WHAT IS COLOR?

TABLE OF CONTENTS

IMAGINE A WORLD WITHOUT COLOR

All the objects that surround us have no color. Color exists only in our minds. Color is a visual sensation that involves three elements – a light source, an object and a viewer. Light from the sun or another light source strikes objects around us, is reflected and modified by the objects, then reaches the receptors in our eyes and is interpreted by our brains into something we call color.

Since color only exists in our minds, explaining the physical aspects of color is just part of the story. The way objects appear to us and the judgments we make about color are determined by a combination of many factors. Some of these factors are easy to measure and some are not.

Individual perceptual differences, eye fatigue and mood of the viewer are as important to a discussion about color as are the properties of light sources and objects. Color as perceived by the human eye cannot be simulated by any instrument, nor can it be reproduced by any printing process.

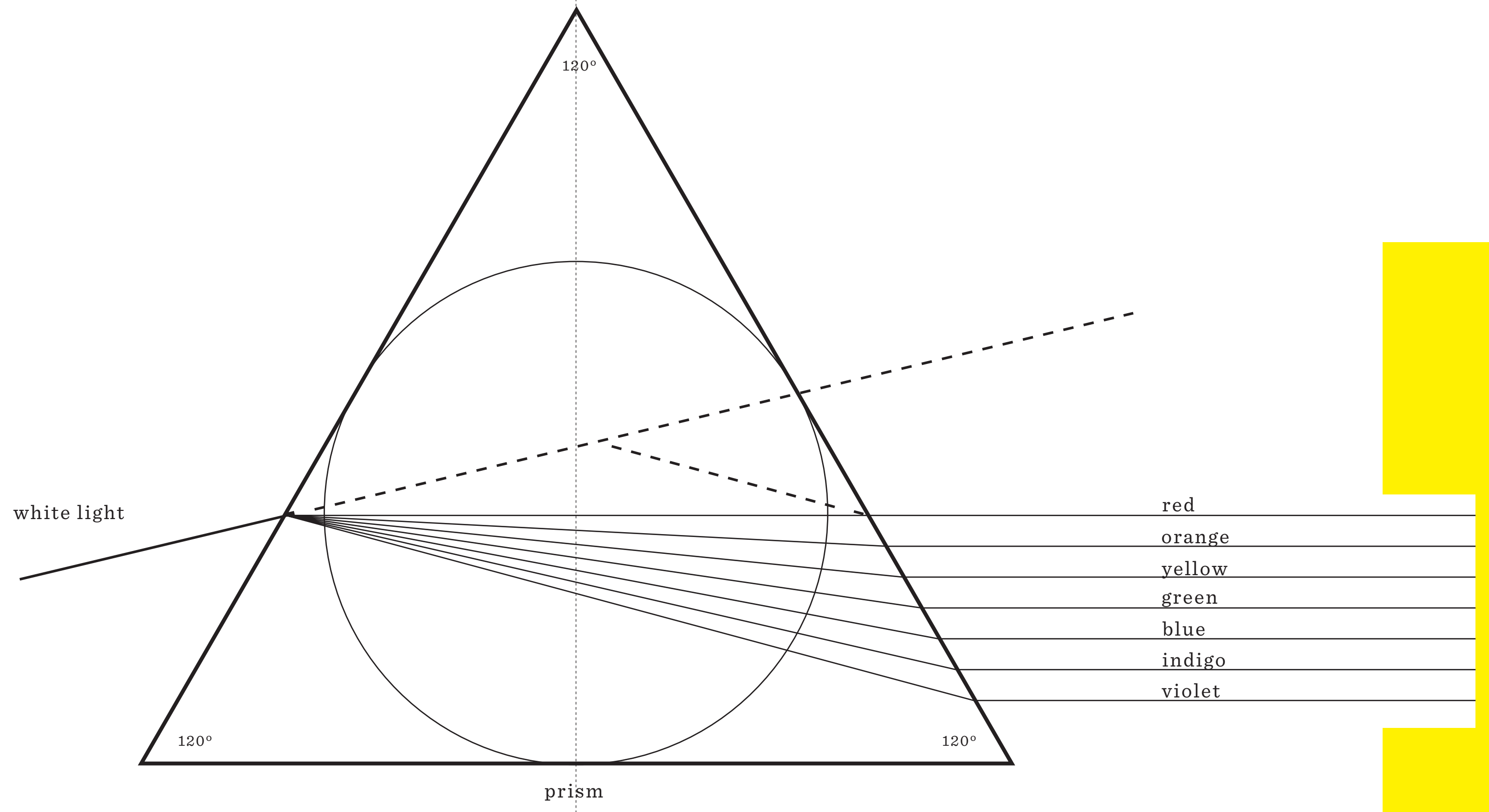
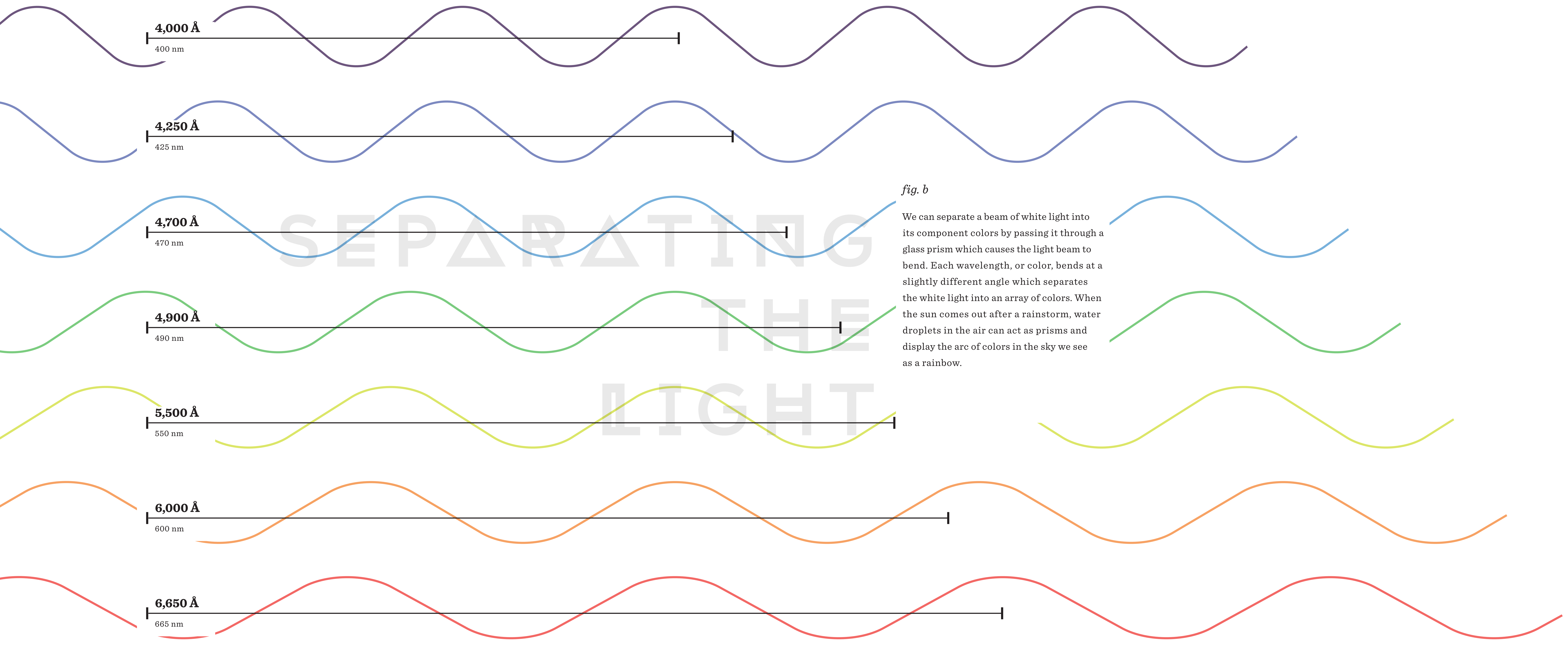


