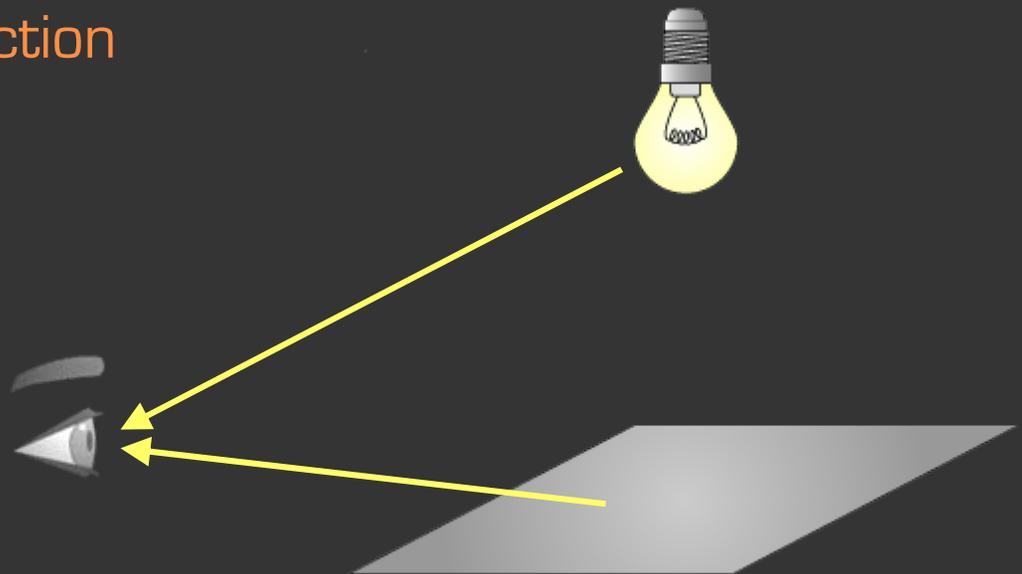
## ▶ Luminance

- flux emitted by apparent surface in a given direction
- $\approx I/m^2$  (or  $M/sr$ )
- $L$  in  $[Cd/m^2]$

### Secondary sources

• Moon	$2\ 500 - 3000$
• White paper ( $\rho = 0.8, E = 400$ lux)	100
• Grey paper ( $\rho = 0.4, E = 400$ lux)	50
• Black paper ( $\rho = 0.01, E = 400$ lux)	5

Minimal luminance perceived:  $10^{-5}$



# Radio- and photometric quantities

- ▶ Luminance measurement
  - Eye = luminance-meter

# Photometry

## ▶ Reading assignment from Textbook:

- "Introduction to Architectural Science" by Szokolay: § 2.1

## ▶ Additional readings relevant to lecture topics:

- "IESNA Lighting Handbook" (9th Ed.): pp. 2-1 to 2-3 + pp. 3-1 to 3-5 + pp. 3-9 to 3-14 + pp. 4-1 to 4-6