

Lecture 2: An Introduction to Colour Models

An important issue in visual media, and multimedia, is colour. Just as there are a multitude of file formats for computer graphics, there are a range of Colour Models commonly used to describe colour both on the computer monitor and on the printed page. By understanding the different ways in which colour can be described or categorised, it is possible to standardise colour output and display in your printed and visual work.

“In order to categorize color in some way that provides consistent communication of that color, the idea of Colour Models came into being. Models of color are methods by which colors are grouped for specific purposes” (Color for Websites, 2000).

What are Colour Models?

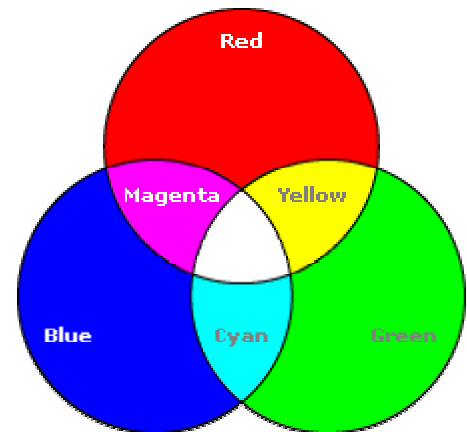
While far from the complete list, the major colour models used to describe colour within multimedia are: Bitmap, Grayscale, RGB, Hexadecimal, Web Safe, CMY/CMYK, Process and Spot/PMS.

Because of the differences in the way colour is displayed in different media, a range of colour models are needed. This being said, many of the models are interrelated, so an understanding of the major types is essential to developing a true understanding of colour representation.

“There are two types of colour models, those that are subtractive and those that are additive. Additive colour models use light to display colour, while subtractive models use printing inks. Colours perceived in additive models are the result of transmitted light. Colours perceived in subtractive models are the result of reflected light. There are several established colour models used in computer graphics, but the two most common are the RGB model (Red-Green-Blue) for computer display and the CMYK model (Cyan-Magenta-Yellow-black) for printing”.

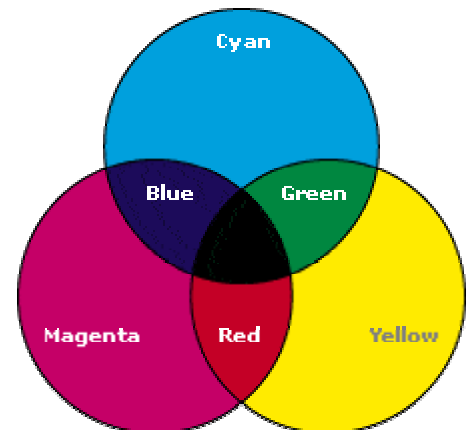
Additive colour model (RGB)

- For computer displays
- Uses light to display colour
- Colours result from transmitted light
- Red + Green + Blue = White



Subtractive colour model (CMY)

- For printed material
- Uses ink to display colour
- Colours result from reflected light
- Cyan + Magenta + Yellow = Black



(<http://www.sketchpad.net/basics4.htm>)

Black, White and Shades of Gray

Bitmap

The simplest of all the colour models is bitmap (not to be confused with the file format of the same name or the subcategory of images also using that term!). Bitmap in terms of colour models refers to a model where there are only 2 possible values: black or white. The bitmap model is infrequently used (due to the lack of tonal transition) except for monotone images such as clipart.

Grayscale

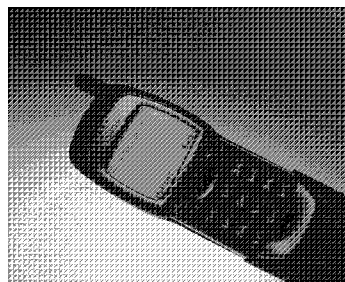
The grayscale colour model (as the name implies) offers a tonal range of grays. An 8bit colour model, grayscale has a pure white, a pure black and 254 shades of gray in-between! The grayscale format is best for images such as black and white photographs or any other image where a range of tonal variation between pure black and white is required.



