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DATABOOK FOR HUMAN FACTORS ENGINEERS

VOLUME II: COMMON FORMULAS, METRICS, DEFINITIONS

Prepared by
MAN FACTORS, INC.

Prepared under
Contract NAS2-5298, November 1969

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DATABOOK FOR HUMAN FACTORS ENGINEERS

VOLUME II: COMMON FORMULAS, METRICS, DEFINITIONS

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Prepared Under
Contract NAS2-5298

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VOLUME II

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DATABOOK FOR
HUMAN FACTORS ENGINEERS

VOLUME II

COMMON FORMULAS, METRICS

AND DEFINITIONS

FOREWORD

As indicated in the Foreword to Volume I, the information contained in this handbook represents data most often used by practicing human factors specialists, as determined by survey of a group of the leading practitioners of human engineering. The purpose of this handbook is to provide a convenient method for taking the most used reference information directly to a job remote from the specialist's regular bookshelf. Although it is recognized that no such collection will be as complete as desired by all users, every effort has been made to include as many topics as feasible within the space limitations of a handbook. The included materials have been taken directly from many sources, and in a few cases represent original data.

Volume I of the two-volume series contains typical human engineering data useful in determining optimum design characteristics of equipment operated or maintained by human operators and/or maintenance personnel.

Volume II contains formulas, nomographs, metrics, conversion tables, symbols, definitions and abbreviations and acronyms that may be rquired at some time during the project activities of typical human engineering specialists. This information, although available from other sources, often requires that the human engineer search through numerous texts, handbooks, specifications and guides in order to find what he needs.

It is hoped that by providing this information in a more convenient form the human engineer will find his job simplified. These volumes are not intended to teach, hence provide little text.

Suggestions for revisions are solicited and should be sent to Mr. Charles Kubokawa, Man-Machine Integration Branch, NASA-Ames Research Center, Moffett Field, California, 94035.

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REVISION SUGGESTION FORM

TO : Mr. Charles Kubokawa
Man-Machine Integration Branch
NASA-Ames Research Center
Moffett Field, Calif., 94035

FROM: Name ______________________

Affiliation ______________________

Address ______________________

Phone ______________________

SUGGESTIONS: Please be as specific as possible. Identify or provide copy of suggested new material. Give specific address as to where material could be acquired. If errors are found, identify by page and paragraph, figure or table title. Be explicit about suggested changes and provide citations or rationale for suggestions.

(Please attach new material to this page)

Section 1

USEFUL FORMULAS AND NOMOGRAMS

Section 1

USEFUL FORMULAS AND NOMOGRAMS

This section contains a selection of formulas and nomograms from the fields of mathematics, physics, chemistry and statistics. There are a great many more nomograms and nomographs available in the literature (and particularly in such trade journals as DESIGN NEWS), however most of those looked at and omitted dealt with detailed design aspects of engineering which the human engineer would not ordinarily be expected to become involved with.

There is, of course, a virtually limitless supply of mathematical formulas and tables from which to choose -- a fact which does not make the selection problem an easy one. Here again it was necessary to take a strictly pragmatic approach. Those finally included represent a composite of judgments -- those of the authors and reviewers.

Since material was derived from many sources it is impossible to give credit to them all. However, we wish to acknowledge in particular our gratitude to the editorial staff of The Chemical Rubber Company, publishers of the universally known and respected HANDBOOK OF CHEMISTRY AND PHYSICS for their permission to use many of the mathematical formulas contained therein. Our thanks also, as mentioned earlier, to the Cahners Publishing Company, publishers of DESIGN NEWS for permission to reproduce many of the nomograms which first appeared in that publication. These appear in this section and in Section 2, principally.

Readers not already fam[illegible]ar with it are urged to consult the following volume (referred to above) for hundreds of additional useful formu[illegible]

Handbook of Chemi[illegible] [illegible]ysics
Chemical Rubber Pu[illegible] Company
18901 Cranwood Parkway
Cleveland, Ohio 44128

ALGEBRA

SUMS OF NUMBERS

The sum of the first n numbers, —

$$\Sigma(n) = 1 + 2 + 3 + 4 + 5 \ldots\ldots + n = \frac{n(n+1)}{2}$$

The sum of the squares of the first n numbers,

$$\Sigma(n^2) = 1^2 + 2^2 + 3^2 + 4^2 + 5^2 \ldots + n^2 = \frac{n(n+1)(2n+1)}{6}$$

The sum of the cubes of the first n numbers,

$$\Sigma(n^3) = 1^3 + 2^3 + 3^3 + 4^3 + 5^3 \ldots\ldots + n^3 = \frac{n^2(n+1)^2}{4}$$

ARITHMETICAL PROGRESSION

If a is the first term; l, the last term; d, the common difference; n, the number of terms and s, the sum of n terms, —

$$l = a + (n-1)d$$

$$s = \frac{n}{2}(a + l)$$

$$s = \frac{n}{2}\left\{2a + (n-1)d\right\}$$

GEOMETRICAL PROGRESSION

If a is the first term; l, the last term; r, the common ratio; n, the number of terms and s, the sum of n terms, —

$$l = ar^{n-1} \qquad s = a\frac{(1-r^n)}{1-r}$$

$$s = a\frac{(r^n-1)}{r-1} \qquad s = \frac{lr-a}{r-1}$$

If n is infinity and r^2 less than unity, —

$$s = \frac{a}{1-r}$$

PERMUTATIONS

If M denote the number of permutations of n things taken p at a time, —

$$M = n(n-1)(n-2)\ldots\ldots(n-p+1)$$

COMBINATIONS

If M denote the number of combinations of n things taken p at a time, —

$$M = \frac{n(n-1)(n-2)\ldots\ldots(n-p+1)}{p!}$$

$$M = \frac{n!}{p!(n-p)!}$$

ALGEBRA

QUADRATIC EQUATIONS

Any quadratic equation may be reduced to the form, —

$$ax^2 + bx + c = 0.$$

Then $x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}.$

If $b^2 - 4ac$ is positive the roots are real and unequal.
If $b^2 - 4ac$ is zero the roots are real and equal.
If $b^2 - 4ac$ is negative the roots are imaginary and unequal.
If $b^2 - 4ac$ is a perfect square the roots are rational and unequal.

CUBIC EQUATIONS

A cubic equation, $y^3 + py^2 + qy + r = 0$ may be reduced to the form, —

$$x^3 + ax + b = 0$$

by substituting for y the value, $x - \dfrac{p}{3}$. Here

$$a = \tfrac{1}{3}(3q - p^2) \text{ and } b = \tfrac{1}{27}(2p^3 - 9pq + 27r).$$

For solution let, —

$$A = \sqrt[3]{-\frac{b}{2} + \sqrt{\frac{b^2}{4} + \frac{a^3}{27}}}, \qquad B = \sqrt[3]{-\frac{b}{2} - \sqrt{\frac{b^2}{4} + \frac{a^3}{27}}},$$

then the values of x will be given by,

$$x = A + B, \quad -\frac{A+B}{2} + \frac{A-B}{2}\sqrt{-3}, \quad -\frac{A+B}{2} - \frac{A-B}{2}\sqrt{-3}.$$

If $\dfrac{b^2}{4} + \dfrac{a^3}{27} > 0$, there will be one real root and two conjugate imaginary roots.

If $\dfrac{b^2}{4} + \dfrac{a^3}{27} = 0$, there will be three real roots of which at least two are equal.

If $\dfrac{b^2}{4} + \dfrac{a^3}{27} < 0$, there will be three real and unequal roots.

In the last case a trigonometric solution is useful. Compute the value of the angle ϕ in the expression, —

$$\cos \phi = \sqrt{\frac{b^2}{4} \div \left(-\frac{a^3}{27}\right)},$$

then x will have the following values:—

$$\mp 2\sqrt{-\frac{a}{3}} \cos \frac{\phi}{3}, \qquad \mp 2\sqrt{-\frac{a}{3}} \cos\left(\frac{\phi}{3} + 120^\circ\right),$$
$$\mp 2\sqrt{-\frac{a}{3}} \cos\left(\frac{\phi}{3} + 240^\circ\right).$$

ALGEBRA

APPROXIMATIONS

If a and b are small quantities, the following relations are approximately true,—

$$(1 \pm a)^m = 1 \pm ma,$$

$$(1 \pm a)^m (1 \pm b)^n = 1 \pm ma \pm nb.$$

If n is nearly equal to m,

$$\sqrt{mn} = \frac{n+m}{2}, \text{ approximately.}$$

If θ is a very small angle expressed in radians,—

$$\frac{\sin\theta}{\theta} = 1 \text{ and } \frac{\tan\theta}{\theta} = 1, \text{ approximately.}$$

SERIES

The expression in parentheses following certain of the series indicates the region of convergence. If not otherwise indicated it is to be understood that the series converges for all finite values of x.

BINOMIAL

$$(x+y)^n = x^n + nx^{n-1}y + \frac{n(n-1)}{2!}x^{n-2}y^2 + \dots$$

$$+\frac{n(n-1)(n-2)}{3!}x^{(n-3)}y^3 \dots + y^n \dots\dots (y^2 < x^2)$$

$$(1 \pm x)^n = 1 \pm nx + \frac{n(n-1)x^2}{2!} \pm \frac{n(n-1)(n-2)x^3}{3!} + \dots \text{etc.} \qquad (x^2 < 1)$$

$$(1 \pm x)^{-n} = 1 \mp nx + \frac{n(n+1)x^2}{2!} \mp \frac{n(n+1)(n+2)x^3}{3!} + \dots \text{etc.} \qquad (x^2 < 1)$$

$$(1 \pm x)^{-1} = 1 \mp x + x^2 \mp x^3 + x^4 \mp x^5 + \dots \qquad (x^2 < 1)$$

$$(1 \pm x)^{-2} = 1 \mp 2x + 3x^2 \mp 4x^3 + 5x^4 \mp 6x^5 + \dots \qquad (x^2 < 1)$$

TAYLOR'S SERIES

$$f(x+h) = f(x) + hf'(x) + \frac{h^2}{2!}f''(x) + \frac{h^3}{3!}f'''(x) + \dots$$

$$= f(h) + xf'(h) + \frac{x^2}{2!}f''(h) + \frac{x^3}{3!}f'''(h) + \dots$$

MACLAURIN'S SERIES

$$f(x) = f(o) + xf'(o) + \frac{x^2}{2!}f''(o) + \frac{x^3}{3!}f'''(o) + \dots$$

EXPONENTIAL

$$e = 1 + \frac{1}{1} + \frac{1}{2!} + \frac{1}{3!} + \frac{1}{4!} + \dots$$

$$e^x = 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \frac{x^4}{4!} + \dots$$

$$a^x = 1 + x\log a + \frac{(x\log a)^2}{2!} + \frac{(x\log a)^3}{3!} + \dots$$

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ALGEBRA

LOGARITHMIC

$$\log_e x = \frac{x-1}{x} + \frac{1}{2}\left(\frac{x-1}{x}\right)^2 + \frac{1}{3}\left(\frac{x-1}{x}\right)^3 + \dots \qquad (x > \tfrac{1}{2})$$

$$\log_e x = (x-1) - \tfrac{1}{2}(x-1)^2 + \tfrac{1}{3}(x-1)^3 - \dots \qquad (2 > x > 0)$$

$$\log_e x = 2\left[\frac{x-1}{x+1} + \frac{1}{3}\left(\frac{x-1}{x+1}\right)^3 + \frac{1}{5}\left(\frac{x-1}{x+1}\right)^5 + \dots\right] \qquad (x > 0)$$

$$\log_e(1+x) = x - \tfrac{1}{2}x^2 + \tfrac{1}{3}x^3 - \tfrac{1}{4}x^4 + \dots \qquad (-1 < x < 1)$$

$$\log_e(n+1) - \log_e(n-1) = 2\left[\frac{1}{n} + \frac{1}{3n^3} + \frac{1}{5n^5} + \dots\right]$$

$$\log_e(a+x) = \log_e a + 2\left[\frac{x}{2a+x} + \frac{1}{3}\left(\frac{x}{2a+x}\right)^3 + \frac{1}{5}\left(\frac{x}{2a+x}\right)^5 + \dots\right]$$
$$(a > 0,\ -a < x < +\infty)$$

TRIGONOMETRIC

$$\sin x = x - \frac{x^3}{3!} + \frac{x^5}{5!} - \frac{x^7}{7!} + \dots$$

$$\cos x = 1 - \frac{x^2}{2!} + \frac{x^4}{4!} - \frac{x^6}{6!} + \dots$$

$$\tan x = x + \frac{x^3}{3} + \frac{2x^5}{15} + \frac{17x^7}{315} + \frac{62x^9}{2835} + \dots \quad \left(x^2 < \frac{\pi^2}{4}\right)$$

$$\sin^{-1} x = x + \frac{x^3}{6} + \frac{1}{2}\cdot\frac{3}{4}\cdot\frac{x^5}{5} + \frac{1}{2}\cdot\frac{3}{4}\cdot\frac{5}{6}\cdot\frac{x^7}{7} + \dots \qquad (x^2 < 1)$$

$$\tan^{-1} x = x - \tfrac{1}{3}x^3 + \tfrac{1}{5}x^5 - \tfrac{1}{7}x^7 + \dots \qquad (x^2 < 1)$$

$$= \frac{\pi}{2} - \frac{1}{x} + \frac{1}{3x^3} - \frac{1}{5x^5} + \dots \qquad (x^2 > 1)$$

$$\log_e \sin x = \log_e x - \frac{x^2}{6} - \frac{x^4}{180} - \frac{x^6}{2835} - \dots \qquad (x^2 < \pi^2)$$

$$\log_e \cos x = -\frac{x^2}{2} - \frac{x^4}{12} - \frac{x^6}{45} - \frac{17x^8}{2520} - \dots \qquad \left(x^2 < \frac{\pi^2}{4}\right)$$

$$\log_e \tan x = \log_e x + \frac{x^2}{3} + \frac{7x^4}{90} + \frac{62x^6}{2835} + \dots \qquad \left(x^2 < \frac{\pi^2}{4}\right)$$

$$e^{\sin x} = 1 + x + \frac{x^2}{2!} - \frac{3x^4}{4!} - \frac{8x^5}{5!} + \frac{3x^6}{6!}$$

$$e^{\cos x} = e\left(1 - \frac{x^2}{2!} + \frac{4x^4}{4!} - \frac{31x^6}{6!} + \dots\right)$$

$$e^{\tan x} = 1 + x + \frac{x^2}{2!} + \frac{3x^3}{3!} + \frac{9x^4}{4!} + \frac{37x^5}{5!} + \dots \quad \left(x^2 < \frac{\pi^2}{4}\right)$$

MENSURATION FORMULAE

PLAIN FIGURES BOUNDED BY STRAIGHT LINES

The **area of a triangle** whose base is b and altitude h

$$= \frac{hb}{2}.$$

The area of a **triangle** with angles A, B, and C and sides opposite a, b, and c, respectively

$$= \tfrac{1}{2}ab \sin C.$$

or

$$= \sqrt{s(s-a)(s-b)(s-c)},$$

where $s = \frac{1}{2}(a + b + c)$.

A **rectangle** with sides a and b has an area $= ab$.

The area of a **parallelogram** with side b and the perpendicular distance to the parallel side h

$$= bh.$$

The area of a **parallelogram** with sides a and b and the included angle θ

$$= ab \sin \theta.$$

The area of a **rhombus** with diagonals c and d,

$$= \tfrac{1}{2}cd.$$

The area of a **trapezoid** whose parallel sides are a and b and altitude h

$$= \tfrac{1}{2}(a + b)h.$$

The area of any **quadrilateral** with diagonals c and b and the angle between them θ

$$= \tfrac{1}{2}ab \sin \theta.$$

The area of a **regular polygon** with n sides, each of length l,

$$= \tfrac{1}{4}nl^2 \cot \frac{180}{n}.$$

For a regular polygon of n sides, each side of length l, the radius of the **inscribed circle**,

$$= \frac{l}{2} \cot \frac{180}{n}.$$

The radius of the **circumscribed circle**,

$$= \frac{l}{2} \operatorname{cosec} \frac{180}{n}.$$

MENSURATION FORMULAE

AREA, RADIUS OF INSCRIBED AND CIRCUMSCRIBED CIRCLES FOR REGULAR POLYGONS

l = length of one side

Name	Number of sides	Area	Radius of inscribed circle	Radius of circumscribed circle
Triangle, equilateral......	3	$0.43301l^2$	$0.28867l$	$0.57735l$
Square	4	$1.00000l^2$	$0.50000l$	$0.70710l$
Pentagon	5	$1.72048l^2$	$0.68819l$	$0.85065l$
Hexagon................	6	$2.59808l^2$	$0.86602l$	$1.0000l$
Heptagon	7	$3.63391l^2$	$1.0383l$	$1.1523l$
Octagon................	8	$4.82843l^2$	$1.2071l$	$1.3065l$
Nonagon.	9	$6.18182l^2$	$1.3737l$	$1.4619l$
Decagon...............	10	$7.69421l^2$	$1.5388l$	$1.6180l$
Undecagon..............	11	$9.36564l^2$	$1.7028l$	$1.7747l$
Dodecagon.............	12	$11.19615l^2$	$1.8660l$	$1.9318l$

Radius of circle inscribed in any triangle, whose sides are a, b, and c, where $s = \frac{1}{2}(a + b + c)$

$$= \frac{\sqrt{s(s-a)(s-b)(s-c)}}{s}.$$

The radius of the **circumscribed** circle

$$= \frac{abc}{4\sqrt{s(s-a)(s-b)(s-c)}}.$$

The **perimeter of a polygon inscribed in a circle** of radius r, where n is the number of sides,

$$= 2nr \sin\frac{\pi}{n}. \qquad (\pi \text{ radians} = 180°)$$

The area of the **inscribed** polygon,

$$= \tfrac{1}{2}nr^2 \sin\frac{2\pi}{n}.$$

The perimeter of a polygon circumscribed about a circle of radius r, number of sides n

$$= 2nr \tan\frac{\pi}{n}.$$

The area of the **circumscribed** polygon

$$= nr^2 \tan\frac{\pi}{n}.$$

MENSURATION FORMULAE

PLANE FIGURES BOUNDED BY CURVED LINES

The **circumference of a circle** whose radius is r and diameter $d (d = 2r)$

$$= 2\pi r = \pi d. \qquad (\pi = 3.14159)$$

The **area of a circle**

$$= \pi r^2 = \tfrac{1}{4}\pi d^2 = .7854 d^2.$$

The **length of an arc** of a circle for an arc of θ degrees

$$= \frac{\pi r \theta}{180}$$

NOTE—In this and following similar formulae r denotes the radius of the circle, (OC, Fig. 1).

For an arc of θ radians the length

$$= r\theta.$$

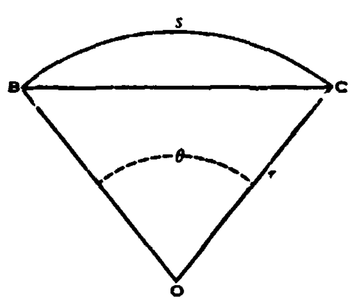


Fig. 1

The **length of a chord** subtending an angle θ

$$= 2r \sin \tfrac{1}{2}\theta.$$

The **area of a sector** where θ is the angle between the radii in degrees

$$= \frac{\pi r^2 \theta}{360}.$$

If s is the length of the arc, the area of the sector

$$= \frac{sr}{2}.$$

The **area of a segment** where θ is the angle between the two radii in degrees

$$= \frac{\pi r^2 \theta}{360} - \frac{r^2 \sin \theta}{2}.$$

If θ is in radians the area $= \frac{1}{2}r^2(\theta - \sin\theta)$.

The **area of the segment of a circle**

$$= \frac{\pi r^2}{2} - \left[x\sqrt{r^2 - x^2} + r^2 \sin^{-1}\left(\frac{x}{r}\right) \right]$$

where r is the radius of the circle and x the perpendicular distance of the chord from the center. The angle must be expressed in radians.

The **area of the ring** between two circles of radius r_1 and r_2, one of which encloses the other,

$$= \pi(r_1 + r_2)(r_1 - r_2).$$

The two circles are not necessarily concentric.

Area of the sector of an annulus. (Fig. 2.) — If angle $GOH = \theta$ and the lines GO and $JO = r_1$ and r_2 respectively, the area $GHIJ = \frac{1}{2}\theta(r_1 + r_2)(r_1 - r_2)$.

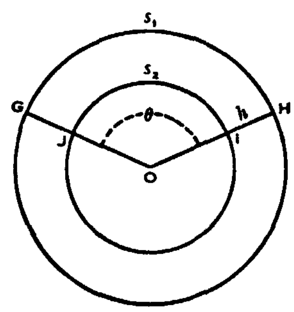


Fig. 2

If s_1 = the length of the arc GH and s_2 = the arc JI and $h = HI = r_1 - r_2$, the area $GHIJ = \frac{1}{2}h(s_1 + s_2)$.

The **circumference of an ellipse** whose semi-axes are a and b

$$= 2\pi\sqrt{\frac{a^2 + b^2}{2}}, \text{ approximately.}$$

The **area of an ellipse** $= \pi ab$.

The length of the **arc of a parabola**, as arc SPQ in Fig. 3, where $x = PR$, and $y = QR$

$$= 2\sqrt{y^2 + \frac{4x^2}{3}}.$$

The area of the section of the parabola $PQRS$, $= \frac{4}{3}xy$.

MENSURATION FORMULAE

SOLIDS BOUNDED BY PLANES

The lateral area of a regular prism = perimeter of a right section × the length.

The volume of a regular prism = area of base × the altitude.

The lateral area of a regular pyramid, slant height l, length of one side of base a, and a number of sides n,

$$= \tfrac{1}{2}nal.$$

The volume of a pyramid = $\tfrac{1}{3}$ area of base × altitude.

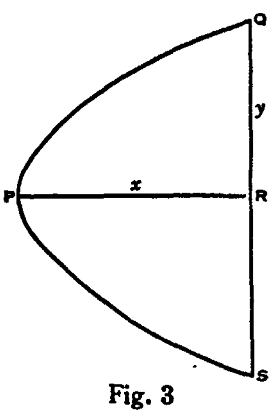


Fig. 3

SURFACE AND VOLUME OF REGULAR POLYHEDRA

Surface and volume of regular polyhedra in terms of the length of one edge l.

Name	Nature of Surface	Surface	Volume
Tetrahedron	4 equilateral triangles	$1.73205l^2$	$0.11785l^3$
Hexahedron or cube	6 squares	$6.00000l^2$	$1.00000l^3$
Octahedron	8 equilateral triangles	$3.46410l^2$	$0.47140l^3$
Dodecahedron	12 pentagons	$20.64578l^2$	$7.66312l^3$
Icosahedron	20 equilateral triangles	$8.66025l^2$	$2.18170l^3$

SOLIDS BOUNDED BY CURVED SURFACES

The surface of a sphere of radius r and diameter $d(= 2r)$

$$= 4\pi r^2 = \pi d^2 = 12.57r^2.$$

The volume of a sphere

$$= \tfrac{4}{3}\pi r^3 = \tfrac{1}{6}\pi d^3 = 4.189r^3.$$

MENSURATION FORMULAE

The **area of a lune** on the surface of a sphere of radius r, included between two great circles whose inclination is θ radians

$$= 2r^2\theta.$$

The **area of a spherical triangle** whose angles are A, B, and C (radians) on a sphere of radius r

$$= (A + B + C - \pi)r^2.$$

The **area of a spherical polygon** of n sides where θ is the sum of its angles in radians

$$= [\theta - (n - 2)\pi]r^2.$$

The area of the curved surface of a **spherical segment** of height h, radius of sphere r

$$= 2\pi rh.$$

The volume of a spherical segment, data as above

$$= \tfrac{1}{3}\pi h^2(3r - h).$$

If a = radius of the base of the segment, the volume

$$= \tfrac{1}{6}\pi h(h^2 + 3a^2).$$

The curved surface of a right cylinder where r = the radius of the base and h, the altitude,

$$= 2\pi rh.$$

The volume of a cylinder, data as above,

$$= \pi r^2 h.$$

The curved surface of a right cone whose altitude is h and radius of base r

$$= \pi r \sqrt{r^2 + h^2}.$$

The volume of a cone, data as above,

$$= \frac{\pi}{3} r^2 h = 1.047 r^2 h.$$

The curved surface of the frustum of a right cone, radius of base r_1, of top r_2 and altitude h,

$$= \pi(r_1 + r_2) \sqrt{h^2 + (r_1 - r_2)^2}.$$

The volume of the frustum of a cone, data as above,

$$= \pi \frac{h}{3} (r_1^2 + r_1 r_2 + r_2^2).$$

The oblate spheroid is formed by the rotation of an ellipse about its minor axis. If a and b are the major and minor semi-axes respectively, and e the eccentricity, the surface

$$= 2\pi a^2 + \pi \frac{b^2}{e} \log_e \frac{1 + e}{1 - e},$$

and volume $= \tfrac{4}{3}\pi a^2 b.$

The **prolate spheroid** is formed by the rotation of an ellipse about its major axis $(2a)$, data as above.

Surface $\quad = 2\pi b^2 + 2\pi \dfrac{ab}{e} \sin^{-1} e,$

volume $\quad = \frac{4}{3}\pi a b^2.$

TRIGONOMETRY

TRIGONOMETRIC FUNCTIONS IN A RIGHT-ANGLED TRIANGLE

If A, B, and C are the vertices (C the right angle), and a, b, and h the sides opposite respectively,

$\sin A = \dfrac{a}{h}, \qquad \cos A = \dfrac{b}{h},$

$\tan A = \dfrac{a}{b}, \qquad \cot A = \dfrac{b}{a},$

$\text{secant } A = \dfrac{h}{b}, \qquad \text{cosec } A = \dfrac{h}{a}.$

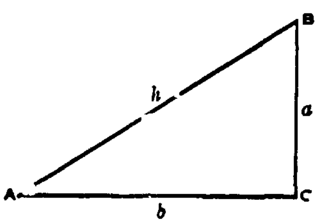


Fig. 4

SIGNS AND LIMITS OF VALUE ASSUMED BY THE FUNCTIONS

Function	Quadrant I		Quadrant II		Quadrant III		Quadrant IV	
	Sign	Value	Sign	Value	Sign	Value	Sign	Value
sin........	+	0 to 1	+	1 to 0	—	0 to 1	—	1 to 0
cos........	+	1 to 0	—	0 to 1	—	1 to 0	+	0 to 1
tan........	+	0 to ∞	—	∞ to 0	+	0 to ∞	—	∞ to 0
cot........	+	∞ to 0	—	0 to ∞	+	∞ to 0	—	0 to ∞
sec........	+	1 to ∞	—	∞ to 1	—	1 to ∞	+	∞ to 1
cosec......	+	∞ to 1	+	1 to ∞	—	∞ to 1	—	1 to ∞

TRIGONOMETRY

VALUE OF THE FUNCTIONS OF VARIOUS ANGLES

	0°	30°	45°	60°	90°	180°	270°
sin........	0	$\frac{1}{2}$	$\frac{1}{2}\sqrt{2}$	$\frac{1}{2}\sqrt{3}$	1	0	-1
cos........	1	$\frac{1}{2}\sqrt{3}$	$\frac{1}{2}\sqrt{2}$	$\frac{1}{2}$	0	-1	0
tan........	0	$\frac{1}{3}\sqrt{3}$	1	$\sqrt{3}$	∞	0	∞
cot........	∞	$\sqrt{3}$	1	$\frac{1}{3}\sqrt{3}$	0	∞	0

RELATIONS OF THE FUNCTIONS

$$\sin x = \frac{1}{\operatorname{cosec} x}. \qquad \operatorname{cosec} x = \frac{1}{\sin x}.$$

$$\cos x = \frac{1}{\sec x}. \qquad \sec x = \frac{1}{\cos x}.$$

$$\tan x = \frac{1}{\cot x} = \frac{\sin x}{\cos x}. \qquad \sin^2 x + \cos^2 x = 1.$$

$$1 + \tan^2 x = \sec^2 x.$$

$$\cot x = \frac{1}{\tan x} = \frac{\cos x}{\sin x}. \qquad 1 + \cot^2 x = \operatorname{cosec}^2 x.$$

$$\sin x = \sqrt{1 - \cos^2 x}. \qquad \cos x = \sqrt{1 - \sin^2 x}.$$

$$\tan x = \sqrt{\sec^2 x - 1}. \qquad \sec x = \sqrt{\tan^2 x + 1}.$$

$$\cot x = \sqrt{\operatorname{cosec}^2 x - 1}. \qquad \operatorname{cosec} x = \sqrt{\cot^2 x + 1}.$$

$$\sin x = \cos(90 - x) = \sin(180 - x).$$

$$\cos x = \sin(90 - x) = -\cos(180 - x).$$

$$\tan x = \cot(90 - x) = -\tan(180 - x).$$

$$\cot x = \tan(90 - x) = -\cot(180 - x).$$

FUNCTIONS OF SUMS OF ANGLES

$$\sin(x + y) = \sin x \cos y + \cos x \sin y.$$

$$\sin(x - y) = \sin x \cos y - \cos x \sin y.$$

$$\cos(x + y) = \cos x \cos y - \sin x \sin y.$$

$$\cos(x - y) = \cos x \cos y + \sin x \sin y.$$

$$\tan(x + y) = \frac{\tan x + \tan y}{1 - \tan x \tan y}.$$

$$\tan(x - y) = \frac{\tan x - \tan y}{1 + \tan x \tan y}.$$

TRIGONOMETRY

FUNCTIONS OF MULTIPLE ANGLES

$\sin 2x = 2 \sin x \cos x.$

$\cos 2x = \cos^2 x - \sin^2 x = 2 \cos^2 x - 1 = 1 - 2 \sin^2 x.$

$\sin 3x = 3 \sin x - 4 \sin^3 x.$

$\cos 3x = 4 \cos^3 x - 3 \cos x.$

$\sin 4x = 8 \cos^3 x \sin x - 4 \cos x \sin x.$

$\cos 4x = 8 \cos^4 x - 8 \cos^2 x + 1.$

$\sin 5x = 5 \sin x - 20 \sin^3 x + 16 \sin^5 x.$

$\cos 5x = 16 \cos^5 x - 20 \cos^3 x + 5 \cos x.$

$\sin 6x = 32 \cos^5 x \sin x - 32 \cos^3 x \sin x + 6 \cos x \sin x.$

$\cos 6x = 32 \cos^6 x - 48 \cos^4 x + 18 \cos^2 x - 1.$

$$\tan 2x = \frac{2 \tan x}{1 - \tan^2 x}.$$

$$\cot 2x = \frac{\cot^2 x - 1}{2 \cot x}.$$

$$\tan 3x = \frac{3 \tan x - \tan^3 x}{1 - 3 \tan^2 x}.$$

$$\sin \tfrac{1}{2}x = \pm \sqrt{\frac{1 - \cos x}{2}}$$

$$\cos \tfrac{1}{2}x = \pm \sqrt{\frac{1 + \cos x}{2}}.$$

$$\tan \tfrac{1}{2}x = \pm \sqrt{\frac{1 - \cos x}{1 + \cos x}} = \frac{1 - \cos x}{\sin x} = \frac{\sin x}{1 + \cos x}.$$

MISCELLANEOUS RELATIONS

$\sin x \pm \sin y = 2 \sin \tfrac{1}{2}(x \pm y) \cdot \cos \tfrac{1}{2}(x \mp y).$

$\cos x + \cos y = 2 \cos \tfrac{1}{2}(x + y) \cdot \cos \tfrac{1}{2}(x - y).$

$\cos x - \cos y = -2 \sin \tfrac{1}{2}(x + y) \cdot \sin \tfrac{1}{2}(x - y).$

$$\tan x \pm \tan y = \frac{\sin (x \pm y)}{\cos x \cdot \cos y}. \qquad \cot x \pm \cot y = \frac{\sin (x \pm y)}{\sin x \cdot \sin y}.$$

$$\frac{1 + \tan x}{1 - \tan x} = \tan (45 + x). \qquad \frac{\cot x + 1}{\cot x - 1} = \cot (45 - x).$$

$$\frac{\sin x \pm \sin y}{\cos x + \cos y} = \tan \tfrac{1}{2}(x \pm y).$$

$$\frac{\sin x \pm \sin y}{\cos x - \cos y} = -\cot \tfrac{1}{2}(x \mp y).$$

$$\frac{\sin x + \sin y}{\sin x - \sin y} = \frac{\tan \tfrac{1}{2}(x + y)}{\tan \tfrac{1}{2}(x - y)}.$$

$\sin^2 x - \sin^2 y = \sin (x + y) \cdot \sin (x - y).$

$\cos^2 x - \cos^2 y = -\sin (x + y) \sin (x - y).$

$\cos^2 x - \sin^2 y = \cos (x + y) \cos (x - y).$

TRIGONOMETRY

RELATIONS BETWEEN SIDES AND ANGLES OF ANY PLANE TRIANGLE

In a triangle with angles A, B, and C and sides opposite a, b, and c respectively,

$$\frac{\sin A}{a} = \frac{\sin B}{b} = \frac{\sin C}{c}.$$

$$a^2 = b^2 + c^2 - 2bc \cos A.$$

$$a = b \cos C + c \cos B.$$

$$\cos A = \frac{b^2 + c^2 - a^2}{2bc}.$$

$$\tan \frac{A - B}{2} = \frac{a - b}{a + b} \cot \frac{C}{2}.$$

$$\sin A = \frac{2}{bc} \sqrt{s(s - a)(s - b)(s - c)},$$

where $s = \frac{1}{2}(a + b + c)$ and $r = \sqrt{\frac{(s - a)(s - b)(s - c)}{s}}$

$$\sin \frac{A}{2} = \sqrt{\frac{(s - b)(s - c)}{bc}}.$$

$$\cos \frac{A}{2} = \sqrt{\frac{s(s - a)}{bc}}.$$

$$\tan \frac{A}{2} = \sqrt{\frac{(s - b)(s - c)}{s(s - a)}} = \frac{r}{s - a}.$$

$$\frac{a + b}{a - b} = \frac{\sin A + \sin B}{\sin A - \sin B} = \frac{\tan \frac{1}{2}(A + B)}{\tan \frac{1}{2}(A - B)} = \frac{\cot \frac{1}{2} C}{\tan \frac{1}{2}(A - B)}.$$

RELATIONS IN ANY SPHERICAL TRIANGLE

If A, B and C be the three angles and a, b, and c the opposite sides,

$$\frac{\sin A}{\sin a} = \frac{\sin B}{\sin b} = \frac{\sin C}{\sin c}.$$

$$\cos a = \cos b \cos c + \sin b \sin c \cos A = \frac{\cos b \cos(c \pm \theta)}{\cos \theta}$$

where $\tan \theta = \tan b \cos A$.

$$\cos A = -\cos B \cos C + \sin B \sin C \cos a.$$

$$\sin \tfrac{1}{2} A = \sqrt{\frac{\sin (s - b) \sin (s - c)}{\sin b \sin c}}$$

where $s = \frac{1}{2}(a + b + c)$.

$$\cos \tfrac{1}{2} A = \sqrt{\frac{\sin s \sin (s - a)}{\sin b \sin c}}.$$

$$\tan \tfrac{1}{2} A = \frac{r}{\sin (s - a)}$$

where $r = \sqrt{\frac{\sin (s - a) \sin (s - b) \sin (s - c)}{\sin s}}$

$$\cos \tfrac{1}{2} a = \sqrt{\frac{\cos (S - B) \cos (S - C)}{\sin B \sin C}}$$

where $S = \tfrac{1}{2}(A + B + C)$.

$$\sin \tfrac{1}{2} a = \sqrt{-\frac{\cos S \cos (S - A)}{\sin B \sin C}}.$$

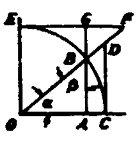
$$\tan \tfrac{1}{2} a = R \cos (S - A)$$

where
$$R = \sqrt{\frac{-\cos S}{\cos (S - A) \cos (S - B) \cos (S - C)}}.$$

$$\frac{\tan \frac{a+b}{2}}{\tan \frac{c}{2}} = \frac{\cos \frac{A-B}{2}}{\cos \frac{A+B}{2}}, \quad \frac{\tan \frac{A+B}{2}}{\cot \frac{c}{2}} = \frac{\cos \frac{a-b}{2}}{\cos \frac{a+b}{2}}.$$

$$\frac{\tan \frac{a-b}{2}}{\tan \frac{c}{2}} = \frac{\sin \frac{A-B}{2}}{\sin \frac{A+B}{2}}, \quad \frac{\tan \frac{A-B}{2}}{\cot \frac{c}{2}} = \frac{\sin \frac{a-b}{2}}{\sin \frac{a+b}{2}}.$$

Trigonometric Formulas



$OC = OB = OE = 1$
$AB = \text{Sin}\ \alpha$
$OA = \text{Cos}\ \alpha$
$CD = \text{Tan}\ \alpha$
$EF = \text{Cot}\ \alpha$
$OD = \text{Sec}\ \alpha$
$OF = \text{Cosec}\ \alpha$
$AC = \text{Vers}\ \alpha = 1 - \text{Cos}\ \alpha$
$BG = \text{Covers}\ \alpha = 1 - \text{Sin}\ \alpha$

