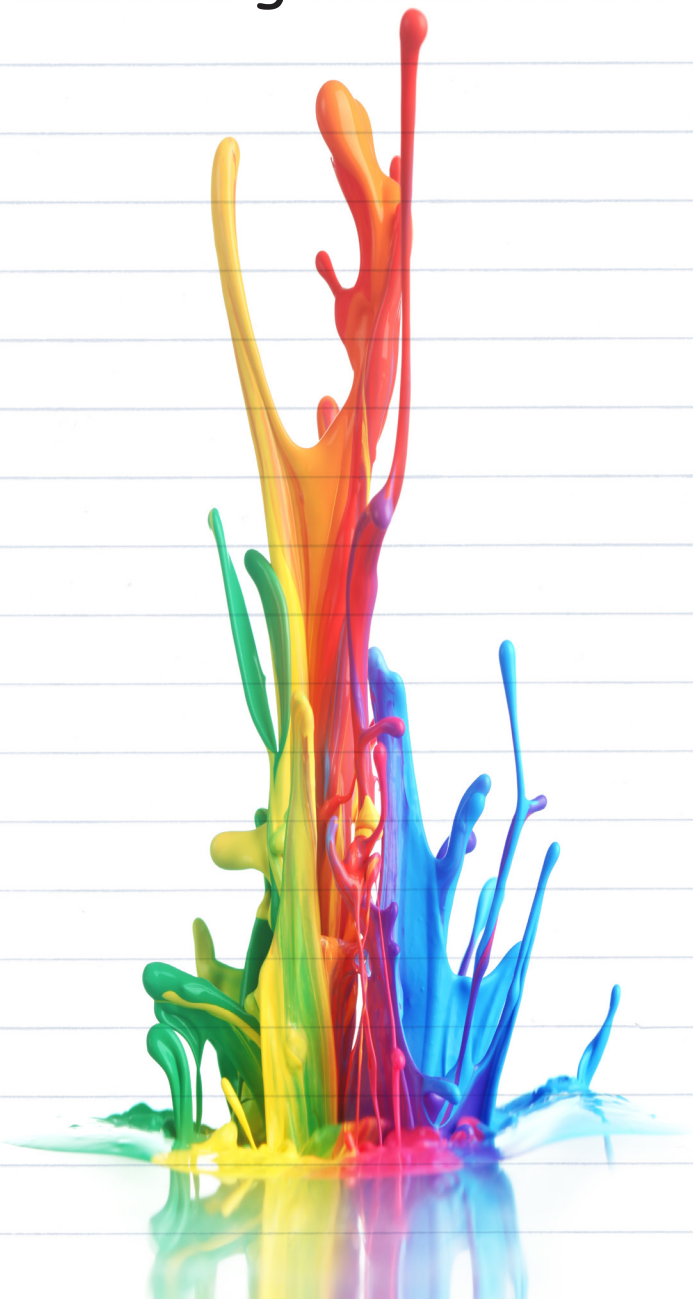
Color Printing

Why do my colors not match the colors I want?

or

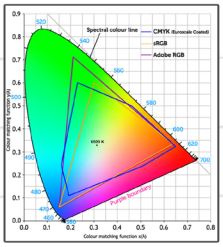
Why won't the printer print the right colors?



A color space is a specific organization of colors. In combination with physical device profiling, it allows for reproducible representations of color, in both analog and digital representations.

RGB
additive

CMYK
subtractive



CMYK Processing Method

Full (output GCR)
Full (Source GCR)
Pure Primaries

Within the CMY color space, a range of colors can be achieved by combining the three primaries. This combination in its turn can be thought of as a hue component (which will require a maximum of two primary colors) and a gray component (a mixture of all three, in an appropriate quantity to give the required saturation). If the gray component is replaced by black ink, the same color is being achieved by using two primaries and black. The act of substituting a quantity of black for the gray component is known as "Grey component replacement" (GCR).

RGB Rendering Intents

Photographic (Perceptual)
Presentation (Saturation)
Relative Colorimetric
Absolute Colorimetric

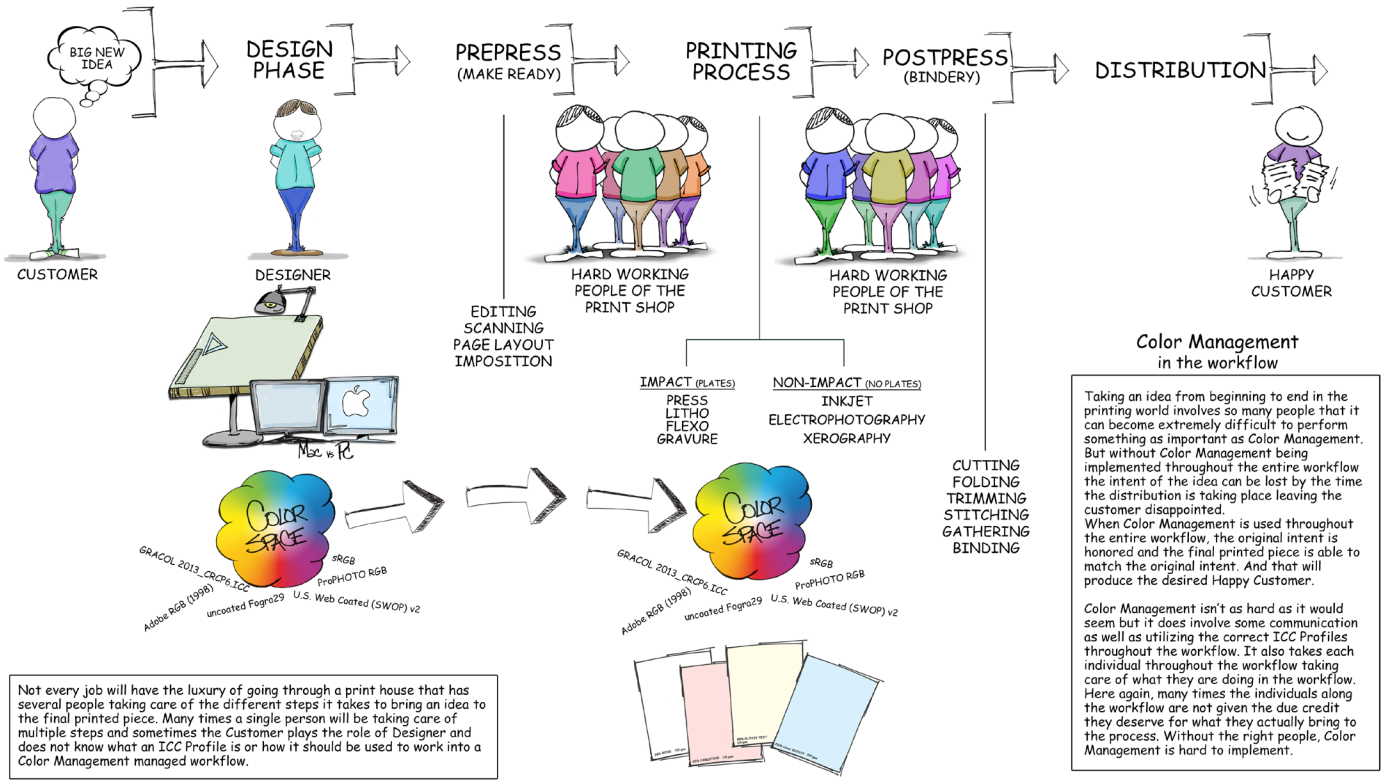
Perceptual
Compresses the total gamut from one device's color space into the gamut of another device's color space when one or more colors in the original image is out of the gamut of the destination color space. This preserves the visual relationship between colors by shrinking the entire color space and shifting all colors – including those that were in

Saturation
Reproduces the original image color saturation (vividness) when converting into the target device's color space. In this approach, the relative saturation of colors is maintained from gamut to gamut. This render intent is primarily designed for business graphics, where the exact relationship between colors (such as in a photographic image) is not as important as are bright saturated colors.

Relative Colorimetric
When a color in the current color space is out of gamut in the target color space, it is mapped to the closest possible color within the gamut of the target color space, while colors that are in gamut are not affected. Only the colors that fall outside of the destination gamut are changed. This render intent can cause two colors, which appear different in the source color space, to be the same in the target color space. This is called "clipping."

Absolute Colorimetric
Colors match exactly with no adjustment made for white point or black point that would alter the image's brightness. Absolute colorimetric is valuable for rendering "signature colors", those colors that are highly identified with a commercial product.

CONVENTIONAL PRINT WORKFLOW FROM IDEA TO DISTRIBUTION



Not every job will have the luxury of going through a print house that has several people taking care of the different steps it takes to bring an idea to the final printed piece. Many times a single person will be taking care of multiple steps and sometimes the Customer plays the role of Designer and does not know what an ICC Profile is or how it should be used to work into a Color Management managed workflow.

Color Management in the workflow

Taking an idea from beginning to end in the printing world involves so many people that it can become extremely difficult to perform something as important as Color Management. But without Color Management being implemented throughout the entire workflow the intent of the idea can be lost by the time the distribution is taking place leaving the customer disappointed.
When Color Management is used throughout the entire workflow, the original intent is honored and the final printed piece is able to match the original intent. And that will produce the desired Happy Customer.