An image with ONLY black and white pixels (and no shades or gray) is ideal for the bitmap colour model.



Where an image has shades of gray, the grayscale model is a better choice



While the bitmap model can be used for images with tonal colour, the result uses dithering or pattern techniques to simulate shading and generally does not work well

Colour models for computer screens/televisions/projection systems

RGB

RGB (Red-Green-Blue) is the model that describes colours for computer screens, televisions and colour projection systems (like data projectors). It is an additive colour model (meaning that red, green and blue light is 'added' together to form other colours). Each colour (red, green and blue) has a possible value of between 0 (no colour) and 255 (full colour) and are expressed in the following way:

R	G	B
0 - 255	0 - 255	0 - 255

The individual number allocated to each colour represents what intensity of each colour is being 'mixed' into the final colour being produced. For example, the RGB value 0, 0, 0 means that no red, green or blue is being added. As such the result will be black (an absence of colour). A value of 255, 255, 255 means that red, green and blue are all being added at full strength. As such, this value is white (the colour which results when red, green and blue are added together equally at full strength in the additive model).

By multiplying the number of potential combinations together (256^3) you can work out that there are a total of 16,777,216 separate colours in the RGB palette. Thinking back to last week's lecture when we talked about colour depth, from this you can ascertain that RGB is a 24bit colour model!

Hexadecimal

The Hexadecimal colour space (often called HEX for short) is based on the RGB colour model. While the actual colours in the Hexadecimal colour model are the same as in the RGB colour model, it is the way they are referred to or numbered which is different. In Hexadecimal, RGB values can be described using less numbers, and it is in this way which colour is most commonly referred to when using HTML.

"Most of the numbers we deal with are written in decimal form, which means that "0" is the lowest value in a given place while "9" is the highest. This means that the successor to the number nine, ten, must be written with a value in the next higher place, i.e. "10". Likewise, ninety-nine is written as "99" while one hundred is written as "100". Because decimal numbers have ten possible digits in a given place, they are referred to as base 10 numbers.

Hexadecimal numbers, on the other hand, are numbers that are written in base 16. That is, there are sixteen possible digits in a given place, therefore, in hexadecimal notation ten is written as "A" while fifteen is written as "F" and sixteen is written as "10". In other words, values greater than nine and less than sixteen are expressed as letters with the highest value being "F".

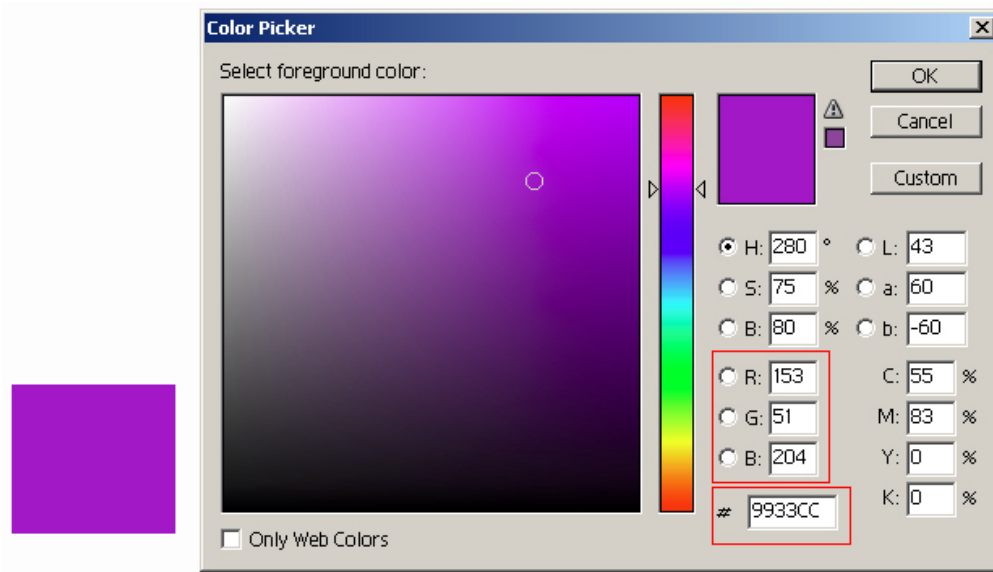
Now, the colours that are displayed on your monitor are a mixture of blue green and red. Each of these colours may be displayed with 256 degrees of intensity. Thus any gradation of a colour may be displayed with a hexadecimal value with two places as: $16 \times 16 = 256$