fig. a

Light is essential for vision. Light causes color. Without light color would not exist. Light that appears white to us, such as light from the sun, is actually composed of many colors. Each color has its own measurable wavelength or combination of wavelengths. (Light travels in waves much like waves produced by dropping a pebble in a pond, except light waves are extremely small.) The wavelengths of light are not colored, but produce the sensation of color.

Light is a form of energy. All wavelengths of light are part of the electromagnetic energy spectrum. The spectrum is a continuous sequence of energy waves that vary in lengths from short to long. Visible light – the wavelengths our eyes can detect – is a small portion of the entire spectrum. At one end of the visible spectrum are the short wavelengths of light was perceive as blue. At the other end of the visible spectrum are the longer wavelengths of light we perceive as red. All the other color we can see in nature are found somewhere along the spectrum between blue and red. Beyond the limits at each end of the visible spectrum are the short wavelengths of ultraviolet light and X-rays and the long wavelengths of infrared radiation and radio waves which are not visible to the human eye.

WITHOUT LIGHT COLOR WOULD NOT EXIST



SEPARATING THE LIGHT

fig. b

We can separate a beam of white light into its component colors by passing it through a glass prism which causes the light beam to bend. Each wavelength, or color, bends at a slightly different angle which separates the white light into an array of colors. When the sun comes out after a rainstorm, water droplets in the air can act as prisms and display the arc of colors in the sky we see as a rainbow.

