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Review

Garden Rainbow

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Abstract

Descartes` theory has the conclusion that rainbow can be observed if the observer looks at a curtain of rain drops and behind him/her Sun is at 42 degrees in the clear sky. We realized an installation that produces a curtain of water drops that is very similar with the natural conditions. Several simple STEM (Science, Technology, Engineering and Mathematics) projects on Science Education as examples of creative activities can be realized. Also this result has touristic importance.

Keywords: Physics, Optics, STEM, Rainbow, Garden rainbow, Touristic places

INTRODUCTION

Rainbow is a fascinating natural phenomenon mentioned even in Bible in connection with Flood and Noah` s Ark (http://en.wikipedia.org/wiki/Rainbow). It is related to both Physics (Optics) and Metheorology. If we are lucky we can see a rainbow one or two times per year. There are some superstitions about it. People enjoy seeing a rainbow and even some believe that it brings luck (it brings smiles, improves moods and wellbeings for sure). A deep and correct understanding of this phenomenon has a positive contribution to a society with a knowledge-based economy (http://ec.europa.eu/research/science-society). Essential science under this phenomenon is at the level of high school Physics (Optics). More detailed and deeper research can produce and some PhD theses. In the following we present the Descartes` theory, the state of the art of observations, our installation and discussions.

Descartes` theory

We emphasize that the handbooks of Physics cover very superficial this subject of the rainbow. Sometimes is given just a picture that makes more confusion than clarifications. Presentation of the theory is needed in order to avoid misconceptions and misunderstandings. Let us follow a ray of light that meet a spherical drop of water. So the theory refers to the spherical drops of water. If drops are bigger they are not any more spherical and the theory cannot be applied. Radius should be less than 1 mm.

It is sufficient to reason in plane. So in Figure 1a, by simple geometry of angles we have for the angle of deviation D(i)=180+2i-4r where i is the angle of incidence, r angle of refraction. The law of refraction sin i=n sin r (n= index of refraction, n=1.33=~4/3 for water). In Figure 1b is represented D(i) in function of i. It can be seen that it is a slow variation (nearly constant). The minimum of this function is obtained by solving dD(i)/di=0, it means di=2dr and differentiating the relation sin i=n sinr we have (cos i)di=n(cosr)dr or $(\sin r)^2=5/12$, $(\sin i)^2=20/27$ it means i= 65 degrees, D(65)=138 degrees, 180-138=42 degrees. The minimum being very wide means that the most rays will be deviated by 138 degrees. This result can be obtained even simpler by drawing many paralel rays over a circle (2 refractions and one reflection) and the result will be many rays with a deviation of 138 degrees. The only condition is to apply correct the refraction law sini=(4/3)sinr.

The refraction index n depends on wavelenght (l). For red l=656.6 nm, n=1.3318, D=137 degrees and 42 minutes. And for violet l= 404,1 nm, l=656.6 nm, D=139 degrees and 24 minutes and violet is inside the rainbow.

