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MILITARY STANDARD

OPTICAL TERMS AND DEFINITIONS

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DEPARTMENT OF DEFENSE

WASHINGTON, D.C. 20301

Optical Terms and Definitions 31 MARCH 1967

MIL-STD-1241

1. This Military Standard is mandatory for use by all Departments and Agencies of the Department of Defense.

2. Recommended corrections, additions, or deletions should be addressed to Commanding Officer, Frankford Arsenal, Philadelphia, Pa. 19137.

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FOREWORD

This Military standard has been arranged alphabetically according to the noun name of the term defined. Terms italicized in the text indicate that the terms are defined elsewhere in the document.

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1. SCOPE

1.1 **GENERAL.** This standard establishes definitions for the words, terms, and expressions peculiar to the general field of optics, except as detailed in 1.1.1 and 1.1.2 below.

1.1.1 *Photographic optics.* The uniform definitions, nomenclature, classification of defects, methods of testing, and measurements pertaining to the field of photographic lenses are contained in MIL—STD—150.

1.1.2 *Physiological and ophthalmic optics.* The terms and definitions related to the fields of physiological and ophthalmological optics should be derived from medical text books or Webster's International Dictionary.

1.2 **APPLICATION.** It is anticipated that this standard be used primarily, but not exclusively, by those nondesigning personnel who must be cognizant of and conversant with optical terminology.

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2. REFERENCED DOCUMENTS

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3. OPTICAL TERMS AND DEFINITIONS

A

Abberration. Generally, any systematic deviation from an ideal path of the *image-forming rays* passing through an *optical system*, which causes the image to be imperfect. Specific aberrations are *spherical abserration, coma, curvature of field, astigmatism, longitudinal chromatic aberration, lateral chromatic aberration*, and *distortion*.

Aberration, chromatic. *Image* imperfection caused by light of different *wavelengths* following different paths through an *optical system* due to dispersion in the *optical elements* of the system.

Aberration, chromatic, lateral. A variation in the size of *images* for light of different *colors* or *wavelenghts* produced by an *optical system*. It is measured as the radial displacement of the image in the first *color*, from the image of the same point in the second color. A direction away from the axial image point is taken as positive, and a direction towards the image point is negative. In the case of *telescopes*, lateral chromatic aberration is a difference in *magnification* for light of different colors, and is measured as the *angular separation* in *apparent field* between the images of the same point in two colors.

Aberration, chromatic, longitudinal. The distance between the *foci* for light of different *colors* measured along the *optical axis*.

Aberrations, least circle of. A synonym for *confusion, least, circle of*.

Aberration, spherical. A symmetrical optical defect of *lenses* and spherical *mirrors* in which *light rays* that come from a common axial point, but strike the lens at different distances from the *optical axis*, do not come to a common *focus*. Spherical aberration of an uncorrected or undercorrected lens is of the type illustrated in figure 1A. Overcorrection is possible, and is illustrated in figure 1B. The radius of a zone is ordinarily specified as the height, h. The distance o-y is called the *lateral spherical aberration*, o-z the *longitudinal spherical aberration*.

Aberration, spherical, lateral. The distance o-y from the axis of a ray a-y whose heights is h, as shown in figure 1A. The axis Y and Z have the paraxial point o as their origin, and are positive in the directions indicated by the arrows. The lateral aberration y, is negative with undercorrection and positive with overcorrection.

Aberration, spherical, longitudinal. The distance o-z along the axis for a *ray* a-y of height h, as shown in figure 1B. The longitudinal sperical aberration, z is negative with undercorrection, and positive with overcorrection.

Aberration, spherical, specification of. A term denoting the magnitude of *spherical* aberration given by one of the following alternatives: (1) the *lateral spherical aberration* is plotted or listed as a function of the hight, h; (2) the *longitudinal spherical aberration* is plotted or listed as a function of the height, h, as shown in figure 1.

Aberration, spherochromatic. The variation in *spherical aberration* for light of different *wavelenghts* or *colors*. Often shown as a graph of the spherical aberration for several specific *wavelengths*, usually defined by the Fraunhofer lines of the solar spectrum.

Abrasive. A material such as silica, silicon carbide, *emery*, cerium oxide, or *rouge* which is used in the optical industry for *grinding* or *polishing optical elements*.

Absorptance. The ratio between the *flux* absorbed by a body and the incident flux.

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This term, and its specifications, are applied to *radiant flux and to luminous flux.*

Absorptance, internal. The ratio of the *flux* absorbed between the entrance and emergent *surfaces* of the *medium*, to the flux that has penetrated the entrance surface. The effects of interreflections between the two surfaces are not included. Internal absorptance is numerically equal to unity, minus the *internal transmittance.*

Absorptance, spectral. The *absorptance* evaluated at one or more *wavelengths.* Spectral absorptance is numerically the same for *radiant* and *luminous flux.*

Absorption, light. The conversion of light into other forms of energy upon traversing the continuous portion of a *medium.* This conversion weakens the transmitted light *beam.* Energy *reflectance* R, *transmittance* T, and absorption A, obey the law of the conservation of energy, $R + T + A = 1$.

Absorption, selective. The act or process by which a substance "takes up" or "soaks up" all the *colors* contained in a *beam* of white light, except those colors which it reflects or transmits. Some substances are transparent to light *waves* of certain frequencies, allowing them to be transmitted, while absorbing waves of other frequencies. Some reflecting *surfaces* will absorb light of certain frequencies and reflect others. The color of a transparent *object* is the color it transmits, and the color of an *opaque* object is the color it reflects.

Absorptivity. The *internal absorptance* per unit thickness of the *medium.* Numerically, absorptivity is unity minus the *transmissivity.*

Accommodation. A function of the human *eye*, whereby its total refracting *power* is varied in order to clearly see *objects* at different distances.

Accommodations, limits of. The distances of the nearest and farthest points which can be focused clearly by the *eyes* of an observer. Usually varies from 4 to 5 inches to *infinity see accommodation*).

Achromat. A contraction of the term *lens, achromatic.*

Achromatic. Having the quality of being free of *chromatic aberration.*

Achromatism. The absence of *chromatic aberration.*

Acuity, visual. The degree of sharpness of vision.

Acutance. Edge sharpness and high edge contrast.

Adaptation, dark. The ability of the human *eye* to adjust itself to low levels of illumination.

Adaptation, light. The ability of the human *eye* to adjust itself to a change in the intensity of light.

Adjuster, image, height of. A glass plate with plane *surfaces*, which is tipped one way or the other in the *line of sight*, in one of the internal *telescopes* of a *rangefinder* or *heightfinder.* It displaces the *image* upward or downward so that its height in the field can be made equal to that of the other telescope. In some rangefinders instead of a glass plate, the height adjuster tilts the optical bar about a front and rear horizontal axis. In Navy usage, this item in a stereoscopic rangefinder is called a "height adjuster," and in a *coincidence rangefinder* a "halving adjuster."

Adjustment, interpupillary. The adjustment of the distance between the *eyepieces* of a *binocular* instrument to correspond to the distance between the pupils of the observer's *eyes.*

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Afocal. An *optical system* whose *object* and image point are at *infinity*.

Aluminizing. The application of a film of aluminum to a *surface*, usually by evaporation.

Analyzer. A polarizing *element* which can be rotated about its axis to control the amount of transmission of incident plane *polarized light*, or to determine the plane of polarization of the incident light.

Anamorphic. A term used to denote different *magnification* along mutually perpendicular radii. The term is also applied to an *optical system* that produces this condition.

Anastigmat. A *lens* in which the astigmatic difference is zero for at least one off-axis zone in the *image* plane. In such a lens the other *aberrations* are sufficiently well corrected for the intended use.

Angle. The amount of rotation of a line around the point of its intersection with another necessary to bring the line into *coincidence* with a second line.

Angle, critical. The *angle of incidence* in a denser *medium*, at an interface between the denser and less dense medium, at which all of the light is refracted along the interface, i.e., *the angle of refraction* is 90°. When the critical angle is exceeded, the light is totally reflected back into the denser medium. The critical angle varies with the *indices of refraction* of the two media with the relationship, $\sin I_c = \frac{n'}{n}$ where I_c is the critical angle; n′ the index of refraction of the less dense medium; n the index of refraction of the denser medium.

Angle, parallactic. The *angular* difference in direction to an *object* as seen from two points of observation. The angle subtended at the object by the *base length* of a *rangefinder*.

Angstrom. A unit of measurement of the *wavelength* of light equal to 10^{-8} *centimeters*.

Angular. Composed of, or measured by, *angles*.

Anisotropic. A term used to denote a substance which exhibits different properties when tested along axes in different directions.

Annealing. The process of relieving unwanted stresses by means of suitable *heat treating*.

Aperture. An opening or hole through which light or matter may pass. In an *optical system*, it is equal to the diameter of the largest entering *beam* of light which can travel completely through the system. This may or may not be equal to the aperture of the *objective*. See *aperture, clear; aperture, relative; aperture, operating, front; aperture, operating rear*.

Aperture, clear. Abbreviated CA. The opening in the mount of an *optical system* or any *component* thereof, that limits the extent of the bundle of *rays* incident on the specific *surface*. It is usually circular and specified by its diameter. Clear aperture is sometimes referred to as "free aperture," or "objective aperture."

Aperture, effective. Equivalent to the diameter of the largest bundle of *rays* that can be imaged by the *optical system*.

Aperture, free. A term sometimes used as a synonym for *aperture, clear*.

Aperture, numerical. Abbreviated NA. The sine of the half-angle of the widest bundle of *rays* capable of entering a *lens*, multiplied by the *index of refraction* of the *medium* containing that bundle of rays.

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Aperture, objective. Sometimes used as a synonym for *aperture, clear.*

Aperture, operating, front. The limiting *aperture* at the front of the *lens.* Usually specified as the maximum diameter of the entrance cone at the front *vertex.* for the specified *field of view* at *infinity focus.*

Aperture, operating, rear. The limiting opening at the rear of a *lens* or *prism.* Usually quantitatively specified as the maximum diameter of the emergent cone for the specified *field of view,* at *infinity focus.*

Aperture, relative. The diameter of the *entrance pupil* of a *lens* or *optical system* measured in terms of the *equivalent focal length* of that lens or system. It is written as a fraction in which *f* the equivalent focal length, is the numerator, and it is symbolized by *f/* followed by a numerical value. For example, *f*/2 signifies that the diameter of the entrance pupil is equal to ½ the equivalent focal length. For an *object* at *infinity,* the denominator of the relative aperture, and the second member N of *aperture ratio,* are identical, providing the *image* is formed in air. Relative aperture is applicable for determining exposure time only when the *object* is at *infinity.*

Apochromat. An *aplanatic lens* in which the *secondary spectrum* has been reduced or in which three colors have been brought to a common *focus,* by the use of special glasses.

Apostilib. A unit of *luminance* equal to $\frac{1}{\pi}$ *candles* per square *meter.*

Arc. A part of the circumference of a circle.

Aspheric. Nonspherical. Aspheric *surfaces* are frequently, but not necessarily, surfaces of revolution.

Aspherical. A term used to characterize a departure from the spherical shape.

Astigmatism. Abbreviated ASTIG. An *aberation* which causes an off-axis point to be imaged as a pair of lines at right angles to each other. Each line is at a different distance from the *image* forming *element* along the *chief ray* of the image forming bundle of rays. The image forming element thus has two *foci,* one radial and the other tangential to the *optical axis.* A sharp image of a point cannot be obtained. A compromise image position must be selected at a point between the two line images at which the image blur is smallest (*circle of least confusion*). *Lenses, lens systems, mirrors,* or mirror systems, or combinations of the two, whose curves are not symmetrical about the axis can produce "axial astigmatism." "Off-axis astigmatism" results naturally with centered spherical surfaces. Axial astigmatism, unless deliberately introduced, is to be considered a defect of workmanship, and not an aberration. It should be noted that in dealing with lenses, astigmatism arises from oblique *refraction,* whereas in the human *eye* it arises from a departure of a surface from a truly spherical form.

Astigmatizer. A *cylindrical lens* that can be introduced into the *line of sight* of a *rangefinder* to form line *images* of point-like sources.

Axes, crystalline. The axis of symmetry in a *crystal* structure.

Axis, cylinder. The meridian perpendicular to that in which the cylindrical *power* functions.

Axis, optical. The line formed by the coinciding *principal axes* of a series of *optical elements* comprising an *optical system.* It is the line passing through the centers of curvatures of the optical *surfaces.* The optical centerline.

Axis, principal. A straight line connecting the centers of curvature of the refracting *surfaces* of a *lens.* In a mechanical

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sense, a line joining the centers of a lens as it is placed in a mount. The principle axis is the *optical axis* of a lens.

Axis, secondary. A line formed by the *chief ray* of an oblique bundle of *rays*.

Axis, visual. An imaginary line from the *object* through the *nodal point* of the *eye* to the fovea, or point of sharpest retinal acuity.

Azimuth, angle of. The *angle* measured clockwise in a horizontal plane, usually from north (may be true north, Y-north, grid north, or magnetic north).

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B

Balsam, canada. An adhesive used to cement *optical elements.*

Barrel, lens. The mechanical structure holding a complete *lens.*

Base, virtual. The actual base or base line of a *rangefinder* or *heightfinder,* multiplied by the *power* or *magnification* of the instrument.

Baume. The designation of scale for hydrometers which are used to measure the specific gravity of a polishing suspension.

Beam. A shaft or column of light; a bundle of *rays.* It may consist of parallel, converging, or diverging rays.

Beamsplitter. An optical device for dividing a light *beam* into two separated beams. A simple beamsplitter is a plane parallel plate, with one *surface* coated with a dielectric or metallic coating, which reflects a portion and transmits a portion of the incident beam; i.e., part of the light is deviated through an *angle* of 90° and part is unchanged in direction. A beamsplitter is often made by coating the hypotenuse face of one of two 45°—90° *prisms* and cementing the hypotenuse faces together. The thickness of the metallic beamsplitting interface will determine the proportions of the light reflected and transmitted. However, in all metallic beamsplitters, an appreciable amount of light is lost by absorption in the metal. It may be necessary to match the reflected and transmitted beam not only for *brightness,* but for *color.* In these cases it will be necessary to use a material at the interface which gives the same color of light, both by *transmission* and *reflection.* Where color matching at the surface or interface cannot be accomplished, a correcting color *filter* may be placed in one of the beams.

Beer, law of. The *radiant flux* transmitted by a solution of absorbing solute in a nonabsorbing solvent is an exponential function of the product of the concentration and thickness of the solution.

Bevel. The shape of the *edge* of a *lens* or *prism.* Bevels are used to prevent chipping, or to achieve mechanical fits.

Bevel, controlled. A *bevel,* also known as "true bevel," whose width and *angle* are controlled to specified dimensions.

Bevel, cup. A *bevel* formed by *grinding* with a cup-shaped tool.

Bevel, machine. A synonym for *bevel, controlled.*

Bevel, protective. The slight removal of a sharp *edge* of glass, without a specification of the diameter. Protective bevel is often called "breaking the edge."

Bevel, sagged. The shape of the *edge* of a *concave surface* when the depth of the plane of the *bevel* to the *vertex* of the surface is controlled to a specified distance.

Binocular. Vision with both *eyes.* A term applied to instruments consisting of two *telescopes,* thereby using both eyes of the observer.

Birefringence. The characteristic of having two *indices of refraction* with different values. Birefringence is the characteristic of certain media, which is dependent on the *angle* between the *ray path* within the *medium* and the *optical axis* (or axes) of the medium. See *refraction double.*

Blackbody. A body which absorbs all the *radiant energy* which strikes it; a perfect radiator and a perfect absorber. It is a contraction of the term "ideal blackbody"

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and is often used synonymously for "ideal radiator," "full radiator," or "complete radiator."

Blackbody, ideal. A synonym for *blackbody*.

Blacking, optical. The light absorbing material applied to the ground *surfaces* of *optical elements*. Such material should have an *index of refraction* as high as that of the underlying glass and must be in direct contact with the glass.

Blank. A pressed-glass mold with the approximate size and shape of the *optical element* to be ground and polished.

Blank, flat. A piece of glass with a rough plano *surface* on each side.

Blank, molded. A blank with basic surface curves attained by heating and forming a specific gram weight of raw glass.

Blank, molded, hot. A synonym for *pressing*.

Blank, rough. A formed piece of glass, neither side of which has been surfaced.

Blank, semifinished. A formed piece of glass, one *surface* of which has been ground and polished to finished curvatures.

Blisters. Elongated *bubbles* or *seeds*, elliptical in shape and longer than one-quarter inch.

Block. A supporting member for holding optical parts during *grinding* and *polishing*. It also denotes the assemblage of optical parts on the supporting member, i.e., a block of *lenses*, or block of *prisms*.

Block, green. A porous ceramic material which is ground to an optical form, and on which a polished plate of glass is sagged by the application of heat. It is capable of transmitting a partial vacuum. The glass contacts the green block surface by the applied vacuum and gravitation, and the upper polished surface of the glass is used as an optical surface. Green block is generally used for forming *aspheric* surfaces of medium precision.

Blocking. The process of attaching *blanks* to a *block* in a position for *grinding* or *polishing*.

Blocking, button. The process of forming a *block* by attaching the *optical elements* to a plate by means of individual buttons of pitch or other thermo-plastic material.

Blocking, contact. The process of forming a *block* by making optical contact with a number of *optical elements* to a large optical element.

Blocking, mold, soft. *Blocking* by means of a pitch ring, pitch button or an entirely pitched block. Pitch, containing a soft filler, is sometimes used between the optical parts to assure no lateral movement.

Blocking, ring. The process of forming a *block* by attaching *optical elements* to a plate by means of a ring of pitch or other thermoplastic material.

Blocking, spot. *Blocking* by means of a *spotted tool*.

Blocking, transfer. A process for precisely controlling thickness and parallelism during the manufacture of plane parallel plates. A number of *elements* are cemented to a *blocking tool* and their upper *surfaces* polished. A second blocking tool is then cemented to the upper polished surface and the original blocking is released. Thus the optical elements are transferred from the first to the second blocking tool without disturbing their relative positions. The second, or unfinished surface can now be polished.

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Block, lens, multiple. A *block* that will accept more than one *lens* or *blank*.

Body. A piece of glass to which a *lens* or *prism* is cemented, and the unit ground and polished as a whole, in order to obtain a sharp *edge* on the finished piece.

Bolometer. An electrical instrument for measuring *radiant energy* by measuring the changes in resistance of a blackened temperature-sensitive device exposed to the radiations.

Boresight. To adjust the *line of sight* of the sighting instrument of a weapon parallel to the axis of the bore. Also applied to the process of aligning other equipment, such as radar mounts, directors, etc. As a noun, the term defines an optical instrument for checking alignment.

Brewster, law of. When the *angle* between the refracted and reflected *ray* is 90°, maximum polarization occurs in both rays. The reflected ray has its maximum polarization in a direction *normal* to the plane of *incidence*, and the refracted ray has its maximum polarization in the plane of incidence.

Brightness. The effect upon sensation by means of which an observer is able to distinguish differences in *luminance*.

Bring-in. A term used to denote the final correction of a polished *surface* or angle to the required precision.

Bubble. A gaseous inclusion in glass.

Bubble, open. A bubble at a polished *surface*, which has been opened by *grinding* or *polishing*.

Bump. An unintentional elevation in a *surface*.

Bundle, axial. A cone of *rays* that emanates from an *object* point which is located on the *optical axis* of the *lens system*.

Burn. A *surface* defect caused by a polisher running dry too long. It occurs with felt or plastic polishers, and may appear as a reddish brown stain.

Burnishing. The process of turning a thin edge of metal over the bevelled *edge* of a *lens* to hold it in its *cell*.

Button. A piece of glass with a high *index of refraction* fused to the *major blank*.

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C

Calipers. An instrument of the shear type used for acurate thickness measurements.

Candela. A unit of *luminous intensity* defined such that the *luminance* of a *blackbody* radiator at the temperature of solidification of platinum is 60 candelas per square *centimeter.*

Candle. A unit of *luminous intensity.*

Candlepower. A unit of measure of the illuminating power of any light source. The number of *candles* in the *luminous intensity* of a source of light. A luminous intensity of one candle produces one *lumen* of *luminous flux* per steradian of solid *angle* measured from the source.

