The Scientific Nature of the Kaleidoscope

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Abstract

This paper explores the early ideas for the kaleidoscope which began as a 'philosophical instrument' in the early nineteenth century. Considering the early work of its inventor, it will look at the background context of science and entertainment and make technical comparisons between the object we know today and some of its nineteenth century equivalents. By illustrating the similarities and differences between todays toy and early examples, it will demonstrate how the scientific origins of the kaleidoscope have been neglected.

Introduction

Invented in 1816 by the natural philosopher Sir David Brewster (1781-1868), the kaleidoscope has undergone many transitions over the last two hundred years but it has always maintained the underlying role that we best know it for today as a toy. Most of us were introduced to the kaleidoscope as children only to find that once the novelty of its unpredictable mesmeric patterns had worn away, it lay discarded and forgotten within the dusty cobwebs of our childhood memories.

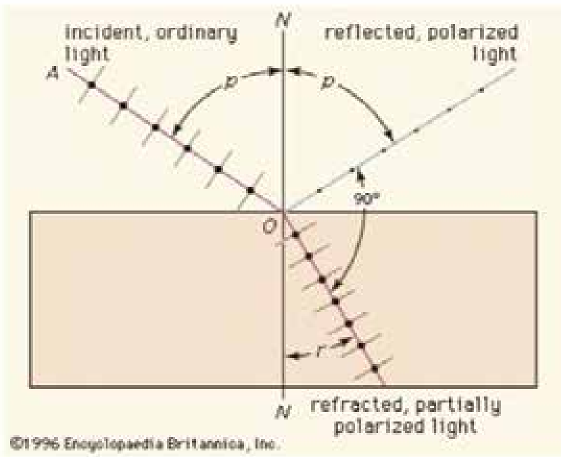
Because of its perceived role of as a 'toy', and with twenty-first century technologies such as smartphones and portable devices being at the forefront of daily life, it is easy to overlook the fact that the kaleidoscope, at its height, was as popular a part of Regency society as these current technologies are in contemporary life. Today, the scientific factors that underpin the workings of the kaleidoscope have lost significance due to its transcendence as an object of amusement, and because it is the colourful and often garish symmetrical patterns that are dominant within our childhood memories of it.

The kaleidoscopes initial success was partly due to its novelty factor and comparisons can be made between the impact it had in the later years of the Regency era and the recent craze for the Pokemon Go augmented reality 'App' which has received much press coverage over the summer of 2016.The kaleidoscope at its inception also invoked a craze with prints and newspaper articles describing it as a 'mania' the like of which had never been seen before (see Fig. 6). As a portable device it was a visual entertainment that could be engaged with on streets, in parks, market places and back yards as a pastime and provide a contrast to the harsh realities of the changing times and hardships brought about by industrialization. Like Pokemon Go, the kaleidoscope was a distraction from reality and could ease the boredom of journeys by foot or coach. This small cylinder of unassuming external appearance delivered an unexpected sense of spectacle with its secret images that could be quickly changed as if by magic.

The transitions that took place to the design of the kaleidoscope within less than a decade of its invention also characterizes the different social hierarchies of Regency life. From the scholars of the Royal Society through to the working man on the street, rich and poor, old and young were fascinated by it before it settled into the social en-

Table showing the quantity of light reflected at various angles of incidence from plate-glass.

Complement of the Angles of Incidence.	Rays Reflected out of 1000.	Complement of the Angles of Incidence.	Rays Reflected out of 1000.
2½°	584	35°	79
5	543	36	74
7	474	37	69
10	412	38	65
12½	356	39	61
15	299	40	57
20	222	46	40
21	210	50	34
25	157	55	29
26	149	60	27
30	112	70	25
31	105	80	25
34	85	90	25