Color Management isn't as hard as it would seem but it does involve some communication as well as utilizing the correct ICC Profiles throughout the workflow. It also takes each individual throughout the workflow taking care of what they are doing in the workflow. Here again, many times the individuals along the workflow are not given the due credit they deserve for what they actually bring to the process. Without the right people, Color Management is hard to implement.

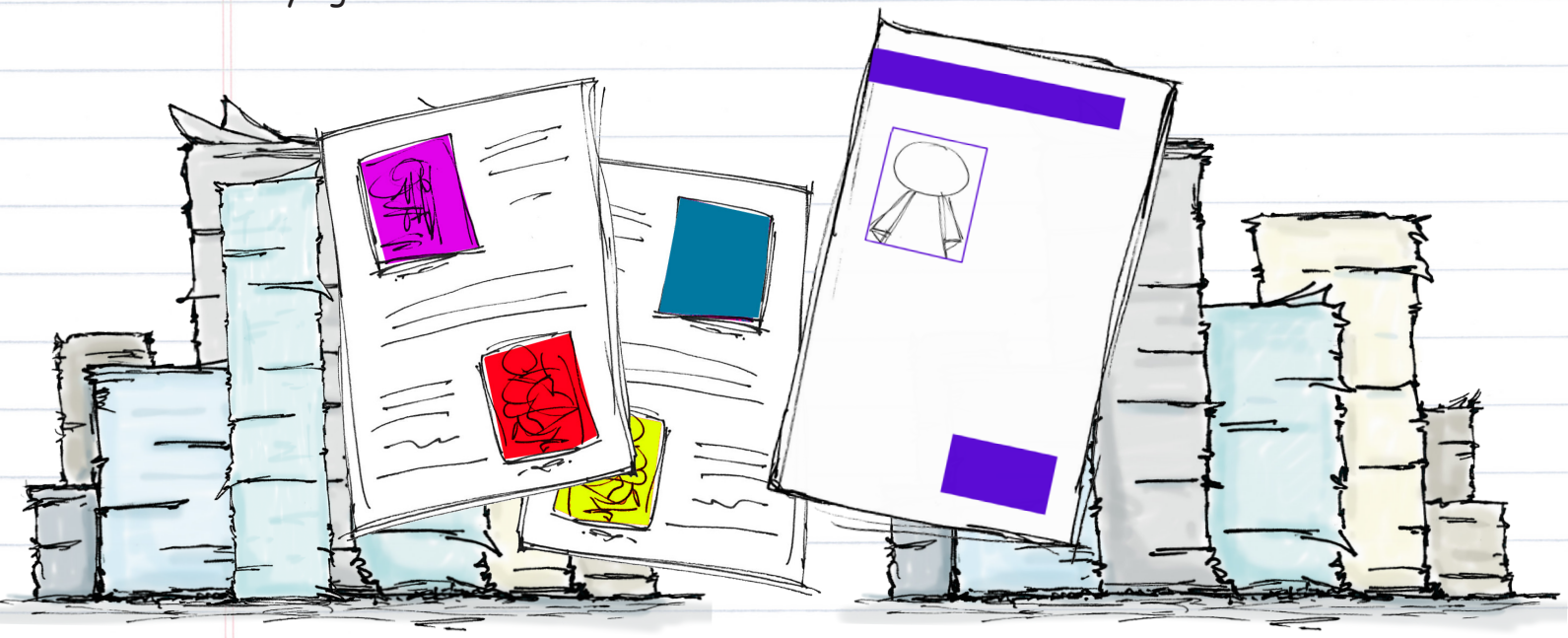
It really is a frustrating thing, isn't it? You spend countless hours designing and making everything just right and then the printer has the audacity to give you the wrong colors!

Can there be a simple answer?

Yes and no, well yes but the answer could come across as being a bit rude and as most of us know, there isn't always just one answer to a question, sometimes, maybe almost always. The tougher the question...

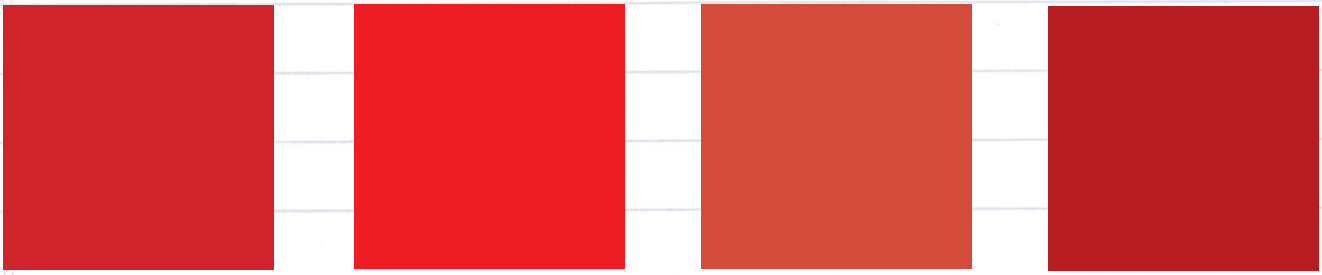
The answer is within the world of printing, meaning there are times that you do not have all of the control you wish you did to get the outcome you desire and then there are times that the world of printing is playing tricks with you, sort of.

I'm trying to be kind and delicate because the world of printing depends on the universe of color and the universe of color honestly doesn't have much room for swaying. The universe of color is actually very exact and it's us that do the swaying.



What is the color Red?
What about Blue and Green? Within that, what is Yummy Purple?

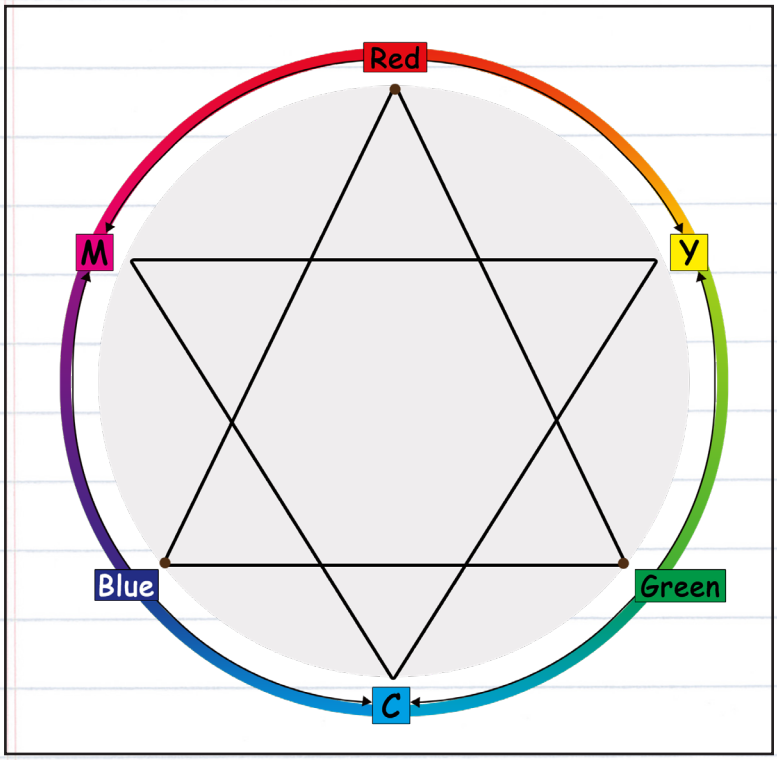
Can you describe what the color Red is? Before you jump to quick, you might want to think about this.



Four squares and they all are, Red, aren't they?
Well they all maybe look somewhat Red and you certainly couldn't say they were Green or Blue but which one, if any is really true Red?
And that's the question within the question!
How do you describe what Red is? Is it firetruck red or maybe strawberry red, red as a good apple red. A little darker red please, no, a bit more lighter red.

The problem is, descriptions alone cannot tell us what Red is and the red you see may not be the red I see, especially if you are standing outside and I am standing inside.

Light has a lot to do with the "colors" we see. However, we will not be addressing the issues that come along with the discussion of how light plays into what color you see.



The reality of it is, each and every color has a unique mathematical number that can be assigned to it and that number is what makes that color the color that it is.

We need a better way to decide what Red is and the best way to do that is to get to the numbers. All colors have numbers and in some ways colors are more numbers than they are colors. Numbers won't lie to us because the numbers won't change. Along with that we need to know that in the digital printing world, Red is not a color. Blue and Green are not colors either, not by themselves or I should say that they do not exist as primary colors. The digital printing world uses Cyan, Magenta and Yellow with Black added in as the forth "color". Black adds a couple of things that the three primary colors cannot do on their own.

First, Black ink or toner adds, as you might suspect, darkness. By adding black to an image, it will get "darker" with a correspondingly higher amount of black.

Secondly, it gives us a way of printing text and lines in a pure black "color".

You will get "black" by adding Cyan, Magenta and Yellow together but it is a processed black, never true black. It will actually look more like a dark muddy brown.