Therefore the hexadecimal number "00" ("0" in decimal form) represents an absence of a colour, while "FF" ("255" in decimal form) represents its maximum intensity. The three values for the three colours are written as a single six character string to produce 16,777,216 possible colours (e.g. the full range of RGB colours). For instance, 000000 is black, FFFFFFFF is white, FF0000 is red, 00FF00 is green, and 0000FF is blue".

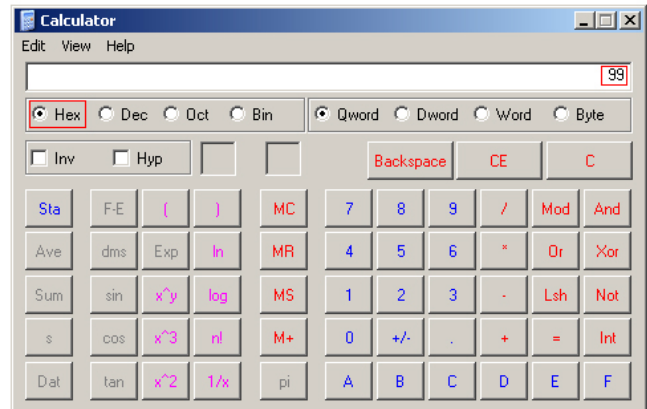
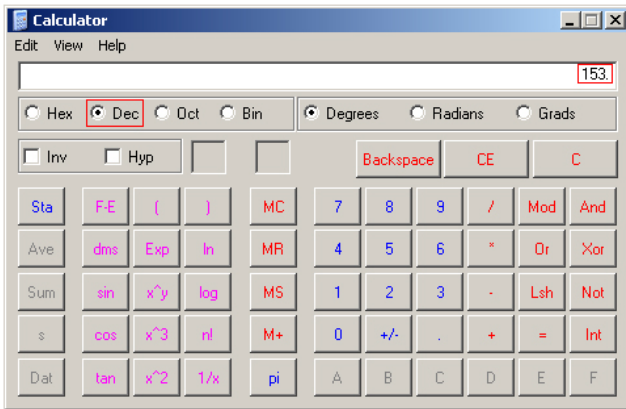
(<http://rainey.bluneptune.com/~felixm/colortest/>)

Remember, because we start numbering at 0, and have 16 values, the Hexadecimal colour model can express every possible RGB colour combination within 6 digits (e.g. 153, 51, 204 becomes 9933CC). The advantage of using Hexadecimal as opposed to RGB is that you can store the same information in less space. In a Hexadecimal code with two digits you can express the numbers 0 through 255. In a decimal code with two digits you can count from 0 to 99. Another advantage is that Hexadecimal (base 16) converts easily to binary (base 2), which is used by computers. A two digit hexadecimal number can range from 0 to 255, which can be expressed in eight digits of binary code.

There are many ways you can convert RGB colour values to Hexadecimal. The easiest two ways are to convert colours in Photoshop or to use a scientific calculator. In Photoshop you can simply sample the colour (or type in the values in the RGB section of the colour dialogue box) and the corresponding Hexadecimal colour will be displayed beneath.



If you're using a scientific calculator, make sure the "Dec" option is enabled and enter the first value (in this case 153 for the red value). Then select the "Hex" option to convert the decimal value to a hexadecimal value. Repeat this for the remaining two values (blue and green) and then put the numbers together in red, green, blue order.



Web Safe Colour

Web safe colour is another colour model, which is related to both the RGB and Hexadecimal colour models. Essentially it is a cut-down version of the RGB palette with only 256 possible colours (of which, in practice, only 216 are used).

