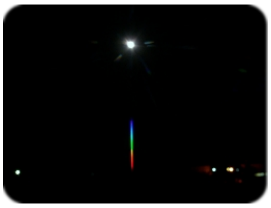
Spectroscopy for young pupils
(not only)



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Spectroscopy for young pupils

(not only)

From sky to earth

All of us have admired the colors of rainbow after a rain. The same colors are also formed on the bottom surface of an optical disk (CD or DVD).

Picture 1

A rainbow

Picture 2

Rainbow colors on a CD surface

What is the common that happens in the sky and on the surface of an optical disk, so the same colors are displayed? In the case of rainbow, light interacts with water droplets and colors are formed. In the case of an optical disk, light interacts with the optical disk's surface and the same colors are formed. In both cases, the formation of colors is a result of light – matter interaction.

Preparation of optical disk

We can easily experiment with the light – optical disk interaction, because we have many disks available in our homes and there is a variety of light sources easily accessible to everyone (sunlight, lamps of various types, lasers, etc).

For our experiments we must properly prepare a CD or DVD by separating the bottom disk from the upper one (pict. 3 – 5).

Picture 3

Using a thin blade, carefully depart the upper disk (cover) from the bottom disk(the one the data are recorded). Keep the bottom disk

Picture 4

Using adhesive tape thoroughly clean the remains of mirror left on the disk.

Picture 5

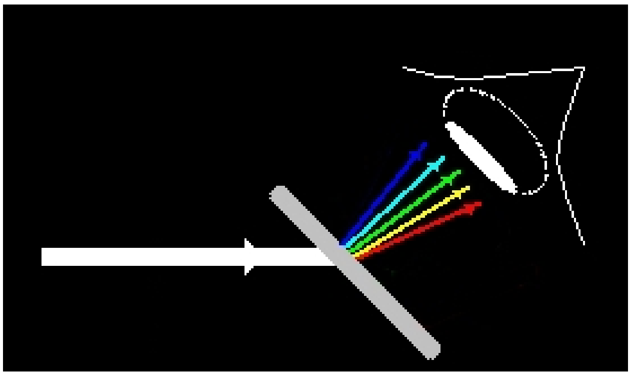
Finally you have a clear disk with some color on it. Remove the color by sinking the disk into a plate with alcohol.

Looking through the optical disk

Having properly prepare our optical disk, we are in a situation to begin our observations. The observations must be done looking the disk at an angle respect to the direction of the light incident on the disk (pict. 6). We can also construct a pair of glasses for bare observations or a single glass to fit it on a camera or video camera (pict. 7).

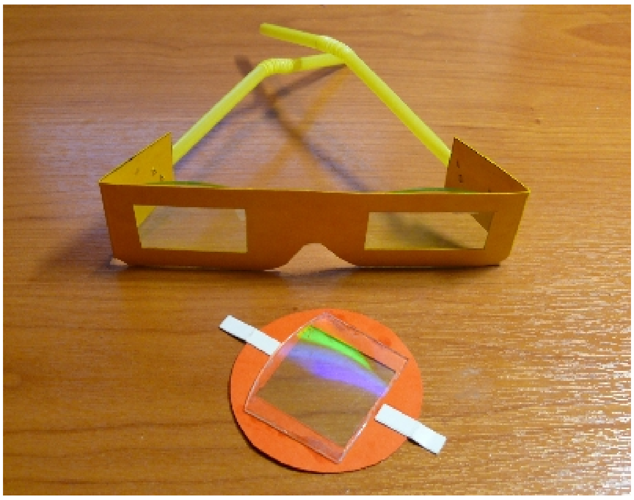
Picture 6

Sense of observation.



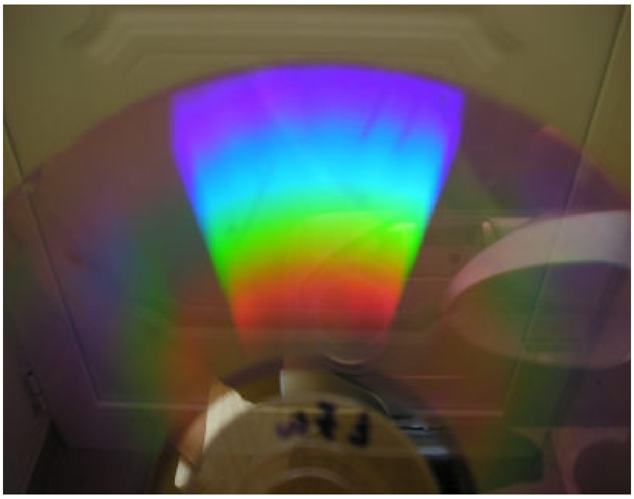
Picture 7

A pair of glasses and a single glass.