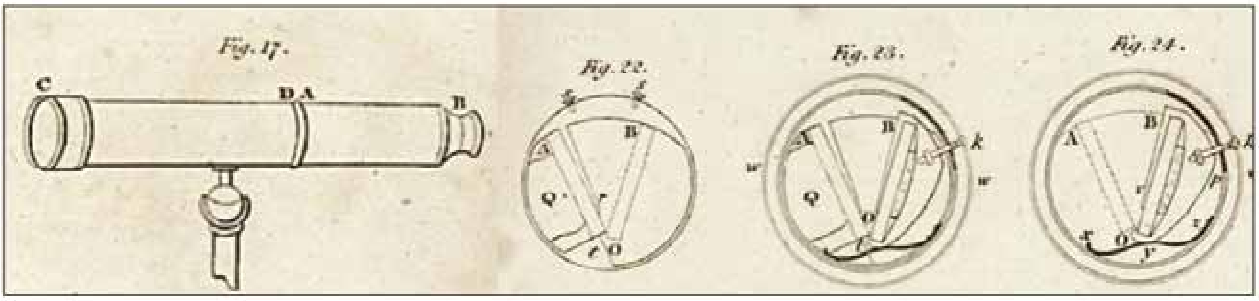


Fig. 1 *Top left: Table of Angles of Incidence of Light (Brewster,* Treatise on Kaleidoscope*, 1819). Top right: Brewster's Law (The* Encyclopaedia Britannica*, 1996). Bottom: Drawing of telescopic (compound) kaleidoscope with stand and adjustable mirror angles of the Bate Kaleidoscope (Brewster 1819* Treatise on Kaleidoscope*).*

Fig. 2 *Left: Carpenter Kaleidoscope demonstrating extended draw tube circa 1818. Right: Wood, paper and tin kaleidoscope circa 1850. (Courtesy of the Bill Douglas Cinema Museum, Exeter University). Authors photographs 2014.*

tertainment, to be enjoyed by all ages, that ultimately contributed to its reputation as a child's toy.

Background to Brewster's Kaleidoscope

Between 1810 and 1816, Brewster was pursuing several areas of research that contributed to the kaleidoscopes invention. One of these was his search for the law of polarisation by reflection which he succeeded in uncovering in 1814 (Fig. 1). His defining theory is now known as 'Brewster's Law' or 'Brewster's Angle' – 'the angle of polarisation by reflection is in proportion to the refractive index of the reflecting material'[1] for which he was awarded the Copley Medal in 1815 and elected as a Fellow of the Royal Society.[2]

Immediately prior to this, Brewster's work had focused on experiments with light, studying the refractive nature of many substances in context with various optical instruments, which he documented in his published book *A Treatise on New Philosophical Instruments for Various Purposes in the Arts and Sciences with Experiments of Light and Colour* in 1813.[3] This work provided the foundations through knowledge of the construction and mechanics of instrumentation, which combined with work Brewster conducted into the polarisation of light, allowed the kaleidoscope to take shape: 'The first idea for this instrument presented itself to me in the year 1814, in the course of a series of experiments into the polarisation of light'.[4] Yet it was not until 1816 that Brewster's experiments and idea physically manifested into the instrument that was to become the kaleidoscope.

Piracy Issues

Brewster took the fashionable approach of the time by combining Greek words to name his invention. K*alos* (beautiful), *eidos* (form) and *scope* (extent of range) which were loosely formulated into 'Kaleidoscope' and embedded the imagination with the idea of what it was capable of achieving. It was an object that could transform anything it selected, no matter how abstract and unattractive, into an aesthetically stimulating symmetrical pattern.

In June 1817 Brewster enrolled a patent for his kaleidoscope (patent no. 4136) which was subsequently granted and so the kaleidoscope went into production.

Initially, the Birmingham optician, mathematical and philosophical instrument maker Philip Carpenter[5] was identified as the 'sole maker' of the kaleidoscope. This quickly expanded to include several other authorised makers who were identified by Brewster in order to meet rapidly growing public demand for the instrument. These authorised makers produced their own versions of kaleidoscopes by agreement with Brewster and could refer to them as 'patent' kaleidoscopes (Fig. 2).

