Color Vision

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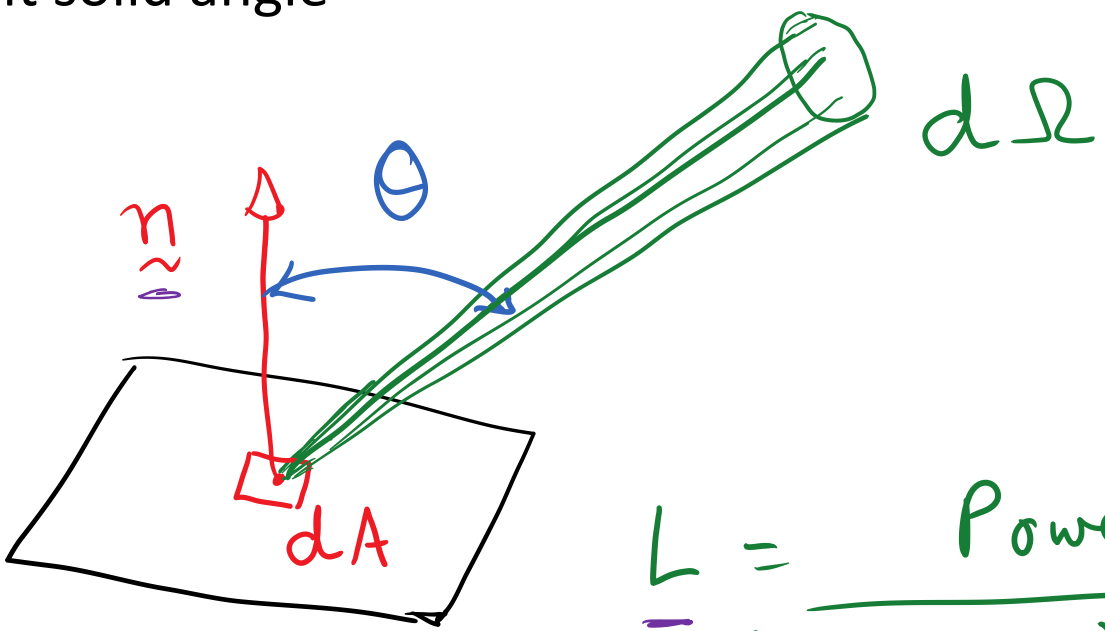
Radiance is a directional quantity

Radiant power travelling in a given direction per unit area (measured perpendicular to the direction of travel) per unit solid angle