Picture 8

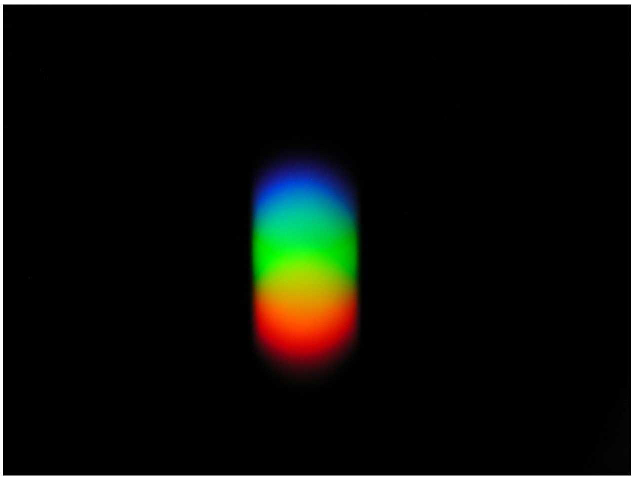
The daylight coming from a window[1], gives a wonderful rainbow when it passes through the optical disk.



1 This observation is best done inside a room than outdoors.

Picture 9

The bright disk of Full Moon splits to overlapping colorful disks, when you look it through the optical disk.

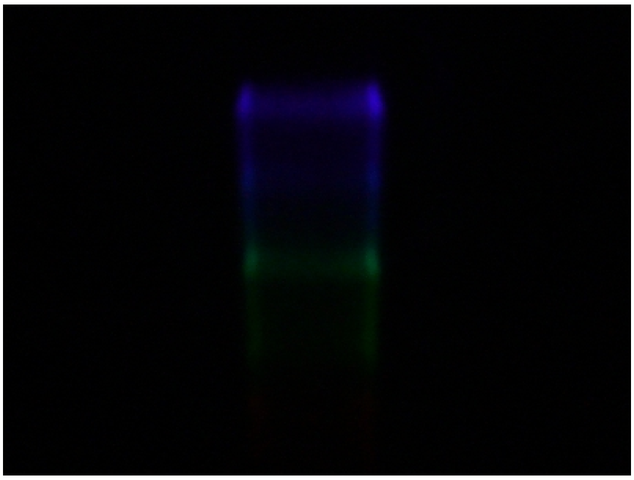


Picture 10

The light of a desktop lamp[2] forms an amazing design of colorful lines when passing through the optical disk and entering our eyes.

Picture 11

A photo[3] of a camping gas flame

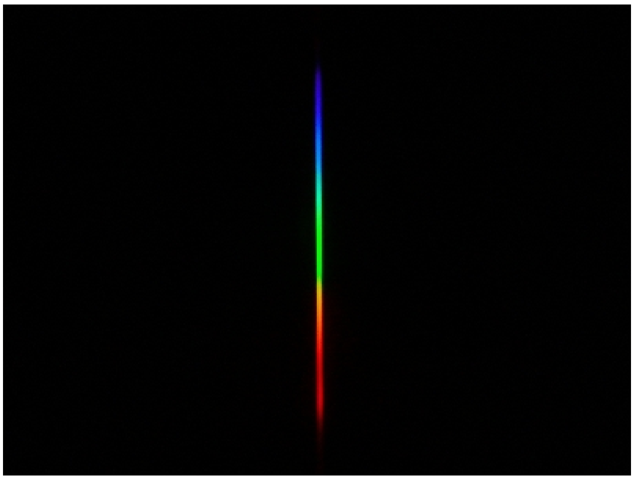


2 Compact Fluorescent Lamp (CFL) or energy saver lamp.

3 This photo was taken at close and long exposure time. It is not recommended to observe the flame at close with naked eyes.

Picture 12

The flame of a candle through an optical disk.



Similarities and differences

Any person who is uneducated about these phenomena, can easily recognize similarities and differences inspecting the pictures 8 to 12. Differences in the shape, in the size, in the length or width can be recognized. The similarity that is usually recognized, is that all pictures contain about the same colors. Of course, this is not the case we are interested. So, we have to move yet.

Using an image processing software, we cut from the central part of each picture (8 – 12) a narrow rectangular section (2 – 3 pixels in width). Then, we create pictures by copying and pasting and placing the parts next to each other (pict. 13).