Case-hardened. A *surface heat-treating* process which produces a highly stressed surface.

Cell. The mechanical structure holding an *element, component,* or *member.*

Cement. An adhesive used to bond *optical elements* together, or to holding devices. There are three general types of cement used in the optical industry, *blocking cement, mounting cement,* and *optical cement.*

Cement, blocking. An adhesive used to bond *optical elements* to *blocking tools.* It is usually a thermoplastic material such as resin, beeswax, pitch, or shellac.

Cement, mounting. An adhesive used to hold *optical elements* in their mounts. It may be either a thermoplastic or chemical-hardening material.

Cement, optical. A permanent and transparent adhesive, which is capable of withstanding extremes of temperature. *Canada balsam* is a classic optical cement although it is being replaced by such modern synthetics as the methacrylates, caprinates, and epoxies.

Cement, thermoplastic. An adhesive whose viscosity decreases as the temperature is raised to a limit. *Canada balsam,* resin, and pitch are common thermoplastic cements.

Cement, thermosetting. An adhesive which permanently sets or hardens at a certain high temperature. Methacrylate is a common thermosetting cement.

Center, cutting. The point on a cutting line which will become the *geometrical center* of the cut *lens.*

Center, geometrical. The physical center of the *lens*; it is on the axis of the lens, halfway between the front and read *vertex.* It is sometimes referred to as the "mechanical center" of the lens to distinguish it from the *optical center.*

Centering. The process of causing the *geometrical center* of a *lens* or *mirror* to coincide with its *optical center* or the mounting of a *lens* or *mirror* such that its *optical axis* is coincident with the optical or mechanical axes of other portions of the system.

Center, mechanical. A term sometimes used as a synonym for *center, geometrical.*

Center, optical. The point, generally within a *lens,* but sometimes exterior to it, at which the *optical axis* intersects the optical path of any *ray* directed at a *nodal point.*

Center, to. To mount a *lens* on a *chuck* so that upon *edging* the lens, the *optical center* will coincide with the *geometrical center.*

Centex. The trade name referring to *lenses* having standard (noncorrected) base curves.

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Centimeter. A unit of metric measurements:

100 centimeters equal one *meter*.

10 *millimeters* equal one centimeter.

2.54 centimeters equal one inch.

Centration, errors of. *Lenses* with spherical *surfaces* are usually designed to be so constructed that the center of curvature of all the surfaces lie on a single straight line termed the axis of the lens. If *aspheric* surfaces are used their individual axis should correspond with the axis of the lens. Failure of compliance with these conditions is termed errors of centration.

Cerium. A *polishing* material (cerium oxide). It has faster polishing action than *rouge* (ferrous oxide) and is cleaner to handle.

Chamfer. Abbreviated CHAM. The process of removing sharp edges by *grinding*.

Characteristics, optical. The qualifications an *optical system* possesses by reason of its optical nature, such as *field of view*, *magnification*, *brightness of image*, *image quality*, correction for *aberrations*, etc.

Chart, Foucault. A test target containing groups of alternate black and white bars spaced at various intervals, which is used to measure the *resolving power* of *telescopes* and *lenses*. This chart is placed at a distance from the site of observation such that the *angular* separations between the centers of adjacent black bars in the various groups have precalculated values. The most closely spaced group whose bars as imaged by an optical instrument can be resolved, determines the resolving power of that instrument.

Chipping. A term sometimes used as a synonym for *cribbing*.

Chromaticity. The combination of the dominant *wavelength* and purity characteristics, but not the photometric magnitude of light.

Chuck. A tube to which a *lens* is fastened for *centering*.

Circle, aiming. An optical instrument for measuring *angles* in azimuth and site.

Cleared-out. A term used to denote a finished circular *edge*. A decentred *lens* is adjusted on a centering *chuck*, so that its *image* runs true, and the lens is then edged. If the edge is circular, it has "cleared out." However, if the decentering is excessive and the lens is edged down to its specified diameter, there can be a portion of the edge which never touches the grinding wheel. The finished lens will not have a circular outline and is said to have not "cleared out."

Clearing. A *grinding* and *polishing* operation on one *surface* of a *blank* to permit a more thorough inspection for quality.

Clips. Small metal pieces placed between the *disc* and the *major* to achieve proper *fusing*.

Coat, hard. A term applied to the process, or to the result of the process, of producing (usually) dielectric coatings that are more durable under adverse conditions than those produced from other processes.

Coating, antireflection. A class of single or multilayer coatings that are applied to a *surface* or surfaces of a substrate for the purpose of decreasing the *reflectance* of the surface and increasing the *transmission* of the substrate over a specified *wavelength* range.

Coating, high-reflecting. A broad class of single or multilayer coatings that are applied to a *surface* for the purpose of increasing its *reflectance* over a specified range of

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wavelengths. Single films of aluminum or silver are common; but multilayers of at least two dielectrics are utilized when low absorption is imperative.

Coatings, protective. Films that are applied to a coated or uncoated *optical surface* primarily for protecting this surface from mechanical abrasion, or from chemical corrosion, or both. An important class of protective coatings consists of evaporated thin films of titanium dioxide, silicon monoxide or magnesium fluoride. For example, a thin layer of silicon monoxide may be added to protect an aluminized surface.

Coat, soft. A term designating the soft coating applied to *coated optics* to differentiate between the harder and more durable coating known as *hard coat*. Certain evaporating coatings are not capable of forming a hard coat and are easily removed by cleaning. Cryolite is a soft coat material.

Coefficient, absorption. The *internal absorptance* of an infinitesimally thin layer of *medium*, divided by the thickness dx of the layer. Thus defined, the absorption coefficient is the coefficient B (λ) in Bouger's law, that that

$$F = F_o e^{-B(\lambda)x}$$

where F_o is the *flux*, F, at a point of reference of $x = 0$.

Coincidence. Agreement as to position. In a *coincidence rangefinder*, the two half *images* of a distant *object* are in "coincidence" when they are in exact alignment.

Collimate. To render parallel.

Collimation. The process of aligning the *optical axis* of *optical systems* to the reference mechanical axes or *surfaces* of an instrument; or the adjustment of two or more optical axes with respect to each other. The process of making *light rays* parallel.

Collimator. An optical device which renders diverging or converging *rays* parallel. It may be used to simulate a distant target, or to align the *optical axes* of instruments.

Colmascope. A *polariscope* for demonstrating *strain* existing in a piece of glass.

Color. The sensation produced by light of different *wavelengths* throughout the *visible spectrum*. The color, shape, and number of *Newton's rings* present, when two *optical surfaces* are placed together. This is a broad term which covers specifications for the above. Color is a synonym for *aberration, chromatic*.

Colorimeter. An optical instrument used to compare the *color* of a sample with a synthesized stimulus. For example, in a three-color colorimeter, the synthesized stimulus is produced by mixtures of three colors of fixed *chromaticity*, but variable *luminance*.

Coma. An *aberration* of a *lens* which causes oblique *pencils of light rays* from an object point to be imaged as a comet-shaped blur.

Compacting. The *heat-treating* process in which the *refractive index* of glass is stabilized near, or at its maximum value, by holding the glass for different periods at suitable degrees of heat below the range of *annealing temperatures*.

Comparator. An inspection instrument, usually a projection device, which presents a composite of a reference contour and the *image* of the actual contour for comparison. More commonly called an "optical comparator," or "contour projector."

Compensator. An *optical element used to* correct for mechanical or optical displacement.

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Component. A subdivision of a *member*. It may consist of two or more parts cemented together, or with near and approximately matching *surfaces*.

Component, metal. A precise metal *prism* or plane parallel plate which is cemented to an *optical element* and remains with it during a series of *grinding* or *polishing* operations. The metal component contains threaded holes for attaching it in various position to a base plate (see fig. 2).

Component, optical. One or more *optical elements* in an *optical system* that singly, or as a group, serve a definite major purpose in arriving at the total performance of the system.

Concave. A term denoting a hollow curved *surface*.

Concentric. The characteristic of having the same center. Circles differing in radius, but inscribed from a single center point.

Confusion, least, circle of. A circle whose perimeter defines the area, for any point in the *field of view*, covered by the smallest *image* (usually of a point source formed by the *lens*).

Conjugate, image. Synonym for *image distance*.

Conjugate, object. Synonym for *object distance*.

Constant, abbe. A mathematical expression for determining the correction for *chromatic aberration* of an *optical system*. It is often called the "Nu value" or "Vee value" and is usually expressed as,

$$v \text{ or } V = \frac{n_D - 1}{n_F - n_C}, \text{ or } \frac{\text{refractivity}}{\text{dispersion}},$$

where n_D, n_F, and n_C are the *indices of refraction* for light of the *wavelengths* of the D line of sodium, and the F and C lines of hydrogen respectively.

Contact, optical. A condition in which two sufficiently clean and close fitting *surfaces* adhere together without *reflection* at the interface. The optically contacted surface is practically as strong as the body of the glass.

Contact, stereoscopic. The result of bringing the target into the same apparent distance plane as the central measuring mark of the *reticle* when using a stereoscopic *heightfinder*. In a stereoscopic telescopic instrument such as a stereoscopic *rangefinder* the *object* space is perceived as three-dimensional with an exaggerated *stereoscopic effect*. If each *eyepiece* is provided with a reticle the observer's *eyes* fuse the pair of reticles to appear as one, located at some particular distance away in the three-dimensional *field of view*. A lateral shift of the *image* produced by one of the *objectives* will cause the entire image field to appear to move toward or away from the spacial position of the reticle thereby bringing any particular target into the same distance plane as the reticle. When this is the case the reticle and the target are in stereoscopic contact.

Convergence. The bending of *light rays* towards each other, as by a *convex or plus lens*.

Convergence, angle of. The *angle* formed by the *lines of sight* of both *eyes* in focussing on any line, corner, surface, or part of an *object*. It is also referred to as "convergent angle."

Convex. A term denoting a *surface* like the outside of a sphere or ball.

Coolant. A fluid used to reduce the temperature rise produced by friction or other causes.

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Cord. A large *stria* in glass.

Cornering. The process of removing the slight overlap that may be found on a *blank* or *pressing*.

Correct, to. To remove slight errors on an *optical surface* by hand or by a special adjustment of a polishing machine. Hand correction is often required in the making of high precision spherical or *aspheric* surfaces as well as flats.

Correction. The process of compensating for, or adjusting the *aberration*, in the optical design stage.

Correction, color. The reduction of *longitudinal, lateral,* and secondary *chromatic aberations*. The color correction may be specified in terms of the Fraunhofer lines in the solar spectrum, indicative of the *wavelength* of *rays* for which the correction has been made; for example, C–F correction.

Countersink. The *concave segment* of a *surface* formed on a *blank* (*major*), on which the *disc* of higher *refractive index* glass will be *fused*.

Cracks, fire. Small clefts or fissures penetrating the *surface* of the glass, usually in the shape of short-hooked crescents. Fire cracks are caused by the sudden heating or chilling of the surface.

Cribbing. The process of breaking the excess glass from the required shape.

Crush. A term denoting a type of *scratch*.

Crust. A stain in a glass *surface*.

Crystal. A natural or artificial substance, such as fluorite, quartz, calcite, or lithium fluoride, used for optical construction.

Crystal, birefringent. A synonym for *crystal, refracting, doubly*.

Crystal, refracting, doubly. A transparent crystalline substance which is *anisotropic* with respect to the *velocity of light*.

Current, dark. The flow of current passed by a photoelectric device when no *radiant energy* is incident thereon.

Curvature. The amount of departure from a flat *surface*, as applied to *lenses*. The reciprocal of the radius of curvature.

Curvature, center of. The center of the sphere of which the *surface* of a *lens* or *mirror* forms a part.

Curvature, field. A synonym for the *aberration* known as *field, curvature of*.

Curve, compensated. A curve computed to attain a desired *vertex power* considering the thickness factor.

Curve, centered. The *surface curvature* designed to minimize the marginal error found in the periphery of a *lens*.

Curve, luminosity. A term so called by the Committee on Colorimetry, Optical Society of America to denote the plot of *luminous relative efficiency* against wavelength.

Curve, luminosity, absolute. A term so called by the Committee on Colorimetry, Optical Society of America to denote the plot of *spectral luminous efficiency* against *wavelength*.

Cutoff. Refers to fused *multifocals*, where the upper portion of the *disc* is of the same *refractive index* as the *major*. After *fusing*, this upper portion blends with the major appearing as one piece of glass. In the case of sharp cutoff *filters*, the term refers to the *wavelength* at which the *transmittance* has fallen to 37 percent. It should be noted that the abbreviation "cut" is used extensively in some publications, such as color filter catalogs.

Cut, runner. A term denoting a type of *scratch*.

Cutting. The process of shaping a *lens* to a given pattern, or of severing a piece of glass along the line of scratch.

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D

Deblocking. The process of removing *optical elements* from a *block*.

Decentering. The process of *grinding* or *edging* a *lens* so that the *geometrical center* and *optical center* do not coincide.

Deep. A term used to denote a condition in which a *concave surface* has too much negative *power*; i.e., its radius of curvature is too short. Cutting material from the center portion of the polisher corrects this condition.

Defects, beauty. Imperfections on *optical surfaces* that are not optically critical, and that do not appreciably impair performance.

Definitions. The degree of clarity of reproduction of the *object* that depends upon a combination of *resolving power* and contrast.

Deflection. A small horizontal (traverse) *angle* by which a weapon is aimed slightly away form the target to allow for factors such as wind or drift.

Density. A term used as a synonym for *density, optical.*

Density, diffuse. Logarithm to the base 10 of the reciprocal of *diffuse transmittance.*

Density, luminous. *Luminous energy* per unit volume.

Density, optical. Logarithm to the base 10 of the reciprocal of *transmittance.*

Density, optical, internal. Logarithm to the base ten of the reciprocal of the *internal transmittance* (also called transmission factor).

Density, uniform. A term used to denote a layered *lens* or *blank*, one layer of which is clear, and the opposite one of absorptive-type glass. The clear portion is surfaced to the desired curvature, while the thickness of the tinted layer remains constant, which results in a lens with equal shade in the center and periphery.

Deviation, angle of. The *angle* through which a *ray* of light is bent by *reflection* or *refraction* (see figs. 8 and 9).

Deviation, constant. That property of certain optical devices, e.g., a *penta prism*, that preserves the *angular* relationship between the entering and emerging *rays* passing through the device, regardless of the orientation of the device in the plane of deviation.

Device, half-shade. A device used to produce at least two fields of *polarized light* in juxtaposition. The *angle* between the planes of polarization of these fields is generally small.

Dialyte. A type of *compound lens* in which the inner *surfaces* of the two *elements* are ground to different curvatures to correct for *aberrations*. The dissimilar faces cannot be cemented together.

Diaphragm. A fixed or adjustable *aperture* in an *optical system*. Diaphragms are used to intercept scattered light, to limit field *angles*, or to limit *image* forming bundles of *rays*.

Diaphragm, antireflection (or glare). A *diaphragm* for eliminating internal reflections and glare in the *field of view* of the instrument.

Diaphragm, iris. A *diaphragm* whose circular *aperture* is smoothly and continuously adjustable, from its minimum to its maximum opening. Because it is composed of a number of overlapping leaves, the name is derived from this iris-like appearance.

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Dichroic. Exhibiting the quality of *dichroism.*

Dichroism. As applied to *anisotropic* materials, such as certain *crystals*, this term refers to the *selective absorption* of light *rays* vibrating in one particular plane relative to the *crystalline axes*, but not those vibrating in a plane at right *angles* thereto. As applied to *isotropic* materials this term refers to the *selective reflection* and *transmission* of light as a function of *wavelength* regardless of its plane of vibration. The color of such materials, as seen by transmitted light, varies with the thickness of material examined. An alternative term for this phenomenon might be *polychromatism.*

Difference, thickness, edge. The maximum difference in thickness near the *edge* in a decentered *lens element.*

Diffraction. The process by means of which the propagation of radiant *waves* or light waves are modified as the wave interacts with an object or obstacle. Some of the *rays* are deviated from their path by *diffraction* at the *object* whereas other rays remain undeviated by diffraction at the object. As the object becomes small in comparison with the *wavelength*, the concepts of *reflection* and *refraction* become useless and diffraction plays the dominant role in determining the redistribution of the rays following *incidence* upon the object.

Diffusion. The scattering of ligth by *reflection* or *transmission. Diffuse reflection* results when light strikes an irregular *surface* such as a frosted window or the surface of a frosted or coated light bulb. When light is diffused, no definite *image* is formed.

Dig. A short *scratch* whose width is sufficient to be measured.

Diopter. Abbreviated DIOPT. A unit of refractive *power* of a *lens* or *prism.* In a lens or *lens system*, it is numerically equal to the reciprocal of the *focal length* measured in *meters.* For example, if a lens has a focal length of 25 *centimeters*, i.e., ¼ meter, its power is 4 diopters.

Diopter, prism. A unit of measure of the refracting *power* of a *prism.* One *diopter* is the power of a prism that deviates a *ray* of light by one *centimeter* at a distance of one *meter* from the prism.

Dip. A hollow in an *optical surface.*

Dipvergence. The vertical *angular* disparity between the *images* of a common *object* seen through the left and right systems in a *binocular* instrument. It is defined as plus, when the right image is below the left image.

Disc. A piece of glass which eventually becomes the bifocal segment as it appears prior to being *fused* to the *major blank.*

Disc, airy. When light from a point source passes through a circular or annular *aperture*, and is brought to a *focus* by means of a *lens*, the *image* so formed is not a point, but owing to *diffraction* by the aperture, is a bright central disc of light surrounded by a series of progressively fainter rings. The central disc is called the Airy Disc by some authorities; others prefer to apply the term to the entire diffraction pattern.

Dispersion. The process by which *rays* of light of different *wavelength* are deviated angularly by different amounts as, for example, with *prisms* and diffraction gratings. The term dispersion is also applied to other phenomena which cause the *index of refraction* and other optical properties of a *medium* to vary with wavelength.

Displacement, object. The movement of *objects* seen through a refracting *prism* towards the *apex* of a prism.

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Distance, eye. The distance from the *vertex* of the last *optical surface* of the visual optical system to the *exit pupil*. Also termed "eye relief."

Distance, eye, clear. The distance from the rear *vertex* of the *eyelens* to the front vertex of the cornea of the *eye* in telescopic systems. Conventionally, this distance is equal to the *eye distance* less ¼ inch.

Distance, focal, flange. Abbreviated FD. The distance measured from the locating surface of the lens mount, to the *principal focus* in the *image* space.

Distance, focal, front vertex. Abbreviated FVD. The distance measured from the *principal focus* in the back space, to the *vertex* of the front *surface*.

Distance, hyperfocal. The distance between the rear *focal point* of a *lens* and the *image* plane when the *object* is not at *infinity*.

Distance, image. The axial distance between the *image* and the *second principal point* of a *lens*.

Distance, interpupillary. Abbreviated IPD. The distance between the two *eye* pupils, when the observer is viewing distance *objects*.

Distance, object. The distance from the *object* to the observer's cornea, or to the *first principal point* of the *objective* in an *optical* system.

Distance, optical. The length of the path covered by a *ray* between two points in a *medium*, multiplied by the value of the *index of refraction* of that medium.

Distance, overall. The physical distance from the *object* point to the *image* point.

Distance, reading, normal. A synonym for *vision, distinct, distance of*.

Distance, working, image. Distance from last *vertex* of *lens* to the *image*.

Distance, working, object. Distance from the *object* to the front *vertex* of the *optical system*.

Distortion. Also called *radial distortion*. An aberration of *lens systems* characterized by the imaging of an extra-axial straight line as a curved line, without necessarily affecting the *definition*. Unsymmetrical, or otherwise irregular distortions of the *image* can also be caused by imperfect centration or irregularity of *optical surfaces*. (See fig. 3).

Distortion, barrel. A form of *distortion, radial*.

Distortion, pincushion. A form of *distortion, radial*.