Disappointingly for Brewster, the patent was ineffectual in protecting his idea. According to an article in the *New Monthly Magazine* (1820)[6] an (unnamed) tradesman was inadvertently responsible for the piracy of the kaleidoscope after he had shown an example of it to certain London opticians to enable them to take orders and manufacture them. These opticians went on to produce their own kaleidoscopes for personal use and in doing so, the idea became public. Other kaleidoscope producers additionally claimed ignorance of there being a patent in place and so 'unintentionally' pirated the idea.

When kaleidoscopes were initially produced, Brewster considered the craftsmanship and precision of it to be paramount and this was reflected within the contexts they were retailed. Many of the initial ones were displayed in the windows and sold in opticians' shops, labelled as 'instruments of science'. As mathematical and optical instruments were made from brass and mounted on brass or turned wooden stands, Brewster's kaleidoscope pitched itself at the same level by following suit. Even though the production of the these required a variety of skilled craftsmen including tin-men, engravers and optical glass workers[7], it was always the retailer who was officially credited with the making of such instruments, identified by their name being engraved on the kaleidoscopes outer body.

At the other end of the scale, the appearance of cheap pirated kaleidoscopes quickly flooded the market and so Brewster's financial recompense for his invention was far less than it could have been had his patent not been breached. His distress at this fact can be clearly seen in a letter to his wife in May 1818:

> 'I called yesterday at Sir Joseph Banks', and met Sir Everard Home, and other wise men there. Both of these gentlemen assured me that had I managed my patent rightly, I would have made one hundred thousand pounds by it! This is the universal opinion, and therefore the mortification is very great. You can form no conception of the effect which the instrument excited in London; all that you have heard falls infinitely short of the reality. No book and no instrument in the memory of man ever produced such a singular effect.'[8]

Those guided by self-interest had been able to see the kaleidoscopes money making potential. To meet the demand, corners were cut, some of Brewster's ideas were trimmed back resulting in many elements of precision and craftsmanship being neglected, with cheaper materials introduced and production being far quicker. The complexities of Brewster's work were overtaken by easy to make variations (see Fig. 2), many

Fig. 3 *Left: Carpenter Object cell with glass gems and offcuts circa 1820 Right: Kaleidoscope pattern in Carpenter with cell in place. (courtesy of Bill Douglas Cinema Museum, Exeter University). Authors photographs 2014.*

of which simplified his intentions to a very basic interpretation and additionally undermined the scientific principles that were at the core of the kaleidoscope.

The 1819 Treatise on the Kaleidoscope

In 1819, two years after the patent had been granted and when kaleidoscope mania was in full swing, Brewster published *A Treatise on the Kaleidoscope* which expounded its virtues and the extent of its use. As the treatise was published retrospectively, Brewster may have hoped his text would build the kaleidoscopes credibility as a philosophical instrument beyond that of a rational amusement. Additionally, the 1813[9] philosophical instrument treatise evidences how Brewster had engaged with the idea of instrumentation that could be useful to the 'fine and useful arts' so reinforcing the ideas and suggestions within the 1819 kaleidoscope treatise.

Brewster was intent on achieving the sensory pleasures that colour and form could offer in a perfectly symmetrical image (Fig. 3).

> 'Colour is a mere accident of light which communicates richness and variety to objects that are otherwise beautiful; but perfection of form is a source of beauty, independent of all colours; and it is therefore only from a combination of these two sources of beauty that a sensation of pleasure can be excited.'[10]

His partial aim was to use his scientific understanding of lenses and light to provide a quality image that the artist could visually translate with ease and so aiding their practice. Although Brewster discusses the kaleidoscopes' value as 'an instrument of amusement'[11] this embodies only a section of the treatise with the majority of its content identifying several uses and examining the complexities of its mechanistic nature. At the point which the *Treatise of the Kaleidoscope* was published in 1819, Brewster was facing an overwhelming challenge to achieve his full expectations for it.