THE VISIBLE SPECTRUM

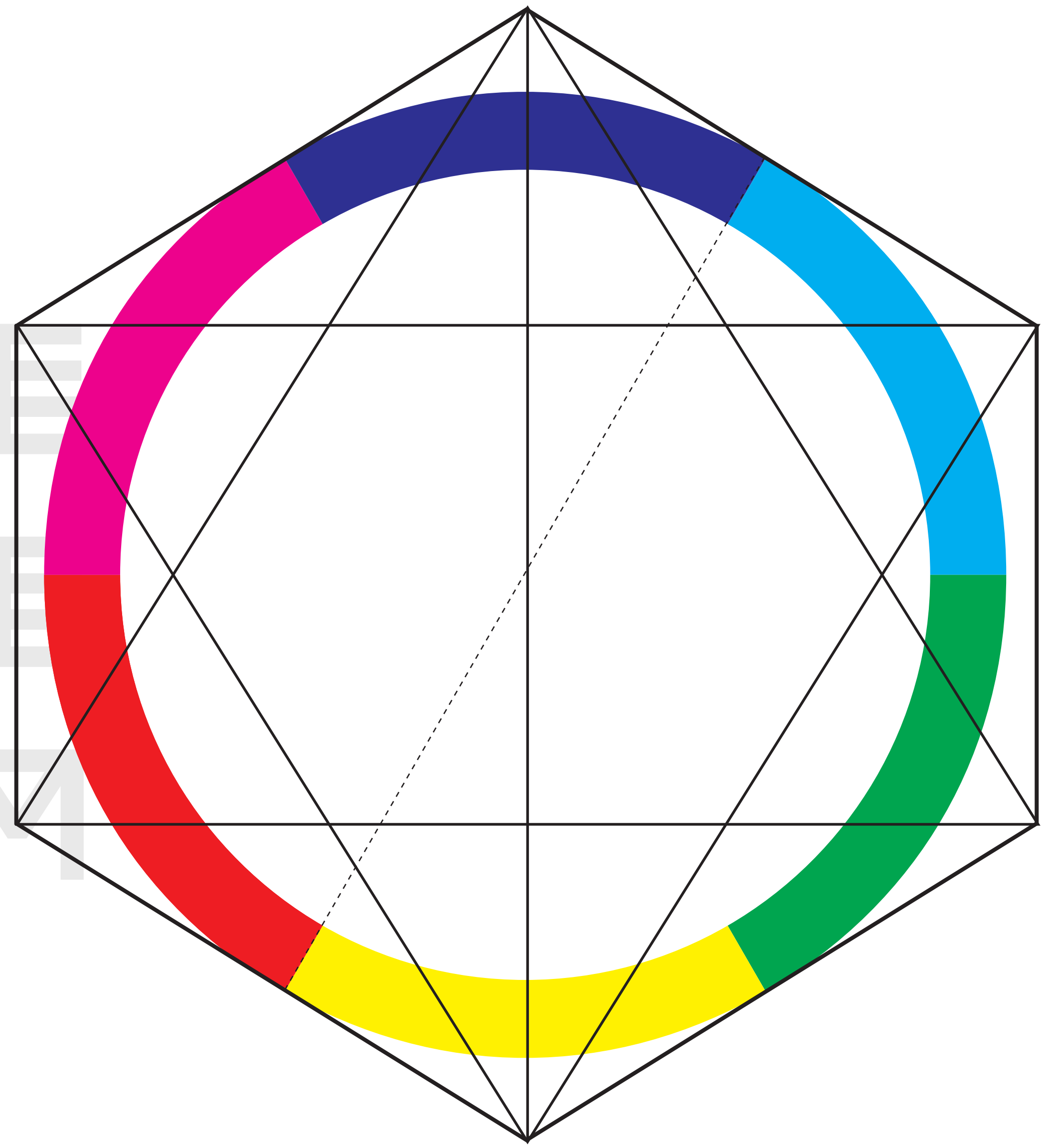


fig. c

The visible portion of the spectrum is divided into thirds, the predominant colors are **blue**, **green** and **red**. These are primary colors of light. Visible colors can be arranged in a circle, commonly known as the color wheel. Blue, green and red form a triangle on the color wheel. In between the primary colors are the secondary colors, **cyan**, **magenta** and **yellow** which form another triangle.

HOW IS COLOR PERCEIVED?

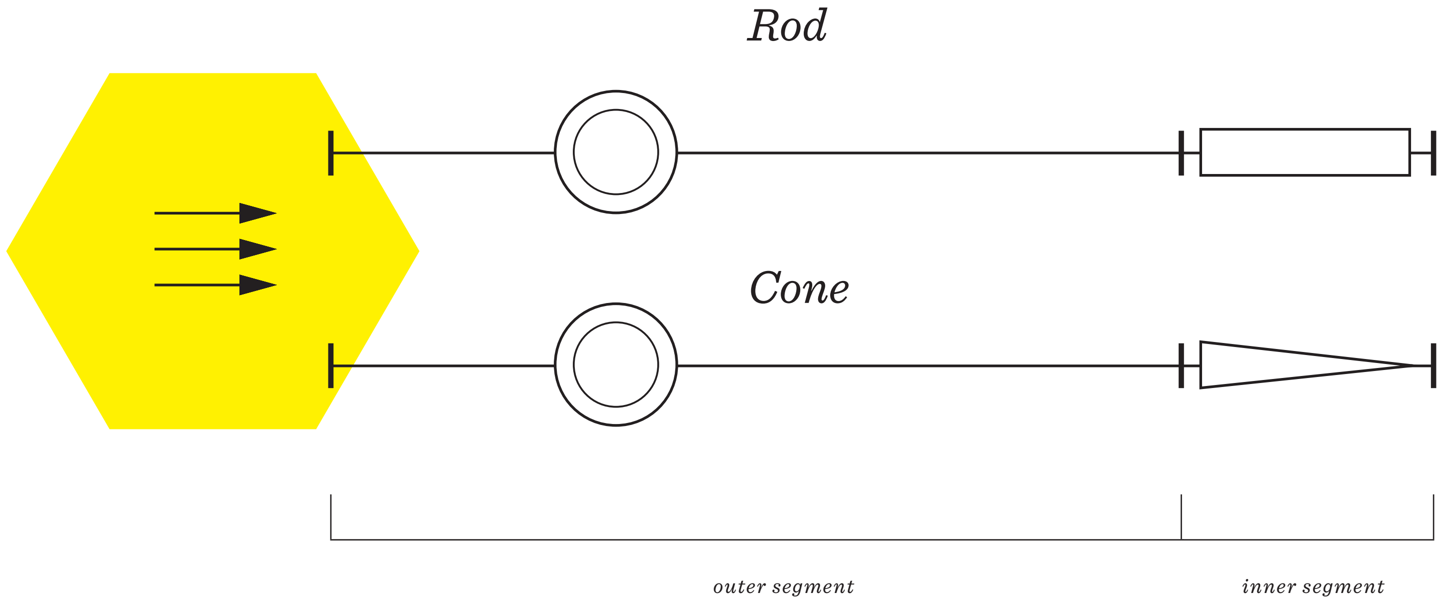
THE HUMAN EYE

Objects in nature derive their color from colorants they possess that absorb or subtract certain wavelengths of light while reflecting other wavelengths back to the viewer. For example, a red apple really has no color, it merely reflects the wavelengths of white light that cause us to see red and absorbs most of the other wavelengths. The viewer (or detector) can be the human eye, film in a camera or a light sensing instrument.

The human eye contains two basic types of light receptors, rods and cones. The rods are sensitive only to the presence of light, not color. The cones are sensitive to color. During normal daytime vision, it is the cones, not the rods that actively contribute to vision. At night, the more sensitive rods take over and give us “night vision.” There are three groups of cones, each sensitive to a portion of the visible color spectrum – red light, green light and blue light. The brain receives signals from the cones, processes them, then evokes the sensation of color. Various combinations of light waves evoke the sensation of other colors.

Color perception varies from person to person. Perception is a subjective phenomenon influenced by many variables including the light source, surrounding colors, mood of the viewer and the individual variations in our visual systems. A small number of people have color-deficient vision. The most common form is the inability to distinguish between reds and greens. These people are considered color-blind. This phenomenon may result from one type of cone missing or a defect that affects analysis in the brain. Color blindness affects 8% of men and less than 0.5% of women.

fig. d



HOW IS COLOR REPRODUCED?