$$L = \frac{\text{Power}}{(dA \cos\theta)(d\Omega)}$$

units are $W\,m^{-2}\,sr^{-1}$

Read more on Wikipedia

Radiance is a function of wavelength

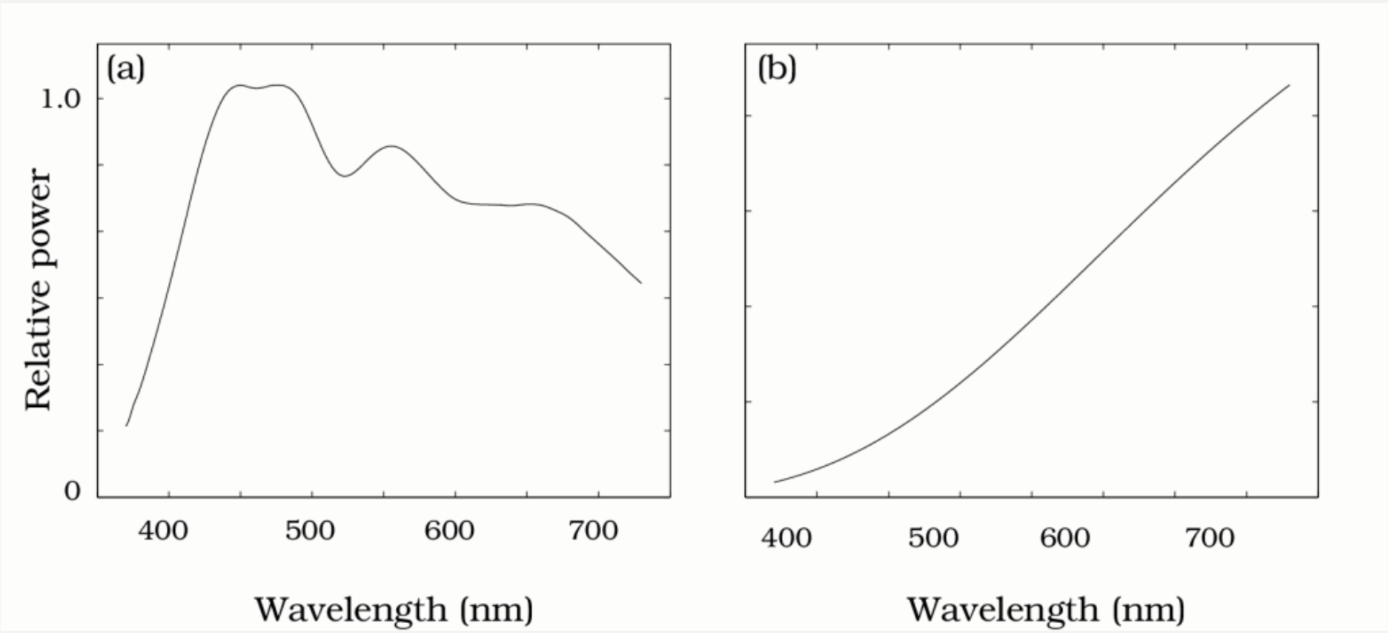
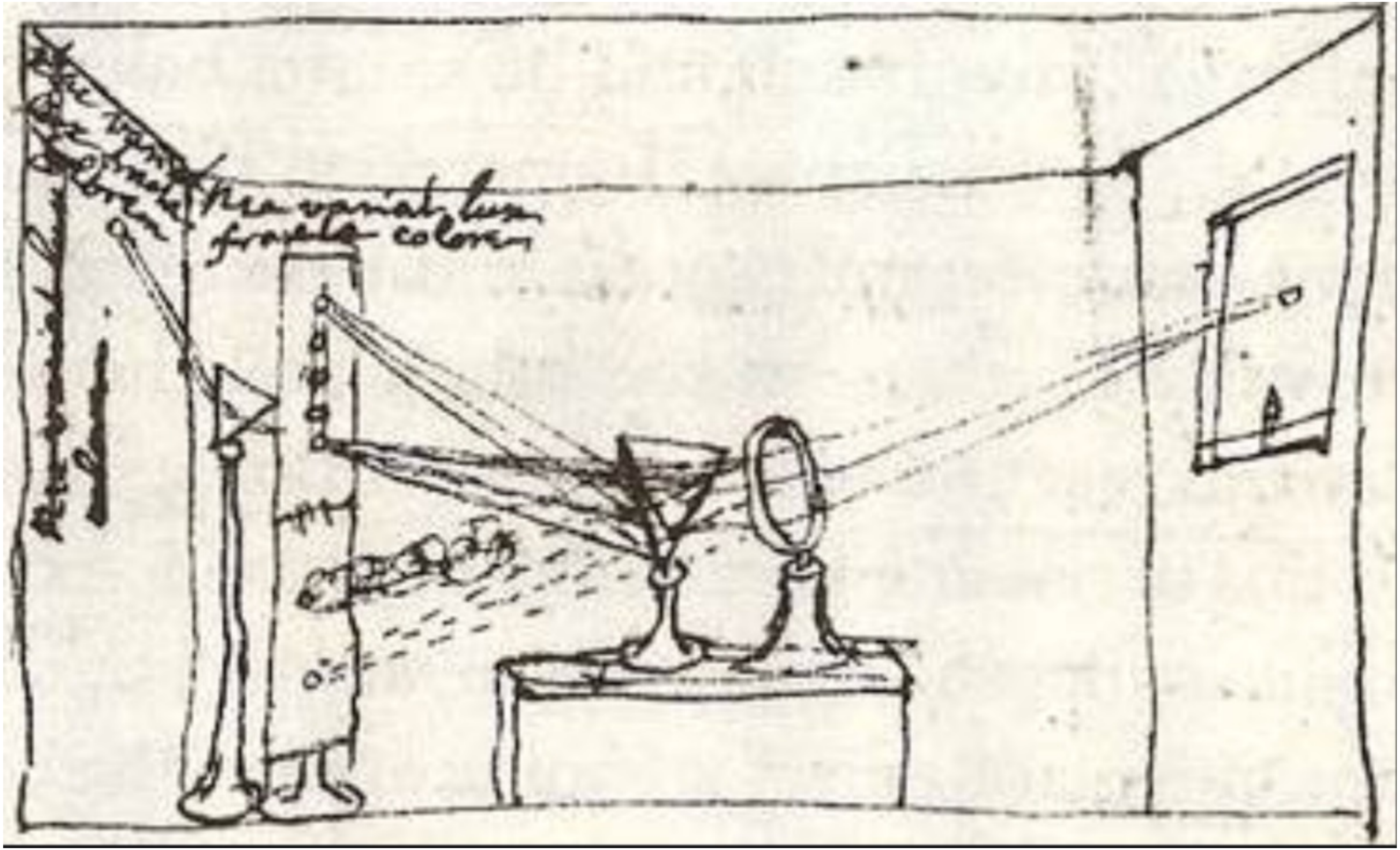
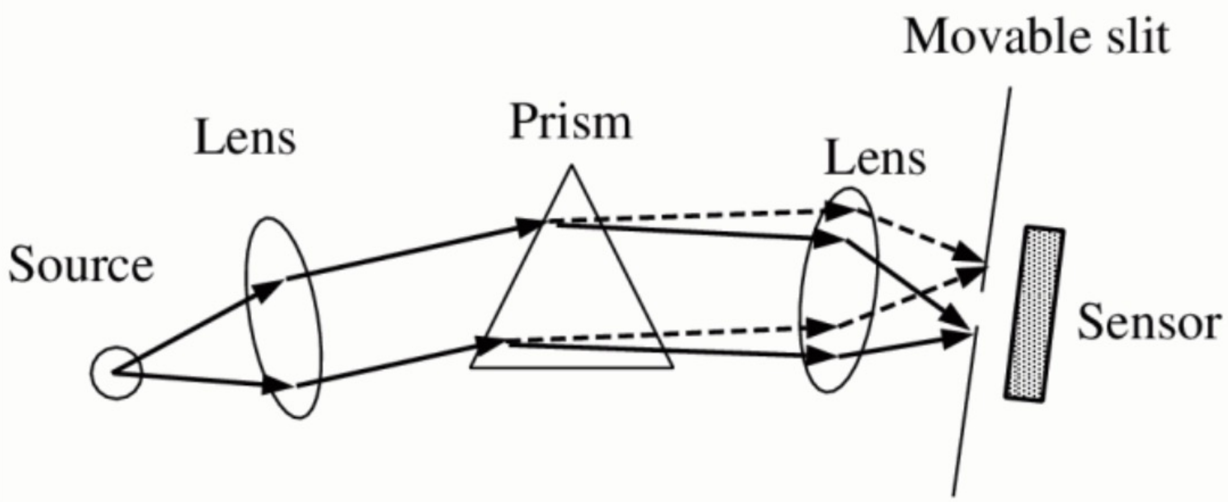