Distortion, radial. A change in *magnification* from the center of the field to any other point in the field, measured in a radial direction to the center of the field. It is an inherent *aberration* of *lens systems*, but can be eliminated or minimized by proper design. "Barrel distortion" results when the magnification decreases with field angle; "pincushion distortion" results when the magnification increases with the field angle. Asymmetry of radial distortion can result from manufacturing errors. The measurement of radial distortion in a *telescope* is $1 - \frac{\tan U'}{M \tan U}$ expressed in percent, where U is the *true field* angle, U′ the *apparent field* angle, and M the central *magnifying power*. The measurement in a *lens* is $1 - \frac{Y_{,}}{y}$ expressed in percent, where Y is the actual height of the *image*, and y is the ideal height.

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Distortion, tangential. An *image* defect resulting in the displacement of image points perpendicular to a radius from the center of the field. It is usually caused by *errors of centration.*

Divergence. The bending of *rays* away from each other, as by a *concave* or *minus lens*, or by a *convex mirror*. In a *binocular* instrument, divergence is the horizontal *angular* disparity between the *images* of a common *object*, as seen through the left and right systems. Divergence is defined as positive when the right image is to the right of the left image.

Doublet. A *compound lens* consisting of two *elements*. If there is an air space between the elements it is called an "air-spaced doublet." If the inner surfaces are cemented together, it is called a "cemented doublet."

Drilling. The process of making a hole in a *lens* to permit its attachment to a mounting.

Drop. A term used as a synonym for *sag*.

Dropping. The process of causing a *blank* or *disc* to form a desired curvature by heating to a sufficiently high temperature.

Dummy. A *lens* formed to a desired curve and then used to form a polisher. It may also be used to denote a piece of glass included in a *block* to fill out the area; it is also referred to as a "surround."

Dynameter, optical. A small low-power *microscope* or *magnifier* with a micrometer scale, used in the precise measurement of the *exit pupil* diameter, *eye distance*, and *magnification* of other optical instruments.

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E

Edge. The flat or angled surface, usually fine ground, which limits the refracting *surfaces* of a *lens* or *prism*.

Edge, broken. A *chamfer* or *protective bevel*.

Edge, dubbed-off. A term used as a synonym for *edge, rolled*.

Edge, rolled. A rapid change of curvature near the *edge* in a *lens* or *prism;* also referred to as a *"turned down edge."*

Edging. The finishing of the *edge* of an *optical element* on a grinding wheel.

Effect, stereoscopic. The sense of relief or solidity resulting when an *object* is viewed by both *eyes*. It is due to the fact that each eye views the object from a slightly different point of view.

Efficiency, luminous, relative. The ratio of the *radiant flux* at *wavelength* λm to that required at wavelength λ for producing equally intense luminous sensations under specified photometric conditions where λm is the wavelength for which the ratio assumes its maximum value of unit. Relative luminous efficiency is often designated by the symbol $V\lambda$ or $V(\lambda)$.

Efficiency, luminous, spectral. *Luminous efficiency of radiation* evaluated as a function of *wavelength*.

Efficiency, radiant. The quotient of the *radiant flux* emitted, divided by the power consumed.

Element. A single uncompounded *lens;* an optical part constructed of a single piece.

Element, optical. An optical part constructed of a single piece of optical material; usually single *lenses, prisms, or mirrors*.

Elevation, angle of. The *angle* between the line of sight (imaginary line from weapon to target), and the line of elevation (formed by axis of bore when weapon is in firing position).

Emergence. A term referring to the trigonometric relation between the emergent *ray* and the *surface* of the *medium* (see *grazing emergence* and *normal emergence*).

Emergence, grazing. A condition in which an emergent *ray* makes an *angle* of 90° to the *normal* of the emergent *surface* of a *medium*.

Emergence, normal. A condition in which a *ray* emerges along the *normal* to the emergent *surface* of a *medium*.

Emery. A natural *abrasive*, prepared from corundum in grades ranging from rough to fine, which is used in the coarse and fine *grinding* of glass.

Emissivity. The ratio of the radiant emittance of a source to the radiant emittance of a *blackbody* at the same temperature.

Emittance, luminous. A term applied to extended sources; the total *luminous flux* emitted by a unit area.

Emittance, radiant. The *radiant flux* given off per unit area of a source.

Emittance, spectral. A term which usually refers to *radiant emittance* as a function of *wavelength*. Where spectral luminous emittance is intended, it should be so specified.

Energy, luminous. The *radiant energy* times the *luminous efficiency of radiation*.

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Energy, radiant. The energy of electromagnetic *waves*.

Erector. A term used as a synonym for *system, erecting*.

Error, centering. A synonym for *centration, errors of*.

Error, marginal. That *distortion* in an ophthalmic *lens* resulting from the *refraction* of *light rays* entering the periphery of the lens *surface*. This error increases in proportion to the *power* of the lens.

Error, oblique. The *image* errors arising from *astigmatism, coma,* oblique *spherical aberration*, lateral color, and *distortion*.

Error, pyramidal. The geometric error of the lack of parallelism among the *edges* formed by the faces of a *prism*. If the sharp edges have been removed by *grinding*, the above definition refers to the line of intersection of two faces extended, as constituting a prism edge.

Error, surface. The departures of an *optical surface* from its specified tolerance or *figure*.

Error, unit of. Abbreviated U.O.E. A unit of measurement in a *rangefinder* corresponding to 12 seconds of arc in the *apparent field*. It is the normally expected error in range due to human and instrumental limitations.

Etching. The marking of a *surface* by acid, acid fumes, or a tool. A process extensively used in the manufacture of *reticles*.

Eye. The organ of vision. Also a term used in the optical industry as follows: assume that a fine ground *convex* or *flat surface* is being polished to make it more steeply convex. The *polishing* then will proceed from the edges and work toward the center, which is not yet polished, but remains fine ground. This central area becomes smaller and smaller as the polishing proceeds, and is called the "eye." The polishing continues until the eye just disappears. In this way the thickness is controlled, and by keeping the "eye" centered, the centering is also controlled.

Eyeguard. A shield of rubber, plastic, or metal used to protect the *eyes* of the observer from stray light and wind, and to maintain the proper *eye distance*.

Eyelens. The *lens* of an *eyepiece* which is nearest to the observer's *eye*. Various types of lenses are used for this purpose.

Eyepiece. An *optical system* used to form an enlarged *virtual image* of the image formed by the *objective*, and to direct the light into the *eye* of the observer. The optical system of an eyepiece usually consists of two *lenses*, an *eyelens* and a *collective or field lens*, but may consist of only one lens or of more than two lenses. Erfle, Ramsden, Huygenian, Kellner, Plossl, and Bertele are various types of eyepieces.

Eyeshield. A term used as a synonym for *eyeguard*.

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F

Falling. A veritcal shift of the *image* from its true position. *Rotating prism* systems are employed in instruments used by the observer to view the entire horizon without changing his position. These systems are used in panoramic sights and in *periscopes*. The complete rotating prism system consists of a *right angle prism* which scans the horizon and an image rotating prism. In order to prevent the viewed image from falling when different parts of the horizon are viewed, the two prisms are so geared that when the right angle prism is rotated through an *angle* 2X the second prism is rotated through an angle x.

Feathers. Feathery *flaws* located inside the body of glass.

Field, apparent. The size of the *field of view* in the *image* space of an optical instrument, as differentiated from the size of the field of view in the *object* space. In the absence of *distortion*, the following relation holds:

$$\tan \frac{a'}{2} = M \tan \frac{a}{2},$$

where a' is the *apparent field*, M the *magnification* of the instrument, and a is the *true field*.

Field, curvature of. An *aberration* of *lenses* which causes the *image* of a plane to be focussed into a curved surface, instead of a plane.

Field, linear. The actual width of the *field of view* at any distance.

Field, split. The *field of view* as seen when observing through some types of *coincidence rangefinders*. It is formed by the juxtaposition of opposite halves of the *images* produced by two *objectives*. The half-images are separated by the halving line.

Field, true. The size of the *field of view* in the *object* space of an optical instrument as distinguished from the size of the field of view in the *image* space (see *apparent field*). More specifically, it is the maximum cone or fan of *rays* subtended at the *entrance pupil* that is transmitted by the instrument to form the usable image.

Figure. The geometrical form of an *optical surface*, usually as defined on a drawing.

Figuring. The process of changing an *optical surface* to improve its performance. In cases where the glass has areas in which the *index of refraction* varies, "figuring" the corresponding areas of the surface will compensate for the errors in the index of refraction.

Filter. Often referred to as "ray filter." It is a device with the desired characteristics of *selective transmittance* and optical homogeneity, used to modify the spectral composition of *radiant flux*. Usually special glass, gelatin, or plastic optical parts with plane parallel *surfaces*, which are placed in the path of light through the *optical system* of an instrument to selectively absorb certain *wavelengths* of light, reduce glare, or reduce light intensity. Colored, ultraviolet, neutral density, and polarizing filters are in common use. Filters are provided as separate elements or as integral devices mounted so that they can be placed in or out of position, as desired.

Filter, polarizing. A *filter* that polarizes the light passing through it.

Filter, ray. A synonym for *filter*.

Fining. A *grinding* process using fine *emery*.

Finish, short. A term used to denote an incomplete polish.

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Fixation, point of. An *object* on which the observer's *eye* is concentrated.

Flare. A *nonimage* forming light which is transmitted through the *lens* to reach the image. It is usually caused by *reflections* from the lens *surfaces*, lens barrel or reflecting surfaces within the barrel, shutter, or lens mount. Flare may be concentrated or diffused.

Flat. A glass *surface* whose radius of curvature is *infinite*. A *convex* surface with too long a radius.

Flat, optical. A test plate having an optically flat *surface*.

Flaw. In a *moulded blank* an inclusion of gas or dirt caused by folding of the glass.

Fluorescence. *Luminescence* that persists for less than about 10^{-8} second after excitation.

Fluorite. The optical form of the crystal fluorspar, calcium fluoride. This material is utilized for its low optical *dispersion*, its low *index of refraction*, and its transparency to *infrared* and *ultraviolet* radiation.

Flux. A term used as a contraction for *radiant flux* or *luminous flux*.

Flux, luminous. The quantity that specifies the capacity of the *radiant flux* to produce the attribute of visual sensation known as *brightness*. Luminous flux is radiant flux evaluated with respect to its *luminous efficiency of radiation*. Unless otherwise stated, luminous flux pertains to the standard photoptic observer.

Flux, radiant. The *radiant energy* crossing or striking a *surface per* unit time usually measured in watts.

F-number. The ratio of the *equivalent focal length* of an *objective* to the diameter of its *entrance pupil*.

Focus. Often used as a synonym for *point, focal*. The term is also used to describe the process of adjusting the *eyepiece* or *objective* of a *telescope*, so that the *image* is clearly seen by the observer. The term is also used to denote the adjustment of the *lens*, plate, or film holder of a camera so that a sharp, distinct image is registered. Also, to move the entire *microscope* body tube with respect to a specimen, to obtain the sharpest possible image.

Focus, fixed. A term used to denote instruments that are not provided with a means of focussing.

Focus, principal. A term used as a synonym for *focus, principal, point of*.

Focus, principal, point of. The point to which incident parallel *rays* of light converge, or from which they diverge when they have been acted upon by a *lens* or *mirror*. A lens has a single point of principal focus on each side of the lens. A mirror has but one principal focus. A lens or mirror has an infinite number of *image* points, real or virtual, one for each position of the *object*.

Fog. A term used to denote the foggy appearance of an incompletely polished *surface* which scatters light. The individual light scattering centers are too small and close together to appear as discrete. The term is also used to indicate the accumulation of moisture on an optical surface.

Fold. A *flaw* caused by folding the plastic surface of a *blank* during the forming of the blank.

Foot-candle. A unit of illuminance equal to one *lumen* incident per square foot. The illuminance (formerly called illumination) of a *surface* placed one foot from a light source having a *luminous intensity* of one *candle*.

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Frequency. The number of crests of *waves* that pass a fixed point in a given unit of time, in light or other wave motion.

Frequency, spatial. The *frequency* of *sine wave objects*. The reciprocal of the distance between maxima of the *object*. Usually expressed in cycles per mm.

Fringe. Abbreviated FRNG. An interference band, such as *Newton's ring*.

Fusing. The permanent uniting of two pieces of glass by means of a high temperature process.

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G

Gage, angle. A term used to denote accurate glass or metal *prisms* of precisely known *angles*.

Gage, brass. A measure for determining the accuracy of the curvature of a *lap* or *lens surface*.

Generating. A term used to denote a rapid *roughing* process for quickly removing glass. It is accomplished by means of coarse *emery* and a regular, or diamond impregnated, *lap*.

Ghost, prism. A term used as a synonym for a *ghost image* formed by a *prism*.

Glass, barium. A term commonly used in reference to a type of glass one of the ingredients of which is barium oxide, which is added for the purpose of increasing the *index of refraction*, while maintaining a relatively low *dispersion*.

Glass, baryta. A type of glass containing lead for increasing the *index of refraction*, together with barium which further increases the index, while maintaining a relatively low *dispersion*.

Glass, compensating. Also called "clear glass," or "clear filter." Where a *filter* is used in converging or diverging light, a change of *focus* would occur upon removing the filter. To avoid this, a clear glass plate of equivalent optical thickness, called a compensating glass, is substituted for the filter.

Glass, crown. A type of *optical glass* of the alkali-lime-silica type. It usually has an *index of refraction* in the 1.5 to 1.6 range and an *Abbe constant* in the 64 to 57 range. Since the positive element of an *achromatic lens* is almost always made of crown glass, it is often referred to simply as the "crown," as differentiated from the negative element, "the flint" (see *glass, flint*).

Glass, field. A hand-held *binocular telescope*, usually of the Galilean type.

Glass, flint. A type of *optical glass* to which lead, or other elements are added to produce generally a higher *index of refraction* (1.6 to 1.9) and a low *Abbe constant* (29 to 51).

Glass optical. A glass which during manufacture is carefully controlled with respect to composition, melting, heat treatment, and other processing in order that its *optical characteristics* such as its *index of refraction, dispersion, transmittance, spectral transmittance*, freedom from *birefringence*, permanence, etc., have the values required for the optical application for which it is to be used.

Glass, raw. A term used to denote any solid state of glass prior to its manufacture as an *element*.

Glass, reading. A low powered *magnifier*, generally of large diameter.

Glass, test. A master *optical surface* which is accurately made to a specified *figure*. It is used to measure the *figure tolerance* of the surfaces of production *elements*.

Glazing. The process of inserting *lenses* into a frame.

Grating, power, resolving, chromatic. The chromatic resolving power determines the minimum *wavelength* difference for any spectral order that can be distinguished as separate. The chromatic resolving power for diffraction gratings is usually stated for cases in which parallel *rays* of light are incident upon the grating and is numerically equal to the number of lines or ruled spacings in the grating (see *order, spectral, diffraction grating*.)

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Grey. A term used to denote an incompletely polished *surface* showing a grayness arising from the remains of fine *grinding*.

Grinding. A term used to denote the process in the fabrication of an *optical element* which gives it a specific geometric shape.

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H

Haze. An aggravated form of *fog* in a polished *surface* caused by light scattering. The defects causing haze are larger than those causing fog, but not large enough to be seen by the unaided *eye* as separated.

Heightfinder. An instrument used to determine the height of altitude of aerial targets by means of optical triangulation. The instruments used employ the stereoscopic principle.

Height, segment. The vertical measurement of distance betwen the uppermost borderline of the bifocal segment and the lower edge of the *lens*.

Height, sharp. The distance from the base to the *vertex* before *edging* a *prism*.

High. In plano work a high *surface* is *convex* and touches a flat *test glass* at its center.

Hole, dirt. A hole in an *optical surface* filled with dirt, such as polishing *abrasive* (see *bubble, dig, pit, scratch*).

Hole, sand. Rough spots on the polished *surface* produced during coarse *grinding*, which subsequent fine grinding did not remove owing, to some extent, to coarse grains of grinding sand becoming mixed with finer grades.

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I

Illuminance. *Luminous flux* incident per unit area of a *surface*. Widely known as "illumination."

Illuminated. A *surface* or *object* is said to be illuminated whenever *luminous flux* is incident upon it.

Image. A representation of an *object* produced by means of *light rays*. An image-forming *optical element* forms an image by collecting a bundle of light rays diverging from an object point and transforming it into a bundle of rays which converge toward, or diverge from, another point. If the rays converge to a point a real image of the object point is formed; if the rays diverge without intersecting each other they appear to proceed from a *virtual image*.

Image, aspect of. A term denoting the orientation of the image, such as normal, canted, *inverted* or *reverted*.

Image, brightness of. A term used to denote the apparent *brightness* of the *image* seen through an *optical system*. This brightness depends on the brightness of the *object*, the *transmission*, *magnification*, *distortion*, and diameter of the *exit pupil* of the instrument.

Image, double. A term used to denote the doubling of an *image* caused by optical imperfections in the *lens system*.

Image, erect. An *image*, either *real* or *virtual*, that has the same spacial orientation as the *object*. The image obtained at the retina with the assistance of an *optical system* is said to be erect when the orientation of the image is the same as with the unaided *eye*.

Image, geometrical. A term used to refer to the location and shape of the *image* of a particle, as predicted by *geometrical optics* alone. The geometrical image is to be distinguished from the diffraction image, which is determined from considerations of both physical and geometrical optics. With completely corrected *objectives*, the geometrical image of two points is again two points, but the actual image or the diffraction image may or may not suggest the presence of an object comprised of two points or two tiny particles.

Image, ghost. Spurious multiple *images* of *objects* seen in optical instruments, caused by the *reflections* from *optical surfaces*. By coating the optical surfaces with low reflection films, the harmful effects of ghosts are greatly reduced.

Image, real. See *image*.

Image, reflection. An *image* formed by a reflecting *surface*. An unwanted reflection image is more properly termed a *ghost image*.

Image, reverted. An *image*, the right side of which appears to be the left side, and vice versa.

Image, virtual. If a bundle of *rays* having a given *divergence* has no real or physical point of intersection of the rays, then the point from which the rays appear to proceed is called the virtual image. The distance of the virtual image is inversely proportional to the divergence of the rays. Since there is no physical intersection of rays there is no real image that can be focused on a screen. The image of any real *object* produced by a *negative lens* or *convex mirror* is always virtual. The image produced by a positive lens of an object located within its *focal length* is also virtual.

Imbalance, vertical. The difference in base up or down prism *power* at corresponding points on the two *lenses* of a pair.

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Incandescence. The emission of light by themal radiation in quantities sufficient to render the source of radiation visible.

Incidence. The act of falling upon, or affecting, as light upon a *surface*.

Incidence, angle of. The *angle* between the *normal* to a reflecting or refracting *surface* and the incident *ray* (see figs. 8 and 9).

Incidence, grazing. A term used to denote light incident at 90° to the *normal*.

Incidence, normal. A term used to denote light incident at 90° to the *surface*.

Inclusion. A term used to denote the presence, within the body of the glass, of extraneous or foreign material (see *bubble, seed, stria*).

Index, absolute. A synonym for *refraction, index of*.

Index, refractive. A term used as a synonym for *refraction, index of*.

Index, refractive, absolute. The *refractive index* of a *medium* relative to that of vacuum. Refractive index and absolute refractive index are numerically identical.

Index, relative. See *refraction, index of*.

Infinity. In the optical industry, a term used to denote a distance sufficiently great so that light *rays* emitted from a body at the distance are practically parallel. Infinity is indicated by the symbol ∞.

Infrared. The visible electromagnetic radiation beyond the red end of the *visible spectrum*. The *wavelengths* range from 768 *millimicrons* to the region of 30 or 40 *microns*. Heat is radiated in the *infrared* region.

Insert, total. The lateral distance separating a vertical line drawn through the *geometrical center* of the distance portion of a *multifocal* and a vertical line passing through the geometrical center of the *segment*.

Inset. The horizontal distance from the 90 degree meridian of a bifocal *lens* to the *geometrical center* of the *segment*.

Intensity, luminous. The ratio of the *luminous flux* emitted by a source, or an element of the source in an infinitesimally small cone about the given direction, to the solid *angle* of that cone. Usually stated as luminous flux emitted per solid angle.

Intensity, radiant. *Flux* radiated per unit solid *angle* about a specified direction.

Intensity, spherical, mean. The average value of intensity of a source with respect to all directions.

Interference. A term used to denote the additive process, whereby the amplitudes of two or more overlapping *waves* are systematically attenuated and reinforced. The term is applied also to the converse process in which a given wave is split into two or more waves by, for example, *reflection* and *refraction* at *beam-splitters*.