ADDITIVE & SUBTRACTIVE

Throughout history, reproducing the colors we see in nature has taken many forms. The media and methods used to reproduce color include paintings, printing presses, color file, color monitors, color printers, etc. There are only two basic ways, however, of reproducing color – **additive and subtractive.**

ADDITIVE COLOR SYSTEM (RGB)

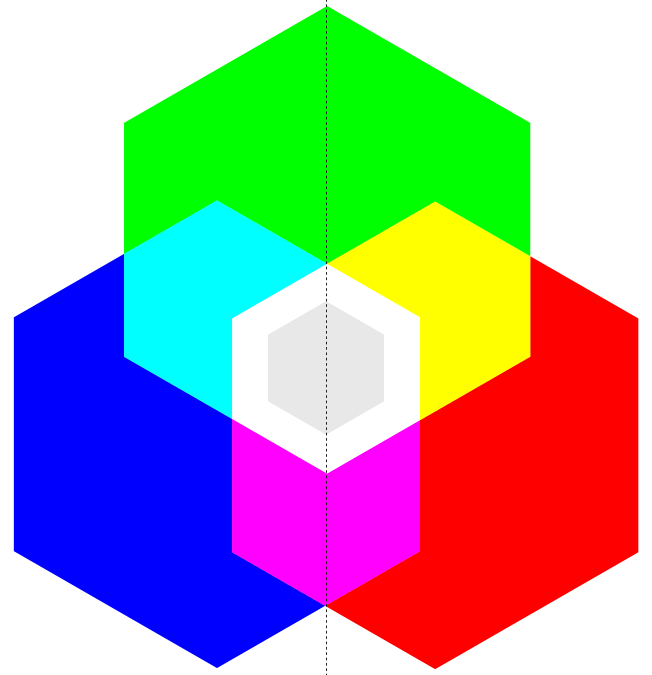


fig. e
additive primaries (rgb)

The additive color system involves light emitted directly from a source, before it is reflected by an object. Light of a specific color, or wavelength (for example, a theatrical spotlight), can be produced by directing white light through a special filter that allows the desired wavelength to pass blocks others. The additive reproduction process mixes various amounts of red, green and blue light to produce other colors. Combining one of the additive primary colors with another produces the additive secondary colors cyan, magenta, and yellow.

To illustrate this, imagine three spotlights, one red, one green and one blue focused from the back of an ice arena on skates in an ice show. Where the blue and green spotlights overlap, the color cyan is produced; where the blue and red spotlights overlap, the color magenta is produced; where the red and green spotlights overlap the color yellow is produced. **When added together, red, green and blue lights produce what we perceive as white light.**

Television screens and computer monitors are examples of systems that use additive color. A mosaic of thousands of red, green and blue phosphor dots make up the images on video monitors. The phosphor dots emit light when activated electronically. It is the combination of different intensities of red, green and blue light that produces all the colors on a video monitor. Because the dots are so small and close together, we do not see them individually, but see the colors formed by the mixture of light. Colors often vary from one monitor to another. This is not now information to anyone who has visited an electronics store with various brands of televisions on display. Also, colors on monitors change over time. Currently, there are no colors standards for the phosphors used in manufacturing monitors for the graphics arts industry.

SUBTRACTIVE COLOR SYSTEM (CMY)

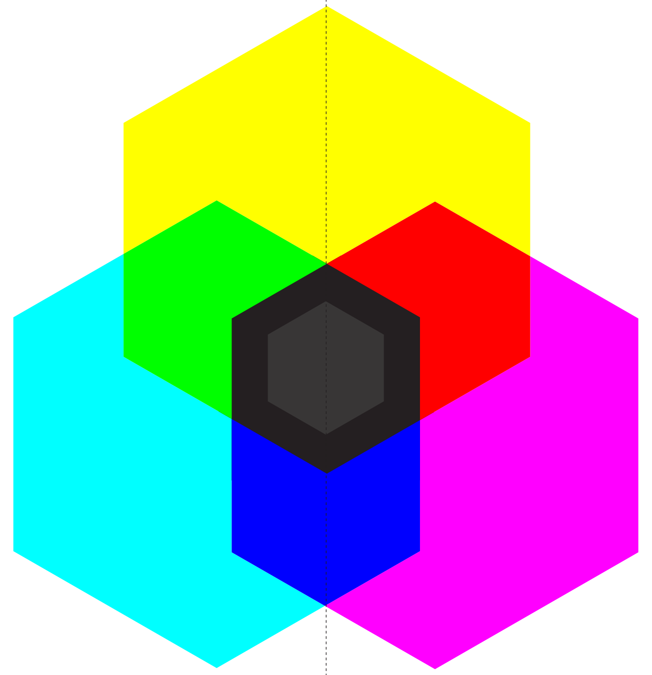


fig. f
subtractive primaries (cmy)

The subtractive color system involves colorants and reflected light. Subtractive color starts with an object (often a substrate such as paper of canvas) that reflects light and uses colorants (such as pigments or dyes) to subtract portions of the white light illuminating an object to produce other colors. If an object reflects all the white light back to the viewer, it appears white. If an object absorbs (subtracts) all the light illuminating it, no light is reflected back to the viewer and it appears black. It is the subtractive process that allows everyday objects around us to show color. Remember the example of the red apple? The apple really has not color. It has no light energy of its own. Colorants in the apple's skin absorb the green and blue wavelengths of white light and reflect the red wavelengths back to the viewer, which evokes the sensation of red.