Radius $1 = \sin^2\alpha + \cos^2\alpha = \sin\alpha\ \text{cosec}\ \alpha = \cos\alpha\sec\alpha = \tan\alpha\cot\alpha$

$$\sin\alpha = \frac{\cos\alpha}{\cot\alpha} = \frac{1}{\text{cosec}\ \alpha} = \cos\alpha\tan\alpha = \sqrt{1-\cos^2\alpha}$$

$$\cos\alpha = \frac{\sin\alpha}{\tan\alpha} = \frac{1}{\sec\alpha} = \sin\alpha\cot\alpha = \sqrt{1-\sin^2\alpha}$$

$$\tan\alpha = \frac{\sin\alpha}{\cos\alpha} = \frac{1}{\cot\alpha} = \sin\alpha\sec\alpha \qquad \sec\alpha = \frac{\tan\alpha}{\sin\alpha} = \frac{1}{\cos\alpha}$$

$$\cot\alpha = \frac{\cos\alpha}{\sin\alpha} = \frac{1}{\tan\alpha} = \cos\alpha\ \text{cosec}\ \alpha \qquad \text{cosec}\ \alpha = \frac{\cot\alpha}{\cos\alpha} = \frac{1}{\sin\alpha}$$

$$\sin(\alpha\pm\beta) = \sin\alpha\cos\beta \pm \cos\alpha\sin\beta \qquad \tan(\alpha\pm\beta) = \frac{\tan\alpha\pm\tan\beta}{1\mp\tan\alpha\tan\beta}$$

$$\cos(\alpha\pm\beta) = \cos\alpha\cos\beta \mp \sin\alpha\sin\beta \qquad \cot(\alpha\pm\beta) = \frac{\cot\alpha\cot\beta\mp 1}{\cot\beta\pm\cot\alpha}$$

$$\sin\alpha + \sin\beta = 2\sin\tfrac{1}{2}(\alpha+\beta)\cos\tfrac{1}{2}(\alpha-\beta) \qquad \tan\alpha + \tan\beta = \frac{\sin(\alpha+\beta)}{\cos\alpha\cos\beta}$$

$$\sin 2\alpha = 2\sin\alpha\cos\alpha \qquad \sin\tfrac{1}{2}\alpha = \sqrt{\frac{1-\cos\alpha}{2}} \qquad \sin^2\alpha = \frac{1-\cos 2\alpha}{2}$$

$$\cos 2\alpha = \cos^2\alpha - \sin^2\alpha \qquad \cos\tfrac{1}{2}\alpha = \sqrt{\frac{1+\cos\alpha}{2}} \qquad \cos^2\alpha = \frac{1+\cos 2\alpha}{2}$$

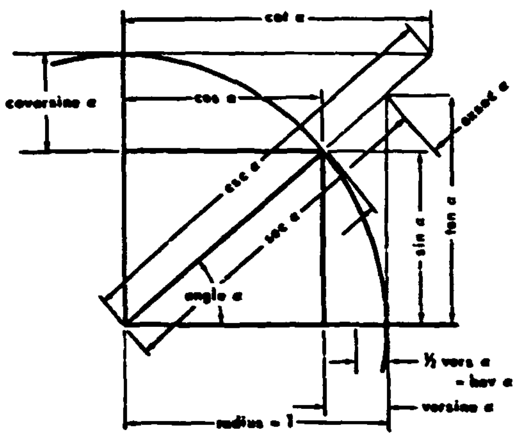
$$\tan 2\alpha = \frac{2\tan\alpha}{1-\tan^2\alpha} \qquad \tan\tfrac{1}{2}\alpha = \frac{\sin\alpha}{1+\cos\alpha} \qquad \tan^2\alpha = \frac{1-\cos 2\alpha}{1+\cos 2\alpha}$$

$$\cot 2\alpha = \frac{\cot^2\alpha - 1}{2\cot\alpha} \qquad \cot\tfrac{1}{2}\alpha = \frac{\sin\alpha}{1-\cos\alpha} \qquad \cot^2\alpha = \frac{1+\cos 2\alpha}{1-\cos 2\alpha}$$

$$\sin^2\alpha - \sin^2\beta = \sin(\alpha+\beta)\sin(\alpha-\beta) \qquad \cos^2\alpha - \sin^2\beta = \cos(\alpha+\beta)\cos(\alpha-\beta)$$

$$\frac{\sin\alpha\pm\sin\beta}{\cos\alpha+\cos\beta} = \tan\tfrac{1}{2}(\alpha\pm\beta) \qquad \frac{\sin\alpha\pm\sin\beta}{\cos\beta-\cos\alpha} = \cot\tfrac{1}{2}(\alpha\mp\beta)$$

Trigonometric Reference Table



	Ratio	Reciprocal	Product
$\sin\alpha =$	$\cos\alpha/\cot\alpha = \tan\alpha/\sec\alpha =$	$1/\csc\alpha =$	$\cos\alpha\tan\alpha$
$\cos\alpha =$	$\sin\alpha/\tan\alpha = \cot\alpha/\csc\alpha =$	$1/\sec\alpha =$	$\sin\alpha\cot\alpha$
$\tan\alpha =$	$\sin\alpha/\cos\alpha = \sec\alpha/\csc\alpha =$	$1/\cot\alpha =$	$\sin\alpha\sec\alpha$
$\cot\alpha =$	$\cos\alpha/\sin\alpha = \csc\alpha/\sec\alpha =$	$1/\tan\alpha =$	$\cos\alpha\csc\alpha$
$\sec\alpha =$	$\tan\alpha/\sin\alpha = \csc\alpha/\cot\alpha =$	$1/\cos\alpha =$	$\tan\alpha\csc\alpha$
$\csc\alpha =$	$\cot\alpha/\cos\alpha = \sec\alpha/\tan\alpha =$	$1/\sin\alpha =$	$\cot\alpha\sec\alpha$

Pythagorean

$\sin\alpha = \sqrt{1-\cos^2\alpha} = \tan\alpha/\sqrt{1+\tan^2\alpha} = 1/\sqrt{1+\cot^2\alpha}$

$\cos\alpha = \sqrt{1-\sin^2\alpha} = 1/\sqrt{1+\tan^2\alpha} = \cot\alpha/\sqrt{1+\cot^2\alpha}$

$\tan\alpha = \sqrt{\sec^2\alpha - 1}$

$\cot\alpha = \sqrt{\csc^2\alpha - 1}$

$\sec\alpha = \sqrt{1+\tan^2\alpha}$

$\csc\alpha = \sqrt{1+\cot^2\alpha}$

Basic Trigonometric Relations with Unit Circle		Functions of $(-\alpha)$
$\sin\alpha$ = opp/hyp = opp/1 = opposite	versine α = vers α = $1-\cos\alpha$	$\sin(-\alpha) = -\sin\alpha$
$\cos\alpha$ = adj/hyp = adj/1 = adjacent	coversine α = covers α = $1-\sin\alpha$	$\cos(-\alpha) = \cos\alpha$
$\tan\alpha$ = opp/adj = opp/1 = opposite	haversine α = hav α = 1/2 vers α	$\tan(-\alpha) = -\tan\alpha$
$\cot\alpha$ = adj/opp = adj/1 = adjacent	exsecant α = exsec α = $\sec\alpha - 1$	$\cot(-\alpha) = -\cot\alpha$
$\sec\alpha$ = hyp/adj = hyp/1 = hypotenuse		$\sec(-\alpha) = \sec\alpha$
$\csc\alpha$ = hyp/opp = hyp/1 = hypotenuse		$\csc(-\alpha) = -\csc\alpha$

Cofunctions of $(\alpha \pm \pi/2)$	Cofunctions of $(\pi/2 - \alpha)$	Functions of $(\alpha \pm \pi)$	Functions of $(\pi - \alpha)$
$\pm\sin\alpha = \cos(\alpha \mp \pi/2)$	$\sin\alpha = \cos(\pi/2-\alpha)$	$-\sin\alpha = \sin(\alpha\pm\pi)$	$\sin\alpha = \sin(\pi-\alpha)$
$\pm\cos\alpha = \sin(\alpha\pm\pi/2)$	$\cos\alpha = \sin(\pi/2-\alpha)$	$-\cos\alpha = \cos(\alpha\pm\pi)$	$-\cos\alpha = \cos(\pi-\alpha)$
$-\tan\alpha = \cot(\alpha\pm\pi/2)$	$\tan\alpha = \cot(\pi/2-\alpha)$	$\tan\alpha = \tan(\alpha\pm\pi)$	$-\tan\alpha = \tan(\pi-\alpha)$
$-\cot\alpha = \tan(\alpha\pm\pi/2)$	$\cot\alpha = \tan(\pi/2-\alpha)$	$\cot\alpha = \cot(\alpha\pm\pi)$	$-\cot\alpha = \cot(\pi-\alpha)$
$\mp\sec\alpha = \csc(\alpha\pm\pi/2)$	$\sec\alpha = \csc(\pi/2-\alpha)$	$-\sec\alpha = \sec(\alpha\pm\pi)$	$-\sec\alpha = \sec(\pi-\alpha)$
$\pm\csc\alpha = \sec(\alpha\mp\pi/2)$	$\csc\alpha = \sec(\pi/2-\alpha)$	$-\csc\alpha = \csc(\alpha\pm\pi)$	$\csc\alpha = \csc(\pi-\alpha)$

Functions of $[\alpha \pm (n)(\pi/2)]$ (n** is even)	Functions of $[\alpha \pm (n)(\pi/2)]$ (n** is odd)	Reciprocal Identities	Pythagorean Identities
* $\sin\alpha = \sin[\alpha\pm(n)(\pi/2)]$	* $\sin\alpha = \cos[\alpha\pm(n)(\pi/2)]$	$\sin\alpha\csc\alpha = 1$	$\sin^2\alpha + \cos^2\alpha = 1$
* $\cos\alpha = \cos[\alpha\pm(n)(\pi/2)]$	* $\cos\alpha = \sin[\alpha\pm(n)(\pi/2)]$	$\cos\alpha\sec\alpha = 1$	$\sec^2\alpha - \tan^2\alpha = 1$
* $\tan\alpha = \tan[\alpha\pm(n)(\pi/2)]$	* $\tan\alpha = \cot[\alpha\pm(n)(\pi/2)]$	$\tan\alpha\cot\alpha = 1$	$\csc^2\alpha - \cot^2\alpha = 1$
* $\cot\alpha = \cot[\alpha\pm(n)(\pi/2)]$	* $\cot\alpha = \tan[\alpha\pm(n)(\pi/2)]$	** "n" is any integer. * Algebraic sign is determined by quadrant in which the angle falls.	
* $\sec\alpha = \sec[\alpha\pm(n)(\pi/2)]$	* $\sec\alpha = \csc[\alpha\pm(n)(\pi/2)]$		
* $\csc\alpha = \csc[\alpha\pm(n)(\pi/2)]$	* $\csc\alpha = \sec[\alpha\pm(n)(\pi/2)]$		

Addition Formulas

$\sin(\alpha \pm \beta) = \sin\alpha\cos\beta \pm \cos\alpha\sin\beta$

$\cos(\alpha \pm \beta) = \cos\alpha\cos\beta \mp \sin\alpha\sin\beta$

$\tan(\alpha \pm \beta) = \tan\alpha \pm \tan\beta / 1 \mp \tan\alpha\tan\beta$

$\cot(\alpha \pm \beta) = \cot\alpha\cot\beta \mp 1/\cot\beta \pm \cot\alpha$

Product Formulas

$\sin\alpha\cos\beta = 1/2\,[\sin(\alpha+\beta) + \sin(\alpha-\beta)]$

$\cos\alpha\sin\beta = 1/2\,[\sin(\alpha+\beta) - \sin(\alpha-\beta)]$

$\cos\alpha\cos\beta = 1/2\,[\cos(\alpha+\beta) + \cos(\alpha-\beta)]$

$\sin\alpha\sin\beta = 1/2\,[\cos(\alpha-\beta) - \cos(\alpha+\beta)]$

$\tan\alpha\tan\beta = (\tan\alpha + \tan\beta)/(\cot\alpha + \cot\beta)$

$\cot\alpha\cot\beta = (\cot\alpha + \cot\beta)/(\tan\alpha + \tan\beta)$

Sum and Difference Formulas

$\sin\alpha \pm \sin\beta = 2 \begin{smallmatrix}\sin\\ \cos\end{smallmatrix}\ 1/2(\alpha+\beta) \begin{smallmatrix}\cos\\ \sin\end{smallmatrix}\ 1/2(\alpha-\beta)$

$\cos\alpha \pm \cos\beta = \pm 2 \begin{smallmatrix}\cos\\ \sin\end{smallmatrix}\ 1/2(\alpha+\beta) \begin{smallmatrix}\cos\\ \sin\end{smallmatrix}\ 1/2(\alpha-\beta)$

$\tan\alpha \pm \tan\beta = \sin(\alpha \pm \beta)/\cos\alpha\cos\beta$

$\cot\alpha \pm \cot\beta = \sin(\beta \pm \alpha)/\sin\alpha\sin\beta$

Double Angle Identities

$$\sin 2\alpha = 2\sin\alpha\cos\alpha = \frac{2\tan\alpha}{1+\tan^2\alpha} = \frac{2\cot\alpha}{1+\cot^2\alpha}$$

$$\cos 2\alpha = \cos^2\alpha - \sin^2\alpha = 1 - 2\sin^2\alpha = 2\cos^2\alpha - 1$$

$$\tan 2\alpha = \frac{2\tan\alpha}{1-\tan^2\alpha} = \tan\alpha(1+\sec 2\alpha) = \frac{2\cot\alpha}{\cot^2\alpha - 1}$$

$$\cot 2\alpha = \frac{\cot^2\alpha - 1}{2\cot\alpha} = \frac{\cot\alpha - \tan\alpha}{2}$$

$$\sec 2\alpha = \frac{\sec^2\alpha}{2-\sec^2\alpha} = \frac{\csc^2\alpha}{\csc^2\alpha - 2} = \frac{1+\tan^2\alpha}{1-\tan^2\alpha} = \frac{1}{2\cos^2\alpha - 1}$$

$$\csc 2\alpha = \frac{\tan\alpha + \cot\alpha}{2}$$

Half - Angle Identities

A minus sign must be prefixed to the radical if the trigonometric function of $\alpha/2$ to be found is negative

$\sin\alpha/2 = \sqrt{(1-\cos\alpha)/2}$	if $\sin\alpha/2$ is +
$\cos\alpha/2 = \sqrt{(1+\cos\alpha)/2}$	if $\cos\alpha/2$ is +
$\tan\alpha/2 = \sqrt{(1-\cos\alpha)/(1+\cos\alpha)} = (1-\cos\alpha)/\sin\alpha = \sin\alpha/(1+\cos\alpha) = \csc\alpha - \cot\alpha$	if $\tan\alpha/2$ is +
$\cot\alpha/2 = \sqrt{(1+\cos\alpha)/(1-\cos\alpha)} = (1+\cos\alpha)/\sin\alpha = \sin\alpha/(1-\cos\alpha) = 1/(\csc\alpha - \cot\alpha)$	if $\cot\alpha/2$ is +
$\sec\alpha/2 = \sqrt{2/(1+\cos\alpha)}$	if $\sec\alpha/2$ is +
$\csc\alpha/2 = \sqrt{2/(1-\cos\alpha)}$	if $\csc\alpha/2$ is +

Square Identities

The notation $\sin^2\alpha$ means $(\sin\alpha)^2$

$\sin^2\alpha = (1-\cos 2\alpha)/2 = (1+\cos\alpha)(1-\cos\alpha) = \sec^2\alpha/(\sec^2\alpha + \csc^2\alpha) = 1/\csc^2\alpha$

$\cos^2\alpha = (1+\cos 2\alpha)/2 = \sin^2\alpha + \cos 2\alpha = \cos\alpha\sec\alpha/(1+\tan^2\alpha) = \cot^2\alpha/(1+\cot^2\alpha) = (\csc^2\alpha - 1)/\csc^2\alpha$

$\tan^2\alpha = (1-\cos 2\alpha)/(1+\cos 2\alpha) = \sec^2\alpha - 1 = (\sec 2\alpha - 1)/\sec 2\alpha + 1)$

$\cot^2\alpha = (1+\cos 2\alpha)/(1-\cos 2\alpha) = (1+\cot^2\alpha)/(1+\tan^2\alpha) = (\csc\alpha - \sin\alpha)/\sin\alpha$

$\sec^2\alpha = 2/(1+\cos 2\alpha)$

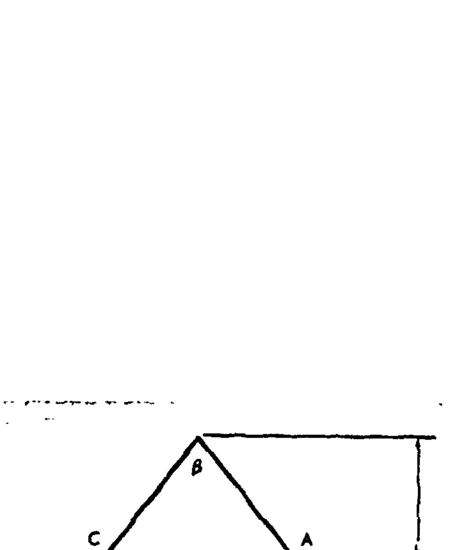
$\csc^2\alpha = 2/(1-\cos 2\alpha)$

Power Series

(α is a number of radians)

$\sin\alpha = \alpha - (\alpha^3/3!) + (\alpha^5/5!) - \cdots + (-1)^{n+1}[\alpha^{2n-1}/(2n-1)!] + \cdots$	
$\cos\alpha = 1 - (\alpha^2/2!) + (\alpha^4/4!) - \cdots + (-1)^{n+1}[\alpha^{2n-2}/(2n-2)!] + \cdots$	
$\tan\alpha = \alpha + (\alpha^3/3) + (2\alpha^5/15) + (17\alpha^7/315) + \cdots$	$-\pi/2 < \alpha < \pi/2$
$\cot\alpha = (1/\alpha) - (\alpha/3) - (\alpha^3/45) - \cdots$	$-\pi < \alpha < 0$ or $0 < \alpha < \pi$
$\sec\alpha = 1 + (\alpha^2/2) + (5\alpha^4/24) + (61\alpha^6/720) + \cdots$	$-\pi/2 < \alpha < \pi/2$
$\csc\alpha = (1/\alpha) + (\alpha/6) + (7\alpha^3/360) + \cdots$	$-\pi < \alpha < 0$ or $0 < \alpha < \pi$

Nomograms for Evaluating Plane Triangles



For the majority of applications including preliminary design, the following nomograms provide a simple and quick method of evaluating the parameters of the plane triangle.

Nomenclature

Area = area of triangle
A = length of side "A"
B = length of side "B" (the base)
C = length of side "C"
h = height of triangle
S = length of perimeter of triangle
α = angle opposite side "A"
β = angle opposite side "B"
γ = angle opposite side "C"

The following nomograms are not limited to right triangles but apply to any plane triangles. They do not apply to spherical triangles.

With a knowledge of two angles and a side, or two sides and an angle, all other angles and sides plus area and height may be determined. If two sides and the height are known, or two angles and the height, the other parameters can be established. Or, if the area plus two other parameters are known, all other relationships can be established.

Nomogram I provides the basic relationships among the two nonbase sides, angles α and γ, and the height of the triangle. It also provides direct relationship between the two sides as functioned by the angles. The perimeter also may be established by this nomogram, or if the perimeter is known, the sides and angles may be evaluated.

Nomogram II relates A, α, B and β and C, γ, B and β.

Nomogram III provides a simple method of determining the area, without need of computation; or if the area is known, of evaluating either the height or base.

Using Nomogram I

To determine the height if C and α are known: Align C with α and extend to intersect h. For example, if C = 7.1 inches and α = 20 deg, h = 24. The 10" indicates that decimal notation can be dropped in the entry and restored in the answer.

To determine the height if A and γ are known: Align A and γ and extend to intersect h. For example, if A = 0.48 cm and γ = 30 deg, h = 0.24 cm.

If sides A and C are known and angle γ is known, the h line may be used as a turning line to relate sides and angles. For example, if A = 4.1 inches, C = 7.1 inches and γ = 30 deg, align C = 7.1 with γ = 30 deg and extend to intersect h. Align this intersection with A = 4.8 inches and read α = 20 deg.

The nomogram may be used to relate the perimeter and sides: Align C with A, intersecting a point on line h. In this case the line is a Reference line and the value of h has no significance. Align the Reference line intersection with B and read S. For example, if C = 30 cm, A = 40 cm and B = 20 cm, S = 90 cm.

Using Nomogram II

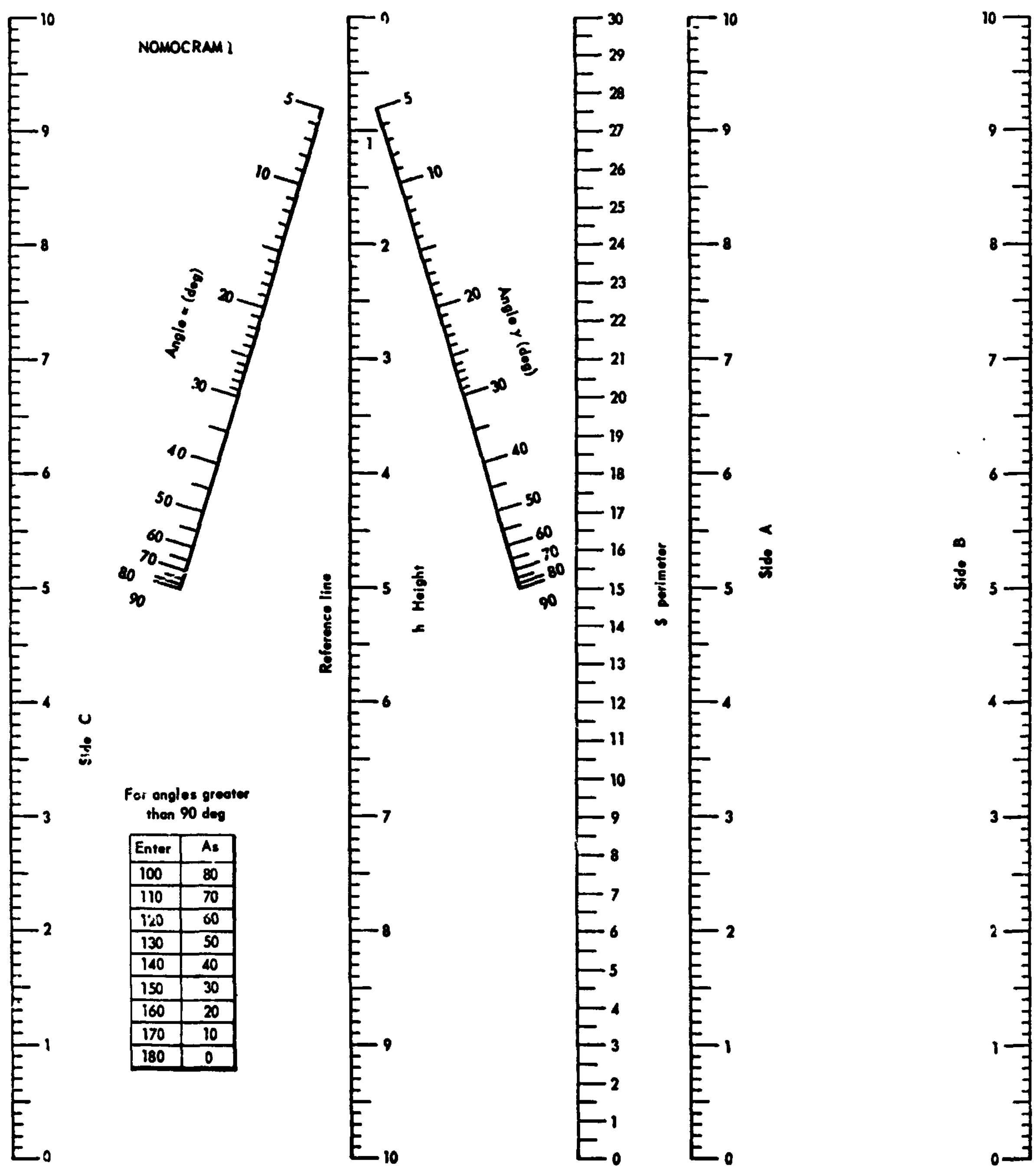
To determine a nonbase side when side B, angle β and angle opposite the nonbase side are known: Align B with the angle opposite and extend to intersect the Reference line. Align this intersection with β and extend to read the nonbase side. For example, if B = 8 inches, β = 30 deg and α = 20 deg, align B = 8 with α = 20 and extend to the Reference line. Align this intersection with β = 30 and extend to read A = 5.5 inches.

Using Nomogram III

To determine area: Align values of B and h and read the intersection on the area line. For example, if B = 3 inches and h = 4 inches, align B = 3 with h = 4 and read area = 6 sq in.

The nomograms provide a simple method of determining all the parameters of a triangle from a knowledge of three. If exact values are required, the following equations may be used.

$$A = B\sin\alpha/\sin\beta \quad (1)$$
$$B = C\sin\beta/\sin\gamma \quad (2)$$
$$C = A\sin\gamma/\sin\alpha \quad (3)$$



Enter	As
100	80
110	70
120	60
130	50
140	40
150	30
160	20
170	10
180	0

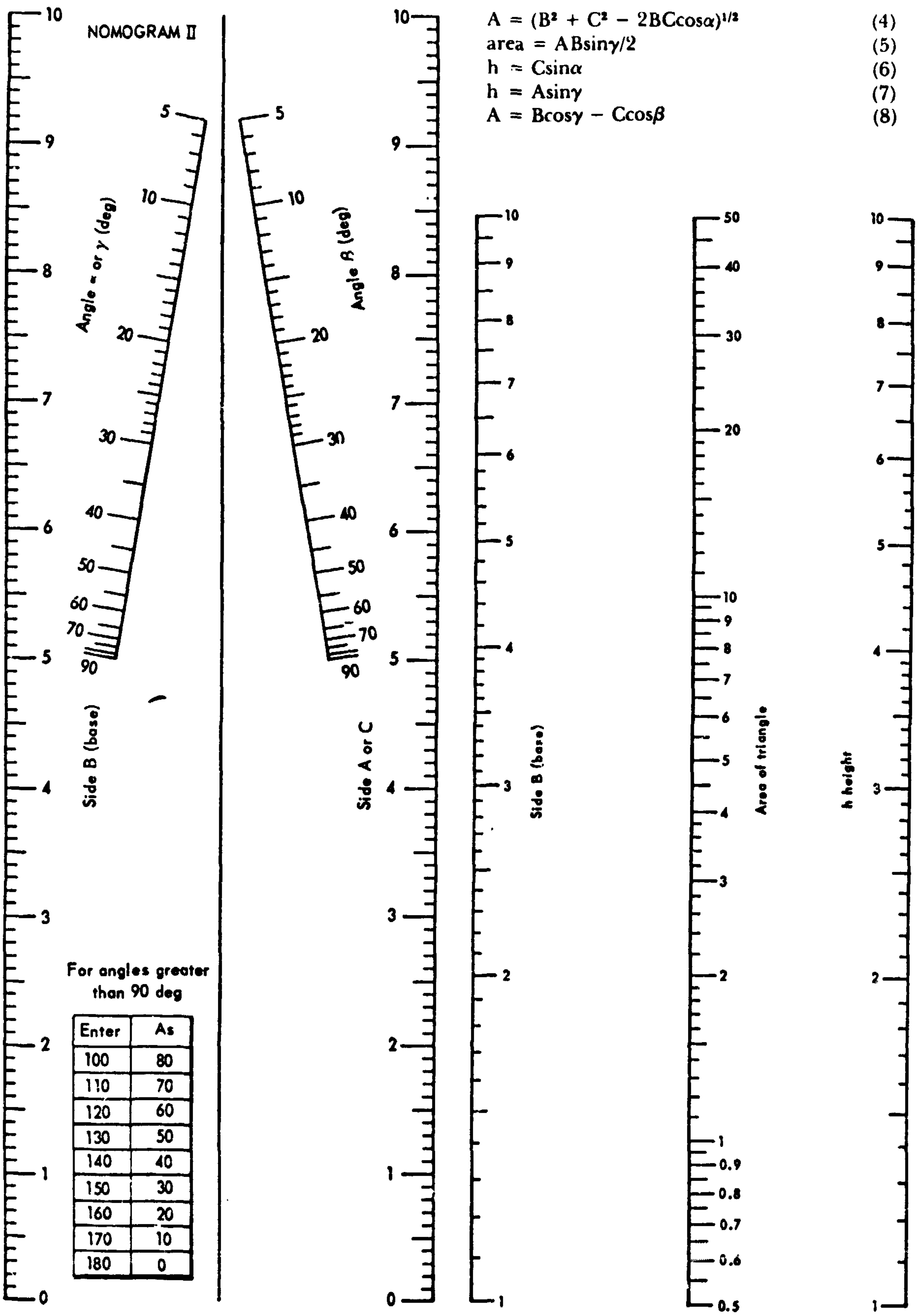
$A = (B^2 + C^2 - 2BC\cos\alpha)^{1/2}$ (4)

area $= AB\sin\gamma/2$ (5)

$h \approx C\sin\alpha$ (6)

$h = A\sin\gamma$ (7)

$A = B\cos\gamma - C\cos\beta$ (8)



Enter	As
100	80
110	70
120	60
130	50
140	40
150	30
160	20
170	10
180	0

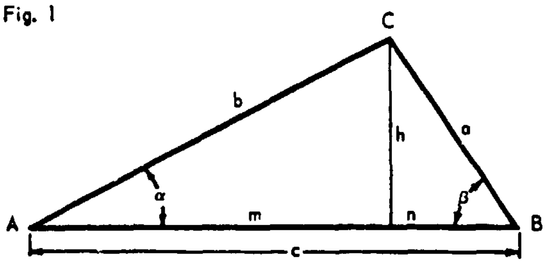
Oblique Triangles

Formulas for Finding Coordinate Dimensions When Side c and Angles α and β Are Known

There are two cases for finding the side h.
From Fig. 1, $m = h \cot \alpha$ and $n = h \cot \beta$

$$c = m + n$$
$$\therefore c = h \cot \alpha + h \cot \beta \text{, or}$$
$$c = h (\cot \alpha + \cot \beta)$$
$$\therefore h = (c)/(\cot \alpha + \cot \beta) \qquad (1)$$

Fig. 1



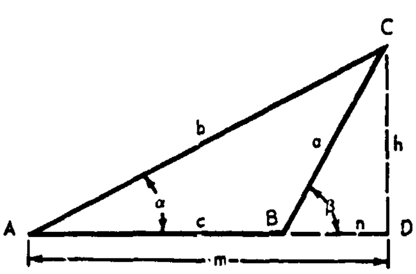


Fig. 2

Adapting this formula for logarithmic computation, let:

$$\cot \alpha + \cot \beta = \left(\frac{\cos \alpha}{\sin \alpha}\right) + \left(\frac{\cos \beta}{\sin \beta}\right)$$
$$= \frac{(\sin \alpha)(\cos \beta) + (\sin \beta)(\cos \alpha)}{(\sin \alpha)(\cos \beta)}$$
$$= \frac{\sin (\alpha + \beta)}{(\sin \alpha)(\sin \beta)}$$

Substituting in (1):

$$h = \frac{(c)(\sin \alpha)(\sin \beta)}{\sin (\alpha + \beta)} \text{, for Fig. 1.}$$

From Fig. 2, $c = m - n = h(\cot \alpha - \cot \beta)$

$$\therefore h = \frac{(c)(\sin \alpha)(\sin \beta)}{\sin (\beta - \alpha)} \text{, for Fig. 2.}$$

ANALYTICAL GEOMETRY

The distance between two points x_1, y_1, and x_2, y_2, — rectangular coördinates:

$$d = \pm \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

For polar coördinates and points r_1, θ_1, and r_2, θ_2:

$$d = \pm \sqrt{r_1^2 + r_2^2 - 2r_1r_2 \cos(\theta_1 - \theta_2)}$$

The area of a triangle whose vertices are x_1, y_1; x_2, y_2, and x_3, y_3:

$$A = \tfrac{1}{2}(x_1y_2 - x_2y_1 + x_2y_3 - x_3y_2 + x_3y_1 - x_1y_3)$$

For polar coördinates and vertices, r_1, θ_1; r_2, θ_2, and r_3, θ_3:

$$A = \tfrac{1}{2}\{(r_1r_2 \sin(\theta_2 - \theta_1) + r_2r_3 \sin(\theta_3 - \theta_2) + r_3r_1 \sin(\theta_1 - \theta_3)\}$$

The equation of a straight line where m is the tangent of the angle of inclination and c, the distance of intersection with the Y axis from the origin:

$$y = mx + c$$

If a line of inclination m passes through the point x_1, y_1, its equation is:

$$y - y_1 = m(x - x_1)$$

The equation of a line through the points x_1, y_1, and x_2, y_2 is:

$$\frac{y - y_1}{y_2 - y_1} = \frac{x - x_1}{x_2 - x_1}$$

If the intercepts on the X and Y axes are a and b respectively, the equation is:

$$\frac{x}{a} + \frac{y}{b} = 1$$

If the length of the perpendicular from the origin is p and its angle of inclination θ the equation is:

$$x \cos \theta + y \sin \theta = p$$

General equation of the straight line:

$$Ax + By + C = 0$$

The equation of a circle whose center is at a, b, and whose radius is c:

$$(x - a)^2 + (y - b)^2 = c^2$$

If the origin is at the center:

$$x^2 + y^2 = c^2$$

The polar equation of a circle with the origin on the circumference and its center at point c, α:

$$r = 2c \cos(\theta - \alpha).$$

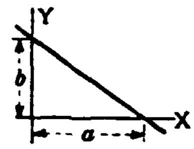
If the origin is not on the circumference, the radius a and the center at a point l, α, the equation becomes:

$$a^2 = r^2 + l^2 - 2rl \cos(\theta - \alpha)$$

Equations of Common Curves

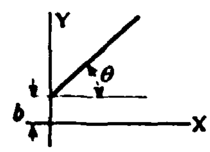
Straight line.

$$\frac{x}{a} + \frac{y}{b} = 1$$



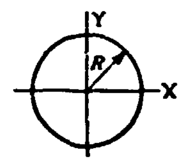
or

$$y = x \tan \theta + b.$$



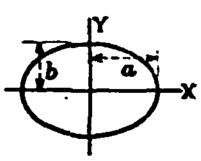
Circle.

$$x^2 + y^2 = R$$



Ellipse.

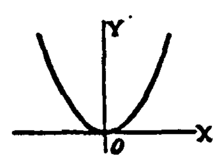
$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1.$$



Parabola (Vertical).

$$y = kx^2$$

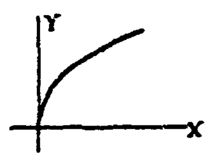
where k is a constant.



Parabola (Horizontal).

$$y = k\sqrt{x}$$

where k is a constant.

