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Research Article

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Portable Rainbow Demonstration Module Design

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Abstract The design of portable rainbow display modules focus on teaching applications. Improving the previous rainbow demonstration device (using a projector, reflective screen) requires more space and darkroom display problems. The portable rainbow display module has a closed sphere and a reduced volume and has a light source and a distributed structure. The enclosed area provides observation only by partial light transmission and does not need to display in the darkroom, which improves the convenience of teaching and demonstration. The module is suitable for the education of physical concepts for children. Students can operate by themselves with adjustable configuration.

Keywords science, demonstration, design, rainbow, teaching-aid

Introduction

The principle of reflection is a basic principle in optical theory. The science of elementary school introduces the phenomenon of reflection. The physics and physics of middle school and the physics of high school all start with this principle when entering optics, which shows its importance. Knowing the law of reflection, students often ask: "Why is the rainbow only semi-circular? Why can't a rainbow be seen at a certain angle? Does the rainbow's different colors come from the same water?". The actual display of rainbow phenomena and different colors of light is helpful for the exploration and verification of academics.

Although it is easy to create a rainbow by spraying water droplets in the classroom, the scope of influence is broad, and it is not easy to grasp the physical conditions, and it also causes inconvenience in the surroundings. This article uses small glass beads as materials to carry out scientific display design. A repetitive dynamic rainbow demonstrates and assists students in verifying the principle of a rainbow phenomenon. The glass beads and the water droplets in the air are both round and have a high refractive index, so controlling the display parameters can demonstrate the rainbow phenomenon.

Historical

In 1266 Roger Bacon measured an angle of about 42 degrees in the sky. A preliminary analysis of the rainbow obtained by ray tracing through a droplet [1].Young demonstrated the interference of light waves by passing a single beam of monochromatic light through two pinholes. Young pointed out the pertinence of his discovery to the supernumerary arcs of the rainbow [2]. Young's explanation based on a wave theory of light. In 1838 Richard Potter pointed out that the crossing of various sets of light rays in a droplet gives rise to caustic curves. [3].

An approximation rainbow theory predicts rainbow as physical optics theories for near-critical scattering reflection [4]. The physic of rainbow is related to industrial applications. Recently, a fabrication method of graded holographic proposed by photopolymer reflection. The rainbow-colored reflection image integrated with detectors to realize portable spectroscopic analyzers [5]. A way detects spherical of a droplet based on a comparison between two droplet diameters author deduced from two different optical interference patterns. The rainbow pattern has identified as coming from a spherical droplet from the interference patterns with a CCD camera [6].

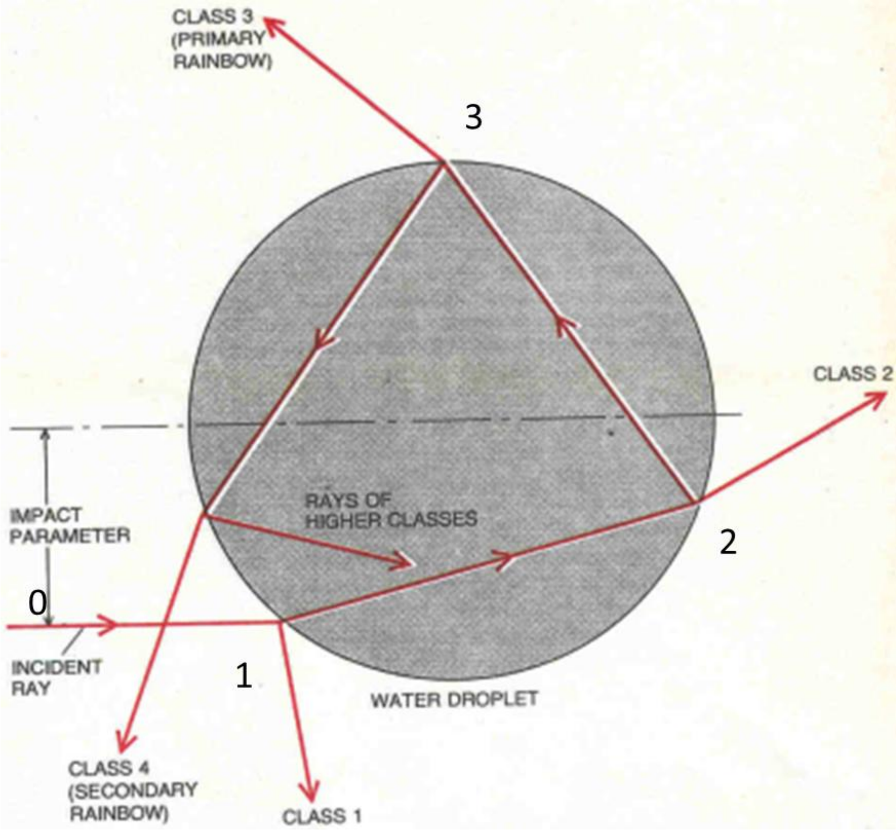

Figure 1: The ray path within droplet [1]

Science Education

Recently, school science has been seen to promote a mythic textbook science rather than present the actual image of science and reflect the nature. To appreciate and effectively use all these developments for meaningful learning, scientific culture must permeate the society and the everyday thoughts of people [7]. The science education is not in a position to offer answers. The engagement with creativity in school science is currently encouraged [8,9].