Brewster's Kaleidoscopes - Telescopic and Polyangular Examples

Brewster dedicates several chapters in the 1819 treatise to describing the components, geometry and uses of variations of kaleidoscopes, two of which are most relevant as an aid to the artist. These are the Carpenter Telescopic (compound) Kaleidoscope and the Bate Polyangular Kaleidoscope.

Both of these kaleidoscopes were reminiscent of optical instruments used for scientific enquiry such as telescopes and microscopes. In Fig. 4 the similarities between the Carpenter Telescopic Kaleidoscope are closely akin to many of the handheld telescopes of the period. The Salom telescope and the Carpenter kaleidoscope are both tubular, comparatively similar in size, contain lenses, an eye (viewing) hole and both are telescopic. Materials are very similar, both are made from brass although the Carpenter Kaleidoscope had a japanned tube and the Salom Telescope a polished rosewood tube. Both also came supplied within the same style of container. Other more complex examples of kaleidoscopes with stands were supplied in boxes with a range of interchangeable lenses and object cells and again these are comparable to the boxed telescopes with multiple lenses and stands of the same period.

Brewster's structural and aesthetic references to the telescope in his ideas for the kaleidoscope are unsurprising when his early scientific experiences are understood. Not only was he familiar with the mechanics and workings of the telescope from his previous research, but he had been knowledgeable on this from an early age, having built his first telescope with the help of Veitch when he was only 10 years old.[1]

The reasoning behind the Carpenter Telescopic Kaleidoscope was not complex, but what it offered was a level of control for the user for viewing external objects at varying distances. Brewster explains that without the aid of the extendable tube, the clarity of objects could be compromised creating defects in the image due to distortion. He expands on this point by claiming that 'without such an extension to its power, the Kaleidoscope could only be regarded as an instrument of amusement.'.[13] The telescopic draw tube allows the viewer to capture a moving or static image from the surrounding environment and removes the

Fig. 4 *Left Top: Nineteenth century Salom & Co. Telescope (www.scientificcollectables.com) Left Bottom: Carpenter Telescopic Kaleidoscope circa 1820 (courtesy of Bill Douglas Cinema Museum, Exeter University). Right: Carpenter kaleidoscope lens (also at BDCM). Authors photographs 2014.*

Fig. 5 *Left and Right: Bate Polyangular Kaleidoscope. (courtesy of Whipple Museum of the History of Science, Cambridge University). Authors photographs 2014.*

need for an object cell. The firework effect of the flames and sparks from fires, flowers blowing in the breeze, crawling insects are just a few of the suggestions Brewster made that were worth observing in this way.

The lens of the Carpenter could be used with or without the draw tube dependent on the distance and size of object being viewed, and dependent on what effect the viewer was aiming to achieve. It is easy to appreciate why Brewster considered this of benefit to artists and craftsmen as it allowed images of the everyday world to be explored in new and exciting ways and to create patterns for use in the decorative arts, such as in the repetitive swags of plaster cornices and the designs for textiles.

Fig. 6 *'Caleidescope Mania or The Natives Astonished'. Tinted printed cartoon (courtesy of the Whipple Museum of the History of Science). Author's photograph, 2014.*

By contrast, the Bate Polyangular Kaleidoscope (Fig. 5) was defined by several factors. Firstly, its reflectors were both tapered and adjustable. Secondly, it did not contain a lens or object cell. The body was also conical in shape rather than tubular and it had a series of angles marked at intervals around the body that aligned the internal reflectors to increase or reduce the number of repeats seen in the pattern. In place of an object cell was a disc of clear glass fixed in position over the end and this made it completely reliant on objects and views from the surrounding environment to create its patterns.

