Radiometry I: Illumination

cs348b
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Administrivia

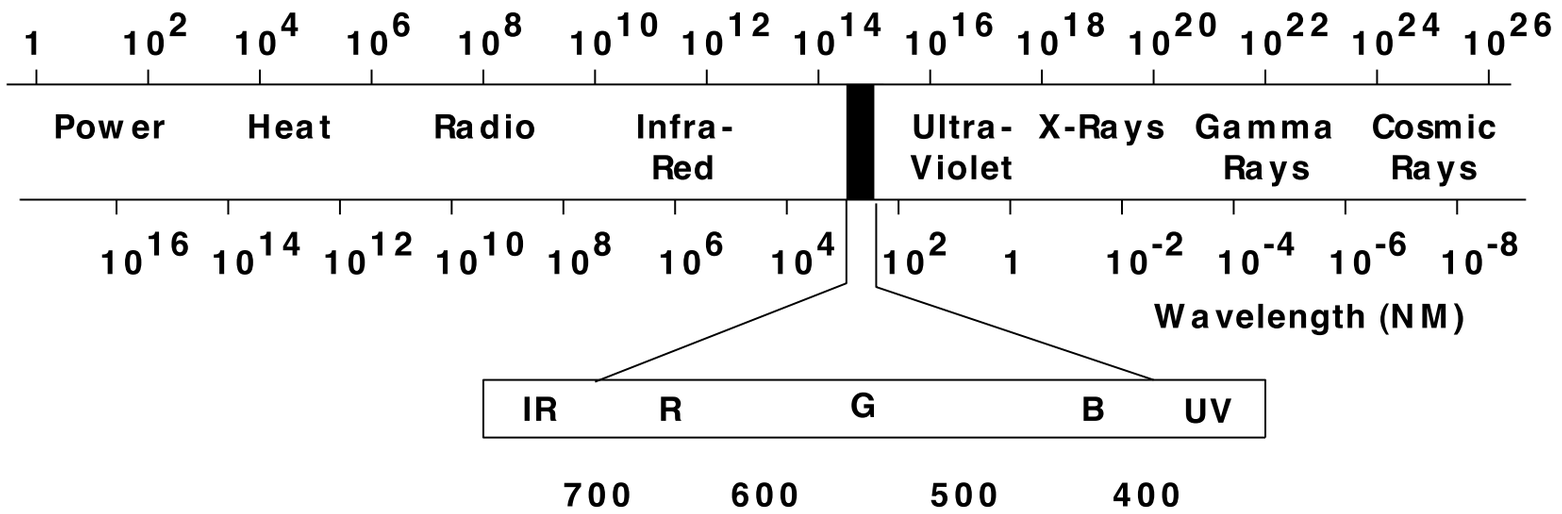
- Extra copies of Irt book
- Bug fix for assignment 1 polynomial.h file

Onward To The Physical Description of Light

- Four key quantities
  - Power
  - Radiant intensity
  - Irradiance
  - Radiance
- Radiometry and photometry

Radiometry

- The measurement of electromagnetic radiation
  - Radiation: propagation of energy through space
  - We will ignore polarization, quantum mechanics
- Frequency distribution of radiation gives color



Spectral Distribution of Energy

- Radiometric quantities are usually wavelength-dependent
  - (Usually not included in equations, for simplicity)