Interferometer. An instrument employing the *interference* of light *waves* for purposes of measurment, such as the accuracy of *optical surfaces* by means of *Newton's rings*, the measurement of *optical paths*, and linear and *angular* displacements.

Interferometer, Twyman-Green. A testing device in which the observer sees a contour map of the emergent *wavefront* in terms of the *wavelength* of the light used in the test.

Inverted. Turned over; upside - down. Usually refers to the effect of a *prism* or *lens* upon the *image*. Inversion is the effect of turning upside-down.

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Irradiance. *Radiant flux* incident per unit area.

Irradiation. The product of irradiance and time, i.e. *radiant energy* received per unit area.

Item, fringe. A term used to denote *lenses* or *blanks* of such *curvature, power,* or type, that they are not used in great quantity.

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J

Jump, image. The apparent displacement of an *object* due to an erroneous prismatic condition in an *optical system*.

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L

Lambert. A unit of *luminance*, equal to $\frac{10^4}{\pi}$ *candles* per square *meter*.

Laminated. A term used to denote that the product consists of different layers of material.

Lap. A tool with a known *surface curvature* which can be imparted to a piece of glass when used with an *abrasive*.

Lapping. A term used to refer to the *grinding* of a rough plano *surface*.

Layout. In the laboratory, this term refers to the process of positioning and marking a *blank* or *lens* preparatory to surfacing or *cutting* and *edging*.

Layout. In manufacturing, this term refers to a quantity of work keyed to a time factor.

Leach. A glass *surface* from which some of the glass constituents have been removed by chemical action.

Length, base. The distance perpendicular to the *line of sight* between the centers of the two *entrance pupils* in a two pupil system.

Length, focal. In a *lens*, focal length is synonymous with *equivalent focal length*. In a *mirror* or single refracting *surface*, it is the distance measured from the *focal point* to the mirror or surface. (See fig. 4).

Length, focal, back. Abbreviated BF. The distance measured from the *vertex* of the back *surface* of the *lens* to the rear *focal point*.

Length, focal, calibrated. Abbreviated CFL. An adjusted value of the *equivalent focal length* of a *lens* mounted in a camera or cone, so chosen that the extreme positive and negative values of *distortion*, are equal in magnitude (over the designated image area).

Length, focal, equivalent. Abbreviated EFL. The distance from a *principal point* to its corresponding *principal focal point*. The *focal length* of the equivalent thin lens. The size of the *image* of an *object* is directly proportional to the equivalent focal length of the *lens* forming it.

Length, front, focal. Abbreviated FFL. The distance measured from the *principal focus* located in the front space, to the *first principal point*.

Lens. A transparent *optical element*, usually made from *optical glass*, having two opposite polished major *surfaces* of which at least one is *convex* or *concave* in shape and usually spherical. The polished major surfaces are shaped so that they serve to change the degree of *convergence* or *divergence* of the transmitted *rays*.

Lens, achromatic. A *lens* consisting of two or more *elements*, usually made of *crown* and *flint glass*, which has been corrected, so that light of at least two selected *wavelengths* is focussed at a single axial point (see *lens, compound*).

Lens, aplanatic. A *lens* which has been corrected for *spherical aberration* and departure from the sine condition freedom from *coma*. It may also be corrected for *color*.

Lens axis of. A term used as a synonym for *axis, principal*.

Lens, bitoric. A *lens*, both *surfaces* of which are ground and polished in a toric or cylindrical form.

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Lens, cartesian. A *lens*, one *surface* of which is a cartesian oval. It produces an *aplanatic* condition.

Lens, collective. A lens of positive *power* (a *field lens*, for example) used in an *optical system* to refract the *chief rays* of *image*-forming bundles of rays, so that these bundles will pass through subsequent *optical elements* of the system. If the entire bundles do not pass through an optical element a loss of light ensues, known as *vignetting*. Sometimes the term collective lens is used incorrectly to denote any lens of positive power.

Lens, compound. A *lens* composed of two or more separate pieces of glass or other optical material. These *component* pieces or *elements* may or may not be cemented together. A common form of compound lens is a two element *objective*, one element being a *converging lens* of *crown glass* and the other a *diverging lens* of *flint glass*. The combination of suitable glasses or other optical materials (plastics, minerals) properly ground and polished reduces *aberrations* normally present in a single lens.

Lens, concave. A term used as a synonym for lens, diverging.

Lens, concavo-convex. A term used as a synonym for *meniscus*.

Lens, concentric. An optical component, usually a single *element*, in which the centers of *curvature* of the *surface* coincide. Concentric lenses thus have a constant radial thickness in all zones.

Lens, condensing. A *lens* or system of lenses of positive *power* used for condensing *radiant energy* from a source onto an *object*.

Lens, converging. Also known as a "convergent lens," "positive lens," "convex lens," "collective lens," and colloquially in some optical shops as a "crown" lens. A *lens* that adds *convergence* to an incident bundle of *rays*. One *surface* of a converging lens may be convexedly spherical and the other plane (plano-convex), both may be *convex* (double-convex, biconvex) or one surface may be convex and the other *concave* (converging meniscus).

Lens, convex. A synonym for *lens, converging*.

Lens, convexo-concave. A synonym for *meniscus*.

Lens, corrected. A *lens* so designed that it is sufficiently free from one or more *aberrations*. Such a lens, for example, may be a simple lens with an *aspheric surface*, or it may be a *compound lens* consisting of several *optical elements* and different glasses.

Lens, cylindrical. A lens with a cylindrical surface. Cylindrical lenses are used in *rangefinders* to introduce *astigmatism* in order that a point-like source may be imaged as a line of light. By combining cylindrical and spherical *surfaces* an *optical system* can be designed which gives a certain *magnification* in a given azimuth of the *image* and a different magnification at right angles in the same image plane. Such a system is designated as being *anamorphic*.

Lens, dispersive. A synonym for *lens, diverging*.

Lens, divergent-meniscus. A *lens* with one *convex surface* and one *concave* surface, the latter having the greater *curvature* or *power*. A negative *meniscus*. Also called a "diverging meniscus lens."

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Lens, diverging. Also known as "divergent lens," "negative lens," "concave lens," "dispersive lens." A *lens* which causes parallel light *rays* to spread out. One *surface* of a diverging lens may be concavely spherical and the other plane (plano-concave), both may be *concave* (double concave) or one surface may be concave and the other *convex* (concave-convex, divergent-meniscus). The diverging lens is always thicker at the edge than at the center.

Lens, double-concave. A *minus lens* having both *surfaces concave.*

Lens, double-convex. A *plus lens* having both *surfaces convex.*

Lens, field. A *positive lens* used to collect the chief rays (field rays) of *image* forming bundles so that the entire bundles or sufficient portions of them will pass through the *exit pupil* of the instrument. A field lens is usually located at or near the *focal point* of the *objective lens.* The field lens increases the size of the field which can be viewed with any given *eyelens* diameter.

Lens, finished. Any *lens* having both surfaces ground and polished to specific dioptric *power* or *focus.*

Lens, meridian of. Any line drawn on a *lens* from edge to edge perpendicular to the *optical axis.*

Lens, minus. A *diverging lens.* A lens with negative *focal length* (focal point towards object).

Lens, negative. A synonym for *lens, diverging.*

Lens, pancratic. See *zoom lens.*

Lens, plano. A *lens* having no curved surface, or whose two curved *surfaces* neutralize each other, so that it possesses no refracting *power.*

Lens, planoconcave. A *lens* with one *surface* plane, the other *concave.*

Lens, planoconvex. A *lens* with one surface plane, the other *convex.*

Lens, plus. A *converging (convex) lens.*

Lens, positive. See *lens, converging.*

Lens, tapered. A *lens* whose cross section shows a greater edge thickness on one side than on the other.

Lens, telephoto. An *objective lens system* consisting of a positive and a negative *component* separated from each other, having such powers and separation that the *back focal length* of the entire system is small in comparison with the *equivalent focal length.* Such lenses are used for producing large *images* of *distant objects* without the necessity of a cumbersome length of the instrument.

Lens, thick. A *lens* whose axial thickness is so large that the *principal points* and the *optical center* cannot be considered as coinciding at a single point on the axis.

Lens, thin. A *lens* whose axial thickness is sufficiently small that the *principal points,* the *optical center,* and the *vertices* of the two *surfaces* can be considered as coinciding at the same axial point.

Lens, tinted. A general term referring to absorptive lenses (see *absorptance, spectral,* and *selective*).

Lens, zoom. An *optical system which* has *components* that move in such a way as to change the *focal length* while maintaining a fixed *image* position. Thus the *image* size can be varied while leaving the *optical system* in a fixed position. Sometimes called a *pancratic lens.*

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Lever, optical. A term applied to the means of amplifying small *angular* movements by reflecting a *beam* of light from a *mirror* or *prism*.

Light, collimated. A light bundle in which the *rays* emanating from any single point in the *object* are parallel to one another. Light from an infinitely distant real source, or apparent source, such as a *collimator reticle*, is collimated light.

Light, parallel. A synonym for *light, collimated.*

Light, pencil of. A narrow bundle of light *rays*, diverging from a point source or converging toward an *image* point.

Light, polarized. A light *beam* whose electric vectors vibrate along the same direction, that is in a single plane containing the line of propagation, is said to be "plane polarized" (often called linearly polarized). If each electric vector can be broken into two perpendicular components that have equal amplitudes and that differ in phase by ¼ *wavelength*, the light is said to be "circularly polarized." Circular polarization is obtained whenever the phase differences between the two perpendicular components is any odd, integral number of quarter wavelengths. If the electric vectors are resolvable into two perpendicular components of unlike amplitudes and differing in phase by values other than 1, ¼, ½, ¾, 1, etc., wavelengths, the light beam is said to be "elliptically polarized."

Light, quantity of. A term applied to the product of *luminous flux* and times.

Light, velocity of. This term usually refers to the speed of *monochromatic* light *waves*, i.e. to the phase velocity. The velocity of light, c_o, in vacuum is 299, 792.5 kilometers per second. The phase velocity in a *medium* is c_o/n where n is the *index of refraction* at the *wavelength* of the light wave.

Light, white. Radiation having a spectral energy distribution that produces the same *color* sensation to the average human *eye* as average noon sunlight.

Line, hair. A fine line having no apparent width on a polished *surface*.

Line, halving. The link which divides the two half *images* in a *coincidence rangefinder*. The two halves of the images produced by the two *objectives* of the instrument must be brought to a point where they match or coincide above and below the halving line.

Lines. A term used to denote *waves* which extend continuously across the glass, so that the *reflection* from the *surface* appears as a line, or series of lines, extending either the full width or a considerable distance across the glass.

Lint. In a cemented *surface* the remains of cloth or paper fibers used in cleaning.

Loupe. See *magnifier*.

Low. A term used to refer to an *optical surface* which touches the *test glass* only at its edges.

Lumen. The unit of *luminous flux*, equal to the *flux* issuing from one-sixtieth of a square *centimeter* of opening of a standard source, and included in a solid *angle* of one *steradian*.

Lumen-hour. A term used to denote the unit quantity of light equal to one *lumen* of *luminous flux* flowing for one hour.

Lumen-second. A term used to denote the unit quantity of light equal to one *lumen* of *luminous flux* flowing for one second.

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Lumerg. A term used to denote *centimeter* gram second unit of *luminous energy*, equal to 10^{-7} *lumen-second*.

Luminance. The ratio of the *luminous intensity* emitted in a given direction by an infinitesimal area of the source, to the projection of that area of the source upon the plane perpendicular to the given direction. Usually stated as luminous intensity per unit area; i.e. *luminous flux* per unit solid *angle* emitted per unit projected area.

Luminescence. The process whereby matter emits radiation which for certain *wavelengths*, or restricted regions of the *spectrum*, is in excess of that attributable to the thermal state of the material and the *emissivity* of its *surface*. The radiation is characteristic of the particular luminescent material.

Luminosity. A term so called by the Committee on Colorimetry, Optical Society of America, to denote the ratio of *luminous flux* to the *radiant flux* in a sample of radiant flux, for example, *lumens* per watt of *radiant energy*.

Lux. A term used to denote the *lumen* per square *meter;* a unit of *illuminance*.

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M

Machine, bowl-feed. A *polishing* machine in which the *rouge* slurry is contained in a bowl and continuously diverted mechanically to flow over the work.

Machine, flat. A *polishing* machine constructed to allow adjustment of the polisher speed and movement for the control of *flat surfaces*.

Machine, stick. A *polishing* machine in which the *lens is* mounted on a wooden stick, allowing a very wide sweep. It is used in the polishing of hemispherical or hyperhemispherical *surfaces*.

Magnification. Magnification is best defined by the following conditions: (1) Lateral magnification is the ratio of the linear size of the *image* to that of the *object*, as used in enlarging *lenses*. (2) Angular magnification is the ratio of the apparent size of the image seen through an *optical element* or instrument to that of the *object* viewed by the unaided *eye*, when both the object and image are at *infinity* (*telescopes*), or when both the object and image are considered to be at the *distance of distinct vision* (*microscopes*). Angular magnification is often used as a synonym for *power, magnifying*.

Magnification, absolute. The *magnification* produced by a *lens* placed in front of a normal *eye* and at such a distance from the eye that either the rear *focal point* of the lens coincides with the center of rotation of the eye or else that the front *focal point* of the eye coincides with the *second principal point* of the lens all under the condition that the *object* is located close to the front focal point of the lens. This magnification is numerically equal to the *distance of distinct vision* divided by the *equivalent focal length* of the lens, with both distances expressed in the same units of length.

Magnification, normal, individual. When a *magnifier* is used by an individual having myopia, or hyperopia, the *magnification* is different from the *absolute magnification* and is called "individual normal magnification."

Magnifier. A *lens* or *lens system* forming a magnified *virtual image* of an *object* placed near its front *focal point*. Magnifiers are also referred to as "loupes," "simple microscopes," or "magnifying glasses." The magnifications of magnifiers range from approximately, 3x to 20x.

Major. A term used to denote a *blank* to which a piece of glass of a different *index of refraction* will be *fused* to make a *multifocal lens*.

Mark, chuck. A term used to denote the marks resulting when, in hand centering, the movement of the *lens* over the face of the centering *chuck* abrades the *surface*.

Mark, generating. A term used to denote the curved marks resulting when, in the process of *generating*, a loose or coarse diamond particle from the generating *lap* scores the work so deeply, that subsequent fine *grinding* or *polishing* will not completely remove the scoring.

Mark, skuff. A term used to denote damage to polished *surfaces* due to careless handling.

Marks, stick. A term used to denote the resulting fine *scratches* when, in hand *centering*, the forked stick used to move the *lens* on the *chuck* marks the rotating *lens surface*.

Match. A term used to denote the condition of identity of visual appearance.

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Material, dichroic. A substance which exhibits *dichroism* in either or both of the senses listed under that definition.

Material, isotropic. A substance which exhibits similar properties when tested along axis in any direction.

Measure, lens. A mechanical device for measuring *surface curvature* in terms of dioptric *power*.

Medium. Tny substance or space through which light can travel.

Member. In a *lens*, the group of parts considered as an entity because of the proximity of the parts, or because it has a distinct, but not always entirely separate function.

Meniscus. A *lens* having *surfaces*, one of which is *convex*, the other *concave*.

Meniscus, concentric. A synonym for *lens, concentric*.

Meniscus, cenverging. A term used to denote a *converging lens*, with one *convex surface* and one *concave*.

Meniscus, side, first. A term used to refer to the operation of *grinding* the *concave surface* of a single vision spherical *lens*.

Meniscus, side, second. A term used to refer to the operation of *grinding* the *convex surface* of a convexo-concave *meniscus*.

Meter. A unit of metric measurement:

1000 *millimeters* equal one meter,

100 *centimeters* equal to one meter,

one meter is equal to 39.37 inches.

Micron (μ). A unit of length in the metric system equal to 0.001 *millimeter*.

Microscope An optical instrument for producing enlarged *images* of small, near *objects*. Microscopes are of two types "simple" and "compound." A simple microscope produces but one image of an object, whereas a compound microscope first forms an image by the *objective lens*, and this primary image is further magnified by an *eyepiece*.

Microscope, compound. See *microscope*.

Microscope, simple. See *microscope*.

Millidiopters. A unit of metric measure equal to 0.001 *diopters*. The *power* of a *lens* in millidiopters is the reciprocal of its *focal length* in kilometers.

Millimeter. A unit of metric measurement:

1000 millimeters equal one *meter*,

10 millimeters equal one *centimeter*,

25.400 millimeters is one inch.

Millimicron (mμ). A unit of length in the metric system equal to 0.001 *micron*. It is also equivalent to 10 *Angstroms*.

Milling. An automatic *generating* process. The abrasion of glass by means of a diamond charged wheel.

Mirror. A smooth, highly polished *surface* for reflecting light. It may be plane or curved. Usually a thin coating of silver or aluminum on glass constitutes the actual reflecting surface. When this surface is applied to the front face of the glass, the mirror is termed a "front surface mirror."

Mirror, mangin. Essentially, a negative *meniscus lens* whose second or *convex surface* is silvered. By carefully choosing the radii, *spherical aberration* can be corrected for any given position of the *image*.

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Mirror, paraboloidal. A *concave mirror* which has the form of a paraboloid of revolution. Sometimes the paraboloidal mirror may consist of only a portion of a paraboloidal *surface* through which the axis does not pass, and is known as an "off-axis" paraboloidal mirror. All axial parallel *light rays* are focused at the *focal point* of the paraboloid without *spherical aberration*, and conversely all light rays emanating from an axial source at the focal point are reflected as a bundle of parallel rays without spherical aberration. Paraboloidal mirrors are free from *chromatic aberration*.

Mirror, surface, first. A term used as a synonym for *mirror, surface, front.*

Mirror, surface, front. An optical *mirror* on which the reflecting *surface* is applied to the front surface of the mirror instead of to the back, i.e. to the first surface of *incidence*.

Mirror, triple. Three reflecting *surfaces*, mutually at right *angles* to each other, arranged like the inside corner of a cube. The triple mirror may be constructed of solid glass in which case the transmitting face is *normal* to the diagonal of the cube, or it may consist of the three plane *mirrors* supported in a precisely constructed metal framework. The triple reflector has a constant deviation of 180° for all *angles of incidence*, hence a *ray* of light incident from any angle is reflected back parallel to itself. Such systems are also known as "corner-cube reflectors," or "retrodirective reflectors."

Modulation. A measure of the variation of *illuminance* across an *image* of a sine wave object. Defined as

$$M = \frac{Imax - Imin}{Imax + Imin}$$

Where Imax is the maximum *illuminance* in the *image*, and Imin is the minimum *illuminance* in the *image*.

Modulation transfer function. The function, usually a graph, describing the modulation of the *image* of a sinusoidal object as the *frequency* increases. Also called sine wave response, and contrast transfer function.

Monochromatic. Composed of one *color*.

Monocular. Pertaining to one *eye*.

Monogramming. The process of putting a "breathe on" type trademark on a *lens*.

Mounting, eccentric. A type of *lens* mounting consisting of eccentric rings that may be rotated to shift the axis of the lens to a prescribed position.

Movement, diopter. A term applied to the adjustment of the *eyepiece* of an instrument to provide *accommodation* for eyesight variations of individual observers. The axial distance through which the *eyepiece* must be moved, to provide a *convergence* of the *rays* emerging from the *eyepiece* of one (1) *diopter*, is calculated from the focal *length* of the eyepiece. If d is the required distance, it can be expressed: 1 diopter = d (in inches).

Multifocal. A *lens* which is characterized by two or more *foci*.

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N

N, n. A symbol used to indicate *index of refraction*. It is usually used with a subscript to indicate the *wavelength* of light, e.g., N_D or n_D indicates the index of refraction for sodium light of 5893 *angstrom* wavelength.

Neutralization. The process of combining of two *lenses* of equal and opposite *powers* to produce a resultant with no power.

Normal. Sometimes called the "perpendicular." An imaginary line forming right *angles* with a *surface* or other lines. It is used as a basis for determining *angles of incidence, reflection*, and *refraction*.

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O

Object. The figure viewed through or imagined by an *optical system*. It may consist of natural or artificial structures or targets, or may be the *real* or *virtual image* of an object formed by another optical system. In the optical field, an object should be thought of as an aggregation of points.