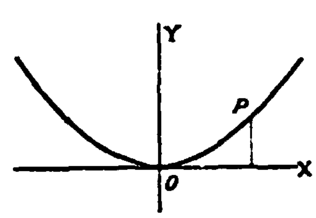


Catenary.

$$y = \frac{1}{k} \cosh kx - 1$$

where k is a constant. The length of arc from O to P

$$= \frac{1}{k} \sinh (kx)$$



CALCULUS

DIFFERENTIALS

$$d\,ax = a\,dx$$
$$d\,uv = u\,dv + v\,du$$
$$d\,\frac{u}{v} = \frac{v\,du - u\,dv}{v^2}$$
$$d\,x^n = n\,x^{n-1}dx$$
$$d\,e^x = e^x dx$$
$$d\,e^{ax} = a\,e^{ax}dx$$
$$d\,a^x = a^x \log_e a\,dx$$
$$d\log_e x = \frac{1}{x}dx$$
$$d\log_a x = \frac{1}{x}\log_a e\,dx$$
$$d\,x^x = x^x\,(1 + \log_e x)\,dx$$
$$d\sin x = \cos x\,dx$$
$$d\cos x = -\sin x\,dx$$
$$d\tan x = \sec^2 x\,dx$$
$$d\cot x = -\csc^2 x\,dx$$
$$d\sec x = \tan x \sec x\,dx$$
$$d\csc x = -\cot x \cdot \csc x\,dx$$
$$d\sin^{-1}x = (1 - x^2)^{-\frac{1}{2}}dx$$
$$d\cos^{-1}x = -(1 - x^2)^{-\frac{1}{2}}dx$$
$$d\tan^{-1}x = (1 + x^2)^{-1}dx$$
$$d\cot^{-1}x = -(1 + x^2)^{-1}dx$$
$$d\sec^{-1}x = x^{-1}(x^2 - 1)^{-\frac{1}{2}}dx$$
$$d\csc^{-1}x = -x^{-1}(x^2 - 1)^{-\frac{1}{2}}dx$$

INTEGRALS

ELEMENTARY FORMS

1. $\int a\,dx = ax.$
2. $\int a \cdot f(x)dx = a\int f(x)dx.$
3. $\int \phi(y)dx = \int \frac{\phi(y)}{y'}dy,$ where $y' = dy/dx.$
4. $\int (u + v)\,dx = \int u\,dx + \int v\,dx,$ where u and v are any functions of x.
5. $\int u\,dv = uv - \int v\,du.$
6. $\int u\frac{dv}{dx}dx = uv - \int v\frac{du}{dx}dx.$
7. $\int x^n\,dx = \frac{x^{n+1}}{n+1},$ except $n = -1.$
8. $\int \frac{f'(x)\,dx}{f(x)} = \log f(x),$ $[d\,f(x) = f'(x)\,dx].$
9. $\int \frac{dx}{x} = \log x,$ or $\log(-x).$
10. $\int \frac{f'(x)\,dx}{2\sqrt{f(x)}} = \sqrt{f(x)},$ $[d\,f(x) = f'(x)\,dx].$
11. $\int e^x dx = e^x.$
12. $\int e^{ax}dx = e^{ax}/a.$
13. $\int b^{ax}dx = \frac{b^{ax}}{a\log b}.$
14. $\int \log x\,dx = x\log x - x.$

Areas of Plane Figures

Nomenclature

a, b, c, d	—Lengths of sides	l, l_1, l_2	—Length of arc
A	—Area	L	—Lateral length or slant height
d, d_1, d_2	—Diameters	n	—Number of sides
c, f	—Length of diagonals	θ	—Number of degrees of arc
h	—Vertical height or altitude	p	—Perimeter
		r, r_1, r_2, R	—Radii

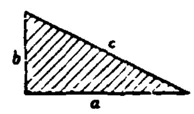
Right Triangle

$p = a + b + c$

$c^2 = a^2 + b^2$

$b = \sqrt{c^2 - a^2}$

$A = \dfrac{ab}{2}$



Equilateral Triangle

$p = 3a$

$h = \dfrac{a}{2}\sqrt{3} = .866\,a$

$A = a^2\dfrac{\sqrt{3}}{4} = .433\,a^2$

General Triangle

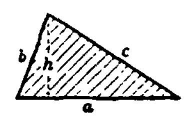
Let $s = \dfrac{a + b + c}{2}$

$p = a + b + c$

$h = \dfrac{2}{a}\sqrt{s(s - a)(s - b)(s - c)}$

$A = \dfrac{ah}{2}$

$A = \sqrt{s(s - a)(s - b)(s - c)}$



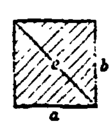
Square

$a = b$

$p = 4a$

$A = a^2 = .5c^2$

$c = a\sqrt{2} = 1.414\,a$



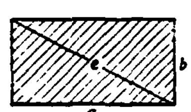
Rectangle

$p = 2(a + b)$

$c = \sqrt{a^2 + b^2}$

$b = \sqrt{c^2 - a^2}$

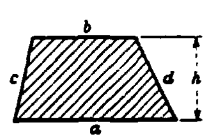
$A = ab$



Trapezoid

$p = a + b + c + d$

$A = \dfrac{(a + b)}{2}h$



Circle

$p = 2\pi r = \pi d = 3.1416d$

$A = \pi r^2 = \dfrac{\pi d^2}{4} = .7854d^2$

$\quad = \dfrac{p^2}{4\pi} = .07958p^2$

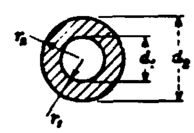
Hollow circle or Annulus

$A = \dfrac{\pi}{4}(d_2^2 - d_1^2) = .7854(d_2^2 - d_1^2)$

$\quad = \pi(r_2^2 - r_1^2)$

$\quad = \pi \dfrac{d_1 + d_2}{2}(r_2 - r_1)$

$\quad = \pi(r_1 + r_2)(r_2 - r_1)$



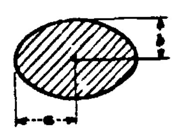
Ellipse

$p = \pi(a + b)$ approximately

$\quad = \pi[1.5(a + b) - \sqrt{ab}]$

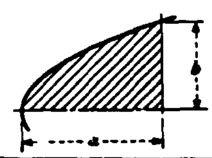
more nearly

$A = \pi ab$



Parabola

$A = \frac{2}{3}ab$



Properties of the Circle

Circumference of circle of diameter 1 $= \pi = 3.14159265$

Circumference of circle $= 2\pi r = \pi d$

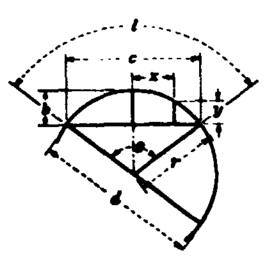
Diameter of circle $=$ circumference $\times$ 0.31831

Diameter of circle of equal periphery as square $=$ side $\times$ 1.27324

Side of square of equal periphery as circle $=$ diameter $\times$ 0.78540

Diameter of circle circumscribed about square $=$ side $\times$ 1.41421

Side of square inscribed in circle $=$ diameter $\times$ 0.70711



Arc, $l = \dfrac{\pi r \theta^\circ}{180} = 0.017453 r\theta^\circ$

Angle, $\theta = \dfrac{180^\circ\, l}{\pi r} = 57.29578\dfrac{l}{r}$

Radius, $r = \dfrac{4b^2 + c^2}{8b}$ Diameter, $d = \dfrac{4b^2 + c^2}{4b}$

Chord, $c = 2\sqrt{2br - b^2} = 2r \sin\dfrac{\theta}{2} = d \sin\dfrac{\theta}{2}$

Rise, $b = r - \dfrac{1}{2}\sqrt{4r^2 - c^2} = \dfrac{c}{2}\tan\dfrac{\theta}{4} = 2r\sin^2\dfrac{\theta}{4}$

Rise, $b = r + y - \sqrt{r^2 - x^2}$ $\quad y = b - r + \sqrt{r^2 - x^2}$ $\quad x = \sqrt{r^2 - (r + y - b)^2}$

POSITIVE AND NEGATIVE POWERS OF TWO					
Positive Powers		**Negative Powers**			
2^0	1				
2^1	2	2^{-1}	1/2	0.5	
2^2	4	2^{-2}	1/4	0.25	
2^3 =	8	2^{-3}	1/8	= 0.125	
2^4 =	16	2^{-4} =	1/16	= 0.062	5
2^5 =	32	2^{-5} =	1/32	= 0.031	25
2^6 =	64	2^{-6} =	1/64	= 0.015	625
2^7 =	128	2^{-7} =	1/128	= 0.007	813
2^8 =	256	2^{-8} =	1/256	= 0.003	906
2^9 =	512	2^{-9} =	1/512	= 0.001	953
2^{10} =	1,024	2^{-10} =	1/1024	= 0.000	977
2^{11} =	2,048	2^{-11} =	1/2048	= 0.000	488
2^{12} =	4,096	2^{-12} =	1/4096	= 0.000	244
2^{13} =	8,192	2^{-13} =	1/8192	= 0.000	122
2^{14} =	16,384	2^{-14} =	1/16,384	= 0.000	061
2^{15} =	32,768	2^{-15} =	1/32,768	= 0.000	031
2^{16} =	65,536	2^{-16} =	1/65,536	= 0.000	015
2^{17} =	131,072	2^{-17} =	1/131,072	= 0.000	008
2^{18} =	262,144	2^{-18} =	1/262,144	= 0.000	004
2^{19} =	524,288	2^{-19} =	1/524,288	= 0.000	002
2^{20} =	1,048,576	2^{-20} =	1/1,048,576	= 0.000	001

Note: Decimal values have been rounded off to the nearest millionth place.

BINARY NUMBERS 0 - 127							
0	0 000 000	32	0 100 000	64	1 000 000	96	1 100 000
1	0 000 001	33	0 100 001	65	1 000 001	97	1 100 001
2	0 000 010	34	0 100 010	66	1 000 010	98	1 100 010
3	0 000 011	35	0 100 011	67	1 000 011	99	1 100 011
4	0 000 100	36	0 100 100	68	1 000 100	100	1 100 100
5	0 000 101	37	0 100 101	69	1 000 101	101	1 100 101
6	0 000 110	38	0 100 110	70	1 000 110	102	1 100 110
7	0 000 111	39	0 100 111	71	1 000 111	103	1 100 111
8	0 001 000	40	0 101 000	72	1 001 000	104	1 101 000
9	0 001 001	41	0 101 001	73	1 001 001	105	1 101 001
10	0 001 010	42	0 101 010	74	1 001 010	106	1 101 010
11	0 001 011	43	0 101 011	75	1 001 011	107	1 101 011
12	0 001 100	44	0 101 100	76	1 001 100	108	1 101 100
13	0 001 101	45	0 101 101	77	1 001 101	109	1 101 101
14	0 001 110	46	0 101 110	78	1 001 110	110	1 101 110
15	0 001 111	47	0 101 111	79	1 001 111	111	1 101 111
16	0 010 000	48	0 110 000	80	1 010 000	112	1 110 000
17	0 010 001	49	0 110 001	81	1 010 001	113	1 110 001
18	0 010 010	50	0 110 010	82	1 010 010	114	1 110 010
19	0 010 011	51	0 110 011	83	1 010 011	115	1 110 011
20	0 010 100	52	0 110 100	84	1 010 100	116	1 110 100
21	0 010 101	53	0 110 101	85	1 010 101	117	1 110 101
22	0 010 110	54	0 110 110	86	1 010 110	118	1 110 110
23	0 010 111	55	0 110 111	87	1 010 111	119	1 110 111
24	0 011 000	56	0 111 000	88	1 011 000	120	1 111 000
25	0 011 001	57	0 111 001	89	1 011 001	121	1 111 001
26	0 011 010	58	0 111 010	90	1 011 010	122	1 111 010
27	0 011 011	59	0 111 011	91	1 011 011	123	1 111 011
28	0 011 100	60	0 111 100	92	1 011 100	124	1 111 100
29	0 011 101	61	0 111 101	93	1 011 101	125	1 111 101
30	0 011 110	62	0 111 110	94	1 011 110	126	1 111 110
31	0 011 111	63	0 111 111	95	1 011 111	127	1 111 111

SHOP ARITHMETIC
REFERENCE RULES

TO FIND CIRCUMFERENCE-
Multiply diameter by 3.1416

TO FIND DIAMETER-
Multiply circumference by 0.3183

TO FIND RADIUS-
Multiply circumference by 0.15915

TO FIND SIDE OF AN INSCRIBED SQUARE-
Multiply diameter by 0.7071
Or multiply circumference by 0.2251

TO FIND SIDE OF AN EQUAL SQUARE-
Multiply diameter by 0.8862
Or circumference by 0.2821

SQUARE-
A side multiplied by 1.4142 equals diameter of its circumscribing circle.
A side multiplied by 4.443 equals circumference of its circumscribing circle.
A side multiplied by 1.128 equals diameter of an equal circle.
A side multiplied by 3.547 equals circumference of an equal circle.

TO FIND THE AREA OF A CIRCLE-
Multiply circumference by one quarter of the diameter.
Or multiply the diameter by the diameter by 0.7854.
Or multiply the circumference by the circumference by 0.7958.
Or multiply the radius by the radius by 3.1416.

TO FIND THE SURFACE OF A SPHERE OR GLOBE-
Multiply the diameter by the circumference.
Or multiply the square of diameter by 3.1416.
Or multiply four times the square of radius by 3.1416.

TO FIND THE VOLUME OF A SPHERE-
Multiply the cube of diameter by 0.5236.

TO FIND THE CUBIC CONTENT OF A CONE-
Multiply the area of the base by 1/3 the altitude.

TO FIND THE AREA OF A TRIANGLE-
Multiply the base by 1/2 the perpendicular height.

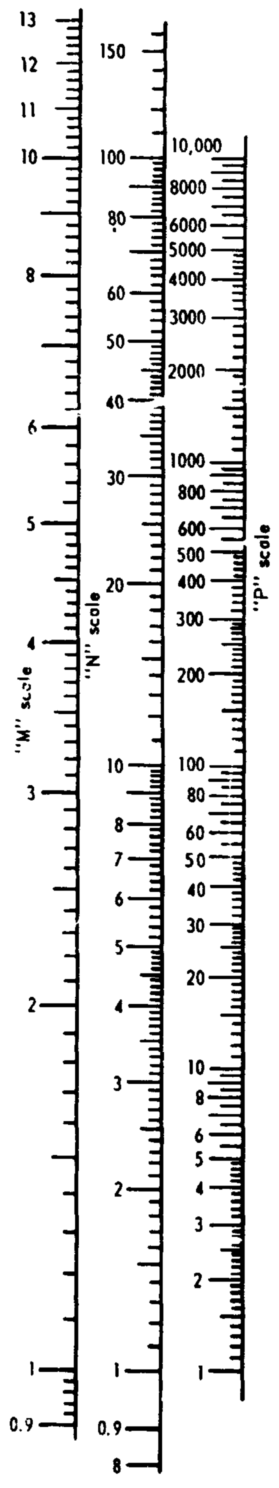
TO FIND THE AREA OF A RECTANGLE-
Multiply the length by the breath.

REFERENCE EQUIVALENTS-
Doubling the diameter of a circle increases its area four times.
Doubling the diameter of a pipe increases its capacity four times.
Tripling the diameter of a circle increases its area nine times.
A gallon of water (U.S. Standard) weighs 8 1/3 lbs. and contains 231 cubic inches.
A cubic foot of water contains 7 1/2 gallons, 1728 cubic inches and weighs 62 1/2 lbs.

To find the pressure in pounds per square inch of a column of water multiply the height of the column in feet by 0.434.
The drag on a flat plate normal to the wind is equal to 32 lbs. per square foot at 100 m.p.h.
The drag and the lift due to the air forces on a body increase as the square of the speed.
The measurements made in a machine shop are usual[illegible]ken in inches or fractional parts of an inch. Most of the prec[illegible]on tools in the shop read in thousandths of an inch. The usual graduations on a scale are in 64ths, 32nds, 6ths, and 8ths of an inch.

To change a fraction to a decimal, divide the numerator by the denominator. For example,in changing 3/16 to a decimal, 3.0000÷ 16 .1875.

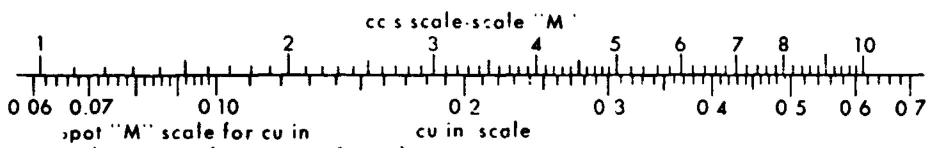
Simple Nomograms for Engineering Calculations



Construction of nomograms covering most straightforward formulas is purely a drafting job, the key being in the selection of the scales used. The scales on a nomogram of the type explained here are invariably logarithmic. For complete coverage three such scales are required, equivalent to a range of values of X, X^2 and X^4. The choice of scales to suit any particular formula can be arrived at by simple analysis. For convenience, a set of typical scales is given. The 'M' scale corresponds to first power values; 'N' is the second power scale and 'P' the fourth power scale. Once having decided the order of scale required, these can be traced or otherwise reproduced on a skeleton nomogram designed for a particular formula.

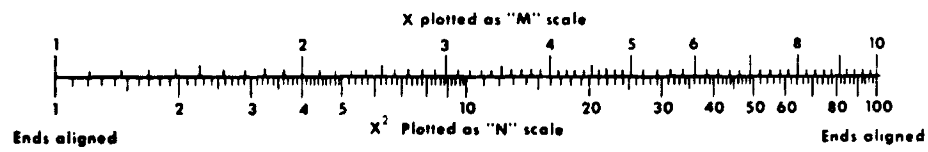
Examples of the use of these scales are given below and on the following pages, covering a wide range of possible applications. The construction process is elementary, accuracy being established merely by correct mechanical alignment of the scales. It is advisable always in constructing a nomogram to check near opposite ends with sample calculations but the possibility of error is small if the basic rules given are followed.

Accuracy obtainable with nomograms with well drawn scales should be comparable with that given by a slide rule of similar length. The nomogram is more foolproof in that the correct order of answer is always established.



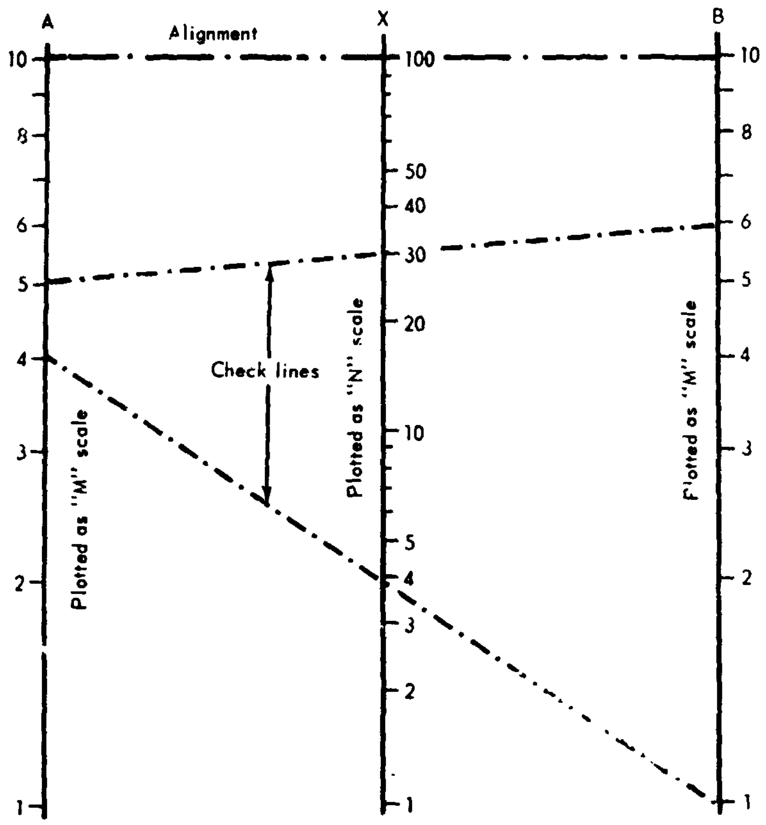
CONVERSION SCALES

EXAMPLE 1. The simplest application of nomogram scales is for conversion of units. The 'M', 'N', or 'P' scales can be used depending on the range to be covered and the available length for drawing or reproducing the scales. Most conversion values can conveniently be accommodated on the 1-10 'M' scale, factoring by 10 or by 100 and so on for larger quantities. The drawing shows the 'M' scale used to prepare a conversion chart for instantaneous conversion of cubic centimeters to cubic inches, and vice versa. The same scale must be used for each of the units, displaced from one another by the appropriate conversion factor. Corresponding values must then lie opposite on the two scales.



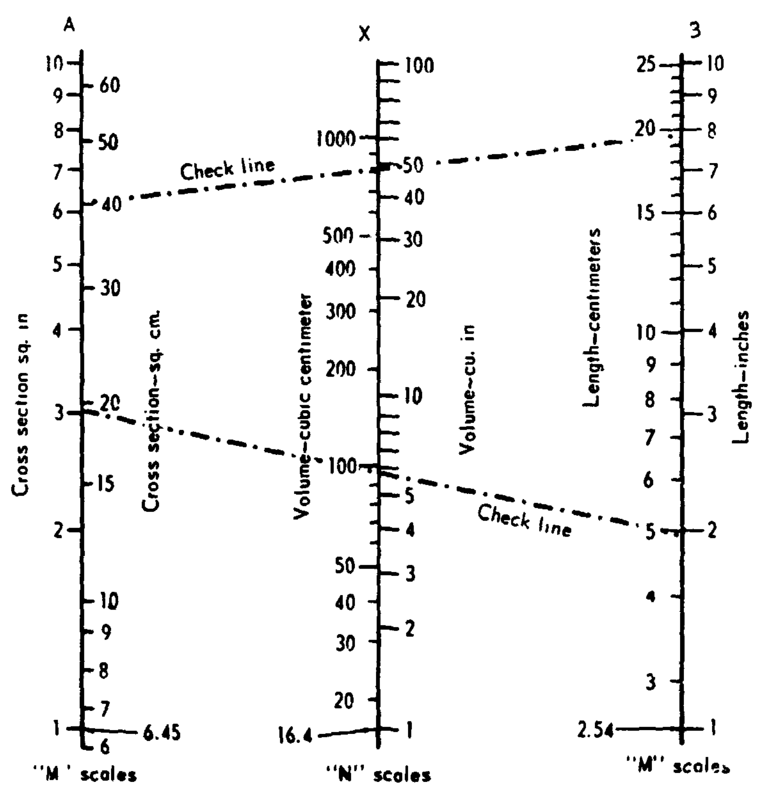
CONVERSION SCALES

EXAMPLE 2. Similar construction may be used for instantaneous reading of squares or square roots, by using 'M' scale for unit values and 'N' scale for second power values. Scales in this instance are aligned at each end. Similarly by using 'P' scale in conjunction with 'M' scale a chart can be drawn for solutions to X^4 and $\sqrt[4]{X}$.



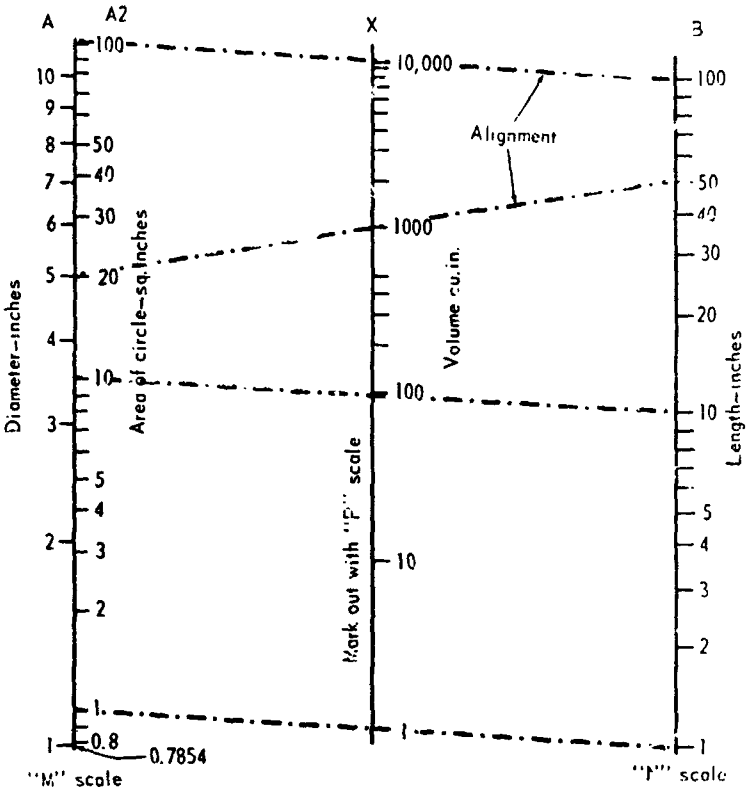
$X = (A)\,(B)$

RULE FOR formulas including a simple product with two variables (A, B) is that variable scales are plotted from 'M' scales at each end of diagram, with answer or X scale plotted as an 'N' scale, suitably aligned. All three vertical scales must be parallel and equally-spaced. A and B scales are normally drawn first. An alignment point on X scale can then be established by calculation and 'N' scale laid out from this point, noting that all three scales read in same direction (for example, either upwards or downwards). Check calculations (check lines) will establish validity of 'N' scale positioning. Same rules apply if formula includes a constant, effect of this merely being a displacement of X scale to accommodate constant.



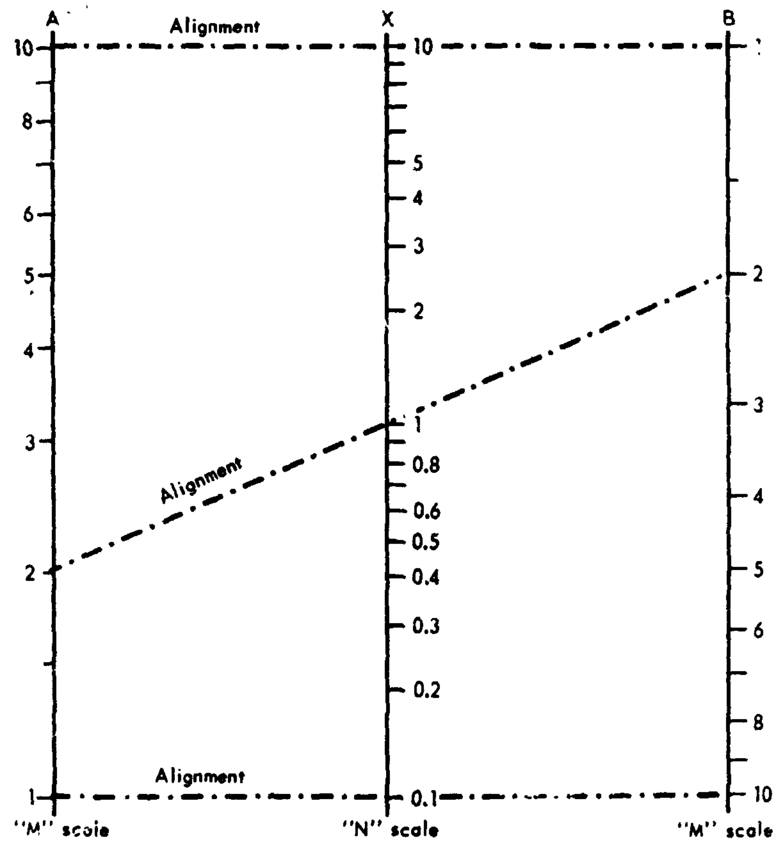
$X = (K)\,(A)\,(B)$ (alternative units)

PARTICULAR VIRTUE of nomogram is that a formula can be fully expressed in alternative units. In example drawn formula is again a straight-forward product, Volume = (length) (cross section), but scales are plotted for both inch and metric units. Construction follows same rules as above, working in one of the units throughout. Each scale is then treated as a conversion scale as in Example 1 for incorporating other units. Actually only two scales need to be 'converted', third following naturally as a normal 'M' or 'N' scale, once positioned. Plotting all three as conversion scales is an alternative method of checking. Completed nomogram can then handle calculations in either of the units, or in mixed units, as well as being available as conversion scales for square and cubic measures in two sets of units involved.



$X = (K)(A^2)(B)$

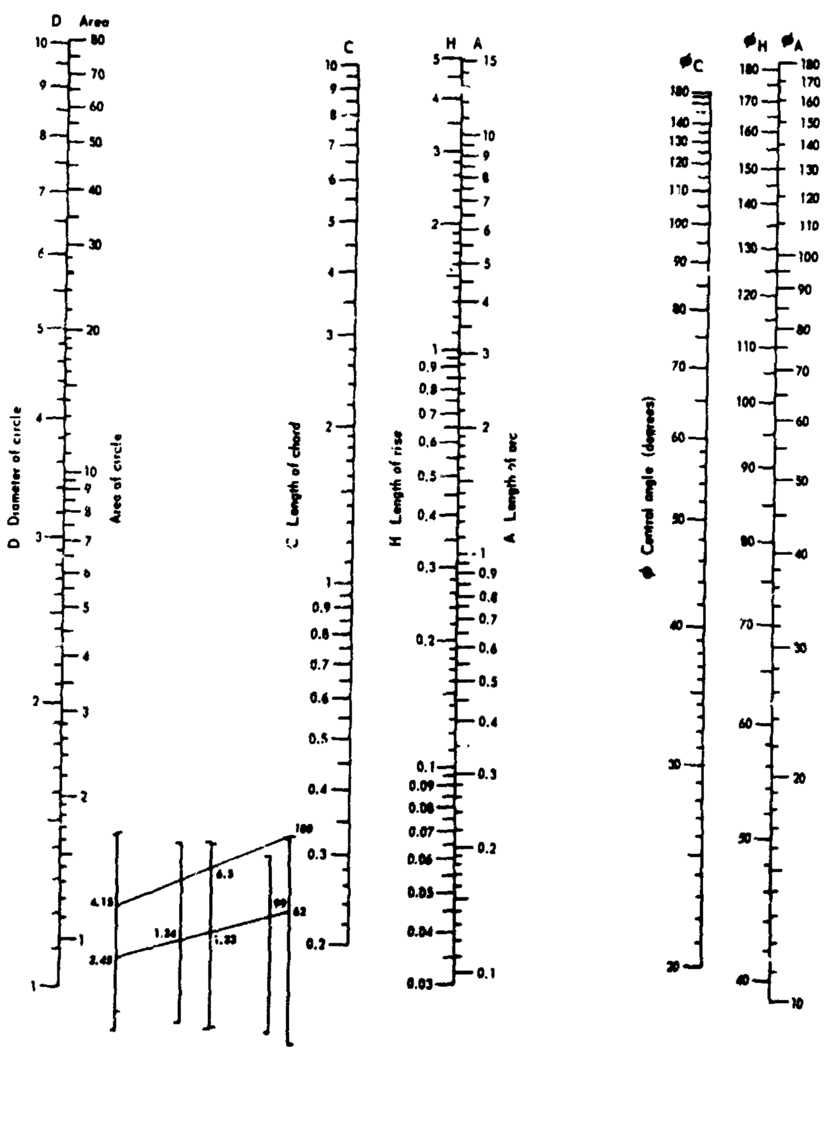
TREATMENT OF a formula of this type still involves plotting a normal product nomogram except that A scale is first converted into an A^2 scale on opposite side of line. This is an 'N' scale and so B scale must also be laid out as an 'N' scale for correct alignment. Solution of X scale then becomes a 'P' scale, position of which can be established and checked by drawing on one or more alignment lines. This practice of establishing a number of fixed points on the X line by alignment lines is to be recommended in this instance.



$X = A/B$

IN A QUOTIENT nomogram A and B scales are reversed in order of reading, with resulting X scale following same order of reading as A scale. Otherwise layout follows on similar lines to a product nomogram. Except where a wider range is required, 'M' scale is usually suitable for A and B scales, when X scale is plotted as an 'N' scale. If, for greater range, 'N' scale is used for laying out A and B scales, X scale will be a 'P' scale. Order of X scale readings are readily established by random check calculations. Three alignment lines are recommended (which are also check lines), position as shown.

Nomogram for Properties of the Circle



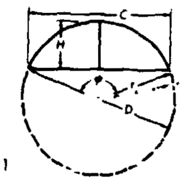


Fig 1

It is frequently necessary to calculate various segments or elements of a circle. The calculations are not difficult, but troublesome, for there are lengthy multiplications and trigonometric functions involved. This nomogram simplifies the calculating processes.

From Fig 1, the following equations can be derived:

$$A = 0.008726\ D\ \phi \quad (1)$$

$$C = D\,(\mathrm{Sin}\ \phi/2) \quad (2)$$

$$H = D/2(\mathrm{Tan}\ \phi/4)\ (\mathrm{Sin}\ \phi/2) \quad (3)$$

Where.

A = arc
C = chord
H = rise
D = diameter of any circle
ϕ = angle in degrees

Example 1.

Find the length of the arc subtended by a central angle of 62 deg if the diameter of the circle is 2.45 inches.

Align ϕ_A = 62 deg with D = 2.45 inches and read A = 1.33 inches.

Example 2.

Determine the length of the chord subtended by a central angle of 61 deg if the diameter of the circle is 2.45 inches. With the same alignment as in Example 1 (ϕ_A = 62 deg, D = 2.45 inches and ϕ_C = 61 deg), read C = 1.24 inches.

The rise is 0.43 inch on the H scale if the angle is 99 deg and the circle is of the same diameter.

Note that the D scale can be extended to any diameter, provided a suitable factor is used to reduce the numerical value to that within the scale and the result is multiplied by the reciprocal of the factor.

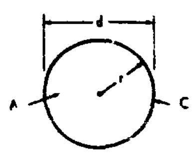
The nomogram can be used to determine circumference of any circle. Because the length of the arc subtended by 180 deg is equal to half the circumference, align 180 deg on the ϕ_A scale and the diameter on the D scale and double the reading on the A scale. (Example. The circumference of a circle of 4.15 inches diameter is (6.5) (2) = 13 inches.)

The area for any circle up to 10 inches in diameter is given opposite the D scale. For a circle with a diameter greater than 10 inches, reduce the diameter by a factor and multiply the value found on the "area" scale by the square of the reciprocal of the factor.

Rules Relative to The Circle

We begin with a common circle and the expressions relating its various parts. From this beginning we expand the concept to the relationship between a unit circle and a unit square and end with the relations between a unit circle and a number of regular unit polygons.

The circle is defined as the locus of all the points in a single plane at an equal distance from a given point. The point is the center of the circle. The diameter is the chord of the circle that passes through this center point and incidently is the longest chord. The circle radius is one-half the diameter and circumference is the total distance around the perimeter.



Beginning with the diameter we now relate all the other parts of a circle to this one part:

d = diameter

$d = 2r$

$d = \frac{C}{\pi}$

$d = 0.3183C$

$d = \left(\frac{A}{0.7854}\right)^{1/2}$

Here are similar relationships relative to the circle radius:

$r = 0.5d$

$r = \left(\frac{A}{\pi}\right)^{1/2}$

$r = \frac{C}{2\pi} = \frac{C}{6.28318}$

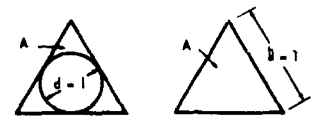
$r = 0.159150$

Here are the relationships based on the circle's area:

A = area

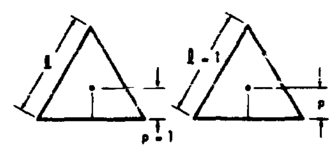
$A = \pi r^2$

REGULAR POLYGONS



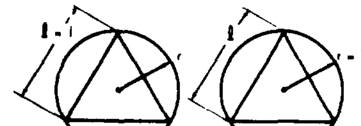
SIDES	NAME	AREA (A) WHEN DIAMETER OF INSCRIBED CIRCLE = 1	AREA (A) WHEN SIDE = 1
3	Triangle	1.299	0.433
4	Square	1.000	1.000
5	Pentagon	0.908	1.720
6	Hexagon	0.866	2.598
7	Heptagon	0.843	3.634
8	Octagon	0.828	4.828
9	Nonagon	0.819	6.182
10	Decagon	0.812	7.694
11	Undecagon	0.807	9.366
12	Dodecagon	0.804	11.196

REGULAR POLYGONS



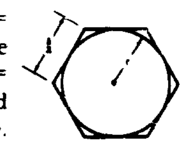
SIDES	NAME	LENGTH (l) OF SIDE WHEN PERPENDICULAR TO CENTER = 1	PERPENDICULAR (p) TO CENTER WHEN SIDE = 1
3	Triangle	3.464	0.289
4	Square	2.000	0.500
5	Pentagon	1.453	0.688
6	Hexagon	1.155	0.866
7	Heptagon	0.963	1.038
8	Octagon	0.828	1.207
9	Nonagon	0.728	1.374
10	Decagon	0.650	1.539
11	Undecagon	0.587	1.703
12	Dodecagon	0.536	1.866

REGULAR POLYGONS



SIDES	NAME	RADIUS (r) OF CIRCUMSCRIBED CIRCLE WHEN SIDE = 1	LENGTH (l) OF SIDE WHEN RADIUS (r) OF CIRCUMSCRIBED CIRCLE = 1
3	Triangle	0.577	1.732
4	Square	0.707	1.414
5	Pentagon	0.851	1.176
6	Hexagon	1.000	1.000
7	Heptagon	1.152	0.868
8	Octagon	1.307	0.765
9	Nonagon	1.462	0.684
10	Decagon	1.618	0.618
11	Undecagon	1.775	0.563
12	Dodecagon	[illegible]	0.518

Given here are the relationships between unit circles or polygons having unit sides with the circles either *inscribed* or *circumscribed*.



If we take any regular polygon we can let A = area, r = radius of the inscribed circle, n = the number of sides and l = length of one side. We then find that

$$A = \frac{rnl}{2}$$

■

Areas of Circles and Sectors, Surfaces and Volumes of Spheres

The conversion chart presented permits direct reading of the circumference of a circle, the area of a circle, the surface area of a sphere and the volume of a sphere for any given diameter, D. Conversely, for a sphere or a given volume the surface area, area of the circle, the circumference and the diameter can be obtained.

Scales are direct reading and anticipate decimal location. Algebraic formulae employed in determination of the geometric quantities are:

Circumference $= \pi D$

Area of the circle $= \pi/4D^2$

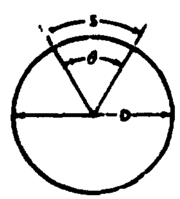
Surface area of the sphere $= \pi D^2$

Volume of the sphere $= \pi/6D^3$

Example:

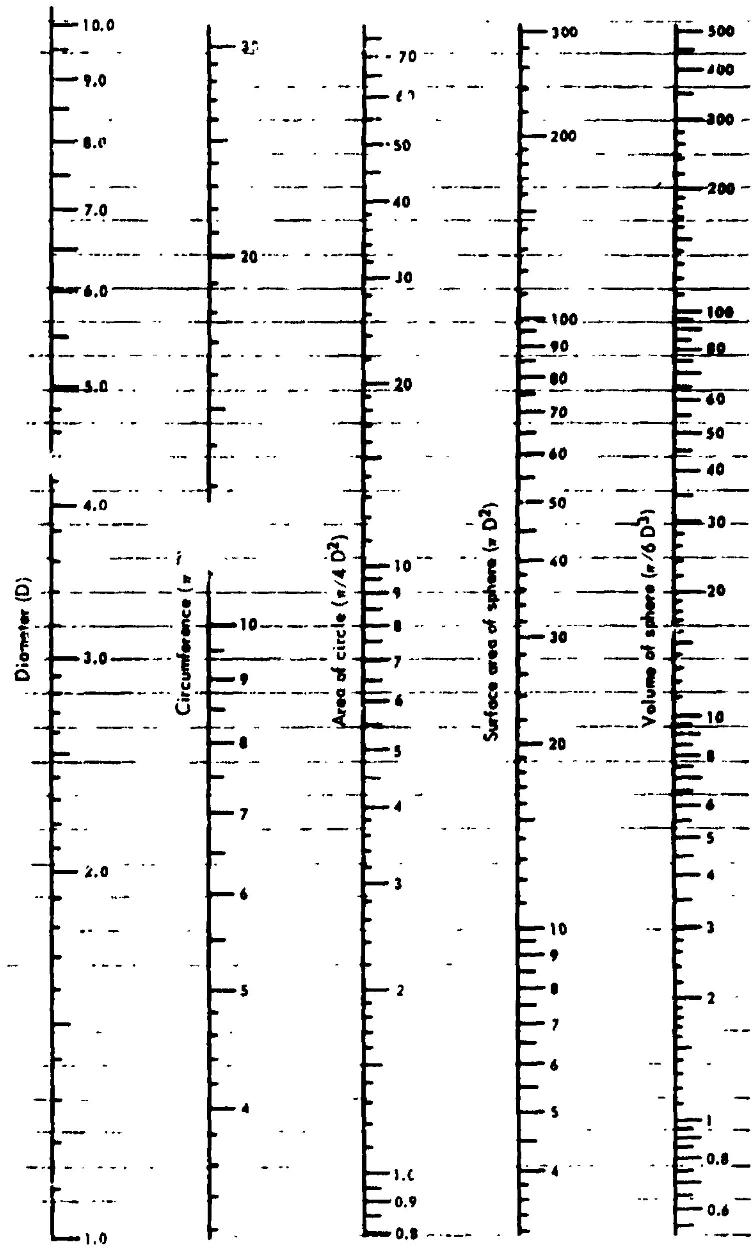
Determine circumference and area of the circle and surface area and volume of the sphere for a diameter of 25 units of length.