Picture 13

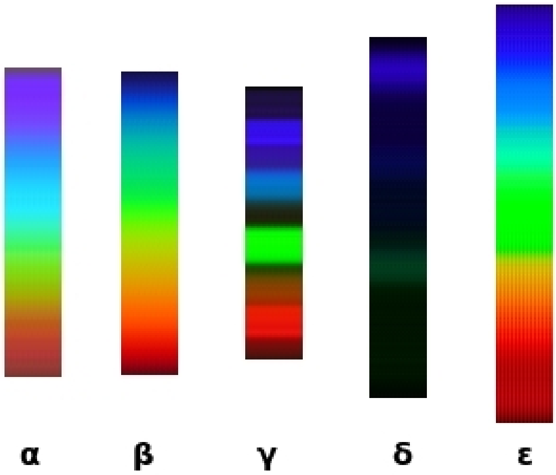
a. *Daylight (pict. 8)*

b. *Full Moon light (pict. 9)*

c. *CFL lamb light (pict. 10)*

d. *Camping gas light (pict. 11)*

e. *Candle light (pict. 12)*



Inspecting the above pictures (a – e), conclusions about our subject can be reached. First, one can easily create two groups (a, b, e) and (c, d) on the basis of progressive (continuous) change of color. In the first group there is a continuous change in color, while in the second group distinct colored lines are seen[4]. In the first group one can distinguish differences int the “quantity” of colors or in the relative proportion (e.g daylight contains more blue color than moonlight), while in the second group, one can distinguish

4 Continuous and non continuous spectra

differences in the number and color of lines.

Light – matter interaction and optical fingerprints

For an object to be seen, light from that object must enter into our eyes. This light emitted from the object “carries” information that is characteristic of that object. If there is a way to “see” this light, we can draw some conclusion about the object (e.g what kind of object it is). Optical disks enable us to “see” the light coming from an object, because they have the property to analyze it. (pict. 6). So, if we place an piece of optical disk between our eye (or a camera) and an object emitting light, then the optical fingerprint of the object will be formed on our retina (or on the camera's CCD).

Optical fingerprints characterize lighting objects as fingerprints characterize humans. Even as the police can find a criminal by matching fingerprints from the scene of crime to fingerprints from its records, so scientists can find out what substances an object consists, by matching optical fingerprints of the body to optical fingerprints of known substances from their records. So, we can consider picture 13a as the daylight fingerprint[5], picture 13b as the Full Moon fingerprint, picture 13c as the CFL lamp fingerprint, picture 13d as the camping gas flame fingerprint and picture 13e as the lighting candle fingerprint.

Some simple applications

Bearing in mind that light emitting objects show their own characteristic optical fingerprints, we will look at optical fingerprints of some common objects and we will try to discern their particular characteristics.

1. Optical fingerprints of household lamps

There are several types of lamps in our homes. Using special glasses made of optical disks (pict. 7) we can see of photograph their optical fingerprints.

Picture 14

Taking the optical fingerprints of household lamps.

5 In fact the atmosphere's optical fingerprint.

Picture 15

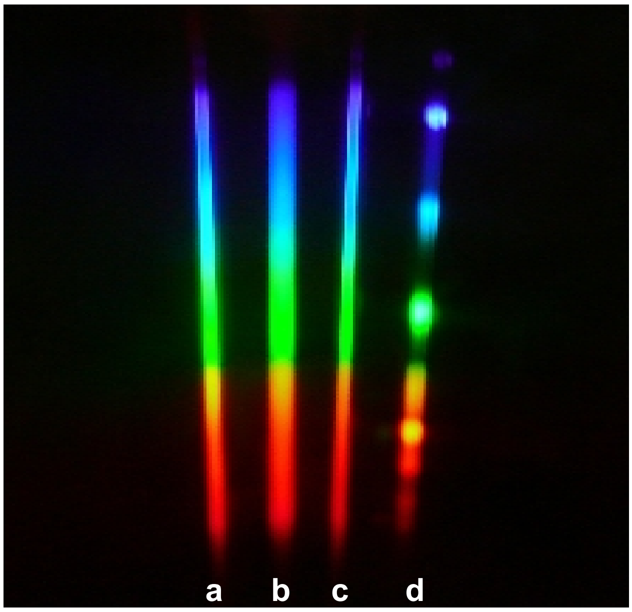
Optical fingerprints of household lamps:

a. *Clear lamp*

b. *Brilliant white lamp*

c. *Daylight lamp*

d. *Compact fluorescent lamp (CFL)*



Lamps such as a, b and c generate light by heating a filament of wound metal wire and their optical fingerprints[6] are continuous. Lamps such as d generate light due to gas excitation and their optical fingerprints are non continuous. It is therefore clear that inspecting the optical fingerprints of the lamps, we can deduce which category they belong[7].

2. Identification of dyes

a. In colored films (transparent bodies)

In picture 16 below, there are three transparent films[8] that are impregnated with three special dyes each of them. These dyes have a special property: *"With the proper combination of them, we can produce dyes of all other colors"*. Can we find out what basic dyes contains an unknown dye, comparing the optical fingerprint of that dye with the optical fingerprints of the three basic dyes?

