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THE EARLY LITERATURE OF OPTICS.

PRESIDENTIAL ADDRESS BY PROFESSOR SILVANUS P.
THOMPSON, D.Sc., B.A., F.R.S.

Delivered March 16th, 1905.

DR. GLAZEBROOK, Ladies and Gentlemen, the honour that you have accorded me in electing me as your President came upon me so suddenly and at such a busy time of the year that it was quite impossible for me to write a formal Presidential address, and I have, therefore, to offer you my apology for not being able, at the moment, to follow the precedent of all those who have sat before me in this chair. But although I am not able to offer you the formal presidential address, I take the opportunity very cheerfully of offering to you some remarks on a branch of the subject of Optics that has for long been of great interest to me, and I trust will not be without interest to you.

I propose to speak of the early literature of Optics, and I have chosen this subject as one which, although time has not permitted me to write anything about it, I have long studied. I have from time to time for many years past made the practice of diving into the early literature of many different branches of science, and I strongly recommend to all the younger men, if not to all members of the Optical Society, the practice of looking up that which has gone before in the science to which they are attached. For, as a matter of fact, all who are really interested in any scientific subject are interested not only in the subject itself, as it stands at the present day, and in its future advances, but they are really interested in knowing how that science has come to be what it is, for no sciences have come into being full fledged.

All have grown by a process of evolution, sometimes from the theoretical and sometimes from the practical side. One invention has led on to another—one mind has moved and re-acted upon another, and so the thing

has grown in many different directions. All these different ramifications that go to make up the whole of any particular science have got histories behind them. When you possess a knowledge of a science, of the facts, the observations, the laws, and the general principles, it is intensely interesting to see how the thing grew, how the facts became known, how the observations were made, how they were correlated in one another, how simple laws were observed, and then more complex, which were afterwards reduced to general principles; and to watch, ever and anon, how point after point that was found out became fruitful—not all at once, very often after a long time—fruitful in practical applications. Not the least interesting part of this study is that of observing who were the men to whom mankind, as a whole, is indebted for these various advances.

Now my reason for recommending this kind of study to the younger men, who are apt, perhaps, to think that all that is needful for them to know is to be found in the text books of the last twenty years, is this, that I earnestly hope they themselves will, in due time, become contributors to the advance of the science, either on the theoretical or the practical side, that they themselves will be among those who carry the advance forward, who will either on a small or a large scale make discoveries, observe new facts, chain together old facts and new ones, advance our knowledge of principles, make useful application of those already known, or discover new ones.

If they would do that, if they would take their part in the progress of the science and its applications, they may be quite sure that the process or processes by which they arrive at any advance will be of the same kind that have been fruitful in the past. No one makes an invention or discovery without some preliminary training. It may not have been in the direct line, but there must be some kind of preliminary training, and there is no surer way of learning how discoveries and inventions are to be made than to see how they were made in the past—to go back to the actual words and writings and descriptions and histories of the men who have made advances in the past.

If you want, for example, to know what Newton did, do not be content to look at the *Encyclopædia Britannica*

for the article on Newton; do not be content to look in the first text books of Optics as to what Newton did: go to Newton himself. Get hold of his own book, or his own published papers, his own lectures, and see exactly how he represents things. You may find at first that it is a little difficult to understand things written in an ancient phraseology—as a matter of fact, a great deal of Newton's work is written in Latin; but the line of progress that Newton had to travel, from point to point, picking up this idea and then that, trying one thing and then another, is essentially of the same kind in any science. When I say essentially, in one sense it is different, because some discoveries are made on the basis of experimental methods, and some by the application of theory. Newton was an unrivalled example of a man who could use both processes.

I recommend you, therefore, strongly, to go back as far as you can, to original treatises, to read the writings of the men themselves, and see how they got at their success—for the method of discovery, though it varies in detail, is not to be told in words. One thing has been borne in upon me in reviewing the early literature of Optics, namely, this: the practical advances did not come first, but the theoretical advances did. Advances in practice were the direct result of the thing having been thought a little onward. Theoretical advances, though seeming perfectly unfruitful, did bear fruit eventually in some kind of practical application.