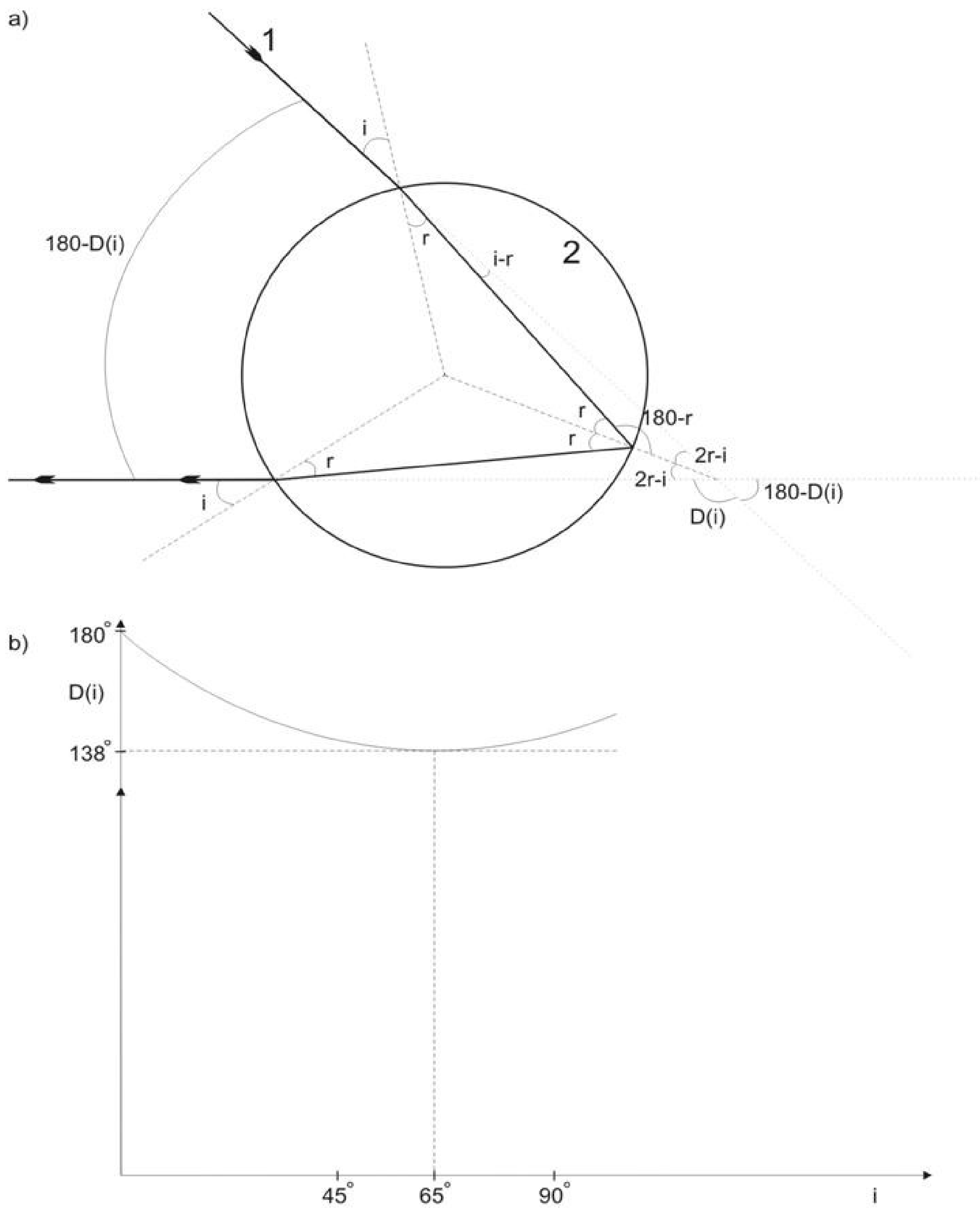

Figure 1a. Ray path in a spherical waterdrop and deviation angle D(i), i incidence angle, r refraction angle
1b.D(i) function of i . (1) ray , (2) waterdrop

The simple theory is needed to have clear in mind that rainbow can be obtained only if the rays are paralel and it comes after 2 refractions and one reflection. No rainbow after 2 refractions. Many times is pronounced the word ¨rainbow" when some colours are observed in an optical experiment. That is just dispersion and not rainbow.

Reasoning in the same line, the rainbow of the second order is obtained at another deviation angle and 180-D=51 degrees. In this case the colours are reversed inside is red colour and outside is violet. The second rainbow has a smaller intensity because of the lost intensity in reflections and refractions. The light is partial polarized by reflection and refraction and could be deeply investigated by quantitative measurements.