“Three or four years ago, most personal computers supported a colour depth of, at best, 8 bits. What does that mean? The digital display of colour tends to be divided into three root colours: red, green, and blue (i.e., RGB). The pixels in your screen then give different intensities to each of these root colours to produce all the other colours. The intensity for each root colour is broken into even units, not because it looks better but because computers like things that way. Currently, and for some time now, that scale has had 256 values. If you start at 0, your scale stops at 255. So, if we have 256 possible values for each of our root colours, that gives a total of 16,777,216 colours ($256 * 256 * 256$), a.k.a. "millions of colours," "True Colour," or "24-bit colour".

Old personal computers didn't have a lot of video memory or very sophisticated video cards, so they could only support a total of 256 colours at a time (out of a possible 16,777,216). 256 colour support, or “colour depth,” is also known as 8-bit colour because it is 2^8 (2 being the basic unit that computers use to store information - a single bit). The questions then are which 256 colours did these old systems use, and why?

As we said, computers like mathematical simplicity, so the palette has to have consistent spacing. We need to find the largest number that can be cubed (to accommodate the three root colours RGB) without its cubed value exceeding 256. That number is 6 ($6 * 6 * 6 = 216$). If you need six points on a scale, you need five spaces. Since we started our scale on 0, not 1, we can divide 255 by 5 and get the result of 51. Therefore, our values are 0, 51, 102, 153, 204, and 255. Any combination of these in the R, G, or B positions results in a valid colour for an 8-bit display. Note that colour values may also be given in hexadecimal form. For example, the decimal (RGB) value triad 51, 204, 102 would be 33CC66 in hex.

In theory, an operating system can display *any* 256 colours, but your machine would take a real performance hit if it had to redraw its palette every time you toggled between applications. Instead, Web browsers convert all colours to static, generic palettes. This gives consistency, which improves performance. The 216 colours we found above are part of the generic palette for both Internet Explorer and Netscape Navigator. You may have noticed, though, that we have 40 colours unaccounted for.

About 20 of those colours are fixed by the operating system itself. Windows and Macintosh, however, don't choose the same set of colours for their system palettes. In order to attain cross-operating system consistency, we eliminate both their system palettes from our design palette. Then there are a few stragglers, which are cut out for simplicity's sake. So, we're back to the evenly spaced 216 colours we got earlier. And that is the web safe - or rather, the cross-Netscape Navigator-Internet Explorer-Windows-Macintosh-8-bit palette”

http://hotwired.lycos.com/webmonkey/00/37/index2a_page2.html?tw=design

As modern systems can display the full range of colours, the Web Safe palette has become less relevant to web design and on-screen display. However, the recent development of hand-held computing devices, picture and video mobile phones and personal organisers etc. (which often only support 8-bit colour) has again brought the Web Safe palette into consideration.

Many experienced designers suggest that even if you don't use the Web Safe colour palette all the way throughout your designs, it's a good idea to choose a web safe colour for your text and background (dithered text is not a pretty sight!). Similarly many designers consider the web safe colour palette when designing logos that are intended for web display as it will ensure that even the most basic system can see the logo as it was intended.