Object, sine wave. An *object* having a sinusoidal variation of *luminance*. It has the advantage that the *image* will have a sinusoidal variation of *illuminance* and the only effect of degeneration by the *lens* system will be to decrease the modulation in the *image* relative to that in the object.

Objective. The optical component which receives light from the *object* and forms the first or primary *image*, in *telescopes* and *microscopes*. In cameras, the image formed by the objective is the final image. In telescopes and microscopes, when used visually, the image formed by the objective is magnified by use of an *eyepiece*.

Objective, aperture of. The diameter of that part of the *objective* which is not covered by the mounting (see *aperture*, clear).

Objective, Maksutov. An *objective* consisting of a spherical reflector, or reflectors, and a weak negative *meniscus* having strongly curved spherical *surfaces* to correct the *spherical aberration* of the reflector(s) without introducing significant *longitudinal chromatic aberration*. The corrector *lens* can also concomitantly correct *coma* and reduce *curvature* of field.

Object, self-luminous and nonself-luminous. Self-luminous and nonself-luminous *objects* need to be distinguished since *image* formation can become quite different depending upon whether or not the object must be regarded as nonself-luminous. A self-luminous object radiates sufficient light *flux* to render its image visible, whereas nonself-luminous objects do not. Image formation with objects that scatter or diffuse the incident illumination markedly, is very similar to image formation with self-luminous objects.

Occluder. A device which completely or partially limits the amount of light reaching the *eye*.

Offset, prism. The term applied to certain *telescopes* having a characteristic offset, due to the mounting of the *prism erecting system* in the body of the instrument.

One-piece. A term referring to *multifocals* consisting of one piece of glass, the *segment*, or segments, having different *curvature* than the main body of the *lens*.

Opaque. Impervious to light, i.e., has zero *luminous transmittance*. A substance which is impervious to light applied to transparent or translucent substances. To make impervious to light.

Ophthalmic. Pertaining to the human *eye*.

Optical. Pertaining to vision and the phenomena of light.

Optical transfer function. The function describing modulation and *spatial phase shift* of the *image* of a sinusoidal *object* with *frequency* as the independent variable.

Optics. That branch of physical science which is concerned with the nature and properties of eletromagnetic radiation and with the phenomena of vision.

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Optics, coated. *Optical elements* or combinations thereof whose refracting or reflecting *surfaces* are coated with one or more thin layers of dielectric or metallic substances. The term is commonly used with reference to *antireflection coatings*. The optical surfaces of optical elements are coated with dielectric materials such as magnesium fluoride, silicon monoxide, silicon oxide, titanium oxide, or zinc sulfide, for the purposes of reducing or increasing *reflections* and for protecting the surfaces.

Optics, crystal. The study of the propagation of *radiant energy* through *crystals*, especially *anisotropic* crystals, and their effects on polarization.

Optics, fiber. A device for relaying an *image* by means of a large number of transparent fibers (filaments), by multiple total internal reflection. The fibers are most commonly glass and less often a highly transparent plastic. Each fiber carries only one element of the image, so that the image is a mosaic in which the cell size is the fiber cross-section rather than a continuous picture. The image may be transformed in almost any desired manner to a randomly scrambled picture, to produce *magnification*, to produce the familiar optical distortions or conversely to correct them.

Optics, fiber, numerical aperture of. The product of the *refractive index* N_0 of the *medium* in contact with the end of the fiber and sin θ_0, where θ_0 is half of the *angle* of the cone of light that is accepted and transmitted by internal *reflections* within the fiber. For fibers whose end-faces are perpendicular to the axis of the fiber: Numerical aperture $= N_0 \sin \theta_0 = \sqrt{N_f^2 - N_s^2}$ where N_f and N_s denotes respectively the refractive indices of the fiber and the medium surrounding the reflecting walls of the fiber.

Optics, geometrical. The branch of science which treats light propagation in terms of *rays*, considered as straight lines in homogeneous *media*.

Optics, physical. That branch of science which treats light as a *wave* phenomenon wherein light propagation is studied by means of *wave-fronts* rather than *rays* as in *geometrical optics*.

Order, spectral, diffraction gratings. When, for example, a *beam* of parallel *rays* of *monochromatic* light pass through a diffraction grating, the emergent rays that have remained undeviated belong to the zero spectral order. The light *flux* in the family of deviated rays that emerge after diffraction at the grating exhibit pronounced maxima along well defined and enumerable directions, on each side of the undeviated beam. The integers that distinguish these directions mark the so called spectral orders.

Orthoscopic. Corrected for *distortion*.

Overcoat. A term used to denote a layer of material applied to a coated *surface to* protect it from physical or chemical action.

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P

Paraboloid, off-axis. A paraboloidal reflector whose center is displaced from the pole of the paraboloid. Usually the pole of the paraboloid lies entirely outside the reflector.

Path, optical. The sum of the *optical distances* along a specified *ray*.

Patina. A thin film or coating which forms on various finished *surfaces*. On optical surfaces it is usually a sign of age.

Pattern. A device used to determine the shape of a *lens* in the cutting or *edging* phase of fabrication. The term is also used to denote the arrangement of markings on a *reticle*.

Peel, orange. A term used to describe the unevened or dimpled appearance of a *lens surface* which has been improperly, or insufficiently polished. A polished surface showing a granular appearance under *magnification*.

Peripheral. Near the boundary or edge of the field of an optical *system;* the outer *fringe*.

Periscope. An optical instrument designed to displace the *line of sight* in a vertical direction. It is used to permit observation over the top of a barricade or out of a tank or submarine.

Phase shift, spatial. The displacement of the *image* of a *sine wave object* from its ideal position. Usually measured in degrees with 360 degrees assigned to a full cycle of the *image*.

Photoelastic. Showing the phenomenon of *birefringence* upon the application of stress.

Photometer. An instrument for comparing the *luminous intensities* of two sources by comparing the *illuminance* they produce.

Photometer, bench. A *photometer* in which the distance between the comparison device, and one or both of the light sources is varied to obtain a match.

Picking. The process of breaking the pitch and removing *lenses* or *blanks* from the *block*.

Pipe, light. A channel through which light is conducted by means of *reflections* by the walls. The usual shape is cylindrical or conical, and usually makes use of *total internal reflection*.

Pit. A term denoting small holes in a glass *surface* which can be seen as small red particles by reflected light.

Pitch. A material used to hold the *lens* to the *block* during surfacing operations. Frequently used as material for *polishing laps*.

Plane. A *surface* which has no *curvature;* a perfectly flat surface.

Plane, focal. A plane through the *focal point* perpendicular to the *principal axis* of a *lens* or *mirror*. The film plane in a camera focussed at *infinity*.

Plane, image. The plane in which the *image* lies, or is formed. It is perpendicular to the axis of the *lens*. A *real image* formed by a *converging lens* would be visible upon a screen placed in this plane.

Plane, object. The plane which contains the *object* points lying within the *field of view*.

Planes, Gauss. Planes lying *normal* to the *optical axis* of a *lens* or *lens system* containing the *Gauss points*.

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Planes, principal. Planes of unit *magnification*, i.e., a *ray* directed at the first principal plane appears to leave the second principal plane at the same height.

Plate, corrector. An *optical element* computed to correct each zone of a reflector, or refractor, for *spherical aberration*.

Plate, Schmidt. An *aspheric* plate placed at, or near, the center of *curvature* of a spherical reflector for correcting *spherical aberration*.

Plate, surface. A plate having a very accurate *plane surface*, used for testing other surfaces, or to provide a true surface for accurately locating a testing fixture.

Plus. A term used to denote a *convex surface* or a *lens* having dioptric *power* or focus.

Point. A unit of *lens* thickness measurement. Five points are the equivalent of one *millimeter*.

Point, aiming. The mark on which a gunner sights when aiming a weapon. This mark may or may not be the target.

Point, focal. The *point* at which a bundle of *rays* from a sharp *image* of an *object*; alternatively, the *point* at which the *object* must be placed for a sharp *image*. The term is also used as a synonym for *focus, principal, point of*.

Point, principal, first. The *principal point* related to the *object space*.

Point, principal, second. The *principal point* related to *image* space.

Points, cardinal. In a *thick lens* or system of lenses, the two *principal points*, two *nodal points*, and two *focal points*. If the optical *medium* is the same in the *object* and *image spaces*, the principal points and the nodal points are coincident.

Points, conjugate. Those pair of points on the *principal axis* of a *mirror* or *lens* so located that light emitted from either point will be focused at the other. Related points in the *object* and *image* are located optically so that one is the image of the other.

Points, Gauss. A synonym for *points, cardinal*.

Points, nodal. Two points within a *lens* of exterior to it such that any *ray* aimed at one will emerge from the lens parallel to itself from the second point (see *points, cardinal* and fig. 5).

Points, principal. The points of intersection of the *principal planes* and the *optical axis* (see *points, cardinal*).

Polarimeter. A *polariscope* equipped with a *half-shade device* and an *angular scale* generally attached to the *analyzer*. It is used to measure the amount of rotation of the plane of polarization by materials placed within it.

Polariscope. A combination of a *polarizer* and an *analyzer* used to detect *birefringence* in materials placed between them or to detect rotation in the plane of polarization caused by materials placed between them.

Polarization, circular. See *light, polarized*.

Polarization, elliptical. See *light, polarized*.

Polarizer. An optical device for converting unpolarized or natural light into *polarized light*.

Polisher, pressing a. The process of shaping a polisher by pressing it with an *optical surface*.

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Polishing. The process of putting a highly finished *surface* on a *lens*.

Polishing, plastic. The process of *polishing* with a plastic pad.

Polychromatism. See *dichroism*.

Power. A measure of the ability to bend or refract light in a *mirror* or *lens*. It is usually measured in *diopters*. In a *telescope*, it is the number of times the instrument magnifies the *object* viewed. For example, if with a six-power instrument, an object 600 yards away is enlarged six times, it appears as it would to the naked *eye* if it were at a distance of only 100 yards.

Power, magnifying. Synonymous with *magnification*, magnifying power is the measure of the ability of an optical device to make an *object* appear larger than it appears to the unaided *eye*. For example, if an *optical element* or system has a magnification of 2-power (2X) the object will appear twice as wide and high. The magnification of an optical instrument is equal to the diameter of the *entrance pupil* divided by the diameter of the *exit pupil*. For a telescopic system, the magnification is also equal to the *focal length* of the *objective* divided by the focal length of the *eyepiece*. Another expression for the magnification of an instrument is the tangent of an *angle* in the *apparent field* divided by the tangent of the corresponding angle in the *true field*.

Power, prism. The *power* of a *prism*, expressed in prism *diopters* is the apparent displacement, in *centimeters*, of an *object* located one (1) *meter* distant from the prism.

Power, radiant. A synonym for *flux, radiant*.

Power, resolving. A measure of the ability of a *lens* or *optical system* to form separate and distinct *images* of two *objects* close together. Because of *diffraction* by the *aperture stop*, no optical system can form a perfect image of a point, but produces instead a small disk of light *(airy disk)* surrounded by alternately dark and bright concentric rings. When two object points are at that critical separation from which the first dark ring of one diffraction pattern falls upon the central disk of the other, the points are just "resolved" or distinguished as separated, and the points are said to be at the limit of resolution.

Power, resolving, chromatic. Some optical components, such as *prisms* and gratings, are used, not to resolve two or more *object* points, but rather to separate two *wavelengths* of nearly equal value. The ability of the instrument to separate two such wavelengths is called chromatic resolving power and is specified as the ratio of the shorter wavelength divided by the difference between the wavelengths.

Power, resolving, theoretical. The maximum possible *resolving power* determined by *diffraction*. Frequently measured as an angular *resolution* determined from

$$\theta = \frac{1.22\lambda}{d}$$

where θ is the limiting resolution in radians, λ is the *wavelength* of light at which the resolution is determined, and d is the diameter of the *effective aperture*.

Power, stereoscopic. The gain in *stereoscopic effect* afforded by a magnifying *binocular* instrument, as compared with the ability of the unaided *eyes*. This power will vary with the separation of the *objectives* and the *power* of the instrument.

Power, vertex. The refractive *power* of a *lens* based on the measurement of the distance between the *vertex* of its rear *surface* and the *principal focus*.

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Pressing. A *blank* with basic *surface* curves attained as the result of forming heat-softened glass by pressing in a *mold*.

Prism. A transparent body with at least least two polished *plane* faces inclined with respect to each other, from which light is reflected or through which light is refracted. When light is refracted by a prism whose *refractive index* exceeds that of the surrounding *medium*, it is deviated or bent toward the thicker part of the prism. See *system, erecting, Abbe prism; prism, amici; prism, porro; prism, rhomboidal; prism, right angle; mirror, triple.*

Prism, Abbe. A direct vision *prism* which inverts and reverts the *image* (erects the image).

Prism, Amici. Also called "roof prism" and "right-angle prism with roof." A form of roof prism consisting of a roof edge formed upon the long reflecting face of a *right-angle prism*. Used as an *erecting system* in *elbow* and *panoramic telescopes*. It erects the *image* and bends the *line of sight* through a 90° *angle*.

Prism, apex of. The thin edge of a refracting *prism*. It is the line of intersection of two refracting faces of a prism.

Prismatic. Pertaining to a *prism*, or the effects produced by prisms.

Prism, base of. The thick edge of a *prism*.

Prism, coincidence. A co[illegible] consisting of a system of small prisms cemented together, used in a *coincidence range-finder* to bring the *images* from the two *objectives* to [illegible] single *eyepiece* for viewing.

Prism, Dove. Also known as "rotating prism." It is used to invert the *image* in one plane without deviating or displacing the axis. Used as the rotating prism in the conventional type of *optical system* of *panoramic telescopes*. Dove prisms and double dove prisms are also used in scanning systems.

Prism, objective. Usually a *right-angle prism* employed in some types of instruments to bend light 90° before it enters the *objective* alternately, a dispersing *prism* placed in front of an *astronomical telescope objective* to produce spectra of all luminous objects in the *field of view*.

Prism, ocular. The *prisms* employed in a *rangefinder* to bend the *lines of sight* through the instruments into the *eyepieces*.

Prismograph. A graphical device for determining *prism power*.

Prism, Pechan. A *prism* composed of two air-spaced prism *elements* each of which has prism angles of 22° 30′, 45° and 112° 30′, as shown in figure 6. This prism has the property of reverting without inverting an *image*, and can be used in convergent or divergent light as well as *parallel light*.

Prism, penta. A five-sided *prism* used to bend light through a constant *angle*, usually 90°, without producing *inversion*. A penta prism can be rotated about an axis parallel to its faces without producing a change in its deviation of 90°.

Prism, Porro. A 45°—90°—45° reflecting *prism* with the *surfaces* forming the 90° angle reflecting the light beam through a [illegible] of 180°.

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Prism, power, resolving, chromatic. The chromatic resolving power of a *prism* is invariably stated for the case in which parallel *rays* of light are incident on the prism, in which the prism is oriented at the *angle* of minimum deviation at *wavelength* λ and in which the entire height of the prism is utilized. The corresponding *resolving power* R, deduced on the basis of Rayleigh's criterion is $R = \lambda/\Delta\lambda = b\ dn/\lambda$ where n is the *index of refraction* of the prism for the wavelength λ and b is the maximum thickness of prism traversed by the light rays. The quantities $dn/d\lambda$ and b are often called the dispersion and base-length of the prism, respectively.

Prism, rhomboidal. A reflecting *prism* whose unpolished side faces are rhomboidal in shape. It has two parallel transmitting faces, and two parallel reflecting faces; the latter are oblique to the former (usually but not necessarily at 45°). This prism has the property of offsetting the optical axis without changing the *aspect of the image*. By rotating the rhomboidal prism around an axis *normal* to the entrance *surface*, the offset emergent axis can be moved parallel to itself in a circular arc; hence pairs of these prisms are often used to provide *interpupillary adjustment* of the *eyepiece* of *binocular* instruments such as stereoscopic *rangefinders* and *heightfinders*.

Prism, right angle. A type of 45°—90°—45° *prism* used to turn a *beam* of light through a right *angle* (90°) with the surfaces forming the 90° angle acting as transmitting faces.

Prism, rotating. See *prism, Dove*.

Prism, roof-angle or roof. A synonym for *prism, amici*.

Propagation, rectilinear. straight line travel; refers to the fact that light travels in a straight line while traveling through a *medium* with a constant *index of refraction*.

Properties, optical. In *optical glass*, those properties which pertain to the effect of the glass upon light, such as *index of refraction, dispersion*, homogeneity, and freedom from defects.

Pupil, artificial. A *diaphragm* or other limitation that confines the *beam* of light entering the *eye* to a smaller cone than does the iris of the human eye.

Pupil, entrance. The *image* of the limiting *aperture* stop formed in the *object* space by all *optical elements* preceding the limiting aperture stop; also used as a term to denote the *aperture* of the *objective* when there are no other limiting stops following it in the system.

Pupil, exit. The *image* of the limiting *aperture stop* in an *optical system* formed by all *lenses* following this stop. In photographic *objectives* this image is *virtual* and is usually not far from the iris diaphragm. In *telescopes* the image is *real* and can be seen as a small bright, circular disc by looking at the *eyepiece* of the instrument directed toward an illuminated area or light source. In telescopes, its diameter is equal to the diameter of the *entrance pupil* divided by *magnification* of the instrument. In Galilean telescopes the exit pupil is a virtual image between the *objective* and eyepiece and acts as an out-of-focus *field stop*.

Pyramid, error due to. The error in the position of the *image* introduced by *pyramidal error* in a *prism*, measured relative to a chosen line of intersection of two prism faces.

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Q

Quality, image. Image quality embraces all the properties of a *lens* or *optical system* affecting the optical performance such as *resolving power; aberrations, image* defects, and contrast rendition. Aberrations contribute to poor image quality. Errors of construction and defects in materials adversely affect image quality. Because of the characteristic effects of aberrations on image quality it is possible to distinguish between their effects and those of accidental errors of workmanship are found .non-spherical *surfaces*, poor polish, *scratches, pits, decentering*, defects in cementing, and scattered light, all of which contribute to deterioration of the image. Defects in glass such as *bubbles, stones, striae*, crystalline bodies, cloudiness, and *strain* play a part in poor image quality.

Quality, surface. A means of specifying allowable flaws by comparison to reference standards of quality. Two graded sets of surface quality standards are used. The first indicates defects of a long nature such as *scratches*, and the second illustrates essentially round defects such as *digs*. Desired surface quality is specified by reference to these in order, e.g., 80–50 or 80/50.

Quartz. A natural mineral composed of silicon dioxide (S_1 O_2) crystallized in the hexagonal crystallographic system. It is uniaxial and optically active. Quartz is used as an *optical medium* in scientific apparatus because of its transparency over a wide interval of the *electro-magnetic spectrum*, particularly the *ultraviolet*.

Quartz, fused. A vitreous (glassy) material resulting from the fusion of crystalline *quartz*. It is optically isotropic, and has a much lower *index of refraction* than crystalline quartz.

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R

Radiance. The *radiant intensity* per unit projected area of an extended source.

Radiation, efficiency of, luminous. A synonym for *luminosity*.

Radiation, (or light), monochromatic. This term refers to the *flux* at one *wavelength* or frequency.

Radiator, complete. A synonym for *blackbody*.

Radiator, full. A synonym for *blackbody*.

Radiator, ideal. A synonym for *blackbody*.

Radiator, thermal. The process at emission wherein the radiated energy is extracted from the thermal excitation of atoms or molecules.

Radiometer. An instrument designed to measure *radiant intensity*.

Range, environmental. The maximum to minimum range of temperature, pressure, humidity, vibration, and biological conditions under which a *lens* can operate and be stored, constitute its environmental range. The range required depends upon the intended use.

Rangefinder. An optical instrument used to determine the distance of an *object* or target by triangulation.

Rangefinder, coincidence. A self-contained distance measuring device operating on the principle of triangulation. Two *images* of the same *object*, simultaneously observed from two points a known distance apart, are matched to determine the range.

