Creative Computing II

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Autumn 2010, Wednesdays:
10:00–12:00: RHB307 & 14:00–16:00: WB316
Winter 2011, TBC

Colour Spaces

Colour Spaces

How to specify a colour?

Examples:

- device-dependent spaces:
  - RGB (Red-Green-Blue)
  - HSB (Hue-Saturation-Brightness)
  - CMY (Cyan-Magenta-Yellow)
  - CMYK (Cyan-Magenta-Yellow-Key)
  - *HSL*, *YCrCb*...

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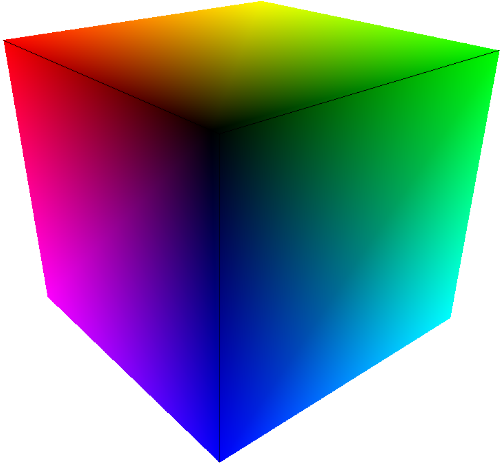
  - CMY (Cyan-Magenta-Yellow)
  - CMYK (Cyan-Magenta-Yellow-Key)
  - *HSL*, *YCrCb*...
- device-independent spaces:
  - CIE XYZ;
  - CIE xyY;
  - CIE La*b*;
  - sRGB;
  - *CIE Luv*, *Adobe RGB*, *Pantone*...

Colour Spaces

The RGB colour space



Colour Spaces

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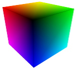

A colour is specified using three numbers:

- the quantity of **red**;
- the quantity of **green**;
- the quantity of **blue**.

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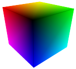

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- the quantity of **red**;
- the quantity of **green**;
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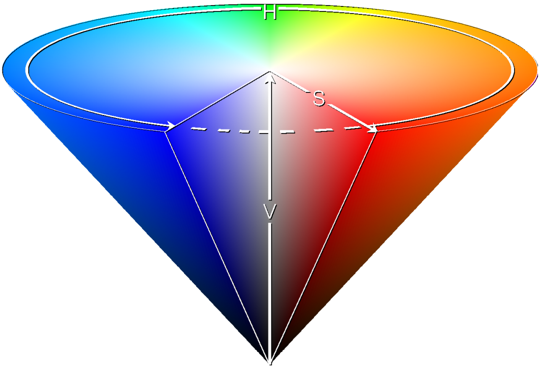
Colours can be represented by a location in 3D space:

- $x_{\text{RGB}} = r$
- $y_{\text{RGB}} = g$
- $z_{\text{RGB}} = b$

Colour Spaces

The HSB colour space



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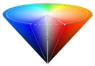
Colour Spaces

The HSB colour space

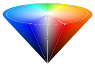


A colour is specified using three numbers:

- the **hue** angle (*which* colour);
- the hue **saturation** (*how much* colour);
- the **brightness** (how much *light*).

Colour Spaces

The HSB colour space



A colour is specified using three numbers:

- the **hue** angle (*which* colour);
- the hue **saturation** (*how much* colour);
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Location of a colour in 3D space:

- $x_{\text{HSB}} = s\beta \cos h$
- $y_{\text{HSB}} = s\beta \sin h$
- $z_{\text{HSB}} = \beta$

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Conversions between RGB and HSB

RGB $\rightarrow$ HSB

- $\max = \max(r, g, b)$;
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- $h = \begin{cases} 0 & \max = \min; \\ \frac{\pi}{3} \times \frac{g-b}{\max-\min} \bmod 2\pi & \max = r; \\ \frac{2\pi}{3} + \frac{\pi}{3} \times \frac{b-r}{\max-\min} & \max = g; \\ \frac{4\pi}{3} + \frac{\pi}{3} \times \frac{r-g}{\max-\min} & \max = b; \end{cases}$

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- $$s = \begin{cases} 0 & \text{max} = 0; \\ 1 - \frac{\text{min}}{\text{max}} & \text{otherwise} \end{cases}$$

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- $\beta = \text{max}$.

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Conversions between RGB and HSB

HSB $\rightarrow$ RGB

- $i = \left\lfloor \frac{3h}{\pi} \right\rfloor$;
- $f = \frac{3h}{\pi} - i$;

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- $f = \frac{3h}{\pi} - i$;
- $$\begin{aligned} p &= \beta \times (1 - s) \\ q &= \beta \times (1 - f \times s) \\ t &= \beta \times (1 - (1 - f) \times s) \end{aligned}$$

Colour Spaces

Conversions between RGB and HSB

HSB $\rightarrow$ RGB

- $i = \left\lfloor \frac{3h}{\pi} \right\rfloor;$
- $f = \frac{3h}{\pi} - i;$
- $$\begin{aligned} p &= \beta \times (1 - s) \\ q &= \beta \times (1 - f \times s) \\ t &= \beta \times (1 - (1 - f) \times s) \end{aligned}$$
- $$(r, g, b) = \begin{cases} (\beta, t, p) & i = 0; \\ (q, \beta, p) & i = 1; \\ (p, \beta, t) & i = 2; \\ (p, q, \beta) & i = 3; \\ (t, p, \beta) & i = 4; \\ (\beta, p, q) & i = 5; \end{cases}$$

Colour Spaces

Additive Colour Models

The RGB model is *additive*

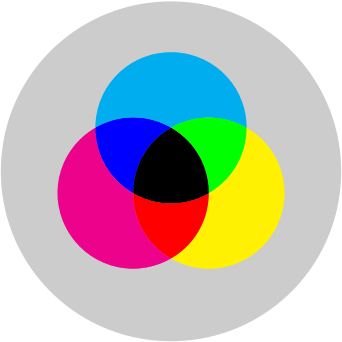
Three primaries:

- colours formed by **linear combination**;
- Grassmann's laws.

