# Fundamentals of Multimedia

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## Chapter 4 :

## Color in Image and Video

- This chapter explores:
  - several issues in the use of color, since color is vitally important in multimedia programs

- in this chapter we shall consider the following topics:
  - Color Science
  - Color Models in Images
  - Color Models in Video.

# Color in Image and Video

- 4.1 Color Science
- 4.2 Color Models in Images
- 4.3 Color Models in Video
- 4.4 Further Exploration

# 4.1 Color Science

- **Light and Spectra**

- Light is an **electromagnetic wave**. Its color is characterized by the wavelength content of the light:

  (a) Laser light consists of a single wavelength: e.g., a ruby (ياقوت) laser produces a bright, scarlet-red beam.

  (b) Most light sources produce contributions over many wavelengths.

  (c) However, humans cannot detect all light, just contributions that fall in the "visible wavelengths".

  (d) Short wavelengths produce a blue sensation, long wavelengths produce a red one.

# 4.1 Color Science

- **Spectrophotometer:** device used to measure visible light, by reflecting light from a diffraction grating (prism حاجز انكسار كالمنشور) (a ruled surface) that spreads out the different wavelengths.

- Figure 4.1 shows the phenomenon that white light contains all the colors of a rainbow.

- Visible light is an electromagnetic wave in the range 400 nm to 700 nm (where nm stands for nanometer, $10^{-9}$ *meters*).