Ratio, aperture. In general, aperture ratio is twice the value ρ_m in the equation.

$$\rho_m = n \sin \alpha_m,$$

where n is the *index of refraction* of the *image* space, and α_m is the maximum *angular* opening of the axial bundle of refracted *rays* as illustrated in figure 7. The speed (i.e, energy per unit area of image) of an *objective* is proportional to the square of its aperture ratio. When the angular opening is small, when n= 1, and when the *object* distance is great, it is approximately true that $n \sin \alpha_m = \frac{D}{2f}$, or that

$$\frac{f}{D} = \text{f-number} = \frac{1}{2\rho_m} = \frac{1}{\text{aperture ratio}}$$

Ratio, telephoto. The ratio of the *equivalent focal length* to the *front vertex focal distance*.

Ray. A contraction of the term *ray, light*.

Ray, chief. The central *ray* of a bundle of rays.

Ray, emergent. A *ray* of light leaving, i.e., emerging from a *medium* as contrasted to the entering or *incident ray*.

Ray, extraordinary. A *ray* which has a nonisotropic velocity in a *doubly refracting crystal*. It does not necessarily obey *Snell's law* upon *refraction* at the *crystal surface*.

Ray, incident. A *ray* of light which falls upon, or strikes, the *surface* of an object such as a *lens* or *mirror*. It is said to be incident to the surface.

Ray, light. The term applied to the lines perpendicular to the *wavefronts* of *waves* of light to indicate their direction of travel.

Ray, ordinary. The *ray* which has an isotropic velocity in a *doubly refracting crystal*. It obeys *Snell's law* upon *refraction* at the *crystal surface*.

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Ray, paraxial. A *ray* of a bundle of rays which approaches the *chief ray* of that bundle as its limiting position. More properly, it is a ray in the sense of Gaussian or first order *optics*.

Ray, principal. In the *object* space, the principal ray is one directed at the *first principal point*, and hence in the *image* space this *ray*, projected backward, would intersect the axis at the *second principal point*.

Ray, reflected. The *ray* of light leaving a reflecting *surface*, representing the path of light after *reflection*.

Ray, rim. A *ray* of an *image*-forming bundle which passes through the rim of the *entrance pupil* or *aperture stop*. Usually used in connection with meridian rays, an "upper rim ray" being one which passes through the top of the pupil or *stop*, and a "lower rim ray" one through the bottom.

Ray, skew. In a system having rotational symmetry, it is a *ray* which does not lie in a plane containing the axis of the system.

Rays, diffuse. See *reflection*.

Rays, field. In the *object* space, they are *rays* which intersect the *optical axis* at the center of the *entrance pupil* of a symmetrical *optical system*. In the *image* space, the same rays emerge from the *exit pupil*. In a *thick lens*, the field ray is the *principal ray*.

Rays, marginal. *Rays* of light passing through an *optical system* near the edge of the *aperture*.

Ream. A nonhomogeneity in flat glass in the form of an approximately plane layer.

Rectilinear. In a straight line. When applied to a *lens*, it indicates that *images* of straight lines produced by the lens are not distorted.

Reek, block. A type of *scratch*.

Reflectance. The ratio of the reflected *flux* to the *incident flux*. This term is applied to *radiant* and to *luminous flux*. Unless qualified, reflectance applies to *specular* (*regular*) *reflection*.

Reflectance, diffuse. The ratio of *flux* reflected diffusely in all directions to the total flux at *incidence* (*specular reflection excluded*). Also called "Total Diffuse Reflectance." Also, the *reflectance* of a sample relative to a perfectly diffusing, and perfectly reflecting standard with 45° *angle of incidence* and observation along the perpendicular to the surface.

Reflectance, diffuse, total. See *reflectance, diffuse*.

Reflectance, spectral. The *reflectance* evaluated as a function of *wavelength*. It is numerically the same for *radiant* and *luminous flux*.

Reflection. When *light rays* strike a smooth, polished *surface* they are bent back into the *medium* whence they came. Specular or regular reflection from a polished surface, such as a *mirror*, will return a major portion of the light in a definite direction lying in the plane of the *incident ray* and the *normal* (see *reflection, angle of*). After specular reflection, light can be made to form a sharp *image* of the original source. Diffuse reflection occurs when the surface is rough and the reflected light is scattered from each point in the surface. These diffuse rays cannot be made to form an image of the original source, but only of the diffusely reflecting surface itself.

Reflection, angle of. The *angle* between the *normal* to a reflecting *surface* and the reflected ray.

Reflection, diffuse. See *reflection*.

Reflection, direct. See *reflection, specular*.

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Reflection, internal, total. The *reflection* which takes place within a substance because the *angle of incidence* of light striking the boundary surface is in excess of the *critical angle*.

Reflection, law of. The *angle of reflection* is equal to the *angle of incidence;* the incident *ray*, reflected ray, and *normal*, all lie in the same plane.

Reflection, mixed. The simultaneous occurrence of *specular* and *diffuse reflection*.

Reflection, regular. See *reflection*.

Reflection, selective. See *absorption, selective*.

Reflection, specular. See *reflection*.

Reflectivity. The *reflectance* of an *opaque* material or of a layer of that material of sufficient thickness so that further increases in thickness do not alter the reflectance.

Reflectivity, spectral. The *reflectivity* evaluated as a function of *wavelength*.

Reflector, annular. A ring-shaped reflector, or a series of ring-shaped reflectors, mounted about a common center.

Reflector, corner-cube. See *mirror, triple*.

Reflector, retrodirective. See *mirror, triple*.

Refraction. The bending of oblique incident *rays* as they pass from a *medium* of one *index of refraction* into a medium of a different index of refraction.

Refraction, angle of. The acute *angle* between the *normal* to a refracting *surface* at the point of *incidence*, and the refracted *ray*.

Refraction, double. The separation of unpolarized light into two plane polarized components by a *doubly refracting crystal*.

Refraction, index of. A number applied the relation between the *angle of incidence* and the *angle of refraction* when light passes from one *medium* to another. The index between two media is called the "relative index," while the index when the first medium is a vacuum is called the "absolute index" of the second medium. The index of refraction expressed in tables is the "absolute index," that is, vacuum to substance at a certain temperature, with light of a certain *wavelength*. Examples: vacuum 1.000, air, 1.000292; water, 1.333; ordinary *crown glass*, 1.516. Since the index of air is very close to that of vacuum, the two are often used interchangeably as being practically the same (see *Snell, law of*).

Refraction, law of. A synonym for *Snell, law of*.

Relief. The discernment of depth or apparent difference in distance that makes the *object* stand out from its background due to *stereoscopic vision*. The impression of relief can be obtained from the arrangement of highlights and shadows when the object is viewed *monocularly*.

Relief, eye. A synonym for *distance, eye*.

Repressing. A synonym for *blank, molded*.

Resolution. Abbreviated RESOLN. The ability of a *lens system* to reproduce an *image* in its finest details (see *power, resolving*).

Resolution, angle of, limiting. The *angle* subtended by two points or lines which are just far enough apart to permit them to be distinguished as separate. The ability of an optical device to resolve two points or lines is called *resolving power* and quantitatively is inversely proportional to the limiting angle of resolution as defined.

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Reticle. A scale, indicator, or pattern placed in one of the *focal planes* of an optical instrument which appear to the observer to be superposed upon the *field of view*. Reticles, in various patterns, are used to determine the center of the field or to assist in the gaging of distance, determining leads, or measurement. A reticle may consist of fine wires, or fibers, mounted on a support at the ends, or may be etched on a clear, scrupulously polished and cleaned plane parallel plate of glass. In the latter case the entire piece of glass is referred to as the reticle. An alternate but less common form of spelling is reticule. In England the term "graticule" is generally used.

Reticule. See reticle.

Reversibility, law of. If the direction of light is reversed, it will travel in the opposite direction over the same path despite the number of times it is refracted or reflected.

Reverted. Turned the opposite way so that right becomes left, and vice versa. It is the effect produced by a *mirror* in reflecting an *image*.

Revolution, angle of, quadrant. The *angle* between the horizontal and the line of elevation. The *angle of elevation*, plus the angle of site, equals the quadrant angle of elevation.

Rings, Newton's. When two polished *surfaces* are cleaned and placed in contact with a thin air film between them, reflected *beams* of light from the two adjacent surfaces interfere to form a series of rings or bands known as Newton's rings or *fringes*. By counting these bands from the point of actual contact the departure of one surface from the other is determined. The regularity of the fringes maps out the regularity of the distance between the two surfaces. This is the usual method of determining the fit of a surface under test to a standard surface of a *test glass*.

Ripples. If a *surface* is polished without an oscillation of the polishing *lap* the polished surface contains approximately parallel *waves* or ripples.

Rotation, optical. The *angular* displacement of the plane of polarization of light passing through a *medium*. The azimuthal displacement of the *field of view* achieved through the use of a *rotating prism*.

Rouge. Iron oxide; a very fine *abrasive* used for *polishing* a *lens surface*.

Roughing. A term used to denote a very coarse *grinding* process.

Rub. A type of *scratch*.

Rule, Prentice's. A means of determining *prism power* at any point on a *lens*. Prism power equals dioptric *power* multiplied by the distance in *centimeters* from the *optical center*.

Run-out, edge. A term used to denote the total wobble, measured in units of length, resulting when a decentered *lens* is rotated about its *optical axis* and the edge of the lens wobbles.

Run-out, image, total. If a decentered *lens* is rotated in a *chuck* whose axis of rotation passes through the *geometrical center* of the rim of the lens, the *image* of an *object* will wobble. If the light source is at an infinite distance, the total image displacement is called the "total image run-out," and is a measure of the *decentering*. Conversely, if the light source is at the *focal point* of the lens the direction of the emergent parallel bundle changes through an *angle* which measures the decentering in *angular* terms.

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S

Saddle. A term used to denote a saddle-shaped polished *surface*, generally an error, whose contours are indicated by the shape of *Newton's rings*. It is a saddle-shaped *image* of a point light source caused by *astigmatism*.

Sag. To cause a sheet of glass to conform to a ceramic or metal form, by heating the glass to its softening point and allowing it to settle. In the geometric sense, it is also used as an abbreviation for "sagitta," the height of a curve measured from the chord.

Scale, brightness. A graduated series of stimuli perceived as having equal differences of *brightness*.

Scale, diopter. A scale usually found on the focusing nut of the *eyepiece* of an optical instrument. It measures the change in the position of the eyepiece necessary to produce a *correction* to compensate the nearsightedness or farsightedness of the individual observer. Thus if the observer knows his *diopter* correction, he can preset the instrument for *focus*. .

Scale, stadia. Graduations on a *reticle* which in conjunction with a rod of definite length can be used to measure distances.

Scratch. Any marking or tearing of the *surface* appearing as though it had been done by either a sharp or rough instrument. Scratches occur on sheet glass in all degrees from various accidental causes. *Block reek* is a chain-like scratch produced in *polishing*. A *runner-cut* is a curved scratch caused by *grinding*. A *sleek* is a hairline scratch. A *crush* or *rub* is a surface scratch or series of small scratches generally caused by mishandling.

Seed. A term used to denote a gaseous inclusion having an extremely small diameter in glass.

Seeds, heavy. Refers to a condition when the fine and coarse *seeds* are very numerous, such as 25 or more to the square inch.

Seeds, scattered. A term used to indicate the condition of a few and occasional easily visible coarse *seeds*. Two or three may be spaced 1 or 2 inches from each other, but one here and there at much greater distances apart is the usual intention of the term.

Segment. A term used to denote glass, with a high *index of refraction*, once it has been fused to the *major* and ground to a curvature which results in added *power*.

Semifinished. A term used to denote a *lens* or *blank* with one *surface* completely finished.

Setup. A term used to describe the adjustments and changes necessary to adapt a machine to perform a different process.

Shading. The sorting of *lenses* by their *color*.

Shadowgraph. A method of demonstration or inspection, using a point source illumination, without the use of any projection *lens* between the *object* and its shadow, the shadow being cast on a distant screen.

Shallow. A term used to denote a *concave surface* when its radius of curvature is too long, i.e. its negative *power* is too small or low.

Shaper, blocking. A *convex*, *concave*, or flat cast iron form used to shape a *soft mold block* of *optical elements*.

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Sharp. A term used to denote a *convex surface* that has too short a radius of curvature. To correct this condition, material is cut from the outer portion of the *polishing* tool.

Sight, angle of. The vertical *angle* between the horizontal and the line of sight (line from weapon to target).

Sight, line of (L.O.S.). The line of vision; the *optical axis* of a *telescope* or other observation instrument. The straight line connecting the observer with the aiming point; the line along which the sights are set.

Skim. A term used to denote streaks of dense *seeds* with accompanying small *bubbles*.

Slab-off. A term used to denote the process of making an abrupt break in a spherical *surface* so that a new center of *curvature* is established for a portion. This has the effect of adding a *prism* to that portion of the surface.

Sleek. A polishing *scratch* without visible conchoidal fracturing of the *edges*.

Snell, law of. When light is passing from a given *medium* to a denser medium, its path is deviated toward the *normal;* when passing into a less dense medium, its path is deviated away from the normal. *Snells' law*, often called the *law of refraction*, defines this phenomenon by describing the relation between the *angle of incidence* and the *angle of refraction* as follows:

$$\frac{\text{The sine of the angle of incidence.}}{\text{The sine of the angle of refraction.}} = \frac{\text{The index of refraction of the medium containing the refracted ray.}}{\text{The index of refraction of the medium containing the incident ray.}}$$

This is written $\frac{\sin i}{\sin i'} = \frac{n'}{n}$.

Sources, light, luminous efficiency of. The ratio of the *luminous flux* emitted to the *power* consumed by the source, for example, *Lumens per* watt applied at the source.

Spar, Iceland. A transparent variety of the natural *crystal* calcite (also called calcspar) that displays very strong *double refraction.* It is calcium carbonate crystallized in the hexagonal rhombohedral crystallographic system, and is uniaxial.

Spatter. A term used to denote the condition resulting when small chunks of material may fly from the hot crucible onto the glass *surface*, and adhere there, in evaporative coatings.

Spectrometer. A *spectroscope* provided with an angle scale capable of measuring the *angular* deviation of radiation of different *wavelengths.* In common usage, the dispersing means may be dispersed with, and the instrument used for measuring *angles* as on or through a *prism.*

Spectroscope. Any one of a class of instruments capable of dispersing radiation into its component *wavelengths* and observing, or measuring, the resultant *spectrum.*

Spectrum. The visual spectrum is the band of *color* produced by decomposing white light into its components by the process of *dispersion.* The rainbow is an example of a spectrum produced by the dispersion of white light by water droplets (see *spectrum, electromagnetic*).

Spectrum, electromagnetic. The entire range of *wavelengths*, extending from the shortest to the longest or conversely, that can be generated physically. This range of electromagnetic wavelengths extends almost from zero to *infinity* and includes the visible portion of the *spectrum* known as light.

Spectrum, primary. The characteristic *chromatic aberration* of a simple nonachromatized *lens* or *prism.*

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Spectrum, secondary. The residual *chromatic aberration, particularly* the *longitudinal chromatic aberration* of an *achromatic lens*. Unlike the *primary spectrum*, it causes the *image* formed in one particular *color* to lie nearest the *lens*, the images in all other colors being formed behind the first at distances that increase sharply towards both ends of the useful *wavelength spectrum*.

Spectrum, visible. The portion of the *electromagnetic spectrum* to which the retina is sensitive and by which we see. It extends from about 400 to about 750 *millimicrons* in *wavelength* of the *radiation*.

Speed, lens. That property of a *lens* which affects the illuminance of the *image*. Lens speed is specified in terms of the following expressions: *aperture ratio, numerical aperture, T-stop,* or *F-number*.

Sphere. A term commonly used to designate a *lens* with two sperical surfaces.

Sphero-cylinder. A *lens* or lens *surface* which is a combination of a *sphere* and a cylinder.

Spherometer. An instrument for the precise measurement of the radius of curvature of *surfaces*.

Spindle. A part of a *surfacing* machine. In the manufacture of *lenses* it is used as a minimum unit of production.

Spots, silver. Spots in a polished *surface* of glass which are *opaque* and have a silvery, metallic, *reflection*.

Steradian. The solid *angle* subtended at the center of a *sphere* by an area on its *surface* numerically equal to the square of the radius. The unit of solid *angular* measurement.

Stint. A term used to indicate a quantity of work or production.

Stock, bad. Glass having defects which were incurred during original manufacture.

Stone. An *opaque* inclusion in glass consisting of undissolved or crystalline material.

Stone, blue. An *edging* stone with a relatively coarse *abrasive*.

Stop. See *stop, aperture;* see *stop, field*.

Stop, aperture. The *diaphragm* which limits the size of the *aperture*.

Stop, field. A *diaphragm* used to delimit the usable field. The field stop is used to produce a sharply defined edge to the field.

Strain. Mechanical tension, compression or shear in *optical glass* by *internal stress* and brought about by improper cooling or *annealing* during manufacture of the glass or the subsequent weakening of molded parts.

Stress, internal. The tension, compression, or shear stresses within an *optical element* usually caused by cooling or improper *annealing*.

Stria. A defect in *optical glass* consisting of a sharply defined streak of transparent material having a slightly different *index of refraction* than the body of the glass.

Striae. Internal imperfections of glass appearing as wavy distortion.

Strings. Wavy transparent lines appearing as though a thread of glass had been incorporated into the sheet.

Stripe. See sleek.

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Sturm, interval of. Separation between two focal lines of an astigmatic *image*.

Surface. A term used to denote one of the exterior faces of an *optical element*. It is also used to describe the process of *grinding* or *generating* the face of an optical element.

Surface, aplanatic. A *surface* is so called, if for each of its points the sum of the *optical distance* to two fixed points on the surface has a constant value.

Surface, cementing. The *surface* of an *element* of a *compound lens* which will form the cemented interface. The curves of this interface are known as "inside curves." To facilitate cementing, the two inside curves should have a slight mismatch so that the two elements strictly contact only at the edges.

Surface, eggy. A defect in the shape of a spherical *surface* causing it to be egg shaped.

Surface, internal. Internal nonoptical surfaces of *lenses* and lens mounts, contribute largely to *flare* by light reflected from them into the *image* space. Consequently such surfaces, when so located as to contribute to flare, are finished with a dull black light-absorbing material.

Surface, ocular. That *surface* of a *lens* which is placed nearest to the *eye*.

Surface, optical. A reflecting or refracting surface that closely approximates the desired geometrical surface (see *lens; flat, optical; mirror, paraboloidal*).

Surface, Petzval. A paraboloidal *surface* on which the *image* lies in the absence of *astigmatism*.

Surface, toric. A *surface* swept out by revolving a circle about an axis that is in the plane of the circle but does not pass through its center. However, the term applied to other *aspheric* surfaces means a surface having different *curvatures* in different sections, the greatest and least *powers* occurring in meridians perpendicular to each other.

Surround. A term referring to both the *color* and intensity of the immediate environment of the *object* or *image* being viewed. In another sense, the term is a synonym to *dummy*.

Swing. The length of the oscillation of a *grinding* or *polishing lap*.

System, erecting. A system of *lenses* or *prisms*, the function of which is to produce an *erect image* which would otherwise be *inverted*. An erecting system may consist of a lens or system of lenses to reimage the *object* or of one or more prisms.

System, erecting, Abbe prism. See *prism, Abbe;* see also *system, erecting, porro prism type 2.*

System, erecting, Porro prism. A *prism* pair designed by M. Porro, in which there are four *reflections* to completely erect the *image*. Each prism has *angles* of 45° and 90°. The hypotenuse faces are parallel and may be either air-spaced or cemented. The edges at the 90° angle of the two prisms are at right angles to each other. The *line of sight* through this system is laterally displaced but not deviated. This system is generally used as an *erecting system* in *binocular* field glasses.

System, erecting, Porro prism type 1. A direct vision prism system containing two *Porro prisms* with their roof edges at right *angles*, and their hypotenuse faces parallel and opposed. This system will *invert* and *revert* the *image* (erects the image) and has the characteristic of displacing the *line of sight* laterally and vertically.

