AN ELEMENTARY TREATISE ON OPTICS. PART II

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ELEMENTARY TREATISE

ON

OPTICS:

PART II.

CONTAINING

THE HIGHER PROPOSITIONS,

WITH THEIR

APPLICATIONS TO THE

MORE PERFECT FORMS OF INSTRUMENTS.

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PREFACE.

The modern history of Optical Science may be considered to commence with the discovery of the law of the refraction of light, by Snellius. To Huygens we are indebted for the discussion of the aberration of pencils refracted by spherical surfaces of media, and he applied his investigations to the construction of his double eye-piece, which remains in high estimation to the present day. By good fortune he secured in it the condition required for achromatism, in addition to the advantages of reduced spherical aberration, to which his views were directed, although the conditions for achromatism in eye-pieces were not discovered until long afterwards.

Sir Isaac Newton having discovered the unequal refrangibility of the differently coloured rays of the spectrum, shewed the great effect of the chromatic dispersion in producing indistinctness of the optical images produced by lenses.

The discovery of the different dispersive powers of different media by Mr. John Dollond, in 1757, and his most successful application of his discovery to the construction of the object-glasses of telescopes, gave a new impetus to the mathematical theory.

We find Clairaut,* D'Alembert,† Euler,‡ and Boscovich,‖ almost simultaneously investigating the properties of refracted

* Mémoires de l'Académie, 1756, 1757, 1762.

† Opuscules, Vol. III. 1764.

‡ The results of many previous papers condensed in his Treatise, Dioptrica, 1769.

‖ Dissertationes quinque ad Dioptricam pertinentes, 1767, and Opuscules, 1785.

pencils, and they have left us their results in laborious and elegant analysis, with, however, great room for improvement in simplicity of method. All these eminent mathematicians investigated the conditions for aplanatism as well as achromatism in the object-glasses of telescopes. Clairaut, in addition, also investigated the aberration in obliquely refracted pencils, and proposed to correct this effect as well as the direct aberration. D'Alembert discusses the primary and secondary foci of a refracted pencil. Boscovich first shewed that the chromatic dispersion of a single eye-glass could not be corrected, except for the point of the image upon the axis, by any form of the achromatic object-glass; and he discovered the construction of the double achromatic eye-pieces, which were hence called Boscovich's eye-pieces. In his later work, he finds the condition of achromatism in combinations of several lenses in eye-pieces. Euler discusses the angle which a given refracted ray makes with the axis of the lens, and compares the relative magnitudes of an object and its image, or successive images, by means of excentrically refracted rays; he also employs the analytical condition for achromatism in combinations of lenses, as used in the eye-pieces of telescopes, but does not keep in view practical cases, during his discussions.

If these various problems had been fully investigated in the neatest and simplest manner of which they admitted, and their results carried out to the cases actually arising in optical instruments, little would have been left for succeeding mathematicians to accomplish. They, however, left the mathematical theory so diffuse and complicated, that few will have had the patience to master entirely their methods, which have hence long remained almost unfruitful.

We do not find that any very important advance in the mathematical theory was made after the above-named illustrious mathematicians, until the Astronomer Royal, Mr. Airy, in his paper, in the "Cambridge Philosophical Transactions," Vol. II. rendered to optical science the great service of applying Euler's analytical method for achromatism to the combinations of lenses for eye-pieces, which had been discussed through circuitous methods by Boscovich. He also undertook, in his paper on the spherical aberrations of eye-pieces, in the next volume, the discussion of oblique pencils through the primary and secondary focal lines, and the nearest approach to a symmetrical area between them, or the circle of confusion, as the focus of each pencil. He also employed the directions of the axes of excentrical pencils to explain the distortion of images.

These discussions, through the circle of confusion, apply to exceedingly small pencils only when the obliquity is small, because the aberration is neglected, and hence the parts of the field of view out of, but near the axes of lenses, cannot be considered as in the actual case of instruments to have been discussed, although for considerable obliquities, when the aperture is not very large, the results are good approximations. These papers of Mr. Airy induced Mr. Coddington to re-write his Optics, so that his work, published in 1829, is not the third edition of his first Treatise, but a new work, and is the one referred to in the present Treatise.

To find the form of the image in any actual case arising in the use of instruments, it is clear that the oblique aberration must be considered, and the formulæ put in such a workable shape, that the form and curvature of the image can be traced. Amidst the complication which the higher optical formulæ assume, the author has succeeded in obtaining working formulæ, which enable him now for the first time, as he believes, to trace the forms of the images, and to find the lenses possessing the desirable properties of more correct images for various given cases, and hence to discuss the properties of eye-pieces more accurately.

The effects of the oblique aberration in the achromatic lenses constituting the powers of the achromatic microscope, were discovered from experiment by Mr. Lister, and published in his paper, in the "Philosophical Transactions" for 1829; and the astonishing advance towards perfection which the microscope has in consequence attained, unaided by mathematical theory, has been a reflection on the state of mathematical physics. It was clear that no creditable Treatise on Optics could now be undertaken without discussing Mr. Lister's discoveries, and if possible to find new properties which experiment could not be expected to reach without the mathematical theory. To some extent the author considers he has filled up this desideratum, and carried theory again in advance of practice.

The old approximations for the aberration applied sufficiently accurately to the object-glasses of telescopes, where the refracted pencil seldom exceeds 3^0 or 4^0 in angular diameter; but as the refracting microscopes are now constructed so that their object-glasses bring very accurately, incident pencils of upwards of 90^0 angular diameter, to a focus, the second approximations can apply only imperfectly to such cases, and hence the author considered that the formulæ for the third approximations ought now to be investigated.

From their increased complexity, these formulæ may not be immediately applied to practice, yet in some future improved state of the world of science, when the mathematician, the computer, and the working optician, shall be brought into harmonious action together, from the necessity to secure further advance, the author trusts they will be found useful.

It has been said in optical treatises, that although a parabolic mirror would give a correct image of a star at the focus, yet the image would not be correct when out of the axis; this seems to leave room to doubt the great advantage of a parabolic over a spherical mirror in the Newtonian telescope, and hence it became desirable to discuss the aberrations of ellipsoidal and parabolic mirrors for oblique pencils, as will be found performed in this work.

The author found that the expressions for the reflexion and refraction of pencils at spherical surfaces could be carried one step further without approximation, than has hitherto been done, and he has hence availed himself of that method. He has studied each proposition, to find what he considered the simplest method of treatment, knowing that to many students, optical formulæ seem sufficiently discouraging without any unnecessary complications or developments. For this reason also he has omitted propositions which had less immediate practical bearing.

The notation introduced by Mr. Coddington must now be considered so far established in this country, that only partial deviations from it should be used. To his last Treatise, which will long be held as the foundation on which succeeding treatises have been constructed, the student is referred who wishes for more extensive study.

To Sir John Herschel also the scientific world is greatly indebted for his excellent Treatise on 'Light,' in the "Encyclopædia Metropolitana." The student will there find many optical developments not to be found in elementary treatises.

LONDON,
DECEMBER, 1850.