$$Q_\lambda = dQ/d\lambda$$

Blackbody Radiator

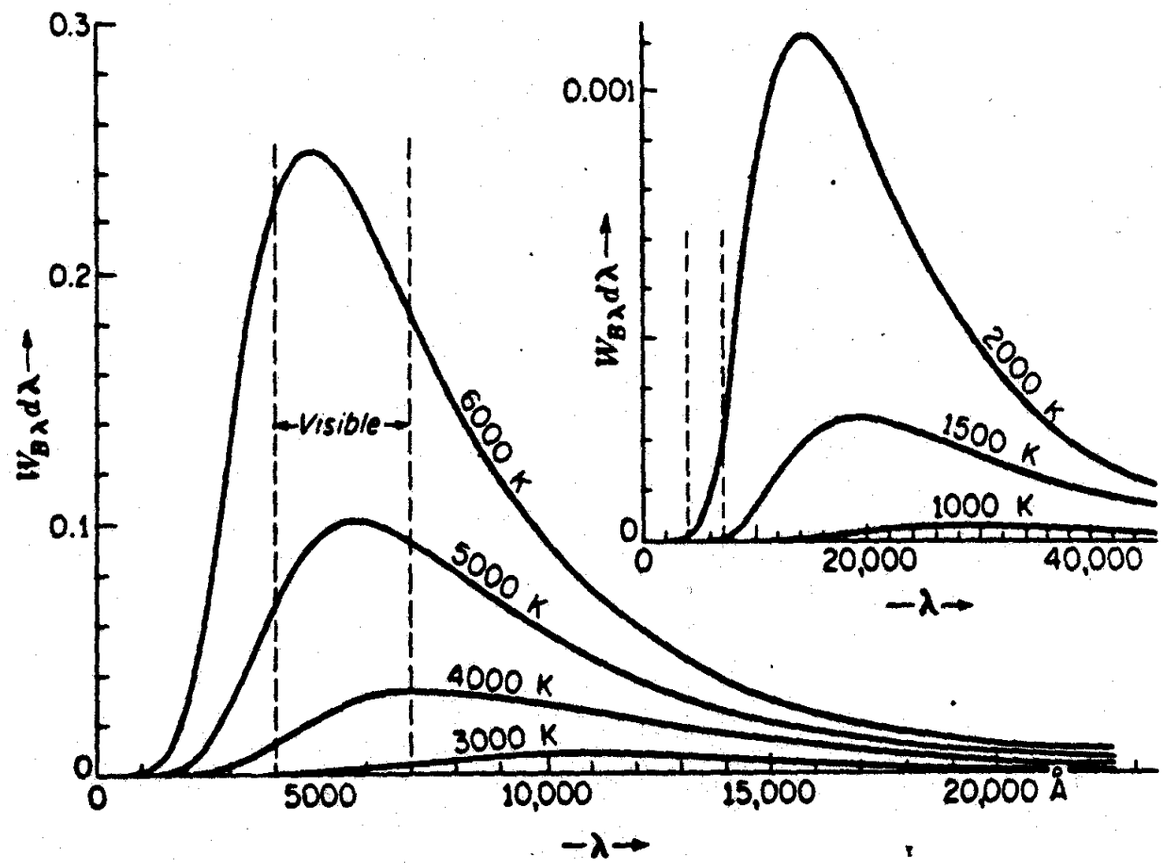


FIGURE 21F
Blackbody radiation curves plotted to scale. Ordinates give the energy in calories per square centimeter per second in a wavelength interval $d\lambda$ of 1 Å. For numerical values, see "Smithsonian Physical Tables," 8th ed., p. 314.