990033 R: 153 G: 000 B: 051	FF3366 R: 255 G: 051 B: 102	CC0033 R: 204 G: 000 B: 051	FF0033 R: 255 G: 000 B: 051	FF9999 R: 255 G: 153 B: 153	CC3366 R: 204 G: 051 B: 102	FFCCFF R: 255 G: 204 B: 255	CC6699 R: 204 G: 051 B: 153	993366 R: 153 G: 051 B: 102	660033 R: 102 G: 000 B: 051	CC3399 R: 204 G: 051 B: 153	FF99CC R: 255 G: 153 B: 204	FF66CC R: 255 G: 102 B: 204	FF99FF R: 255 G: 153 B: 255	FF6699 R: 255 G: 102 B: 153	CC0066 R: 204 G: 000 B: 102
FF0066 R: 255 G: 000 B: 102	FF3399 R: 255 G: 051 B: 153	FF0099 R: 255 G: 000 B: 153	FF33CC R: 255 G: 051 B: 204	FF00CC R: 255 G: 000 B: 204	FF66FF R: 255 G: 102 B: 255	FF33FF R: 255 G: 051 B: 255	FF00FF R: 255 G: 000 B: 255	CC0099 R: 204 G: 000 B: 153	990066 R: 153 G: 000 B: 102	CC66CC R: 204 G: 102 B: 204	CC33CC R: 204 G: 051 B: 204	CC99FF R: 204 G: 153 B: 255	CC66FF R: 204 G: 102 B: 255	CC33FF R: 204 G: 051 B: 255	993399 R: 153 G: 051 B: 153
CC00CC R: 204 G: 000 B: 204	CC00FF R: 204 G: 000 B: 255	9900CC R: 153 G: 000 B: 204	990099 R: 153 G: 000 B: 153	CC99CC R: 204 G: 153 B: 204	996699 R: 153 G: 102 B: 153	663366 R: 102 G: 051 B: 102	660099 R: 102 G: 000 B: 153	9933CC R: 153 G: 051 B: 204	660066 R: 102 G: 000 B: 102	9900FF R: 153 G: 000 B: 255	9933FF R: 153 G: 051 B: 255	9966CC R: 153 G: 102 B: 204	330033 R: 051 G: 000 B: 051	663399 R: 102 G: 051 B: 153	6633CC R: 102 G: 051 B: 204
6600CC R: 102 G: 000 B: 204	9966FF R: 153 G: 102 B: 255	330066 R: 051 G: 000 B: 102	6600FF R: 102 G: 000 B: 255	6633FF R: 102 G: 051 B: 255	CCCCFF R: 204 G: 204 B: 255	9999FF R: 153 G: 153 B: 255	9999CC R: 153 G: 153 B: 204	6666CC R: 102 G: 102 B: 204	6666FF R: 102 G: 102 B: 255	666699 R: 102 G: 102 B: 153	333366 R: 051 G: 051 B: 102	333399 R: 051 G: 051 B: 153	330099 R: 051 G: 000 B: 153	3300CC R: 051 G: 000 B: 204	3300FF R: 051 G: 000 B: 255
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009999 R: 000 G: 153 B: 153	669999 R: 102 G: 153 B: 153	99CCCC R: 153 G: 204 B: 204	CCFFFF R: 204 G: 255 B: 255	33CCCC R: 051 G: 204 B: 204	66CCCC R: 102 G: 204 B: 204	339999 R: 051 G: 153 B: 153	336666 R: 051 G: 102 B: 102	006666 R: 000 G: 102 B: 102	003333 R: 000 G: 051 B: 051	00FFCC R: 000 G: 255 B: 204	33FFCC R: 051 G: 255 B: 204	33CC99 R: 051 G: 204 B: 153	00CC99 R: 000 G: 204 B: 153	66FFCC R: 102 G: 255 B: 204	99FFCC R: 153 G: 255 B: 204
00FF99 R: 000 G: 255 B: 153	339966 R: 051 G: 153 B: 102	006633 R: 000 G: 102 B: 051	336633 R: 051 G: 102 B: 051	669966 R: 102 G: 153 B: 102	66CC66 R: 102 G: 204 B: 102	99FF99 R: 153 G: 255 B: 153	66FF66 R: 102 G: 255 B: 102	339933 R: 051 G: 153 B: 051	99CC99 R: 153 G: 204 B: 153	66FF99 R: 102 G: 255 B: 153	33FF99 R: 051 G: 255 B: 153	33CC66 R: 051 G: 204 B: 102	00CC66 R: 000 G: 204 B: 102	66CC99 R: 102 G: 204 B: 153	009966 R: 000 G: 153 B: 102
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009900 R: 000 G: 153 B: 000	33FF00 R: 051 G: 255 B: 000	66FF00 R: 102 G: 255 B: 000	99FF00 R: 153 G: 255 B: 000	66CC00 R: 102 G: 204 B: 000	00CC00 R: 000 G: 204 B: 000	33CC00 R: 051 G: 204 B: 000	339900 R: 051 G: 153 B: 000	99CC66 R: 153 G: 204 B: 102	669933 R: 102 G: 153 B: 051	99CC33 R: 153 G: 204 B: 051	336600 R: 051 G: 102 B: 000	669900 R: 102 G: 153 B: 000	99CC00 R: 153 G: 204 B: 000	CCFF66 R: 204 G: 255 B: 102	CCFF33 R: 204 G: 255 B: 051
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FFCC00 R: 255 G: 204 B: 000	FFCC66 R: 255 G: 204 B: 102	FFCC33 R: 255 G: 204 B: 051	CC9933 R: 204 G: 153 B: 051	996600 R: 153 G: 102 B: 000	CC9900 R: 204 G: 153 B: 000	FF9900 R: 255 G: 153 B: 000	CC6600 R: 204 G: 102 B: 000	993300 R: 153 G: 051 B: 000	CC6633 R: 204 G: 102 B: 051	663300 R: 102 G: 051 B: 000	FF9966 R: 255 G: 153 B: 102	FF6633 R: 255 G: 102 B: 051	FF9933 R: 255 G: 153 B: 051	FF6600 R: 255 G: 102 B: 000	CC3300 R: 204 G: 051 B: 000
996633 R: 153 G: 102 B: 051	330000 R: 051 G: 000 B: 000	663333 R: 102 G: 051 B: 051	996666 R: 153 G: 102 B: 102	CC9999 R: 204 G: 153 B: 153	993333 R: 153 G: 051 B: 051	CC6666 R: 204 G: 102 B: 102	FFCCCC R: 255 G: 204 B: 204	FF3333 R: 255 G: 051 B: 051	CC3333 R: 204 G: 051 B: 051	FF6666 R: 255 G: 102 B: 102	660000 R: 102 G: 000 B: 000	990000 R: 153 G: 000 B: 000	CC0000 R: 204 G: 000 B: 000	FF0000 R: 255 G: 000 B: 000	FF3300 R: 255 G: 051 B: 000
CC9966 R: 204 G: 153 B: 102	FFCC99 R: 255 G: 204 B: 153	FFFFFF R: 255 G: 255 B: 255	CCCCCC R: 204 G: 204 B: 204	999999 R: 153 G: 153 B: 153	666666 R: 102 G: 102 B: 102	333333 R: 051 G: 051 B: 051	000000 R: 000 G: 000 B: 000								

