Hong Kong Student Science Project Competition 2022

Extended Abstract (Investigation)

Team Number: JBPE112

Project Title: God Doesn't Play Dice with the Rainbow

Project Type: Investigation

To our best knowledge and after thorough literature research, as at 18/6/2022 , there ~~are~~ / are no* similar works. If there are, the reference links are as below:

The enhancement our project has made for the existing related products or research is summarized as below:

***Please delete if not applicable. HKSSPC values the originality of works. Students must conduct literature research thoroughly to ensure that their works are unique, and to list relevant reference materials to complement the research or invention.**

I. Background

Rainbows symbolize hope after bad times. Many people would slow down their steps to look up to the sky when there's a rainbow above. However, unlike the equally astonishing natural phenomenon aurorae, there are few attempts to actively predict the occurrence of rainbows. Whether rainbows tend to appear in summer or winter, after a torrential downpour or a calming drizzle, we would like to understand the scientific theories behind.

The formation involves refraction, total internal reflection and dispersion when sunlight passes through water droplets. Numerous optical and mathematical calculations explaining its formation has been done by scientists since a long time ago. One of the study by Austin & Dunning (1988) had found that the angle of between the incident ray and the emergent ray from the water droplet is 42°13' and 40°30' for red and violet rays, respectively.

However, some assumptions were made so that they might not be applicable to the real-life scenario. Moreover, they involved excessively complex mathematics that are hardly comprehensible to the general public. Therefore, we carried out this scientific investigation to find out under what conditions rainbows can be observed in real-life scenario.

II. Objectives

To find out the conditions, including the zenith angle of the sun, the direction of the observer from the azimuth direction of the sun, the distance between water droplets and the observer for observing a rainbow in real-life scenario.

III. Hypothesis

Taking an inductive research approach, no formal hypotheses were made for this research. We investigated whether rainbow can be observed with varying zenith angles of the sun, directions of the observer from the azimuth direction of the sun, and distances between water droplets and the observer.

IV. Methodology

Materials
Two black fabrics
Meter rules
A garden mist spraying bottle
An iPad with a visual clinometer application "SeeLevel - visual clinometer" by Sten Kaiser
A measuring tape

Experiment 1: Relationship between the zenith angle of the sun and rainbow formation

The time and zenith angle were recorded and measured first. Water droplets were then sprayed to search for the presence of a rainbow. When a rainbow is observed 1.5m from the water droplets, the altitude should be recorded instantly from the clinometer reading. Same procedures are repeated for 10° intervals clockwise and counterclockwise cumulatively until the rainbow is no longer visible. The experiment was repeated every 20 minutes.

Experiment 2: Relationship between the altitude of the rainbow and distance between the water droplets and the position of the observer

The time and zenith angle were recorded and measured first. Water droplets were then sprayed to search for the presence of a rainbow. When a rainbow is observed 1m from the water droplets, the altitude should be recorded instantly from the clinometer reading. Same procedures are repeated at 1.5m, 2m, 3m, 4m, 5m, and 6m respectively. The experiment was repeated every 20 minutes.

V. Results

Table 1: Zenith angle of the sun and altitude of the rainbow at different time

Time	Height of meter rule (m)	Shadow Length (m)	Zenith angle of the Sun (°)	Rainbow observed?	Altitude of the rainbow observed from the azimuth direction (°)		
					Red	Green	Violet
2:40pm	1	0.55	61.19	✗	/	/	/
3:00pm	1	0.69	55.39	✗	/	/	/
3:15pm	1	0.82	50.65	✗	/	/	/
3:30pm	1	0.9	48.01	✗	/	/	/
3:45pm	1	1.02	44.43	✗	/	/	/
4:00pm	1	1.15	41.01	✓	4	/	/
4:20pm	1	1.38	35.93	✓	8	6	5
4:40pm	1	1.61	31.85	✓	11	11	9
5:00pm	1	1.89	27.88	✓	17	15	14
5:20pm	1	2.26	23.87	✓	20	19	18
5:40pm	1	2.8	19.65	✓	23	22	21
6:00pm	1	3.8	14.74	✓	29	29	27

We observe that the closer the time gets to the evening, the longer the length of the shadow of the sun, and the smaller the zenith angle of it. By analysing the results in Experiment 1, an increase in altitude is observed due to the decreasing solar zenith angle, allowing us to proceed further calculations, also showing that rainbow moves correspondingly to time change.

Meanwhile, according to Experiment 2, the altitude remains unchanged with the increase in the distance between the observer and raindrops. Thus, we can draw a conclusion that the increase in altitude of the rainbow depends merely on relationship with time but not position from where the observer sees.

Table 2: Altitude of the rainbow at different distance between raindrops and observer

Time	Height of meter rule (m)	Shadow Length (m)	Zenith angle of the Sun (°)	Altitude of the green centre of the rainbow observed from the azimuth direction (°)						
				Distance between raindrops and observer						
				1m	1.5m	2m	3m	4m	5m	6m
4:10pm	1	1.21	39.57	3	4	4	4	4	4	4
4:20pm	1	1.38	35.93	6	6	6	6	6	6	5
4:40pm	1	1.58	32.33	9	10	10	11	11	11	11
5:00pm	1	1.84	28.52	15	15	15	15	15	15	15
5:20pm	1	2.48	21.96	20	20	20	20	20	20	20
5:40pm	1	2.87	19.21	23	24	24	24	24	25	24
6:00pm	1	3.78	14.82	28	28	28	28	28	*	*

Still, despite the possibility of inaccuracies, including the missing data owing to the blockade of the sun by buildings or trees, or slight deviation caused by the width of rainbow, the mathematical calculations in previous investigation have greatly supported its reliability. The equivalent results of solar zenith angle 42° have clearly visualised the arithmetic idea and brought those formulae into the real world.

Through analyzing the data in the experiment, prediction can be easily computed. People can be more likely to observe rainbow in an efficient way by considering the weather conditions and improved results collected.

VI. Conclusion

Through simulating a rainbow and analysing the data collected in the experiments, we found out the condition for observing the rainbow are: (1) an angle of about 42 degree between the incident sunlight ray and emergent ray, which more or less agree with the mathematics calculations, and it represents the angle between the zenith angle of the sun and observers' view in real-life scenario; (2) the sun is at the back of the observer while raindrops is in front of the observer. As long as these variables are met, no matter what direction or angle we move, we can see the rainbow correspondingly to our position, which have entered the particular range of the cone of reflected ray.

☐ **Our project is developed based on our school's previous project and the enhancement is as below:**