Figure 4.4. The spectral power distribution of two important light sources are shown: blue skylight (a) and the yellow disk of the sun (b).


Nec variat lux fracta colorem

(a)



(b)

Wavelength (nm)	Color[a]
700	red
610	orange
580	yellow
540	green
480	blue
400	violet

[a]Viewed in isolation

Figure 4.2. A spectroradiometer is used to measure the spectral power distribution of light. (a) A schematic

Any test light can be matched by a mixture of three lights

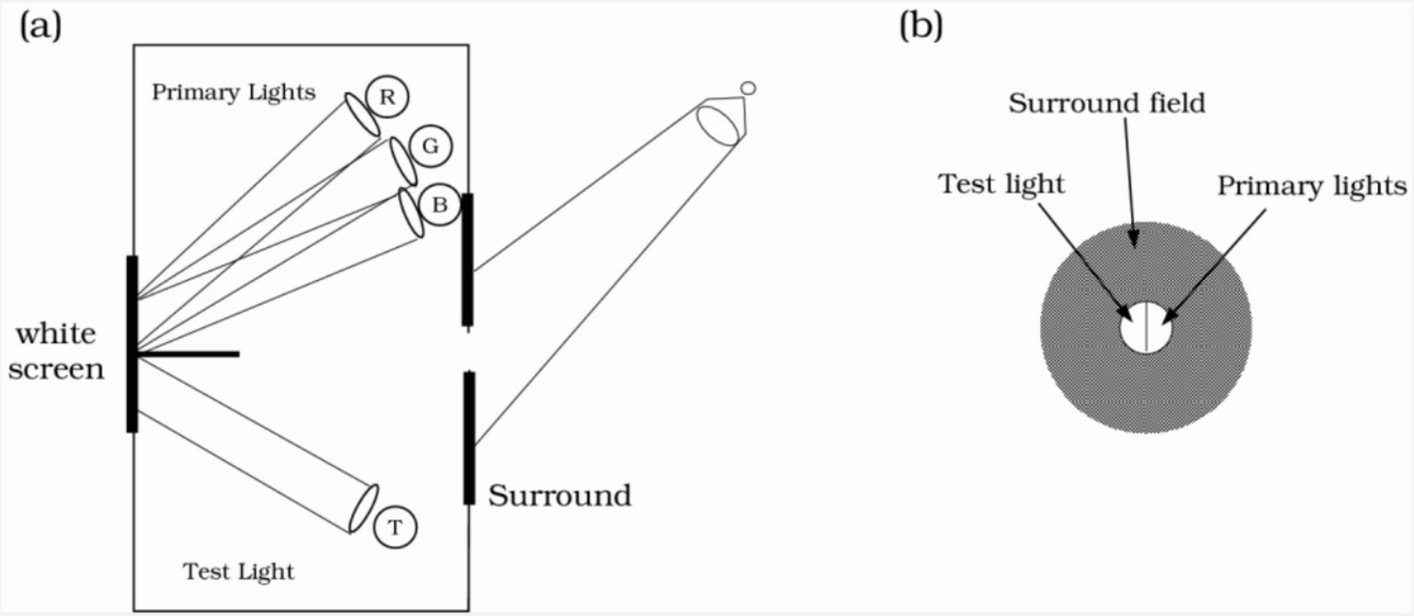


Figure 4.12: The color-matching experiment.} The observer views a bipartite field and adjusts the intensities of the three primary lights to match the appearance of the test light. (a) A side-view of the experimental apparatus. (b) The appearance of the stimuli to the observer. (After Judd and Wyszecki, 1975.