Diameter	Circumference of circle	Area of circle
2.5 x 10 (units)	7.85 x 10 (units)	4.9 x 10² (units)²
Surface area of sphere	**Volume of sphere**	
19.6 x 10² (units)²	8.2 x 10³ (units)³	



Scales are also amenable to areas of sectors and length of arc subtended, S. In such cases, it remains to determine area and circumference of the circle from the scales and correct in direct proportionality according to the value of θ. For θ in radians this correction amounts to $\theta/2\pi$. For θ in degrees this correction amounts to $\theta/360$.

In the case of surface area or volume of a sphere a similar approach may be directly applied. A hemisphere has exactly one half the volume and one-half the surface area of the sphere. Many other direct ratios of a similar nature occur and may be employed directly with the scale values presented.



Nomograms for the Properties of the Sphere

These nomograms provide a simple method of determining properties of spheres and spherical shapes. Properties evaluated include: segments, lunes, chords, zones, angles and interrelationships.

The Volume of a Spherical Sector

Use Nomogram I. Extracting the decimal notation as indicated by 10^n, enter the value of R on the right-hand scale. Extracting the decimal notation as indicated by 10^m, enter h on the left-hand scale. Align these values, intersecting the volume on the V_{SECTOR} scale. Restore the decimal notation as indicated by 10^{m+2n}.

The Volume of a Segment of One Base

Use Nomogram II. Illustrated in **Fig. 2a.** Enter the value of r_1 h_1 on the right-hand line. Extracting the decimal notation as indicated by 10^n, enter the value of h_1 on the left-hand scale. Align these values, intersecting the volume on the $V_{SEGMENT}$ scale. Restore the decimal notation as indicated by 10^{3n}

The Volume of a Segment of Two Bases

Use Nomogram II. Illustrated in **Fig. 2b** for parallel bases and **Fig. 2c** for nonparallel bases. Step 1: Enter the value of r_2 h_2 on the right-hand scale. Extracting the decimal notation as indicated by 10^n, enter the value of h_2 on the left-hand scale. Align these values, intersecting the volume on the $V_{SEGMENT}$ scale. Restore the decimal as indicated by 10^{3n}. Step 2. Enter the value of r_1 h_1 on the right-hand scale. Extracting the decimal notation as indicated by 10^n, enter the value of h_1 on the left-hand scale. Align these values, intersecting the volume on the $V_{SEGMENT}$ scale. Restore the decimal notation as indicated by 10^{3n}. Step 3: Subtract the second volume (Step 2) from the first (Step 1).

The Area of a Zone

Use Nomogram I. Extracting the decimal notation as indicated by 10^n, enter the value of R on the right-hand line. Extracting the decimal notation as indicated by 10^m, enter the value of h on left-hand scale. Align these values, intersecting the area on the A_{ZONE} scale. Restore the decimal notation as indicated by the 10^{n+m}.

The Area of a Lune

Use Nomogram III. Extracting the decimal notation as indicated by 10^n, enter the value of R on the right-hand line. Enter the value of the included angle, α, in degrees on the left-hand line. Align these values, intersecting the area on the A_{LUNE} scale (on the same side of the line as the angle selected). Restore the decimal notation as indicated by 10^{2n}.

The Cross-Sectional Area

Use the left-hand portion of Nomogram IV. Extracting the decimal notation according to 10^n, enter the value of L. Project horizontally to the cross-sectional area scale and read $A_{SECTION}$. Restore the decimal notation as indicated by 10^{2n}.

The Spherical Chord

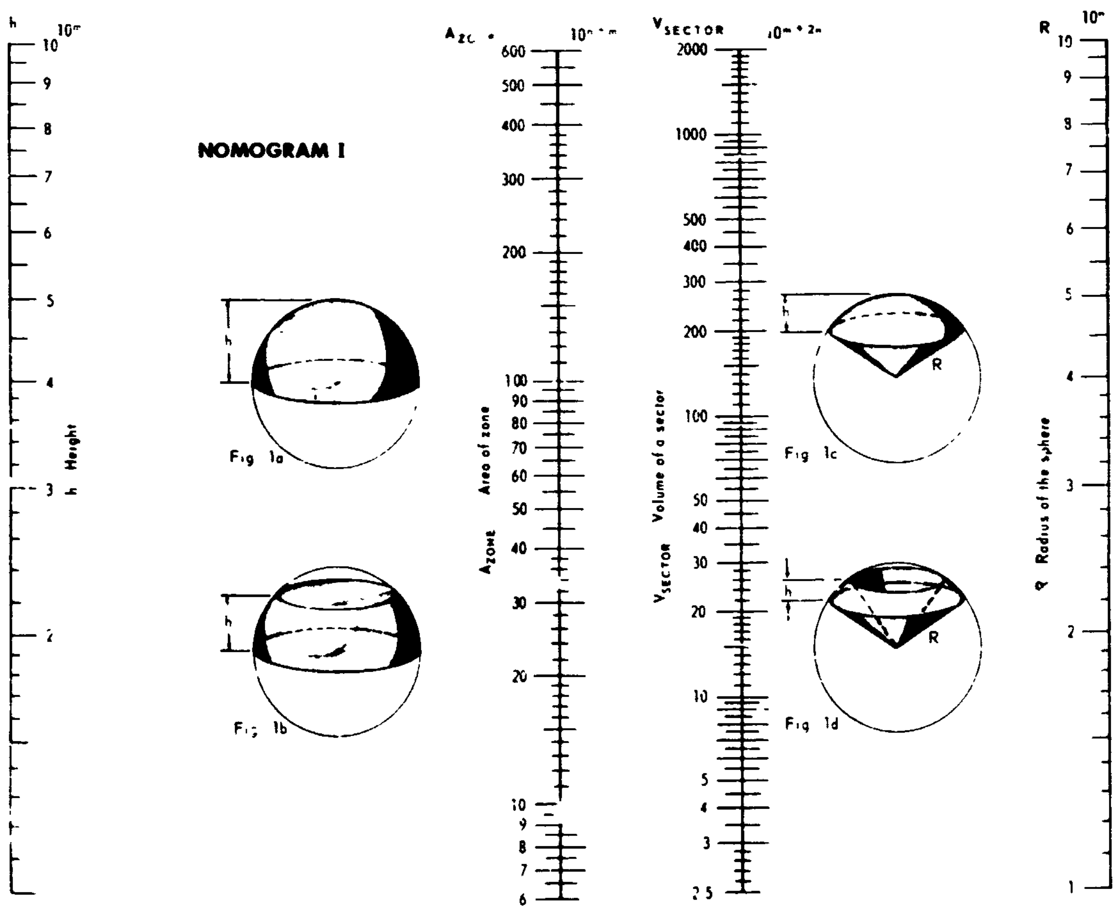
Use Nomogram IV. Extracting the decimal notation as indicated by 10^n, enter the value of R or D on the right-hand scale. Enter the value of θ, the included angle, on the slant scale. Align these values, intersecting L, the chord length, on the left-hand scale. Restore the decimal notation as indicated by 10^n

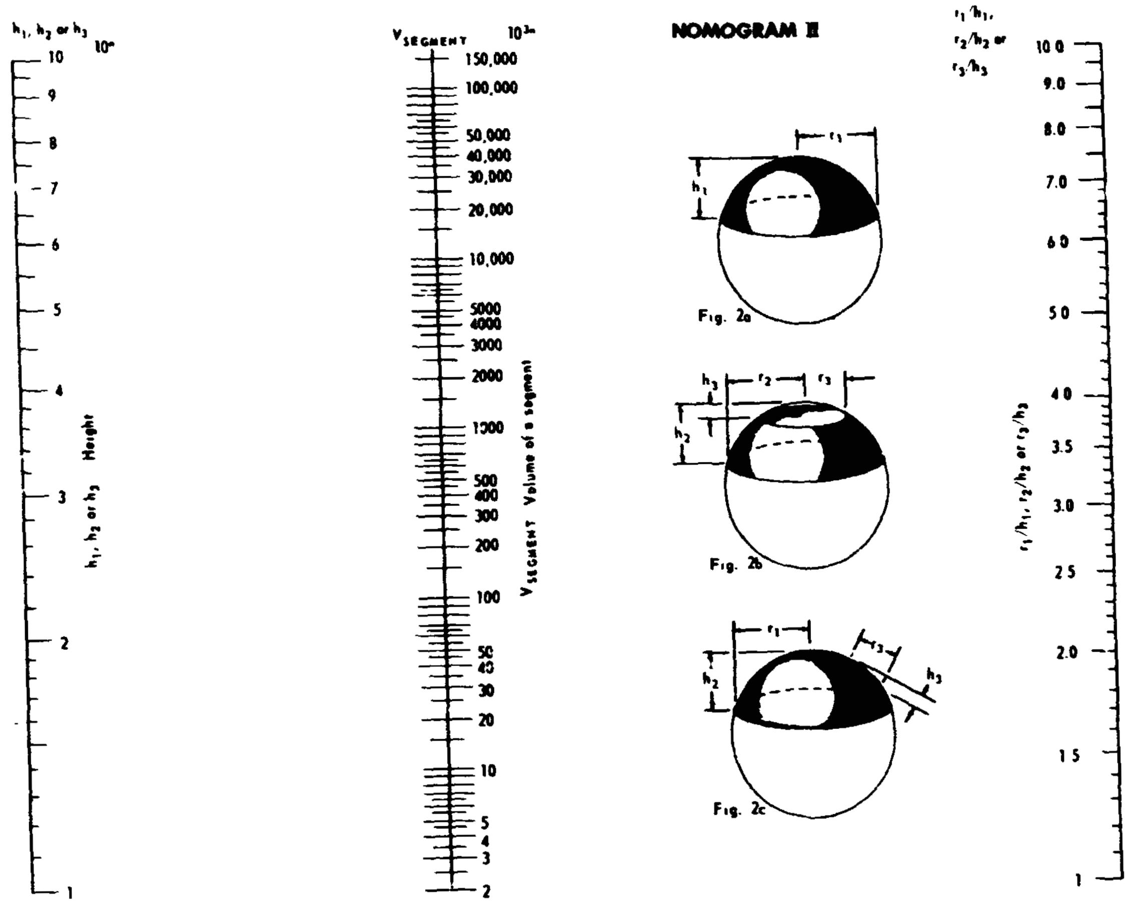
The Chordal Depth

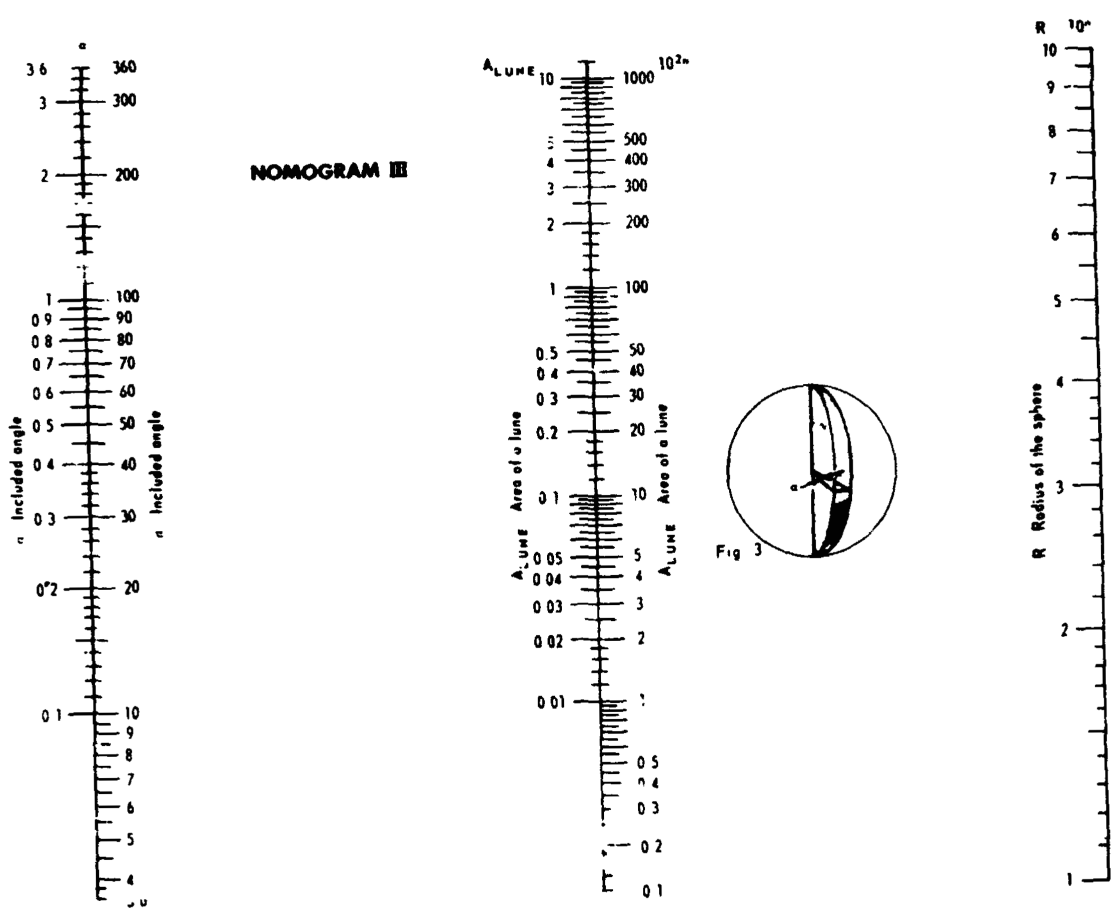
Use Nomogram V. Relationships illustrated in **Fig. 5.** Extracting the decimal notation according to 10^n, enter the value of R on the right-hand scale. Enter the value of θ, the included angle, on the slant scale. Align these values, intersecting the value of h_r, the chordal depth, on the left-hand scale. Restore the decimal notation as indicated by 10^n.

The Chordal Height

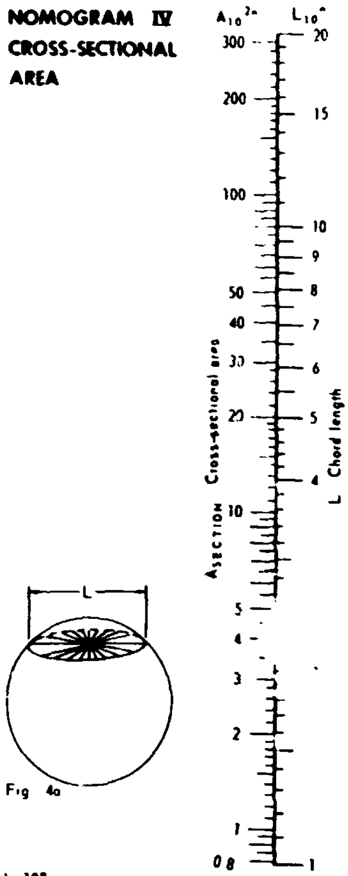
Use Nomogram V. Extracting the decimal notation according to 10^n, enter the value R on the right-hand scale. Enter either the value of θ, the included angle, on the slant scale or h_r, the chordal depth, on the left-hand scale. Align these values, intersecting h_o on the center scale. Restore the decimal notation as indicated by 10^n.



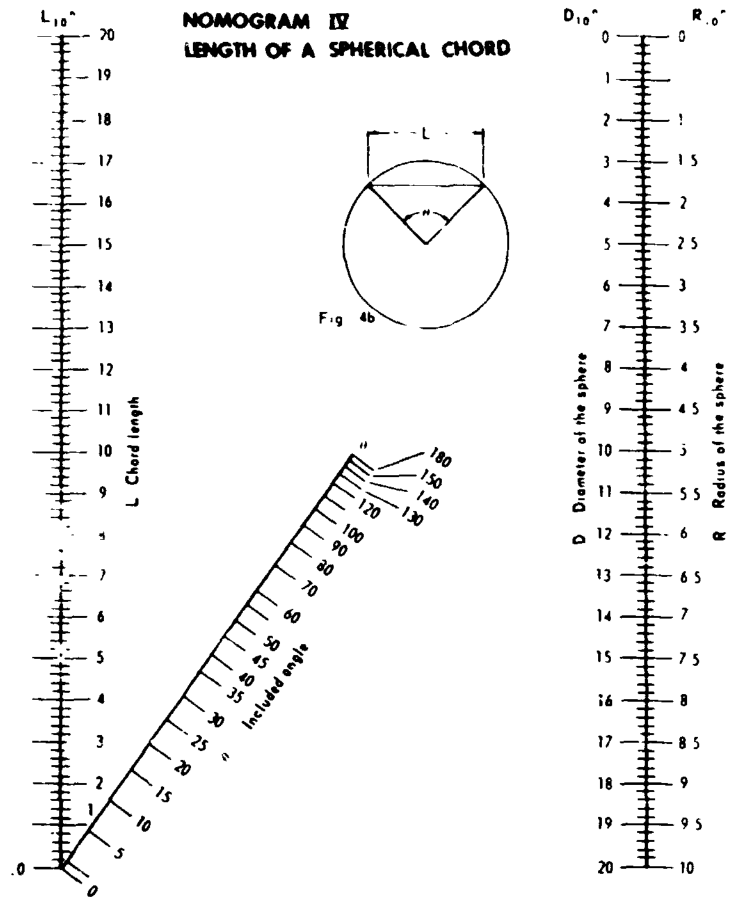

NOMOGRAM II
h1, h2 or h3 Height
V SEGMENT Volume of a segment
r1/h1, r2/h2 or r3/h3
Fig. 2a
Fig. 2b
Fig. 2c

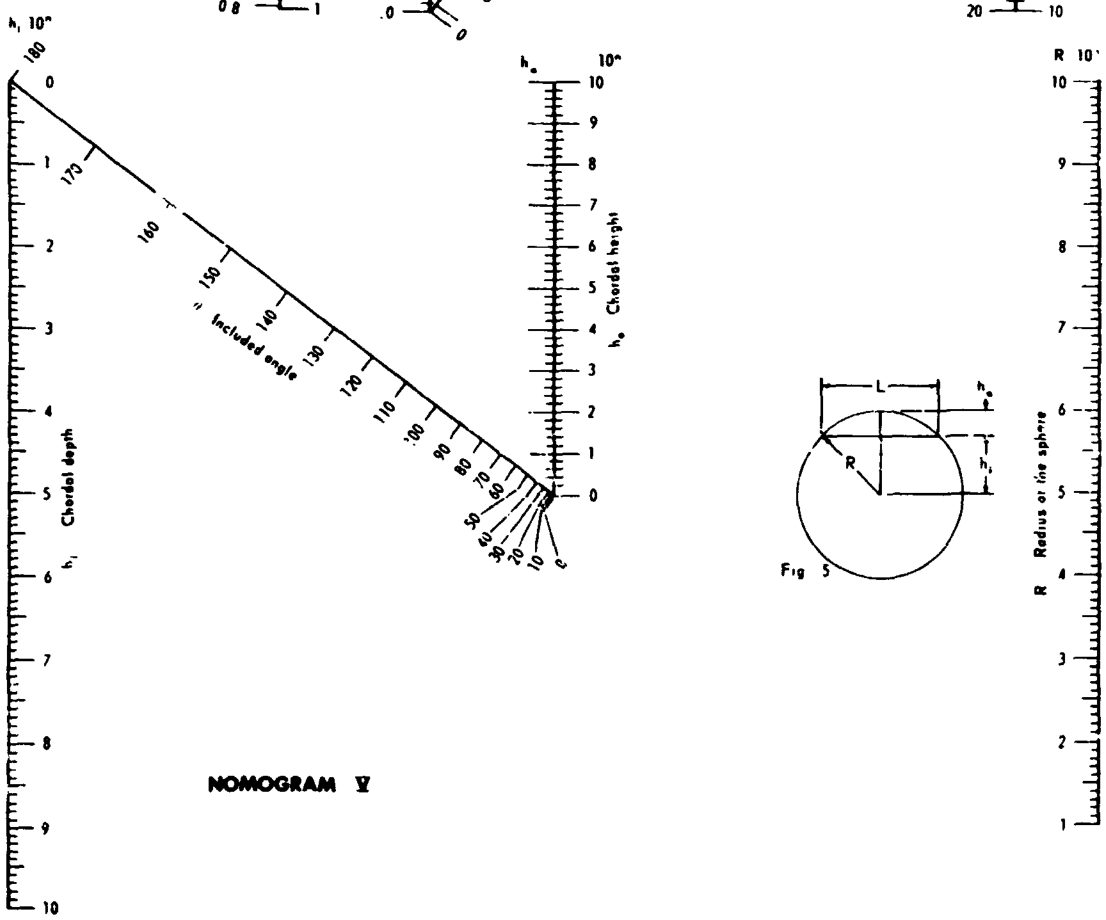

NOMOGRAM III
α Included angle
A LUNE Area of a lune
Fig 3
R Radius of the sphere

NOMOGRAM IV
CROSS-SECTIONAL AREA



NOMOGRAM IV
LENGTH OF A SPHERICAL CHORD





NOMOGRAM V

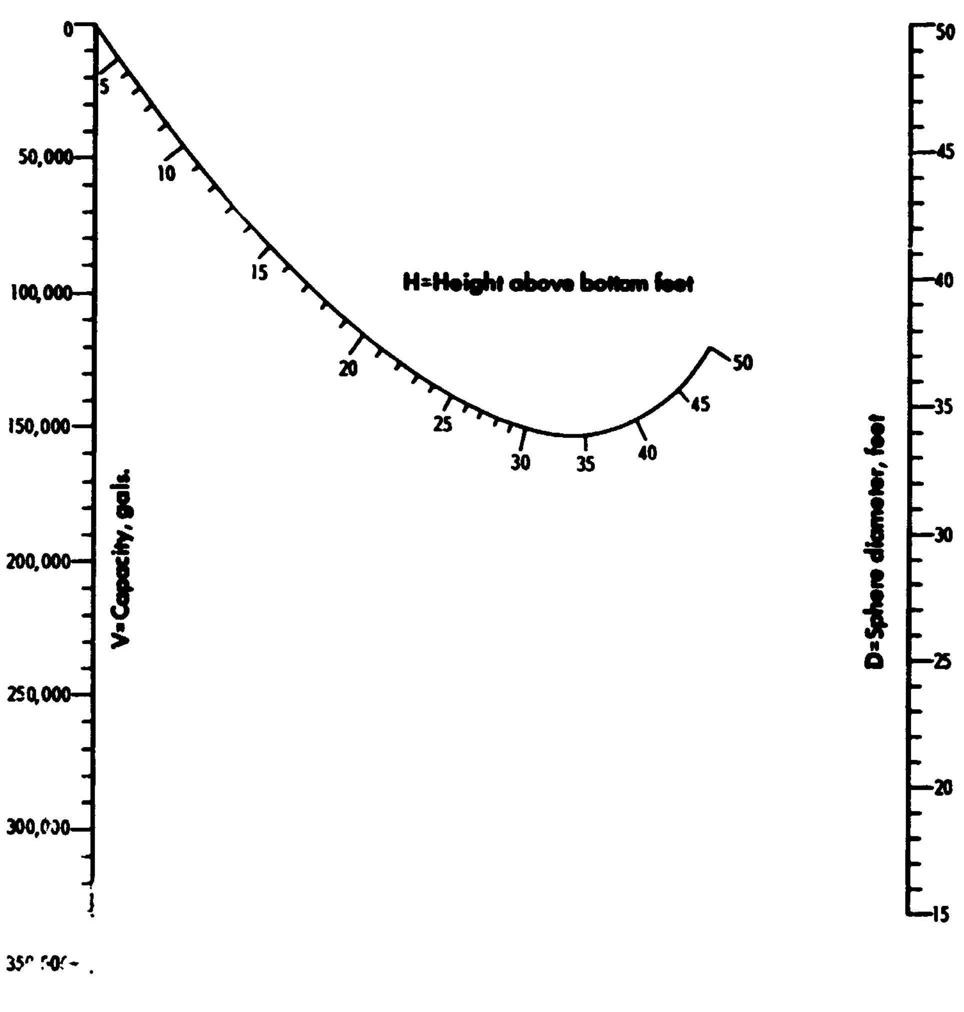
Nomogram for Partial Volumes of Spheres

Nomenclature:
V=capacity, gallons
H=height above bottom, feet
D=sphere diameter, feet.
The nomogram represents the equation:

$$V = 7.48\,\pi\,(H^2)\left(\frac{D}{2} - \frac{H}{3}\right)$$

Example:
What is the volume in a 50-ft-diameter sphere filled to a height of 15 ft?

Solution:
Align D=50 with H=15 and read V=106,000 gal.



Surface Area of an Ellipsoid

The accompanying curves will simplify determination of the surface area of an ellipsoid.

Nomenclature:

a = ellipse major semi-axis

b = ellipse minor semi-axis

E = eccentricity = $\sqrt{1-(b/a)^2}$

When an ellipsoid is formed by rotating an ellipse about its minor axis, it is known as an oblate spheroid and its surface area is given by:

$$A_o = 2\pi a^2 + \pi\left(\frac{b^2}{E}\right)\ln\left(\frac{1+E}{1-E}\right)$$

which may be reduced to:

$$A_o = 2\pi a^2\left[1 + \left(\frac{b^2}{2a^2E}\right)\ln\left(\frac{1+E}{1-E}\right)\right]$$

or

$$A_o = Xa^2$$

When an ellipsoid is formed by rotating an ellipse about its major axis, it is known as a prolate spheroid and its surface area is given by.

$$A_p = 2\pi b^2 + 2\pi\left(\frac{ab}{E}\right)\sin^{-1}E$$

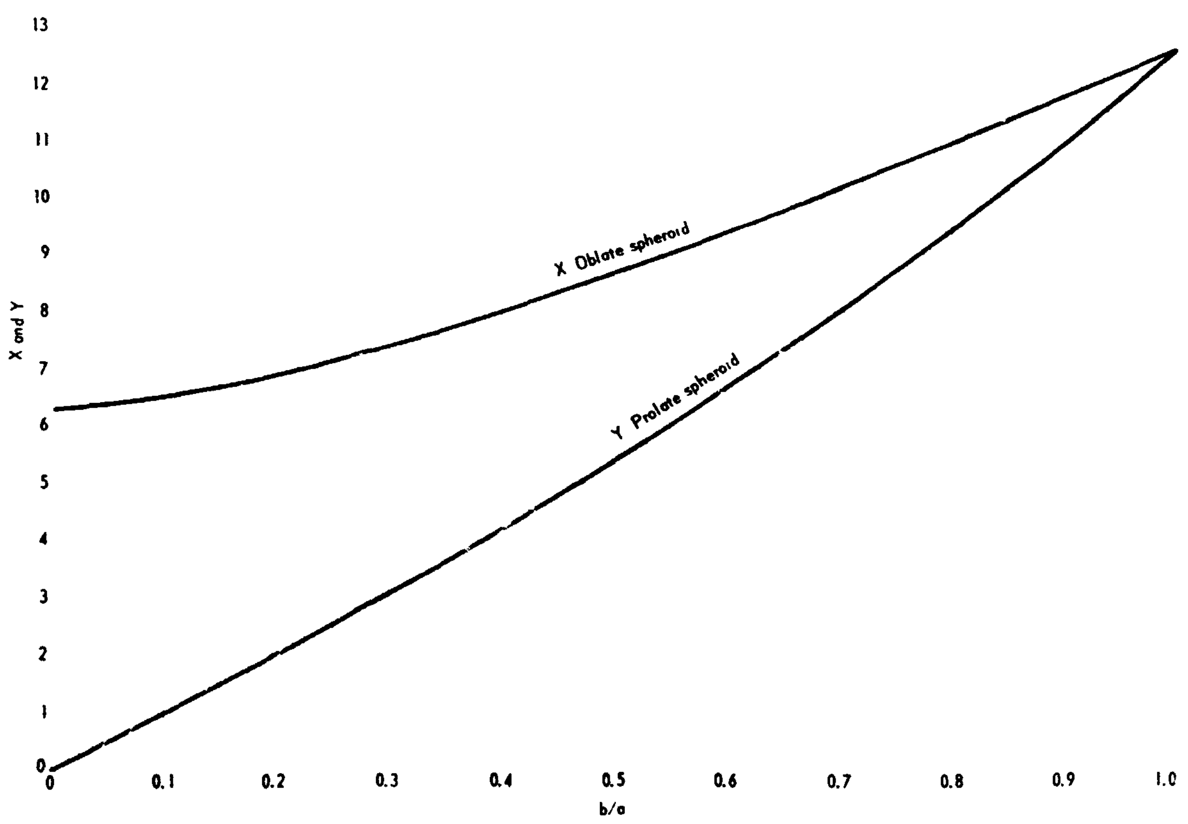
which may be reduced to:

$$A_p = 2\pi a^2\left[\frac{b^2}{a^2} + \left(\frac{b}{a}\right)\left(\frac{\sin^{-1}E}{E}\right)\right]$$

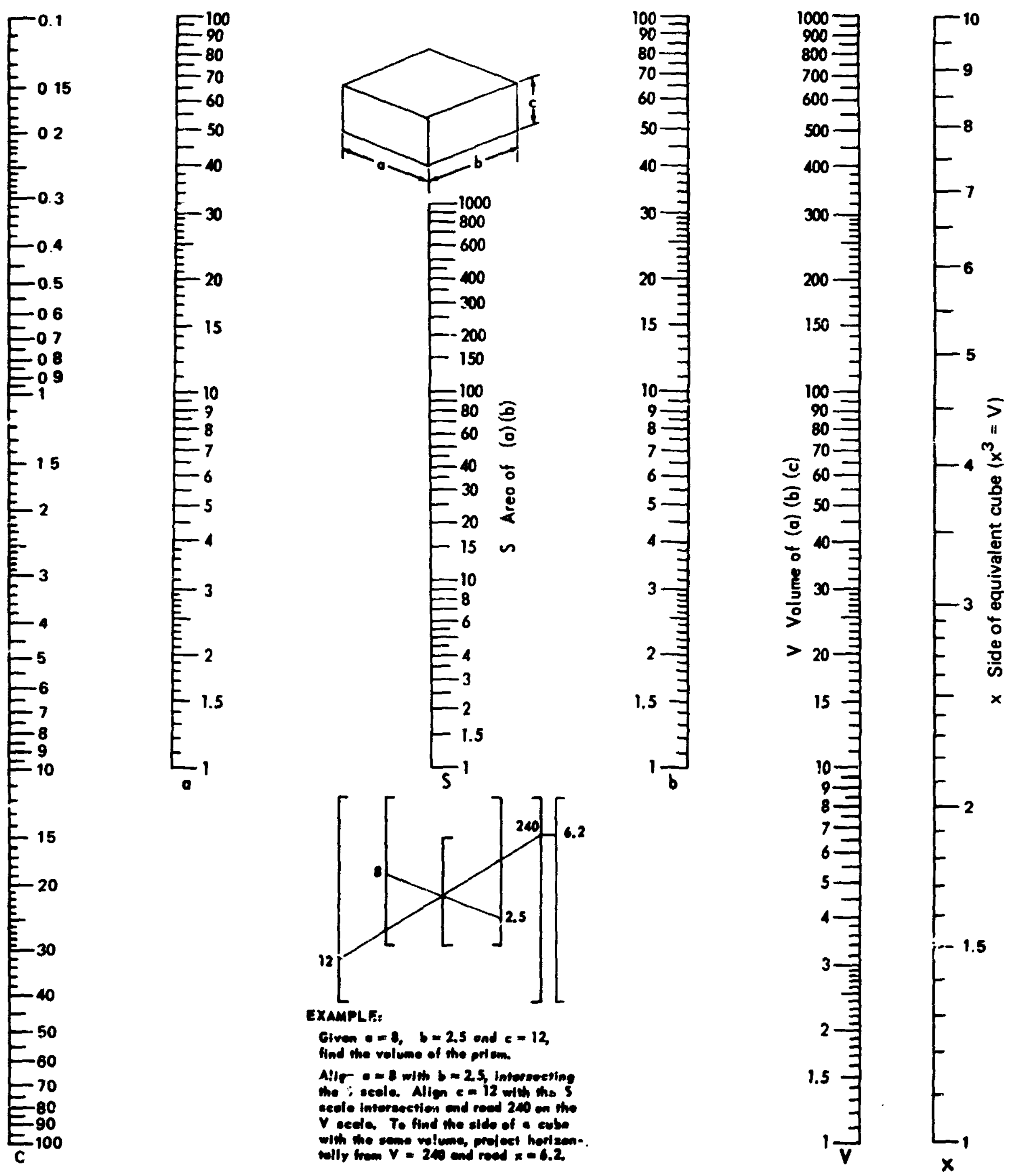
or

$$A_p = Ya^2$$

The accompanying chart gives values for X and Y as functions of the ratio b/a.



Nomogram for Volume of a Rectangular Parallelepiped



EXAMPLE:

Given a = 8, b = 2.5 and c = 12, find the volume of the prism.

Align a = 8 with b = 2.5, intersecting the S scale. Align c = 12 with the S scale intersection and read 240 on the V scale. To find the side of a cube with the same volume, project horizontally from V = 240 and read x = 6.2.

Perimeter of an Ellipse

The standard formula for calculating the perimeter of an ellipse arithmetically is tedious and awkward to use:

$$P = \pi(A + B)\left[1 + \frac{(A - B)^2}{4(A + B)^2} + \frac{(A - B)^4}{64\,(A + B)^4} + \frac{(A - B)^6}{256(A + B)^6} + \cdots\right]$$

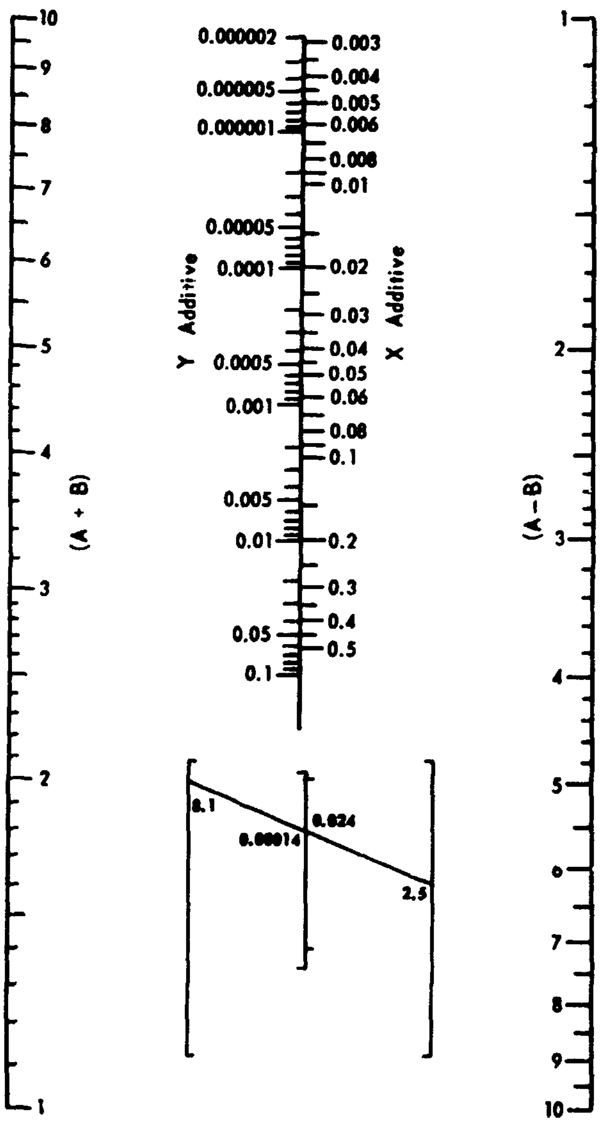
An approximate solution is given by calculating perimeter as (π) $(A + B)$, but this is only valid when $(A - B)$ is very small.

The nomograms have been constructed to enable the basic formula to be applied rapidly to the practical order of accuracy required. The basic formula is rewritten:

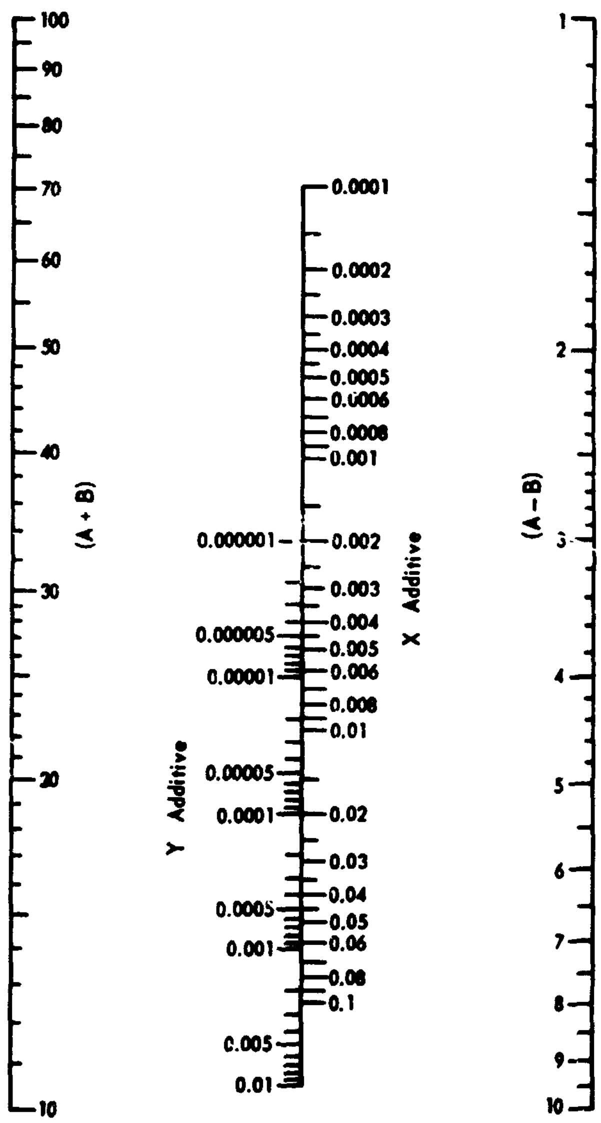
$P = \pi(A + B)\,(1 + X + Y)$

Nomograms I or II give immediate solutions for

NOMOGRAM I



NOMOGRAM II



"X" and "Y" for the known (A + B) and (A − B) values. Use either Nomogram I or Nomogram II, according to the (A + B) scale value required. The "X" additive is read off the top center scale and the "Y" additive off the bottom center scale in both cases.