Now, this early literature of Optics is provided, happily for us, with certain keys or indexes, by which we may learn where it exists. It is not in the encyclopædias, although some of them give fairly full histories of the subject. There is an admirable history of Optics, the "History and Present State of Discoveries Relating to Vision, Light, and Colours," written more than a hundred and thirty years ago, by Dr. Joseph Priestly, and if you are concerned with the subject as it existed down to the time of Priestly, there is not in the English language anything that will give you the history of the earlier phases of the science with greater precision. Besides Priestley's history there are several others, one by Dr. J. C. Fischer, a General History of Physics, published in about five volumes, in 1843. The first volume

deals with Optics before Newton, and the second, Optics in the time of Newton and his contemporaries. Another History of Optics is that of Dr. Emil Wilde, published in 1838. There is also a Bibliography of the Literature of Optics, by Professor Dove, published about 1840.

I cannot claim to have gone to any extent outside the books I have mentioned; but I should be false to the principle I have suggested to you, of going to original sources, if I had taken my history of Optics only from Priestley, Fischer, Wilde, or Dove, or from the Encyclopædias. What I have done is to try to get hold of the books themselves. I have ventured to bring down a section of my optical library, a score of books almost all anterior to the time of Newton, in order that I may tell you a few of the things to be found in this early literature of Optics.

Those who have begun to read this subject will know that the earliest reference to Optics is in the writings of the Greeks, which show that they had some very strange notions as to optical principles in general. The first reference is to be found in the writings of Pythagoras, who flourished about 600 B.C. In those early years the Greeks got some ideas of Optics, and one, which we can hardly understand nowadays, was that light or vision, or whatever you may call it, consisted in the presence of rays which went out from the eyes of people and settled upon things they were looking at. To us, who are accustomed to think of light coming from an object to the eye, the idea of the vision going out from the eye in the form of rays seems incomprehensible. I believe it to be a part of the Greek mode of thought which made the mind of man the centre of everything, and the whole universe a kind of metaphysical creation that somehow or other depended upon the individual.

Another primitive idea very hard to understand is found in Plato, who held that colour was a species of flame which played upon the surface of objects. The Greek ideas of colour were very different from ours. In the first place they did not know of the existence of as many colours as we have. They only recognised very few tints. In proof of this you have only to read Mr. Gladstone's Homeric Studies. They had not got, apparently, the same developed sense of colour that we have. They thought very simply of the matter—just as a man might

do who had not learnt the names of colours, and said that one thing looked warm and another cold, or one thing looked dark and another light. They had a very primitive colour perception. Mr. Gladstone held the view that Homer had not got so far as to understand the colour blue. I believe the theory has been advanced that man began to recognise the colours at the red end of the spectrum—that red was the first colour to be recognised by primitive man, and that yellow and green followed, and that blue was quite a late discovery. If not, then why should Homer describe the sea as being wine-coloured?

Another idea of Plato's was that light consisted of corpuscles which were shot out from luminous bodies and entered the eye. In that respect Plato differed from the earlier Greeks. Another idea was that when you saw in a mirror an image of a thing, your eye projected that image through the mirror to some point in the space at the back. That was part of the old idea of the eye sending out the rays. I have taken these few points in order that we may see how extremely primitive were the ideas of the earliest writers.

There are, then, three conflicting ideas as to the nature of light, rays shot out from the eyes to things, corpuscles which came from the things to the eye, and, lastly, the wave theory, which is quite a modern thing. Now, about the year 350 B.C., we come upon the writings of Aristotle. While Aristotle did not give us anything bearing directly upon the subject of Optics he controverted the idea of his time, that the eye shot out corpuscles or sent out rays. All things in those days were classed as belonging to one of the four elements, earth, air, water, fire. As the eye was neither earth, air, nor water, it must be a fiery body. With regard to the eye shooting out corpuscles or rays, Aristotle objected to that on the ground that if the eye was a fiery body why did we not see in the dark? He considered that objection was really sufficient to disprove the old idea. In other branches of Optics Aristotle did give us, certainly, some further advance, namely, in his book on Meteors. He treats of the rainbow, too, as having three colours, and in the same book he talks about the scintillation of the stars—why they twinkle.

It is rather surprising in a man of such gigantic

intellect, who had gone round the whole range of sciences as they existed in those days, that he did not give more attention to the science of Optics than we find in his writings.