The diagram shows a color wheel with Cyan, Magenta and Yellow as the primary colors. Red, Green and Blue are the Complementary numbers.

A complementary color? What is a complementary color?

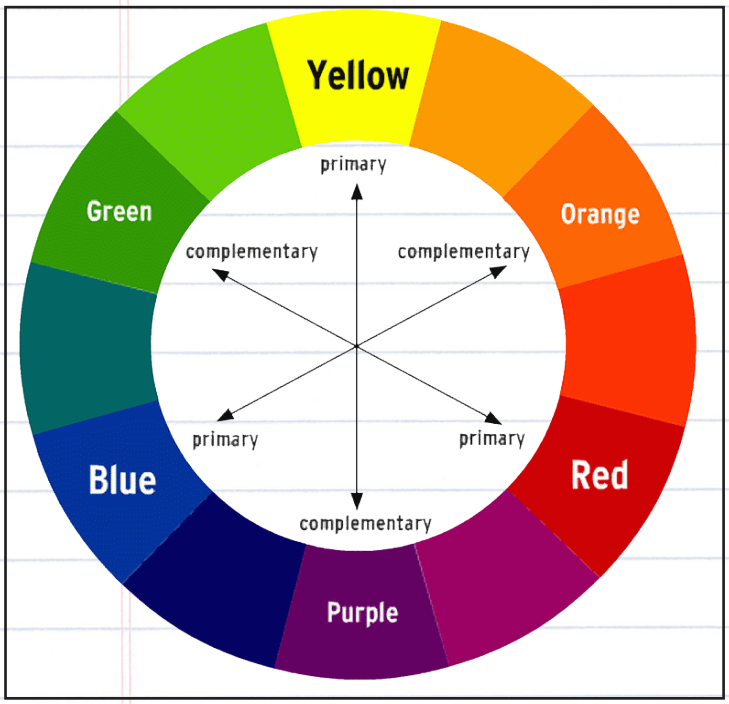
> Marion Bobby-Evan states, "Complementary colors are two colors that are on opposite sides of the color wheel. At the heart of color theory, complementary colors are the opposite hues on the color wheel. In their most basic form, they are one primary color and the secondary color that is created by mixing the other two primaries. For instance, the complementary color to yellow is purple, which is a mix of blue and red."
>
> But we must first remember what color circle we use in the world of digital printing, otherwise we will not be speaking the same colors.
>
> "A printer's color wheel works off of the same concept as a standard painter's color wheel except the primary colors are different. Instead of red, yellow, and blue, the printer's color wheel relies on magenta, cyan, and yellow, which are the ink colors used to print images. This results in different secondary and tertiary colors."

So we must first remember that we are discussing digital printing here and not what I am sure you are thinking of when you were much younger. Because I would almost bet you that you are thinking that the primary colors are red, blue and yellow. And your memory isn't incorrect, no sir!

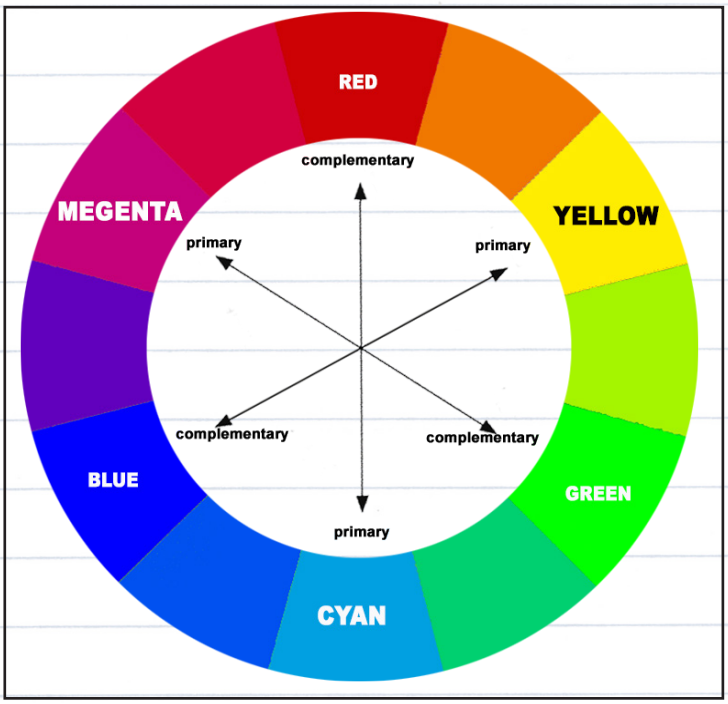
Here's what the Crayola people have to say about primary colors. And who could argue with Crayola?

"Primary colors include red, blue and yellow. Primary colors cannot be mixed from other colors. They are the source of all other colors. Secondary colors are mixed from two primary colors adjacent to each other on the color wheel. The secondary colors are orange, green and violet."

And Crayola isn't wrong, well not wrong when you are looking to color a coloring page with a set of Crayola Crayons.



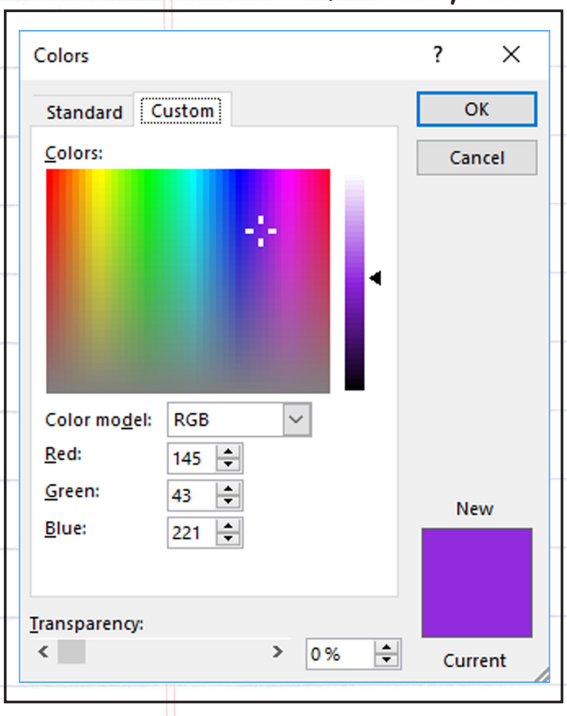
Red, Yellow, Blue Primary Color Wheel

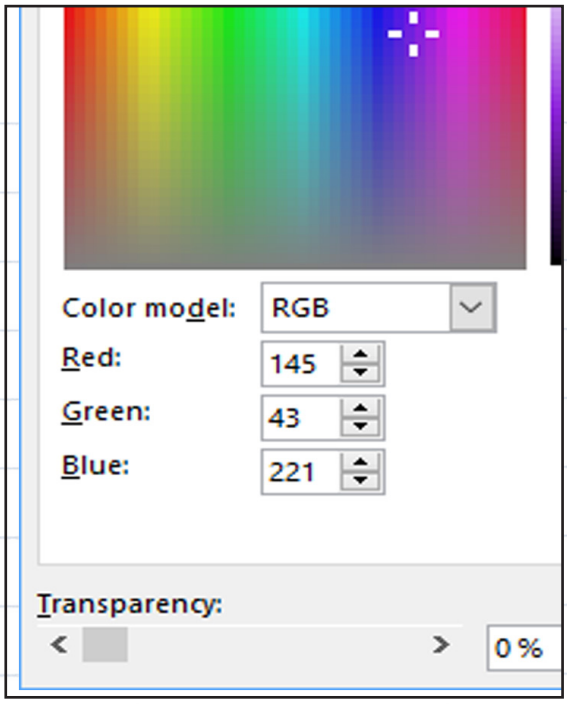


Cyan, Megenta, Yellow Primary Color Wheel

But we are looking at the world of digital printing so we need to look at things from that point of view. That brings us back to having Cyan, Magenta and Yellow as the primary colors making up the rest of the colors we see while adding in Black when necessary.

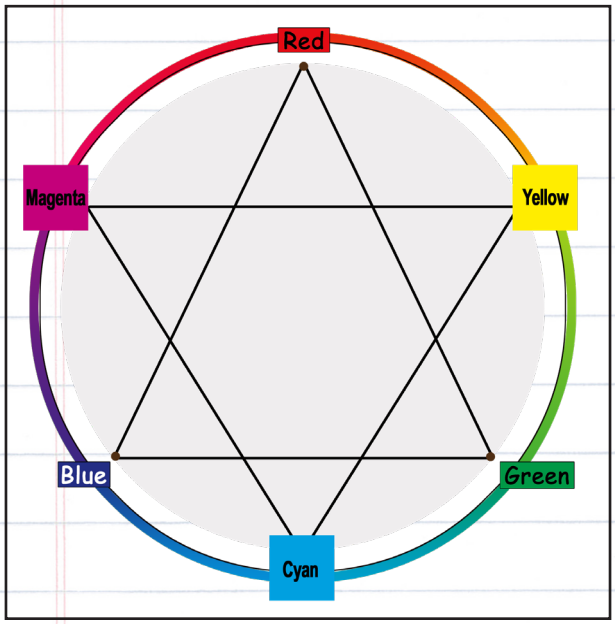
Well then, there you have it. What more do we need? We should be able to print Red anytime we want. However, we haven't even taken a step towards being able to describe what Red is. Let alone Yummy Purple. I love Yummy Purple and I am sure you would love Yummy Purple too but what is it? So here is how I usually get my Yummy Purple when working in Microsoft Word, I use the color picker and it's right around there! That's my Yummy Purple, I picked it and decided to name it. Any issue with that? Yes, actually there is a problem with that and it is





where we will start.