The state of the art

It is known an installation for an artificial rainbow (Miguel, 2005). Several fountains spread water drops vertically. The observer stays above and looks down. It is more likely looking from an airplane to a cloud. The rainbow

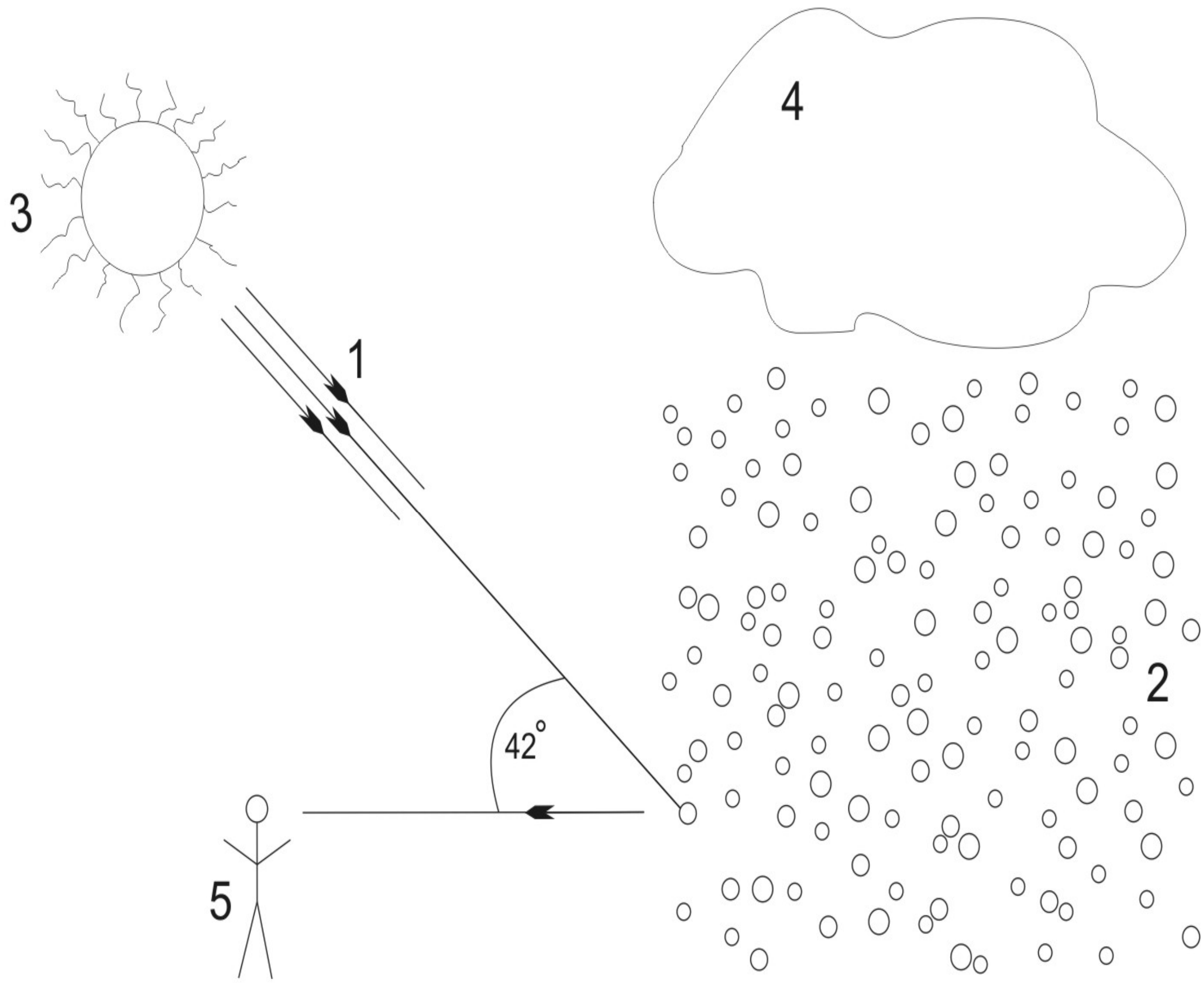

Figure 2. Natural conditions for observing rainbow, (3) Sun, (4) cloud, (5) observer

can be seen from above. Below we will present an installation that produces rainbow in conditions very similar with the natural ones and is much simpler to be built.

