

## Explanation of the Basic Models of Color Mix in the Classroom for Physics

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**Abstract.** The article describes the demonstrations that allow you to show the basic color mixing models, and presents the developed simple colorimeter.

To understand the features of additive color mixing, which is used in self-luminous objects, an enlarged image of the monitor screen is used and the developed bluetooth lamp, the main element of which is the RGB LED. It is shown that by sending a combination of three numbers you can get the color of different hues and saturations.

The features of the subtractive color mixing model are clearly demonstrated by mixing paints. The achromaticity of the eyes of each student is determined with the help of a multicolored strip, the colors to which smoothly change as in the quasi-continuous spectrum of visible light.

At the end of the article a detailed description and calibration process of the color sensor is presented, which allows determining the quantitative composition of the color of paper, fabric and plastic.

**Keywords.** Color Mixing Models, RGB LED, Colorimeter.

### 1. Introduction

Among the various methods used for better mastering new material, a special place is occupied by demonstrations of real physical phenomena and processes. They provide a basic, deep perception of the educational material, broaden the horizons and create a sensory-empirical basis of knowledge [1], that is, they are an important method of cognitive activity of a student.

One of the elements of the "Optics" section is the material "The human eye, as a selective photodetector", which examines the physical aspects of a person's vision, various color

models and their perception.

Therefore, vivid demonstrations of the basic models of color shift will not only improve the absorption of the material, but also check the features of the color vision of each student.

### 2. Demonstration of color mixing models

The most common color mixing models are the additive and subtractive models [2].

It is known from a school biology course [3] that a normal human eye contains three types of cones sensitive to different regions of the visible spectrum: red (long wavelength), green (medium wave) and blue color (short wavelength).

To demonstrate an additive model based on the addition of colors of self-luminous objects, a white monitor screen [2] is used, which is viewed at high magnification (Figure 1). On the screen you can clearly see red, blue and green stripes, which, under normal consideration (without magnification), merge. The eye in this case, simultaneously perceives all the rays of the same intensity with different wavelengths and sends a signal to the brain, which summarizes all the information and therefore the monitor screen is white.



**Figure1. Additive model (by the example of a monitor screen)**

The student remembers that the main colors of this model are red, green and blue - the RGB model, and the mixture of all these colors gives a white color.

In the digital world, each color is characterized by saturation, which can take 256 values - from 0 to 255. Therefore, to

demonstrate the additive color mixing model in digital format, an RGB bluetooth lamp was developed, the functional diagram of which is presented on Figure 2.

For mixing colors used 30 W RGB LED. The color with which the lamp is lit is controlled by using signals with wide-band pulse modulation, which is generated by the Arduino Pro mini board (based on the Atmega 328 microcontroller).

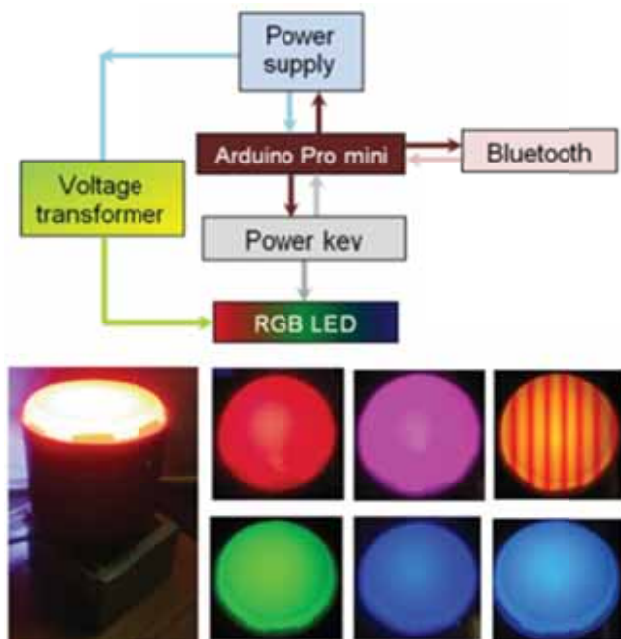


Figure 2. RGB bluetooth lamp

The control signal of each channel of the RGB LED goes to the base of the bipolar transistor operating in the key mode (power switch), which allows changing the saturation of each color separately (see Figure 2 blue color). The lamp is controlled by a smartphone with the help of a specially developed program in the App Inventor 2 environment via the Bluetooth module. The value of the RGB code is sent to the hardware serial port of the microcontroller.