6 Spectra
7 Filament heating or gas excitation
8 These are films used in digital photo printing.

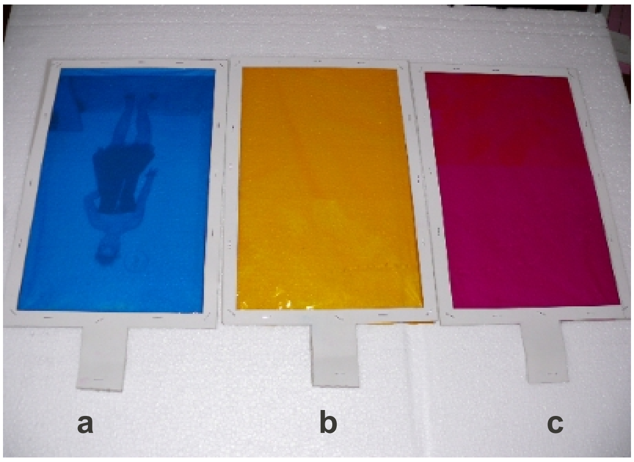
Picture 16

Three transparent films impregnated with:

a: *anti-red dye*

b: *anti-blu dye*

c: *anti-green dye*[9]

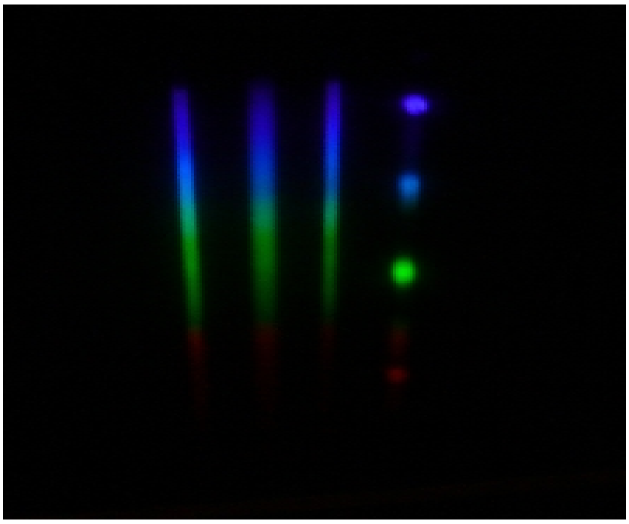


Picture 17

Taking the optical fingerprints of dyes.

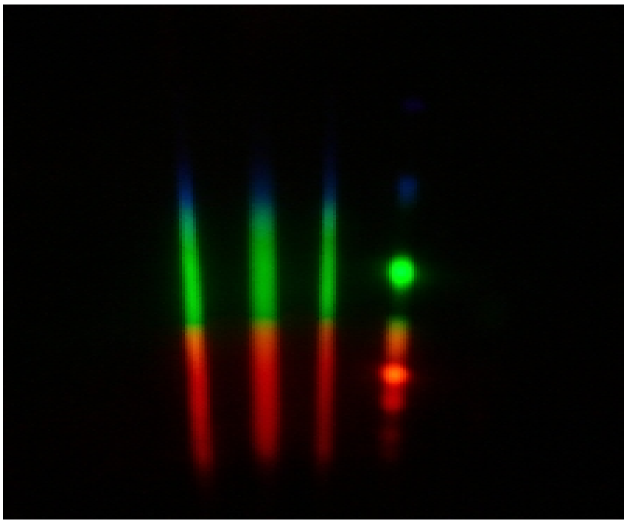
Picture 18

The optical fingerprints of anti-red dye.



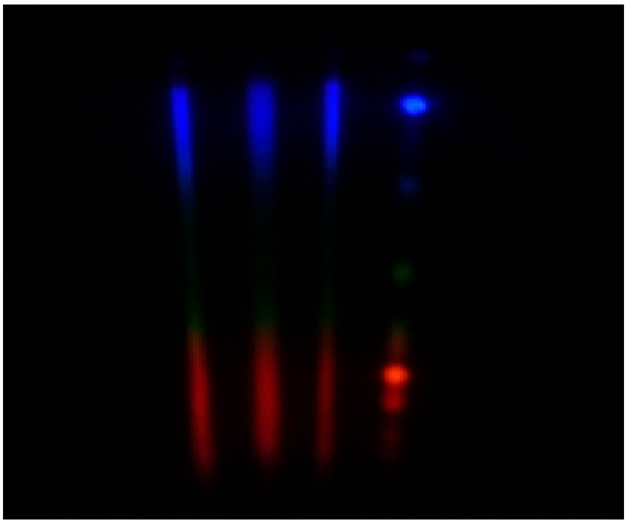
9 The meaning of these names will be clear next.