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System, erecting, Porro prism type 2. Also referred to as Abbe's modification of the Porro prism erecting system, or Abbe prism erecting system. It is a direct vision prism system which can be thought of as consisting of two pairs of 45°—90° right angle *prisms* of equal size, in which the reflecting *surfaces* in each case are the hypotenuse faces. Each pair is constructed with the 45° face of each prism opposed to the 45° face of the adjacent prism, and each hypotenuse face is rotated to deviate the *line of sight* 90°. Between the pairs, the line of sight is deviated 180° resulting in a total system deviation of 360°. In contradistinction to the type 1 system, conventionally this system is manufactured in three pieces with the second and third prisms made as one *porro prism*, or in two pieces with the first and second pieces paired, and the third and fourth pieces paired. This combination will displace the line of sight only laterally or vertically, depending on orientation.

System, lens. Two or more *lenses* arranged to work in conjunction with one another.

System, lens, centered. A *lens system* in which the *principal axes* are coincident.

System, optical. A combination of *optical components* arranged so as to perform one or more optical functions.

Systems, optical, catadioptric. An *optical system* containing both *lens* (dioptric) and curved *mirror* (catoptric) *optical components*. Occasionally, a single component may be catadioptric, serving simultaneously as a lens or mirror.

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T

Talbot. A term used to denote the *meter-kilogram-second* unit of *luminous energy* equal to ten million *lumergs;* also equal to one *lumen*-second.

Teleobjective. An *objective lens system* consisting of a positive and a negative *component* separated from each other, having such *powers* and separation that the *back focal length* of the entire system is small in comparison with the *equivalent focal length.* Such lenses are used for producing large *images* of distant *objects* without the necessity of a cumbersome length of the instrument.

Telescope. An *afocal* optical instrument containing a *system of lenses* or *mirrors,* usually but not always, having a *magnification* greater than unit, which renders distant *objects* more clearly visible by enlarging their *images* on the retina of the *eye.* Telescopes have two major uses: observing and pointing as in the measurement of *angles,* and in aiming.

Telescope, astronomical. A *telescope* which produces an inverted *image.*

Telescope, auxiliary. A small *telescope,* placed between the *eyepiece* of an optical instrument and the observer's *eye,* to increase the overall *magnification* of the *image.* This type of telescope is usually of low magnifying *power.*

Telescope, Cassegrainian. A *telescope* in which the *rays,* after *reflection* from a primary *paraboloidal mirror,* fall upon a smaller secondary *convex* hyperboloidal mirror that reflects the rays back through an opening in the center of the primary where the *image* may be examined with an *eyepiece.* This term has been broadened to include any type of secondary mirror from which the light is reflected through an opening in the primary mirror.

Telescope, collimating. A *telescope,* the mechanical axis of which, referred to the outer cylindrical surface of the tube, is coincident with its *optical axis.* In this telescope instead of an *eyepiece,* a *reticle* and generally an illuminating system replaces the *eyepiece.* This telescope provides bundles of parallel *light rays,* i.e. it *images* the reticle at *infinity.* It is generally used for optical adjustments where parallel light is necessary.

Telescope, elbow. A refracting *telescope* which bends the *line of sight* 90° by means of a *prism.*

Telescope, Gregorian. A *telescope* in which the *rays,* after *reflection* from a primary *paraboloidal mirror,* fall upon a smaller secondary *concave* ellipsoidal mirror that reflects the rays back through an opening in the center of the primary where the *image* may be examined with an *eyepiece.*

Telescope, Newtonian. A *telescope* in which the *rays,* after *reflection* from a primary *paraboloidal mirror,* fall upon a smaller plane mirror, from which the light is reflected laterally outside the tube where it can be examined with an *eyepiece.*

Telescope, panoramic. A *telescope* so designed that the *image* remains erect and the position of the *eyepiece* is unchanged as the *line of sight* is pointed in any horizontal direction.

Telescope, terrestrial. A *telescope* which produces an *erect,* or natural, *image.*

Temperature, color. The temperature of a *blackbody* that emits light of the same *color* as the body in question. Color temperature is expressed in degrees Kelvin.

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Temperature, luminance. The temperature of an *ideal blackbody* that would have the same *luminance* as the source in question for some narrow spectral region.

Temperature, radiation, total. The temperature at which a *blackbody* radiates a total amount of *flux* equal to that radiated by the body under consideration.

Test, Hartman. A test for *spherical abberation*, departure from the sine condition, or *coma* in which *incident rays* from a point source are isolated by means of small holes in a disk positioned in front of the *lens* or *mirror* under test. The *focal points* of the rays entering the lens or mirror at varying heights are then compared in the *image* space.

Test, knife edge, Foucault. A method of determining the errors in an *image* of a point source by partially occluding the light from an image by means of a knife edge. The same test may be used to measure the errors in refracting or reflecting *surfaces*.

Theory, electromagnetic. The theory of propagation of energy by combined electric and magnetic fields embodied in Maxwell's equations.

Thickness, center. The thickness of a *lens* measured at the optical field.

Threshold, luminance. A contraction of the term *threshold, luminance, absolute.*

Threshold, luminance, absolute. A term used to indicate the lowest limit of *luminance* necessary for vision.

T-number. The equivalent f-number of a fictitious *lens* that has a circular opening and 100 percent *transmittance*, and that gives the same central illumination as the actual lens under consideration.

$$\text{T number} = \frac{\text{E. F. L.}}{\text{Diameter of T-stop}}$$

or

$$\text{T number} = \frac{\text{E. F. L.}}{2} \sqrt{\frac{\pi}{At}}$$

where E. F. L. is the *equivalent focal length*, A is the area of the *entrance pupil* and t is the *transmittance* of the *lens system*.

Tolerance, figure. The allowable deviation from the specified *figure* or geometrical form. It may be defined in terms of *fringes* or *wavelength*.

Tolerance, wedge. A means of specifying the allowable *edge thickness difference* or *decentering* of a *lens*.

Tool, blocking. An instrument for supporting optical parts to be cemented to it, or mounted in plaster.

Tool, grinding. *Laps* of cast iron or other suitable material used with a slurry or silicon carbide, aluminum oxide, or emery, for *grinding optical surfaces*.

Tool, radius. A metal instrument of *convex* or *concave curvature* to which *lens* castings or semifinished lenses are cemented with only their edges in contact with the instrument.

Tool, spotted. A metal instrument for holding a *block* of *lenses* in which seats for one *surface* of the lenses have been formed, and to which the lenses are cemented. These tools have the advantage of not requiring blocking plaster, are permanent, and prevent distortion of the finished surface.

Toric, side first. A term used to refer to the process of *grinding* the *toric surface* of a single vision *spherocylindrical lens*.

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Toric, side, second. A term used to refer to the process of *grinding* the *concave surface* of a *sphero-cylindrical lens.*

Transmission. The process of conduction of *radiant energy* through a *medium.*

Transmission, selective. See *absorption, selective.*

Transmissivity. The *internal transmittance* for unit thickness of a nondiffusing substance.

Transmittance. The ratio of the *flux* transmitted by an *object* to the *incident flux.* This term and its specializations are applied to *radiant* and to *luminous flux.* Unless qualified, the term applied to regular (specular) transmission.

Transmittance, diffuse. The *transmittance* measured with diffusely *incident flux.* Also, the ratio of the *flux* diffusely transmitted in all directions to the total incident flux.

Transmittance, internal. The ratio of the *flux* transmitted to the second surface of a *medium* to the corresponding flux that has just passed through the first surface, i.e. the *transmittance* from the first *surface* to the second surface. Internal transmittances does not include the effects due to interreflection between the two surfaces.

Transmittance, luminous. The ratio of the *luminous flux transmitted* by an *object* to the incident luminous flux.

Transmittance, radiant. The ratio of the *radiant flux* transmitted by an *object* to the incident radiant flux.

Transmittance, selective. The property of variation of *transmittance* with *wavelength.*

Transmittance, spectral. *Transmittance* evaluated at one or more *wavelengths.* Numerically the same for *radiant* and *luminous flux.*

Transmittancy. The ratio of the *transmittance* of a solution to that of an equal thickness of the solvent.

Transposition. Changing the relative curves of a *lens* without changing its refractive value.

Travel, horizontal. A term used to denote the rotation of an instrument (or the *line of sight* of an optical instrument) in a horizontal plane; traverse.

Treating, heat. The process of subjecting glass to temperature cycling to induce physico-chemical reactions which change the properties (see *annealing, case hardening, compacting*).

Triplet. A *three-lens component* of an *optical system* which may or may not be cemented.

Truing. The process of making a *surface* to conform accurately to a required curvature.

T-stop. The equivalent, perfectly transmitting, circular opening of diameter D such that

$$\pi \left(\frac{D}{2}\right)^2 = tA$$

where A is the area of the *entrance pupil* of the *objective* and where t is the *transmittance* of the *lens system.*

Type, invert. The type of *image* observed in certain *coincidence rangefinders.* When in *coincidence,* the upper half *image* appears to be the mirrored *reflection* of the lower half image.

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U

Ultraviolet. Those *rays* of *radiant energy* immediately beyond the violet ends of the visible *spectrum* and in of the order of 390 to 100 *millimicrons*.

Unblocking. The process of removing *optical elements* from a *block*.

Uncut. A term applying to *lenses* with both *surfaces* finished but not yet cut to any shape.

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V

Value, nu. A term for *constant, Abbe.*

Value, vee. A term for *constant, Abbe.*

Vector, electric. A term referring to the electric field associated with an electromagnetic *wave* and hence with a light wave. The electric vector specifies the direction and amplitude of this electric field.

Vertex. The point of intersection of the *optical axis* with any *optical surface.*

View, field of. In general, the maximum cone or fan of *rays* passed by an *aperture* and measured at a given *vertex.* In an instrument, field of view is synonymous with *true field.*

Vignetting. A term used to denote the loss of light through an *optical element* due to the entire bundle not passing through.

Vision, binocular. The simultaneous use of both *eyes* in the process of vision.

Vision, distinct, distance of. The near-point distance of the normal *eye* conventionally given the value of 10 inches or 25 *centimeters.* This value is used in calculating the designated *magnification* of a simple *magnifier* or *eyepiece.*

Vision, double. A malfunction of a *binocular* instrument causing two *images* to be seen separately instead of being fused. It is caused by the *optical axes* of the two *telescopes* not being parallel. In minor cases, the *eyes* will adjust themselves to compensate for the error of the instrument until the images are superimposed and only one *object* is seen (see *dipvergence* and *divergence*).

Vision, stereoscopic. Vision in depth of three dimensions due to the spacing of the *eyes.* This spacing permits the eyes to see *objects* from slightly different points of view.

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W

Wash. In a cemented surface a streak appearing as a striation caused by *index of refraction* variations in the cement.

Watch, lens. A dial depth gage graduated in *diopters*.

Wave. Vibration; a form of movement by which all *radiant energy* of the *electromagnetic spectrum* is assumed to travel. It is also used to denote a type of *surface* defect, usually due to improper *polishing*.

Wavefront. A surface *normal* to a bundle of *rays* as they proceed from a source. The wavefront passes through those parts of the *waves* which are in the same phase. For parallel raps, the wavefront is a plane; for rays diverging from or converging toward a point, the wavefront is spherical.

Wavelength. The length of a *wave* measured from any point on one wave to the corresponding point on the next wave; usually measured from crest to crest. Wavelength determines the nature of the various forms of *radiant energy* which comprise the *electromagnetic spectrum;* it determines the *color* of light.

Wedge. A *prism* with a very small *angle* between the refracting *surfaces*. Wedges may be circular, oblong, or square in outline.

Wedge, correction. In *rangefinders* and heightfinders, a rotatable or sliding wedge-shaped element used to divert the *line of sight* in a precise manner in order to correct errors in the *optical system* caused by temperature variation or any other errors of *collimation*.

Wedge, measuring. A *wedge* in a *rangefinder* or *heightfinder* to displace the *image formed* by one *telescope*, so that it coincides with that formed by the other telescope, thus affording a measurement of the *parallactic angle* between the *line of sight* of the two telescopes. There are two principal types of measuring wedges. The sliding wedge is mounted on slides parallel to the *optical axis*, between the *objective lens* of one telescope, and its *focal plane*. It produces an *image* displacement equal to the product of the deviation of the wedge multiplied by its distance from the focal plane. Compensating wedges rotate simultaneously through equal *angles* in opposite directions. The pair of equal compensating wedges, which is mounted in front of one telescope, is equal to a wedge having a variable *angle of deviation* in the plane of triangulation, but none at right angles to it.

Wedge, rotating. A circular optical wedge (*prism* of small refracting *angle*) mounted to be rotated in the path of *light rays* to divert the *line of sight* to a limited degree (see *wedge, correction, wedge, measuring*).

Width, face. (of a bevel). The actual width of a *bevel* rather than its width projected along the *aperture* of the *lens*.

Width, segment. The lateral measurement of a *multifocal segment* at its greatest width.

Window. A piece of glass with plane parallel *surfaces* used to admit light into an optical instrument, and to exclude dirt and moisture.

Window, correction. Optical *wedges* of very small *angles*. They admit light, seal out dirt and moisture, and are so mounted that they may be rotated to compensate for the accumulated errors in the entire system. Two are used as end windows on some *rangefinders*.

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Z

Zones. Concentric *waves* in a polished *surface* which appear as zones in the *Newton's rings* when a *test glass* is applied to the surface.

Zylene. Fluid used to aid inspection of semifinished *blanks*.

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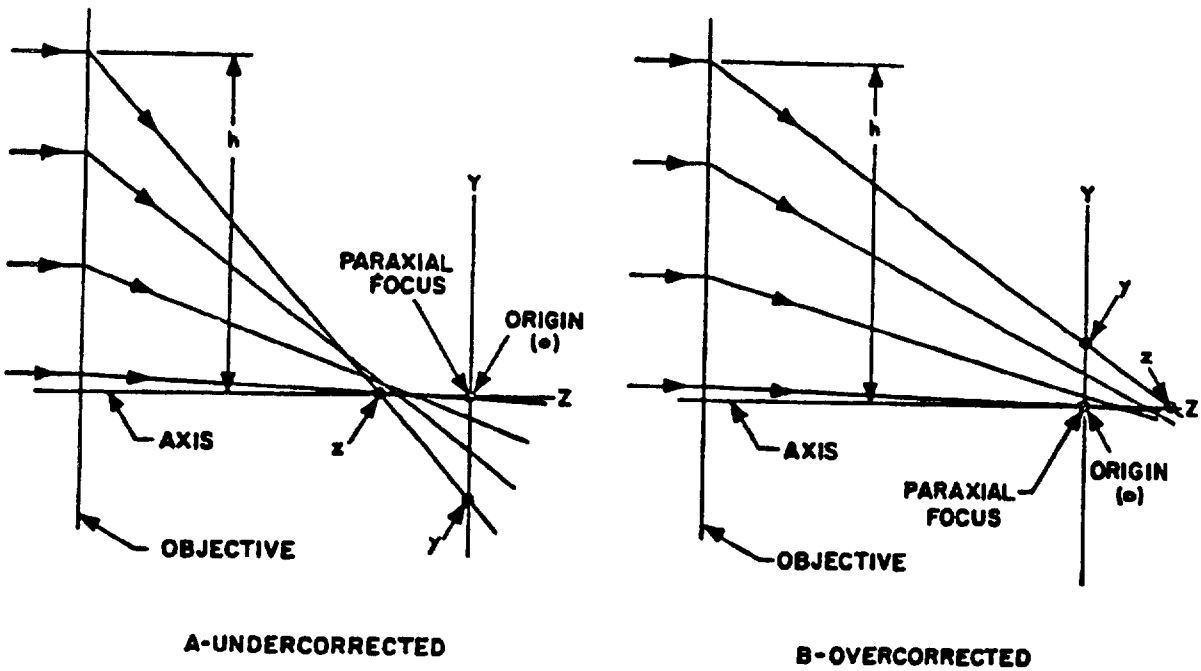

FIGURE 1. *Diagram illustrating spherical aberration.*

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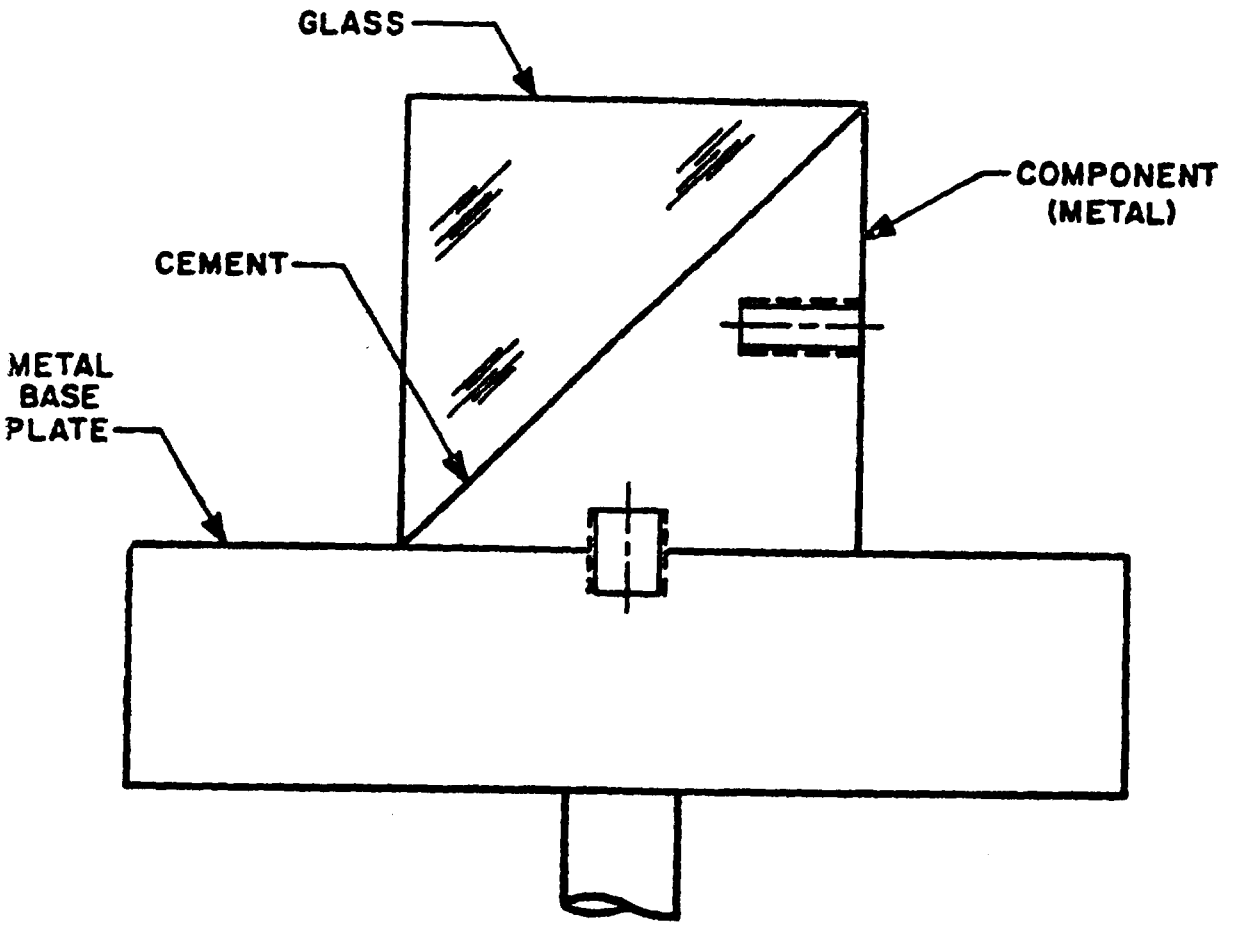

