Essay

Beautiful Experiments: Newton's Decomposition of Sunlight

Virginia Cain

University of Essex

Abstract

Robert P. Crease, a member of the philosophy department at the State University of New York, at Stony Brook and the historian at Brookhaven National Laboratory, recently asked physicists to nominate the most beautiful experiment of all time (2002). I have chosen to write about Newton's decomposition of sunlight with a prism because it is one I find inspiring and interesting. There is meaning attached to the experiment, and one's definition of beautiful can be applied in different ways. In this article I will be describing the design of this particular experiment as carried out by Newton, as well as discussing the results, and what can be inferred or deduced from them.

Keywords: Newton, decomposition of sunlight, experiment.

Essay

Newton thought of this experiment whilst he was at home. He was isolated by the plague and consequently had a lot of time in which to hypothesise and think freely. To begin his experiment, Sir Isaac Newton required only a prism, a blacked out room, a wall and a single ray of sunlight. These few simple things would work together to create an experiment that defied the common view of light and how it worked that was held at the time. This would subsequently lead to many more complicated experiments. Newton's first task was to black out a room in his home by closing the window shutters and moving objects out of the way of the beam of sunlight, which was to enter the room, by cutting a small hole in one of the shutters. This allowed the light to enter into the room, but in a way that was perfect for studying refraction, as there was no confusion as to which rays

were being refracted, or what they were being refracted off of. Newton then placed the prism in front of the sunlight in a position that would make it refract onto the opposite wall.

Newton saw that once the white sunlight had passed through the prism and had been refracted, it not only changed direction to shine onto the opposite wall, it also separated into a rainbow effect. He found that refracted white light turns into a spectrum of colours; red, orange, yellow, green, blue, indigo and violet. This had only before been seen in a rainbow, which in those days was not regarded as scientific, but as a beautiful anomaly. Being that there existed a very religious culture at the time, many still believed the rainbow to be a sign from God as a promise that he would never again flood the earth (The Bible). Newton, in being able to create an "artificial" rainbow, immediately undermined the superstitious interpretation of rainbows.

Once Newton had discovered this spectrum he moved the prism from one side to the other, and as he did so he noticed that when the prism moved one way he would get red light, and as he rotated it to the other side, it would travel through the colours to reach violet. He then moved the experiment forward by placing a second prism in front of one of the refracted beams; for example, red. He found however that the second prism would refract the direction of the light but it would not change its colour or create a new spectrum. This discovery made him move the experiment another step further to get into the details of why this was and if it were absolute; was there a circumstance in which the red light would change? Newton tried such things as refracting the coloured light with more prisms, reflecting it off of things that in normal light were a different colour; for example, blue or yellow. He continued to try additional, more complicated methods of changing the colour and yet could not. He concluded that once refracted into a single colour, light could not then change into any other colour.

This led to the conclusion that while white light is a composition of several different colours, each of those colours was indivisible. The most amazing part of this discovery was not the fact that white light separated per second, it was what could be inferred from it. From looking at all the results from this experiment it was concluded that it is the combination of all of the very different colours in the light spectrum that combine to become pure white light. Therefore Newton found that white light was only formed by the composition of all of the colours in the light spectrum. This was a very controversial discovery; for as it stood the belief about white light was that it was the purest form (from Aristotle). If this was the case then logically coloured light had to have been changed in some

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way. Therefore when Newton suggested that white light was merely a mergence of coloured light, there was uproar, particularly from the German poet J. W. Goethe whom then resorted to verbally attacking Newton.

Merely describing the experiment as Newton carried it out does not necessarily bring us any closer to answering the question, why is this a beautiful experiment? In order to answer this we must first look at what Newton did during this experiment and why he did those things. One may question; why did he choose a particular type of prism and not a sphere or a cube? Or what lead him to think about the refraction of light during his time in voluntary isolation? Before Newton even began to think about the composition of white light, he was interested in the behaviour of light. Newton noticed, as many others did, that light would reflect off of a shiny surface. He also saw that when travelling through bodies of differing densities light would refract. These two observations made Newton wonder what light was 'made' of. His theory was that light behaved as though it was composed of particles or tiny masses. He believed that they behaved in the same way as snooker balls or planets.