Nearly a hundred years after Aristotle we come upon Euclid. It was known that Euclid had written a book on Optics, but it was for a long time supposed that it was lost, and I have often congratulated myself on this supposition and thought that had this not been so we might have been learning "Euclid" instead of Optics, just as, until the last year or two, the schoolboys who ought to have been learning Geometry were learning "Euclid" instead.

Euclid's Optics, however, has been found. It existed, embedded in other treatises, but we do not quite know to this day how much is Euclid's and how much is a later addition, as like many other ancient books it has been edited and added to. This book is in two parts: the first on general Optics and the second part on Catoptrics. Each part is divided into two sections, and starts off with axioms or postulates, or whatever you choose to call them, and then goes on with a number of theorems and develops the subject much in the same way as his Geometry was developed. This was about the date of 260 B.C.

A few years later we come upon that famous man, Hero of Alexandria, the inventor of water clocks, and also of the penny-in-the-slot machine. This same Hero of Alexandria dabbled in Optics. He was considering the law of reflection. You have a mirror, in front of which you have an object, and the eye—both of them, possibly, at unequal distances; and a ray passes from one to the other, being reflected at the mirror on its way. He says the particular direction taken by that ray to the mirror will be such that the total length of its path is the shortest possible distance. That states the "principle of least time" as a principle in Optics, right away back to 260 B.C.—that principle which Fermat developed afterwards and also Hamilton, and of which Mr. Chalmers has made such excellent use in our own day.

About the same time, or a little later than Hero, we have Archimedes, the man who wanted only a fulcrum and a lever, with which he said he could move the world

—the man who discovered the principle of hydrostatics, the principle of specific gravity, and the theory of displacement—by which, when a body is placed in water it causes a displacement equal to its own volume. You know the story how it is said that he found this out when he was bathing, and was so pleased that he rushed out of the bath and ran down the street crying “Eureka.” Archimedes was acquainted with the law of reflexion, although he left no writings on the subject. There is a tale told of him that at the time Syracuse was besieged by the Romans, he employed the rays of the sun which he focused on the ships of the Romans and set them on fire, and thus delivered the people of Syracuse from the siege.

There exists a considerable literature on the burning mirror of Archimedes. Here is a book published in 1646, by Athanasius Kircher. This book deals with a great many things in which we are not at all interested. It treats very largely on how to make sun dials and water clocks; then there is a little bit about surveying instruments and astronomical instruments. And right at the end of the book there is something on the laws of reflexion and refraction (page 282), and it mentions the burning mirror of Archimedes. Certainly, it is not a contemporary account, as Archimedes lived about 150 B.C., and this book was published in 1646 A.D. A matter of 1,800 years difference of date is an important fact; but here is a picture of the way in which Archimedes set those ships on fire. It is not the only picture that I possess of the mirror of Archimedes. Another is to be found in a treatise on Optics by the Arabian, Alhazen, printed in Basel in 1622. It is mentioned in other treatises published in 1582, 1640, and 1730, from all of which it is clear that the mirror of Archimedes attracted a great deal of attention on the part of those who were interested in Optics. The earliest mention of it is to be found in the writings of a certain man named Anthemius, who lived about 550 A.D. Seeing that it was, therefore, some 700 years before any mention was made of it, one is justified in thinking that the burning mirror of Archimedes was an entirely spurious affair. There is no doubt that he did study Optics, and that he did also concern himself in the siege of Syracuse, and helped the defenders by inventing

catapults, and other mechanical means of defence; and someone, apparently, 700 years later or thereabouts, mixed up his optical studies with his feats on behalf of the defenders of Syracuse.

Then we come upon the writings of the Roman, Seneca, who investigated the rainbow, discovered the colours of the prism and compared them with the rainbow. Then there was Claudius Ptolemy, who lived 100 A.D. His treatise is a perfectly wonderful work. Books 1 and 2 had been lost; book 3 related to convex and flat mirrors, book 4 treated of concave mirrors; and then there was book 5, where, for the first time, we come upon a chapter on Dioptrics. Ptolemy found that the angle of refraction in water was three quarters of the angle in air.

A little earlier than Ptolemy was Pliny, in whose works there was a chapter on mirrors. The early mirrors were all of metal. The earliest mention of a mirror made of glass, silvered at the back, is in a book written in 840 A.D.