THE LIMITATIONS OF COLOR REPRODUCTION

WORKING WITH LIMITATIONS

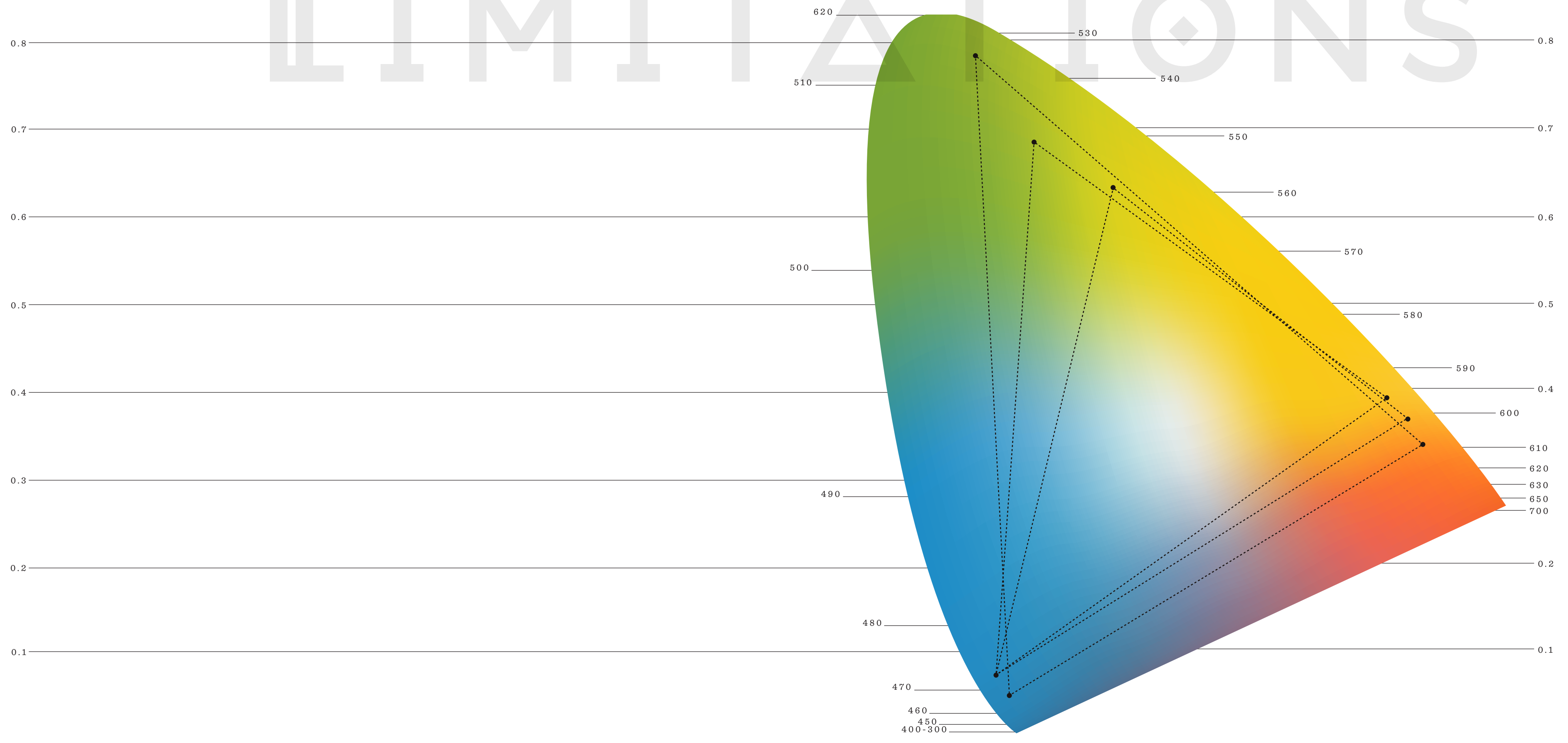


fig. g

The colors we see in nature represent an extremely wide range of colors. When it comes to reproducing color, however, we run into limitations. No color reproduction system (color film, color monitors, printing presses, etc.) can reproduce the entire range of colors we see in nature.

HOW MANY COLORS ARE THERE?

01_*printing press:* 5-6 THOUSAND

02_*photographic film:* 10-15 THOUSAND

03_*computer screen:* 16 MILLION

04_*human eye:* BILLIONS

fig. h

Color gamut is another term for “range of colors.” Each color reproduction system has its own color gamut. For example, the gamut of colors that can be reproduced on photographic film is greater than the gamut of colors that can be produced with process color inks on paper using the offset printing process. Computer screens display more – and different – colors than can be produced on color film or most color printing devices.