Most energy outside of the visible range

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Sunlight

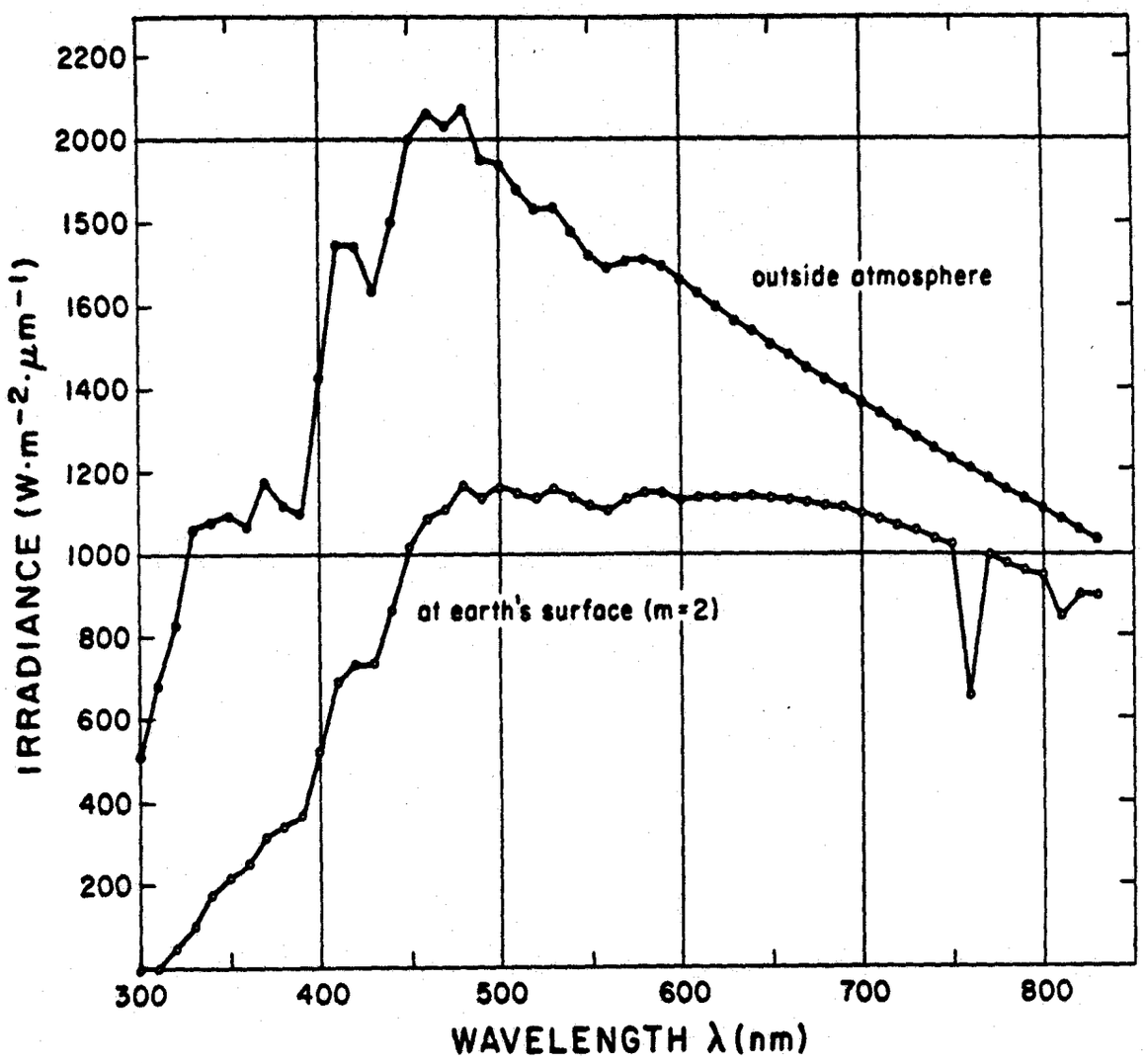
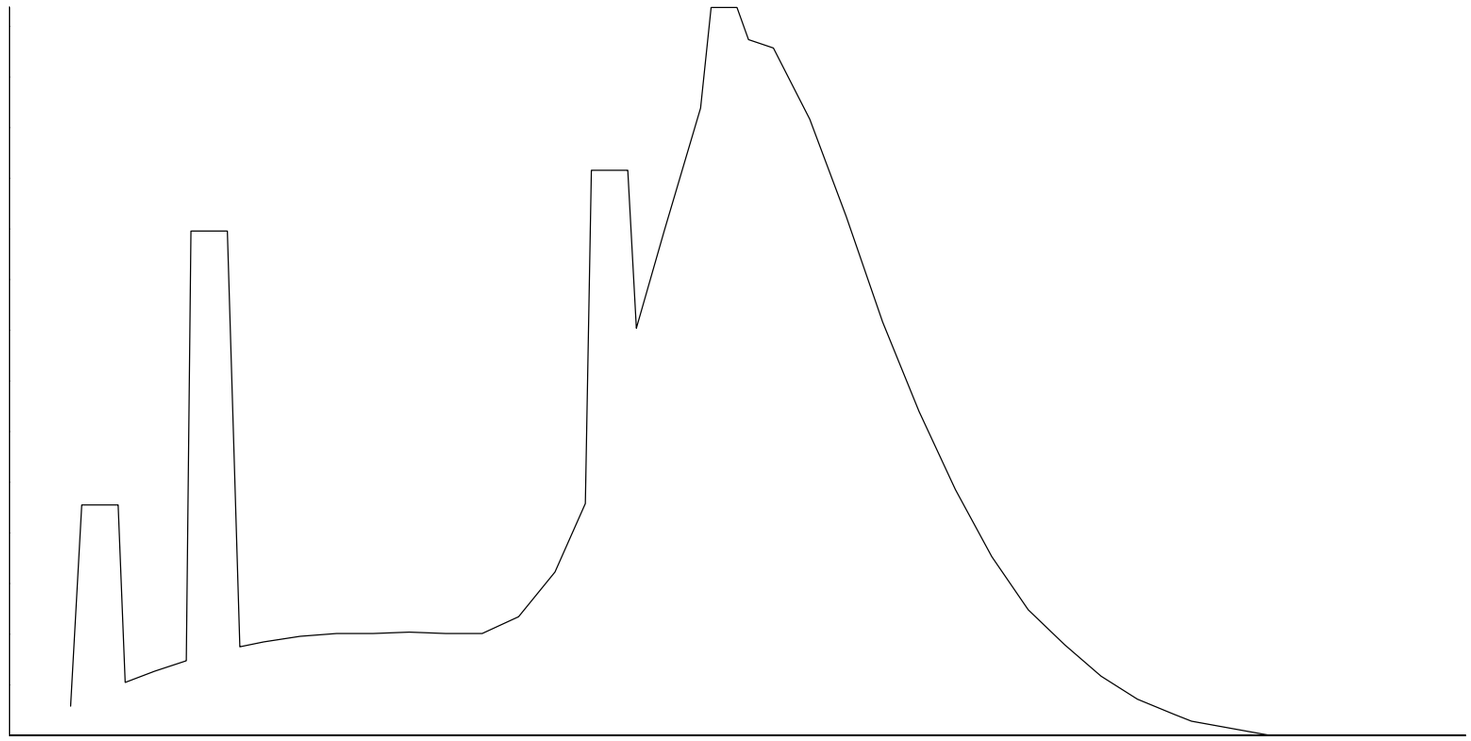