The 216 Netscape Navigator/Internet Explorer/Windows/Macintosh 8-bit palette 'web safe' colour palette.

<http://www.lynda.com/hexh.html>

Colour Models for printing

CMY/CMYK Colour Model

“The CMYK (Cyan – Magenta – Yellow - black) model is based upon the combination of four inks commonly used to print images. Upon close inspection of a printed color image, one can see that what appears to be a solid color is actually composed of tiny dots of cyan, magenta, yellow, and black. When light shines on a printed image, part of the spectrum is absorbed by the inks while the rest is reflected off to create visible colors. Because this is a reflected rather than direct light source, printed CMYK colors cannot achieve the same level of brightness as RGB colors on a display monitor and thus appear darker and more saturated. A CMYK color is represented with a series of four percentages corresponding to the four inks; for example, a sky blue color would be: C=60% Y=40% M=0% K=0%”

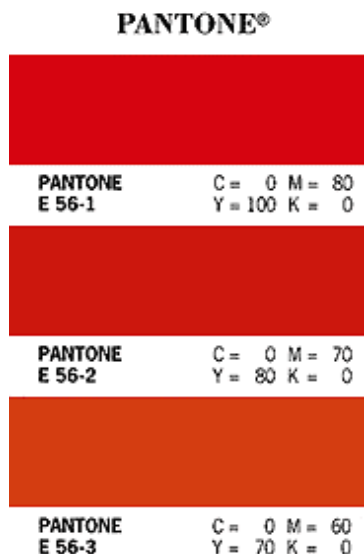
<http://et.sdsu.edu/sphares/colormodels.htm>

With the CMYK colour model, it is possible to describe a total of 100^4 colours (100,000,000). In practice, however, it is standard to ‘round’ the percentages describing each of the inks to the nearest 5 or 0. For example, while it is possible to describe a CMYK colour as 61, 22, 78, 92 it would be much more common to represent this as 60, 20, 80, 90. Generally, individual percentiles are only used when an *exact* colour match is required.