From a didactic point of view, a recent paper presents new results in obtaining a rainbow in laboratory (Dragia and Stefan, 2016).

Another recent review paper contains an up to date research on observation rainbows in nature and the recent theory (Alexander, 2016).

Our setup

From the theory comes a clear conclusion: to observe a rainbow, an observer should look toward a curtain of rain drops under a cloud and behind him/her should be Sun in a clear sky at 42 degrees. In other words, it is needed to be a day with half the sky in clouds (and from clouds to rain) and the other half of the sky to be clear and Sun should be at 42 degrees (it means at a time between 15-17 hour in the afternoon). As we see we should be lucky enough to meet such conditions; no wonder that we can see a rainbow one or two times per year. (Figure 2).

As we cannot move Sun we need to wait until afternoon at 15-17 hour and hope to have a rain at the East Horizon. To not wait too much we decided to produce the rain. So we used a simple installation (Figure 3).

We realized an installation that provides water drops at a certain height (more than H=4m)

Above the soil that realizes a curtain of water drops. This is like in real conditions and is very different from other artificial rainbows. It contains a pump that sends water along a hose that is situated above the soil using some pillars. Water drops are made by sprayers. For observation is needed a sunny day and the Sun should be at an angle of 42 degrees in the sky above the horizon. Installation should be at a height H more than