Picture 19 caption and image:



Picture 19

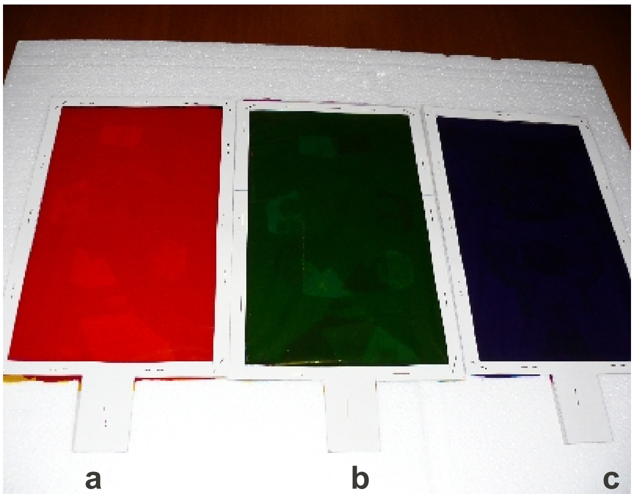
The optical fingerprints of anti-blue dye.



Picture 20

The optical fingerprints of anti-green dye.

Next, we will try to find out what dyes contain three other films that are seem to have red, green and blue color.



Picture 21

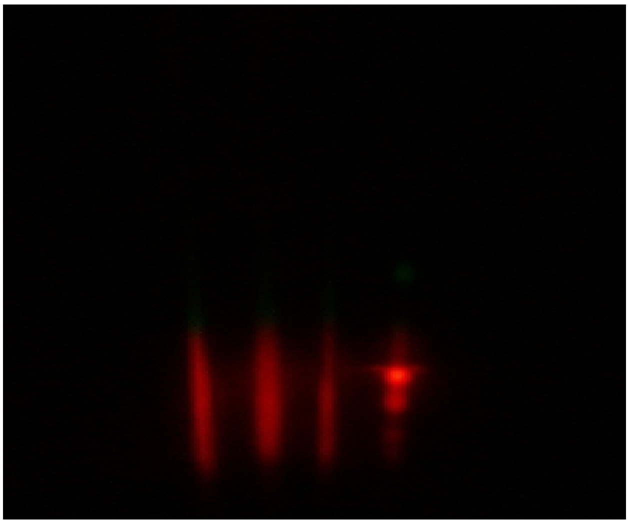
***a.** Red film*

***b.** Green film*

***c.** Blue film*

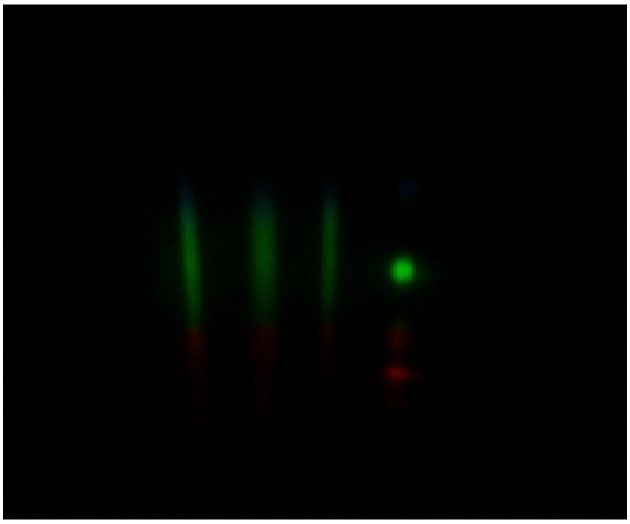
Picture 22

The red film seems to contain anti-blue and anti-green dye[10]*.*



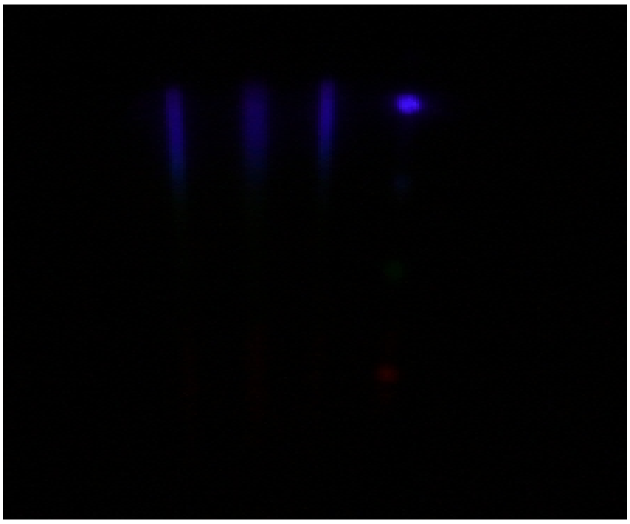
Picture 23

The green film seems to contain anti-blue and anti-red dye.



Picture 24

The blue film seems to contain anti-green and anti-red dye.



10 In this point, the teacher should be careful. Depending the film width and light intensity, some unwanted colors may go through the film and cause confusion. So, some tests are needed before.