FIGURE 2. *A typical component.*

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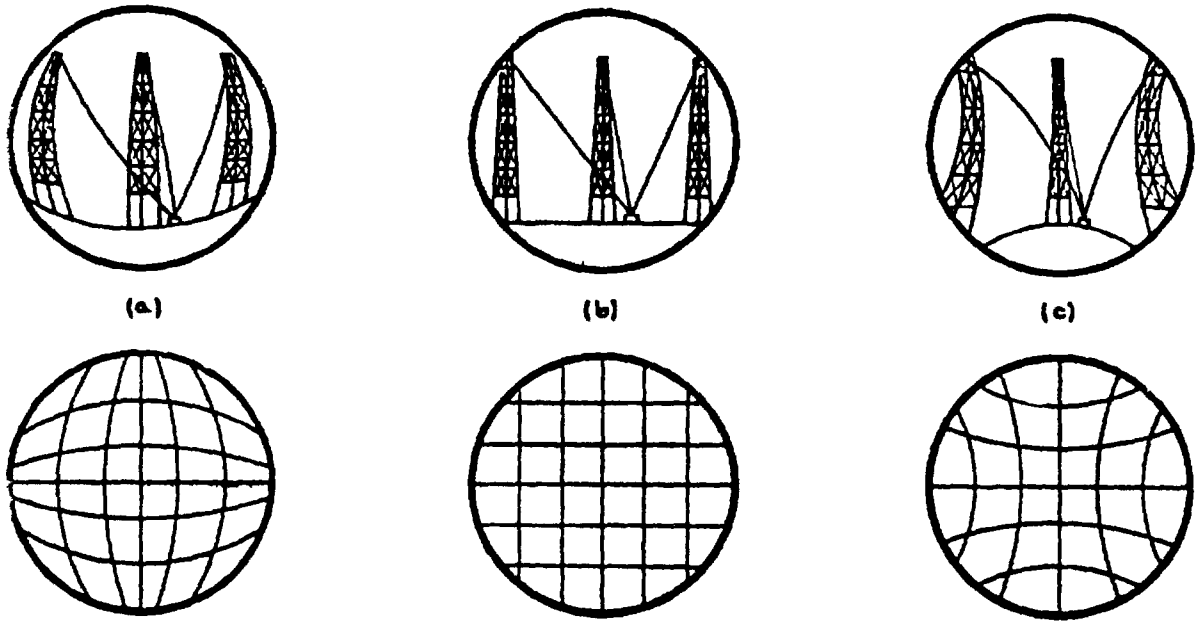

(a). IMAGE HAS BARREL OR NEGATIVE DISTORTION
(b). IMAGE IS FREE FROM DISTORTION
(c). IMAGE HAS CUSHION OR POSITIVE DISTORTION

FIGURE 3. *Images formed by a lens.*

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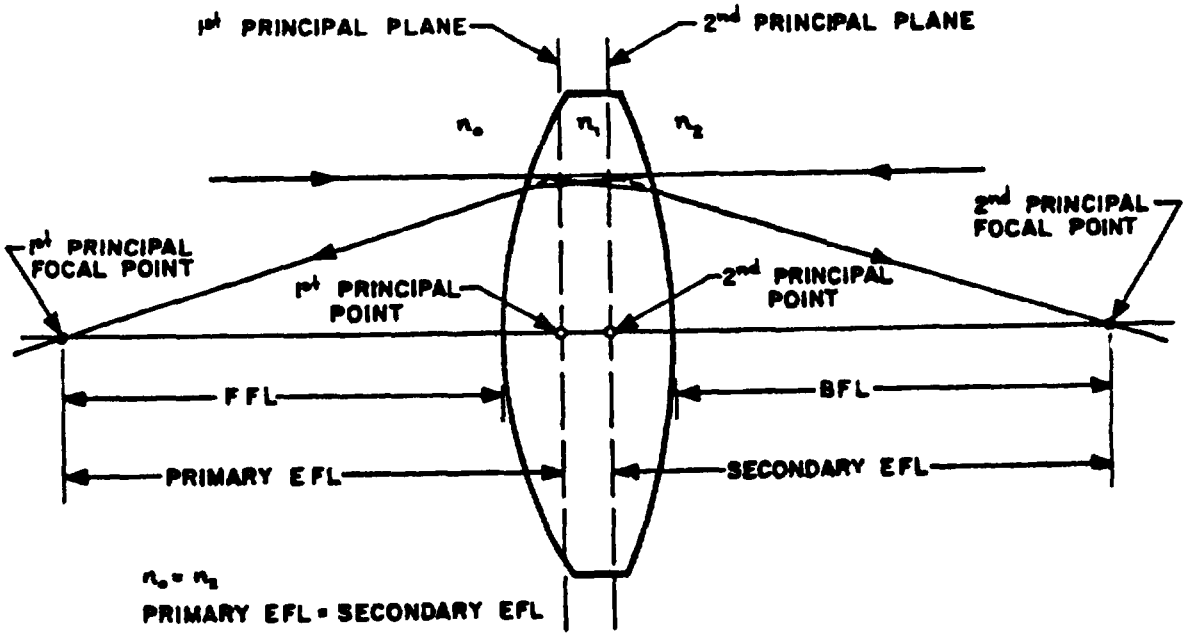

FIGURE 4. *Focal lengths, principal points, and principal planes.*

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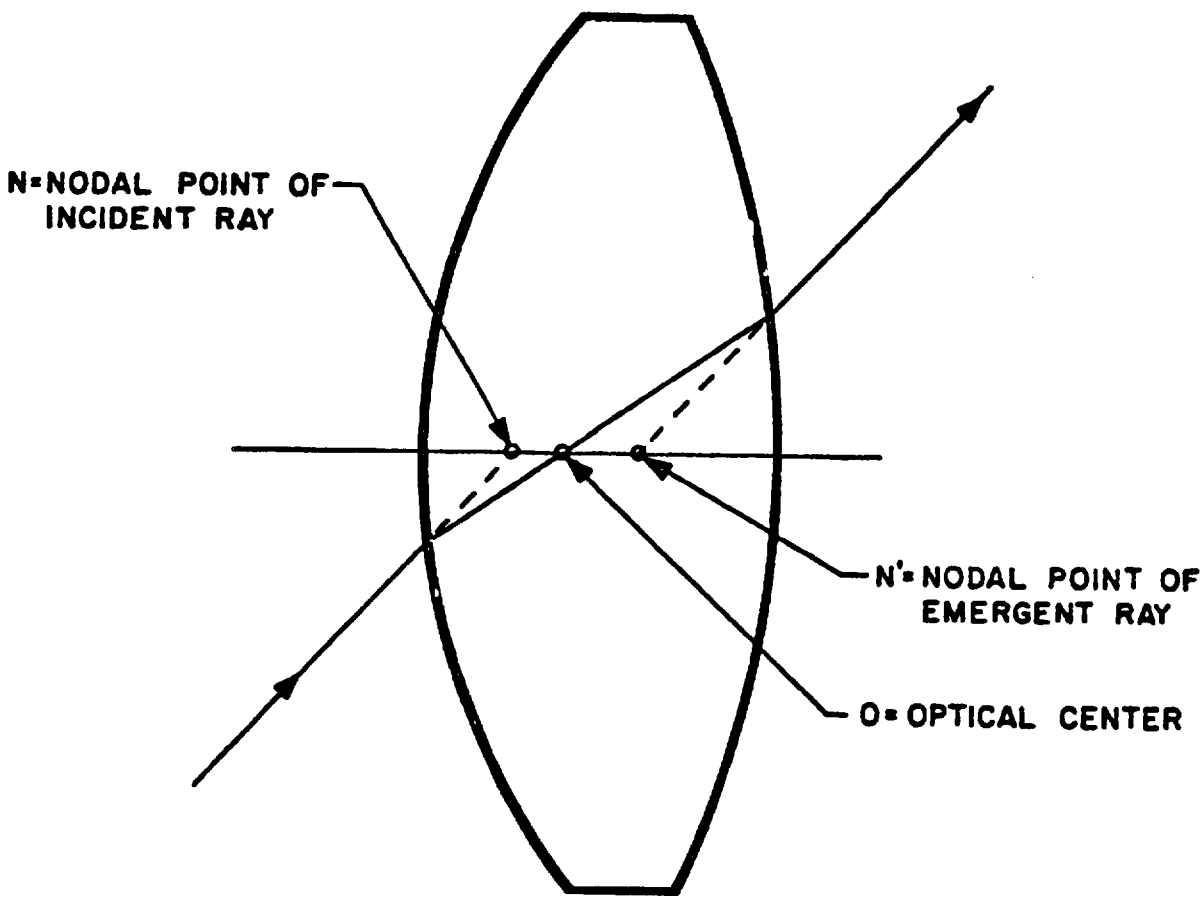

FIGURE 5. *Illustration of nodal points.*

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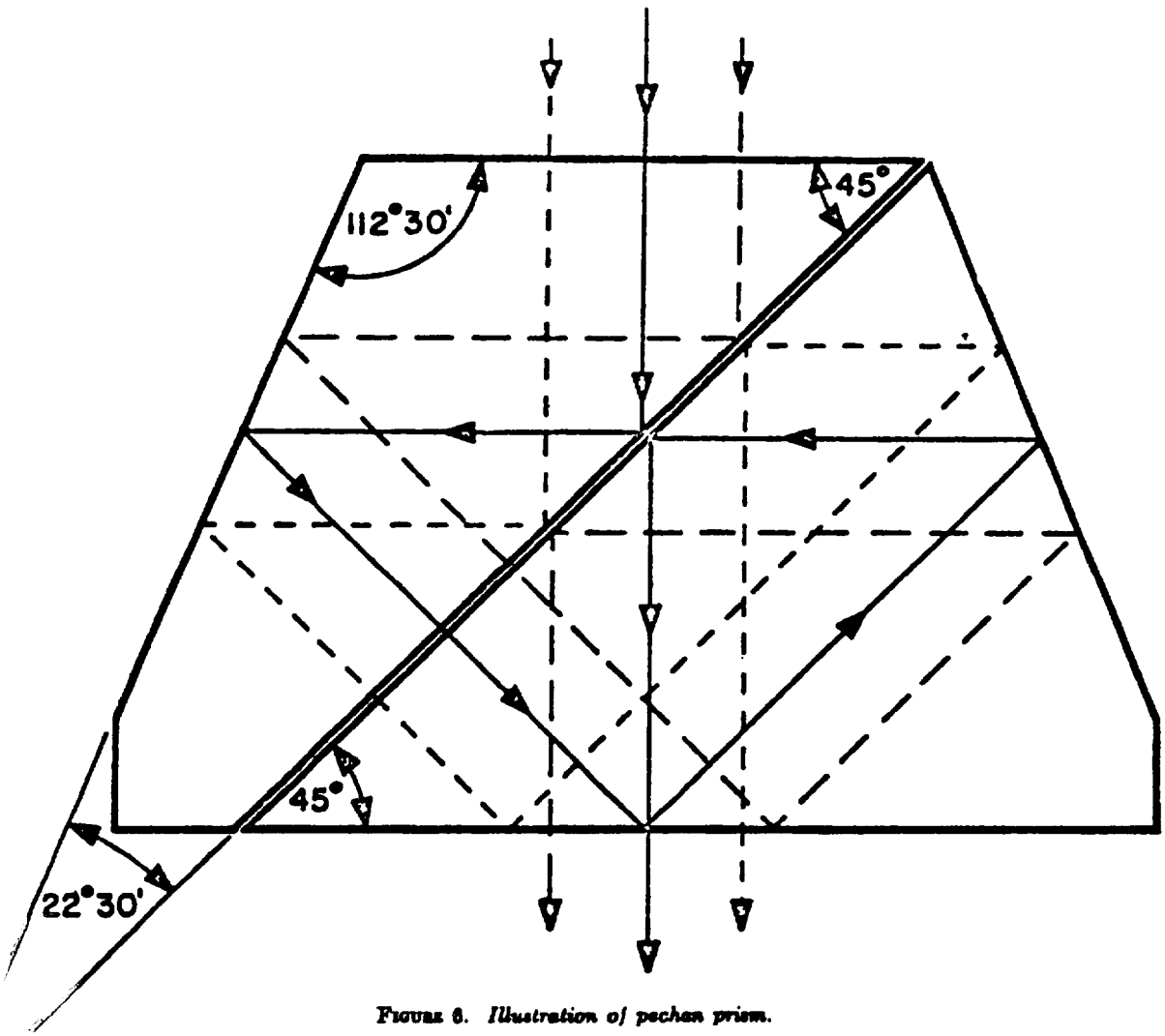

FIGURE 6. *Illustration of pechan prism.*

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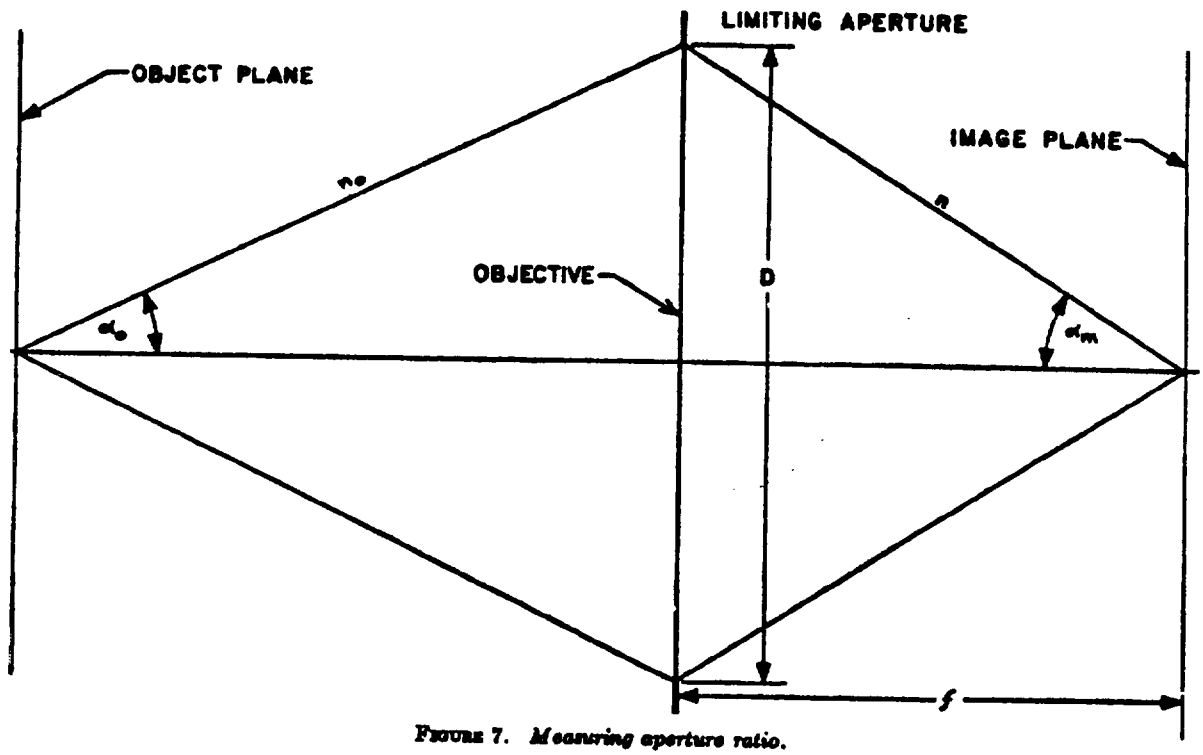

FIGURE 7. *Measuring aperture ratio.*

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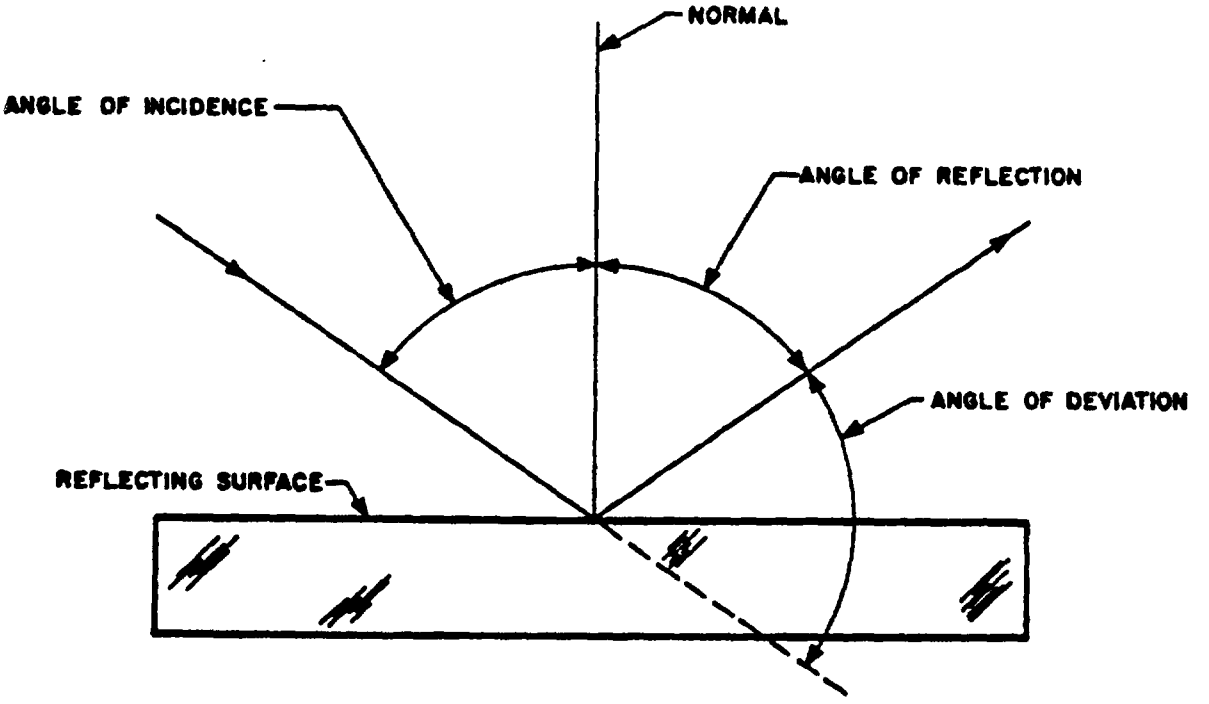

FIGURE 8. *Illustration of angle of reflection.*

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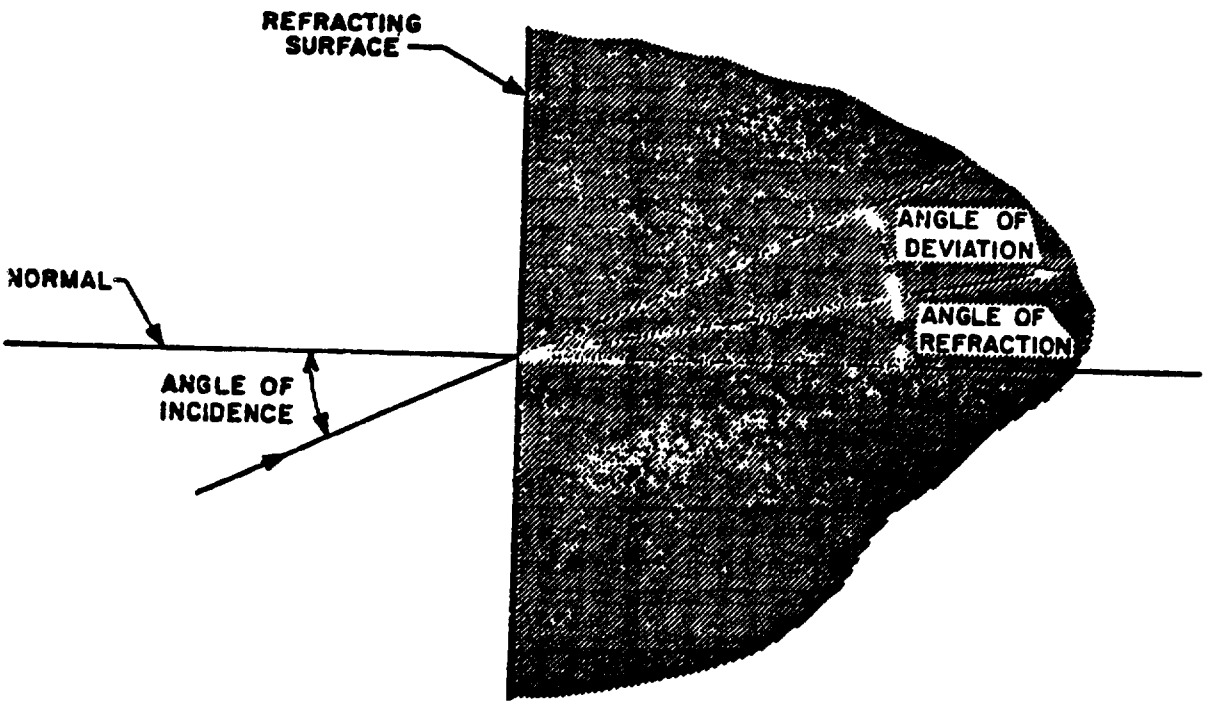

FIGURE 9. *Illustration of angle of refraction.*

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