The appropriate value of (1 + X + Y) is then entered on the right-hand scale of Nomogram III and connected to the (A + B) value on the left-hand scale. Perimeter is read off the intersection on the center scale.

Example:

If in a given ellipse A = 5.3 inches and B = 2.8 inches, find the perimeter.

Solution:

(A + B) = 8.1 inches

(A − B) = 2.5 inches

Using these values on Nomogram I:

X additive = 0.024

Y additive = 0.00014

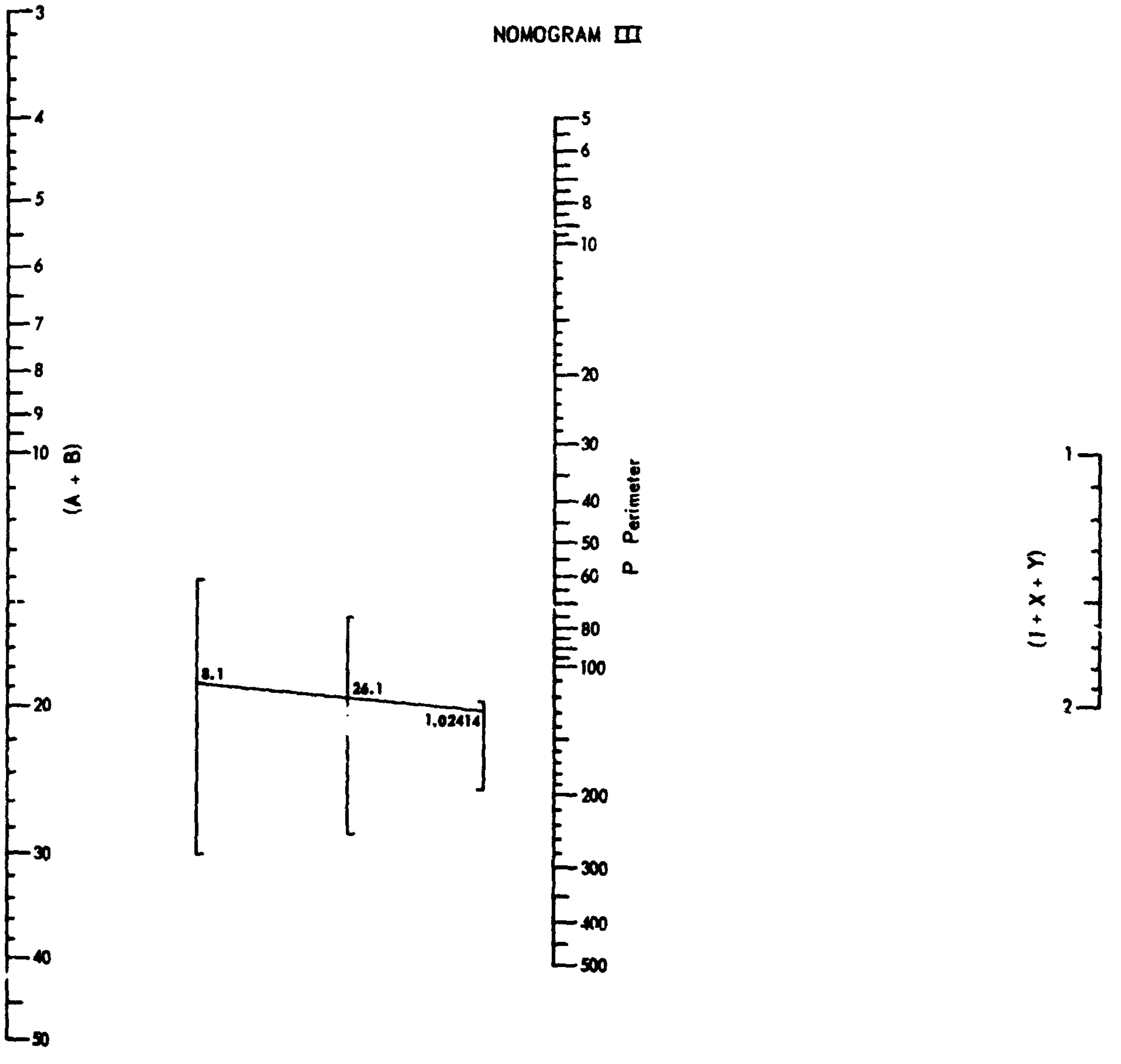
$\therefore$ (1 + X + Y) = (1 + 0.024 + 0.00014) = 1.02414 (Note: The "Y" value is small enough to ignore for most practical purposes.)

Enter (1 + X + Y) = 1.02414 on Nomogram III and read P = 26.1 inches.

For accuracy greater than that given by Nomogram III, Nomograms I or II can be used for obtaining the "X" and "Y" additives and the final solution worked by logs.

Nomogram III also can be used for quick, approximate solutions by ignoring the additives and projecting across to value 1 on the right-hand scale

NOMOGRAM III



Rapid Graphing of Ellipses, Parabolas and Hyperbolas

Charles C. Works, Denver, Colo.

The following procedures will permit construction of exact ellipses and aid in rapid plotting of any arbitrary points and tangents of parabolas and hyperbolas of any specified shapes. Computations, tables and special instruments are not required.

Construction of an Ellipse

If the major axis of a horizontal ellipse is (2a) units and its minor axis is (2b) units, then its equation is $(x^2/a^2) + (y^2/b^2) = 1$, expressed in rectangular coordinates (x, y) whose origin is the center of the ellipse. As shown in Fig. 1, a strip of plastic, metal or cardboard is cut to a length of (a + b) units. A small notch is cut in one edge of the strip at a distance of (a) units from the left end and (b) units from the right end. An inside right-angle is rigidly fastened to the drawing material along the required axes. This right-angle is conveniently formed by the inside edge of a flat carpenter's square or by two perpendicular straightedges. A pencil point is held in the notch and the strip is moved so that the corners are always in contact with the legs of the right-angle. Starting from a position between the axes, the strip is moved until it coincides with one axis; then it is returned to its original position and moved until it coincides with the other axis. This procedure accurately constructs one quadrant of the ellipse. Repositioning the right-angle along the coordinate axes allows construction of the other three quadrants.

Construction of a Line Tangent to an Ellipse

The two focal points of the ellipse are at a distance of $\sqrt{a^2 - b^2}$ units from its center along the major axis. Referring to Fig. 2, a circle of radius (a) is drawn around the ellipse, concentric with it. A right-angle is placed so that one edge passes through a focal point, with the vertex on the circle and the other edge passing through the given point of tangency. The second edge is then tangent to the ellipse. This procedure is useful in drawing an ellipse through plotted points.

Construction of a Parabola

If the focal point of a vertical parabola is (c) units from its vertex, then its equation is $y = x^2/4c$, referred to rectangular coordinates with the vertex taken as the origin. As shown in Fig. 3, a horizontal line is drawn (4c) units below the x-axis and the vertex of a right-angle is placed at the origin. The intersection (P) of the right-angle with this horizontal line is taken as the x-coordinate of a point on the parabola. Then, the intersection of the right-angle with a vertical line through (P) gives the y-coordinate of this point. Plotting of points is very rapid if an inside right-angle is used and a pin is inserted at the origin to act as a pivot for the angle. The right-angle may consist of two perpendicular straightedges taped together.

Tangents to a Parabola

A right-angle is placed so that one edge passes through the focal point and its vertex is on the x-axis, as illustrated in Fig. 4. The other edge passes through the given point of tangency. This edge, then, is exactly tangent to the parabola. This method considerably reduces the number of points that need to be plotted in order to draw an accurate curve.

Construction of a Hyperbola

A vertical hyperbola whose two vertices are (b) units from the origin along the y-axis, and whose two asymptotes have slopes of ($\pm$ b/a), will have the equation $(y^2/b^2) - (x^2/a^2) = 1$ when plotted on rectangular coordinate paper. Referring to Fig. 5, a circle of radius (b) units is drawn about the origin and a horizontal line is drawn (a) units up from the x-axis. Then a right-angle is placed so that one edge passes through the origin and the vertex is on the circle. The intersection of this edge (extended if necessary) with the horizontal line is the x-coordinate of a point on the hyperbola. The intersection of the other edge with the y-axis gives the y-coordinate of the point.

Plotting of points is even more rapid if two triangles are fastened together (by taping, for example) as shown in Fig. 6 so that the coinciding edges overlap for a distance of (b) units, and the inside right-angle formed by the combined triangles is pivoted about a pin inserted in the origin. This method eliminates need for the circle.

Construction of Tangents to a Vertical Hyperbola

The two focal points are located $\sqrt{a^2 + b^2}$ units above and below the origin. A circle of radius (b)

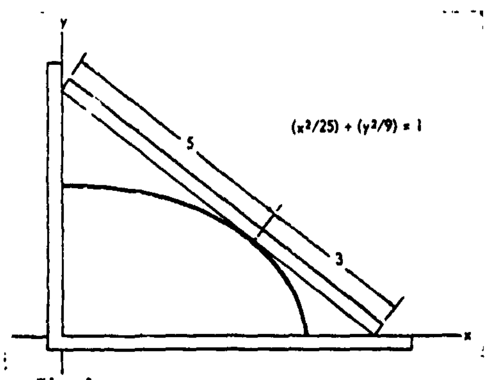


Fig. 1 Construction of an ellipse

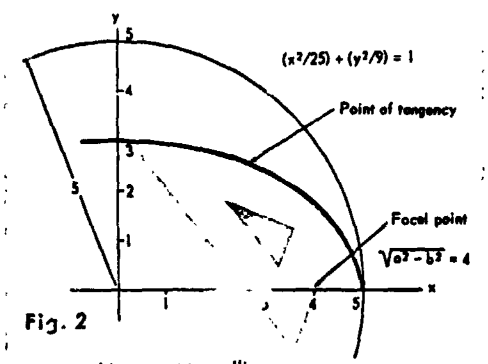


Fig. 2 Line tangent to an ellipse

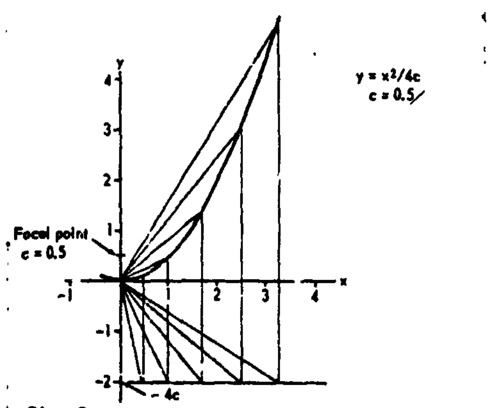


Fig. 3 Construction of a parabola

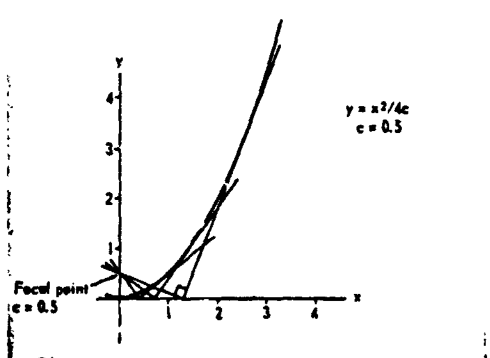


Fig. 4 Lines tangent to a parabola

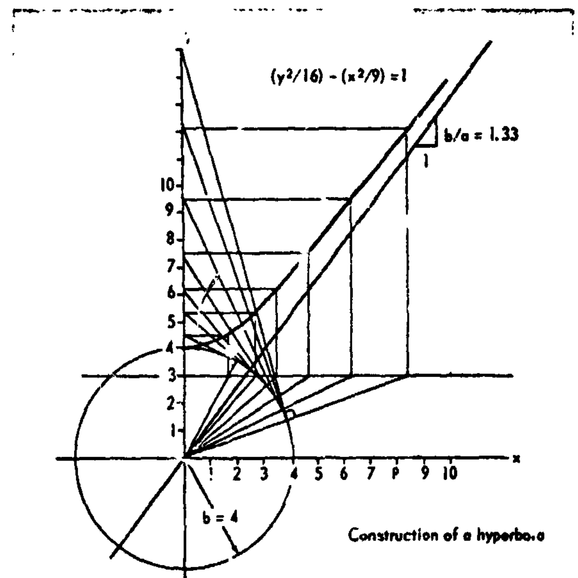


Fig. 5 Construction of a hyperbola

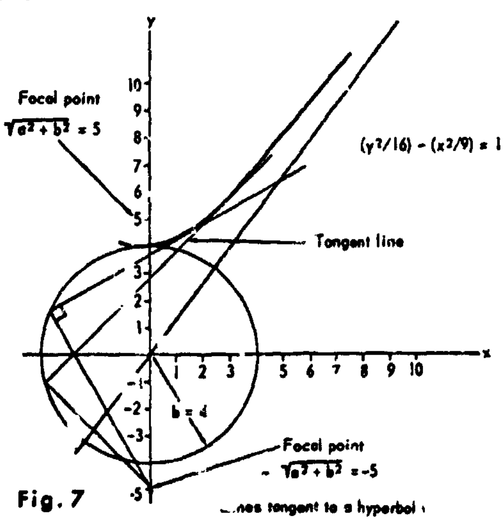


Fig. 7 Lines tangent to a hyperbola

is drawn about the origin as shown in Fig. 7. A right-angle is placed so that one edge passes through a focal point, the vertex lies on the circle, and the other edge passes through a given point of tangency. This edge, then, is tangent to the hyperbola.

Construction of Right Hyperbolas and Other Curves

If a right hyperbola with equation $y = k/x$ $(k>0)$ is referred to new axes formed by rotating the previous axes clockwise 45 deg, its equation becomes $(y_1^2/2k) - (x_1^2/2k) = 1$. This is treated like the vertical hyperbola with $a = b = \sqrt{2k}$, as shown in Fig. 8.

Horizontal parabolas and hyperbolas and vertical ellipses are treated by letting $x_1 = y$ and $y_1 = x$, that is by interchanging x and y in the equations.

Construction of Approximation Circles at Vertices

A curve is closely approximated near a given point by a circle with the same curvature and having a common tangent to the curve at that point ("osculating" circle). The approximation is especially close when the point is on an axis of symmetry. This greatly reduces the number of points or tangents that need to be plotted. Figs. 9-12 give the general center and radius of each vertex circle on an axis of the above curves.

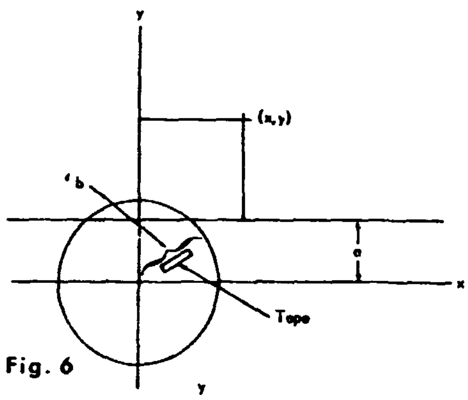


Fig. 6

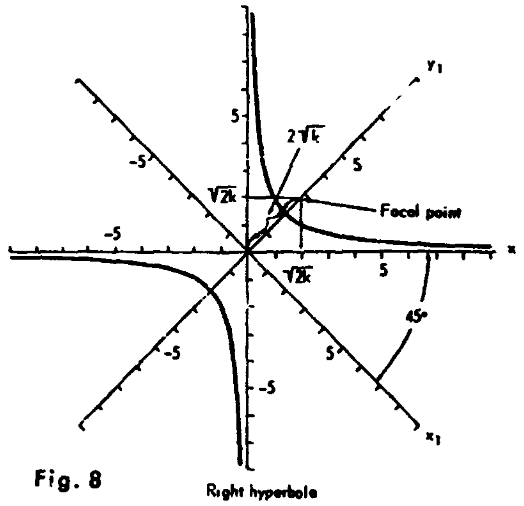


Fig. 8 Right hyperbola

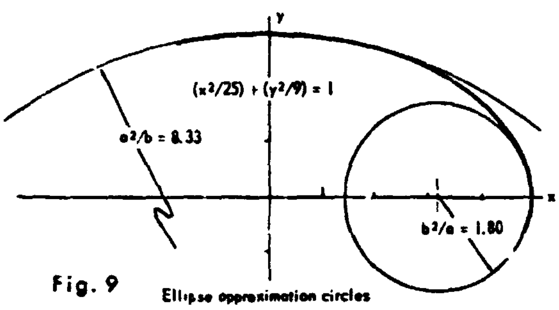


Fig. 9 Ellipse approximation circles

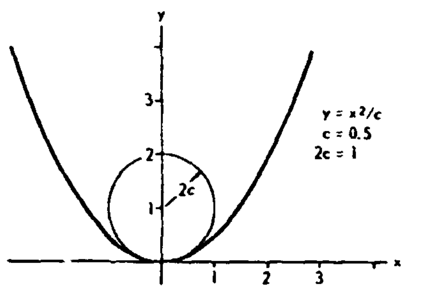


Fig. 10 Parabola approximation circle

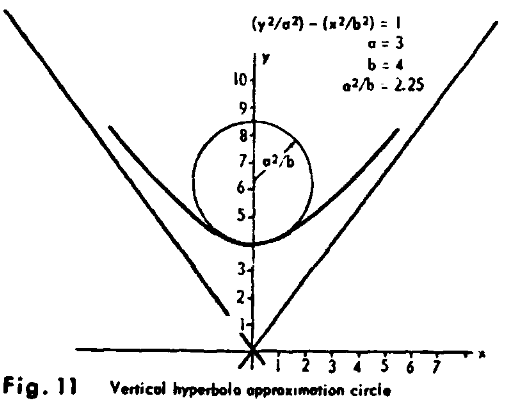


Fig. 11 Vertical hyperbola approximation circle

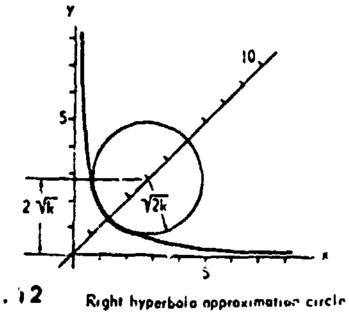


Fig. 12 Right hyperbola approximation circle

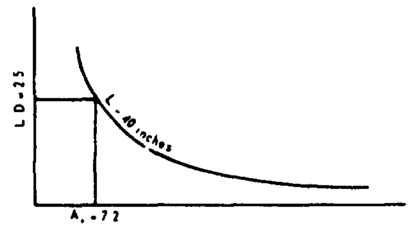
Surface Area of a Cone

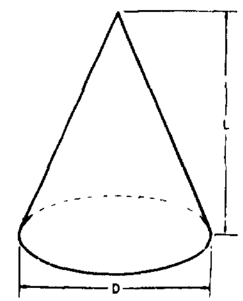
This chart will simplify the determination of the surface area of a cone.

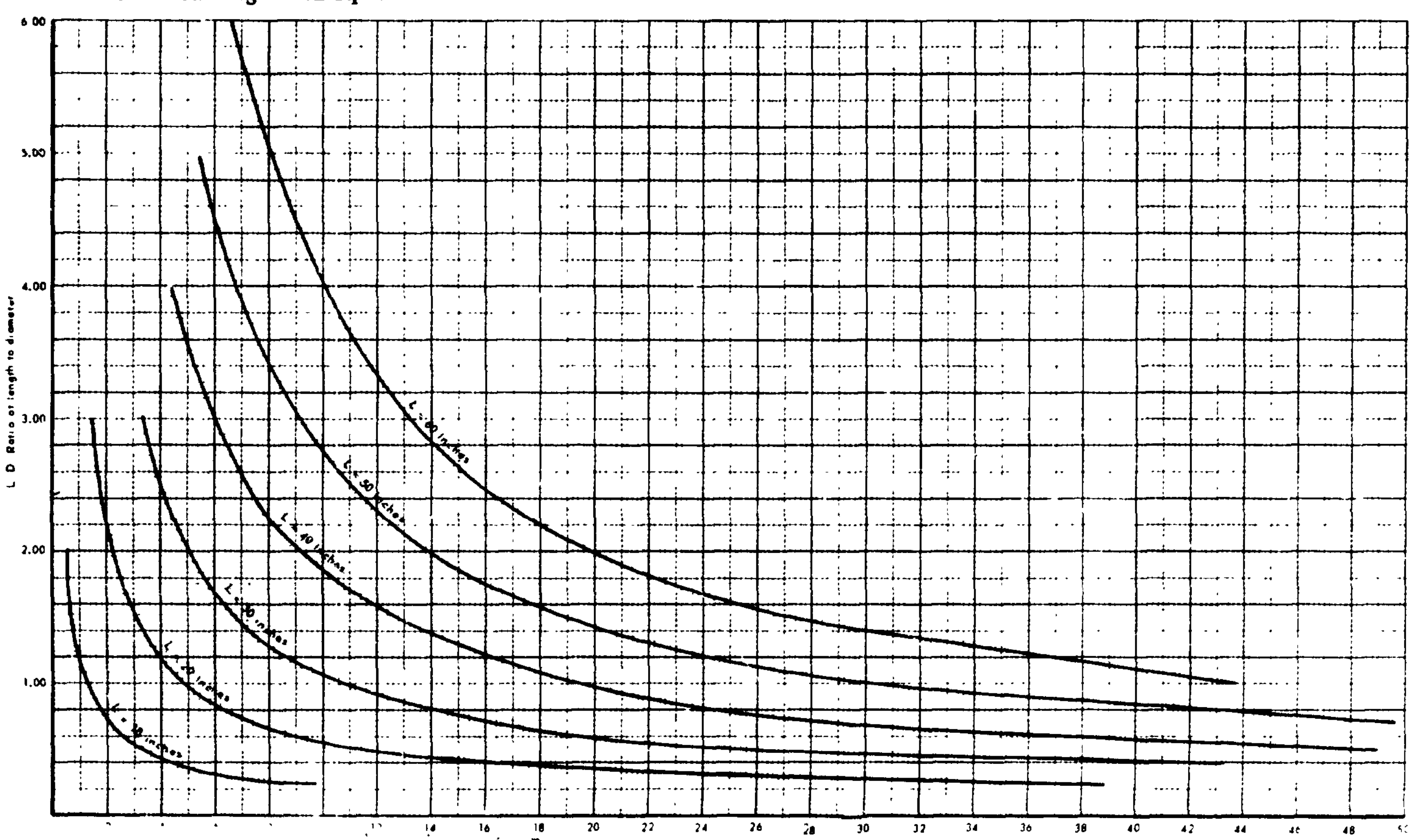
The chart is used as follows: (1) Divide the cone length in inches by the cone base diameter in inches and (2) enter the abcissa with the L/D value, and project horizontally to the appropriate L line, thence downward to read surface area in sq ft.

Example: Find the surface area of a cone 40 inches in length and 16 inches in dia.

Solution: L/D = 40/16 = 2.5. Enter at L/D = 2.5 and project to L = 40, thence downward to read A_S = 7.2 sq ft.







Exponents and Logarithms Reference Sheet

In addition to the better-known formulas, this article compiles change-of-base, interpolation and conversion formulas along with a table of conversion constants usually not found in texts and handbooks.

DEFINITIONS

Exponents:

An integral exponent is a count of the number of times a given quantity (the base) appears as a multiplying factor in a term. Thus, (a)(a)(a)(a) = a^4. The whole expression is called "the fourth power of (a)" or "(a) taken to the fourth power" or "the exponential of 4". In this expression, (a) is the base and 4 is the exponent. This definition leads to the laws of exponents. Fractional, irrational and imaginary exponents then are defined to agree with these laws.

Logarithms:

The logarithm of a number to a given base is defined as the exponent to which that base must be raised in order to equal the given number. That is, "$\log_b A = x$" means the same as "$b^x = A$". By treating a logarithm as an exponent, the laws of logarithms are developed from the laws of exponents.

NOMENCLATURE

a, b = any positive numbers used as bases
p, q = any numbers used as exponents
A, B = any positive numbers whose logs are taken
$j = \sqrt{-1}$
m, n = any real integers
θ = any angle (in radians)
$\log A = \log_{10} A$
$\ln A = \log_e A$

EXPONENTS

General Laws:

$b^p b^q = b^{p+q}$	The product of powers with the same base is the base taken to the sum of the exponents.
$b^p/b^q = b^{p-q}$	The quotient of powers with the same base is the base taken to the difference of the exponents.
$a^p b^p = (ab)^p$	The product of powers with the same exponent is the product of the bases taken to the exponent.

Special Powers:

$b^1 = b;\ 1^p = 1$	These equations are true for all numbers.
$b^0 = 1,\ b \neq 0$ $0^p = 0,\ p \neq 0$	The symbol 0^0 has no algebraic meaning, because $0^{p-p} = 0^p/0^p = 0/0$, which can have any value, and thus is undefined.

Fractional Exponents:

By defining fractional powers as radicals, all laws above are preserved. Thus,

$$b^{-1/2} = 1/\sqrt{b} = \sqrt{b}/b$$

$$b^{2/3} = \sqrt[3]{b^2} = (\sqrt[3]{b})^2$$

Complex and Negative Bases:

DeMoivre's theorem gives the n different equations:

$$(x + jy)^{m/n} = \left(\sqrt{x^2 + y^2}\right)^{m/n}$$

$$\left[\cos\left(\frac{m}{n}\theta + \frac{2k\pi}{n}\right) + j\sin\left(\frac{m}{n}\theta + \frac{2k\pi}{n}\right)\right]$$

Where:

$k = 0, 1, 2, \ldots (n-1)$

θ (in radians) is an angle in the quadrant of (x, y) whose tangent is (y/x).

Complex Exponents:

Euler's theorem gives the single equation:

$$e^{j\theta} = e^{j(\theta+2n\pi)}$$

$$= \cos(\theta + 2n\pi) + j\sin(\theta + 2n\pi)$$

Where: $e = 2.718+$.

LOGARITHMS

Defining Equation:

$$b^{\log_b A} = A\ ,\ b \neq 1$$

This expresses the fact that an exponential of a number is the same thing as an antilog of the number. That is, using a number as an exponent and taking a log of the number are converse operations; they reverse each other's effects, thus restoring the original number. All

other log formulas develop from this definition.
Formulas for Computing:

General Formulas:

Product:

$$\log_b AB = \log_b A + \log_b B$$
$$AB = \text{antilog}\,(\log A + \log B)$$

Quotient:

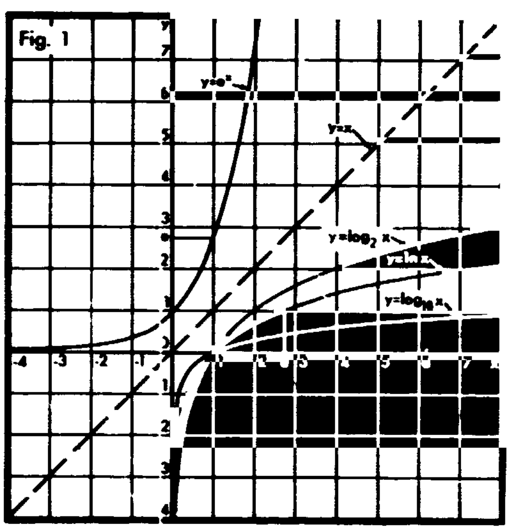
$$\log_b A/B = \log_b A - \log_b B$$
$$A/B = \text{antilog}\,(\log A - \log B)$$

Power:

$$\log_b A^p = p \log_b A$$
$$A^p = \text{antilog}\,(p \log A)$$

Special Formulas:

$$\log_b 1 = 0$$
$$\log_b b = 1$$
$$\log_b (1/A) = -\log_b A$$
$$\log(1/A) = (10 - \log A) - 10$$



When no base is indicated, the base is understood to be 10. If A or B are negative or imaginary, first perform the computation disregarding signs and then prefix the proper sign to the result.

Change-of-Base Formulas:

$$\log_a A = \log_b A/\log_b a = (\log b/\log a)\ \log_b A$$
$$\log_a b = 1/\log_b a = \log b/\log a$$
$$a^p = b^{p \log_b a} = b^{p (\log a/\log b)}$$

In computations involving powers or changes-of-base, the logarithms used are often themselves long numbers. Hence, it is convenient to multiply or divide them by again using logs, prefixing the proper sign to the first antilog taken. Thus,

$$A^p = \text{antilog antilog}\,(\log\log A + \log p)$$
$$\log_a A = \text{antilog}\,(\log\log b + \log\log_b A - \log\log a)$$
$$\log\log_a b = (10 - \log\log_b a) - 10$$

Conversion Constants:

$e =$	2.71828	18284	59045	
$\log e =$	0.43429	44819	03252	
$\log 2 =$	0.30102	99956	63981	
$\ln 2 =$	0.69314	71805	59945	
$\log \pi =$	0.49714	98726	94135	
$\ln 10 =$	2.30258	50929	94046	
$\log_2 10 =$	3.32192	80948	87361	
$\log_2 e =$	1.44269	50408	88963	
$\log\log e =$	9.63778	43113	00537	−10
$\log\log 2 =$	9.47860	97723	45675	−10
$\log\ln 2 =$	9.84082	54610	45138	−10
$\log\ln 10 =$	0.36221	56886	99463	
$\log\log_2 10 =$	0.52139	02276	54325	
$\log\log_2 e =$	0.15917	45389	54862	

Common Conversion Formulas:

The change-of-base formulas with appropriate constants give:

$$10^p = \text{antilog}\ p = e^{2.303p} = 2^{3.322p}$$
$$e^p = \text{antilog}\,(0.4343p) = 10^{0.4343p} = 2^{1.4427p}$$
$$2^p = \text{antilog}\,(0.3010p) = 10^{0.3010p} = e^{0.6931p}$$
$$\log A = 2.303 \ln A = 0.3010 \log_2 A$$
$$\ln A = 0.4343 \log A = 0.5931 \log_2 A$$
$$\log_2 A = 3.322 \log A = 1.4427 \ln A$$

Complex and Negative Numbers:

$$\ln(x + jy) = (1/2)\ \ln(x^2 + y^2) + j(\theta + 2m\pi)$$

This follows from Euler's and DeMoivre's theorems. As special cases:

$$\ln(-x) = \ln x + j(2m - 1)\pi,\ x>0$$
$$\ln(jy) = \ln y + j(2m + 1/2)\pi,\ y>0$$

All equations of this article thus can be extended to complex numbers when the quantities involved are finite.

CALCULUS FORMULAS

Derivatives of Powers:

$$D_x u^p = p u^{p-1} D_x u$$
$$D_x b^v = (\ln b)\ b^v D_x v$$
$$D_x u^v = u^v (\ln u)\ D_x v + v u^{v-1} D_x u$$

Where: u and v are variables whose values depend on x.

Integrals of Powers:

$$\int_1^x y^{-1}\,dy = \ln x$$

$$\int_0^x y^p\,dy = x^{p+1}/(p + 1),\ p \neq -1$$

$\int_{-\infty}^{x} b^y\,dy = b^x/\ln b = (\log e/\log b)b^x$

Logarithms:

$D_x \log_b u = (\log e/\log b)(1/u)D_x u$

$\int_0^x \ln y\,dy = x \ln x - x$

INTERPOLATION

The following procedures, based on Taylor's theorem, are more accurate than the usual linear interpolation.

Let N be the table entry closest in value to the desired entry. Let $(N+h)$ be the value whose exponential or log is to be approximated. Note that h can be positive or negative. Let M be the table entry on the other side of $(N+h)$, away from N. Then:

$$|h| \leqq (1/2)|M - N|.$$

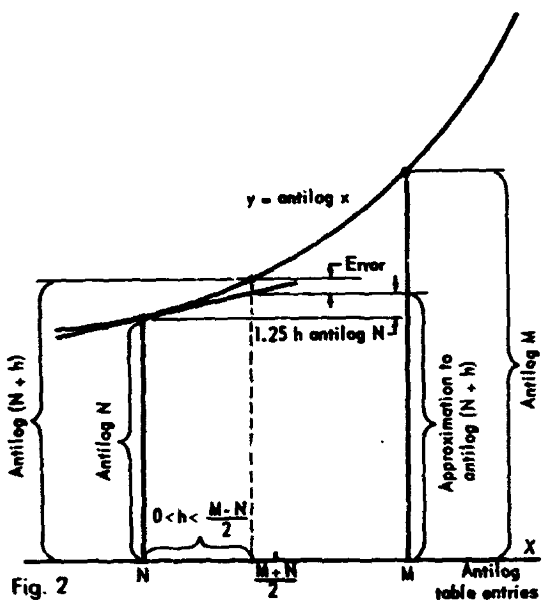


Fig. 2

Exponentials:

$e^{N+h} \approx e^N + he^N$

If $h<0$ then $|\text{error}| < (h/2)he^N$

If $h>0$ then $|\text{error}| < (h/2)he^{N+h} < (h/2)he^M$

Antilogs: (See Fig. 2)

antilog $(N+h) \approx$ antilog $N + (\ln 10)\,h$ antilog N

If $h<0$ then $|\text{error}| < (h/2)(\ln 10)\,h$ antilog N

If $h>0$ then $|\text{error}| < (h^2/2)(\ln 10)$ antilog M

Logarithms Base 10: (See Fig. 3)

$\log(N+h) \approx \log N + \log e\,(h/N)$

If $h<0$ then $|\text{error}| < (1/2)\log e\,(h/N)^2$

If $h>0$ then $|\text{error}| < (1/2)\log e\,(h/M)^2$

Logarithms Base e:

$\ln(N+h) \approx \ln N + h/N$

If $h<0$ then $|\text{error}| < (1/2)(h/N)^2$

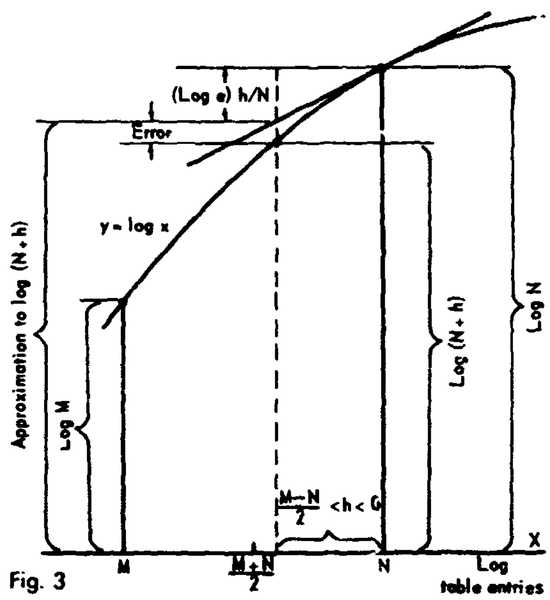


Fig. 3

If $h>0$ then $|\text{error}| < (1/2)(h/M)^2$

More Accurate Formulas:

$10^{N+h} \approx 10^N + (\ln 10)h\,10^N + h/2[(\ln 10)h\,10^N]$

If $h<0$ then $|\text{error}| < |h/3|\,[(\ln 10)(h^2/2)10^N]$

If $h>0$ then $|\text{error}| < (\ln 10)(h^3/6)\,10^M$

$\log(N+h) \approx \log N + 2(\log e)[(h/2N) - (h/2N)^2]$

If $h<0$ then $|\text{error}| < 2(\log e)(4/3)\,|h/2N|^3$

If $h>0$ then $|\text{error}| < 2(\log e)(4/3)(h/2M)^3$

Corresponding formulas for exponentials and natural logarithms are obtained by replacing 10 by e and omitting $(\ln 10)$ and $(\log e)$.

The Basic Laws of Physics

The following laws and formulas of physics include those most often used in mechanical enginee ing.

For convenient reference a topical index is given below. The numbers refer to the items in this article.

THE BASIC LAWS OF PHYSICS

12–Acceleration
3–Addition, Vector
31–Adhesion
23–Angular Momentum
21–Angular Velocity
30–Buoyancy
8–Center of Gravity
9–Center of Mass
22–Centrifugal Force
22–Centripetal Force
31–Cohesion
5–Composition, Vector
23–Conservation of Angular Momentum
19–Conservation of Energy
20–Conservation of Momentum
28–Density
19–Energy, Conservation
18–Energy, Kinetic
17–Energy, Potential
6–Equilibrium, Vector
34–Expansion, Thermal
14–Falling Bodies
27–Flow from Orifice
22–Force, Centrifugal
22–Force, Centripetal
34–Gas, Expansion
14, 15–Gravity
8–Gravity, Center of
29–Gravity, Specific
35–Heat, Specific
10–Inertia
18–Kinetic Energy
24–Kinetic Energy of Rotation
34–Linear Expansion
27–Liquid Flow from Orifice
34–Liquids, Expansion
26–Liquids, Pressure
9–Mass, Center of
20–Momentum, Angular
20–Momentum, Conservation
10, 13, 15, 16–Newton's Laws
27–Orifice, Flow from
18–Potential Energy
26–Pressure in Liquids
7–Resolution of Vectors
24–Rotation
1–Scalars
34–Solids, Expansion
11–Speed
29–Specific Gravity
35–Specific Heat
4–Subtraction of Vectors
34–Thermal Expansion
2–Vectors
3–Vector Addition
5–Vector Composition
6–Vector Equilibrium
7–Vector Resolution
4–Vector Subtraction
11, 21–Velocity
33–Viscosity
34–Volume Expansion
17–Work

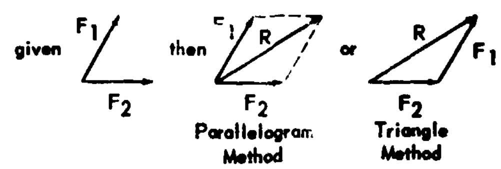
1. Measurable Quantities which have only Magnitude are called SCALARS, as Mass, Volume, Area, etc.
Scalar Quantities are always added Arithmetically.