An extreme example of metamerism

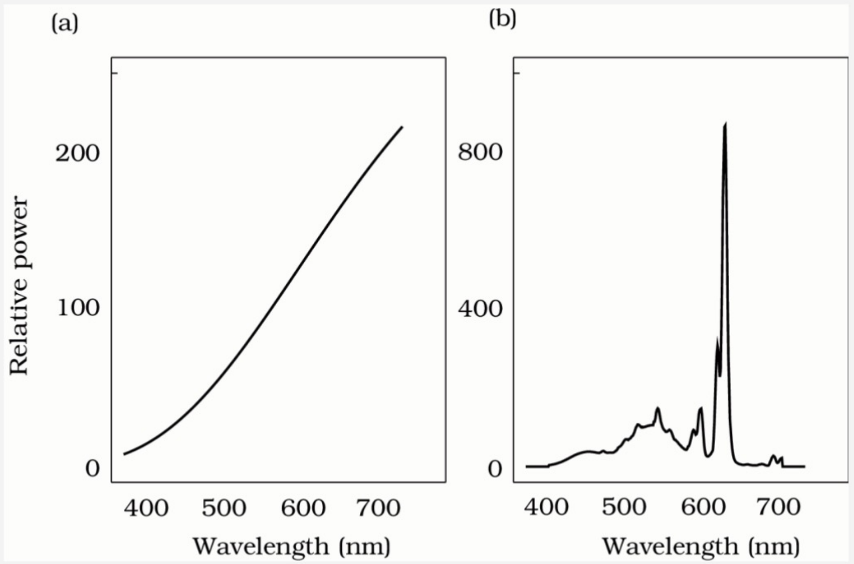
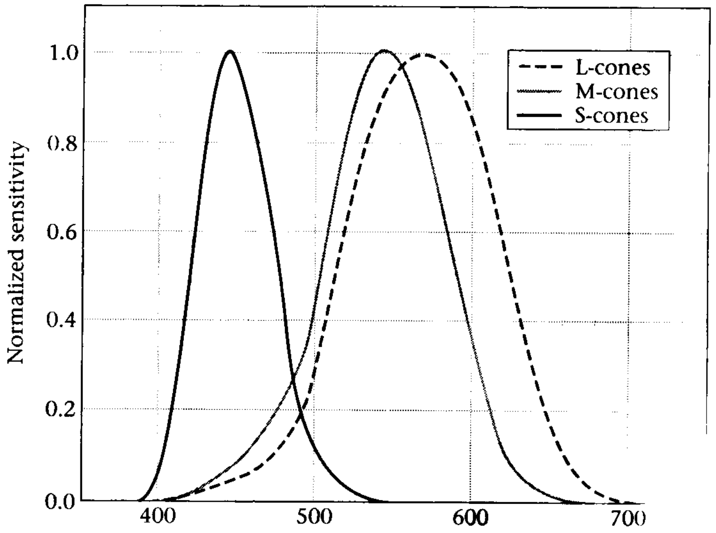


Figure 4.13: Metameric lights. Two lights with these spectral power distributions appear identical to most observers and are called metamers. The curve in part (a) is an approximation to the spectral power distribution of the sun. The curve in part (b) is the spectral power distribution of a light emitted from a conventional television monitor whose three phosphor intensities were set to match the light in (a) in appearance.

Young-Helmholtz Trichromacy theory

- There are three cone types with different spectral sensitivity curves

The three cone types have different spectral sensitivity functions



The principle of univariance

- The response of a photoreceptor is a function of the number of photons absorbed
- Thus a weak light at the wavelength of peak sensitivity could have the same response as a strong light at a wavelength of lower sensitivity
- The response of a cone with spectral sensitivity $S(\lambda)$to a light with spectral power distribution $L(\lambda)$ is given by

$$\int S(\lambda)\, L(\lambda)$$

We can approximate the spectral power distribution and receptor sensitivity function as vectors indexed by wavelength

$$\text{Cone absorptions} \quad \begin{pmatrix} \mathrm{L} \\ \mathrm{M} \\ \mathrm{S} \end{pmatrix} = \begin{pmatrix} \text{L cone wavelength sensitivity} \\ \text{M cone wavelength sensitivity} \\ \text{S cone wavelength sensitivity} \end{pmatrix} \begin{pmatrix} \rotatebox{90}{\text{Test spectral power distribution}} \end{pmatrix}$$