Scientific display design is to let students operate to show scientific phenomena. The doing is more in-depth into the mind than pure mathematical derivation, inspiring new ideas and applications. Many physics exhibition seminars have held in Taiwan. Teachers and students participate in the use of everyday objects to show scientific phenomena with creativity.

Figure 1 shows that when a light is an incident from the left side (location 0), it refracts at the first air and glass interface, and the second position (glass and air interface). The light then travels along the interior of the glass, where it is refraction at location 3 (glass and air interface). The ray in location 3 creates rainbow that people can see. At the location 2, part of the light refracted to the right, but the black paper absorbs the light and does not affect the rainbow observation. This analysis help students understand that the rainbow is a phenomenon caused by the refraction of these balls. The simplest static rainbow [10] demonstrated by using tiny glass beads stuck to non-reflective black cardboard (Figure 2).

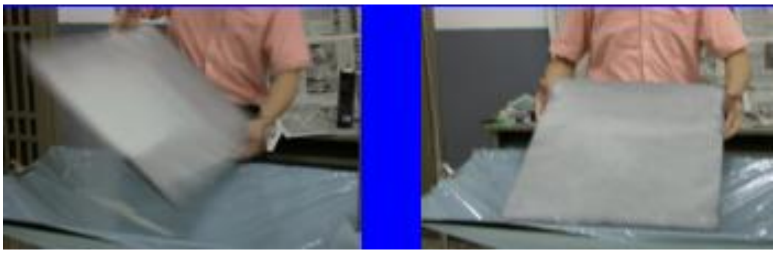

Figure 2: Small glass beads on black cardboard [10]. The cardboard is coated with glue, the glass beads are sprinkled on the cardboard, and the cardboard is shaken to evenly distribute the glass beads.

In [11] authors built a three-dimensional rainbow demonstration to convey of the phenomenon — raindrops in this demonstration represented by acrylic spheres arranged on pillars within a cubic volume. Defocused imaging with a camera reveals a mosaic — a round-bottom flask filled with water to project a circular rainbow on a screen with a hole with a sufficient distance between the flask and the screen. The wall-effect introduced a splitting of the bows [12].

Optical principle

The refractive index of glass is larger, the angle produces a rainbow is slightly different. When light enters a transparent bead, the light path of the rainbow is similar to Figure 1. The relationship between the deflection angle δ, the incident angle i and the refraction angle r obtained by geometric optics satisfies [3]

$$\delta = 2(i-r)+180-2r \tag{1}$$

By Snell's theorem, n is the refractive index of the bead, which can be derived to satisfy the incident angle i

$$\cos i = \sqrt{\frac{n^2-1}{3}} \tag{2}$$

For water droplets, n = 1.333 (yellow) $i = 59^\circ$, $r = 40^\circ$, $\theta = 180^\circ$ $\delta = 42^\circ$.

For glass beads, n = 1.5, so the we obtained $i = 49.8^\circ$, $r = 30.6^\circ$, $\theta=22.8^\circ$.

The rainbow made by the glass beads has an observed angle of 22 between the rainbow and the incident light. The glass beads produce a neon angle of observation of 88.5 °, which is almost perpendicular to the glass screen, so it is not easy to be seen.

Rainbow Demonstration

Previous design

The dynamic rainbow display is proposed by Lin [10] to simulate the mechanism of water droplets falling from the sky under the action of gravity. Store the tiny glass beads in an acrylic tube with a preset gap on one side. We guide the glass beads to slide down like a waterfall. Under the illumination of the front light source, this simulate the rainbow phenomenon caused by the water droplets shining through the sky in the sky. User can repeat the experiments by using glass beads to replicate water droplet.

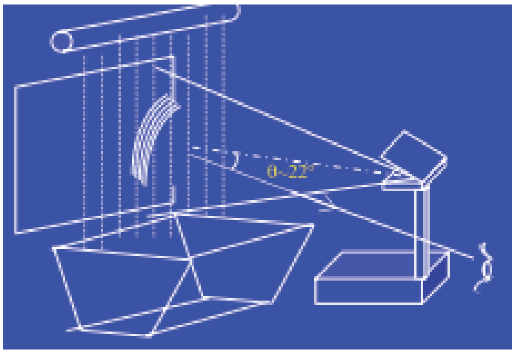

Figure 3: The falling setup of the glass beads [10]. The upper tube has glass beads, and the lower acrylic groove is connected to the beads dropped above. When the light is projected forward, a rainbow is created where the beads are sprinkled.