2. Measurable Quantities which have both Magnitude and Direction are called VECTORS.

Vector Quantities are added Vectorially.

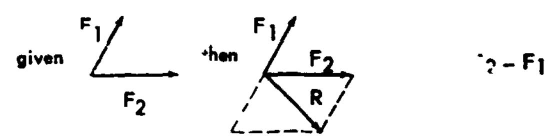
A Vector Quantity is represented by an Arrow, the length of which is proportional to the Quantity, and its direction is Parallel to the Direction of Action.

3. VICTOR ADDITION



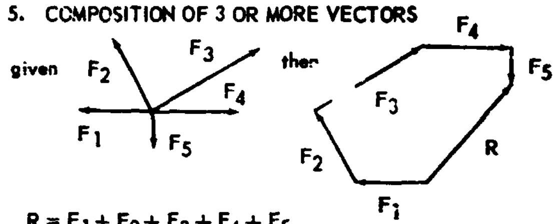
$F_1 + F_2 = R$

4. VECTOR SUBTRACTION



$F_2 - F_1$

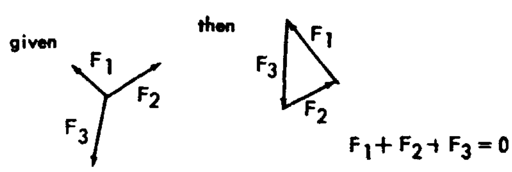
5. COMPOSITION OF 3 OR MORE VECTORS



$R = F_1 + F_2 + F_3 + F_4 + F_5$

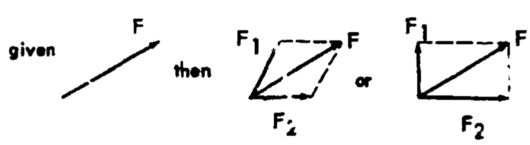
6. EQUILIBRIUM
(Forces prevent the body from moving)

A Body is in Equilibrium when the Vector Sum of all of the Forces acting on the Body is Zero.



$F_1 + F_2 + F_3 = 0$

7. RESOLUTION OF VECTORS
(To find 2 or more Vectors Equivalent to the Original One).

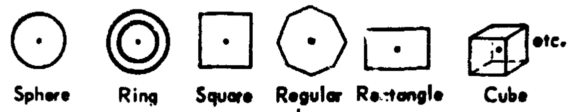


$F = F_1 + F_2$

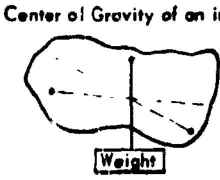
8. CENTER OF GRAVITY

The Center of Gravity is a point inside or outside of a body about which the body, if set turning, will rotate freely with uniform angular velocity.

The CENTER OF GRAVITY of all Regular Shaped Objects is at the Geometrical Center, thus:



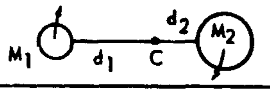
Center of Gravity of an irregular shaped body.



Lines determined by the weight will cross at a Common Point which is the Center of Gravity.

9. CENTER OF MA :

Center of Mass is the point on a line between two bodies about which the two bodies would revolve freely.



$M_1 \times d_1 = M_2 \times d_2$

10. NEWTON'S FIRST LAW

"A Body at Rest or in Motion will remain at rest or in motion unless some External Force is applied to it."

INERTIA is the property of a Body which tends to resist a change in its state of Rest or Motion when an External Force is applied.

11. SPEED AND VELOCITY

VELOCITY is the Rate of Change of Position.

Velocity is a VECTOR QUANTITY since it has both Magnitude and Direction.

if S = total distance
t = time
V = uniform velocity

then $V = \frac{S}{t}$; $S = Vt$; $t = \frac{S}{V}$

if V_0 = mean velocity
V_1 = initial velocity
V_2 = final velocity

then for Uniformly Varying Velocity;

$$V_0 = \frac{V_1 + V_2}{t} \qquad S = \frac{V_1 + V_2}{2} \times t$$

When Travel is in a Straight Line, Speed and Velocity are numerically equal.

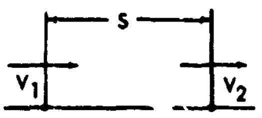
Along a Curved Path, the Speed of a body may be Constant while Velocity is Continually Changing due to its Change in Direction.

12. ACCELERATION

When the Velocity of a Body increases it is said to be Accelerated.

When the Velocity of a Body decreases it is said to have Negative Acceleration or Deceleration

If S = distance traveled
V_1 = initial velocity
V_2 = final velocity
t = time
a = acceleration



then $a = \frac{V_2 - V_1}{t}$; $V_2 = V_1 + at$; $V_1 = V_2 - at$

13. NEWTON'S SECOND LAW

"The rate at which the Momentum of a body changes is equal to the Force Acting, and takes place in the Straight Line in which the Force acts".

if F = force applied
t = time
M = mass
V_1 = initial velocity
V_2 = final velocity
a = acceleration

then $F = \frac{MV_2 - MV_1}{t} = M\left(\frac{V_2 - V_1}{t}\right)$

but since $\frac{V_2 - V_1}{t} = a$ (acceleration);

then by substitution $F = Ma$

14. GRAVITY AND FALLING BODIES

IF g = acceleration due to gravity = 32 ft/sec/sec
= 980 cm/sec/sec
s = distance traveled
t = time
V = velocity

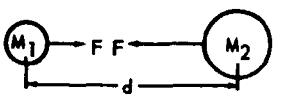
then for a Falling Body starting from Zero Velocity;

$S = \frac{1}{2} gt^2$ and $V = gt$
or combining the two equations; $V = \sqrt{2gs}$

If a body is dropped vertically and another is projected horizontally, both bodies will reach the ground at the same time.

15. NEWTON'S LAW OF GRAVITY

"Any two bodies attract each other with a force which is proportional to their masses, and inversely proportional to the square of the distance between them"



$F = G \times \frac{M_1 \times M_2}{d^2}$

where G = Newtonian Constant of Gravitation = 6.773×10^{-8}

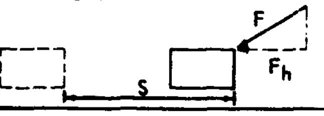
16. NEWTON'S THIRD LAW

"To every Action there is always an Equal and Opposite Reaction Force".

17. WORK

Work = Force x distance $\qquad W = F \times s$

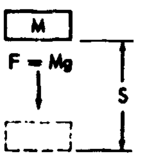
In the above formula, Force must act in the Same Direction as the Distance.



$W = F_h \times S$

18. POTENTIAL ENERGY and KINETIC ENERGY

A body is said to have POTENTIAL ENERGY if by virtue of its Position or State it is able to do work.



Potential Energy = $F \times S = Mg \times S$

The KINETIC ENERGY of a body is its ability to do Work by virtue of its Motion.

given M = mass
V = linear velocity

then Kinetic Energy = $\frac{1}{2} MV^2$

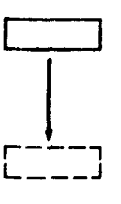
19. CONSERVATION OF ENERGY

a. In transforming energy from one form of energy to another, energy is always conserved.

b. Energy is never created or destroyed.

c. The sum total of all energy in the Universe remains constant.

example:



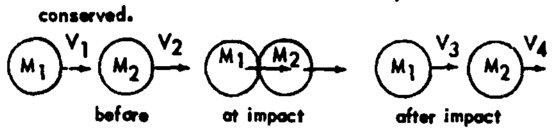
Potential Energy

Potential Energy plus Kinetic Energy

Kinetic Energy

20. CONSERVATION OF MOMENTUM

When two bodies collide with each other, momentum is conserved.



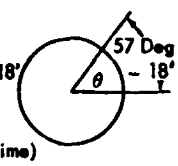
$M1\ V1 + M^2\ V2 = M1\ V3 + M2\ V4$

21. ANGULAR VELOCITY

Rotary Motion is measured by RADIANS (θ).
A Radian is the Angle subtended by an Arc whose length is equal to the Radius of the circle.

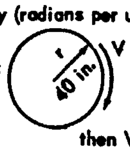
2π radians = 360 Deg.

1 radian $= \frac{360 \text{ Deg.}}{2 \times 3.1416} = 57$ deg $- 18'$



if V = linear velocity
r = radius of the circle
ω = angular velocity (radians per unit of time)

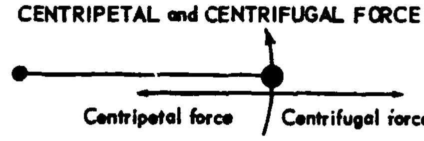
then $V = r\omega$ example:



if $\omega = 3$ radians/sec

then $V = 3 \times 40$ in. = 120 in/sec

22. CENTRIPETAL and CENTRIFUGAL FORCE



Centripetal Force is the force preventing mass from leaving its circular path.

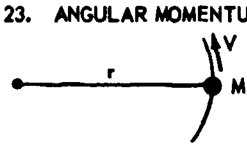
If the centripetal Force is removed, the Mass will change its course to a line tangent to the circle due to CENTRIFUGAL FORCE.

if M = mass
V = linear velocity
r = radius
ω = angular velocity in radians

then $F = M\frac{V^2}{r}$

or $F = M r \omega^2$

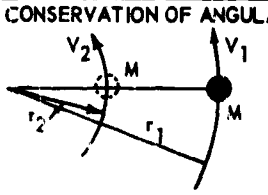
23. ANGULAR MOMENTUM



if M = mass
V = linear velocity
ω = angular velocity in radians
r = radius

then Angular Momentum = M V r
$= M r^2 \omega$

24. CONSERVATION OF ANGULAR MOMENTUM



$M\ V_1\ r_1 = M\ V_2\ r_2$

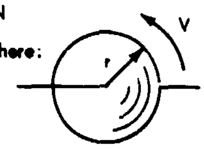
(or) $M\ r_1^2\ \omega_1 = M\ r_2^2\ \omega_2$

For the same Angular Momentum, a decrease in Radius must be compensated by an increase in Velocity.

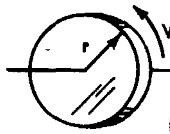
25. KINETIC ENERGY OF ROTATION

if M = mass
V = linear velocity
ω = angular velocity in radians
r = radius

for a sphere:



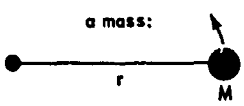
K.E. = 1/5 MV^2
K.E. = 1/5 $Mr^2\ \omega^2$



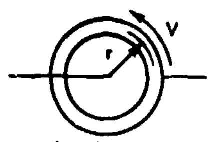
then for a disc:

K.E. = 1/4 MV^2
K.E. = 1/4 $Mr^2\ \omega^2$

a mass:



K.E. = 1/2 MV^2
K.E. = 1/2 $Mr^2\ \omega^2$



then for a ring:

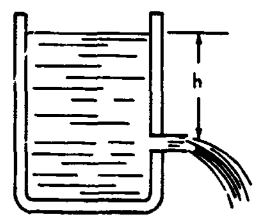
K.E. = 1/2 MV^2
K.E. = 1/2 $Mr^2\omega^2$

26. PRESSURE IN LIQUIDS

a. The pressure at any point is equal to the weight of a liquid column of unit cross-section, and reaching from that point to the top of the liquid.

b. The pressure at one point is the same as the pressure at any other point at the same level.

27. LIQUID FLOWING FROM AN ORIFICE



VELOCITY $= \sqrt{2g\ h}$

where g = 32 ft/sec/sec
= 980 cm/sec/sec

28. DENSITY

The Density of Matter, whether in the solid, liquid or gaseous state, is defined as the Mass per Unit Volume.

$D = \frac{M}{V}$

29. SPECIFIC GRAVITY

Specific Gravity $= \frac{\text{Weight of a Given Substance}}{\text{Weight of an Equal Volume of Water}}$

30. BUOYANCY

Archimede's Principle – "A body floating or submerged in a liquid is buoyed up by a force equal to the weight of the liquid displaced".

A Body will float in a liquid if its specific gravity is less than the specific gravity of the liquid.

A Body will sink in a liquid if its specific gravity is greater than the specific gravity of the liquid.

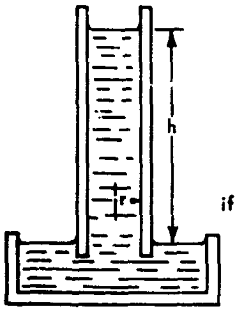
A Body floating in a liquid will displace a volume of the liquid equal in weight of the floating body.

31. ADHESION and COHESION

ADHESION is the attraction between Different kinds of Molecules.

COHESION is the attraction between Like kinds of Molecules.

32. CAPILLARITY



Liquids rise in Capillary Tubes because of the Adhesive force between the Liquid and the Material of the Tube is greater than the Cohesive force of the liquid.

if $T =$ surface tension of the liquid
$r =$ radius of the bore of the tube
$D =$ density of the liquid
$g =$ acceleration of gravity
32 ft/sec/sec
980 cm/sec/sec
$h =$ height the liquid will rise in the tube.

then $h = \frac{2T}{r D g}$

33. VISCOSITY

Viscosity is the frictional resistance offered by one part or layer of a liquid as it moves past an adjacent part or layer of the same liquid.

The Viscosity of a liquid Decreases as the temperature Increases.

Viscosity is most important as a measure of the lubricating quality of oils.

34. THERMAL EXPANSION

a. SOLIDS

The LINEAL COEFFICIENT OF THERMAL EXPANSION is the change in unit length of a substance for one deg. rise in temperature.

if $a =$ linear coefficient of thermal expansion (to be found in a table of coefficients)
$L =$ length
$T =$ rise in temperature (T final minus T at start)
$e =$ elongation

then $e = a \times L \times T$

b. LIQUIDS

The VOLUME COEFFICIENT OF THERMAL EXPANSION is the change in unit volume of a substance for one deg. rise in temperature.

if $V =$ change in volume
$\beta =$ volume coefficient of thermal expansion (to be found in a table of coefficients)
$V =$ the original volume
T rise in temperature (T final minus T at start)

then $V = \beta \times V \times T$

c. GASES

The Volume of a Gas varies Directly with the Temperature and Inversely with the Pressure.

if $T =$ Absolute Temperature (Kelvin)
$V =$ volume
$P =$ pressure

then $\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$

35. SPECIFIC HEAT

The CALORIE is the amount of heat necessary to raise the temperature of 1 gram of Water 1 degree Centigrade.

SPECIFIC HEAT is the amount of heat necessary to raise the temperature of 1 gram of a substance 1 degree Centigrade. (the Specific Heat of Water is unity)

if $Q =$ calories
$S.h. =$ specific heat of the substance (to be found in a table of Specific Heats)
$M =$ mass of the body in grams
$T =$ temperature rise (T final minus T at start)

then $Q = S.h. \times M \times T$

Basic Laws Of Electricity and Magnetism

For convenient reference, a topical index is given below. The numbers refer to the items of this article.

28-Alternating Current
12-Atoms
4-Attraction & Repulsion, Magnetic
14-Attraction & Repulsion, Static Electricity
13-Behavior of Static Electricity
32-Cells in Series & Parallel
31-Chemical Effect of Electric Current
27-Current, Induced
26-Effects of an Electric Current
10-Electric Field
30-Electric Motor
17-Electric Potential
26-Electrical Current Effects
20-Electrical Power
18-Electrical Units, Practical
11 to 33-ELECTRICITY
11-Electricity, Static
31-Electrolysis
31-Electrolytic Cells
29-Electromagnet
27 to 29-ELECTROMAGNETISM
12-Electron and Proton
14-Electrostatic Repulsion & Attraction
15-Electrostatic Unit of Charge
31-Faraday's Law of Electrolysis
16-Field, Electric
7-Field, Magnetic
5-Force, Magnetic
31-Heat Produced by Electric Current
21-Heating, Electrical
27-Induced Current & Induced Magnetism
21-Joule's Law of Electric Heating
27-Lenz's Law
8-Lines of Magnetic Force
1-Magnet Definition
1-Magnetic Attraction & Repulsion
29-Magnetic Effects of Electric Current
7-Magnetic Field
5-Magnetic Force
8-Magnetic Lines of Force
2-Magnetic Materials
3-Magnetic Poles
1 to 10-MAGNETISM
27-Magnetism, Induced
9-Magnetism Theory
19-Ohm's Law

1. A MAGNET is a body which has the property of attracting iron and steel, and which if suspended freely will turn so as to point in a definite direction.

2. TYPES OF MAGNETIC MATERIALS

A Material that is quite easily magnetized under the stimulation of a Magnetic Field is described as having high PERMEABILITY.

A Material retaining its magnetic properties after the Exciting Field has been removed is described as having high RETENTIVITY.

Most Magnetic Materials having High Permeability have Low Retentivity. Most Magnetic Materials having High Retentivity have Low Permeability.

Magnetized Materials having High Permeability and Low Retentivity are called TEMPORARY MAGNETS.
Magnetized Materials having High Retentivity are called PERMANENT MAGNETS.

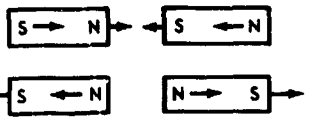
3. MAGNETIC POLES

A magnet has two poles at its ends. If suspended freely it will rotate to a North-South direction. The Pole pointing toward the North Pole is called the "N" pole, and the opposite pole is the "S" pole. The two poles of a magnet have exactly the same strength.

4. MAGNETIC ATTRACTION AND REPULSION

Unlike Magnetic Poles attract each other:–

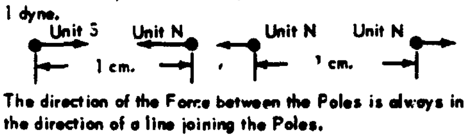
Like Magnetic Poles repel each other



5. MAGNETIC FORCE

The Magnitude of the Force between two Magnetic Poles is directly proportional to the Pole Strength, and inversely proportional to the Square of the Distance Between Them.

6. A UNIT MAGNETIC POLE is one whose Pole Strength is such that when it is placed at a distance of 1 cm. from a Pole of exactly the same kind, the Force between the two is 1 dyne.



The direction of the Force between the Poles is always in the direction of a line joining the Poles.

If the pole strengths are m_1 and m_2 units, the distance between them is r cm., and F is force in dynes,

then $$F = \frac{m_1 \times m_2}{r}$$

7. MAGNETIC FIELD

The region about a Magnet where its influence can be detected is called a Magnetic Field.

7. cont'd

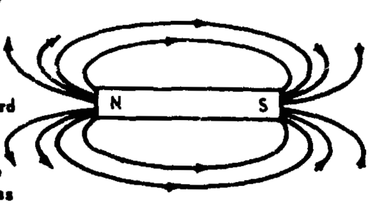
The Direction of a Magnetic Field is that of a · · e acting upon an isolated "N" pole.

The Intensity of the Magnetic Field at any po· . · the force which would be exerted upon a Unit Pole placed there.

The Unit of Field Intensity is the OERSTED, . ·d is the intensity of a Magnetic Field in which a Unit Magnetic Pole experiences a force of 1 dyne.

8. **LINES OF MAGNETIC FORCE**

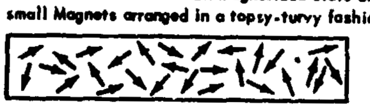
Lines of force of a Magnetic Field are directed away from the "N" pole ·· toward the "S" pole.



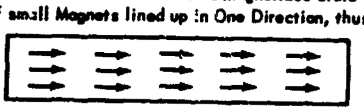
Lines of ·· ce can never cross one another

9. **THEORY OF MAGNETISM**

A Magnetic Material when in an Un-magnetized State consists of small Magnets arranged in a topsy-turvy fashion, thus:–



A Magnetic Material when it is in a Magnetized State consists of small Magnets lined up in One Direction, thus:–



10. **PROOF OF THE MAGNETIC THEORY**

Experimentally, the following proof of the Theory is found:–

1– Heating or jarring a magnet causes it to lose its Magnetic Properties, and reversely a magnetic material can be Magnetized by jarring it or heating it and allowing it to cool in a Magnetic Field.

2–A Permanent Magnet, when broken, will be found to retain its Two Opposite Poles in each of the pieces regardless of their size.

3– A Magnetic Material becomes slightly longer when Magnetized (due to the re-arrangement of the magnetic particles).

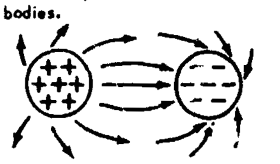
4– When a Magnetic Material is subjected to a Magnetic Field which changes rapidly from one direction to another, Heat is developed in the mat. ial. This effect is called HYSTERESIS, and is due to the friction developed by the shifting of the positions of the magnetic particles.

11. **STATIC ELECTRICITY** is Stationary Electricity
CURRENT ELECTRICITY is Electricity in Motion

Static Electricity can be either a Negative (-) or a Positive (+) charge.

An Object charged with either a Negative or a Positive charge will remain static until another Object carrying the opposite charge is brought close enough to cause a flow of electricity between the two bodies.

The direction of the flow will be from the Positively Charged Object to the Negatively Charged Object.

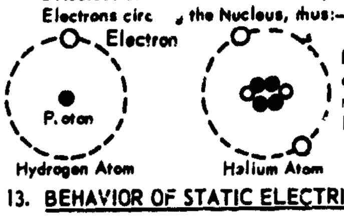


12. **Positive Units of Electricity are called PROTRONS**
Negative Units of Electricity are called ELECTRONS

The ELECTRON h ·s been shown to be the sm·· ·st indivisible piece of Negative Electricity.

A positive unit or Proton is 1846 times as heavy as the negative Electron.

ATOMS of various elements have been shown to consist of a Nucleus of P· · s and Electrons, with one or more Electrons circ · the Nucleus, thus:–



Each Element consists of a different arrangement of Protons and Electrons.

13. **BEHAVIOR OF STATIC ELECTRICITY**

Substances which conduct electricity easily are called CONDUCTORS.
Substances which resist the flow of electricity are called INSULATORS.

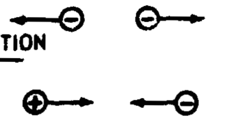
On an INSULATOR the charges remain where they are placed.

On a circular CONDUCTOR the charges placed on it space themselves uniformly due to the force of repulsion of the individual charges.

On a pointed conductor there will be an accumulation of charges at the point as the mutual repulsion between the units will cause them to move to the greatest distance from the remainder of the charges.

14. **ELECTROSTATIC REPULSION**

Like Charges of Electricity repel each other.



ELEC ·ROSTATIC ATTRACTION

Unlike Charges of Electricity attract each other.

15. **ELECTROSTATIC UNIT OF CHARGE** (unit charge) is a quantity of electricity which, when placed 1 cm. distance from an equal quantity, will be acted upon by a force of 1 dyne.

16. **ELECTRIC FIELD** is the region about a charged body, and the intensity of an Electric Field at any point is the force which would be exerted upon a Unit Positive Charge at that point.

The Electrostatic unit of Field Strength is DYNES PER UNIT CHARGE.

if $\mathcal{E}$ = field strength
F = force in dynes
Q = number of unit charges

then $\mathcal{E} = \frac{F}{Q}$

and if r=distance in cm. from charge Q

then $\mathcal{E} = \frac{Q}{K r^2}$

(K is the dielectric constant which is unity for a vacuum, 1.000586 for air)

17. **ELECTRIC POTENTIAL**

The Potential at any point is the work which must be done upon a Unit Positive Charge to move it from an infinitely great distance up to the point in question.

✓ 18. **PRACTICAL ELECTRICAL UNITS**

QUANTITY OR CHARGE–The COULOMB is a quantity of electricity equal to 3×10^9 electrostatic units of charge. The coulomb also equals 6.25×10^{18} electrons.

CURRENT– The AMPERE is a unit of current which is equal to a rate of flow of electric charge of 1 coulomb per second.

WORK–The ERG is the work done when a force of 1 dyne is applied through a distance of 1 centimeter.

ENERGY–The JOULE is the amount of work or energy equal to 10^7 ergs.

POWER–The WATT is the power expenditure of 1 joule per second.

ELECTROMOTIVE FORCE and POTENTIAL DROP–The VOLT is the difference in potential between two points when a charge of 1 coulomb either requires or expends 1 joule of energy in moving from one point to another.

RESISTANCE–The OHM is a resistance across which there is a potential drop of 1 volt when the current is 1 ampere.

✓ 19. **OHM'S LAW**–The current in a circuit equals the electromotive force in that circuit divided by the resistance of the circuit.

if I = rate of flow of current in AMPERES then $I = \frac{E}{R}$

E = pressure in VOLTS — also $E = I \times R$
R = resistance in OHMS — also $R = \frac{E}{I}$

20. **ELECTRICAL POWER**

if P = power in WATTS

then $P = I \times E$
also $P = \frac{E^2}{R}$
also $P = I^2 \times R$

21. **JOULE'S LAW OF ELECTRIC HEATING**–The heat produced in a conductor is proportional to the resistance of the conductor, to the square of the current and to the time.

if ω = energy in joules
R = resistance in ohms
I = current in amperes
t = time in seconds

then $\omega = R \times I^2 \times t$

and if H = heat in calories

then $H = 0.239\, R \times I^2 \times t$

and if P = power in watts

then $P = R \times I^2$

22. **RESISTANCE OF WIRES**

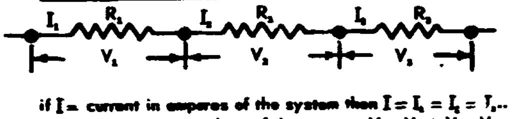
In calculating the resistance of wires, it is common practice to express the length of the wire in feet, and the cross-sectional area in circular mills (C.M.)

A circular mill is the cross-sectional area of a circle with a diameter of .001 inches.

Resistance of Various Materials-(ohms per C.M. per foot)

Aluminum	19.3	Manganin	258.
Carbon	24000 to 42000	Mercury	575.
Constantan	295.	Nichrome	660.
Copper	10.4	Platinum	66.
Iron	72. to 84.	Silver	9.9
Lead	125.	Tungsten	33.
		Zinc	36.7

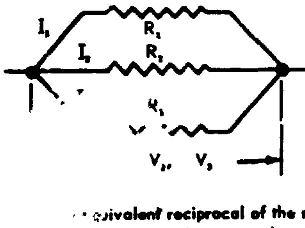
23. **RESISTANCES IN SERIES**



if I = current in amperes of the system then $I = I_1 = I_2 = I_3 \ldots$
R = Resistance in ohms of the system $V = V_1 + V_2 + V_3 \ldots$
V = potential drop of the system $R = R_1 + R_2 + R_3 \ldots$

"The equivalent resistance of several devices connected in series is equal to the sum of their individual resistances."

24. RESISTANCES IN PARALLEL



$I = I_1 + I_2 + I_3 \ldots$
$V = V_1 = V_2 = V_3 \ldots$
$\frac{I}{R} = \frac{I}{R_1} + \frac{I}{R_2} + \frac{I}{R_3} \ldots$

"..quivalent reciprocal of the resistances of several devices connected in parallel is equal to the sum of their individual reciprocal resistances."

25. THERMAL COEFFICIENT OF RESISTANCE

The resistance of a Metallic Conductor USUALLY increases as the temperature is raised.

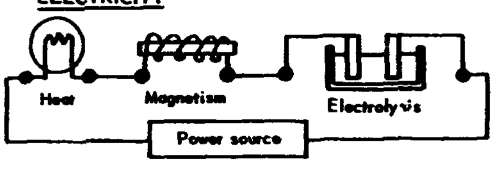
if R_o = original resistance
R_t = resistance after temperature change
α = temperature coefficient of resistance per degree C
t = temperature change in degrees C

then $R_t = R_o(1 + \alpha t)$

Following are the TEMPERATURE COEFFICIENTS OF RESISTANCE for a number of common materials:-

Aluminum	0.0038	Mercury	0.00090
Carbon	-0.00025	Nichrome	0.00017
Constantan	-0.00004 to +0.00001	Platinum	0.0038
		Silver	0.0040
Copper (at 20 deg. C)	0.00393	Tungsten	0.0045
Iron	0.0062	Zinc	0.0037
Lead	0.00043		
Manganin	0.00002 to 0.00005		

26. THE THREE PRINCIPAL EFFECTS OF CURRENT ELECTRICITY



27. ELECTROMAGNETISM

The Field produced by the flow of current through a Coil depends on the number of turns of wire, the length of wire and its cross-sectional area, the nature of the material inside the coil, and the strength of the current flowing.

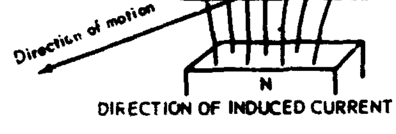
AMPERE'S LAW for the Force on a Conductor –
"Any conductor carrying a current and located in a magnetic field will be pushed by a force that is proportional to the flux density, to the current and to the length of wire."

if F = force in dynes
β = flux density in gausses
I = current in amperes
L = length in centimeters

then $F = \frac{B \times I \times L}{10}$

FARADAY'S PRINCIPLE
"When a magnetic field cuts a conductor, or when a conductor cuts a magnetic field, an electric current will flow through the conductor if a closed path is provided by which the current can circulate."

The Current is induced only while the Magnetic Field is changing.



DIRECTION OF INDUCED CURRENT

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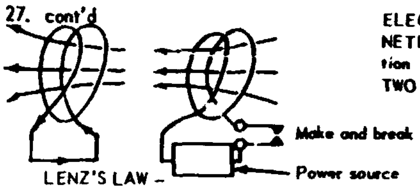
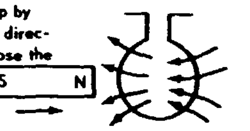


ELECTROMAGNETIC INDUCtion BETWEEN TWO COILS

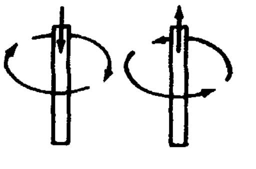
LENZ'S LAW –
Whenever a current is set up by a flux through a circuit, its direction will be such as to oppose the act which caused it.



28. ALTERNATING CURRENT

If the Conductor in a Magnetic Field changes its direction of motion through a magnetic field, the direction of flow of the induced current in the conductor will be reversed.

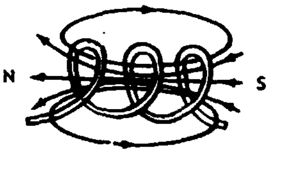
29. MAGNETIC EFFECTS PRODUCED BY AN ELECTRIC CURRENT

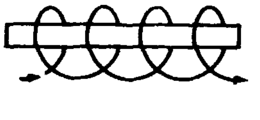


A wire carrying an electric current creates a magnetic field around the wire. The magnetic effect is the same at all points equidistant from the wire.

AN EASILY REMEMBERED RULE –
If a wire carrying a current is grasped in the right hand so the thumb takes the direction of the current, the fingers will take the direction of the lines of force encircling the conductor.

A wire carrying a current, and in the form of a helix, will produce a very intense magnetic field. This arrangement is called a solenoid or electromagnet.



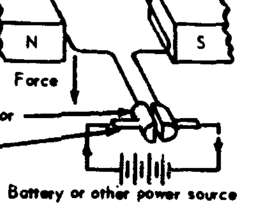


Introduction of a soft iron bar at the center of the helix will increase the available magnetic force. If the bar is fixed or stationary in the coil, the unit will be an ELECTROMAGNET.

If the bar is free to slide in the coil, the unit is called a SOLENOID, and if the bar is inserted at one end of the coil it will tend to equalize the magnetic field by motion into the coil.

30. THE ELECTRIC MOTOR

Cause of Rotation of a Motor illustrated by the turning effect of two wires in a magnetic field



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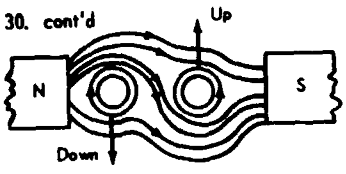


Illustrating the operation of a direct current motor.

The commutator revolving with the wire coil keeps the current flowing in the same direction through the coil, thus causing continuous rotation.

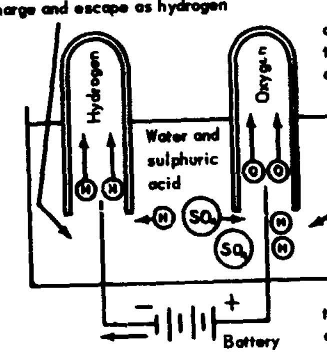
31. PRODUCTION OF A CHEMICAL EFFECT (ELECTROLYSIS)

FARADAY'S LAW OF ELECTROLYSIS –

1. The mass of a substance liberated in an electrolytic cell is proportional to the quantity of electricity passing through the cell.
2. When the same quantity of electricity is passed through different electrolytic cells, the masses of the substances liberated are proportional to their chemical equivalents.

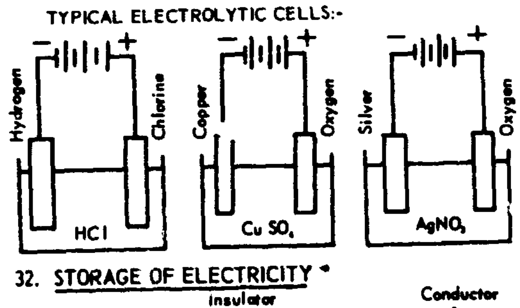
ELECTROLYSIS OF WATER:–

at this electrode the positively charged H-ions give up their charge and escape as hydrogen



at this electrode the negatively charged SO_4 gives up its charge & robs a molecule of water of its hydrogen to re-form sulphuric acid & thereby releasing an atom of oxygen

TYPICAL ELECTROLYTIC CELLS:-



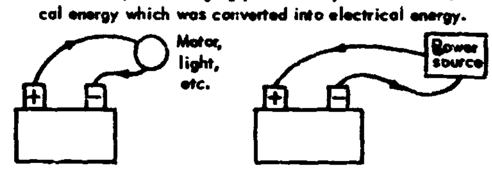
32. STORAGE OF ELECTRICITY

A small amount of electricity can be stored in a CONDENSER

A Condenser consists of conducting plates separated by a non-conducting material.

The amount of electricity that can be stored in a condenser depends on the area of the plates, the distance between the plates and the voltage on them, as well as the efficiency of the insulating layers. A condenser acts as a temporary storage battery.

A More Permanent and Larger Capacity storage unit is the type which depends on Chemical Action to put an electrical charge into motion.
The chemical action which produces a flow from the battery can be restored by a current flowing in the opposite direction from that which is used to draw it from the battery. Although it is called a "Storage Battery" there is no more electricity in a battery after it has been charged than there was before; the charging process only restores the chemical energy which was converted into electrical energy.



A "Dry Cell" is one which produces an electric current by chemical means, but is not capable of being "Re-charged", or the materials which react chemically to produce the current cannot be returned to their original state electrically.

If Cells are connected in SERIES, their combined electromotive force is the sum of the e.m.f.'s of the individual cells.

if cells are connected in parallel, and are equal cells, their combined e.m.f. is the same as the e.m.f. of any of the individual cells.

24-Parallel Resistances
2-Permeability
3-Pole, Magnetic
6-Pole, Unit Magnetic
17-Potential, Electric
20-Power, Electrical
18-Practical Electrical Units
10-Proof of Magnetic Theory
12-Proton and Electron
14-Repulsion & Attraction, Static Elec.
22-Resistance of Wires
24-Resistances in Parallel
23-Resistances in Series
2-Retentivity
23-Series Resistance
29-Solenoid
11,13-Static Electricity
32-Storage of Electricity
25-Temperature Coefficient of Resistance
9-Theory of Magnetism
15-Unit Charge, Electrostatic
6 Unit Magnetic Pole

Space, Time, Velocity, and Acceleration Formulae

Often when solving problems involving space, time, velocity, and acceleration, the designer is looking for an answer, such as acceleration; however the "unknown" elements which he possesses do not fit into the well known acceleration formulas. If he does have sufficient information to solve the problem, he can find the answer by looking up additional formulas, search for charts, etc.

The following information presents all basic linear motion formulas with all their variations. The designer can tell at a glance whether or not he has sufficient information to solve his problem and choose the applicable formulas. In addition, all terms used are specifically defined.