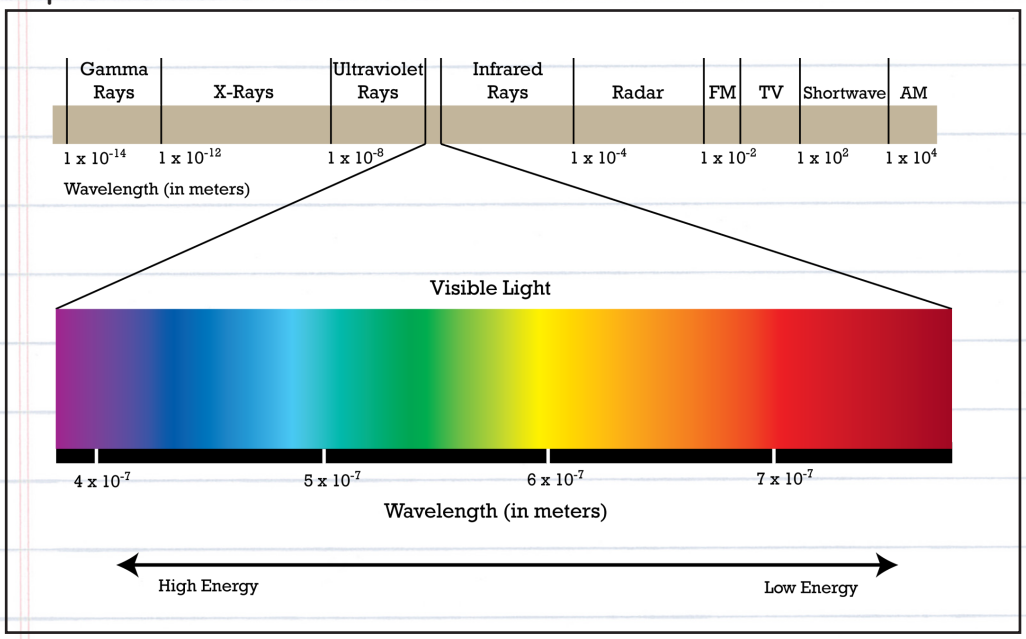
First, let's take a look at the boxes with the numbers in them. If you remember back a few pages, I said all colors were really just numbers, but, it is important to know which numbers are the numbers we want to use and when. That does sound confusing, doesn't it? First, let's notice that in Microsoft Word the color I am playing with is from the RGB color space and in the RGB color space each color is made up of a combination of Red, Green and Blue. WAIT! Are these a new set of Primary colors?!?!? Yes, yes and no. Certainly they are when you are talking to someone that only uses the RGB color space for what they do, say a computer monitor or a television set, a camera or maybe a scanner. Many devices we use each and every day are solely in the RGB color space but before you get too confused, take a look at our color wheel and you'll find we haven't really left our new printing primary colors at all. So while we can see that in our Primary world of Cyan, Magenta and Yellow there are the other three, Red, Green and Blue; they don't always play well together or maybe I should say when going from one to the other.



Programs like Microsoft Word live in the RGB color space which is quite different from the CMYK color space but both must play with each other if we are ever going to be able to describe what Red or Yummy Purple is and then to print those on a consistent and repeatable way. But in one way it brings us to looking at the numbers and that's where we want to finish,

color by the numbers. So maybe we need to go back to what we are even seeing in the first place. Why? Because we as humans can only see a limited amount of color and that limited amount of color is what all of the other color spaces we play with are based on.

Here is what we know is or are the wavelengths of the stuff we know is there. The main part you need to see from this diagram is what we know of the Visible Light Spectrum.

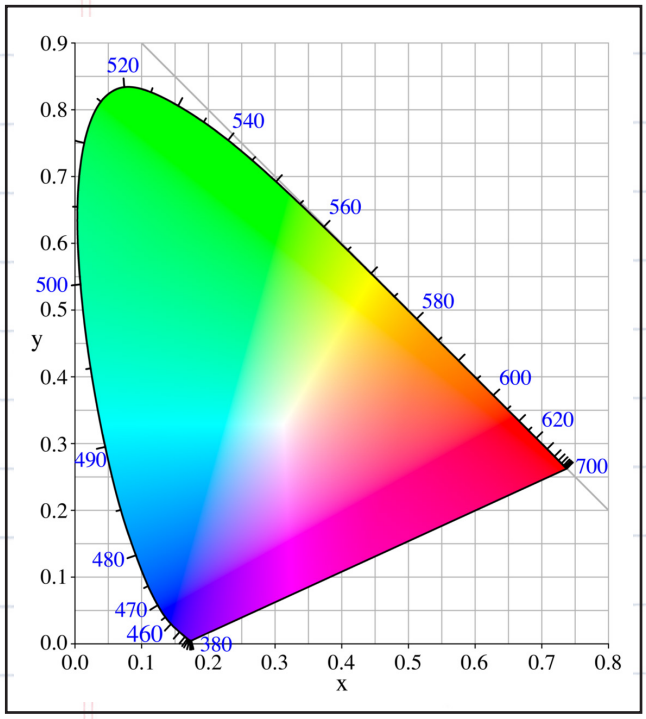


"The visible light spectrum is the segment of the electromagnetic spectrum that the human eye can view. More simply, this range of wavelengths is called visible light. Typically, the human eye can detect wavelengths from 380 to 700 nanometers." So says the good people at NASA (https://science.nasa.gov/ems/09_visiblelight). And the people at NASA know some things.

And this is where it all starts, we can only see what we can see but devices can see more and sometimes what we would think is invisible isn't as long as you have something that can see it and...I am off track just a tad.

So let us wonder back into the realm of what humans can see and get back on track, yes and thank you. Since we know that our eyes can see from approx. 390 nm to 700 nm in the light spectrum, some greater minds than mine placed that on a diagram as seen below. And there are all of the colors you and I can take advantage

of, but not ALL other devices and that is where the other color spaces come into play. And play with each other is what they need to do because like it or not, they all over lap each other and we use them all just about each and every day.



"Consider this problem. You just designed a wonderful "thingamajig."

You want to have it made out of plastic and metal and it should all be exactly the same color red. You found a manufacturer in Vancouver, B.C. who can build your thingamajig for a reasonable price. However, you are concerned that the plastic and metal be exactly the same color and that this color be exactly the red that you specify.

You hired a lawyer who will write your contract with the manufacturer. Your lawyer says that you have to define your color very precisely.

How are you going to do it?

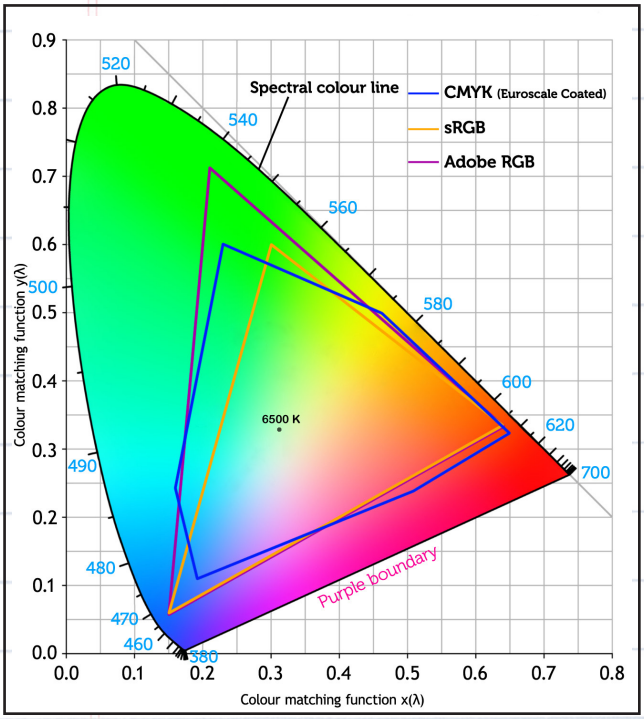
Well you can do it the same way that Eastman Kodak defines its famous yellow package. They specify the color of their package on the CIE Chromaticity Diagram.

In this diagram all colors that plot in the same location in this color space will look exactly the same to a Standard Observer." (http://www.yorku.ca/eye/ciediag.htm)

That should help clear everything up! Right? No. I know, it likely continues to confuse you since all we want to do is print some Red and Yummy Purple and have it print as Red and Yummy Purple!