Then, coming down by a great jump from the end of the first century, and the times of Pliny and Ptolemy, we pass to the eleventh. During that thousand years, which were sometimes called the ages of faith, there was no faith in Optics; and until the Arabs reintroduced the science it was practically dead. Among the Arabs who wrote on Optics there was Alhazen, who lived about 1038 to 1100, to whom we owed the use of the magnifying glass, although, strange to say, he did not speak a word about spectacles. Then there was Roger Bacon, who lived in Oxford about 1250, and who died in 1268. He described the use of two lenses in combination, although it was doubtful if he used them as a telescope. Doubtless, he used them as a kind of magnifying glass—one above the other. Spectacles were unknown to him, but they are mentioned shortly afterwards, in 1299, by Redi, who spoke of a certain eye salve which would make an old man read more clearly—"vetri appellati occhiali" (glasses called spectacles).

Here is Porta's book on Natural Magic, dealing with many wonderful things such as the production of new planets, of changing metals, counterfeiting precious stones, the wonders of the lode-stone, of physical experiments, beautifying woman—(laughter)—of distillation,

of purifying and tempering steel, of some choice things in the art of cookery, of hunting, fowling, and fishery, of invisible writing, of burning glasses and the wonderful sights seen by them, of spectacles, whereby one could see very far beyond imagination—(laughter)—and how to see things in a chamber where things are not—(laughter). Giovanni Baptista Porta also wrote a book called "*De Refractione*," published in Naples in 1593. The particular copy of this work which I have brought with me, is of very exceptional interest, as it contains Porta's own manuscript notes, showing that he was getting ready for a second edition. He was the first man to notice the contraction of the pupil of the eye on going from a dark room to a light one.

Then we come to Kepler, who discovered a great part of the laws by which the planets moved. He discovered the "position" of the image, by which, he said, he meant that when you are looking at it, it was the point towards which the eyes converge. He likened this locating of the image to a sort of triangulation. He also discovered spherical aberration and proposed hyperbolic lenses to get rid of spherical aberration. He was, moreover, the first man to put a draw-tube on a telescope.

As to who invented the telescope there is no absolute certainty, but there seems to be no doubt but that it was a Dutchman. Galileo never claimed to be the inventor. He heard the thing had been done and he set to work to do it in his own way. A certain Arias Montanus, a theologian, had claimed that the telescope was known at the beginning of the Christian era, and in support of his contention he referred to the fourth chapter of Matthew and the eighth verse, and said that the kingdoms of the earth could not all have been seen at the same time unless the devil had invented the telescope. (Laughter.).

Time fails me to do more than mention the writings of Robert Boyle, a writer of many treatises, and who touched nothing that he did not adorn. Boyle tried to measure the pressure exerted by light on the surfaces of things, and he also investigated phosphorescence. Lastly, there is Robert Hooke (1635-1678), who was Secretary of the Royal Society and contemporary with Newton. He was a man who, like Boyle, went round a great many subjects, improving anything

that he touched upon. He was the first one to divide a circle accurately by using a screw to make the divisions, and he was the first man to use a dark glass on a telescope for observing the sun. His treatise, the *Micrographia*, is now very rare. This brings us to the time of Newton and Huyghens, the creators of Modern Optics; so that here we might fitly consider the earlier literature to end.

In concluding my address I hope I have interested those present in the earlier productions in Optics, and caused them to feel that there was a great deal to be learned by going to the original sources, and seeing how the science grew up to be what it was to-day. (Cheers.)

Dr. GLAZEBROOK, in moving a vote of thanks to Dr. Thompson for his address, said it had been most interesting and instructive, and was all the more valuable because it was so very distinct from what they usually listened to. To those who were struggling day by day with the practical affairs of life, it was a good thing to be carried back to those old times and to learn what was done for the subject they of the present day were studying, by those who lived so long ago. He would like to enforce what Dr. Thompson had said by a small personal recollection as to the value of original research. When he first went to Cambridge he was one day invited to the house of the Master of one of the Colleges, by whom he was asked what he was learning.

He said that he was just commencing to read Newton. The Master at once presumed he was reading it in the original, but he replied that he was reading Dr. Frosto's edition. He had a severe rating for what the Master described as the wickedness of trying to read Newton in anything but the original. Later in life, Mr. Leslie Stephen invited him to write on Newton for the Dictionary of National Biography, he thought he knew something about it and set aside a Christmas vacation to do the work in. By the end of the vacation he had on his table a pile of books dealing with Newton, which far exceeded in number those which Dr. Thompson had just been showing, but he had not written a single note. Term came and the matter had to be dropped till the summer vacation. He found that in order to make a thorough study of what men had done in the past it was necessary to go to the original works. He had

great pleasure in asking those present to offer a hearty vote of thanks to Professor Thompson for the very interesting address he had given them.