Unlike the Carpenter, the Bate was more of a static kaleidoscope intended to be set in place on an adjustable telescopic stand and although this could be altered to a small degree, it was limited to observing objects that moved before its field of vision between the reflectors, rather than moving the kaleidoscope itself across and around to find images. It was the adjustability of the reflectors that allowed control of how the image was viewed within the aperture of the Bate which offered an alternative to the portability factor of the Carpenter, but again, the benefits of the Bate were explained by Brewster as being useful to the arts.

Development of the Kaleidoscope

By 1820, across Europe and beyond, the kaleidoscope had become widespread. A recounting of its impact in one particular letter of 1818 sent by Flint during his travels through America, shows how quickly the kaleidoscope crossed the Atlantic. It also shows how the progression it made towards the child's toy we know it as today began very early on in its existence: 'The kaleidoscope of Dr. Brewster is here fabricated in a rude style, and in quantities so great, that it is given as a plaything to children.'[14]

These 'ruder style' handheld kaleidoscopes which had also flooded Regency Britain were constructed from materials such as wood, card, paper and leather. The fragments used for its patterns were mainly broken coloured glass and lamp-worked glass offcuts along with other bits of coloured materials. These were loosely placed into the tube or sometimes fixed within an object cell at the end. They were shaken, the cell turned or the whole tube rotated to produce their patterns. So the kaleidoscope ended up as a 'range' of instruments to suit a variety of incomes, but the cheaper ones were the poorer quality rip offs of the original ideas that were less concerned with the scientific aspects and it is these types of kaleidoscopes that best reflect the toys we use today.

For those who did not possess the means to own a kaleidoscope in the Regency era, a penny was the price that was asked to 'pay for peeping' by those who embarked on earning a living from this. The kaleidoscope could be bought from hawkers and larger ones were set up on street corners for their views to be rented and Brewster himself recounts his experience of paying a penny for a view through one of these.[15]

Kaleidoscope mania was causing such distraction and extremities of behaviours that it was parodied in illustrations of the time (Fig. 6). Newspaper articles recounted incidents of fights breaking out between sellers, poems were attributed to it, debates ensued as to the originality of its invention and calculations were made as to the probability of repeating any pattern:

> 'Supposing it to contain twenty small pieces of glass or other objects and that ten changes are made in each minute it will take the inconceivable space of 462,880,899,576 years and 360 days to go through the immense variety of changes it is capable of producing.'[16]

Kaleidoscopes were even produced in miniature using precious metals and jewels as items of fine jewelry for ladies to wear and use on their excursions.

By the end of the Regency period the kaleidoscope was perceived less as the highly crafted optical instrument of scientific enquiry that Brewster had patented and more as a passing amusement. Although the patent kaleidoscopes did continue to exist, they were in the minority, superceded by simpler and make your own versions. It was not until 1873, five years after Brewster's death, that another popular more sophis-

Fig. 7 *Bush Parlour-scope and diagram (courtesy of the Bill Douglas Cinema Museum, Exeter University). Authors photographs 2014.*

ticated version was produced in America by Charles G. Bush (Figs 7 and 8). Bush's patent application (US patent no. 143,271) was to improve the kaleidoscope through adaptations, most notably this included a liquid filled glass ampule with an air bubble. This parlour-scope style kaleidoscope was fixed in place on a stand with an object cell that was styled as a ships wheel. This wheel cell contained pieces of twisted glass, glass jewels as well as the 'hollow glass object with two immiscible liquids and an air-bubble contained therein'[17], and the liquid filled glass ampule had the effect of creating a pattern as the liquid and air bubble moved within it.

The Bush design became a very popular device in the later part of the nineteenth century which pushed the parameters of the kaleidoscope back towards rational enquiry, helping to reinforce differences between (what could be perceived as) adult and child's toys. The Bush parlour-scope is, however, just one example of a number of patent adaptations to the original Brewster idea.