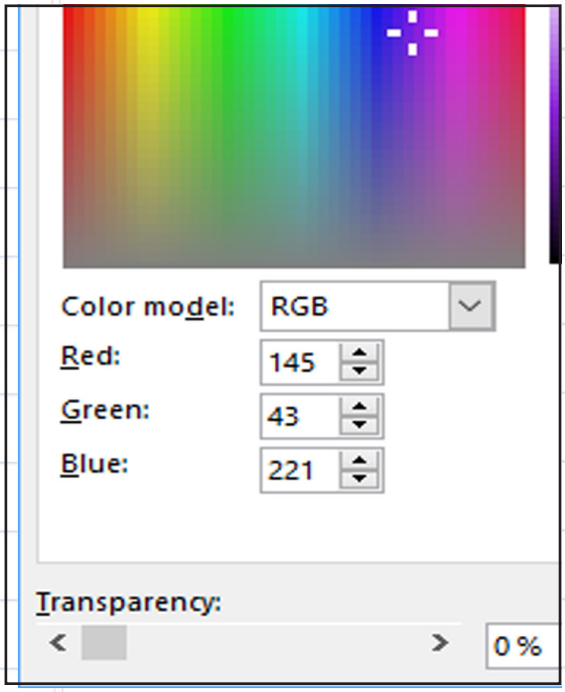
For the love of Pete and Mike and Sam!

Oh, by the way, that diagram is know as the "1931 CIE Chromaticity Diagram" and you will be happy to know that pretty much all of us color geeks know that diagram very well, as well as the following diagram. For it is within this diagram that we start to shape out the other color spaces that we tend to use every day and which if you give me just another minute of your time will bring us back to why Microsoft Word and the Yummy Purple we picked may or may not be able to print on your printer.



Ahh! You thought I had forgotten where we were heading!

So here's the color picker from Microsoft Word and right from the start we are running into an issue. You see, no pun intended, if we are going to work from the numbers and we want to use the CIE Chromaticity Diagram, we would need to use numbers that are the right numbers and those numbers would be using LAB. We use the LAB color space because it is a device independent color space.



"The LAB color model is a three axis color system and LAB colors are absolute, meaning that the color is exact. It's what's known as device independent; meaning that the LAB color space is the only way to communicate different colors across different devices. An object's color is measured in LAB color with a spectrophotometer." (https://hidefcolor.com/blog/color-

management/what-is-lab-color-space)

By being device independent and by being exact in the definition of where a color ***is*** and not ***what*** a color is we can absolutely define what Red is and what Yummy Purple is and then consistently reproduce these colors across devices and across color spaces as long as a Color Management system is in place.

But the problem exists that Microsoft Word doesn't work with LAB color formulas, RGB formulas but not LAB.

So are we just out of luck and we need to throw away that silly Microsoft program?

No. However if you want to have some fun, certainly, throw it away! Go on! Be daring with that part of your life! No, please no. Stop. I'm just pulling your leg.

Let's get serious here. You want to use Microsoft Word and you want Microsoft Word to print your Yummy Purple color each and every time that you use it.

AND, there it is! The actual issue with everything we do in printing colors! Did you see it? (pun may be intentional there)

Many times it's all a game of expectations and the referee is the LAB color space Police. There isn't really any LAB Police, I'm pulling your leg again. But there is the LAB numbers and they do a couple of things for us. One very important thing that the LAB color space does is it keeps all of the colors in the exact spot that they are in, always. And that is a good thing and if you could always just use LAB color numbers to define and work with things, you would be all set. But alas, most of us don't work with those during our everyday lives. Even color geeks don't.

Why? From as simple a point as I can give you, because we deal with devices and devices don't play with device independent colors naturally.

We play with devices that need Device Dependent Colors, RGB and CMYK.

But they do use the LAB color space because the LAB color space is in fact the

Universal Translator for all of these devices and because of that the colors you are expecting to see many times don't end up making you very happy.

WHAT DOES DEVICE DEPENDENT AND DEVICE INDEPENDENT MEAN?

This is an interesting and sometimes confusing question.

It has to do with different forms of color spaces and how a device renders color information.

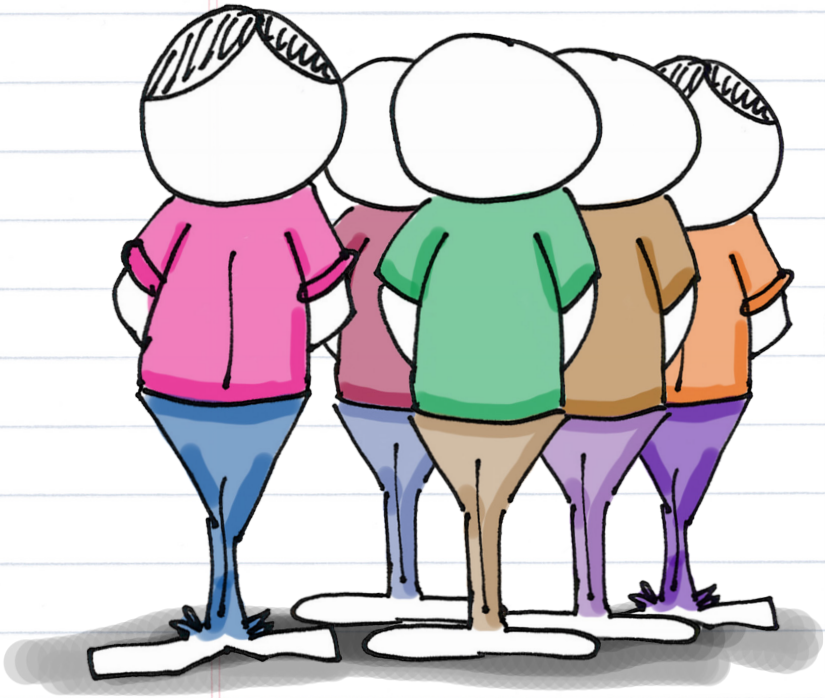
Device Dependent refers to the CMYK gamut a printer/press can print to – it's behavior. All printers/ presses print differently, therefore they have Device Dependent profiles, or color gamuts. Basically, CMYK values for one device will print differently on another CMYK device. See the difference here between SWOP and GRACoL CMYK color profiles – these are device dependent profiles illustrated in the LAB color space.

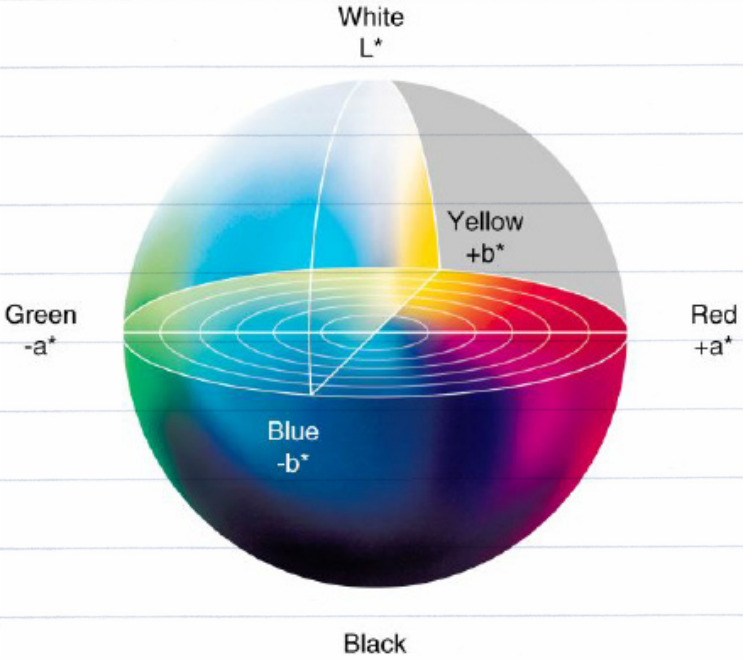
Another device dependent also refers to between the difference in Adobe RGB and sRGB color profiles.

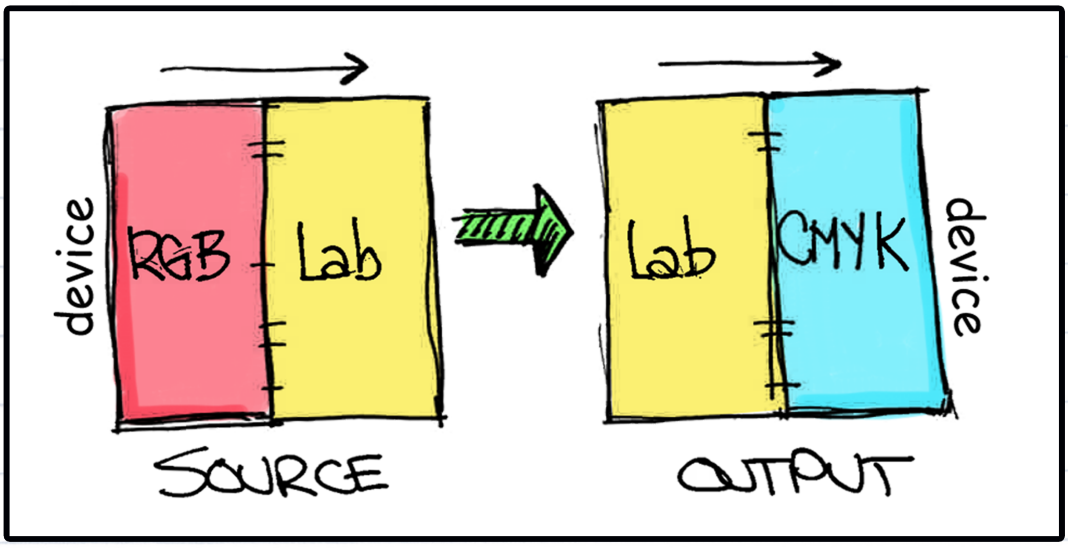
Device Independent refers to the LAB Color Space. LAB values (50,0,0 – neutral gray) are absolute values that have a known color value. This is the color sensation that are eye processes and how spectro-photometers communicate color values between devices.