# 4.1 Color Science

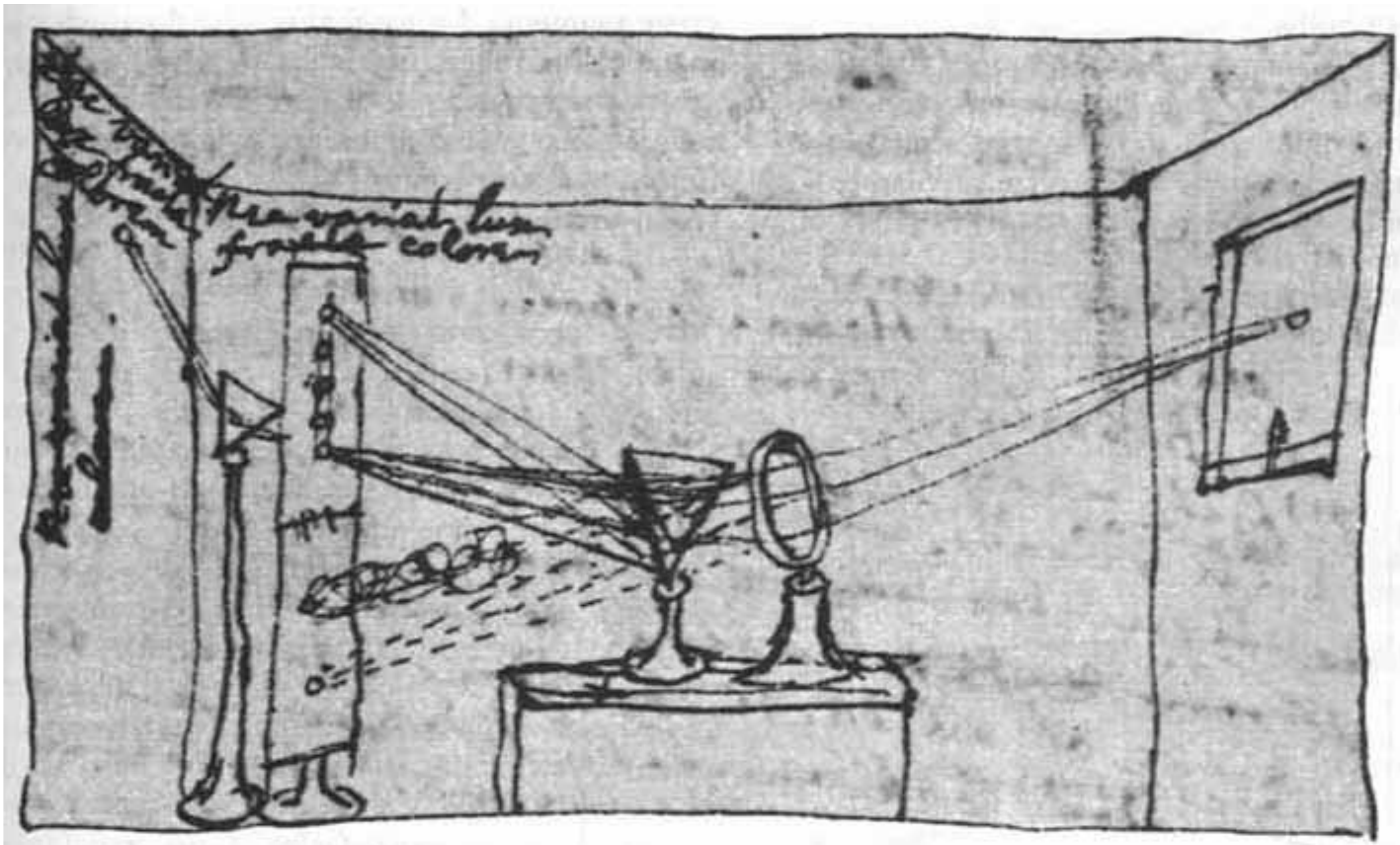
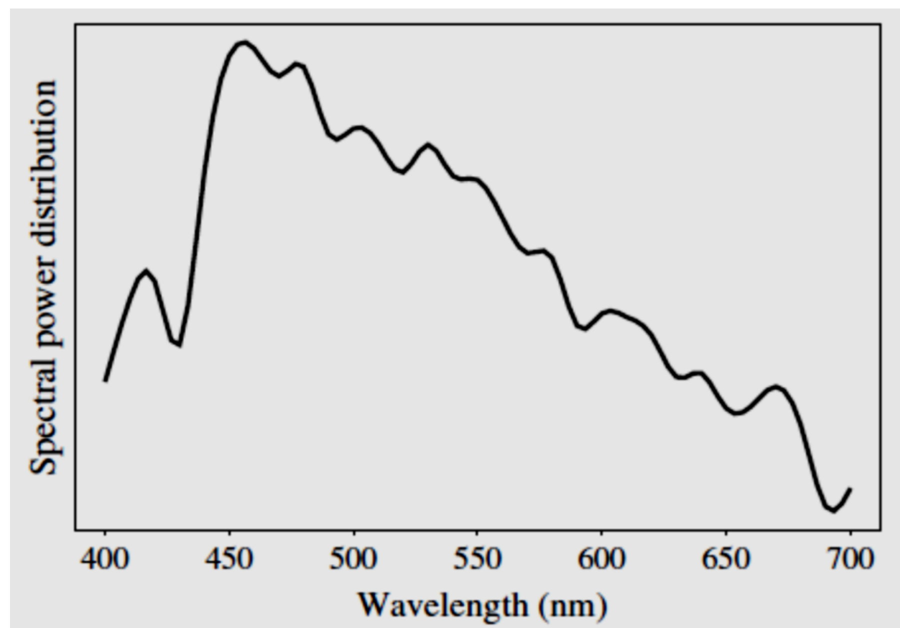


Fig. 4.1: Sir Isaac Newton's experiments.

# 4.1 Color Science

- Fig. 4.2 (See Book) shows the relative power in each wavelength interval for typical outdoor light on a sunny day.
- This type of curve is called a Spectral Power Distribution (**SPD) or a spectrum.**
- The symbol for wavelength is $\lambda$. This curve is called $E(\lambda)$.



# 4.1 Color Science

- **Human Vision**
- *The eye works like a camera, with the lens focusing an image* onto the retina شبكية (upside-down and left-right reversed).

- *The retina consists of an array of rods and three kinds of* cones. See images (rods_cones, rods_cones1).
- *The rods come into play when light levels are low and produce* a image in shades of gray ("all cats are gray at night!").

- *For higher light levels, the cones each produce a signal.* Because of their differing pigments, the three kinds of cones are most sensitive to red *(R), green (G), and blue (B) light.*

- *It seems likely that the brain makes use of differences R-G, G-B, and B-R, as well as combining all of R, G, and B into* a high-light-level achromatic channel.