You will remember from earlier that as a subtractive colour model the combination of Cyan, Magenta and Yellow inks should be enough to produce black – and in theory this is true. In practice, however, due to impurities in the printing inks, the combination of these colours results in a dark murky brown. To combat this, it is typical for printers to use a black ink to enable the printing of a ‘pure’ black. Sometimes, however, printers will use just the CMY model (this is more common when printing a very pale full colour image without deep shades or black within the image). CMYK printing is also called ‘full colour’ or ‘process’ printing, which can be a bit confusing as in 1968 Pantone introduced the “Four-Colour Process Guide” to also describe CMYK (or process) colour.

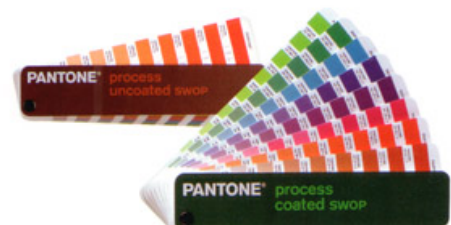
Pantone Four-Colour Process Guide

The Pantone Four-Colour Process Guide relates to CMYK in that it is a sample of the possible number of colours. As we discussed earlier, it is possible to describe 100,000,000 different colours using the CMYK colour model. In practice, however, there is unlikely to be any visible difference between 100, 99, 100, 100 and 100, 100, 100, 100. The Pantone Four-Colour Process Guide is a printed booklet, which has around 3000 commonly, used CMYK colours (expressed in 10% increments). The books are designed to allow *exact* colour matching to take place between computer and press.



Using the Pantone Four-Colour Process Guide, you can specify with extreme accuracy the output of your CMYK colours. One limitation of the CMYK model, is that it can not produce very ‘pure’ bright colour – CMYK colours are typically darker and less vibrant than RGB colours. This is particularly evident in bright reds, hot pinks and electric blues. To combat this, Pantone introduced another system – Spot/Solid Colour.

On an aside – the Four-Colour Process Guide comes in three varieties: coated, uncoated and matte. This is because colours can look slightly different depending on what ‘stock’ or paper type they are printed on.



Spot/Solid Colour (also called the Pantone Matching System or PMS)

Where process colour is made up of a combination of Cyan, Magenta, Yellow and Black, spot colour is a *premixed* ink. Because the colour is mixed before printing (very much like mixing paint!) it is possible to achieve a vibrancy of colour not possible when combining four inks on the actual page.

There are a lot of reasons why spot colour might be used, but the major two are:

- To get a perfect match of colour (for a logo etc.) when process colour can not achieve this (the Kellogg's cereal packets are a good example of this)
- When a print job is being printed in only one or two colours – it is cheaper to mix the exact colour(s) required and run the paper through the printing press once or twice than have to run the paper through the press four times to achieve the same result in CMYK

Like the Pantone Four-Colour Process Guide, PMS colours are presented in a booklet and come in coated, uncoated and matte versions. A total of 1,114 colours are represented in the standard guide, although recently Pantone has produced a range of other guides to assist in the specification of other non-standard inks such as:

- Tints (where a PMS colour is printed at a percentage of its full value)
- Duotone (where two PMS colours are printed one on top of another at different percentages to enable a range of colours)
- Metallic inks
- Florescent inks
- Pearlescent inks

The conversion from process to PMS is a tricky one, but to help with this Pantone have produced a guide to assist designers in choosing colours which can be represented by both colour models.

In fact, there are now a range of books which list RGB/Web Safe/Process/PMS colour equivalents, so that a designer can ensure logos etc. can appear identical across a range of media.



Further Reading

Color for Websites

Author: Holzaschlag, Molly E.

www.color

Author: Pring, Roger

Color graphics: the power of color in graphic design

Author: Triedman, Karen

Digital color and type

Author: Carter, Rob