Overview

- Display hardware
  - How are images displayed?

- Raster graphics systems
  - How are imaging systems organized?

- Color models
  - How can we describe and represent colors?
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Display Hardware

• Video display devices
  ◦ Cathode Ray Tube (CRT)
  ◦ Liquid Crystal Display (LCD)
  ◦ Plasma panels
  ◦ Thin-film electroluminescent displays
  ◦ Light-emitting diodes (LED)

• Hard-copy devices
  ◦ Ink-jet printer
  ◦ Laser printer
  ◦ Film recorder
  ◦ Electrostatic printer
  ◦ Pen plotter
Cathode Ray Tube (CRT)

Figure 2.4 from H&B

Liquid Crystal Display (LCD)

Figure 2.16 from H&B
Display Hardware

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Raster Graphics Systems

Figure 2.29 from H&B

Frame Buffer

Figure 1.2 from FvDFH
Frame Buffer Refresh

Refresh rate is usually 30-75Hz

Figure 1.3 from FvDFH

Color Frame Buffer

Blue channel
Green channel
Red channel
Color CRT

Figure 2.8 from H&B

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**Electromagnetic Spectrum**

- Visible light frequencies range between ...
  - Red = $4.3 \times 10^{14}$ hertz (700nm)
  - Violet = $7.5 \times 10^{14}$ hertz (400nm)

![Electromagnetic Spectrum Diagram](image)

**Visible Light**

- The color of light is characterized by ...
  - Hue = dominant frequency (highest peak)
  - Saturation = excitation purity (ratio of highest to rest)
  - Brightness = luminance (area under curve)

![Visible Light Diagram](image)
**Color Perception**

Spectral-response functions of each of the three types of cones on the human retina.

**Tristimulus theory of color**

**Color Models**

- RGB
- XYZ
- CMY
- HSV
- Others
RGB Color Model

Colors are additive

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Plate II.3 from FvDFH

RGB Color Cube

Grayscale

Green (0, 1, 0)

Yellow (1, 1, 0)

Cyan (0, 1, 1)

Black (0, 0, 0)

White (1, 1, 0)

Blue (0, 0, 1)

Magenta (1, 0, 1)

Red (1, 0, 0)

Figures 15.11 & 15.12 from H&B
**RGB Spectral Colors**

Amounts of RGB primaries needed to display spectral colors

![RGB Spectral Colors Diagram](image1.png)

Figure 15.5 from H&B

**XYZ Color Model (CIE)**

Amounts of CIE primaries needed to display spectral colors

![XYZ Color Model (CIE) Diagram](image2.png)

CIE primaries are imaginary

Figure 15.6 from H&B
CIE Chromaticity Diagram

Normalized amounts of X and Y for colors in visible spectrum

Figure 15.7 from H&B

CIE Chromaticity Diagram

Compare Color Gamuts
Identify Complementary Colors
Determine Dominant Wavelength and Purity

Figures 15.8-10 from H&B
**RGB Color Gamut**

Color gamut for a typical RGB computer monitor

![RGB Color Gamut Diagram](image)

Figure 15.13 from H&B

**CMY Color Model**

Colors are subtractive

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Plate II.7 from FvDFH
CMY Color Cube

Figure 15.14 from H&B

HSV Color Model

Figure 15.16&15.17 from H&B
Summary

- **Display hardware**
  - Monitors: CRTs, LCDs, etc.
  - Hard-copy: printers, plotters, etc.

- **Raster graphics systems**
  - Display processors
  - Frame buffers
  - Video controllers
  - Devices cannot display all visible colors

- **Color models**
  - Tristimulus theory of color
  - Different color models for different devices, uses, etc.