

## Lab 4

### Additive color mixing

At UW-Madison we use old white light projectors for this lab, which are no longer commercially available but they are nice and bright, project a circular image with sharp edges, and use R, G and B color filters which burn easily, but can easily be changed. The three projectors are shown in Fig. 1.



Fig. 1

We power these projectors through dimmers, so the intensity of each color can be varied. When all three spots overlap they form white, as shown in the photograph of Fig. 2.



Fig.2

We ask the students to use a hand-held inexpensive spectrograph, look at the spot from the red projector, then the spot from the green projector and verify that neither has any yellow light. Overlapping the two spots shows yellow. Using the spectrograph again reveals no yellow bands. Yellow is really only a mixed color, there are no yellow wavelengths present. This is the most striking demonstration of additive color mixing.

We then ask them to point the fourth white projector onto the green spot. Note that the hue has not changed, only the saturation changed. The green is now less saturated, that is,

it has a higher percentage of white. Now change the intensity of the white and green projectors so that green has the same brightness as the red spot, but less saturation.

We also ask the students to draw a color triangle, place blue and green on it. Where would a less intense blue be located?

Add B and G in equal proportions. Calculate the fractions of red and green, and place the mixed color on the color triangle. Now add two times more G than B. Then two times more B than G. Then use B only. Where are all these colors on the triangle? Notice that they are all along the line between G and B. For equal intensities of B and G the resulting color point is located half way between G and B. If there is twice more G than B the point is twice farther from B than from G, and vice versa.

### **Complementary colors**

Two colors are complementary when their addition produces white.

Add R and G, what do you see?

What is complementary to the above hue? To answer ask yourself: what do I need to add to R and G to get white? The answer of course is B.

Move one projector so that the two complementary hues are seen side by side, with white where they overlap. Look at the color triangle in your notebook: where are the complementary colors located in relation to white?

What color would you expect to be complementary to R? To G? Try it!

### **Color matching**

The students are provided with an assortment of colored papers. Choose a colored piece of paper and illuminate it with the white projector. Project a single spot of light making all three RGB projectors overlap. Adjust their intensities to match the color of the paper. Cut off a small piece of paper, paste it in your notebook, and next to it write how much R, G and B you had to add to match that color. Repeat for one or two additional colors.

Not all colors can be matched by mixing RGB. A possible reason for failure is if the color to match is too bright for the projectors used. In this case use a neutral density filter to dim the color to be matched. High saturation of spectral colors is another possible reason for failure. In this case the color to be matched must be desaturated by adding a little complementary color to it. E.g. if you are trying to match spectral cyan you will fail, but if you desaturate it by adding a little red to it (use another projector with a red filter in it, and add just a little: keep the intensity of red very low).

It is possible that this lab could be done equally well, or even better, using LED projectors, but we have not tried them yet.

This and many other fun experiments on color and color mixing can also be done digitally, directly on the web, or downloaded and installed on individual computers for each student. They are available on the NSF-funded website at Boston University:

<http://lite.bu.edu/vision/applets/Color/Color/Color.html>