ADDITIVE COLOR VS SUBTRACTIVE COLOR

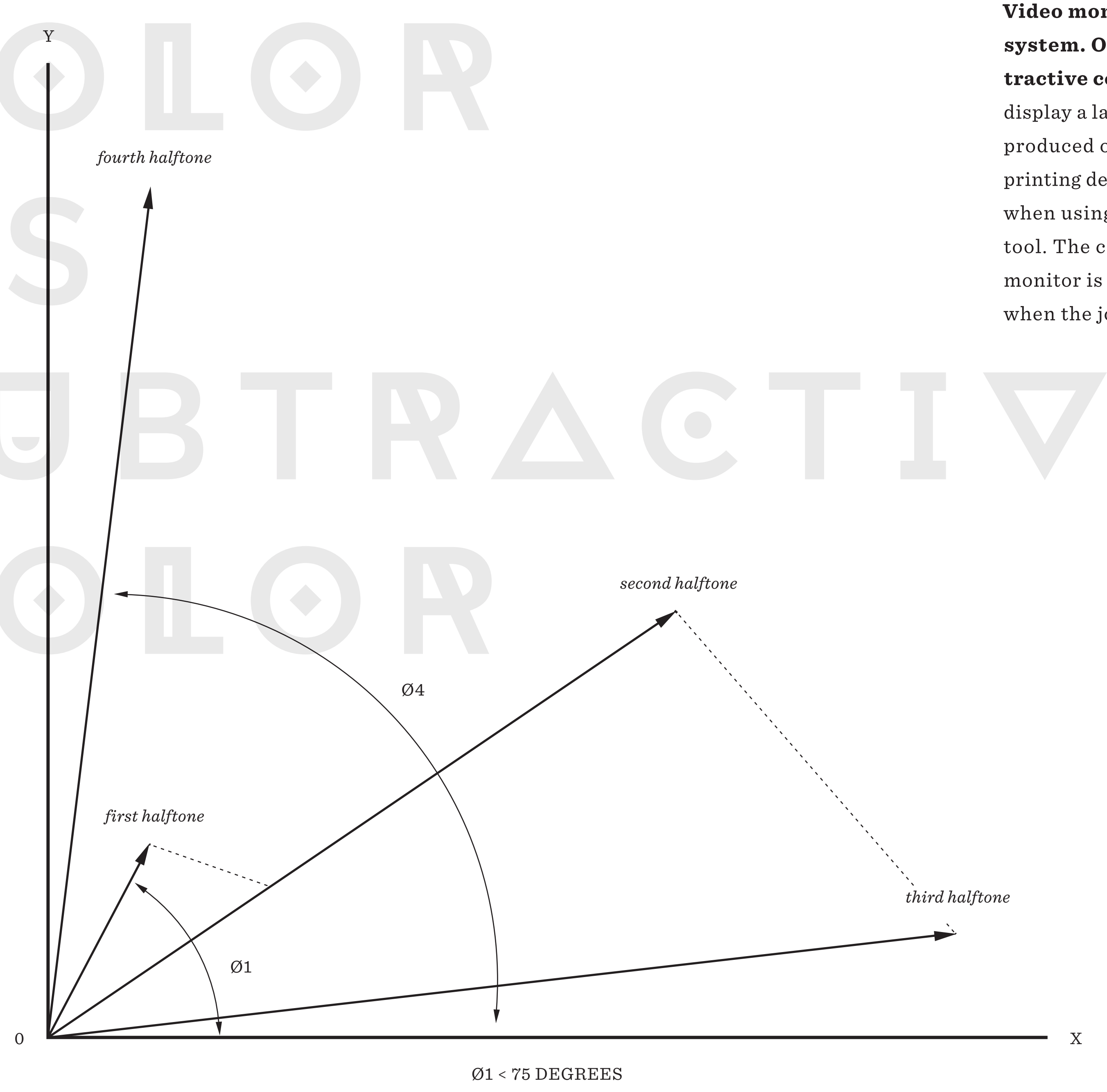


fig. i

Video monitors use the additive color system. Offset printing uses the subtractive color system. Computer screens display a larger gamut of colors than can be produced on press and by most color printing devices. This is important to know when using the computer as a design tool. The color you see on your computer monitor is probably not what you will get when the job is printed.

The limitations of the offset printing (subtractive) process are due in part to the image screening process and in part to the type of paper used to print the image. The screening process converts an original continuous-tone image, such as a color photograph, into a pattern of small dots for each process color so the image can be printed with a pigment (wax, toner, ink) or dye on paper.

A continuous-tone image shows a continuous density range between lighter and darker areas. An ink-printable image (screened image) is made up of small dots which creates the illusion of lighter and darker tones. A screened image can be produced using a fixed grid pattern of different-sized dots, or by varying the number of randomly placed, same-sized dots – or a combination of the two.

SCREENING PROCESS

fig. j

In offset printing, to be ink-printable, a continuous-tone image such as a photograph is converted into small dots of varying sizes using a camera and a halftone screen or, more commonly, a digital scanner. The original color image is separated into four separate halftone images – one for each of the three process colors and one for black. Historically, reproduction of continuous-tone images has relied on halftone screening methods that produced dots of different sizes in a fixed grid pattern. To be reproducible on press, each area of the original image is converted to a certain dot size to give the same visual appearance as the original image. When printed, areas with larger dots appear darker than areas with smaller dots. The size of each halftone dot is measured in terms of dot area percentage, from 1% to 100%. In a conventional halftone image, the dot size changes proportionately to the tonal value of the original image.

The coarseness of the grid, or screen ruling, determines the distance from the center of one dot to another. Newer digital screening methods produce very small, similar-sized dots randomly placed, not on a fixed grid. In these screened images, the number of small dots in a given area changes proportionately to the tonal value of the original image. Regardless of the screening method, a continuous-tone image must be converted into small dots to be reproducible on press.

The goal of four-color process printing is to create the illusion of continuous-tone color. Reproducing good tone is considered the first and foremost objective in achieving good color reproduction. The primary factor that limits color reproduction with subtractive color systems is tone compression.

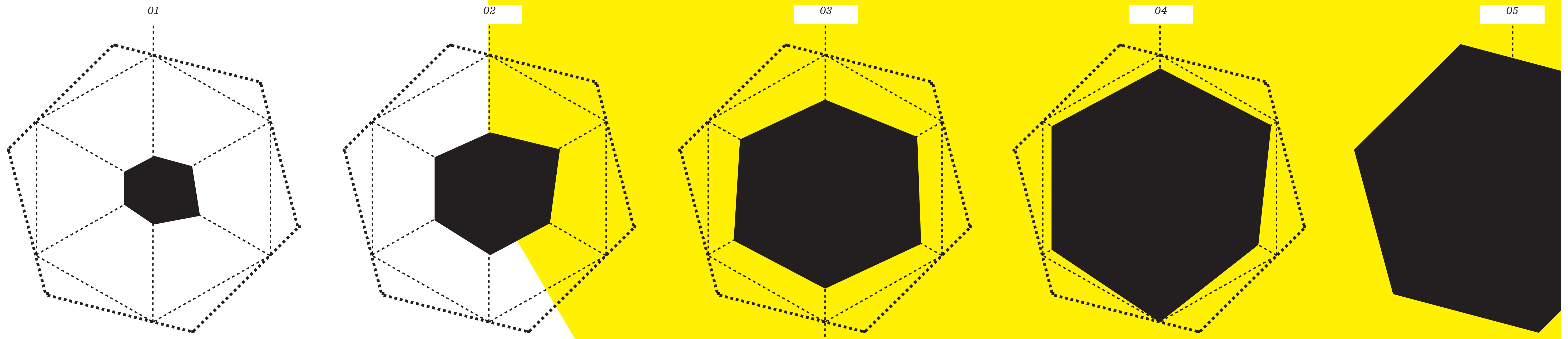


fig. j

Arrows indicate points of joining with adjacent halftone dots. A halftone dot does not start to join with all of the adjacent halftone dots at the same time.

TONE COMPRESSION

What is tone? Tone is actually the lightness/darkness value of an image. The tonal range of an image is the transition from the highlight (or minimum density) to the shadow (or maximum density) areas. On a printed sheet, the highlight areas have minimum ink coverage and the shadow areas have maximum ink coverage.