Fig. 1(1.2.1). NASA standard data of spectral irradiance ($W \cdot m^{-2} \cdot \mu m^{-1}$) for the solar disk measured outside the atmosphere (solid dots) and at the earth's surface at air mass 2 (open circles). Data points are those given in Table 1(1.2.1). Neighboring data points have been connected by straight lines for illustrative purposes only.

Fluorescent Light



Spikes make accurate representation difficult

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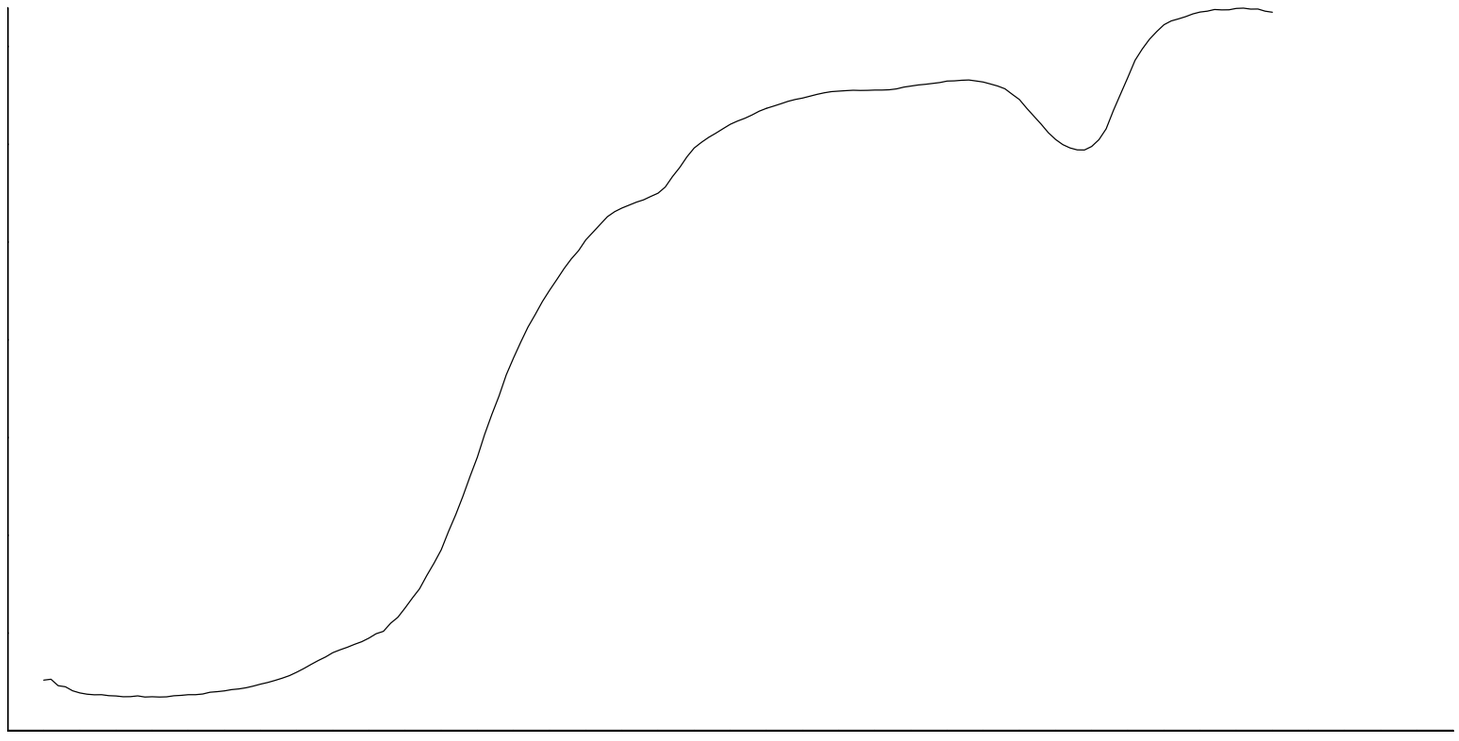
Lemon Skin



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Spectral Representations

- Arbitrarily complex spectral distributions represented with basis functions
- Classic efficiency vs accuracy trade-off
  - Polynomials, Gaussians, delta functions, step functions, ...
  - RGB is a poor / ill-defined choice!