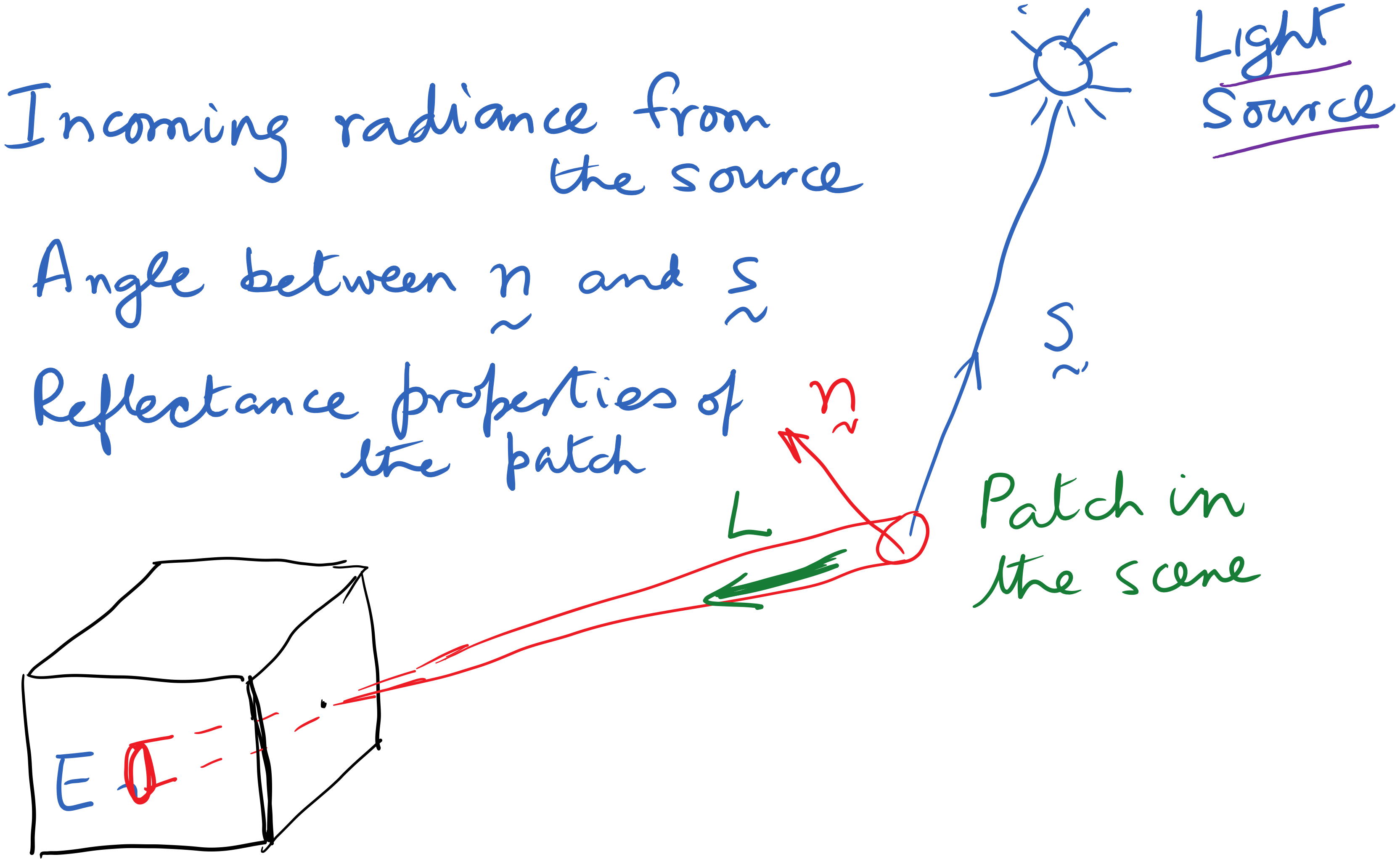
$$\mathbf{r} = \mathbf{B}\mathbf{t}$$

Figure 4.18: Cone photopigments and the color-matching functions. If we measure the wavelength sensitivity of each of the cone photopigments, we can create a 3 x N system matrix to describe the cone absorptions. Then, we

We get metamers when two lights result in the same (L,M,S) values

What causes the outgoing radiance at a scene patch?

- Incoming radiance from the source
- Angle between $\underset{\sim}{n}$ and $\underset{\sim}{s}$
- Reflectance properties of the patch