In the case of reflection, his particle theory would easily explain that when a particle hits a shiny surface it 'bounces' off like a snooker ball would do. However, his particle theory on refraction gets a bit more complicated. With regards to refraction, Newton believed that the particles behaved in a way that resembled planets. By this he meant that when light travels from air into water, the particles are attracted towards the water, which then speeds them up. This would explain why we see light or even an object skew out of shape when it passes through water. There was however a contradictory theory of the behaviour of light, which stood that light in fact behaved like a wave. This was initially proposed by Robert Hooke and later by Christian Huygens. Although this theory was around at the same time as Newton's was, he did not consider it to have any basis. He was adamant that light was composed of particles. He further tried to prove this theory by using his decomposition of light experiment. He stated that the reason the prism gave off this spectrum of colours was that each particle was a different mass depending on its colour. He said that a red particle had a greater mass than a violet particle, which explained the separation of colours. A possible reason that Newton chose to do this experiment with a prism may have been that as he followed the work of Descartes he could have taken his original experiment for decomposing light and simplified it.

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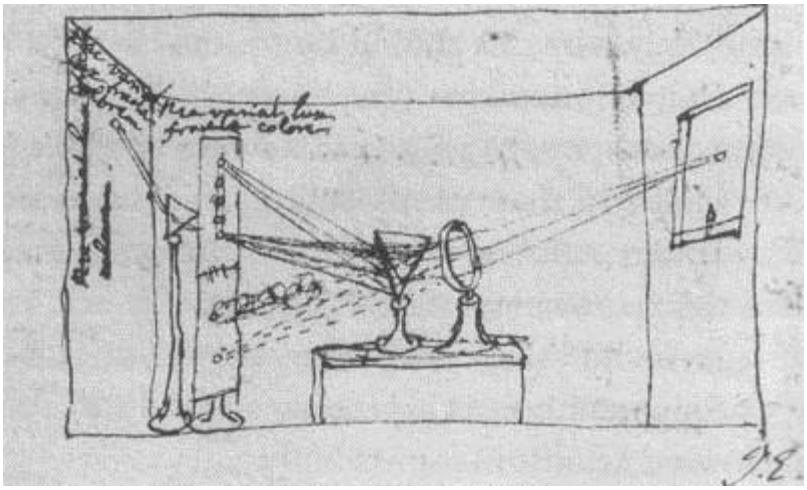

Figure 1:Decartes prism experiment model.

It is clear that there are definite similarities between Descartes' and Newton's methods; such as the prisms and the single ray of light. However there appear to be other forms of obstacles that alter the experiment. It is highly likely that Descartes' original theory of the decomposition of light and his experiment influenced Newton's own theory (A.Sabra, 1981, p.13).

We have looked at what Newton did for the experiment, what his results were and what could be inferred from them, and how and why he originally came to do this experiment. From here we can begin to look at the possibilities for why Newton's decomposition of light with a prism experiment is considered to be beautiful.

The term 'beautiful' is defined as: "adj. 1. Possessing beauty; aesthetically pleasing. 2. Highly enjoyable; very pleasant" (1987). This definition is merely the general, descriptive, objective way of assigning meaning to the word. However, beauty is a relative concept, rather than an absolute and consequently it is only possible to answer the question - what makes this a beautiful experiment? - by perceiving it subjectively. The reason for this is because when speaking of beauty, it cannot be understood uniformly and universally. People draw upon many elements to decide what is beautiful and why, such as; culture, peers, role models and personal preference. This makes the question of beautiful experiments a very difficult one to answer, because by definition an experiment is objective; it begins with a hypothesis but does not mould depending on the preference of the scientist. An experiment is scientific; it has a clear reasonable method and depends

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upon minimal outside influences in order to gain reliability and accuracy. Whereas using the word beautiful to describe something implies it can be looked at subjectively, using opinions formed from all possible influences in a person's life. How is it therefore possible to bring these two concepts together in a coherent and sensible manner?