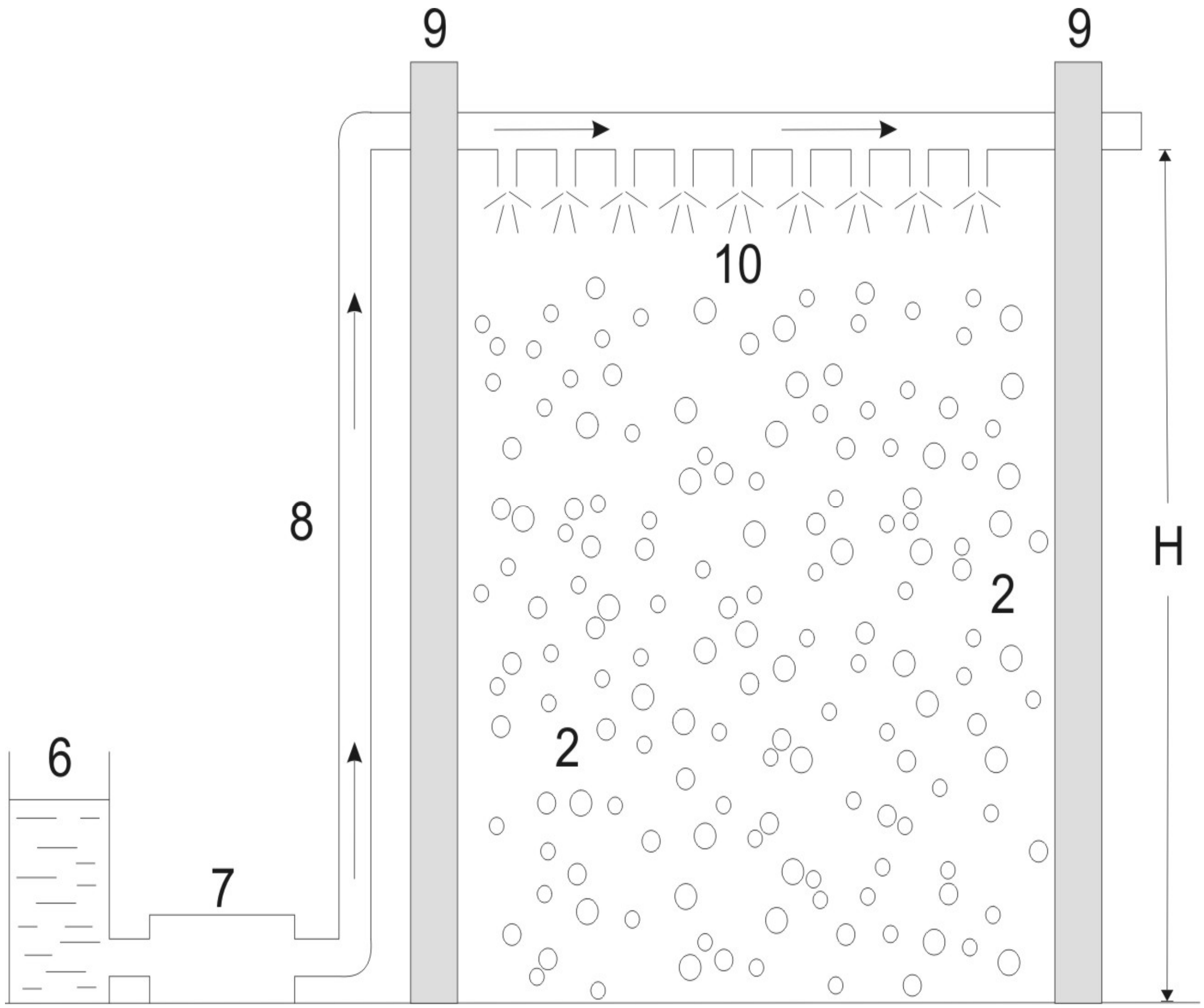

Figure 3. Simple installation. (6) vase withwater (7) pump (8) hose (9) pillars (10) sprayers

4m, a length L=2H and the best place of observation is at D=H in front of the curtain of water drops. The curtain should be perpendicular on the vertical plane determined by observer and Sun. By a good understanding of the theory we can extend the conditions of observation. When Sun is above 42 degrees we can use a ladder and when Sun is under 42 degrees we can make a hole in soil and look toward curtain from such a hole.

DISCUSSIONS

In Picture 1 we observe a rainbow and the authors I.G.(left) and I.D.(right) in the garden of I.D. First critic is that rainbow is of small intensity. This can be solved by using 2, 3 or 4 hoses with sprays that will produce more water drops. Using such an installation many superstitions can be spread away. People will observe that rainbow is determined by water drops and Sun light. Putting off the pump the rainbow will disappear or if Sun goes behind a cloud the rainbow will disappear. Many quantitative measurements can be made. The refractive index n is different between temperature 0C and 40C. This should be reflected in accurate measurements of the geometrical parameters of the rainbow. Also can be used salted water (at sea side) and sweet water. Again measurements should show difference. It can be installed in different places in schools, in touristic places, between two houses, two blocks of flats, between 2 hills (touristic place 1), between 2 mountains (touristic place 2).

The installation can be mounted above a lake. If it is no wind a surprise will be for the future experimenters.

The projects based on this installation are perfect for a STEM activity. Some simple geometry of angles, practice on using reflection and refraction laws, simple mathematical analysis and practice of drawing with respecting the refraction law at the boundary water-air. Not to mention the quantitative measurements. Being used at the popular level new details can be solved. Practicing with such an installation some conclusions can show up that could be useful for in-vestigating metheorological problems like distance from

Picture 1. The authors I.G.(left) and I.D.(right) in front of the rainbow in the garden of I.D.

the observer and the clouds, the structure of the clouds etc. Finally, accurate optical measurements (polarization, interference) can be made.

As a general comment we state that a solid understanding helps to modify, to improve, to optimize a certain physical phenomenon as we did before (Grosu and Baltag, 1994; Grosu and Ursu, 1986; Grosu and Ursu, 1982; Grosu and Featonby, 2016).

Present results could have application as a tool for improving the well-being of healthy people (tourists) or for different health care reasons.

CONCLUSION

We do believe that the present results will open the opportunity

-to deeply study rainbow from high school to university

-to help the public understand that rainbow is related to Physics and Metheorology and no room for any superstitions.

-to offer to touristic business ideas to improve the attractiveness of touristic places.

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