The LAB Color Space is the common denominator in communicating color values in Color Management workflow.

https://hidefcolor.com/blog/color-management/what-does-device-dependent-and-device-independent-mean Rick Rys







The above diagram shows the normal everyday path that a file takes when it is being printed. In this case we are starting with a color space that is RGB and printing to a device that is in the CMYK color space. To get from one color space to the other, the "color information" must be translated.

Why?

Because RGB and CMYK don't speak the same language and the CMYK wouldn't know how to print colors from the RGB color space without some help.

Pretty much in the same way that if you only spoke Portuguese and I spoke only English, we would need a translator to be our go between or we wouldn't be able to have a conversation.

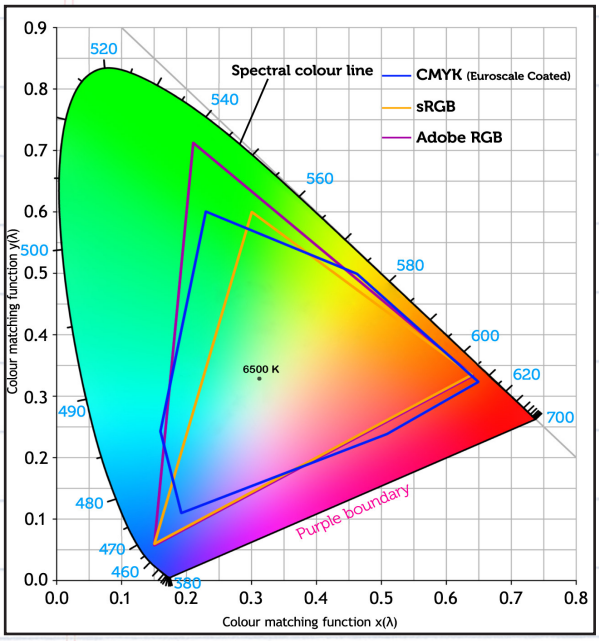
Good? Yes and no, yes? The translator part I think you get but I am wondering if you may be asking, what is a color space? Yes, it's not a bad questions at all!

So, what is color space?

"A range of colors can be created by the primary colors of pigment and these colors then define a specific color space. Color space, also known as the color model (or color system), is an abstract mathematical model which simply describes the range of colors as tuples of numbers, typically as 3 or 4 values or color components (e.g. RGB). Basically speaking, color space is an elaboration of the coordinate

system and sub-space. Each color in the system is represented by a single dot."

www.arcsoft.com



Here is the LAB color space diagram with three more color spaces shown inside of it. Since the LAB color space is the "largest" color space we have, all other color spaces that we deal with will land themselves within the range of what we have in the LAB color space.

Now the problem is, there are almost an endless number of color spaces, well, honestly not endless, but quite a few.

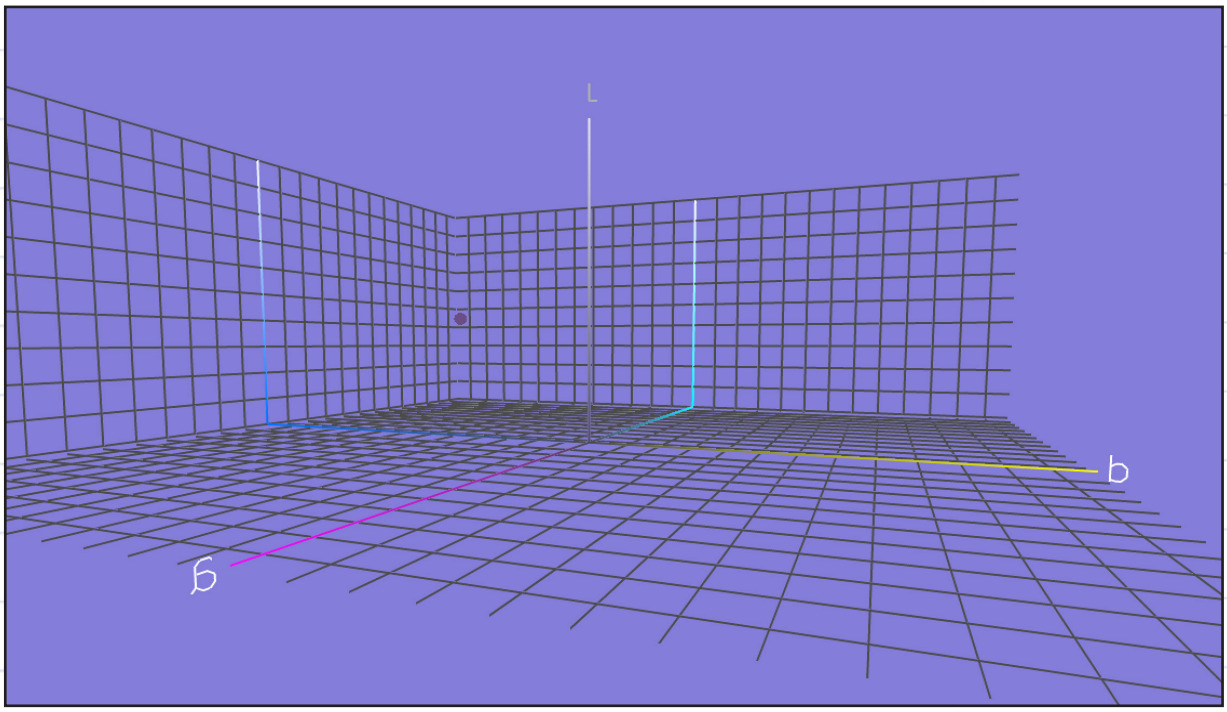
In the RGB land of color spaces there are:

- RGB
- sRGB
- Adobe RGB (specifically Adobe RGB 1998)
- Adobe Wide Gamut RGB
- Apple Standard
- ProPhoto RGB
- eciRGB v2
- scRGB
- DCI-P3 (used primarily for digital movie projection)
- YIQ, YUV, YPbPr, YCbCr, ICtCp and on and on they go

And then let's not forget about the CMYK color space. We can start with the name grabbers:

- ISO Uncoated FOGRA29L
- ISO Coated FOGRA39L
- GRACoL2006_Coated1v2
- CGATS21-2-CRPC6 also known as GRACoL2013_CRPC6 or just GRACoL2013
- SWOP2006
- Japan Color 2011
- TOYO Offset Coated

And the list just keeps going for both sides of the color world.
By now you may well be asking, what was the question in the first place? And if you remember back it simply was, why won't my printer print the right color? AND, you may just be getting the impression that the answer isn't really a simple one. In that you would be correct. For if the answer were simple, many books on the subject of color and color theory wouldn't have been written.
That of course doesn't help you at this very moment for you still have the question of why our Yummy Purple isn't always printing in the Yummy Purple we expect to see.
So EXPECTATIONS shows its ugly head again!
There are realistic expectations and unrealistic expectations in almost everything you are involved in, printing and life in general. But at some point you must think about what is it that you are really expecting to happen when it comes to printing the colors you want to print and then you will need to ask yourself if that is realistic or not.



Here is our Yummy Purple, R145, G43, B221 in LAB charted space. Meaning our Yummy Purple lives at the following coordinates in the LAB color space, L42, a63, b-72.

If we continue to use the same formula we will always have Yummy Purple right there. The next question though is, can we expect our CMYK printer to be able to print that spot from the LAB color space?

That's a great question. How can we know if that color can even play with the CMYK color space and then I'll throw something in that we haven't even discussed yet. Once we know a color will land itself in the color space of choice, we need to know if the device we want to use can handle the color. In other words does the device's Gamut have the room for the color?

What is Gamut? Glad you asked!