Radiant Energy and Power

- Energy (Q)
  - Joules
  - Time usually not important in graphics
    - (Film exposure, sunburn)
- Power (Φ)
  - Watts
  - Energy per unit time $\Phi = dQ/dt$
  - Spectrum gives wavelength distribution of power

$$\Phi_\lambda = d\Phi/d\lambda$$

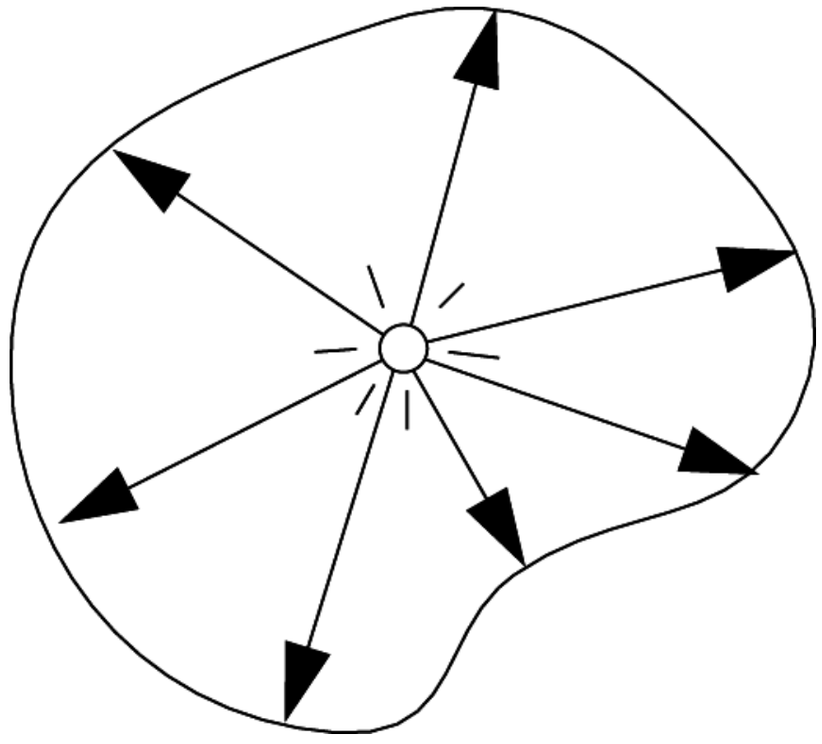
Light Sources

- Spectral emission distribution
- Angular emission distribution
- Spatial emission distribution

Intensity

$$I = d\Phi / d\omega$$ Watts/steradian

$$\Phi = \int_{\Omega} I(\omega) d\omega$$

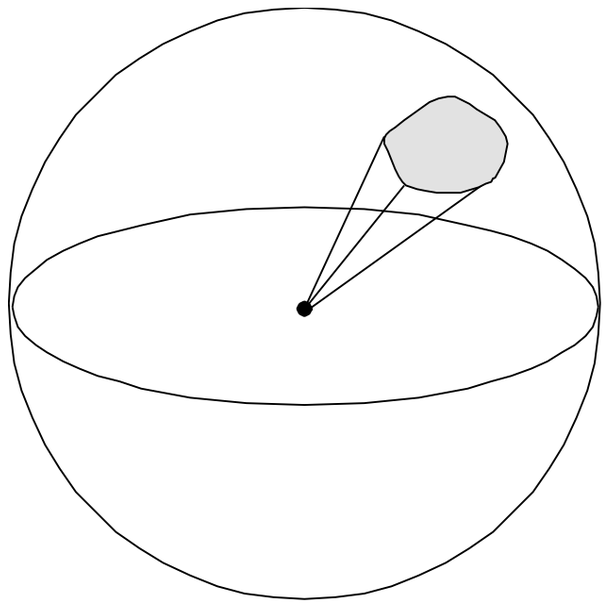


Isotropic point source:

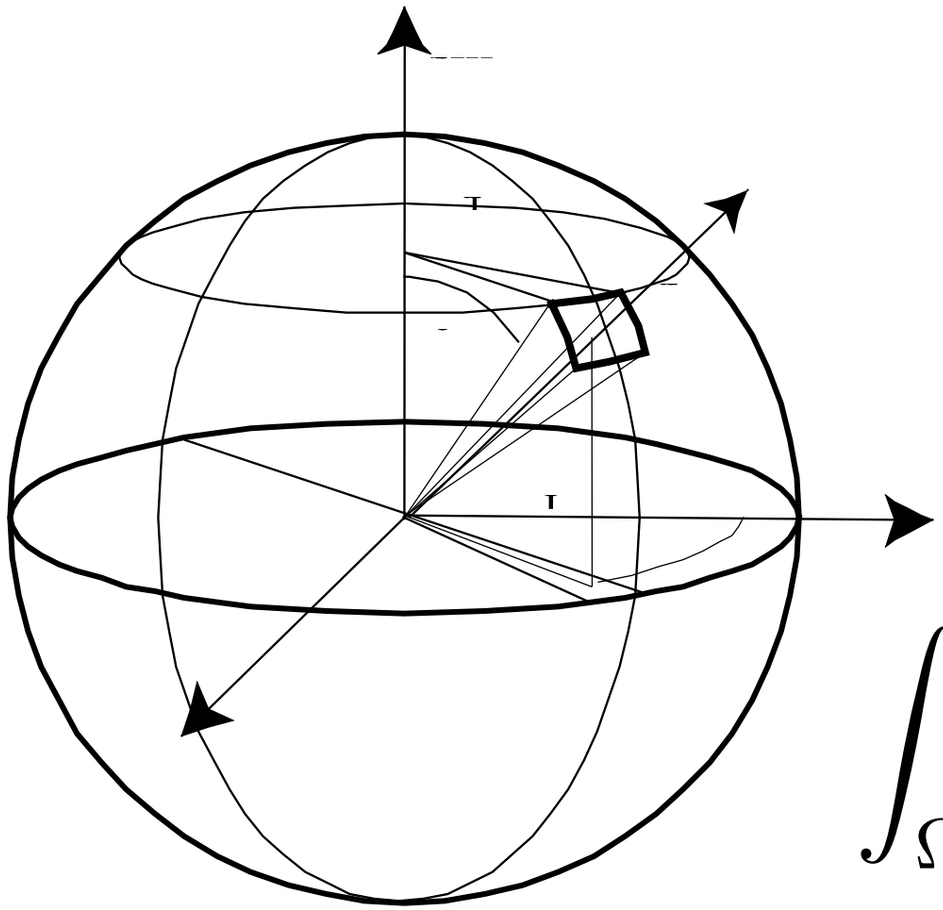
$$\Phi = 4\pi I$$

Measuring Angles

- Plane angle (radians)
  - Length of arc subtended by object divided by radius $\theta = s/r$
- Solid angle (steredians)
  - Area of sphere subtended by object divided by radius squared
  - Examples...