β. In colored paper sheets (opaque bodies)

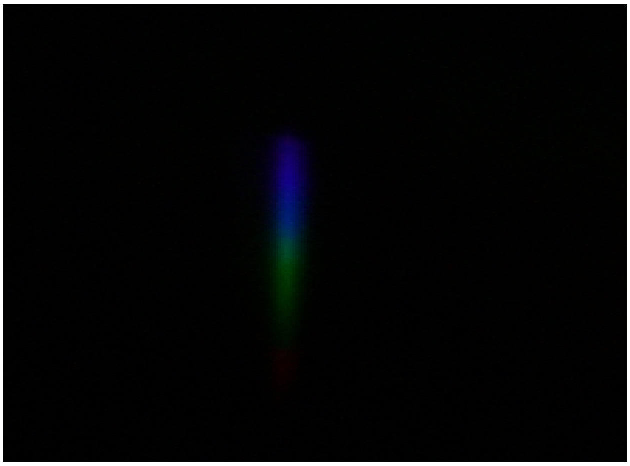
Next, we will try to detect dyes in colored sheets of paper. For this purpose we will use glossy paper and observe the optical fingerprints by reflection. The lamp we use has similar optical fingerprint to the lamps a, b and c of figure 15.

Picture 25

Taking the optical fingerprints of colored sheets of paper.

Picture 26

The blue sheet seems to contain anti-green and anti-red dye.

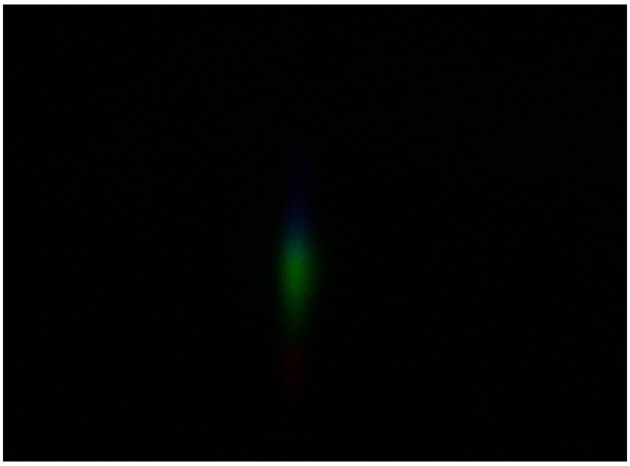


Picture 27

The cyan sheet seems to contain anti-red dye.

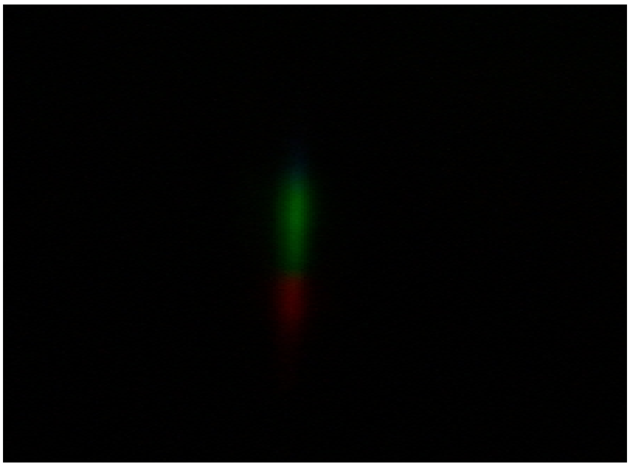
Picture 28

The green sheet seems to contain anti-blue and anti-red dye.



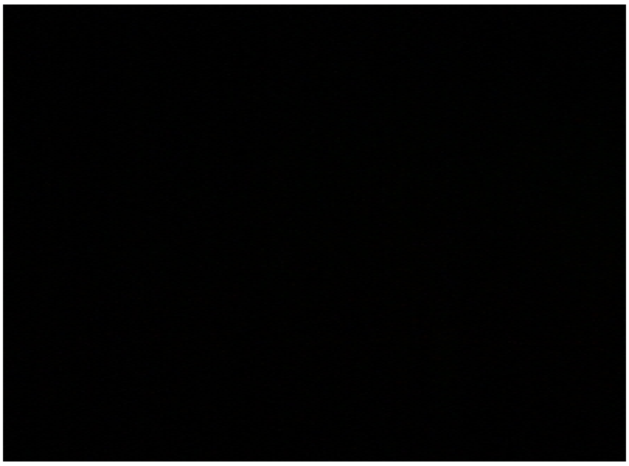
Picture 29

The yellow sheet seems to contain anti-blue dye.



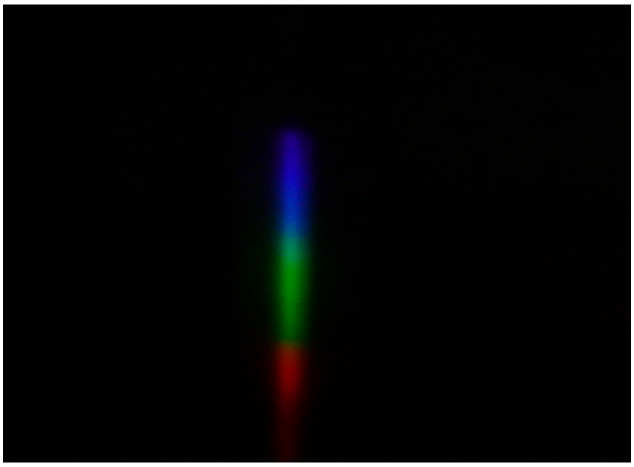
Picturer 30

The red sheet seems to contain anti-blue and anti-green dye.