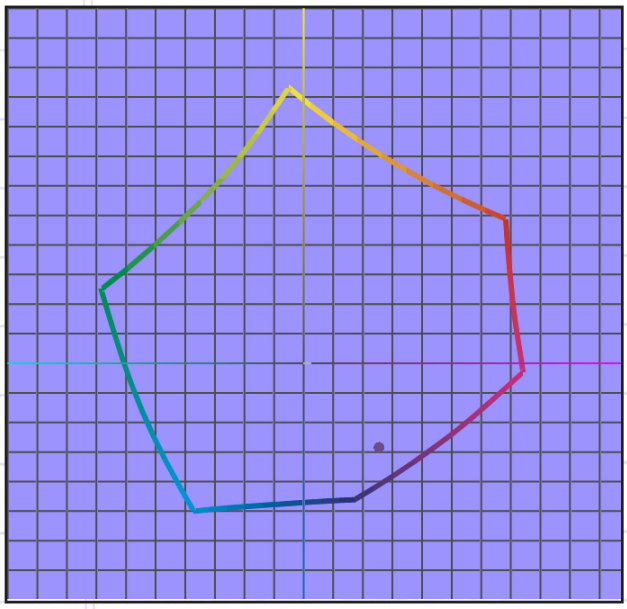
gam·ut

noun

the complete range or scope of something.
"the whole gamut of human emotion"

synonyms: range, spectrum, span, sweep, compass, scope, area, breadth, width, reach, extent, catalog, scale, sequence, series; variety

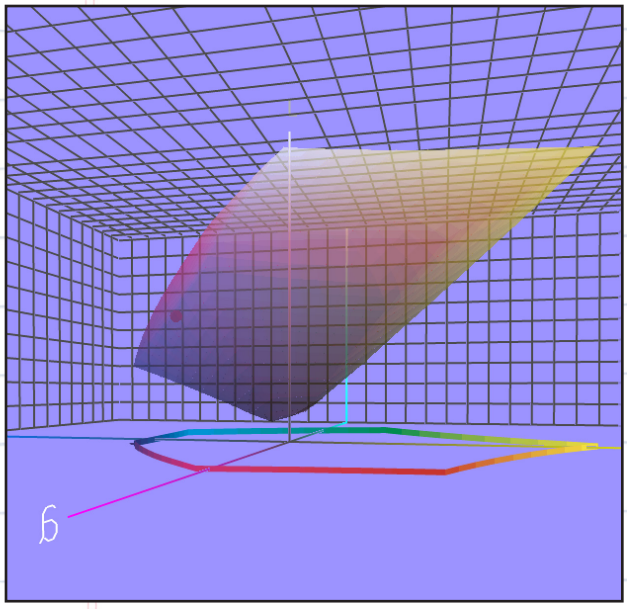
"the complete gamut of human emotion"



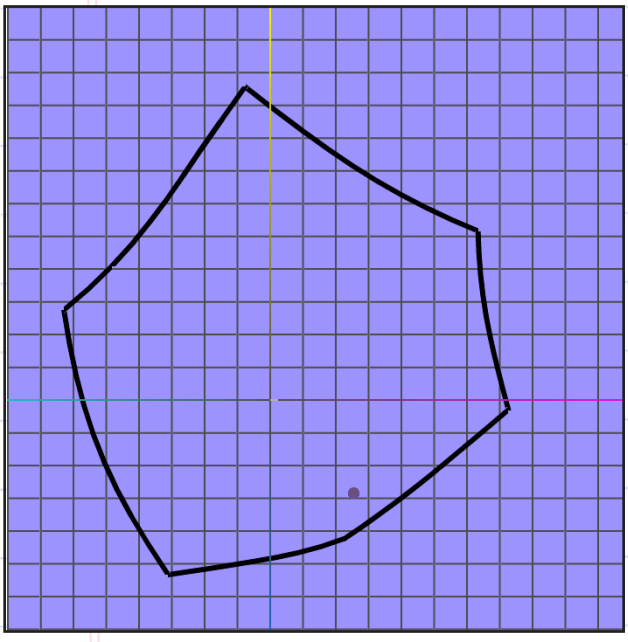
Let's take a look at our Yummy Purple and at a standard CMYK color space known as GRACoL2006.

The very first question and actually the only real question to ask is, does Yummy Purple stay within the boundaries of the CMYK color space we want to use, namely GRACoL2006?

And we can see that from a 2D perspective, it does.



For the fun of it, I have also given you a look at the 3D representation of our Yummy Purple and GRACoL2006. It certainly does live and or reside within the GRACoL2006 color space. So that's a good start but now we must make sure that our printer can play with it because we may have a device that does not have the gamut to reproduce a color in the GRACoL color space.



Here is our Yummy Purple as it falls in the scope of a Canon imagePRESS C750.

It's there!

Hence and forever more let it be known that YUMMY PURPLE can be printed from a printer.

Half of the battle has been conquered!

Why then are we right back where we started?

The question is still hanging out there because what you've come to expect as Yummy Purple isn't

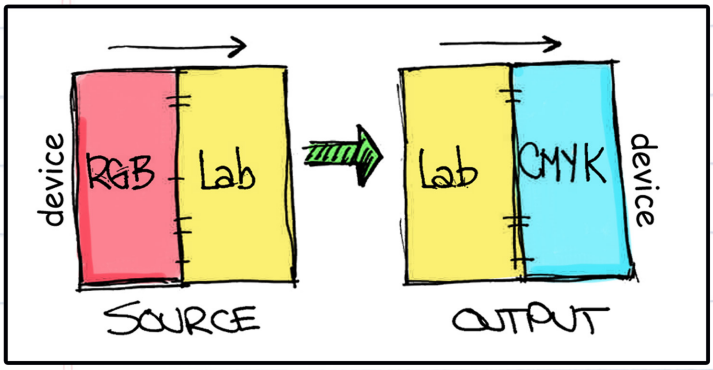
what you see when my printer prints it instead of the deskjet you print to most of the time.

To some extent I need you to go back to the realistic expectations and the un-realistic expectations that life always throws at us because I am about to say something that may sound worse than I mean it to sound but I need to say it.

If you are printing to a deskjet printer that may cost around $100 and I am printing to a printer that costs $100,000, which one would you say prints in a more accurate fashion for what we give it to print?

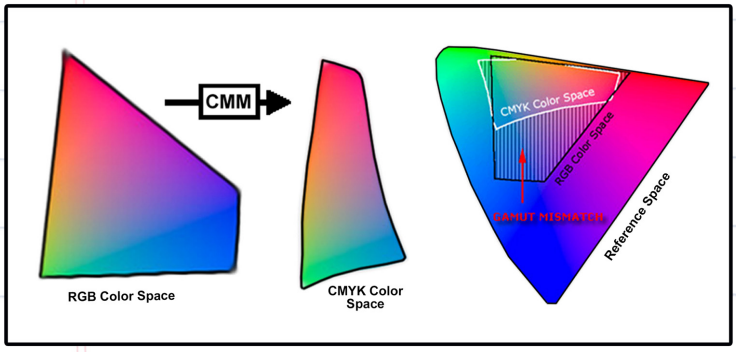
YES! The $100 printer, of course!

I'm sure you know I wanted you to say the big fancy $100,000 printer and I can give you alot of real reasons why it is the more accurate printer but let me go back to what our expectations are and see if when we put into play the translators that must be used to take the device information from the input source to the output source can explain why we are still having issues.



Do you recall seeing this before? It shows that we must translate each color as it goes from one source to another. There's no getting around it.

The diagram below it shows this in a little different way and may give you a better look at what we many times are going from and going to. The RGB color space is much larger than the CMYK color space and while we now know that our Yummy Purple falls within our fancy printer's gamut what I can't guarantee for you



is that the translator in the deskjet is translating the same way that the fancy translator translates. And all that means is that the very information that is in the document structure can be translated differently by different translators or using the real world terms, the Color Management Module will not always match up between devices.

Color Management Module (CMM) – The software that does the calculations to convert files from one color profile to another. Examples of CMMs are Adobe ACE, Heidelberg CMM, Kodak CMM, Agfa CMM, and others. (Digital Technology Group, Inc.)

And this is where things can give you some false results for your expectations. It's in the software that is being asked to do the conversions for us and the $100 deskjet is not going to have say, the gurth in the conversion software that the $100,000 printer does.

And sometimes that's why the Yummy Purple you have come to love doesn't appear the same when it is printed on a different printer from the one you are used to.

And that brings us full circle. have we answered the question? Sure we have but it may not be the answer everyone wants to hear. Can you get each printer to print the Yummy Purple or the Red Red and even the Cookie Dough Chocolate Brown you want?

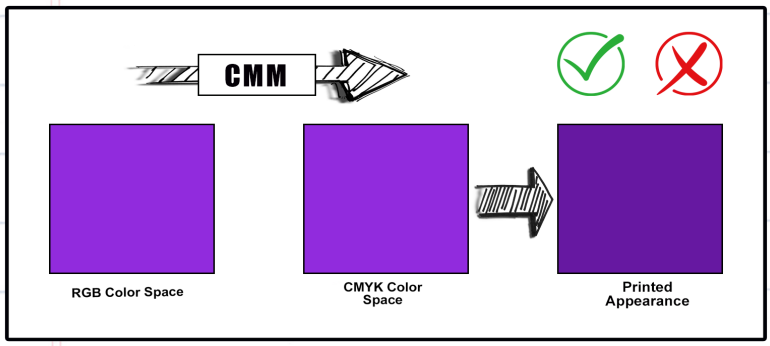
Yes, but you may not want to know what the cost of that would be. That discussion lands us in the middle of a Color Branding thing that is way out of the scope of this but suffice it to say we can get you where you want to be in some more simplistic ways.

Just for the fun of it, the range of pricing for good color branding can be millions. "While some of the most iconic brands in the world cost hundreds of millions of dollars to create, others got away with a check for just $15. Some spent nothing."

