# *1. Three-Color Light*

Introduction to Three-Color Light

Many of us were taught at a young age that the primary colors are red, yellow, and blue. Our early experiences with color mixing were blending together paints where yellow and blue make green and the three colors stirred together make colors ranging from brown, gray, or black. From this we have two errors in our understanding of color. First, primary colors can be mixed together to create all other colors. Second, that red, yellow, and blue are *the* primary colors.

When we talk about primary colors, we generally think about three colors which can be mixed together to create all of the colors of the rainbow. Have you ever tried to make black out of your red, yellow, and blue? Even more difficult—try to make fluorescent pink, silver, or gold. Primary colors cannot make all other colors, but they can make the most colors from the fewest starting resources.


Adding Color Pigments
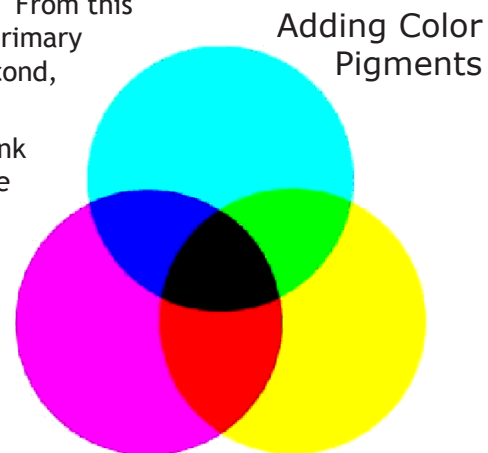
Difference Between Pigments and Light

There are two sets of primary colors: one for pigment (dyes and paints) and another for light. Look at the printing process for the color pages of your local newspaper or a

color printer, and you will see that the rainbow of colors is created from four colors of ink: cyan, magenta, yellow, and black. Modern printing has found that combinations of cyan, magenta, and yellow (which are very specific shades of blue, red, and yellow) can create the maximum number of colors. When mixed together in equal parts, the three create black (or gray). In printing, the black ink has been added as a fourth color to use less ink. To see how this works, take a microscope or magnifying glass to a color picture in the morning paper or a magazine.

What you see up close is a series of overlapping dots of various sizes and transparency in those four colors. You may even see a newspaper once in a while where the color layers were not properly lined up so the images appear to be double and the picture colors are not right.

In light, the primary colors are red, green, and blue. Despite what you learned in paint, when you mix yellow and blue light the result is white. Likewise, magenta + green makes white; and cyan + red makes white. Color television and computer monitors use the three primary colors of light to display thousands or millions of

Adding Color Light
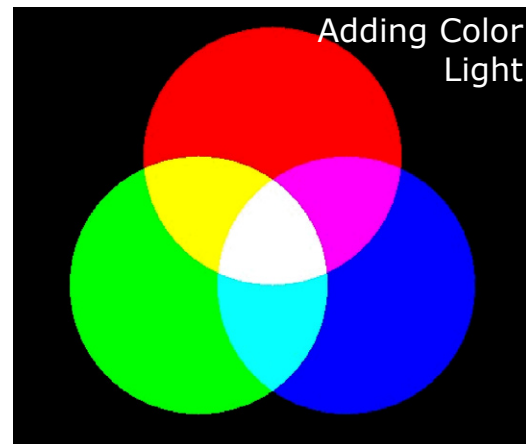
different colors. If you take a magnifying glass to your computer monitor or television, you will see a regular pattern of red, green, and blue lines or dots. Each of these glows at varying intensities, just as a color printer drops varying amounts of ink. In both cases, what you perceive is the mixing of the primary colors and up to 16.8 million different colors on the screen.

With a microscope or magnifying glass examine a color picture in the morning paper or a magazine. Look for the overlapping dots of various sizes and transparency in four colors of ink: cyan, magenta, yellow, and black.

With a magnifying glass, examine your computer monitor or television. Look for the regular pattern of red, green, and blue lines or dots.

How does the paper print dots compare with what you see on the computer monitor or TV?

The difference between mixed pigments and mixed light rests on how light gets reflected and absorbed. Pigment and paint are substances that absorb specific wavelengths of light, **subtracting** them from the light energy reflected by the surface. A blue painted surface will absorb all colors of light except the blue, which it reflects back. The reflected light reaches your eyes and you perceive the color blue. A colored light bulb or a computer monitor is a light source which shines or adds light energy of specific wavelengths. A red light bulb shines red light directly to your eyes and you perceive the color red.

Computer Monitors

A number of different technologies are used at present for computer displays or monitors. The two most common are the cathode ray tube (CRT) and the liquid crystal display (LCD; common in laptop computers). Here is a brief introduction to the CRT, although this is only the tip of the iceberg.

