

1 INTRODUCTION

1.1 SCOPE

In 1952 the Ordnance Corps published ORDM 2-1, Design of Fire Control Optics. The purpose of that publication was to make available to engineering and design personnel all pertinent optical data that had been accumulated by Frankford Arsenal. In the meantime, the rapidly increasing application of optical features in the design of military systems, and the accelerated rate of over-all technical advancement in the optical field bypassed ORDM 2-1 to such an extent that, in 1958, a tri-service project was initiated to gather and present, in a single volume, up-to-date engineering information, formulas, and calculations currently applicable in the design of individual optical elements and complete optical systems. Military handbook MIL-HDBK-141 is the result of that project.

This Department of Defense handbook was developed by a leading optical manufacturer under Department of the Army Contract DA-36-038-ORD-20590. Major contributions were made by a group of recognized authorities in the field of optical design. All work was performed under the guidance of Frankford Arsenal.

Although many excellent reference works at the college and advanced-design level are available, there is a lack of transition among them from one subject to another. To provide this needed transitional feature, MIL-HDBK-141 presents as nearly as possible the full range of subjects encountered in the field of optical design, including sections covering fundamentals, principles of design, and design data.

The first seven sections serve mainly to acquaint the reader with the basic concepts of optics, and to introduce the mathematical notation employed in later sections. These initial sections require that the reader have a working knowledge of analytical geometry, differential and integral calculus, and physics.

The sections on principles of design introduce typical design considerations encountered in basic types of optical systems. Included are discussions on system aberrations and their computation and correction. The computing schemes described should enable the designer to work efficiently and accurately.

The remaining sections of the handbook apply to various commonly used components and combinations, discussions of problems and solutions in special design areas, and data on general topics related to problems of optical design and manufacture.

1.2 DEFINITIONS.

1.2.1 Symbols and Notations. The following symbols are used in this handbook. Table I contains the English alphabet notation, Table II, the Greek alphabet, and Table III, the mathematical symbols.

TABLE I

Symbol	Usage	Symbol	Usage
A	Area, points, linear dimension.	H	Magnetic vector.
\bar{A}	Aperture area.	h	Diameter of a mirror, fringe width.
a	Real number, points, mirror aperture, amplitude of a wave. Special (Geometrical optics): 3rd order chromatic aberration.	I	Angle of incidence; positive if the ray can be made coincident with the normal to the surface by rotating the ray in a clockwise direction by an angle less than 90° .
B	Points, 3rd order surface contribution for spherical aberration.	I'	Angle of refraction; positive if the ray can be made coincident with the normal to the surface by rotating the ray in a clockwise direction by an angle less than 90° .
b	Real number, coefficient of a power series. Special (Geom. optics): 3rd order chromatic aberration.	I_c	Critical angle.
C	Points. As a subscript denotes red light using hydrogen line. Special (Geom. optics): 3rd order surface contribution for astigmatism.	i	Imaginary number, paraxial angle of incidence.
c	Points, constant velocity for all electromagnetic waves in a vacuum, curvature; positive if the center of curvature is to the right of a surface.	i'	Paraxial angle of refraction.
D	Lens diameter. As a subscript denotes yellow light using sodium line. Special (Geom. optics): distortion.	$J_n(x)$	Bessel function of order n.
d	Thickness, pupil diameter in mm., as a subscript denotes yellow light using helium line. Special (Geom. optics): distance or distance along a ray (not along optical axis).	K	Absorption constant, constant of proportionality, optical constant, optical direction cosine, Ratio of the energy density at the diffraction head when objective is out-of-focus by an amount to the energy density at the diffraction head when objective is in focus.
E	Electric vector, 3rd order contribution for distortion.	k	Image surface, $2\pi/\lambda$.
F	Principal focal point. As a subscript denotes blue light of hydrogen line. Total flux radiated by a surface.	L.	Distance, optical direction cosine.
f	Focal length of a lens; positive if the first principal point is to the right of the first principal focus. A function related to the phase changes on reflection at the reflecting coated surfaces.	l	Path length through the particular medium.
f'	Focal length of a lens; positive if the second principal focal point is to the right of the second principal point.	M	Magnification ratio, optical direction cosine, unit normal vector.
		MP	Magnifying power.
		m	Lateral magnification.
		N	Number of inter-reflections, nodal point of a lens.
		n	Index of refraction, optical constant of an homogeneous isotropic film, n^{th} order of terms.
		O	Origin, object surface.

TABLE I (Cont.)

Symbol	Usage	Symbol	Usage
o	As subscript pertains to object.	v	Velocity of light in vacuum, size of field of view.
P	Object point, principal point of a lens. Special (Geom. optics): Petzval contribution.	W	Energy density or energy flux.
P'	Image point.	w	Optical half-width of the Fabry-Perot fringes.
\bar{P}	Partial dispersion ratio.	X, Y	Rectangular coordinate system of the Z plane, with subscripts they denote the position coordinate of the ray intercepts on the subscript surface.
PD	Interpupillary distance.	X_ν	Radii of the dark fringes.
Q	Incident unit ray vector, quaternion, ratio.	X_μ	Radii of the bright fringes.
Q'	Reflected unit ray vector.	x	Distance along X-coordinate.
q	Scalar coefficient.	Y	Radius of entrance pupil.
R	Radius, reflectance, resolving power in seconds of arc.	\bar{Y}	Height of chief ray.
r	Radius.	Y_ν	Admittance when electric vector is perpendicular to the plane of incidence in the ν th layer.
S	Object conjugate of a lens, surface of a lens, time-averaged Poynting vector.	\bar{y}	Object height, height of oblique paraxial ray.
S'	Image conjugate of a lens.	y_ν	Admittance when the magnetic vector is perpendicular to the plane of incidence in the ν th layer.
T	Internal transmittance, time-averaged energy transmittance, period.	Z	The abscissa of the rectangular coordinate system used. In general the axis of propagation or optical axis; with subscript, denotes a position coordinate of the ray intercept on the subscript surface. Complex number, sag.
t	Thickness measured along optical axis, Special: (Physical optics): time.	z	Distance along Z axis.
U	Angle between meridional ray and optical axis, vector.		
u	Angle between paraxial ray and optical axis, polar coordinate.		
V	Distance, optical path, vector, wavefront.		