Bidirectional Reflectance Distribution Function

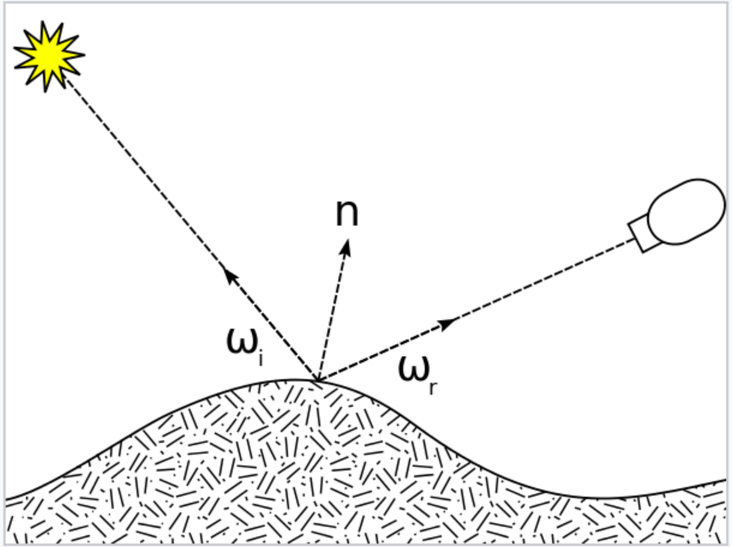


Diagram showing vectors used to define the BRDF. All vectors are unit length. ω_{i} points toward the light source. ω_{r} points toward the viewer (camera). n is the surface normal.

$$f_{\mathrm{r}}(\omega_{\mathrm{i}},\,\omega_{\mathrm{r}}) = \frac{\mathrm{d}\,L_{\mathrm{r}}(\omega_{\mathrm{r}})}{\mathrm{d}\,E_{\mathrm{i}}(\omega_{\mathrm{i}})} = \frac{\mathrm{d}\,L_{\mathrm{r}}(\omega_{\mathrm{r}})}{L_{\mathrm{i}}(\omega_{\mathrm{i}})\cos\theta_{\mathrm{i}}\,\,\mathrm{d}\,\omega_{\mathrm{i}}}$$

where L is radiance, or power per unit solid-angle-in-the-direction-of-a-ray per unit projected-area-perpendicular-to-the-ray, E is irradiance, or power per unit *surface area*, and θ_{i} is the angle between ω_{i} and the surface normal, $\mathbf{n}$. The index i indicates incident light, whereas the index r indicates reflected light.