A CRT consists of a negatively charged heated metal filament, called a *cathode*, inside a glass vacuum tube. Coming out from the cathode is a ray of electrons. A positively charged metal piece, called the *anode*, attracts the electron beam and focuses it onto the screen at the front of the glass vacuum tube, which is the front of the monitor. When excited by the beam, a coating of phosphors on the screen glows. A color CRT has three electron beams and the screen is coated with phosphors that glow in three different colors: red, green, and blue (RGB). Each electron beam will excite only the dots or lines on the screen that have been coated for its color (i.e. the beam for red excites the dots coated in a red phosphor).

Naming Colors

People have given many names to the colors they see. When Isaac Newton wrote down the colors he saw in the rainbow, he chose to break them out into seven names. We still use that list of names today, although you may find it difficult to pick out the color indigo or the color violet somewhere in the room.

There are a number of basic color names that people refer to: red, orange, yellow, green, blue, purple, brown, white, and black. But individual people may not agree on what to call a specific block of color. Is it red, orange-red, salmon, burnt-sienna, or watermelon? Naming or distinguishing between colors is a very subjective process. As you study light and color throughout this course, you may find that what you think is pure red has more blue in it than the computer's pure red. Don't let that confuse you; when it comes to studying color it is not the name of the color that matters most.

Creating Colors

Part I: Create Colors

In the Tri-Color Creation Chart, guess the combination of red, green, and blue intensity values that would create the color in the left column. Enter your guess in the **ColorBasics** program (using the *Make Colors* tab) and see what color is created. Write what you would call that color in the 5th column. If it doesn't match, use the extra columns to guess again.

Tri-Color Creation Chart

Guess the color intensity combination to create the following colors:

	Red Intensity	Green Intensity	Blue Intensity	What color is your 1st guess?	Extra guesses Red	Green	Blue
Pure Red							
Pure Green							
Pure Blue							
White							
Black							
Yellow							
Violet							
Orange							
Pink							
Your favorite colors:*							
Your least favorite colors:*							

*Write the name of your color in the left column, and then make your guesses.

Roses are red,

Violets are blue,

How can I express them

In saturation, value, and hue?

Part II. Predictions

Now that you have started to see how the computer creates different colors from the primary colors of light—red, green, and blue—try to translate the colors from the computer's point of view.

With the Tri-Color Prediction Chart, you are given a set of intensity values for several "mystery" colors. Using what you learned from the Tri-Color Creation chart, predict what color is produced by these color intensity values. After you have written your guess in the chart, enter the intensities into the **Make Color** tab of **ColorBasics** and write the color you see in the column on the right. Use the last few lines of the chart to try some colors of your own design.

Tri-Color Prediction Chart

Red Intensity Value	Green Intensity Value	Blue Intensity Value	What color do you guess this is?	What color do you see with ColorBasics?
100	100	0		
0	100	100		
100	0	100		
75	75	75		
50	50	50		
25	25	25		
100	50	50		
100	50	0		
100	0	50		
50	100	50		
0	100	50		
0	50	100		
75	50	25		

Part III. Tri-Color Game

Test your understanding of how a computer creates color from intensities of red, green, and blue with a little competition. Using the *Play With Colors* tab of *ColorBasics*, play the game against another student or against the computer. Try to match the red, green, and blue intensities of the "secret" color. The software will keep track of the number of guesses each player uses to match the secret color.

Here is how you play:

1. **Select the level of difficulty for your game.** There are three levels of difficulty that determine how close the guess color must be to the secret color in order for the colors to 'match'. On Easy, the guess must match the secret color to within 15% of each of the 3 color intensities; Medium is to within 10%; and Hard is to within 5% of the secret color.

2. **Select your opponent** from the menu button next to 'Opponent': "Play a Person" or "Play the Computer."

3. **Click "Set Secret Color."** If you are playing a person, Player 1 enters 3 color intensity values in the boxes on the secret color window that pops up. Player 2 should cover his/her eyes or look away while Player 1 enters the numbers. If you are playing the computer, a color is randomly set.

4. **Try to reproduce the color:** make the right box color the same color as the left box color.

5. **Once the color is matched, you can explore** the colors that match for the level selected by clicking on "Explore Matched Colors", then you can switch roles and Player 2 will set a secret color.

6. **Play as many rounds as time permits.** Your scores appear at the bottom right corner of the screen.

The winner is the player who took the LEAST number of tries to match the colors.

Note: The game can be played with more than 2 players by dividing players into team 1 and team 2.

Fill in the Tri-Color Reference Chart as you wish to summarize the "formulae" for common colors in terms of intensity values of the three primary colors. Keep it handy—it will help you in interpreting color digital images.

Tri-Color Reference Chart

Use data that you've already collected as well as both software programs (**TriColor** and **Game_TriColor**) to fill the color intensity values on this chart.

Color	Red Intensity Value	Green Intensity Value	Blue Intensity Value
Black			
White			
Red			
Yellow			
Green			
Cyan			
Blue			
Magenta			
Orange			
Purple			
Brown			
Pink			
Light Gray			
Medium Gray			
Dark Gray			