The density range between the highlight and shadow areas can vary from one image to another. One image may have a narrow tonal range while another image can show a wide tonal range regardless of the tonal range, the number of density levels in a screened image. In other words, the number of density levels of an original is usually far greater than what is achievable on press. This means the tonal range of an original image must be compressed during the image reproduction process. The result is tone compression which requires that certain parts of the tonal range must be emphasized at the expense of others. Because of this inevitable compromise, a decision must be made as to what parts of an original image are the most important to reproduce accurately. The entire tonal range of an original image is usually difficult to reproduce on press. Detail in the highlight ares may have to be sacrificed to hold the detail in the shadow ares or vice versa.

Tone compression is more manageable if the original image is produced using special photographic techniques. An experienced photographer can adjust the lighting of a subject to change the contrast, or reduce the tonal range, of the original image to match the capabilities of the reproduction process. A low-contrast image requires less tone compression than a high contrast image and is easier to reproduce on press.

PAPER BASE

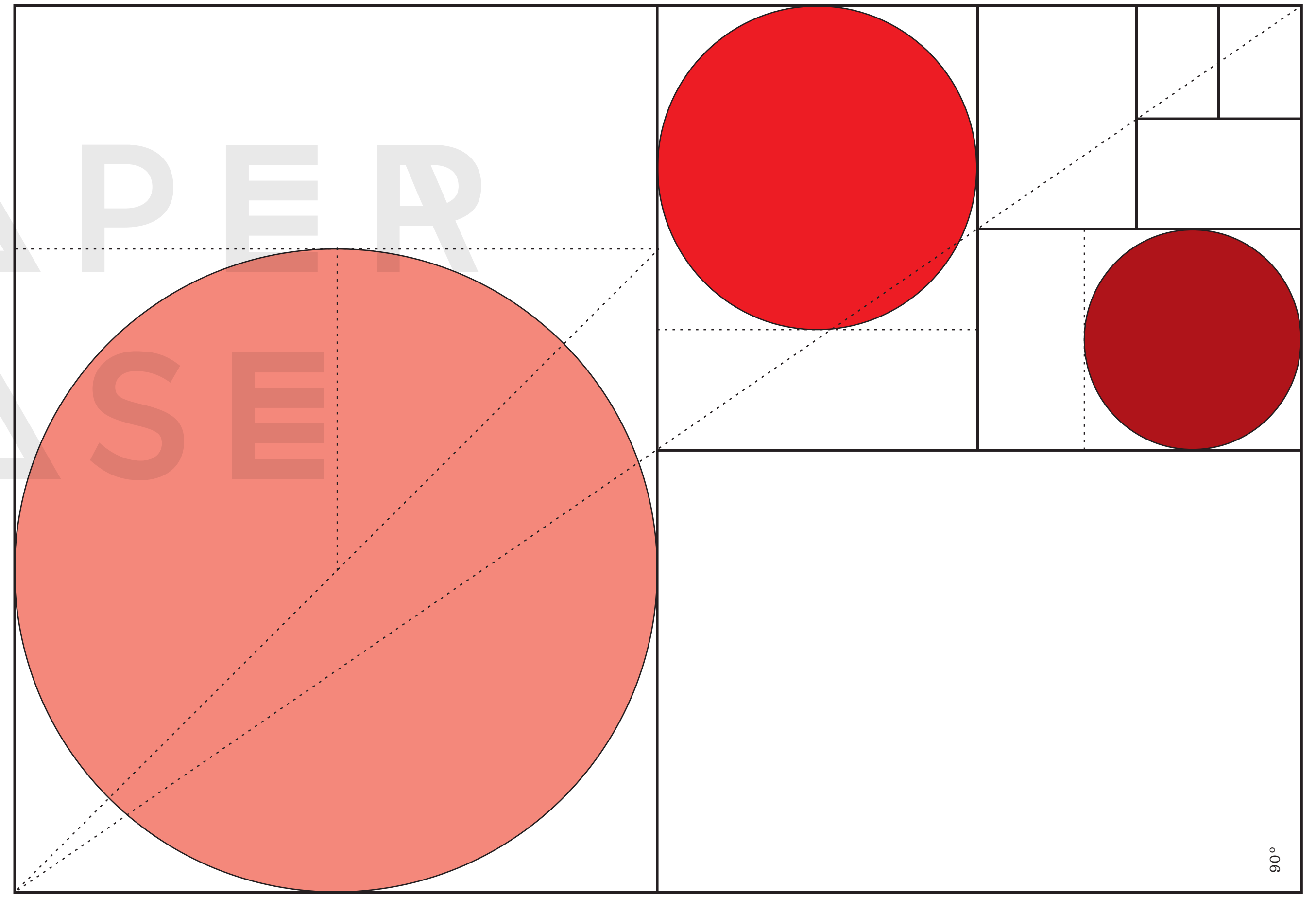


fig. k

Another factor that affects the amount of colors reproducible by the subtractive process is the type of substrate – usually paper – used to print the image. As discussed earlier, offset printing uses transparent color inks that act as filters an subtract portions of the white light striking the image on paper to produce other colors. It is the paper that reflects any unabsorbed light back to the viewer. Paper stocks vary in color, gloss, brightness, texture and absorbency. A press that prints on coated paper produces a wider range of colors than a press that prints on uncoated paper. This is because the rougher surface of the uncoated paper scatters the light and reduces the amount of light reflected back to the viewer. Smooth, glossy white paper returns more light back to the viewer. The range of colors on a substrate such as newsprint, which is usually rough, uncoated and yellowish, is more limited. A paper with a bluish cast will absorb some red and green wavelengths and cause colors to appear grayer than if printed on white paper. The effect of the paper base is so important to the appearance of a printed sheet that it can be considered a fifth color.

THE ROLE OF A COLOR PROOF

fig. l

Once a print job is on the press, changes are costly. The primary role of a color proof is to predict what a job will look like when printed. Using a color proof – and knowing what to look for in a proof – saves time and money by allowing changes to be made before a job goes on press. A proof serves as a communication and quality control tool at many steps in the production process.
It is used within a production environment to monitor how a job is progressing. It is used with the customer to determine if color correction is necessary.
It is used with the printer to check image quality and serve as a pressroom guide. A color proof often serves as a “contract” between the printer and the customer. This means the customer expects that the printed sheet will look like the proof. In the pressroom, the press operator makes adjustments to produce printed sheets that match the proof.