Picture 31

The black sheet seems to contains anti-blue, anti-green and anti-red dye..



Picture 32

The optical fingerprint of white sheet.

Question: What dye does it contain[11]?

3. Printer inks

Printer inks contain cyan, yellow and purple (magenta) dyes to produce all other colors.

Picture 33

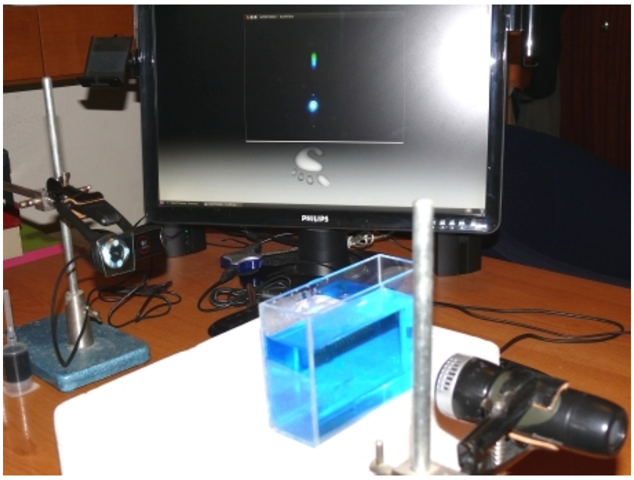
Printer ink solutions.

11 The right answer is that it doesn't contain any of the anti-blue, anti-green and anti-red, but something else.

Using a setup like the one in the following picture, we can observe the spectra of colored aqueous solution of these dyes and draw conclusions such as what dyes are in a solution of specific color or how the perception of color was created.

Picture 34

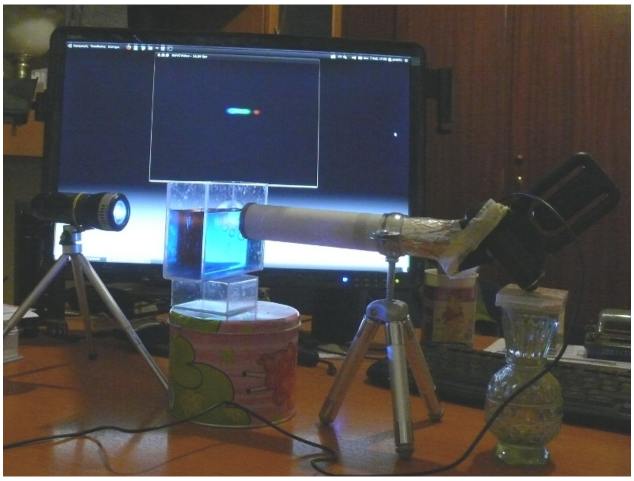
Observing the spectra of a cyan solution via a web-camera and a piece of CD attached to it. The cyan light coming out of the solution and its spectrum are shown in the center of the computer screen.



Using a simple spectroscopic device adapted to a webcamera, we can go a bit deeper in the perception of color.

Picture 35

The solution contains equal amounts of cyan, yellow and magenta inks and in our eyes appears bluish.



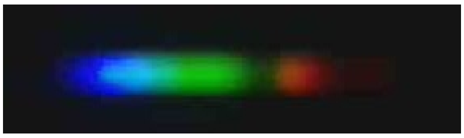
Picture 36

***a.** The spectrum of the lamp used.*

***b.** The spectrum of the light emerging from the solution. It seems that this color due to the absorption of visible light of specific frequencies.*

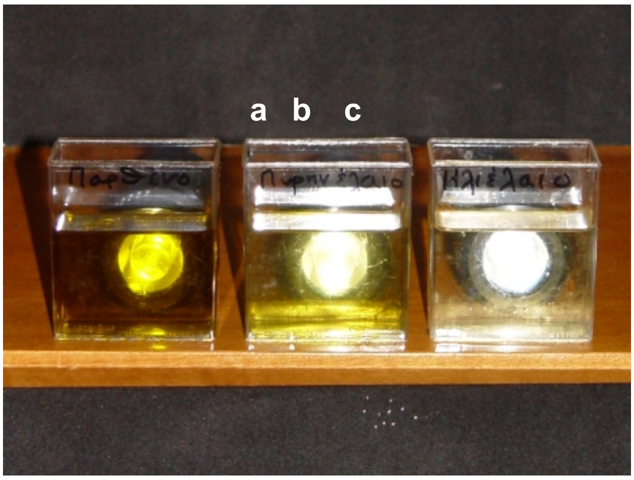
a

b



3. Oils

There are many types of oils on the supermarkets selves and food scandals have often erupted because of the higher quality oil rigging with inferior oils. We will examine the optical fingerprints of three types of oils that are widely available in the market (virgin olive oil, pomace oil and sunflower oil pict. 35) and try to see if we can recognize them. For this purpose we will examine the optical fingerprints after the light passes through their mass and then through a piece of optical disk. The lamp we use has similar optical fingerprint to the lamps a, b and c of figure 15. Then we will mix virgin olive oil with sunflower oil at 50% proportion and try to see if we can find the fraudulence examining its optical fingerprint (pict. 36, 37).