# 4.1 Color Science

- **Spectral طيفي Sensitivity of the Eye**
- *The sensitivity of our receptors is a function of wave*-length (Fig. 4.3).
- *The Blue receptor sensitivity is not shown to scale because* it is much smaller than the curves for Red or Green – Blue is a late addition, in evolution.
- Fig. 4.3 shows the overall sensitivity as a dashed line – this important curve is called the **luminous** efficiency function.
  - It is usually denoted *V ( λ ) and is formed as the sum of the response* curves for Red, Green, and Blue.

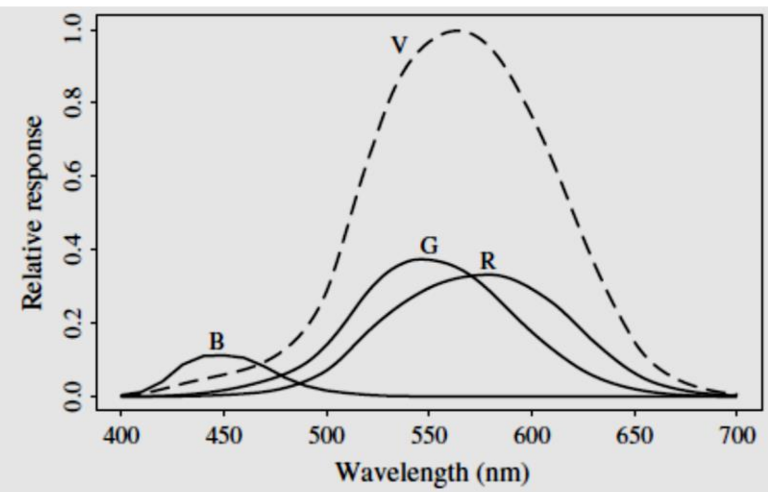



**Fig. 4.3** R,G, and B cones, and luminous-efficiency curve V(λ)

# 4.1 Color Science

- **Spectral طيفي Sensitivity of the Eye**
- The eye is most sensitive to light in the middle of the visible Spectrum طيف.

- The eye has about 6 million cones, but the proportions of *R, G, and B cones* are different.
- They likely are present in the ratios 40:20:1
- So the achromatic اللوني channel produced by the cones is thus something like $2R + G + B/20$.

# 4.1 Color Science

**Image Formation**

- In most situations, we actually image light that is reflected from a surface.
- Surfaces reflect different amounts of light at different wavelengths, and dark surfaces reflect less energy than light surfaces.
- then the reflected light filtered by the eye's cone

