Color
Additive Color
Subtractive Color
Additive & Subtractive Color Spaces
Subtractive Reflection Processes
Subtractive Ink Technology

50%  
C (Cyan)

25%  
C’

70%  
M (Magenta)

45%  
M’

25%  
Y (Yellow)

0%  
Y’

K = min (C, M, Y)
C’ = C - K
M’ = M - K
Y’ = Y - K

25%  
K (Black)
Subtractive Ink Technology

50%  70%

25%

25%  45%

0%  25%
CMY

CMY

Original Full Color
CMY vs. CMYK

Wikipedia, CMYK separation
Halftoning

Analog halftone dots

Printer spots
Halftoning Image
Halftoning Dither Matrix

Number of intensity levels = $n^2 + 1$
### Dither Matrix

The dither matrix is given by:

\[
\begin{bmatrix}
6 & 8 & 4 \\
1 & 0 & 3 \\
5 & 2 & 7 \\
\end{bmatrix}
\]

- $B = \text{value of white (Imax)} - \text{Intensity (I)}$
- For a 3 x 3 matrix, Imax = 9
- $B = 9 - I$
- Ink is dropped at all pixels whose dither matrix value is less than $B$
Dither Matrix – Ten intensity levels

Values of $B = 9 - I$
Dither Matrix – Ten intensity levels

Values of B = 9 - I

Values of I

Values of B
Color Laser Printing

Color Laser:

Electrophotographic printing using a laser beam and colored toners
Laser Printer

1. Controller
2. Photoconducting drum
3. Charging Roller
4. Laser Beam
5. Rotating Mirror
6. Developer Roller
7. Toner Hopper
8. Belt Assembly
9. Paper Tray
10. Charging Wire
11. Cleaning Blade
12. Fuser
1. **Charge** - A photoconductive surface is given a uniform electrostatic charge on its surface.

2. **Expose** - A laser “writes” the image on the photoconductor.

3. **Develop** - Fine toner particles are transported by electrostatic forces to the photoconductor.
Laser Printing

4. Transfer - the developed image is transferred from the photoconductor to the paper by contact

5. Fuse - the transferred image is permanently fixed to the paper by pressure or heat

6. Clean - the photoconductor drum is cleaned
Laser Print Heads

Two versions of a laser print head. a) A typical gas laser printhead and b) A typical diode laser printhead.
Canon Copier
Thermal Bubble Ink Jet

- Initial state with fluid at rest.
- Resistor is heated and bubble nucleates.
- Bubble grows to maximum size and ejects fluid out of nozzle.
- Bubble collapses; drop breaks off.
- System returns to initial conditions.
Inkjet Color Systems

- 4 ink systems: Black, Cyan, Magenta, Yellow
- 6 ink systems: Black, Cyan, Magenta, Yellow, Photo Cyan (light Cyan), Photo Magenta (light Magenta)
- 8 ink systems: Black, Cyan, Magenta, Yellow, Photo Cyan (light Cyan), Photo Magenta (light Magenta), Medium Gray, Light Gray
Resolution Limits

- resolution is a function of contrast sensitivity

Image: Schematic showing resolution targets and luminance profiles, illustrating resolvable and unresolvable images.
Resolution

Specific Resolution - measured in dots per inch (horizontally) or lines per inch

Current ink jet resolution → 2400 dpi
1200 or 2400 lines per inch

Laser printing is higher

Total Resolution - defined as the total number of dots horizontally or lines vertically

The larger the picture size, the higher the total resolution
Resolution Limit for Reading at 18"

The triangle subtended by a 30 second angle

Sine of 30 sec = sine of 1/120 deg

= sin (0.0083333333)

= 0.000145444

Thus 18"sin(30 sec)

= 0.002617994"
How Many Dots Fit Within the Human Resolution Limits?
What is the total picture resolution in dots?

- Current printer resolution
  2400 x 1200 dpi
How many dots (inkjet drops) per pixel?

iPhone5 with 8MP camera

• Assume 3200 x 2400 pixels
DPI and PPI

Conceptual comparison of pixels per inch and dots per inch.
Ink Droplets on Paper

Water based drying

Roller pressure drying

http://www.imaging.org/ist/resources/tutorials/inkjet.cfm
Dye vs pigment

cross-section near the paper surface
Inkjet Drop Size

<table>
<thead>
<tr>
<th>picoliters</th>
<th>relative drop size</th>
<th>year</th>
</tr>
</thead>
<tbody>
<tr>
<td>86</td>
<td>70μm</td>
<td>1991</td>
</tr>
<tr>
<td>50</td>
<td>45μm</td>
<td>1995</td>
</tr>
<tr>
<td>32</td>
<td>40μm</td>
<td>1996</td>
</tr>
<tr>
<td>10</td>
<td>26μm</td>
<td>1997</td>
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<tr>
<td>4</td>
<td>19μm</td>
<td>1999</td>
</tr>
<tr>
<td>0.01</td>
<td>3μm</td>
<td>2002</td>
</tr>
</tbody>
</table>

relative drop sizes in picoliters (trillionths of liters)

(3 micron, 10 fl)
Thermal-wax Transfer: Heated wax is melted onto special paper or transparency film.
Dye Sublimation Printing

Dye Sublimation: Vaporized dyes transfer to special paper
Dye Sublimation Output

Dye primary colors
The human eye blends four individual color dots into a single color.
The image area of the plate picks up ink from the ink rollers. The water rollers keep the ink off of the non-image areas. Each plate then transfers its image to a rubber blanket which transfers the image to the paper. The plate does not touch the paper, thus the term "offset" lithography. All of this occurs at an extremely high speed.
Close-up of rollers. The top series of rollers transfers the yellow ink to the rubber "blanket" cylinder (bottom roller), and then to the paper that is passing horizontally under the "blanket."
Web-press paper-feed system showing the double roll of paper just before the splice from the smaller roll (on the bottom) to the larger roll. Each roll of paper weighs nearly 1 ton and is sufficient for 9,000 impressions (72,000 printed pages).
Canon PIXMA MX532  
(January 2014)

- **Printing Technology:** Allows you to print and scan from mobile devices
- **Cloud Technology:** Allows you to print directly from Cloud services
- **Maximum Print Resolution:**
  - 4800 x 1200 optimized dpi
- **Photo Print Speed:**
  - 4" x 6" Borderless Photo: 46 seconds
  - Print documents and web pages at 9.7 images per minute for black, and 5.5 images per minute for color.

$149.99+
Epson Expression ET-2500 EcoTank
August 2015

- ISO Print Speed: 9 ISO ppm in Black, 4.5 ISO ppm in color
- Droplet Size: 3 droplet sizes, as small as 3 picoliters
- Maximum Print Resolution: 5760 x 1440 dpi
- Mobile Printing via Epson Email Print or Kindle Fire

$379.99
**HP Officejet Pro 8630 Printer**
*(June 2014)*

- **Built-in wireless networking**
- **Print Speed:**
  - Black: Up to 21 ppm
  - Color: Up to 16.5 ppm
- **Print Resolution:**
  - Black: Up to 1200 x 1200 dpi
  - Color: Up to 4800 x 1200 dpi

$199.00
End...