To be useful, a color proof must match the color, tonal range and visual appearance of the printing process. First, the colorants of the proofing system must simulate both the primary and secondary hues produced by the printing inks. Next, the proof must simulate the tone compression inherent in the printing process used. Finally, a roof must match the overall appearance of the printed sheet. Factors that affect overall appearance include the substrate, or paper stock, and gloss level.

A common pitfall is to judge a proof on how pleasing it is to the eye without considering how well it represents the printing process. If a proof cannot be matched on press, the proof creates frustrations for the press operator and unrealistic expectations for the customer.

SUMMARY

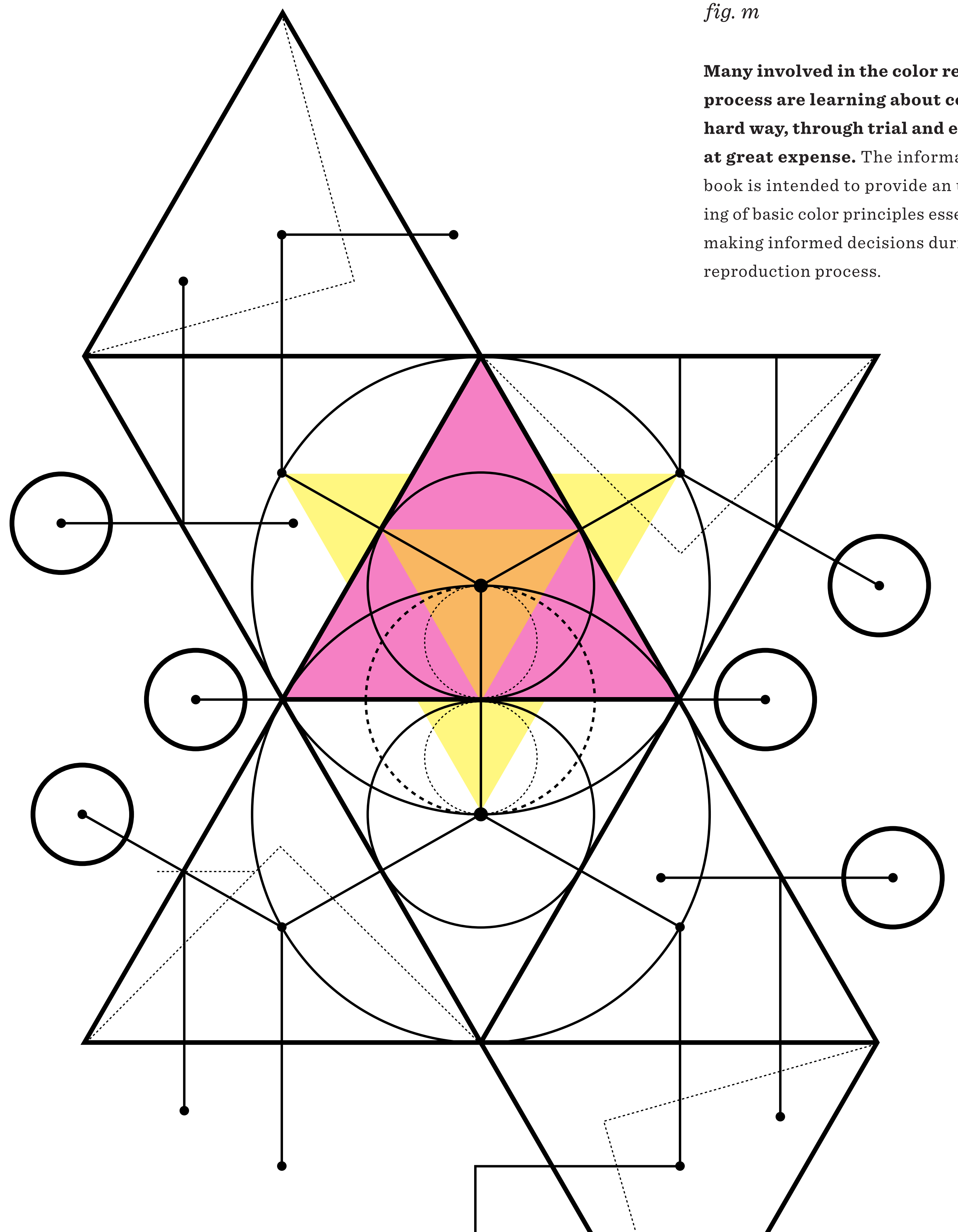


fig. m

Many involved in the color reproduction process are learning about color the hard way, through trial and error – often at great expense. The information in this book is intended to provide an understanding of basic color principles essential for making informed decisions during the color reproduction process.

It is important to know what color is: a visual sensation that involves three elements – a light source, an object and a viewer. Without light, color would not exist. Light that appears white to us, such as light from the sun, is actually composed of many colors. If visible light is divided into thirds, the predominant colors are red, green and blue, which are the primary colors of light.

There are only two ways of reproducing color – additive and subtractive. Additive color involves the use of colored lights.
It starts with darkness and mixes red, green and blue light together to produce other colors. When combined in equal amounts, the additive primary colors produce the appearance of white. Subtractive color involves colorants and reflected light.
It uses cyan, magenta and yellow pigments or dyes to subtract portions of white light illuminating an object to produce other colors. When combined in equal amounts, pure subtractive primary colors produce the appearance of black.

It is the subtractive process that allows everyday objects around us to show color. For example, a red apple really has no color. Colorants in the apple's skin absorb the green and blue wavelengths of white light and reflect the red wavelengths back to the viewer, which evokes the sensation of red. All color printing processes use the subtractive process to reproduce color. Printing presses use transparent color inks that act as filters and subtract portions of the white light striking the image on paper to produce other colors.

WHAT IS COLOR?