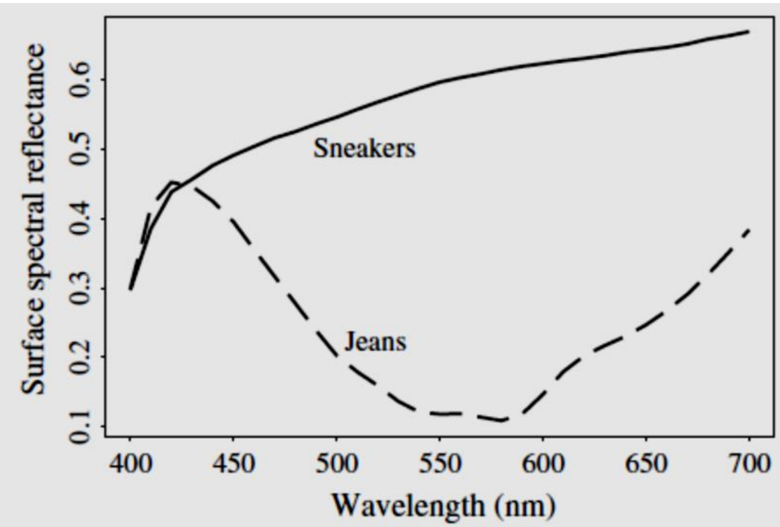



**Fig. 4.4** Surface spectral reflectance functions $S(\lambda)$ for objects

# 4.1 Color Science

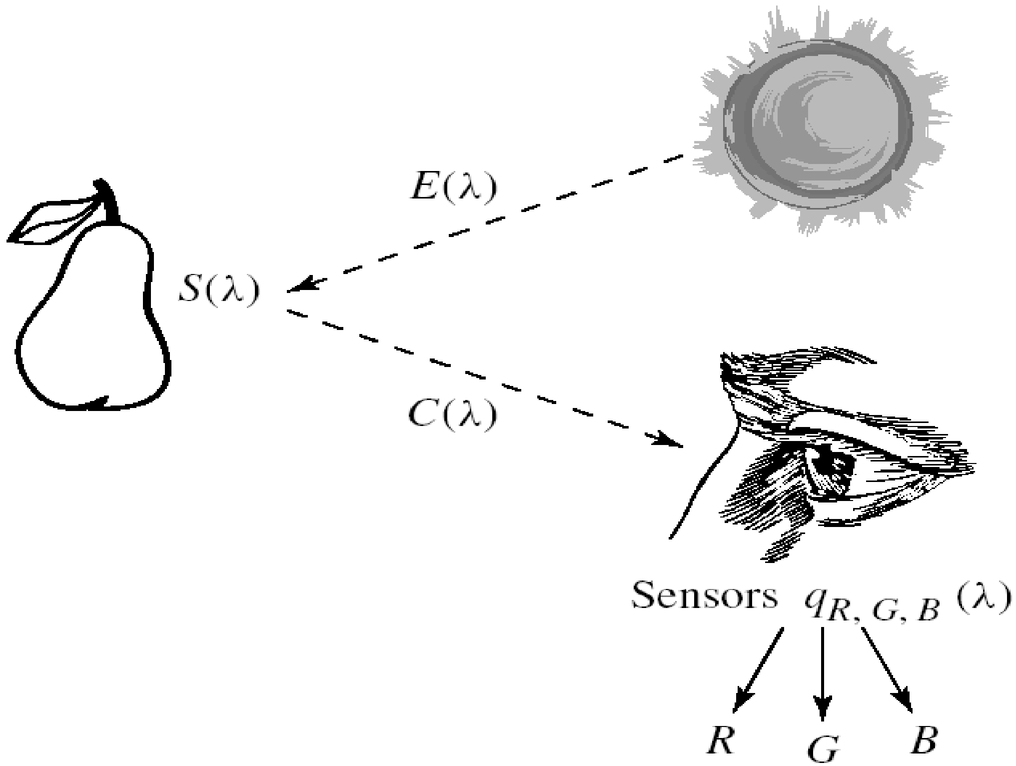



Fig. 4.5: Image formation model.

$$
\begin{aligned}
R &= \int E(\lambda)\, S(\lambda)\, q_R(\lambda)\, d\lambda \\
G &= \int E(\lambda)\, S(\lambda)\, q_G(\lambda)\, d\lambda \\
B &= \int E(\lambda)\, S(\lambda)\, q_B(\lambda)\, d\lambda.
\end{aligned}
$$

# 4.1 Color Science

**4.1.5.Camera Systems**

- Camera systems are made in a similar fashion; a good camera has three signals produced at each pixel location (corresponding to a retinal position).

- Analog signals are converted to digital, truncated to integers, and stored. If the precision used is 8-bit, then the maximum value for any of *R; G;B is 255, and the minimum is 0.*

# 4.1.6. Gamma Correction

- In TV systems, The light emitted is actually roughly proportional to the voltage raised to a power; this power is called “gamma,” with symbol γ. The value of gamma is around 2.2.
- We can precorrect for this situation by actually applying the inverse transformation before generating TV voltage signals. It is customary to append a prime to signals that are “gamma-corrected” by raising to the power (1/γ) before transmission.

$$R \rightarrow R' = R^{1/\gamma} \Rightarrow (R')^{\gamma} \rightarrow R$$

$$V_{out} = \begin{cases} 4.5 \times V_{in} & V_{in} < 0.018 \\ 1.099 \times (V_{in}^{0.45} - 0.099), & V_{in} \geq 0.018 \end{cases}$$

