Primary Colors

Workshop #5 Physics 102 Feb 21-22, 2008

Name: _________________________ Workshop Instructor: _______

Lab Partner(s):_________________ Time of Day of Workshop: ____

Part I: Introduction

If we only saw the *intensity* of the visible light that strikes our eyes, then we would only see in black and white. But most people see millions of distinct *colors*. They are *trichromats.* This means that their retinas process information about the intensity of light by using three types of sensors. These sensors are called red, green and blue cones. Each is sensitive to light in a particular range of color. The sensitivity is in the red, green and blue wavelength ranges, respectively.

These three types of information (i.e., the intensity of light reaching the retina in the three wavelength regions) allows us to distinguish all the colors. We examine, in this workshop, the implications of the fact that we are trichromats.

The equipment in the room is ample for eight separate groups. Work with either one partner or two, but no more. You should work together and discuss the lab, as you go. But *each* of you should perform all the experiments. Equally important, you are required to write down your *own answers* and to turn in your *own worksheet*.

If you are colorblind, (as a substantial number of people are), please make a note on this sheet. Note the type that you have, if you know.. Discuss any differences in your results with those of your partner(s).

A. Equipment

A light box and a power source.

Six colored filters. The first three filters are red, green and blue. These colors are called the *additive primaries*. The remaining three filters are yellow, cyan and magenta. These three colors are known as the *subtractive primaries*.

Two plastic slides.

White paper.

B. Getting Familiar with the Equipment

1. **SAFETY: The light box gets very hot. Avoid touching it. Remove any filter (or turn off the light box) when you are not studying colored light. If you do not do this, the filters will melt. You can use a pencil or a pen to gently remove the colored filters. Also, at the end of the lab hour, check that there are the same six filters on the white paper, as in your arrival at the lab table.**

2. Examine the light box. If it is not connected to the power supply, plug the two wires from the light box into the power supply. The box is turned on when the switch on the power supply is in the **on** position.

   The front end of the box has mirrored flaps that open out. When the lamp is on, beams of light come out of the front and out of the sides of the box. You can use the mirrors to direct the two side beams so that they combine with each other. Or, they can be used so as to combine one side beam (or both) with the beam that comes out of the front. You can also insert any of the colored filters onto the box, in order to color the beams.

3. To view the combined lights, aim the front of the box at the side of a white box about 20 cm in front of the light box. Note that 20 cm is a little less than the width of this sheet of paper.

4. Practice mounting each filter on the front end of the box. (Close the two side flaps.) Turn on the lamp to see what each of the filtered colors looks like on the white paper. Do this for all six filters, in turn. In addition to red, green, blue and yellow, you should have *magenta* (a deep pink) and *cyan* (a blue-green color).

5. Now, practice *combining beams* of light, using the mirrored end of the box. This does not mean overlapping filters. Instead, combine two *light* beams. Do this by placing any chosen filter over the central opening and any other chosen filter over either side opening. Leave the other side closed, so that there are only two beams. Adjust the mirrored flaps so that the two beams of light combine on the paper.
Write down below the two colors chosen and also the observed color of the combined beam.

   The two filters: The observed color of the combined beam:

6. Now, *overlap* the same two filters. Do this by placing both in front of the central opening. Close both side flaps. Record the color that emerges below:

7. Compare your results of combining light in parts 5 and 6. Did you get the same result? Which of these ways of combining is *additive* combining?

Part II: Mixing Colors via Color Addition

As discussed in lecture yesterday, the three *additive* primaries are red, green and blue. The trichromatic theory of vision makes the assumption that any known color can be reproduced by combining these three primaries. So, by varying the relative intensities of these three colors, you can match any given color. This assumption is consistent with all experiments.

By color *addition*, we mean that the light is combined. What reaches our eye is light of *every* component that is added.

Experiments with Color Addition

Combine colors in twos, selecting from the three additive primaries. Before you mix the colors, take a quick guess as to the resulting color. Your guess can be derived from personal experience, or from your observations of the experiments performed in yesterday's lecture.

You can place one filter at the side, and one at the front center. If so, close the door to the side not used. Or, you can use the two sides. If you do this, block out the center opening with one of the plastic slides at your table.
It may be a good choice to place the blue filter at the central opening, when using blue as one of the two filters.

1. Record your *guess* first, for all three pair combinations:
   Then, record the color you *observe* for each pair combination

Guess	**Observation**
R + G =	R + G =
R + B =	R + B =
G + B =	G + B =

Now, combine *all three* additive primaries. Try green or blue at the central opening. Guess the result first, then observe and record.

Guess: R + G + B = **Observation**: R + G + B =

Part III: Experiments with Color *Subtraction:* Use of the *Additive* Primaries as the Colors Combined

In color subtraction, the two colors combined do not add. Instead, each color subtracts some of the light incident on it.

One way to do this is to stack two filters on top of each other. Then, you can view the overhead lights through the overlapping filters. Alternatively, you can use the light box, by putting both filters in front of a *single* beam from your box.

You observe the color of the light that gets through *both* filters.

1. Predict the result of combining red light and green light by color subtraction.

   Hint: If white light is incident on a red filter, then the red component is transmitted. It is easiest to model white light as a roughly equal combination of red, green and blue light. Then, the green and blue components are absorbed. A similar argument tells you what happens when white light is incident on a green filter.

   Your argument for the prediction of red and green subtraction:

   Your observation of the result for red and green subtraction:

2. Take a piece of white paper to the front table. There, you will find a red and a green marker. Predict the result of mixing these two colors on paper. Prediction and reason:

   Observation:

   Is this color addition or color subtraction?

Part IV: Experiments with Color *Subtraction:* Use of the *Subtractive* Primaries as the Colors Combined.

The three remaining filters not used are yellow, magenta and cyan. These three colors, you may note, are the three results of combining the three additive primaries in pairs. (See your results of Part II.)

1. What color (or colors) is absorbed by the *magenta* filter? Why?

2. What color (or colors) is absorbed by the *cyan* filter? Why?

3. In the lecture of yesterday, we used a "block" method to determine the result of color subtraction. In this approach, two rows are drawn for the two colors to be combined. Then, the incident white light is replaced by three rays, (red, green and blue). The absorption or non-absorption of these three rays is noted, for each row. To emerge, the ray must escape absorption in *both* rows.

   Apply this approach to determine the result of color subtraction for cyan and magenta.

4. **Observe** the result of subtractive combining of cyan and magenta by using overlapping filters. Compare your observation with your prediction, below.

5. Repeat parts 3 and 4 for the subtractive combining of yellow and cyan.

6. In lecture yesterday, we showed (by both prediction and by observation) that the subtractive combining of yellow and magenta yields red as the resultant color.

How do the three results of color subtraction of yellow, magenta and cyan in pairs (results found in parts 4, 5 and 6) compare with the three primary additive colors?

Can you now guess why yellow, magenta, and cyan are called the three *subtractive* primaries?