SIMPLIFIED METHOD OF TRACING RAYS THROUGH ANY OPTICAL SYSTEM OF LENSES, PRISMS, AND MIRRORS

Published @ 2017 Trieste Publishing Pty Ltd

ISBN 9780649012473

Simplified method of tracing rays through any optical system of lenses, prisms, and mirrors by Ludwik Silberstein

Edited by Trieste Publishing Pty Ltd.
Cover @ 2017

www.triestepublishing.com

LUDWIK SILBERSTEIN

SIMPLIFIED METHOD OF TRACING RAYS THROUGH ANY OPTICAL SYSTEM OF LENSES, PRISMS, AND MIRRORS

Trieste

SIMPLIFIED METHOD OF TRACING RAYS THROUGH ANY OPTICAL SYSTEM

5438 Alexander Ziwet

SIMPLIFIED METHOD OF TRACING RAYS

THROUGH ANY

OPTICAL SYSTEM

OF LENSES, PRISMS, AND MIRRORS

BY

LUDWIK SILBERSTEIN, PH.D.
LECTURER IN NATURAL PHILOSOPHY AT THE UNIVERSITY OF ROME

WITH DIAGRAMS

LONGMANS, GREEN AND CO.
39 PATERNOSTER ROW, LONDON
FOURTH AVENUE & 30TH STREET, NEW YORK
BOMBAY, CALCUTTA, AND MADRAS
1918

PREFACE

THE aim of the present volume is to set forth a method of treating the geometrical optics of any given system *intrinsically*, that is to say, without introducing any artificial scaffolding and, therefore, without any *arbitrary splitting* of the entities involved in the problem of tracing a luminous ray through the several surfaces of a system. The resultant formulae, in vector language, of course, as the only appropriate means of intrinsic expression, will then be free of any unnecessary elements, and therefore, if finally translated into any set of scalar formulae for the practical use of the numerical computer, will contain no superfluous, geometrical or arithmetical, complications.

Our purpose is not to treat the whole subject of geometrical optics, but exclusively, or almost so, that part of it which is called by the short name of "ray tracing." This is notoriously the most laborious part of the computer's patient work, and becomes, without question, a formidable task when he has to deal with skew rays and non-centred systems. The problem thus limited can be put shortly :—Given the ray incident upon any system of lenses, mirrors, and prisms, find the emergent ray.

The advantages of the vectorial method of resolving it must not be judged by the conspicuous shortness of the resultant formulae alone, but also by the simplicity of their deduction, as compared with the usual method, and by the facility of recalling the formulae, or of reconstructing them if forgotten. Again, the nature of the proposed method is such as to make the help of drawings—which, especially in the case of skew rays, become, in the best standard treatises, exceedingly complicated—almost superfluous. This circumstance will be particularly welcome to readers who are not endowed with strong visualising powers. In connection therewith the often troublesome discrimination of sign will become almost automatic.

As already indicated, the mathematical idiom to be employed to secure these advantages and to prevent the intrusion of foreign and artificial elements is Vector Algebra. The reader whose acquaintance with that natural language of space-relations is but slight need not, on that account, be deterred from studying the methods to be described. For they will involve only the rudiments of vector algebra: namely, the addition and the scalar multiplication of vectors together with an occasional application of the vector product of two vectors. A reader who is entirely ignorant of the subject could, in a few hours, acquire this amount of knowledge from one of the existing treatises on it. For instance, the first twenty pages of the author's *Vectorial Mechanics* (Macmillan, 1913) contain all that is required and even more. It is unnecessary, perhaps, to point out that the rudiments of vector addition and multiplication, thus readily learnt, will be found useful in other connections, such as the study of electro-magnetism and kinematics. It is, however, permissible to urge that British students, above all others, should be more widely acquainted with the language of vectors, so powerful and yet comparatively so little used. For it is their own patrimony. After due acknowledgment has been paid to Grassman it remains true that the vector method originated in this country through the creative genius of the great Hamilton, and was shaped into a practical instrument of investigation by Oliver Heaviside's pioneer work of simplification, seconded in America by the independent and equally successful efforts of J. Willard Gibbs.

In order to avoid digressions in the text of this volume it will be well to give here a few explanations of the symbols to be used and to collect the very meagre number of vector formulae which will be required for our purpose. Vectors will be printed in Clarendon, small or capital type. Thus

$$\mathbf{A},\ \mathbf{r},\ \text{etc.}$$

will be vectors. Their sizes or absolute values will be denoted by the corresponding Italics, as A, r in the above case. If $r=1$, then $\mathbf{r}$ is called a unit vector. The vector sum of two vectors will be denoted, as usual, by $\mathbf{A}+\mathbf{B}$. The scalar product of two vectors $\mathbf{A}$, $\mathbf{B}$ will be written simply $\mathbf{AB}$, and their vector product, which will not often be needed, **VAB**. With these symbols the only formulae required will be:

$$\mathbf{A}+\mathbf{B}=\mathbf{B}+\mathbf{A}\,;\quad \mathbf{AB}=\mathbf{BA}\,;\quad \mathbf{VAB}=-\mathbf{VBA},$$
$$\mathbf{A}(\mathbf{B}+\mathbf{C})=\mathbf{AB}+\mathbf{AC}\,;\quad \mathbf{VA}(\mathbf{B}+\mathbf{C})=\mathbf{VAB}+\mathbf{VAC}.$$

Similarly for the product of two sums of any number of vectors. If γ is the angle contained between the two vectors **A**, **B**, then

$$\mathbf{AB}=AB\cos\gamma,$$

and the *size* of the vector product **VAB** is

$$|\mathbf{VAB}|=AB\sin\gamma.$$

The scalar autoproduct of a vector **A**, or its "square," will be written

$$\mathbf{AA}=\mathbf{A}^2=A^2.$$

If **r** is a unit vector, it is evident that $\mathbf{r}^2=1$. The angle γ between two unit vectors **a**, **b**, is given by

$$\mathbf{ab}=\cos\gamma.$$

The mutual perpendicularity or orthogonality of any two vectors **A**, **B** is equivalent to $\mathbf{AB}=0$, while their parallelism is expressed by $\mathbf{VAB}=0$. Instead of the latter the form $\mathbf{A}\parallel\mathbf{B}$ will sometimes be employed. The concurrency (or equal sense) of parallels and its reverse will, whenever needed, be expressly stated. Finally, for any **A**, **B**, **C**,

$$\mathbf{VAVBC}=\mathbf{B}(\mathbf{CA})-\mathbf{C}(\mathbf{AB}).$$

Scarcely more than what has here been set down will be required for following freely the course of the deductions.

The main subject will, now and then, be illustrated by examples or exercises. These will, for the sake of better discrimination between essentials and accessory matter, be printed in small type.

I gladly take the opportunity of expressing my best thanks to Mr. Frank Twyman, Manager to Messrs. Adam Hilger, Ltd., for encouraging this little work, and to my friend Prof. T. Percy Nunn for reading and revising the diction of the MS. My thanks are also due to the Publishers for the care they have bestowed on the book.

L. SILBERSTEIN.

LONDON, April 1918.
RESEARCH DEPT., ADAM HILGER, LTD.