From the rainbow to the chemistry of colours

We have all seen rainbows with their impressive colors – they are a 2-dimensional bow, why do we never see a straight rainbow?

- **INVOLVED DISCIPLINES:** physics, aesthetics, mathematics, technology
- **KEYWORDS:** analysis of sunlight, reflection, refraction, dispersion, rainbow, color harmony, three-dimensional structure
- **AGE GROUP:** 13–17 years
- **MATERIALS:** MDF plates, sheets plexiglass, polystyrene balls, colored wooden rods (50 cm length), plastic spheres, red and violet markers, strings with the colors of the rainbow plus white, metallic rod (110 cm long 10 mm diameter), plexiglas tube (20 mm diameter), 250ml beaker, laser point, cardboard, polyurethane foam, water, milk.
- **PROJECT HEAD:** Ilias Kalogirou
- **INSTITUTION:** Institution: Central Laboratory of Natural Sciences in the prefecture of Ilia / Peloponnese, Pyrgos, Greece

CONCEPT/OBJECTIVE

The construction of a pedagogical model for a spectacular natural phenomenon, i.e. the rainbow, gives mental satisfaction through the explanation provided and the aesthetic perfection of it. We try to explain the formation of the rainbow – a scientific explanation is complex – with a simple construction and a simple description.

SPECIAL CHARACTERISTICS OF THE PROJECT

Firstly this project is an innovative piece of work. It is a simple three dimensional construction and can therefore be easily reproduced. It refers to rainbows that we all have seen and been impressed by inquiry-guided instruction.

PROJECT DESCRIPTION

Path of the light in a raindrop

Each raindrop has a circular cross section. Because water in a beaker has a circular cross section, the path of light in water of beaker is similar to the path in a raindrop. We observe the path of a beam of light as it enters into the water in a beaker (having added earlier a drop of milk to the water) (Photo 1). The beam of light is generated by a green laser pointer. At points A, B and C we have reflection and refraction. That is, in the water of the beaker we have two refractions (at A and C) and one reflection at B. In the case of a raindrop, the incident beam at A is coming from the sun and the outgoing ray at C enters the eye of the observer. Thus we have the formation of the rainbow. If we move the laser beam onto a horizontal plane, we observe the movement of traces of the reflected and outcoming rays on the cardboard. In the case of sunlight and raindrops when the incidence rays are at a certain angle on the droplet we have strong light from outgoing rays at C. This is the light which an observer sees during rainbow formation.

Why is the rainbow an arc?

When sunlight strikes raindrops it is analyzed to the known colors of the rainbow due to dissipation.The angle between the solar rays and outgoing red rays is 42 degrees while the violet is 40 degrees and the other colors have intermediate values. We have constructed a model for the analysis of sunlight by raindrops (photo 2). The white wooden rods represent the sun's rays, the red and purple represent outgoing