Modern Kaleidoscopes

When Brewster described the basic level of mechanics for the kaleidoscope to function, he identified that it was the combination of two plain mirrors set at angles that produced 'highly pleasing effects, from the multiplication and circular arrangement of the images of objects placed at a distance from their extremities'.[18] Harley's more recent description of how to work the kaleidoscope is not that dissimilar: 'multiple reflections in the mirrors show symmetrical patterns which change as the coloured fragments are moved. The number of the reflections and the complexity of the patterns depend upon the angle between the mirrors.'[19] Two hundred years on and the basic component parts, optics and mechanics of the kaleidoscope have not altered. Whatever the style of kaleidoscope today, the formula for the creation of the patterns remains the same: mirrors + coloured fragments + light which when moved = changeable symmetrical patterns.

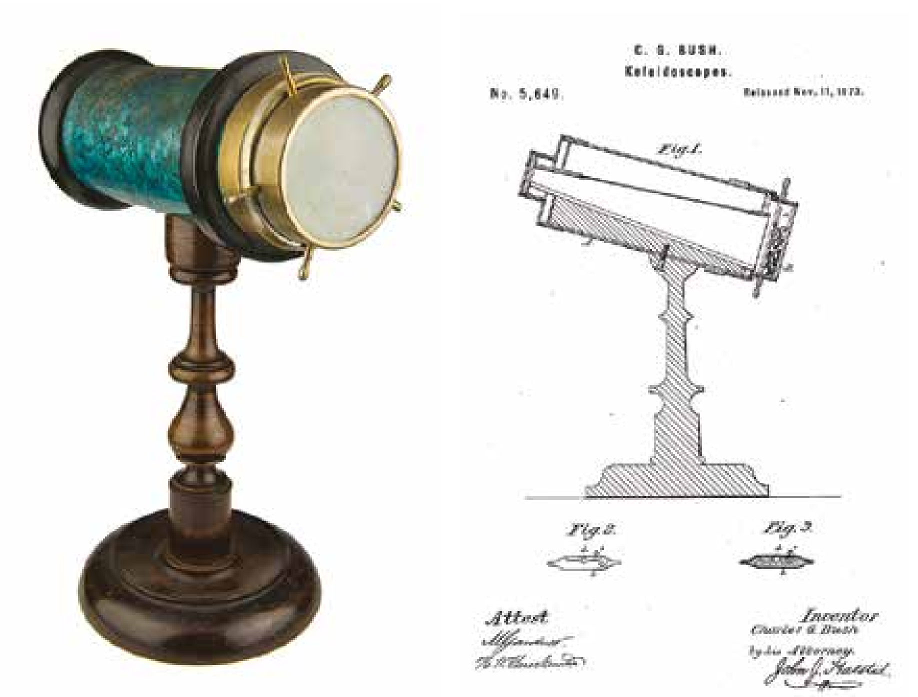


Fig. 8 *Left: Bush Parlour-scope ships wheel. Right: View through Bush Parlour-scope showing the liquid filled glass ampule. (courtesy of the Bill Douglas Cinema Museum, Exeter University). Authors photographs 2014.*

For a basic kaleidoscope to function, there are several components that it has to contain within a tubular body. The kaleidoscopes body, as in the Regency and Victorian pirated versions, is still made from cardboard or metal (tin) tube containing reflectors of equal length and width that are fixed in position at angles so that the reflective surfaces are facing inwards (usually between 2 or 3 mirrors). An aperture at one end acts as a viewing 'peep' hole and a translucent object cell at the other end contains coloured fragments that move upon rotation of either the cell or whole kaleidoscope. For the kaleidoscope to produce a pattern, light is crucial. The light enters the object cell positioned at one end of the tube with the viewing aperture (eyehole) being positioned at the opposite end.

The variations in designs of current day kaleidoscopes include those which contain oil filled wands with glitter and tiny foil shapes which slowly filter through the oil as the kaleidoscope is rotated by 180º resulting in sparks of light, creating the effect of fireworks, inspired by the Bush oil filled glass ampule examples of the late nineteenth century. Other examples include marbles positioned in place of the object cell which rotate or, externally placed removable wheels of colour which sit on a spindle and can be moved by hand.