Differential Solid Angles



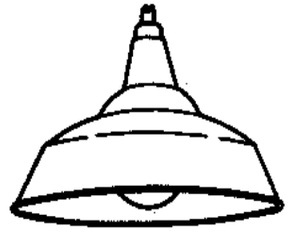
$$d\omega = \sin\theta d\theta d\phi$$

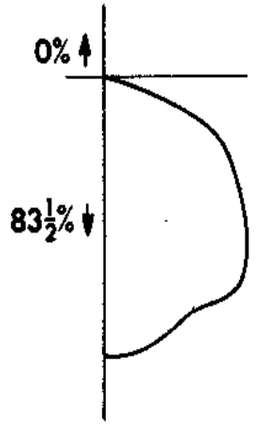
$$\int_\Omega f(\omega) d\omega =$$

$$\int_0^{2\pi} \int_0^{\pi} f(\theta,\phi) \sin\theta d\theta d\phi$$

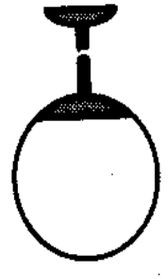
Goniometric Diagrams

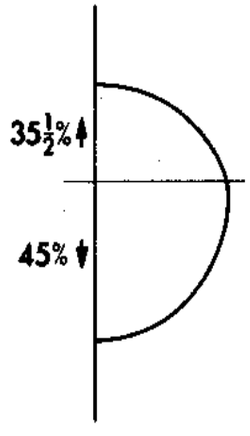
3





Porcelain-enameled ventilated standard dome with incandescent lamp





Pendant diffusing sphere with incandescent lamp

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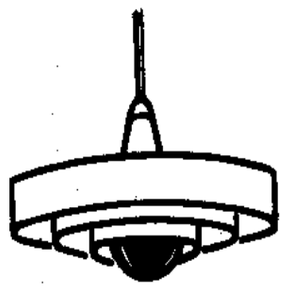
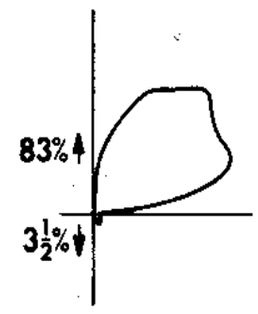
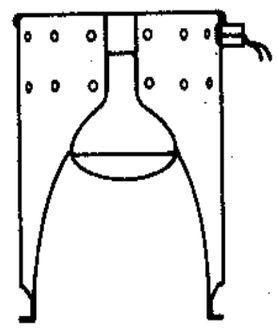
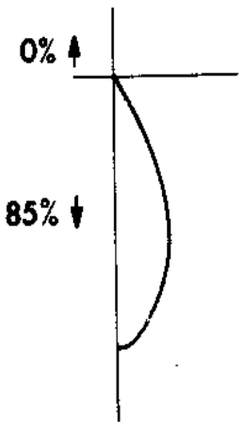




