

Lab Sim 11: Color

INTRODUCTION

Do you see the same colors as I do? Does anyone see color the same way? Can my dogs see colors?

In one sense, color is an absolute: we perceive differences in the wavelengths of visible light as colors. As the sun emits its light, anyone with the appropriate tools can measure the wavelengths present. Visible light wavelengths range between approximately 400nm (violet) to 700nm (red).

When that white sunlight strikes your blue shirt, only the blue light reflects (the other wavelengths are absorbed). And here's where it gets subjective because no one can ever really know for sure what that blue looks like to someone else. Color vision is amazing, but what's also fascinating is how colors of light combine, and how it's different than how colors of pigment (paint, ink, etc.) combine.

OBJECTIVES

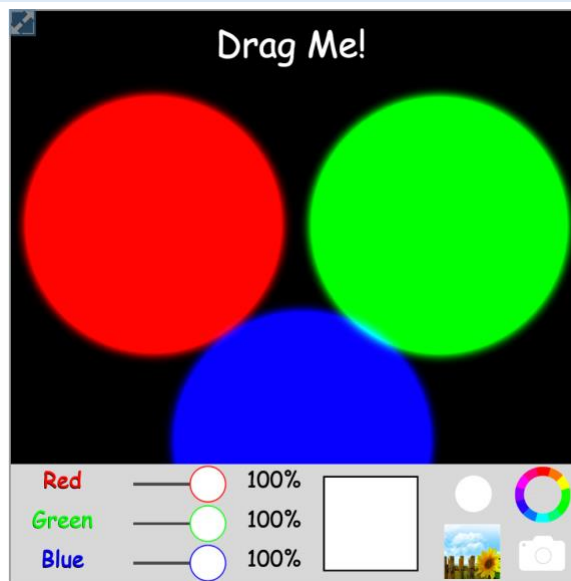
- Relate the concept of color to specific wavelengths of electromagnetic waves
- Define the rules for mixing colors of light
- Demonstrate the difference between additive and subtractive primary colors
- Observe the difference between mixing colored pigments and mixing colored light
- Examine differences in human and animal color vision

EQUIPMENT

- Internet-capable device with the ability to run a browser
- Paper, pencil, calculator
- Patience—lots of patience

PROCEDURE

1. Read this handout completely before you try to dive in. It will save you time and frustration later. If you are able to print it, you will not have to tab between windows—you can look at this and the circuit simulator at the same time.
2. Do you have paper and pencil handy? Go get it, I'll wait. Don't forget your calculator.
3. In a browser window, navigate to the [RGB Color Interactive](#). Don't try to start doing the lab yet! Just verify that the interactive opens properly. Unfortunately, this particular sim does not have a downloadable App for your phone.
4. The figure on the right shows what the interface looks like on the web page. You can pull on the lower right corner to re-size the window and make it bigger. You have three adjustable sliders that control the intensity of the three colored lights. The large white box shows the result of mixing all three lights. On the far right, you can choose a background for the three lights.



QUESTIONS

(2 POINTS EACH)

Examine what happens when you drag the three circles, making them overlap each other. Make sure all three circles overlap!

1. (1 point) What color is the area where all three of the circles overlap each other?

A) Black.	C) Red.	E) Blue	G) Magenta.
B) White.	D) Green.	F) Cyan.	H) Yellow.
2. (1 point) What color do you see where **only** the RED and GREEN circles overlap? (Use the slider to turn the BLUE light down to 0%.)

A) Black.	C) Red.	E) Blue	G) Magenta.
B) White.	D) Green.	F) Cyan.	H) Yellow.
3. Is this the result you would expect if you took red paint and mixed it with green paint (or maybe red PlayDoh (or modeling clay) mixed with green PlayDoh (or modeling clay))?

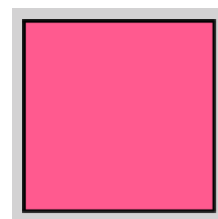
A) Yes! Mixing colors of light is exactly the same as mixing colors of paint.
B) No. You would never get yellow paint if you mixed red and green pigments together!
C) Maybe. What we see on the screen doesn't really show what mixing colors of light would look like.
4. Now use the slider to reduce the GREEN light to 50% (± a few % is fine). Now what color is the overlap?

A) Black.	B) White.	C) Red.	D) Orange.
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- E) Yellow F) Green. G) Blue. H) Violet.

5. (1 point) Reduce the RED slider to 50%, keeping the GREEN at 50%. Now turn BLUE back up to 100%. Describe the color of the overlap (the color in the box). What do you see? **No wrong answer here!** Just describe what you see.