The kaleidoscopes popularity within the last 30 years has seen a resurgence, it still retains its toy status but there are also many artisan examples that are using the kaleidoscope as a decorative object and are aiming for the perfect symmetrical image. Additionally, the rise of steampunk has added another postmodern angle to it as a scientifically styled object. These examples are by no means exhaustive.

Conclusion

Within a few short years and less than a decade after its invention, the kaleidoscope only fulfilled a part of Brewster's original intentions. What began for Brewster as an incidental object that developed from his optical research left a mark on society in many ways, only some of which are briefly addressed in this paper.

The scientific factors of the original designs may not have stood the test of time but the kaleidoscope we know today has played a part in shaping our visual perceptions.

Yet the point remains that although todays kaleidoscopes engender the same base level components and principles to function as Brewster's Regency kaleidoscopes did, it has remained scientifically only partially understood even though it has survived as a child's toy for two hundred years.

Acknowledgments

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Notes

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Details of future events, meetings, exhibitions, etc. should be sent to the Editor. For up-to date information of Society's events, see the SIS website, www.sis.org.uk.

Thursday 2 March 2017 Farnborough, UK

Visit to the Farnborough Air Sciences Trust. The history of aircraft R & D at Farnborough through displays and collections, including Cody's plane head-up displays, original Whittle jet engine, cameras, instruments, radio telephony, gyros, simulators, space satellites, flight recorders, and carbon fibre models. Military interest in the potential of aerial warfare began with the founding of the School of Ballooning in 1888. Farnborough then became the headquarters of the Air Battalion of the Royal Engineers (ABRE) in 1911 and the following year in April that of the Royal Flying Corps (RFC), soon to become the RAF.

10.00-10.30 Arrival, tea and coffee
10.30 Introductory talk followed by guided tour
12.30 Buffet
1.30 Visiting outside exhibits and the outside store (torch advisable)

Tea/coffee at the end of our visit. Regrettably we will not be able to get in to the wind tunnels. Cost £20. Parking: limited on site but if you continue past the entrance there is a layby labelled 'No Parking'. Ignore the sign and you may park there.
Address: Farnbourgh Air Sciences Trust, Trenchard House, 85 Farnbourgh Rd., Farnbourough, GU14 6TF. See flyer in this *Bulletin*.

Sunday 30 April 2017, London UK

Spring Antique Scientific Instrument Fair at the Double Tree by Hilton, 92 Southampton Row, London WC1 4BH from 10.00am to 3.00pm. Further details: http://www.tideswel.demon.co.uk/ASIF/ and scientificfair.blogspot.com. The Autumn fair will be on 22 October 2017.

Sunday 25-Monday 26 June, Oxford UK and environs (provisional)

The aim is to have the Society's AGM on Sunday at Combe Mill (Fig. 1); a Victorian steam- and water-powered saw-mill serving the Blenheim Palace Estate, the home of the Duke of Marlborough. In the 1970s it was transformed into a working museum. The afternoon will be spent in Oxford at the Museum of the History of Science and the Natural History Museum; both have been provisionally booked, with Monday being an all day visit to the National Trust property Waddesdon Manor, built in the style of a French château for Baron Ferdinand de Rothschild in the 1870s and 80s.

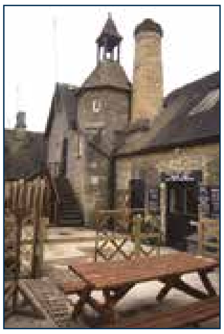

Fig. 1 *Engine house of Combe Saw Mill housing an 1852 boiler and rotative beam engine.* © Copyright *Chris Allen and licensed for reuse under this Creative Commons Licence.*

Friday 10 November 2017, London, UK

The 5th Turner Memorial Lecture will be delivered by Dr Silke Ackermann at the Society of antiquaries, Burlington House, Piccadilly, London W1J 0BE. Lecture title to announced.