It is firstly essential to look at what beauty could mean to those who were involved in the poll; scientists (or more precisely, physicists). Although beauty may not be a scientific term, it must be certain that many scientists find beauty in their work and the work of others, because beauty can be seen in anything. For example a mathematician could see beauty in symmetry or in the way that maths is a universal language, or in the way various equations work. A biologist may find beauty in the way everything in the human body works in a specific way, so that biological systems communicate and together keep the body functioning; for example the way blood is transported around the body so that oxygenated and deoxygenated blood do not mix. A physicist may find beauty in such things as using simplicity to explain the complex, or perhaps beauty is being proven wrong. This can be seen in Young's light-interference experiment, in which he shows that light must be a wave as it has interference patterns. Or for something to be simply unexplainable, like the extremely complex theory of quantum mechanics, which even some of the greatest minds still cannot truly understand and master.

So what is it about Newton's decomposition of light experiment that made physicists vote it as the fourth most beautiful experiment? It could be these scientists decided that part of what makes an experiment beautiful is what repercussions it has on the scientific field it is part of. For perhaps an experiment with no consequence is one without meaning and perhaps meaning is a form of beauty. This would make Newton's experiment beautiful because it completely turned the concept of white light on its head, not only in science; it also had an impact on religion at the time as well. Newton had discovered that white light could only be if it was a compound of the light spectrum. For science this was the complete opposite to previous notions that white light was pure and coloured light must have been changed. In a religious context it meant that Newton was claiming rainbows that are seen in the sky are not simply a miracle, a sign from God. He had in fact made them scientific and taken God out of them, which would have been an almost blasphemous thing to do. Therefore by causing people to think over what they merely believed to be true, because they had been told so, or had no better explanation, Newton's experiment was considered beautiful.

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Another reason why Newton's experiment could be considered beautiful is the mere simplicity of it. He needed very few pieces of apparatus, no specialised equipment and no need for a laboratory, or any elaborate or expensive planning. By simply placing a glass prism in front of sunlight he had practically completed the experiment, all he needed to do then was explain his results. But from such a simple experiment he managed to alter the thinking on light from the original theory over to his with proof. This leads to another possible reason for the beauty of this experiment, in a way Newton not only turned the theory regarding light upside-down, but he also changed scientific method.

From what we can tell, Newton was originally studying refraction with a prism, not the decomposition of light, and he managed to stumble onto an experiment within an experiment. Once he had performed the refraction experiment and noticed that the white light decomposed into the colours of a rainbow, he did follow-up experiments and developed a conclusion. The beauty of this experiment however is that he managed to come up with an experiment and conclusion without a hypothesis. This completely goes against scientific method, yet it worked, and his findings and conclusions cannot to this day be contradicted, showing that the strict scientific way is not always the best way.

It could be argued that not only physicists would find this experiment to be beautiful. It is possible for people such as philosophers (who may or may not study science), or those who are religious, to find his experiment beautiful on a symbolic level. It could be seen that many different, maybe even imperfect, things come together to become a single perfect entity. It could also be considered that it is beautiful to be able to explain everyday phenomena; for this to be understandable at many different levels and to hold within itself truths, which to this day are still being explored.

The final way in which Newton's experiment could be considered beautiful is simple and obvious, yet it may not have been considered even by physicists, it is simply aesthetics. Whether you are a scientist or not, you cannot help but find beauty in the image of a simple, clean, white beam of light travelling through the darkness, through a gleaming, transparent, glass prism and then dispersing through the other side in a spectrum of all the colours of the rainbow. Although this may not be scientifically or abstractly beautiful, it is in fact beautiful in the simplest from of the word.

In conclusion, Newton's decomposition of light with a prism could be considered to be a beautiful experiment because of the fact that it is so simple and yet created a far more complicated way of

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looking at light and its properties. Within its simplicity it managed to do a very rare thing indeed, which was to completely contradict both science and religion simultaneously, encourage people to observe light and rainbows from both sides, and think more closely. This experiment also managed to inadvertently contradict the scientific method of developing a hypothesis, performing an experiment and coming to a conclusion which confirms or denies your hypothesis. He did this by setting up different experiments and discovering a new one in the process without the need for a second hypothesis. This was contradictory because logically, there would be no reason for an experiment without a hypothesis to test. Then of course Newton's experiment is physically and aesthetically beautiful, and from the point of view of philosophy or religion, beauty can be found within its symbolism.

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