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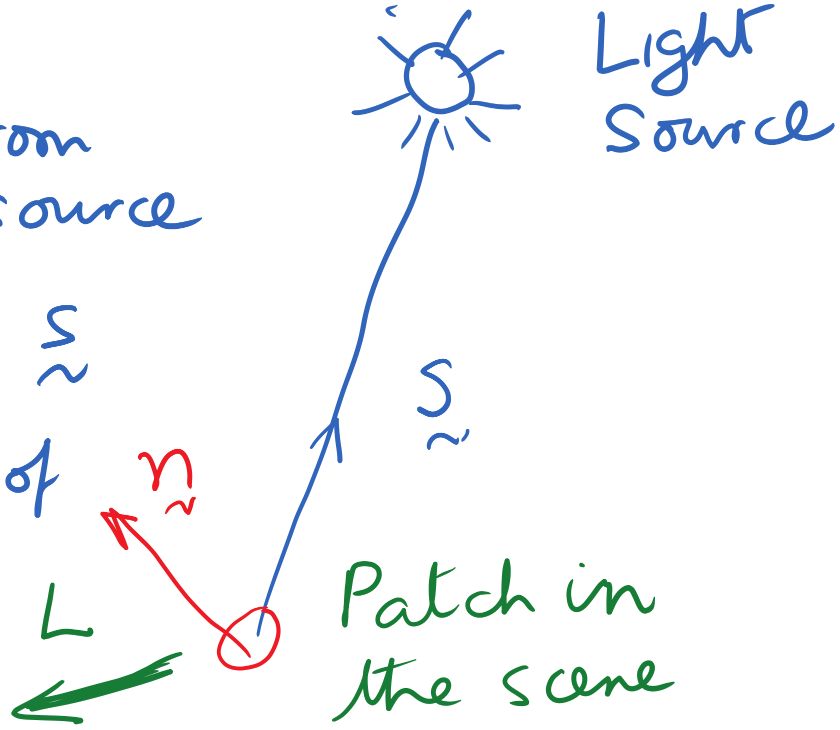
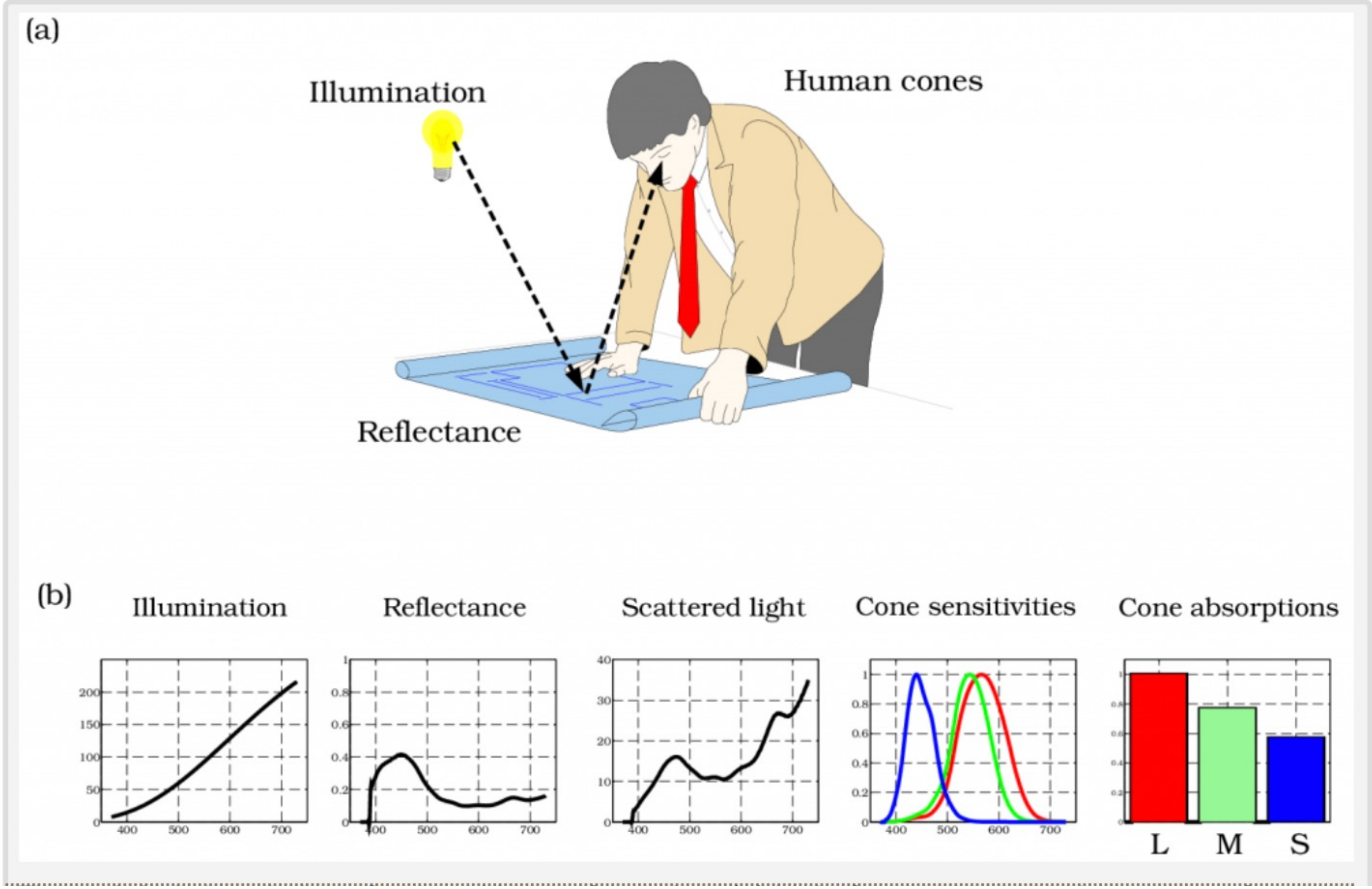


Two special cases:

- Specular surfaces - Outgoing radiance direction obeys angle of incidence=angle of reflection, and co-planarity of incident & reflected rays & the surface normal.
- Lambertian surfaces - Outgoing radiance same in all directions

Outgoing = Reflectance * Incoming



Dichromatic model of color