TABLE II

Symbol	Usage	Symbol	Usage
α	Absorption coefficient, angle, angular magnification, direction cosine with respect to X axis.	θ	Angular limit of resolution, angular measurement.
β	Absorption coefficient, angle, direction cosine with respect to Y axis.	λ	Wavelength.
γ	Constant, direction cosine with respect to Z axis.	μ	Magnetic permeability.
Δ	Total phase difference, increment of change.	ν	Abbe constant, extinction coefficient, frequency of vibration, integer.
δ	Angle of deviation, phase difference.	ρ	Amplitude reflectance.
ϵ	Dielectric constant.	σ	Electric conductivity, phase change, unit vector.
ζ	Abscissa.	τ	Amplitude transmittance.
η	Ordinate.	ϕ	Angle, phase angle, power of a thin lens.
κ	Extinction coefficient.	Φ	Optical invariant.
		ω	Angular velocity, angle.

TABLE III

Symbol	Usage	Symbol	Usage
\pm	Plus or minus.	*	Transverse chromatic aberration for some oblique ray displaced from the ray passing through $y_1=0$.
=	Equal to.	$\sqrt{\quad}$	Square root.
\equiv	Identity, defined as.	$n\sqrt{\quad}$	n^{th} root.
\approx	Nearly equal to.	Σ	Summation operator.
\sim	Similar to, special designator when used to overline a capital letter.	\sum	Sigma-summation operator.
\rightarrow	Approaches (from left hand side).	∞	Infinity.
\leftarrow	Approaches (from right hand side).	[]	Brackets; multiplication or matrix operators.
$>$	Greater than.	∂	Denotes partial differentiation.
$<$	Less than.	\int	Integration operator.
\leq	Less than or equal to.	\int	Integration operator.
\geq	Greater than or equal to.	π	Pi = 3.1416. π radian = 180° .
$^\circ$	Degree.	e	Base of Napierian or natural logarithm = 2.71828.
\therefore	Therefore.	Π	Quaternion summation operator.
()	Parentheses; multiplication operator.		

1.2.2 Terms. In general, the terms used in this handbook conform to Military Standard No. 1241, Optical Terms and Definitions; where special terms are used, the definitions are given in the text. An alphabetical index is provided at the end of the volume for easy reference to these definitions.

1.3 REFERENCE DOCUMENTS.

1.3.1 The following government publications are used in direct reference or provide related information valuable in the general field of optical design:

JAN-G-174 Optical Glass
MIL-STD-12 Abbreviations for Use on Drawings
MIL-STD-34 General Requirements for the Preparation of Drawings for Optical Elements and Optical Systems
MIL-STD-106 Mathematical Symbols
MIL-STD-150 Photographic Lenses
MIL-STD-1241 Optical Terms and Definitions

1.3.2 The following commercial publications are used in direct reference or provide related information valuable in the general field of optical design:

Ballard, S. S., McCarthy, K. A., Wolfe, W. L., State-of-the-Art Report: Optical Materials for Infrared Instrumentation, (Report No. 2389-II-S: I.R.I.A, Univ. of Michigan, 1959).
Bennett, A. H., Jupnik, H., Osterberg, H. and Richards, O. W., Phase Microscopy, (John Wiley and Sons, 1951).
Born and Wolf, Principles of Optics, (Pergamon Press, 1959).
Committee on Colorimetry, The Science of Color, (Thomas Crowell Co., 1954).
Conrady, Applied Optics and Optical Design, Parts 1 and 2 (Dover Publications Inc., 1960).
Drude, Theory of Optics, (Dover Publications Inc., 1960).
Hardy and Perrin, The Principles of Optics, (McGraw - Hill, 1932).
Holland, L., Vacuum Deposition of Thin Films, (John Wiley and Sons, 1956).
International Lighting Vocabulary Vol. I (CIE. - I.I. - 1957).
Jacobs, Fundamentals of Optical Engineering, (McGraw-Hill, 1943).
Jenkins and White, Fundamentals of Optics, (McGraw-Hill, 1957).
Johnson, B. K., Optics and Optical Instruments, (Dover Publications Inc., 1960).
Journal, Optical Society of America.
Linfoot, Recent Advances in Optics, (Oxford, 1955).
Martin, Technical Optics, (Pitman, 1948).
National Bureau of Standards, Circular No. 526, Optical Image Evaluation, (1954).
Optical Industry Directory, (Optical Publishing Co., 1961).
Sawyer, Experimental Spectroscopy, (Prentice-Hall, 1951).
Searle, Experimental Optics, (Cambridge Univ. Press, 1926).
Sears, F. W., Optics, (Addison-Wesley Press, Inc., 1949).
Strong, Concepts of Classical Optics, (Freeman, 1958).
Strong, Procedures in Experimental Physics, (Prentice-Hall, 1953).
Taylor, The Adjustment and Testing of Telescope Objectives, (Grubb, Parsons and Co., 1946).
Twyman, Prism and Lens Making, (Hilger, 1957).
Wagner, Experimental Optics, (John Wiley and Sons, 1929).