Definition of Terms

A = Acceleration or deceleration—Ft/Sec/Sec (32.2 for gravity)
D = Distance—Ft (May be used in lieu of "H" in vertical free fall)
E = Energy—Ft—Lbs
F = Force—Lbs
H = Height—Ft—(May be used lieu of "D" with A—32.2)
M = Mass— $\frac{W}{32.2}$ = $\frac{Lb\text{—}Sec^2}{Ft}$
T = Time—Seconds
V_a = Average velocity—Ft/Sec
V_f = Final velocity—Ft/Sec
V_i = Initial velocity—Ft/Sec
W = Weight—Lbs

To Find	Formulae					
A	$\frac{V_f - V_i}{T}$	$\left(\begin{matrix}\text{When}\\ V_i = 0\end{matrix}\right) \frac{V_f}{T}$	$\left(\begin{matrix}\text{When}\\ V_i = 0\end{matrix}\right) \frac{V_f^2}{2D}$	$\frac{2D}{T^2}$	$\frac{WV_a}{FT}$	$\frac{F}{M}$
D	V_aT	$\frac{T(V_i + V_f)}{2}$	$\left(\begin{matrix}\text{When}\\ V_i = 0\end{matrix}\right) \frac{V_f T}{2}$	$\frac{V_a^2}{2A}$	$\frac{AT^2}{2}$	$\frac{E}{F}$
E	FD	WH				
F	MA	$\frac{M(V_f - V_i)}{T}$	$\frac{E}{D}$	$\frac{WV_a}{AT}$		
H	$\frac{E}{W}$	$16.1\ T^2$				
M	$\frac{W}{32.2}$	$\frac{F}{A}$	$\frac{FT}{V_f - V_i}$			
T	$\frac{D}{V_a}$	$\frac{2D}{V_f + V_i}$	$\frac{V_f - V_i}{A}$	$\left(\begin{matrix}\text{When}\\ V_i = 0\end{matrix}\right) \frac{V_f}{A}$	$\left(\begin{matrix}\text{When}\\ V = 0\end{matrix}\right) \frac{2D}{V_f}$	
	$\sqrt{\frac{2D}{A}}$	$\frac{\sqrt{H}}{4}$	$\frac{WV_a}{FA}$	$\frac{M(V_f - V_i)}{F}$		
V_f	$2V_a - V_i$	$\left(\begin{matrix}\text{When}\\ V_i = 0\end{matrix}\right) 2V_a$	$\frac{2D}{T} - V_i$	$\left(\begin{matrix}\text{When}\\ V_i = 0\end{matrix}\right) \frac{2D}{T}$	$AT + V_i$	$\left(\begin{matrix}\text{When}\\ V_i = 0\end{matrix}\right) AT$
V_i	$2V_a - V_f$	$\frac{2D}{T} - V_f$	$V_f - AT$	$V_f - \frac{FT}{M}$		
W	$\frac{AFT}{V_a}$	32.2 M	$\frac{E}{H}$			

Speed-Altitude Nomogram

This nomogram finds basic speed factors used in aircraft design with an accuracy sufficient for most problems. Simultaneous readings can be made when any two of these four variables are known:

- Altitude or density
- Mach Number
- True Airspeed
- *Equivalent airspeed or dynamic pressure*

The nomogram is based on the ICAO (International Civil Aviation Organization) standard atmosphere, which assumes *a linear temperature variation from 59F at sea level to minus 69.7F at the tropopause* (36,089 ft) and a constant temperature of minus 69.7F for higher altitudes. Thus different equations hold above and below the tropopause. This requires *different methods for reading scales.*

One straight line is used to read all variables for altitudes below the tropopause. At higher altitudes, two lines are needed. The first line takes care of all variables except true airspeed. A second line pivoted *on the Mach Number and drawn through the tropopause altitude* finds the true airspeed.

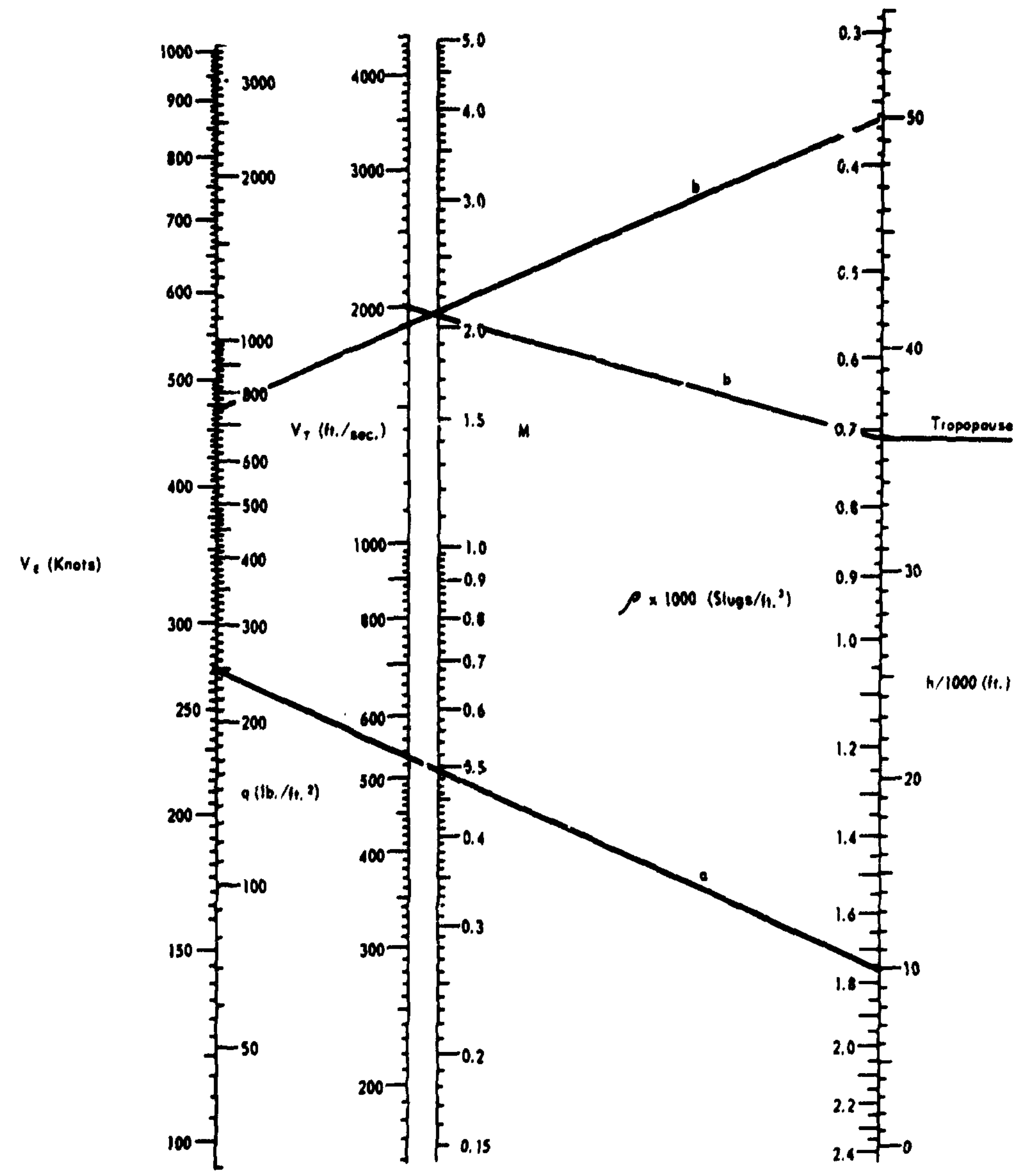
Nomenclature:

V_T = True airspeed, ft/sec
V_E = Equivalent airspeed, $(V_T\delta^{1/2})$, knots
δ = Density ratio, (ρ/ρ_0), dimensionless
q = Dynamic pressure, lb/sq ft
M = Mach number, (V_T/a), dimensionless
ρ = Mass density, slugs/cu ft
h = Altitude, ft
a = Local speed of sound, ft/sec

Examples:
Determine the Mach number, true airspeed, dynamic pressure and mass density for a plane flying at:

(a) *10,000 ft and an equivalent airspeed of 274 kts*
(b) 50,000 ft and an equivalent airspeed of 470 kts

(a) Using a straight line, connect 10,000 ft on the h scale with 274 knots on the V_E scale. This cuts all the scales at correct values, giving M = 0.50, V_T = 559 ft/sec, q = 255 lb/sq ft, ρ = 0.00175.
(b) Connect 50,000 ft on the h scale with 470 knots on the V_E scale. This cuts all scales except the V_T scale at correct values, giving M = 2.10, q = 748 lb/sq ft, ρ = 0.000362. An extended line connecting M = 2.10 with the tropopause (h = 39,089 ft) gives V_T = 2030 ft/sec.



Mach Number Nomogram

The nomogram presents the relation between Mach number, speed and temperature according to the equations:

$$M = \frac{V}{a} \quad \text{and} \quad a = a_o\sqrt{\frac{T}{T_o}}$$

Altitude according to the ICAO (International Civil Aviation Organization) standard atmosphere is also shown along the temperature scale.

The ICAO standard atmosphere is defined in metric units with the altitude in kilometers and the temperature in degrees centrigrade (C) or degrees Kelvin absolute (K). Between sea level and 11 kilometers (36,089 ft), the temperature decreases linearly with increasing altitude (6.5C per kilometer). Above 11 kilometers the temperature is constant.

Sea level temperature: 15C = 288.16K

At and above 11 kilometers (36,089 ft): –56.5C = 216.66K

Sea level speed of sound: 340.3 meter/sec = 761.50 mph

1 kilometer = 1000 meter = 3280.8 ft = 0.6214 statute miles.

Nomenclature:

M = Mach number, dimensionless

V = aircraft speed, mph

a = speed of sound, mph

a_o = 761.5 mph (ICAO sea level speed of sound)

T = absolute air temperature, deg K

T_o = 288.16 deg K (ICAO sea level temperature)

Example I:

Determine the Mach number at 20,000 ft and 1000 mph in ICAO standard atmosphere.

Solution:

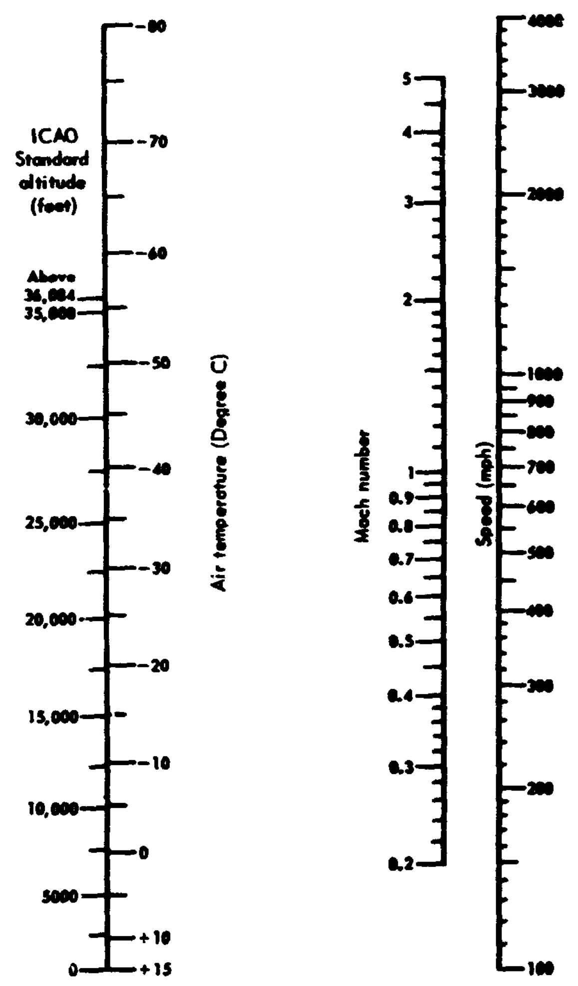
Draw a straight line through 20,000 ft and 1000 mph on respective scales. Read Mach number at the intersection between this line and the Mach number scale, M = 1.4

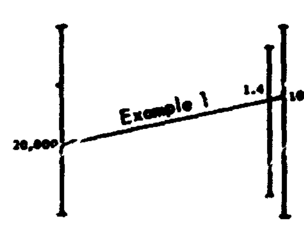
Example 2:

Determine the speed at 40,000 ft at Mach number 0.5 at a temperature of 20C above ICAO standard atmosphere.

Solution:

The altitude is higher than 36,089 ft, so the temperature is the same as at 36,089 ft. Read standard temperature from the temperature scale at this altitude. – 56.5C. Add 20C which gives – 26.5C. Then draw a straight line through – 36.5C and Mach number 0.5 on respective scales. Read the speed at the intersection between the extension of this line and the speed scale, ≅ 350 mph.





MODEL ATMOSPHERE

(Based on The ARDC Model Atmosphere, 1959)

$$\rho = \frac{\text{lbs sec}^2}{\text{ft}^4} = \text{slugs/ft}^3$$

$$\rho/\rho_0 = \text{relative density}$$

ALT H FT X 10^3	TEMPERATURE t		PRESSURE	DENSITY ρ	
	°F	°C	in. Hg	ρ	ρ/ρ_0
0	59.0	15.0	29.92	.002377	1.0000
1	55.4	13.0	28.86	.002308	.9710
2	51.8	11.0	27.82	.002241	.9428
3	48.3	8.1	26.82	.002175	.9150
4	44.7	7.1	25.84	.002111	.8881
5	41.2	5.1	24.90	.002048	.8616
6	37.6	3.1	23.98	.001987	.8359
7	34.0	1.1	23.09	.001927	.8107
8	30.5	-.8	22.23	.001869	.7863
9	26.9	-2.8	21.39	.001811	.7619
10	23.4	-4.7	20.58	.001756	.7387
11	19.8	-6.7	19.80	.001701	.7156
12	16.2	-8.7	19.03	.001648	.6933
13	12.7	-10.7	18.30	.001596	.6714
14	9.1	-12.7	17.58	.001546	.6504
15	5.5	-14.7	16.89	.001496	.6294
16	2.0	-16.7	16.22	.001448	.6092
17	-1.6	-18.7	15.58	.001401	.5894
18	-5.1	-20.6	14.95	.001355	.5700
19	-8.7	-22.6	14.35	.001311	.5515
20	-12.3	-24.6	13.76	.001267	.5330
25	-30.0	-34.4	11.12	.001066	.4485
30	-47.8	-44.3	8.903	891. X 10^{-6}	.3748
36.5	-69.7	-56.5	6.573	694.	.2920
40	-69.7	-56.5	5.558	587.	.2469
50	-69.7	-56.5	3.444	364.	.1531
60	-69.7	-56.5	2.135	226.	.09508
70	-69.7	-56.5	1.324	140.	.05890
80	-69.7	-56.5	.8218	86.8	.03652
82	-69.7	-56.5	.7471	78.9	.03319
90	-57.2	-49.6	.5131	52.5	.02209
100	-40.8	-40.4	.3264	32.1	.01350
110	-26.2	-32.3	.2113	20.0	.00841
120	-8.3	-22.4	.1391	12.7	.00534
130	9.9	-12.3	.0929	8.19	.00345
140	24.1	-4.4	.0630	5.36	.00225
150	40.4	4.7	.0433	3.56	.00150
155	48.5	9.2	.0602	2.92	.00123
160	48.5	9.2	.0300	2.43	.00102
170	48.5	9.2	.0209	1.69	.00071
175	48.5	9.2	.0174	1.41	.00059
180	37.8	3.2	.0145	1.20	.00050
190	13.5	-10.3	.0099	.865	.00036
200	-10.6	-23.7	.0067	.612	.00026

IMPACT PRESSURE VS AIRSPEED

Sea Level - Standard Atmosphere

Note: Supersonic pressures are free stream pressures ahead of shock wave

Airspeed			Impact Pressure (Pitot minus Static) Compressible Adiabatic		
Mph	Knots	Ft/Sec	In. H_2O	Lb/Ft^2	$Lb/In.^2$
20	17.4	29.3	0.197	1.023	0.007
40	34.8	58.7	0.738	4.095	0.028
60	52.1	88.0	1.774	9.222	0.064
80	69.5	117.3	3.158	16.41	0.114
100	86.9	146.7	4.943	25.69	0.178
120	104.3	176.0	7.131	37.06	0.257
140	121.7	205.3	9.729	50.56	0.351
160	139.0	234.7	12.740	66.21	0.460
180	156.4	264.0	16.171	84.04	0.584
200	173.8	293.3	20.031	104.1	0.723
220	191.2	322.7	24.322	126.4	0.878
240	208.6	352.0	29.055	151.0	1.049
260	225.9	381.3	34.251	178.0	1.236
280	243.3	410.7	39.908	207.4	1.440
300	260.7	440.0	46.046	239.3	1.662
320	278.1	469.3	52.665	273.7	1.901
340	295.5	498.7	59.785	310.7	2.158
360	312.8	528.0	67.424	350.4	2.433
380	330.2	557.3	75.602	392.9	2.728
400	347.6	586.7	84.338	438.3	3.044
450	391.0	660.0	108.679	564.8	3.922
500	434.5	733.3	136.888	711.4	4.940
600	521.4	880.0	206.47	1073	7.45
700	608.3	1026.7	296.52	1541	10.70
760.9	661.2	1116.1	363.48	1889	13.12
1000	869.0	1466.7	742.74	3860	26.81
1200	1042.8	1760.0	1265.74	6578	45.68
1400	1216.6	2053.3	2080.06	10,810	75.07
1600	1390.4	2346.7	3331.75	17,315	120.24
1800	1564.2	2640.0	5239.98	27,232	189.11
2000	1738.0	2933.3	8075.29	41,967	291.44

PULLOUT RADIUS (FEET) AT VARIOUS VELOCITIES AND ACCELERATIONS

The table and formula below express ratio of apparent weight to actual weight at bottom of pull-out.

Velocity - Knots

Acceleration - Gravities	180	200	220	240	260	280
2	2871	3544	4288	5103	5989	6946
3	1436	1772	2144	2552	2995	3473
4	957	1181	1429	1701	1996	2315
5	718	886	1072	1276	1497	1737
6	574	709	858	1021	1198	1389
8	410	506	613	729	856	992
10	319	394	476	567	665	772
12	261	322	390	464	544	631
15	205	253	306	365	428	496
18	169	208	252	300	352	409
20	151	187	226	269	315	366

Velocity - Knots

Acceleration - Gravities	300	320	340	360	380	400
2	7974	9073	10242	11483	12794	14176
3	3987	4537	5121	5742	6397	708[illegible]
4	2658	3024	3414	3828	4265	4725
5	1994	2268	2561	2871	319[illegible]	[illegible]544
6	1595	1815	2048	2297	2559	2835
8	1139	1296	1463	1640	1828	2025
10	886	1008	1138	1276	1422	1575
12	725	825	931	1044	1163	1289
15	570	648	732	820	914	1013
18	469	534	602	675	753	834
20	420	478	539	604	673	746

$$\text{Gravities} = 1 + \frac{.0886V^2}{r}$$

where: V = velocity in knots
r = pull-out radius in feet

TURN RADIUS AT VARIOUS VELOCITIES AND ACCELERATIONS

The table and formula below express ratio of apparent weight to actual weight in a correctly banked turn.

Velocity	Acceleration - Gravities									
Knots	2	3	4	5	6	8	10	12	15	20
150	1150	704	514	407	337	251	200	167	133	100
200	2045	1252	914	723	599	446	356	296	237	177
250	3195	1957	1429	1130	935	697	556	463	370	277
300	4601	2817	2058	1627	1347	1004	801	666	532	399
350	6262	3835	2801	2214	1833	1367	1090	907	725	543
400	8179	5009	3658	2892	2395	1785	1424	1185	947	709
450	1.70	6339	4630	3660	3031	2259	1802	1499	1198	898
500	2.10	7826	5715	4518	3742	2789	2225	1851	1479	1108
550	2.55	9470	6916	5467	4527	3375	2692	2240	1790	1341
600	3.03	1.85	8230	6507	5388	4016	3204	2666	2130	1596
700	4.12	2.52	1.84	8856	7334	5466	4361	3628	2899	2172
800	5.38	3.30	2.41	1.90	9579	7139	5695	4739	3786	2837
900	6.81	4.17	3.05	2.41	2.00	9036	7208	5998	4792	3591
1000	8.41	5.15	3.76	2.97	2.46	1.84	8899	7404	5916	4433
1500	18.93	11.59	8.47	6.69	5.54	4.13	3.30	2.74	2.19	9974
2000	33.65	20.61	15.05	11.90	9.85	7.34	5.86	4.87	3.89	2.92
3000	75.72	46.37	33.86	26.77	22.17	16.52	13.18	10.97	8.76	6.57

Note: Figures above line in feet - below line in nautical miles.

Gravities $= \sqrt{1 + \frac{.00784V^4}{r^2}}$ **where: V = velocity in knots, r = turn radius in feet**

Centrifugal Force Nomogram

This nomogram provides a simple method of approximating the centrifugal force of a weight spinning about a point at a specified distance The nomogram solves the equation:

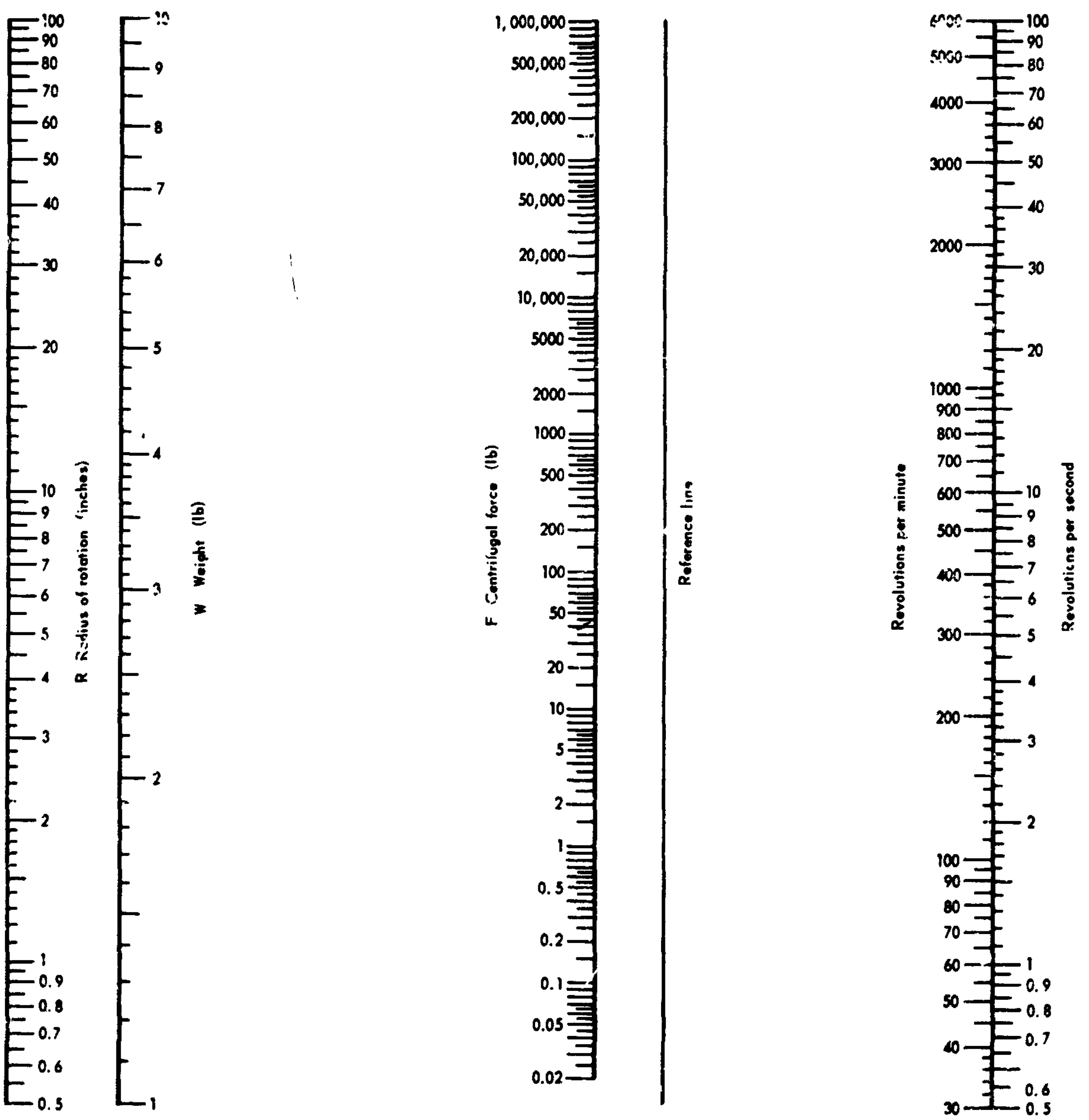
$$F = WRN^2/35,200$$

Where:

F = centrifugal force, lb
R = radius of rotation, inches
W = weight, lb
N = rpm

Example: If a weight of 15 lb is spinning at 1350 rpm at a radius of 10 inches, determine the centrifugal force

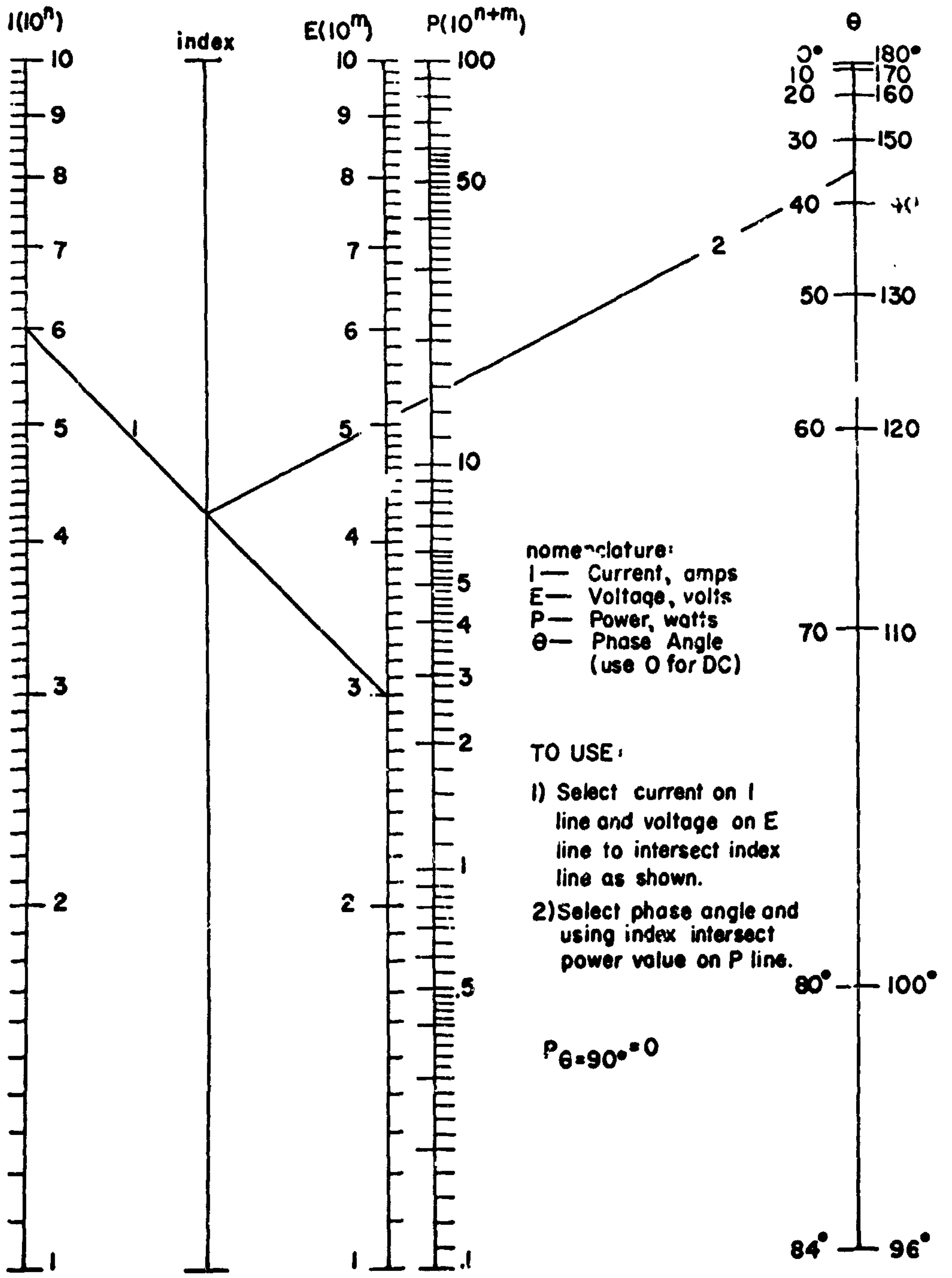
Solution: Align R = 10 with N = 1350, intersecting the Reference line. Entering W = 15 as 1.5, align this point with the Reference line intersection and read F≈780 lb Restoring the decimal point, F = 7800 lb.



Power Nomograph

THE NOMOGRAPH presents a simplified method of determining power with a knowledge of the phase angle, current, and voltage. By using a phase angle equal to zero, dc values can be determined.

Input values of current and voltage have the power of ten extracted and returned in summed form to the output, thus the graph can be utilized for any range of values.



Specific Gravity, Weight and Volume

The nomogram may be used to determine specific gravity if volume and weight of a material are known. Also, weight or volume for materials of different specific gravity may be determined.

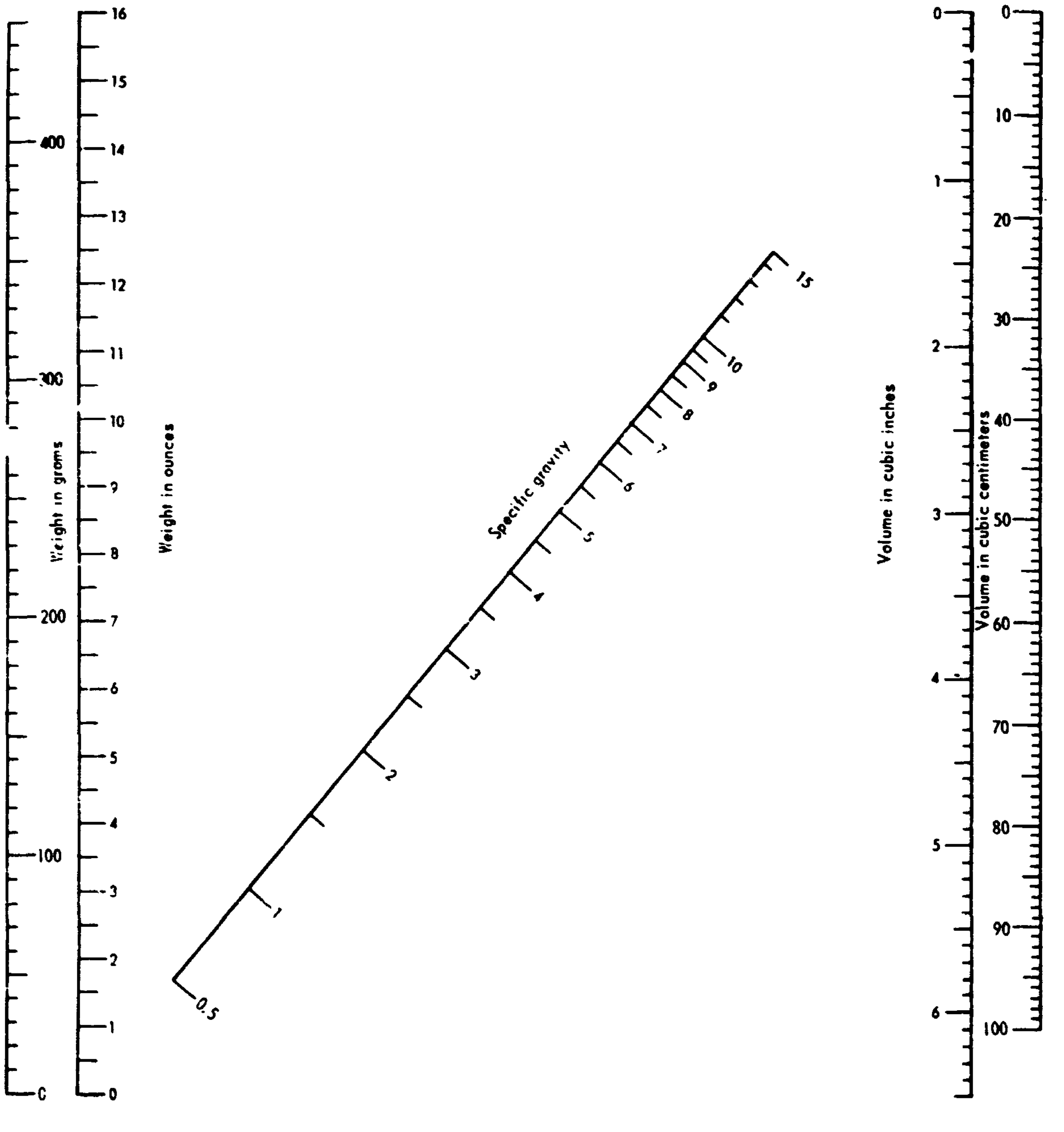
Example 1: Determine the weight of a piece of rolled copper with a specific gravity of 9, and which is 1.25 cu in in volume.

Solution: Align volume = 1.25 cu in with specific gravity = 9 and read weight = 6.5 oz.

Example 2: Determine the specific gravity of a piece of material that weighs 5.5 oz and has a volume of 3.25 cu in.

Solution: Align 5.5 oz on the weight scale with 3.25 cu in on the volume scale, intersecting the specific gravity scale at 2.9.

To use the gram or cubic centimeter scales, align the values horizontally to intersect the ounce and cu in scales, respectively. Do not connect values on the gram and cubic centimeter scales directly.



Gas Density Found By Nomogram

Tables giving the density or specific gravity of gases and vapor are widely available. However, most of these tables are based on standard atmospheric pressure and temperature. Here is a nomogram for finding gas density at conditions other than standard atmospheric.

The nomogram solves the gas density equation:

$$d = \frac{MP}{356\,C}$$

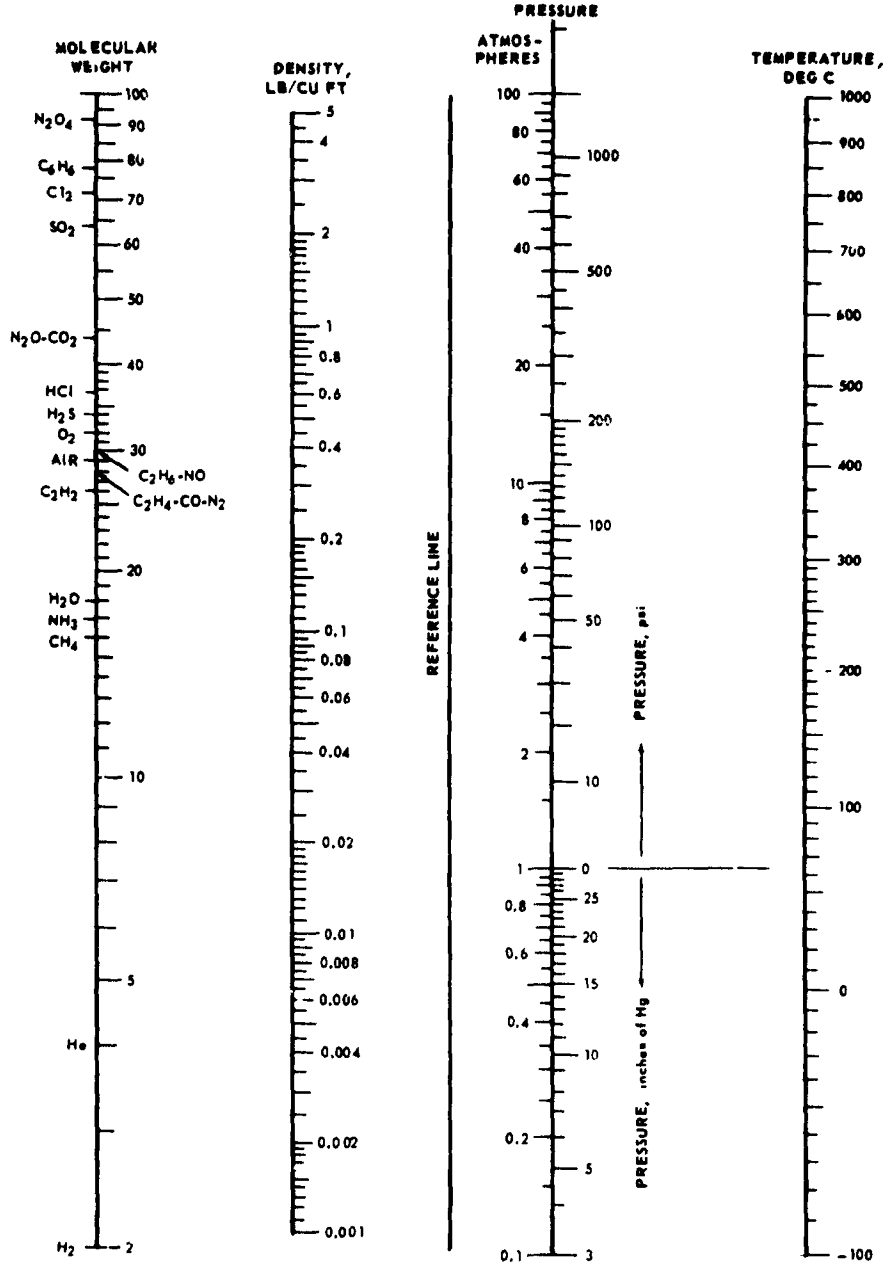
where

d = gas density, lb/ft³
M = molecular weight
P = absolute pressure, atmospheres
C = temperature, centigrade

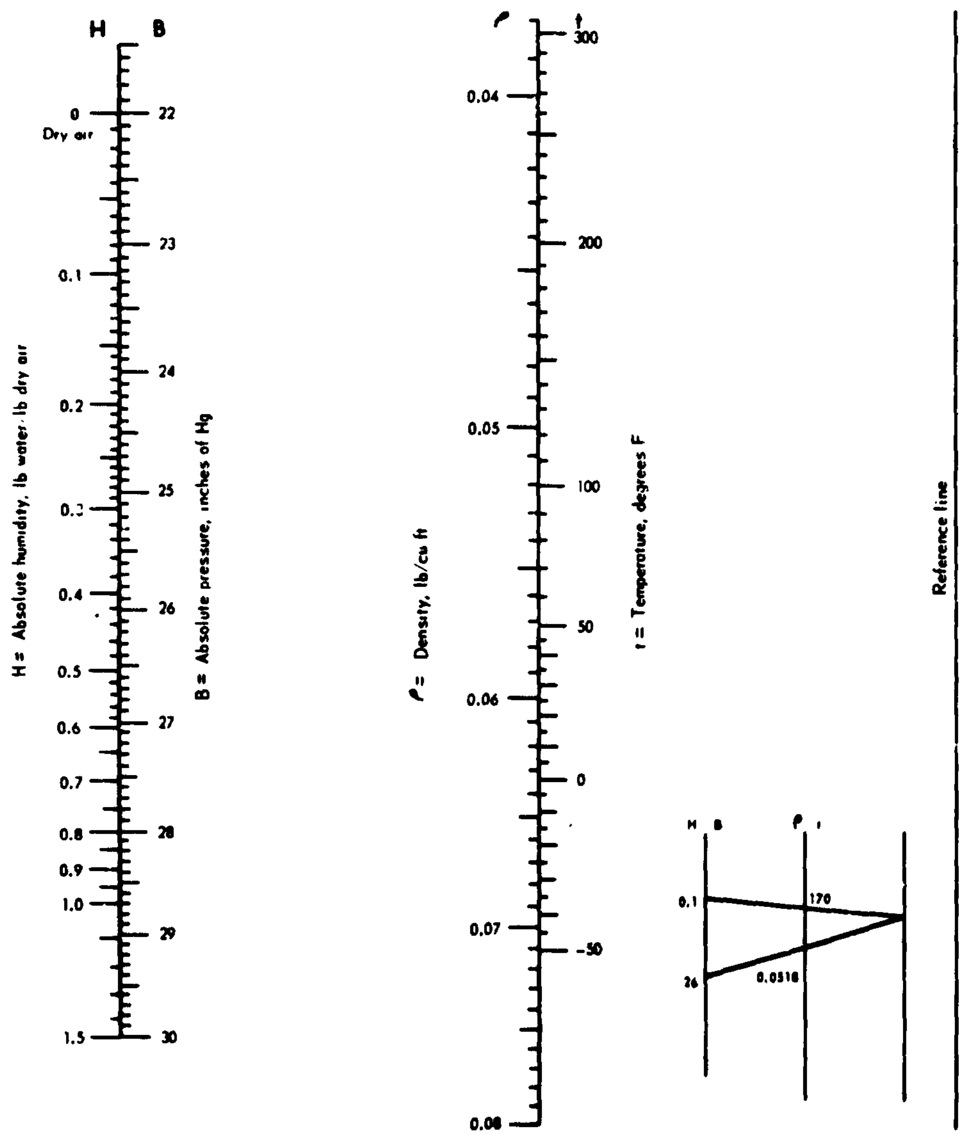
A sample problem will demonstrate how the nomogram operates.