DR. WALMSLEY said he should like to have the honour and the pleasure of seconding that motion. To him it had been a delightful thing to listen to Dr. Thompson's address and to hold in his hand such valuable relics of the past. It was certainly a good thing to pass from the strife and strenuousness and turmoil of the present day back into those old days when discoveries were separated by centuries, and when those discoveries were, in some instances, due to the imaginations of subsequent writers and not to the people to whom they were ascribed. He had the greatest pleasure in asking them to testify their appreciation of the intellectual treat from their new President by passing a hearty vote of thanks.

The vote was carried with acclamation.

PROFESSOR THOMPSON, in acknowledging, said he was glad he had succeeded in interesting them, and he hoped he had even done more than that, that, indeed, he had induced them to read for themselves those earlier portions of the literature of Optics. If so, he was quite sure they would find many other things that he had not touched upon, of very, very great interest, and things which, if they did not bear fruit immediately, would remain with them as useful mental property to come into use in due time. (Cheers.)

MR. AITCHISON said he should like to say a few words before the meeting closed, in explanation of the instrument which was on the table. The subject of the testing of binoculars had in recent years attracted considerable attention, and during the presidency of Dr. Glazebrook attention had been called to the work of the National Physical Laboratory, in the testing of optical instruments. Up to the present time they were able to get Government certificates with regard to many things, but there seemed to have been no standard with regard to testing one of the most important things in daily use—the binocular field glass.

When he (Mr. Aitchison) started the manufacture of field glasses he was not satisfied with the methods then in vogue, and he attempted to devise something better. With the assistance of Dr. Drysdale and the head of his factory (Mr. Kendall) an instrument had been devised,

and that which he was now showing was a distinct improvement on the one they had previously been using in their workshops, and he (Mr. Aitchison) believed that in the future they would be able to get even better results. However, this instrument before them would, he thought, be found of considerable interest and a starting point for some set of standards by which they would be able to get some reliable estimate as to the value of field glasses.

DR. C. V. DRYSDALE said the object of the instrument was for the particular purpose of ascertaining in a binocular glass when the axes of the glass were parallel. They would, doubtless, be aware that, recently, attention had been called to the considerable strain on the ocular muscles liable to be caused if the two axes of the glass were not parallel. Furthermore, in the case of a prism glass they would be aware of the fact that unless the two prisms which effected the inversion of the image inside the glass were strictly perpendicular the result would be that the image would be slightly turned round from the true vertical position. Therefore, the arrangement before them was devised with the object of enabling those two errors to be observed simultaneously and corrected.

The first portion of the apparatus consisted simply of a projection lantern, throwing a cross like a lantern slide, upon a small screen. In order, however, to focus the image on the screen, a large lens was mounted in front of the screen, distant from it by its focal length, so that when the light coming out from the projecting tube was parallel, the image was, of course, brought to a focus on the screen. By having two similar tubes, in each of which there was a very intense source of light, such as obtained by a Nernst lamp, the two images were superimposed, and if a binocular in perfect adjustment was placed in the path of the rays the image would remain single on the screen.

But if there was any want of parallelism the cross would appear double, and a movement of two centimeters of the cross on the screen was equivalent to a want of parallelism of one degree in the binocular.

DR. GLAZEBROOK said he wished to express the great interest he took in the instrument, and his gratitude to Mr. Aitchison in presenting the whole outfit to the

National Physical Laboratory in order that they might be in a position to test binoculars in a satisfactory manner.

MR. HORACE BECK said he was extremely interested in the instrument which appeared to him to be a most ingenious device, and he thought it ought to do all that was claimed for it.

The PRESIDENT asked the meeting to return a hearty vote of thanks to Mr. Aitchison and to Dr. Drysdale for his exposition of the instrument. The Society would be very glad, he was sure, to hear that Mr. Aitchison had been so good as to put the invention to national uses by offering it to the National Physical Laboratory. They should also congratulate themselves that the apparatus had been thought out and constructed in England. The vote of thanks was accorded by acclamation, and the meeting then terminated.