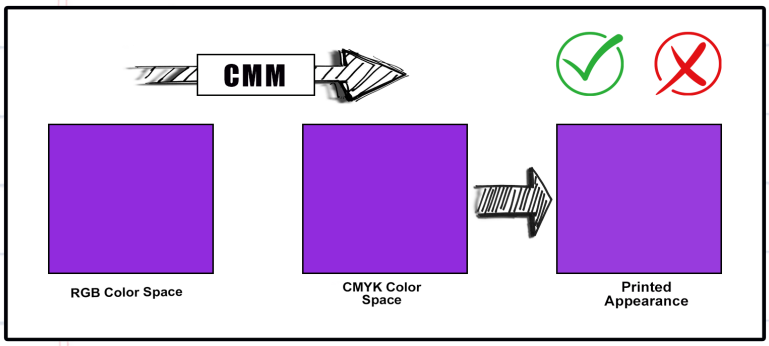
See the full story at: https://www.businessinsider.com/heres-how-much-the-worlds-most-iconic-logos-cost-companies-2013-3

So here is our Yummy Purple and let us remember that our RGB formula is R145, G43, B221.

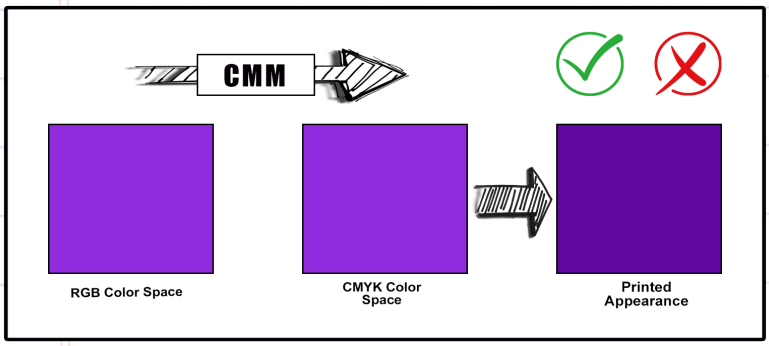
We know that when we are going to print, the information will be going thru the CMM (Color Management Module) and be translated into the CMYK color space and then printed by the printer you are sending it to.



For a simply color management solution you would first decide that Yummy Purple will always be the same RGB formula, always. You must stick to that because differing even a little bit will change everything.



So let's say that you print to three different printers and the results are to the left.



The question then is which printer is printing the color correctly?

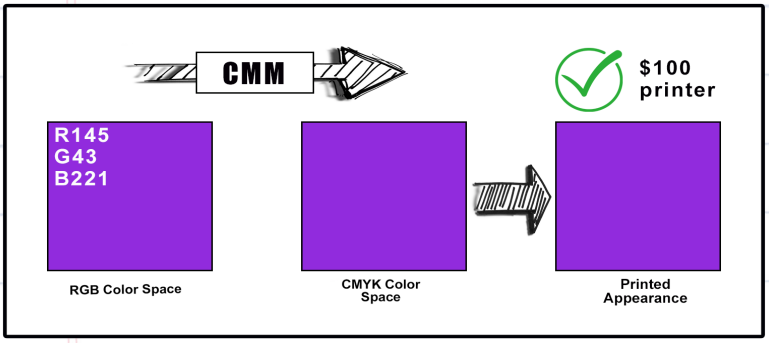
On the $100 deskjet you have very little control on what the CMM is doing but on the $100,000 printer there is quite a bit of control you have for the CMM and one of the things we can control is Input and Output color space profiles. Now we are going to step back into what color space are you working in when you are designing the document. Likely, you happen to be working in the sRGB color space. We can on higher end printing systems set the RIP (raster image processor) for the correct input

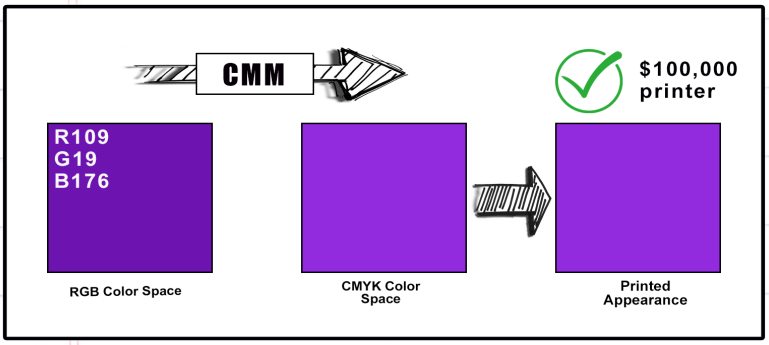
source color space profiles. That means we are able to set the RIP for sRGB and when your file comes into the RIP it keeps the original color intent and then translates that for the correct CMYK output profile.

Because of this, you may very well be seeing a difference between the $100 printer and the $100,000 printer.

If, the output on the $100,000 is not what you want the solution can be as simple as going back and changing the formula for Yummy Purple.

WAIT! I said you shouldn't do that! Yes I did, but to give you what you want, you may need to understand that what you are seeing on your monitor (RGB color space) may not be what the color looks like after printing in the CMYK printer. So if you tweak your formula to get what you want on the $100,000 printer and then lock that in and use it when you know you will be going to the $100,000 printer, you should get the color you want each and every time.





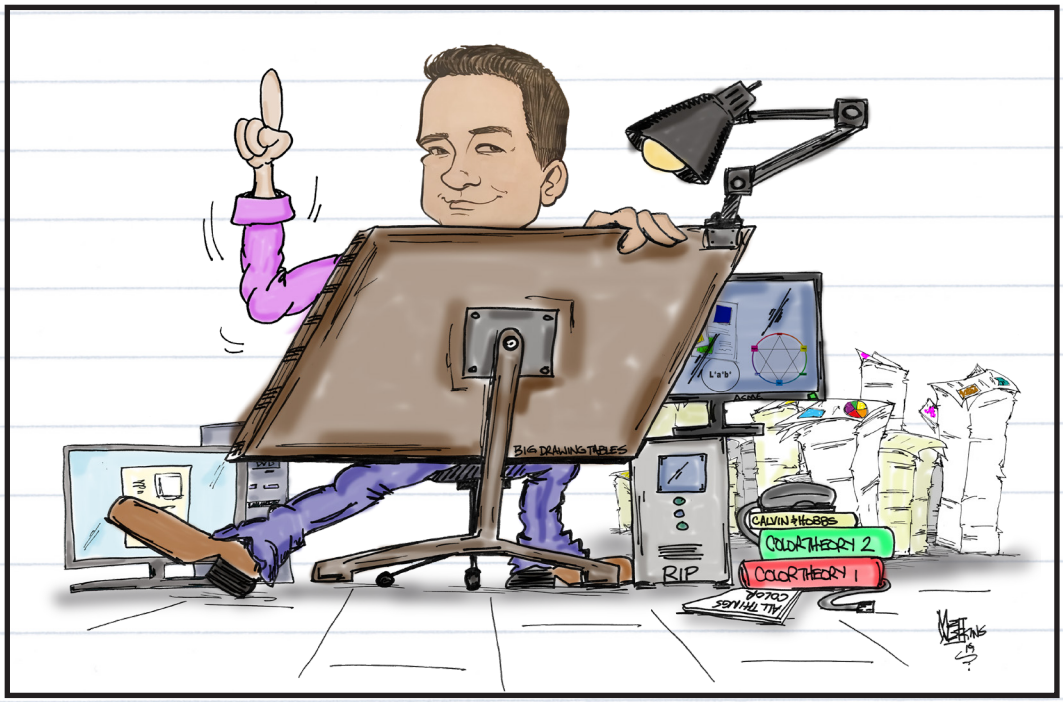
My point is that you may need to make some changes to get what you want when you print and understand that the realistic expectations must include how the world of printing works with these things known as color spaces and color translations between those color spaces.

Then you may want to ask about those colors known as PMS colors or PANTONE.

There again, that's a whole nother item altogether and something you really don't want to tackle just yet.

PANTONE colors fall into that branding stuff and how and why and really, you may want to let me dive into that another time.

Just remember that we are talking about expectations and how that plays into Color Management. If you have a Color management system inplace whether it be big or small will help you see the expected results in your color printing.



By day, Matthew Watkins is a Color Analyst in the Digital Printing World and at night or on the weekends you can find him behind his drawing table or behind one of several types of cameras and then possibly infront of his computer either editing files like this one or video and maybe even a photo or two.
He holds several industry certificates including but not limited to, Idealliance G7 Expert, EFI Fiery Expert, Adobe certifications, some Microsoft certifications and other things that say he might actually know something about something.
For the most part he is a self proclaimed color nerd/geek and loves nothing more than to learn all he can about the wonderful fun filled universe that is all things color.
He is also a certified trainer and enjoys giving as much of his knowledge away as others will let him. "Sharing is the best part of knowing something."
He is married to the best wife in the whole wide world and has four of the best kids you could come across. He resides in the state of confusion and Illinois, which some might say are one in the same. On a hot summer day you might find him lounging in the back yard pool or in front of the TV if the Cubs are playing. If, of course, he has the day off!

Should you like to reach him, he can be found at his Linkedin page:
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