PHOTO 1

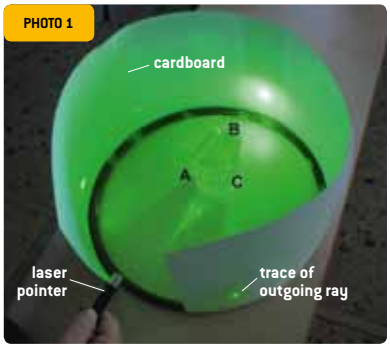


PHOTO 2

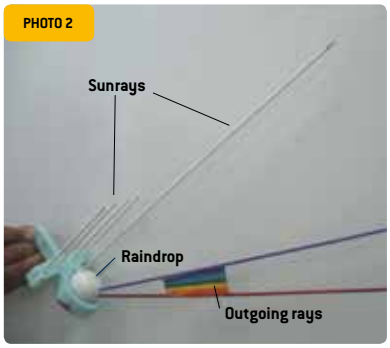


PHOTO 3

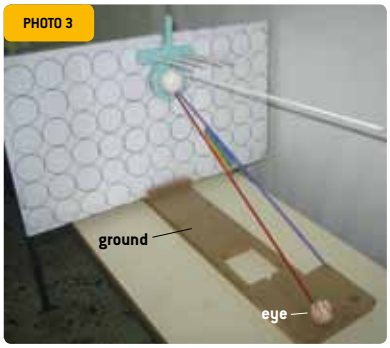


PHOTO 4

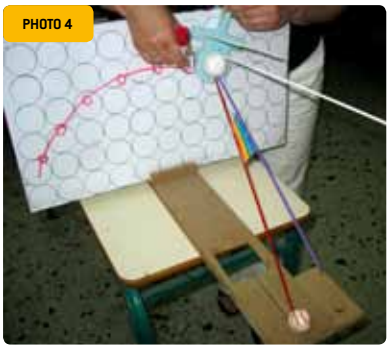


PHOTO 5

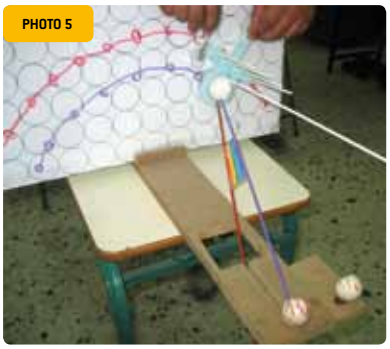
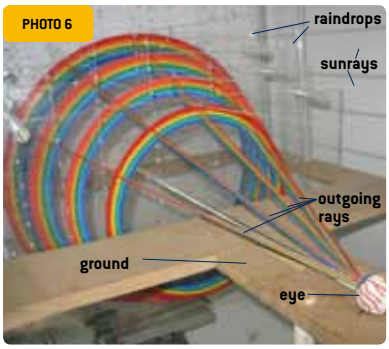
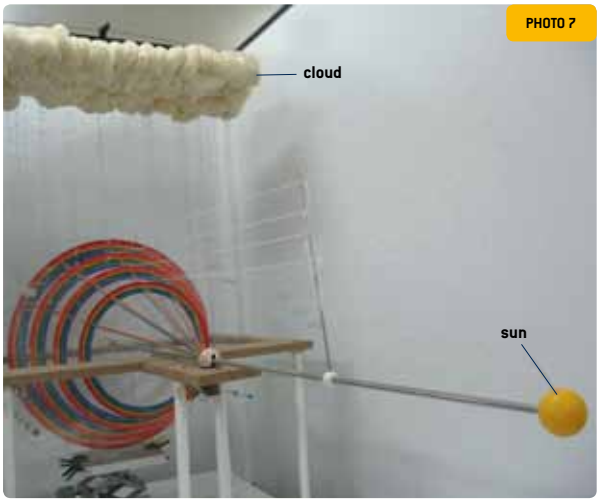


PHOTO 6



rays. The rays of other colors are in between (only one part of them shown). The white ball of polystyrene represents a raindrop and the blue piece of polystyrene supports the rest. In photo 3 we have a configuration where the black circles on the vertical plexiglas represent raindrops in the atmosphere and the brown MDF piece represents the ground. On the ground we have placed a white plastic ball that represents the eye of the observer (at a horizontal distance from the plane of raindrops). The analysis of sunlight to the colors of the rainbow will happen in every raindrop. Which of the drops (designed on the plexiglas) will send the red ray to the eye?

PHOTO 7



One of these drops is the white polystyrene sphere in the position shown in photo 3. Are there any other drops in the same vertical plane to send the red ray to the eye? If we move the white ball (raindrop) onto the plane of plexiglass so that the red ray is continuously visible to the eye, so that the rays from the sun will remain parallel to each other (photo 4), then we see that all these raindrops are on an arc of circle. The raindrops that give violet rays in the eye are lower than the previous (because the deviation of violet light is greater than red). Similarly, these raindrops will be located on an arc that is below the previous (photo 5). The raindrops which give the other colors will be on intermediate arcs of the two previous. All of these colored arcs are the rainbow. With the help of this model we can understand why:

- Each observer sees his own rainbow (if we put a second eye next to last, we see that the cycles are different).
- When the horizontal distance between the observer and the area of rain increases, then the radius of the rainbow increases.

Three dimensional model of the rainbow

The center of the rainbow, the eye of the observer and the sun are in line. The area of rain has a width and therefore there is a large number of levels (like the previous plexiglas) on which rainbows with different radii are created. Thus the rainbow has depth. If the area of the rainbow involves any objects (clouds, trees, etc.) we will observe the three-dimensional form, or we will see a flat color zone. In our three dimensional model (photo 6,7) we can see the 3D form of the rainbow (if there is no ground, e.g. from an airplane the rainbow is a full circle), the sunrays (white strings), the outgoing rays (colored strings), the raindrops and the cloud which gives the rain.

» In accordance with the title of the programme, "Winning Hearts and Minds in Science Teaching" we chose this work as it serves the concept of beauty (winning hearts) and favours supervision during teaching (winning minds). I learned many things from my study on the creation of a rainbow, things that I had so far ignored. I felt very happy when I saw my listeners celebrating understanding the natural phenomenon of the rainbow, as I explained it to them in simple words. «

UM WAS GEHT ES?

Warum ist der Regenbogen eigentlich ein Bogen und wie wird er dreidimensional? Die Faszination und Schönheit des Regenbogens sind Ausgangspunkt dieses Projektes.