The dynamic rainbow display uses a projector, a reflective screen and a strip of tubing, and a glass bead added with reflective paint (approximately 0.17 to 0.34 mm in diameter). First, the acrylic body cut along the length of the tube to a gap of about 2~3mm and a range of about 60cm. Place the glass beads and sprinkle them (Figure 3). Projector or slide projector light source at a distance of about 1~2 m and project under the acrylic tube. The rainbow occurs near the 22-degree angle [10].

Portable module design

Since the device uses a projector and a reflective screen, it is necessary to place the light source at 1-2 meters, so it is also required to use a larger space and a dark room for display. In the design we first consider the convenience of operation, the process of glass beads sprinkling and recycling completed quickly. Secondly, it is necessary to reduce the volume of the displayed object, and only a small space is required for observation. It is best to show objects that can be carried by hand and viewed without borrowing a classroom or projector.

The portable rainbow display module is a closed sphere and a built-in light source, and the rainbow display teaching machine reduced to a convenient carrying size (50 cm in diameter). The enclosed sphere transmits light only in a partial area, providing an opportunity for observation. The position of the light transmission is precisely the section of the rainbow light reflection. When the light source placed at 30 cm, we can see the appropriate rainbow normal perspective on the glass bead screen. The closed sphere only transmits light in a part of the area so that the opaque portion can block the ambient light of the outside; this can be beneficial for rainbow observation. Because it does not display in the darkroom, the convenience of teaching and demonstration is improved.

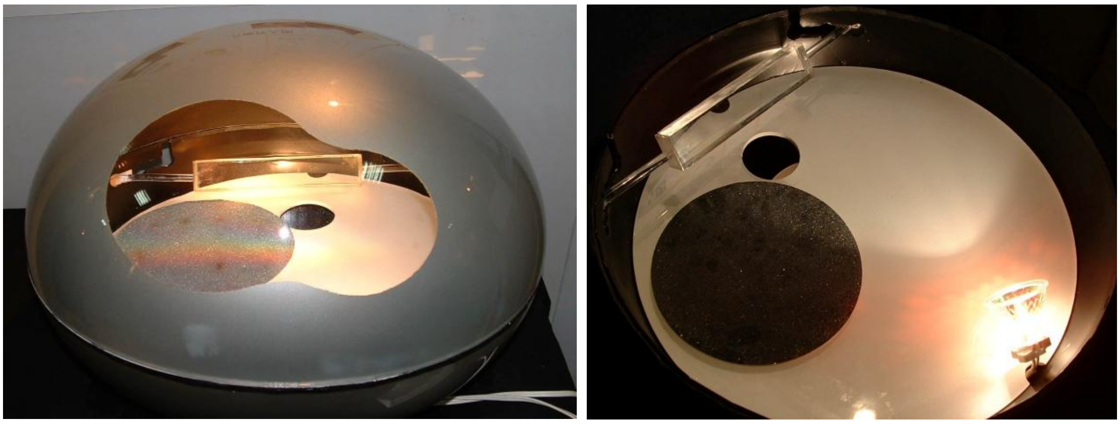

Figure 4: Portable rainbow display module

The arrangement of the glass beads is as shown in Fig. 4. The projection bulb is located above the cover. When projected on the surface of the glass bead, we can observe the rainbow stripes through the curved window. At this time, the angle between the person and the light is 22.8 degree. Because the light source is close to the bead reflection surface, only a portion of the rainbow can be seen. Since the angle of the light has been fixed, we have added a reflective acrylic strip to increase the variation. Part of the reflected light is projected onto the surface of the glass bead at different angles via a rotating acryl strip, which built a variable rainbow streak and provided the variation and interest during observation.

There is opening slot on top and a splicing groove at the bottom, and the cross section is inverted trapezoidal to collect the falling small glass beads. The glaze beads fall at a speed, and it takes a lot of material to maintain the flow, which is not convenient for the students to observe. We found that the primary use of schoolchildren is to manipulate and change the angle of projection of light, thereby increasing the proportion of self-operation of the students.

Conclusion

The portable rainbow display module is a closed sphere and a built-in light source and a reflecting surface, which reduces the specific content of the rainbow display teaching and is convenient to carry. The display module has a light source that is illuminated by a small glass bead drop section to observe the color halo generated by the reflection of the rainbow. A plane with small glass spheres is placed underneath to facilitate observation of static light reflections. Because a static view is easy to grasp, students can move from static to dynamic display. The closed sphere transmits light only in a part of the area and does not need to perform rainbow display in the darkroom, which improves the convenience of teaching and demonstration.

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