Concentric ring unit with incandescent silvered-bowl lamp





R-40 flood with specular anodized reflector skirt; 45° cutoff

Irradiance

- How much light is arriving at a point on a surface?
  - Power per unit area

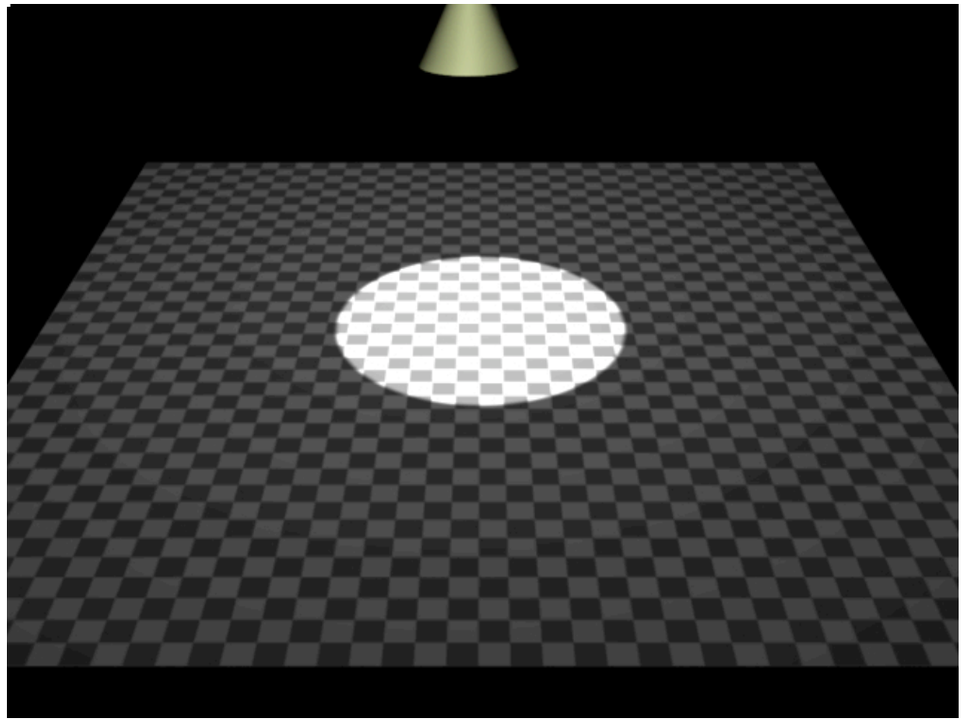
$$E = d\Phi / dA$$

$$\Phi = \int_A E(x) dA$$

Lambert's Cosine Law

- Incident irradiance varies according to the cosine of the incident angle

$$E = E_0 \cos\theta$$



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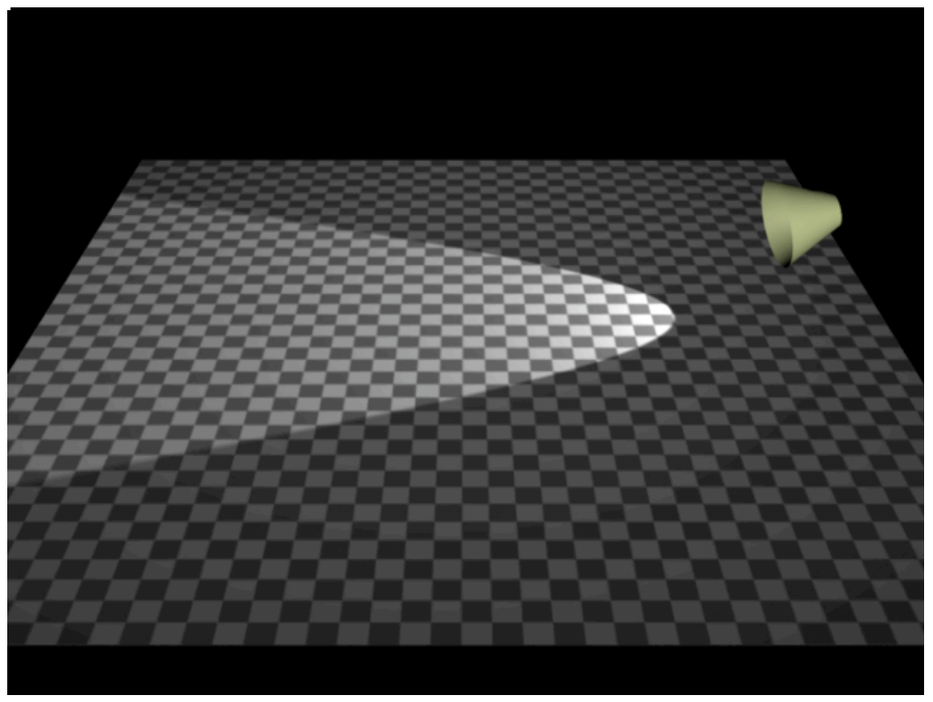

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Inverse Square Falloff Law

- Irradiance decreases with square of the distance from a point source
- Look at projected solid angles...

Radiance

- Area and solid angle density of flux
  - Think area lights, not point lights: intensity per unit area, or irradiance per unit angle
- Unlike irradiance, flux, includes directional distribution

$$L = \frac{d\Phi}{d\omega dA \cos\theta}$$

Key Properties of Radiance

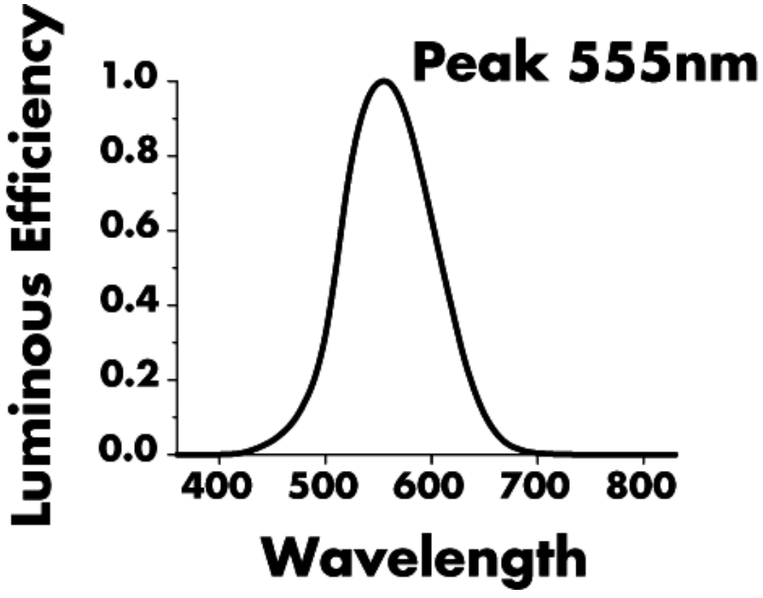
- Invariant along rays
  - Carry radiance along rays in ray-tracer
- Response of sensor is proportional to incident radiance
  - Image is a 2D set of rays
- Fundamental quantity that characterizes light in environment
  - Other quantities can be derived from it

Exercises

- Total flux from Lambertian disk source?
- Total flux from cone spotlight
- Total flux from disk with cone angular distribution
- Irradiance from disk directly above surface

Photometry

- Quantities in terms of effect on standard human observer (photopic conditions)
- Luminous efficiency curve



$$X_p = 683 \int_\lambda V(\lambda) X_r(\lambda) d\lambda$$

Photometry vs Radiometry

- Radiometry: physical measurement of electromagnetic energy
- Photometry: perceptually-based measurement
- But we don't want to waste our time on radiation outside the visible range
  - So judiciously apply photometric computations to help prioritize...

Photometric vs. Radiometric Quantities

- Luminous flux / radiant flux
- Luminous intensity / radiant intensity
- Illuminance / irradiance
- Luminance / radiance