Colour Spaces

Subtractive Colour Models

Light filters:



Three 'primaries', each *subtracting* light from white:

- **cyan** (−red); **magenta** (−green); **yellow** (−blue).

Colour Spaces

Subtractive Colour Models

Printing solid colours:

- white comes from light reflecting from the paper;
- colour achieved by filtering through coloured inks.

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CMYK or *process colour* model:

- inks for the **c**yan, **m**agenta and **y**ellow primaries;

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Subtractive Colour Models

Printing solid colours:

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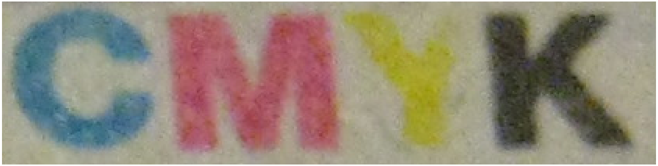
CMYK or *process colour* model:

- inks for the **c**yan, **m**agenta and **y**ellow primaries;
- '**k**ey' ink:
  - not necessarily pure black;
  - cheaper than mixing subtractive primaries;
  - allows fine-detail on (black) text.

Colour Spaces

Subtractive Colour Models

Primaries:



Colour Spaces

Subtractive Colour Models

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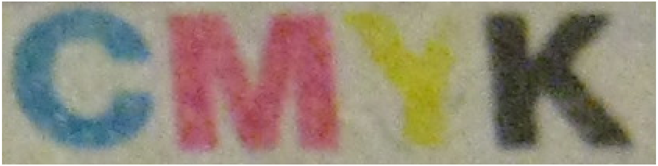
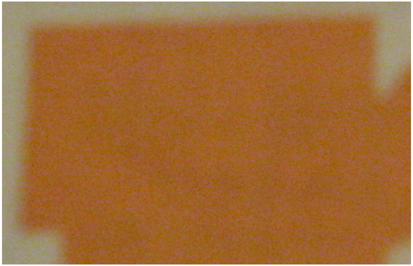


Mixtures can form other solid colours:



How to *lighten* colours in subtractive models?

- with light projector and filters: add white;
- in printing: **halftoning**.

Colour Spaces

Colour Mixing: Area Averaging

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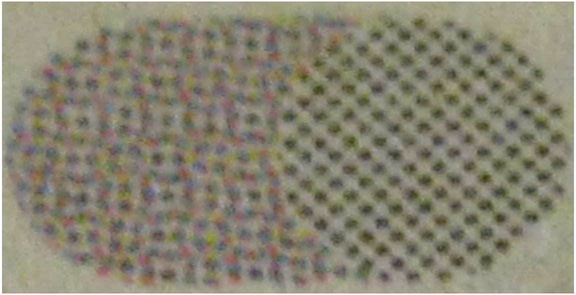

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Colour Mixing: Area Averaging

Colour mixture by *averaging*:

- visual system itself performs the mixing.

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Uses of averaging by **area**:

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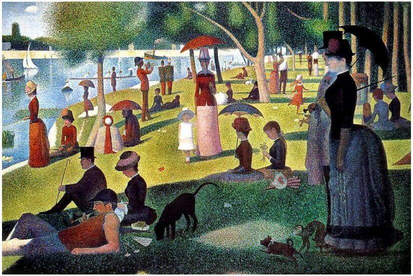
Colour Mixing: Area Averaging

Colour mixture by *averaging*:

- visual system itself performs the mixing.

Uses of averaging by **area**:

- dithering (on digital displays);
- halftoning (in printing);
- pointillism:



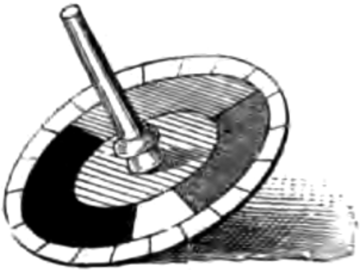
Un dimanche après-midi à l'Île de la Grande Jatte, G. Seurat (1859–1891)

Colour Spaces

Colour Mixing: Time Averaging

Averaging over **time** by the visual system:

- used by James Clerk Maxwell (1831–1879) in colour systematization.



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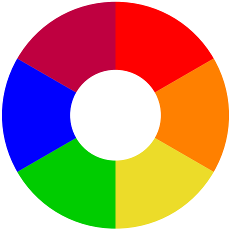
Colour Spaces

Colour Mixing: Pigments

red, yellow and blue "primaries"

- convenient for school paints;
- perceptually reasonable (cf. opponent process).



Mixing paints *much* less systematic (in general) than this.

- same colours can be *metamers*;
- physics and chemistry of mixing affects colour.