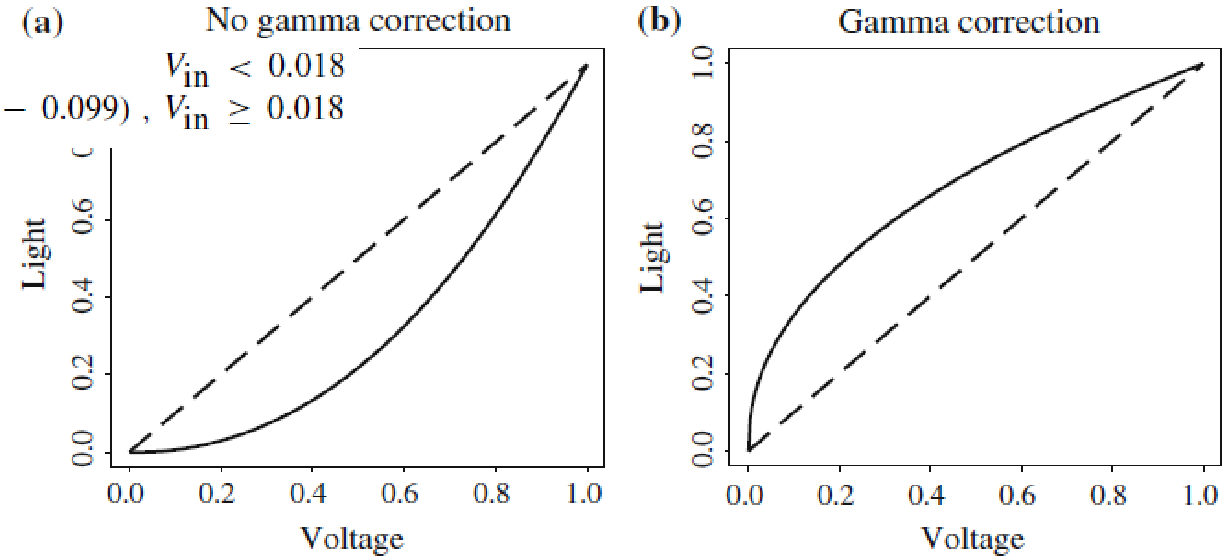



**Fig. 4.6** a Effect of putative standard CRT (mimiced by an actual modern display) on light emitted from screen (voltage is normalized to range 0..1). b Gamma correction of signal

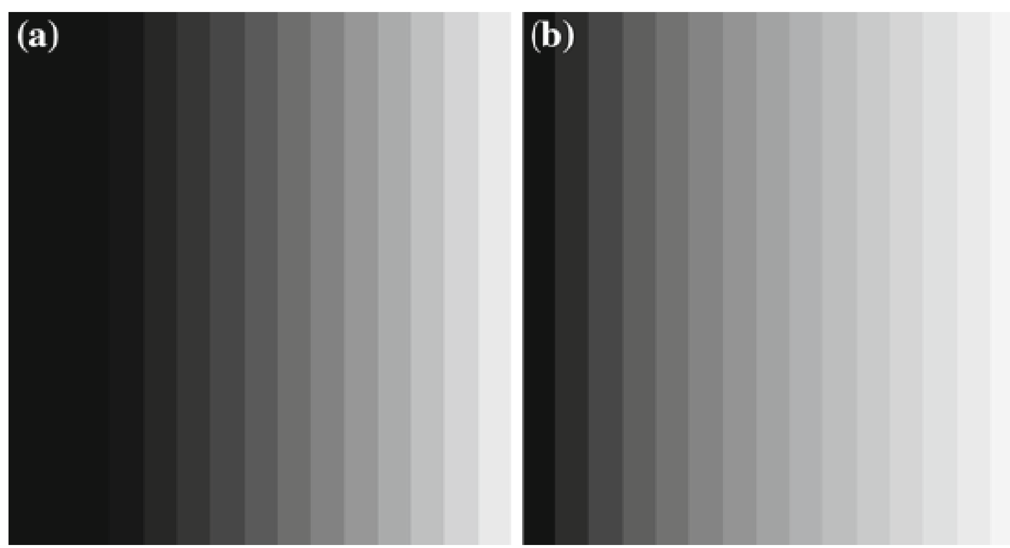



**Fig. 4.7** a Display of ramp from 0 to 255, with no gamma correction. b Image with gamma correction applied

- ادامه مطلب در مورد سیستم‌های مختلف رنگ در ارائه ضمیمه

# End of Chapter 4