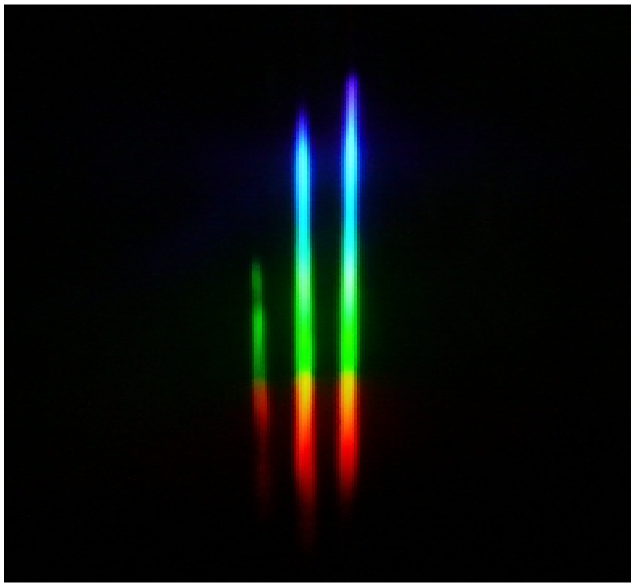


Picture 37

a. *Virgin olive oil*

b. *Pomace oil*

c. *Sunflower oil*



Picture 38

Optical fingerprints:

a. *Virgin olive oil*

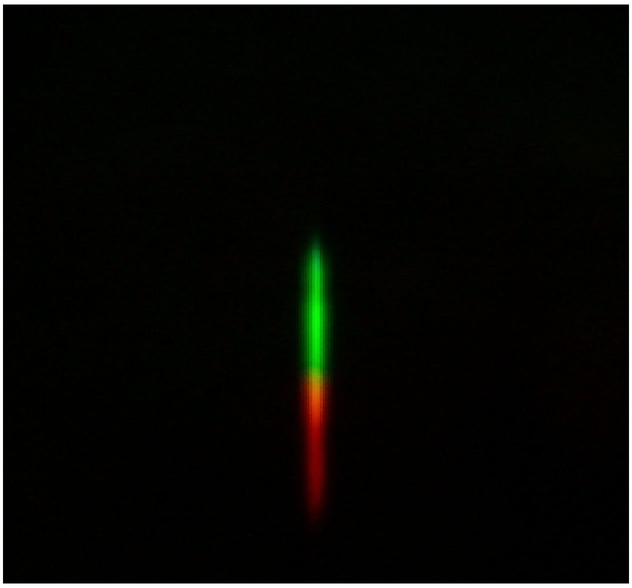
b. *Pomace oil*

c. *Sunflower oil*

There is market difference between virgin olive oil and other oils.

Picture 39
Optical fingerprint of virgin olive oil rigged with sunflower at 50% proportion.

There are clear differences in the green and red areas.



Students activities

The following activities are in fact ideas for activities and they can be modified by the teacher to fit better the level and requirements of his class.

1. Simple observations - practice

Students practice the use of optical disk on the analysis of light. This activity is necessary for students to understand the relative positions of the source of light, the optical disk and the light detector (eye, camera etc). Students can observe lamps, colored solutions, colored films, etc.

2. Find the lamp

The teacher shows students incandescent and compact fluorescent lamps behind a translucent screen and ask them to find what lamps are energy saver.

3. What color the films are;

Bearing in mind that the dyes we use are anti-red, anti-green and anti-blue, the teacher makes frames as in pictures 16 and 21 using only cyan, yellow and purple (magenta) films. Then ask students to setup an experiments to find out what films the frames contain.

4. What ink the solution contains;

Using printer inks, the teacher makes colored solutions of red, green and blue color. Then ask students to setup an experiment to find out what inks have been used for each color. Having the teacher properly practice his students, can even ask them to find out the approximate proportions of inks have been used.

5. Find the virgin olive oil

The teacher presents his students oils and then ask them to setup an experiment to find out the virgin olive oil.

6. Field activities

Many interesting field activities can be done using a piece of CD or DVD or a handmade spectroscope. Students can observe the light of sunrise and sunset, the moon, the city at night, etc.