The color of an object is determined by the color(s) of light that it reflects. So, a blue shirt appears blue because it reflects blue light and absorbs the rest of the colors. Examine the color swatch on the right, which represents the color of an old bridesmaid's dress that your mother wore in the '70s. Adjust the sliders until the overlap of all three circles matches this color swatch.

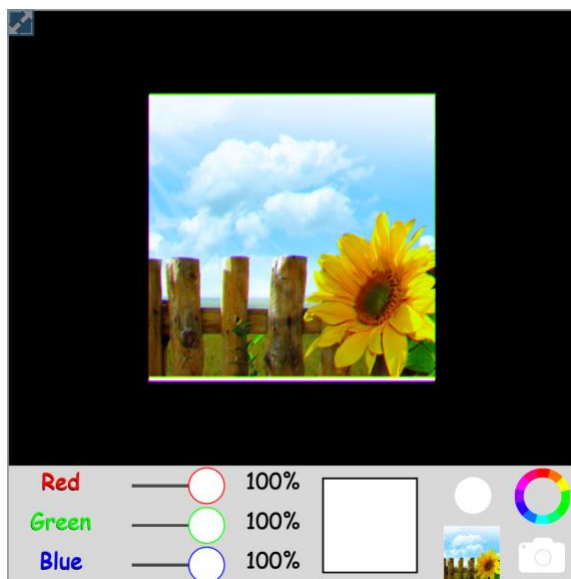


6. What colors are being reflected, and in what proportion?
 A) This color reflects the most red (100%) and the least green (40%) light.
 B) This color reflects the most green (100%) and the least blue (60%) light.
 C) This color reflects the most blue (100%) and the least red (50%) light.

Since you're looking at all the old photos, your grandmother shows you her prom picture from the '70s, and your grandfather is wearing a funky-fashionable baby-blue tuxedo. You really can't believe it, but there it is, in living color.

7. (1 point) Mix the colors until you find the matching shade of baby blue. Express your answer in the following format: X, Y, Z where X is the % RED, Y is the % GREEN, and Z is the % BLUE. There will be a range of acceptable responses because not everyone will perceive the colors the same way! (But if you claim that 43, 0, 57 is baby blue, we need to have a chat!)

Turn all three colors up to 100%. Now overlap the circles directly on top of each other, so you only see a single circle. Choose the sunflower background image as shown on the right. The sky should look blue, and the flower is yellow.



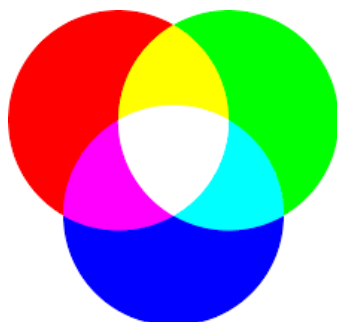
8. Turn the RED and GREEN sliders down to 0%. What color do the yellow flower petals appear when illuminated with only blue light?
 A) Black. E) Blue
 B) White. F) Cyan.
 C) Red. G) Magenta.
 D) Green. H) Yellow.
9. Why?
 A) Because the petals are absorbing all the blue light.
 B) Because the petals are reflecting all the blue light.
10. Why do the clouds disappear???
 A) Because the white clouds absorb the blue light.
 B) Because the white clouds reflect the blue light!

A while back, 'Blue-Blocker' sunglasses were a popular As Seen on TV product (ask your dad). Adjust all three sliders to 60%, which simulates an ordinary pair of sunglasses. Pay careful attention to the details (like the clouds or the weed to the left of the flower).

11. (1 point) Do Blue Blockers work? Slide BLUE to 40%.
 A) No. There is no difference in the images, either in color or contrast.
 B) Yes. The colors seem a little yellowish, but there is more/sharper contrast.

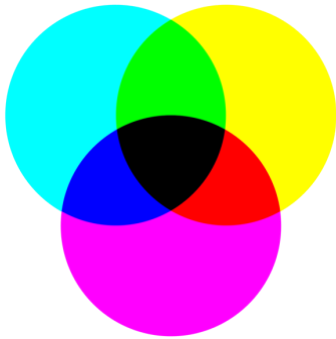
If you're having a hard time with this, try re-setting everything to 60% and then taking the RED back to 40%. Put everything back at 60% again, then take the GREEN down to 40%! It might be easier to see by comparison.

