Colors in CSS

- Use: fonts, borders, backgrounds
- Provides semantic signal:
  - **Green** – go, success, complete, solution
  - **Red** – stop, failure, incomplete, problem
  - **Yellow** – yield, warning, attention
- Helps to set mood/emotion/tone:
  - **Bright** – cheerful, playful, positive
  - **Dark** – somber, serious, negative
  - **Warm** – energetic, alert, active
  - **Cool** – calm, tranquil, peaceful
Elementary Color Theory

- Combination of
  - Physics: wavelengths in nm
  - Biology: perception of “red” vs “yellow” vs...

- Visible spectrum: 390-700nm
  - Spectral colors: rainbow, single wavelength
  - Nonspectral colors (pink, brown, white...) result from presence of *multiple* wavelengths
Power Spectrum = Color
Color Perception

- Human eyes have 3 types of cones
  - Respond to different wavelengths (LMS)
- Perceived color = eye's cone response
Metamerism

- Different (continuous) spectra that stimulate our eyes in identical ways
  - Consequence: Different spectra with indistinguishable (to humans) color

- Example: white
  - Spectrum 1: all wavelengths equally present
  - Spectrum 2: a few wavelengths present, stimulating LMS cones equally

- Consequence: Any continuous spectrum can be projected down to 3 components (as far as human eyes are concerned)
  - XYZ “tristimulus values”
  - Not truly independent (overlap of response), so any 2 give the 3\(^{rd}\); ie a 2D space...
CIE 1931 xy Chromaticity

Max luminance (100%)

Perceivable colors

Spectral (pure) colors
There are two ways to combine colors

1. Subtractive: Color is a filter
   - Mixing = filter out both
   - Used for printing (& dyes, paints, gels)

2. Additive: Color is a light source
   - Mixing = sum
   - Used for monitors
Subtractive Color Mixing: CMYK

- Filters transmit different *spectra*
  - Mixture transmits the *product* of both
  - Mix all three primaries = black

- Primary colors: cyan, magenta, yellow
  - Black (K) added for quality and cost
  - Traditional set (RYB) popular for painting

Primary yellow (transmits R & G) (absorb B)
Colors as Filters

Yellow: Filters out (only) blue

Rosi et al., Euro. J. of Physics, 37(6), 2016
Additive Color Mixing: RGB Cube

primary
secondary

blue
cyan

magenta

red
green

yellow

#fff /* white */
#000 /* black */

http://www.flickr.com/photos/ethanhein/3103830956/
Color Mixing: sRGB Gamut
Gamuts for Monitors

And Many More Gamuts...
HSL Color Wheel (50% Lightness)

Hue

Saturation

HSL Color Wheel (100% Sat)

HSL Color Space: 3D Cylinder
HSL Color Space: 3D Cylinder
HSL Grid for Red (i.e. 0, S, L)

- (0, 75%, 88%)
- (0, 100%, 50%)
- (0, 0%, 25%)
CSS Color Values

- Keywords: case-insensitive identifiers
  red, navy, firebrick, chocolate

- RGB as decimal (0-255), percentage, or hex
  \[\text{rgb} \ (255, \ 0, \ 0) \ /* \text{pure red} */\]
  \[\text{rgb} \ (100\%, \ 0\%, \ 0\%)\]
  \[#ff0000\]
  \[#f00 \ /* \text{expand by doubling each digit} */\]

- HSL (Hue, Saturation, Light)
  - Hue (0-360) is angle on color wheel: 0 is red, 120 green, 240 blue
  - Saturation & light are both %'s
    \[\text{hsl} \ (0, \ 100\%, \ 50\%) \ /* \text{full bright red} */\]

- Alpha channel (transparency): 1 is opaque!
  \[\text{rgba} \ (255, \ 0, \ 0, \ 0.5)\]
  \[\text{hsla} \ (0, \ 100\%, \ 50\%, \ 1)\]
Color Keywords: 147 (141 dist.)

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<th>aliceblue</th>
<th>antiquewhite</th>
<th>aqua</th>
<th>aquamarine</th>
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<th>beige</th>
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</tbody>
</table>
Color Depth

- “Depth” = # of bits in representation
  - 8 bits → 256 different colors
  - 24 bits → 16,777,216 different colors (eg 8 bits each for r, g, b)
- Alpha may be (incorrectly) included
  - rgba is a point in 4-dimensional space
- Problem: image color depth > display color depth
  - Quantization: each pixel gets closest available color (leads to banding)
  - Dithering: add noise, which looks better!
Quantization of Continuous Func
Quantization vs Dithering

original

quantized

dithered
Quantization vs Dithering

Original Image  GIF without dithering  GIF with dithering

HTML `<img>` Tag Attributes

- `src`: location (URL) of image file
- `width, height`: 
  - Area in *window* to reserve for image 
  - Image is *scaled* to those dimensions 
  - These attributes affect browser flow, regardless of when/if image is displayed
- `alt`: text to show if graphic can not be displayed or seen (ie alternative)
- `title`: text to *augment* displayed graphic (eg tooltip)
Image Representation

- Raster vs vector graphics
  - Raster: stored pixel-by-pixel
  - Vector: mathematical description

- Compression of raster images
  - Lossy: better compression, lower quality image
  - Lossless: largest file size, best quality
Major Formats

- **GIF**
  - Raster graphics, lossy compression (oldest)
  - 8 bit, basic transparency (on/off)
  - Frame-based animation (groan)
  - Good for small file size, crisp lines, logos

- **JPEG**
  - Raster, lossy compression
  - 24 bit, no transparency
  - Good for photos, gradual gradients

- **PNG**
  - Raster, lossless (but still often good) compression
  - Variable depth, full alpha transparency
  - Good replacement for GIF (but no animation)

- **SVG**
  - Vector graphics
  - Good for crisp lines, simple logos, graphs
Scaling Images

○ Vector graphics scale perfectly

○ Raster images should be *pre-scaled*
  ○ Width (height) attributes of image tag should match actual width (height) of image
  ○ Why?
  ○ Cloud services can help (eg cloudinary.com)
Alternative: CSS

```css
.button {
    display: inline-block;
    padding: 0.3em 1.2em;
    margin: 0 0.3em 0.3em 0;
    border-radius: 2em;
    box-sizing: border-box;
    text-decoration: none;
    font-weight: 300;
    color: #FFFFFF;
    background-color: #4eb5f1;
    text-align: center;
    transition: all 0.2s;
}
```
Summary

- Color theory
  - Perception, metamerism
  - Mixing: subtractive, additive
  - RGB, HSL, keywords

- Images
  - Quantization and dithering
  - Raster graphics vs vector graphics
  - Formats jpeg, png, gif, svg
  - Tradeoffs of size, quality, features