To demonstrate mixing colors, a three-digit code is sent from the phone, each of which is in the range from 0 to 255. The student observes that when mixing colors, the resulting color is brighter, and the sum of all three (RGB) components of maximum saturation gives white. Pulse band modulation can be seen only by looking at the luminous lamp through the camera of the phone. The observed image is

alternating stripes of the same color tone, but of different saturation (see Figure 2. orange color).

To demonstrate *the subtractive color mixing model*, ordinary paints are used. The attention of the student is focused on the fact that the main components of this model are the colors obtained by subtracting the additive model from the white color of the primary colors.

On the table have glasses with diluted colors: blue, red and yellow. Next, the student himself mixes them to obtain the secondary colors of the model: green, orange, purple (see Figure 3). When it is absorbed that the colors are a kind of light filter, that is, if you mix blue and yellow paint, then the first cuts off the long-wave part of the spectrum, and the second (yellow) - short-wave. Consequently, only the middle part of the visible spectrum remains and the eye sees green paint.



Figure 3. Subtractive model (mixing paints)

Special attention is paid to the fact that the mixture of the three main components of this model gives a color close to black, but not saturated black. This explains the addition to

the three primary colors of the subtractive black model. To evaluate the chromaticity of each student's vision, he is invited to study the quasi-continuous spectrum of visible light (Figure 4) and determine the number of bands of different light shades [4]. Further, depending on the results of the calculations, it is possible to estimate in which region of the visible spectrum, which type of cones work best, that is, determine to the dichromates, trimchromamots or tertrochramats the eye.



Figure 4. To determine the chromaticity of vision

### 3. Designed colorimeter and its calibration

Next, students are introduced to the scientific approach of determining color and the corresponding instruments — colorimeters, which provide color information by a set of three numbers corresponding to the components of the RGB model.

A budget simple colorimeter was developed at the Department of Physics of NTU "KhPI" to determine the color, the functional diagram of which is presented in Figure 5. The sensitive element of the device is the color sensor TCS34725 [5], which consists of 12 photodiodes of 3 each with red, with green and blue light filters, and 3 without a light filter. The sensor has built-in ultraviolet and infrared filters and it is possible to adjust the gain and integration time, which makes it possible to amplify the signal and accumulate it longer in case of weak illumination of the object. The sensor is controlled via the I2C bus using the Arduino Uno board. To eliminate the influence of ambient light on sensor data, it was placed in a protective opaque cylindrical housing. To display information, a TFT screen is used, which displays three RGB coordinates and a rectangle whose color is similar to the color of the object under study.

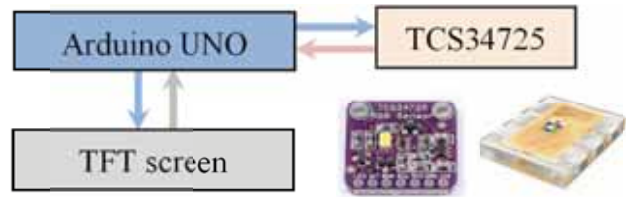


Figure 5. Color sensor and circuit developed colorimeter

In order for the color sensor to correctly determine the coordinates of the RGB components of the model, it was calibrated with the help of a monitor screen of the three colors of different saturation that is illuminated with a different color of the monitor screen and printed on a color printer. In both cases, the color saturation (blue, green and red) was changed in 25 steps from 0 to 255. Dependencies of the output signal voltage of each sensor channel were plotted on the saturation for each color. Based on the data obtained, a software for the microcontroller was developed, which allowed the output of the color sensor to be converted to RGB coordinates and automatically distinguish the material of the object (various reflection coefficients), the color of which is determined: plastic, paper, cloth. Figure 6 shows examples of the work of the colorimeter on various materials.



Figure 6. Examples of the work of the colorimeter: blue and red plastic; white, green and orange paper; magenta fabric

### 4. References

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