12. Design your own sunglass lenses. Because everyone's vision is slightly different, what lens tint would you prefer? Adjust the sliders and find a tint that 'feels right' to your own eyes. Express your answer in the following format: X, Y, Z where X is the % RED, Y is the % GREEN, and Z is the % BLUE. **No wrong answer here!**



RED, GREEN, and BLUE are called the additive primary colors of light. As you saw above, you can combine these three colors in varying proportions to make any color of light. But these are probably not the primary colors you were taught in grade school: red, yellow, and blue.

13. (1 point) Did your grade school or art teachers lie to you? Were they just wrong?
 A) They were not wrong, and they were not lying. Red, green, and blue are simply not primary colors, and it doesn't matter whether you are talking about light or paint.
 B) They were wrong, but maybe they just didn't know it? Red, yellow, and blue are not primary colors, whether you are mixing light or mixing paint.
 C) They were not wrong, but they were not quite right, either. Mixing light and mixing pigment (paint, ink, etc.) are not the same thing. RGB = primary for light, but RYB = primary for pigment.

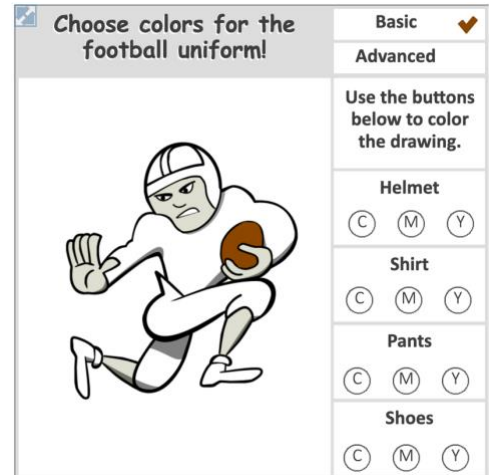


14. Why are RED, GREEN, and BLUE called **additive** primary colors?
- A) Because any two of these colors add up to make the third:
 $RED + GREEN = BLUE$, or $GREEN + BLUE = RED$, or $BLUE + RED = GREEN$
 - B) Because adding all three of these colors makes black: $RED + GREEN + BLUE = BLACK$
 - C) Because adding all three of these colors makes white: $RED + GREEN + BLUE = WHITE$
 - D) It's a historical term, but no one actually knows what it originally meant.

Books, magazines, brochures, etc., are all printed using **CYAN, MAGENTA, YELLOW, and BLACK (CMYK)** pigments. The ink cartridges in a color printer are also CMYK. These are called **subtractive primary colors** and are shown on the left.

To see the results directly of CMY color mixing, you can switch to the [Painting With CMY Interactive](#). It's self-explanatory: just click on the C M Y dots to mix the colors. (Pro

Tip: The Advanced option is pretty fun for creating some unusual combinations!)



15. What color is the football helmet when you mix using CYAN + MAGENTA?
- A) Black.
 - B) White.
 - C) Red.
 - D) Green.
 - E) Blue
 - F) Cyan.
 - G) Magenta.
 - H) Yellow.
16. How do you make the football jersey **RED**?
- A) $MAGENTA + YELLOW = RED$
 - B) $CYAN + MAGENTA = RED$
 - C) $CYAN + YELLOW = RED$
 - D) $C + M + Y = RED$
17. Why are **CYAN, MAGENTA, and YELLOW** called **subtractive** primary colors?
- A) Because subtracting all three of these colors makes white:
 $CYAN - MAGENTA - YELLOW = WHITE$
 - B) Because they are formed by subtracting one color from white light:
 $WHITE - RED = CYAN$, or $WHITE - GREEN = MAGENTA$, or
 - C) Another historical term that nobody actually remembers!

$WHITE - BLUE = YELLOW$



Humans see color because we have specialized sensors (called cones) lining our retinas that are sensitive to specific frequency ranges corresponding to red, green, and blue. Some people can't see certain colors because their red and green cones overlap in sensitivity (which, somewhat surprisingly, results in less, not more, color sensitivity). Some animals, like our dogs, can't see color the way we do because they only have two types of color-sensitive cones.

The top image (Skittles!) simulates what human color vision defects look like. The bottom figure (dog toys!) shows what colorful toys look like to people, as opposed to how your dog sees those objects.



18. (1 point) True or false: A person suffering from **protanopia** would have difficulty separating the green from the orange Skittles.
19. (1 point) You are buying a new toy for your dog! You and your pupper will be playing with it outside, in the grassy yard. What's the **worst** color you could pick because it will be the hardest for your dog to see?
- A) Red.
 - B) Yellow
 - C) Blue.
 - D) Violet.