Given: Methane gas (CH_4) at a pressure of 10 atmospheres and a temperature of 300C. Find the gas density under these conditions.

Solution: Connect 300C on the temperature scale with 10 on the atmospheres pressure scale. Extend this line to intersect the reference line. Connect the intersection with the reference line to methane (CH_4) on the molecular-weight scale. The second line intersects the density scale, where we find that the density of methane is 0.21 lb/ft³ under the conditions given



Density of Moist or Dry Air



The average molecular weight, $\overline{M}$, of a mixture of substances is equal to sum of the weights of the individual pure components, $W_1 + W_2 + W_3 + \ldots$, divided by the total number of mols:

$$\overline{M} = \frac{W_1 + W_2 + W_3 \ldots}{\frac{W_1}{M_1} + \frac{W_2}{M_2} + \frac{W_3}{M_4} \ldots} \qquad (1)$$

Where : M_1, M_2, M_4, . . . are the molecular weights of the individual pure components.
Let H be the pounds of water vapor contained in one pound of dry air, then:

$$\overline{M} = \frac{H+1}{\frac{H}{18} + \frac{1}{29}} = \frac{29(H+1)}{1.61\ H+1} \qquad (2)$$

The density of a gas which follows the perfect gas law can be written:

$$\rho = \frac{(B)(\overline{M})}{21.85(t+460)} \qquad (3)$$

Where: B = absolute pressure, inches of Hg
ρ = lb/cu ft
$\overline{M}$ = average molecular weight
t = degrees F

Substituting (2) in (3):

$$\rho = \frac{0.825\ 3\ (H+1)}{(t+460)(H+0.622)} \qquad (4)$$

The accompanying nomogram is a graphical solution of Eq. 4.
For pressures beyond scale values, note that if B is multiplied by 10, then ρ must be multiplied by 10.

Example: Air with an absolute humidity of 0.10 lb of water per lb of dry air is heated to 170F. If the absolute pressure is 26 inches of mercury, what is the density of the moist air?
Solution: Align H = 0.10 with t = 170 and continue to the reference line; align this inte tion with B ⇔ 26 and read ρ = 0.0518 lb a.

Barometric Pressures
At Various Altitudes

The nomograms solve the following equations:

$(W_a)\ (T) = 2.704\ P_o$ (1)

$(W_a)\ (T) = 1.325\ h$ (2)

$(dA)\ (W_a) = dP$ (3)

$A = (P_o/W_a)\ (2.3026\ \mathrm{Log}\ P_o/P)$ (4)

Nomenclature:

- W_a is weight of air lb/ft³
- P_o is atmospheric pressure at sea level, psi
- P is atmospheric pressure at altitude, psi
- T is absolute temperature in degrees Fahrenheit (459.2 + T Fahr.)
- h is height of barometric pressure, inches of mercury.
- dA is altitude differential, feet.
- dP is pressure differential, psi.
- A is altitude, feet.

The weight of mercury is taken as 0.49 lb/in³.

In applying formulas (3) and (4), isothermal conditions are assumed. The temperature of air decreases with altitude and so the density of air must also vary accordingly. Answers obtained by the use of formulas (3) and (4) are accurate within 0.2 to 0.3 percent within scale values indicated. Formula (4) is used in place of formula (3) for higher altitudes because error in formula (3) becomes quite large above 5000 ft.

Example 1:
What is the weight of air when the temperature is 50F and the pressure is 14.7 psi?

Solution:
1. Locate 50 degrees on the T scale.
2. Locate 14.7 on the P_o scale.
3. Connect these two points by a straight line and read 0.078 on the W_a scale.

Example 2:
If the temperature is 32F, and the barometric pressure is 30.8 inches, what is the weight of air?

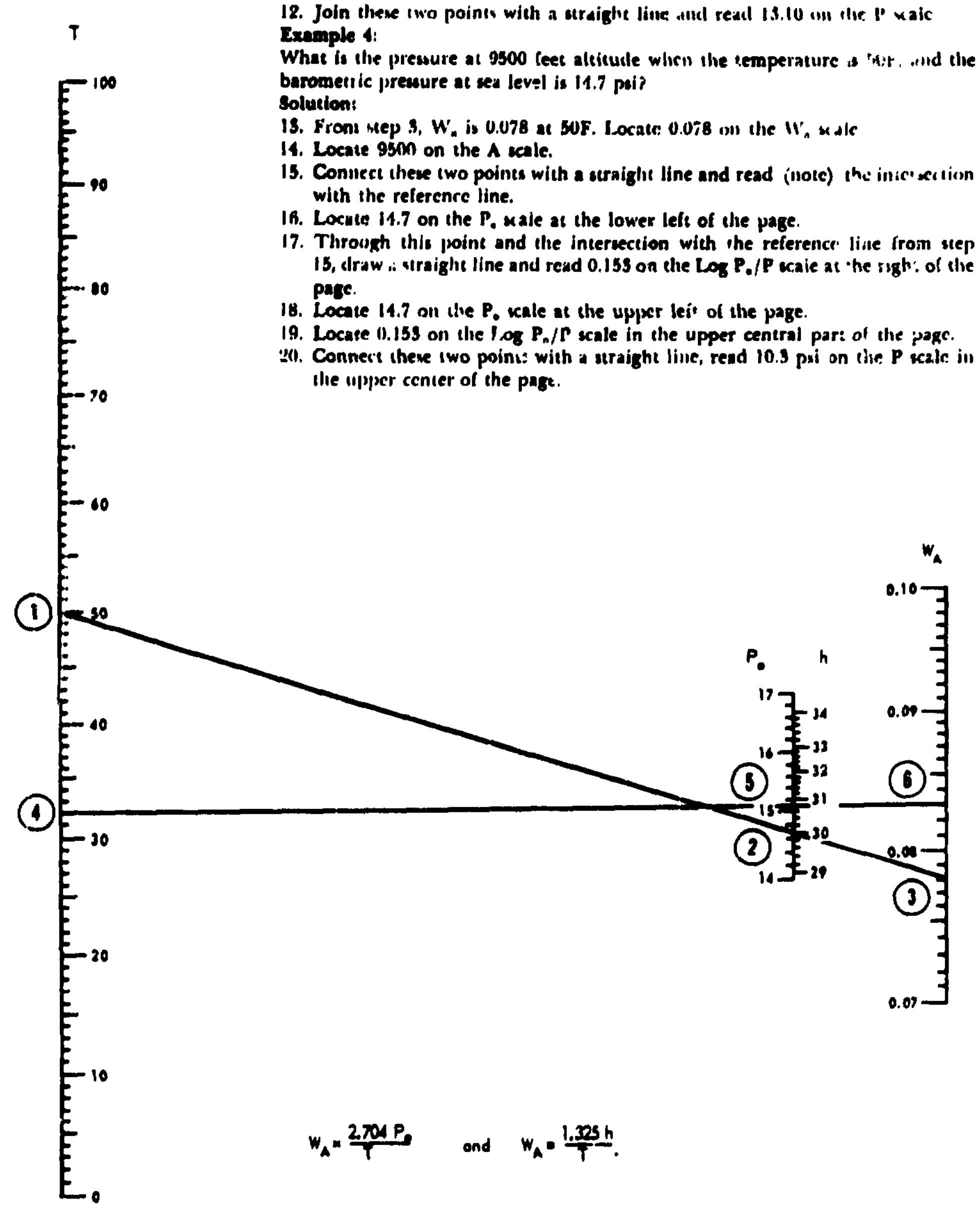
Solution:
4. Locate 32 degrees on the T scale.
5. Locate 30.8 on the h scale.
6. Connect these two points with a straight line and read 0.083 on the W_a scale.

Example 3:
What is the pressure at 3000 feet altitude when the barometric pressure at sea level is 14.7 psi, and the temperature is 50F?

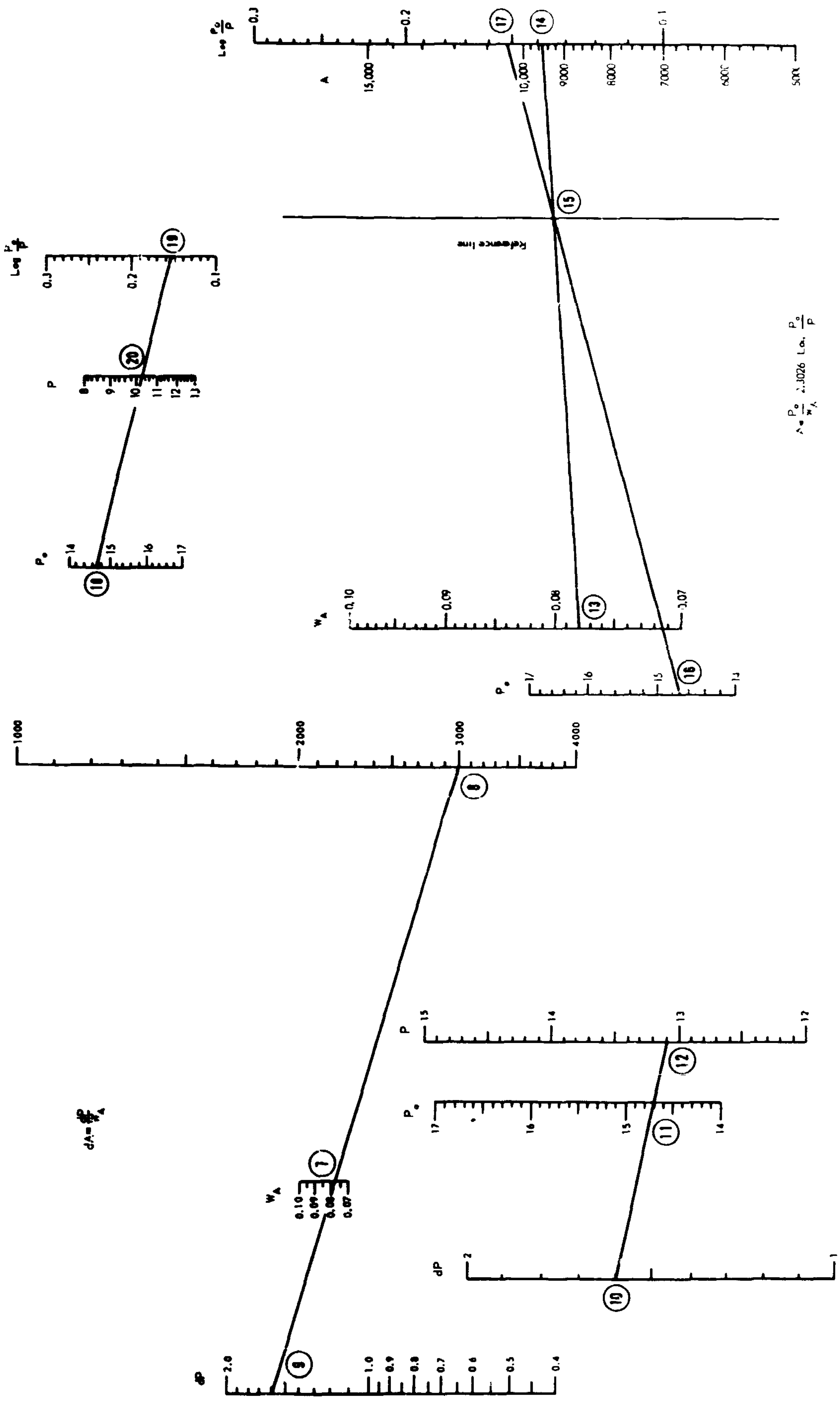
Solution:
7. From step 3, the weight of air is 0.078 lb/ft³ at 50F. Therefore, locate 0.078 on the W_a scale.
8. Locate 3000 on the dA scale.
9. Connect these two points with a straight line and read 1.6 on the dP scale.
10. Locate 1.6 on the dP scale in the center of the page.
11. Locate 14.7 on the P_o scale.
12. Join these two points with a straight line and read 13.10 on the P scale.

Example 4:
What is the pressure at 9500 feet altitude when the temperature is 50F, and the barometric pressure at sea level is 14.7 psi?

Solution:
13. From step 3, W_a is 0.078 at 50F. Locate 0.078 on the W_a scale.
14. Locate 9500 on the A scale.
15. Connect these two points with a straight line and read (note) the intersection with the reference line.
16. Locate 14.7 on the P_o scale at the lower left of the page.
17. Through this point and the intersection with the reference line from step 15, draw a straight line and read 0.153 on the Log P_o/P scale at the right of the page.
18. Locate 14.7 on the P_o scale at the upper left of the page.
19. Locate 0.153 on the Log P_o/P scale in the upper central part of the page.
20. Connect these two points with a straight line, read 10.3 psi on the P scale in the upper center of the page.



$W_A = \frac{2.704\ P_o}{T}$ and $W_A = \frac{1.325\ h}{T}$.


Log $\frac{P_o}{P}$
A
Reference line
W_A
P_o
P
dA
dP
$dA = \frac{dP}{W_A}$

Noise Measurement

Control or alleviation of noise radiated from auxiliary machinery in plants is being recognized and attacked vigorously. The three scales in this article will be helpful in the field of noise measurement.

Sound Pressure—Sound Pressure Level

Fig. 1 shows the relationship between sound pressure levels in decibels and sound pressure in microbars. The smallest sound that normally can be heard is about 0.0002 dyne/cm² or 0.0002 microbar, which is equivalent to 0 decibel. Doubling of any sound pressure corresponds to an increase in sound pressure level of 6 db. A change in sound pressure by a factor of 10 corresponds to a change in level of 20 db.

It is customary to use sound pressure levels (db) in place of sound pressures. These functions are related by the formula:

$$db = 20 \log_{10} (p/p^0)$$

Where p is the sound pressure existing at the measuring device and p^0 is the reference pressure.

The reference pressure of 0.0002 microbar is internationally used, however, other reference values can be and are used, and should be indicated to remove any ambiguity.

Combining Noise Levels

Fig. 2 may be used to compute noise levels that exist if two or more sounds, measured separately, are combined. The summation is not the simple addition of the individual sound levels.

Example 1: Two fans, when run separately, each produce (at a given position) a level of 70 db. Determine combined noise level.

Solution: Because the difference between the two levels is 0 db, Fig. 1 indicates that 3 db should be added to either individual level, producing a "total" level of 73 db.

Example 2: The noise produced by one motor-generator is 70 db and that of a second motor is 66 db. Determine combined noise level.

Solution. Difference in levels is 4 db. Fig. 2 indicates approximately 1.5 db should be added to the higher noise level. Thus, combined level = 71.5 db.

Background Noise Correction

Occasionally, it is necessary to measure noise from a machine when background noise is also present. If background level is not significantly greater than noise level of the machine, Fig. 3 will aid in correction for presence of additional noise.

Example: Measured sound pressure level of an operating machine is 80 db. When the machine is stopped, the level drops to 74 db. Determine sound level due to the machine alone.

Solution: Difference in levels is 6 db. Fig. 3 indicates that approximately 1.5 db should be subtracted from the overall reading. Thus, sound level due to the machine alone = 80 - 1.5 = 78.5 db.

SOUND PRESSURE - SOUND PRESSURE LEVEL

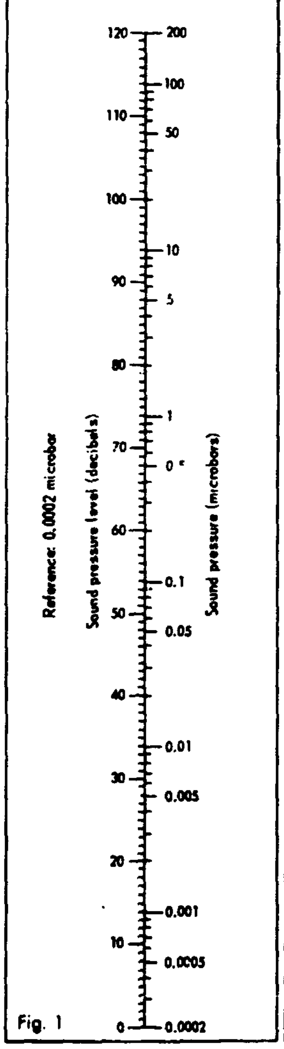


Fig. 1

COMBINING NOISE LEVELS

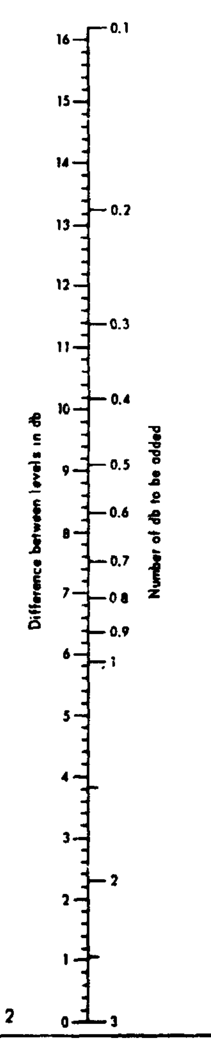


Fig. 2

BACKGROUND NOISE CORRECTIONS

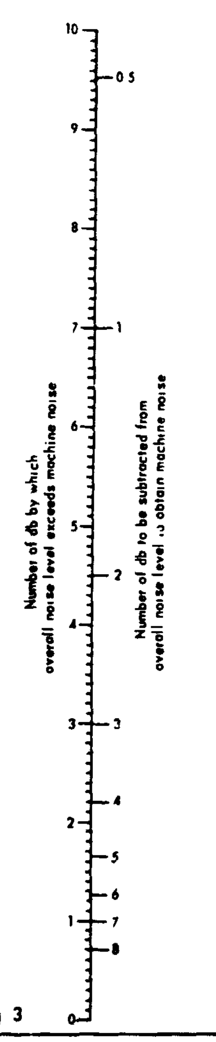
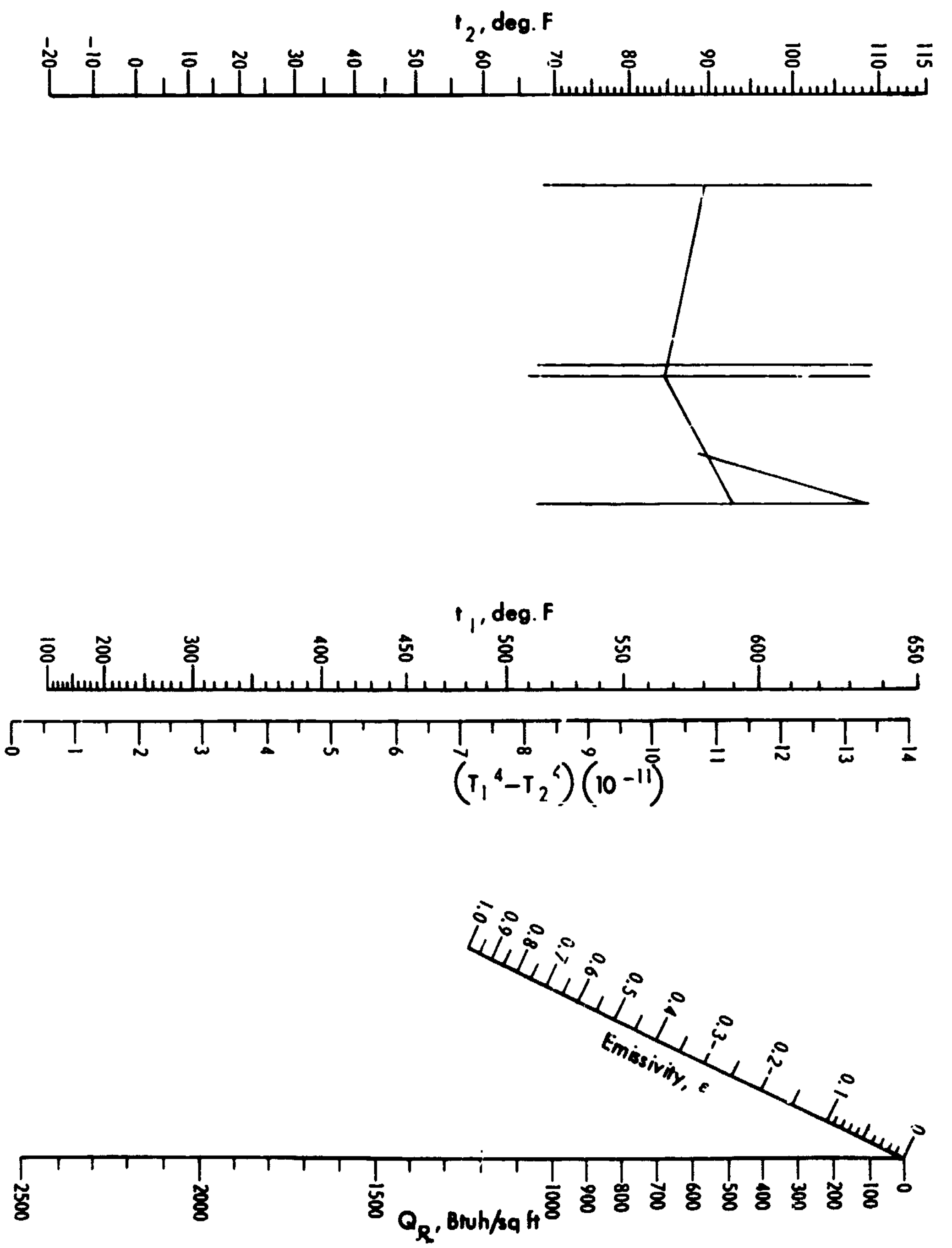


Fig. 3

Radiant Heat Transfer

The nomogram solves the equation:
$Q_R=(1.73)(10^{-9})(\epsilon)(T_1^4-T_2^4)$
Where $T=t$ degrees $F+460$.
Example:
Surface ($\epsilon=0.90$) of a pipe is at 460F. If room temperature is 62.5F, what is the radiant heat loss per sq ft of surface?
Solution:
Align $t_2=62.5F$ with $t_1=460F$ and continue to third scale; align intersection with $\epsilon=0.90$. Read $Q_R=1000$ Btuh/hr/sq ft.



Radiant-Heat Transmission Design Chart

This chart solves for the transfer of radiant energy between a gray body and black-body surroundings.*

$$q_{net} = 0.1714\, A\epsilon \left[\left(\frac{T_2}{100}\right)^4 - \left(\frac{T_1}{100}\right)^4\right]$$

where q_{net} is the heat flux in B.t.u. per hour, A the surface area of the gray body in sq ft, ϵ the emissivity, and where T_2 and T_1 are the temperatures of the gray body and the black-body surroundings in degrees Rankine. The subscript 1 refers to the surface that has the lower temperature and 2 to the higher temperature.

This design chart may also be used for solving other problems in radiant-heat transfer if the chart value of h_r/ϵ be multiplied by appropriate geometry, interchange and emissivity factors.

In comparison with similar plots using the temperatures of the two surfaces as parameters, this chart has the advantage that the change in h_r is small with respect to Δt. This is very pronounced at high temperatures where radiant-heat transmission usually is the controlling mechanism.

Example 1. Find the radiant heat-transfer coefficient for a bare steam pipe with a surface temperature of 300F, if the surroundings are at 80F. Assume that the surroundings are black bodies and that the emissivity of the pipe is 0.80.

Solution 1. $\Delta t = t_2 - t_1 = 300 - 80 = 220F.$

$$t_{av} = \frac{1}{2}(t_2 + t_1) = \frac{1}{2}(300 + 80) = 190F.$$

Entering 220F as the abcissa on the chart, we estimate the intersection with the 190F line, and read by interpolation the ordinate $h_r/\epsilon = 1.94$. Allowing for the given emissivity we get $h_r = 1.94\,\epsilon = (1.94)(0.90) = 1.75$ B.t.u./hr (sq ft)°F.

Example 2. Infinite parallel gray walls are at 1800F and 1200F and have emissivities of 0.65 and 0.25 respectively. Find the heat-transfer coefficient to the energy transmitted by radiation.

Solution 2 $\Delta t = t_2 - t_1 = 1800 - 1200 = 600F$

$$t_{av.} = \frac{1}{2}(t_2 + t_1) = \frac{1}{2}(1800 + 1200) = 1500F.$$

Read from the design chart, $h_r/\epsilon = 53$ B.t.u./hr. (sq ft)°F. For parallel gray walls the factor =

$$\frac{1}{1/\epsilon_1 + 1/\epsilon_2 - 1}$$

must be introduced, therefore

$$= \frac{1}{1/0.65 + 1/0.25 - 1} = 0.22, \text{ and } h_r = 53\,\epsilon$$

$$= (53)\,(0.22) = 11.7 \text{ B.t.u./hr. (sq ft)°F}$$

*The value used for the Stefan-Boltzmann constant has been calculated from the best value recommended by Mark W. Zemansky in his book "Heat Transmission and Thermodynamics," 4th ed., McGraw Hill (1957) σ = 5.672 erg/sec cm², deg⁴

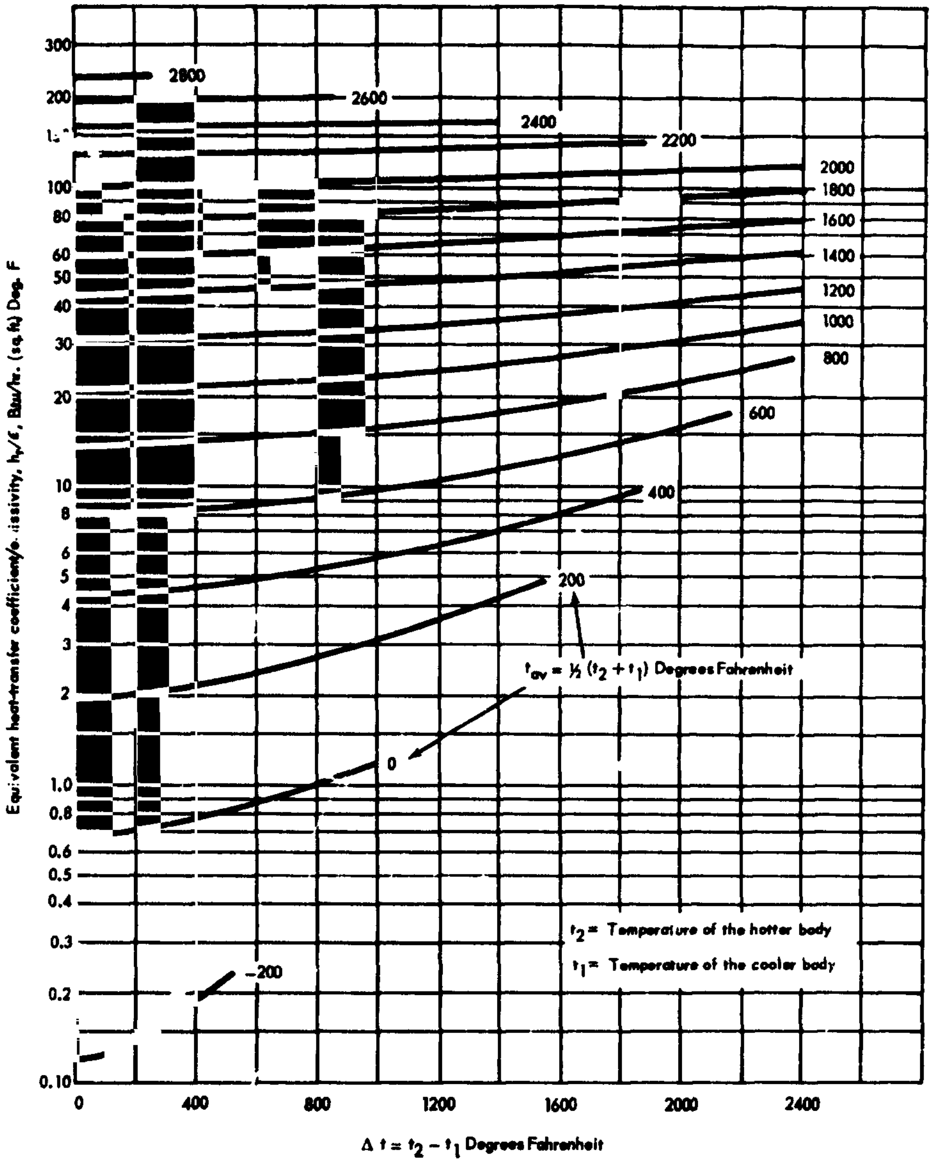


FIG. 1 – CHART FOR THE EQUIVALENT HEAT-TRANSFER COEFFICIENT FROM THE RADIATION EQUATION

Color Temperature

Color temperature is a term sometimes used to describe the color of the light from a source by comparing it with the color of a *blackbody*, a theoretical "complete radiator" which absorbs all radiation that falls on it, and in turn radiates a maximum amount of energy in all parts of the spectrum. A blackbody, like any other incandescent body, changes color as its temperature is raised. The light from a White fluorescent lamp is similar in color to the light from a blackbody at a temperature of approximately 3500° Kelvin*, and the lamp is accordingly said to have a color temperature of 3500°K. The light from a Daylight fluorescent lamp is bluer, and the blackbody must be raised to 6500°K to match it. Hence the Daylight lamp has a color temperature of 6500°K.

Color temperature is not a measure of the *actual temperature* of an object. It defines *color only*. Some light sources, such as a sodium vapor lamp, or a Green or Pink fluorescent lamp, will not match the color of a blackbody at any temperature, and therefore no color temperatures can be assigned to them.

* Kelvin is a temperature scale which has its zero point at −273° Centigrade.

TERMINOLOGY AND MEASUREMENTS

QUANTITY	SYMBOL	UNIT	DEFINITION
Luminous Intensity (Candlepower) Light density in a specified direction.	I	Candle (c) The luminous intensity of a source expressed in candles is its Candlepower (cp)	The standard unit of luminous intensity in a given direction is the *International Candle*. An ordinary wax candle has a luminous intensity in a horizontal direction of approximately one candle. The International Candle is the basic quantity in all measurements of light. Candlepower is always a property of a source of light, and gives information regarding luminous flux at its origin.
Luminous Flux Time rate of flow of light. Light is actually a form of radiant energy in motion. In common practice, however, the time element is neglected, and luminous flux is considered as a definite quantity.	F	Lumen (lm)	A lumen is the light flux falling on a surface one square foot in area, every point on which is one foot from a uniform point source of one candle. (Such a surface is a one-foot-square section of a sphere of one-foot radius, with a one-candle source at its center.) The lumen differs from the candle in that it is a measure of light flux *irrespective of direction*.

Light travels in straight lines, unless it is modified or re-directed by means of a reflecting, refracting, or diffusing medium.

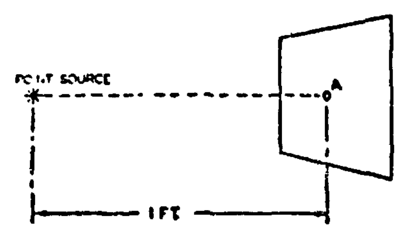
Light waves pass through one another without alteration of either —for example, a beam of red light will pass directly through a beam of blue light unchanged in direction or color.

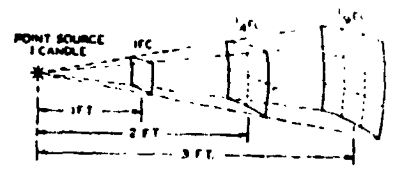
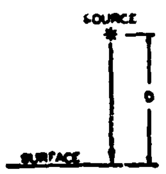
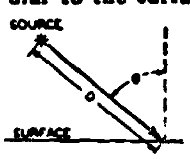
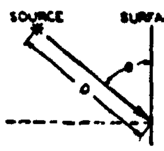
Light is invisible in passing through space unless some medium (such as dust) scatters it in the direction of the eye.

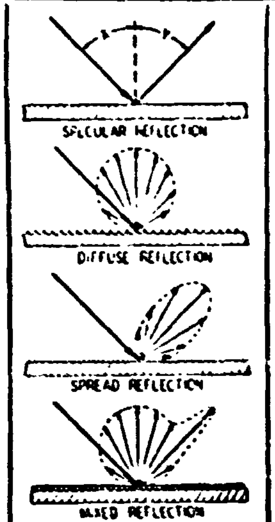
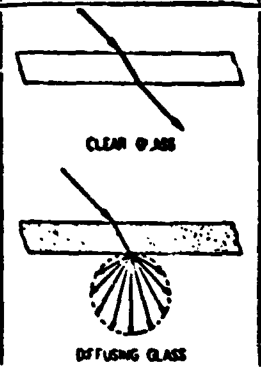
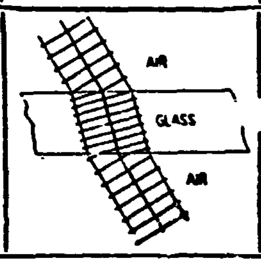
COLOR TEMPERATURES
Degrees Kelvin
(Approximate Values)

Blue Sky	10,000 to 30,000
Overcast Sky	7000
Noon Sunlight	5250
Fluorescent Lamps	
Daylight	6500
Cool White	4500
White	3500
Warm White	3000
500-Watt Daylight Incandescent Lamp	4000
Photoflood Lamp	3415
General Service Incandescent Lamps	2500 to 3050
Candle Flame	1800

FUNDAMENTAL EQUATIONS	METHOD OF MEASUREMENT	PRINCIPAL USE
CP = Footcandles x D^2 (D = Distance in feet from source to illuminated surface) See Illumination. $MSCP = \frac{Lumens}{12.57}$ (Mean spherical candlepower is the average candlepower of a source in all directions.)	Candlepower measurements are primarily a laboratory procedure requiring special instruments. Rough estimates of the candlepower of a source or fixture can be made in the field by (1) holding a light meter at a distance of at least five times the greatest dimension of the source; (2) aiming the cell of the meter directly at the source; and (3) multiplying the footcandle reading by the square of the distance in feet. (See Fundamental Equations.) There must of course be no other light in the room, and it may be necessary to make allowance for light reflected from walls and ceilings.	Candlepower is used not only to indicate the luminous intensity of a source in one particular direction; candlepower measurements are often taken at various angles around a source or a fixture, and the results plotted to give a *candlepower distribution curve.* Such a curve shows luminous intensity in any direction, and from it illumination calculations can be made. (See section on Distribution Curves, and Chapter Six, Point-By-Point Method.)
Lumens incident on a surface = Footcandles x Area (sq. ft.) Lumens emitted or reflected by a surface = Footlamberts x Area (sq. ft.) Lumens = MSCP x 12.57 (Since a sphere of one-foot radius has a surface area of 4π (12.57) square feet, a uniform point source of one candle must produce 12.57 lumens. The same relationship exists between the mean spherical candlepower of any source and its total lumen output.)	Lumen measurements of light sources are a laboratory procedure requiring special equipment. The lumens falling upon a surface may, however, be estimated with the aid of an ordinary light meter. First obtain footcandle readings at various points on the surface in order to arrive at an average value; then multiply the average footcandles by the area of the surface in square feet. (See Fundamental Equations.)	The lumen is used primarily to express the total output of a light source. It can also be used to indicate amount of light absorbed, transmitted, or reflected. The Lumen Method (see Chapter Six) of calculating illumination provides average footcandle values by the use of relatively simple formulas.

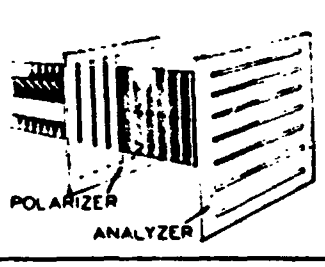
QUANTITY	SYMBOL	UNIT	DEFINITION
Illumination **Density of luminous flux on a surface.** **Luminous flux may be called the *cause*, and illumination the *effect* or result.**	**E**	**Footcandle (fc)**	**A footcandle is the illumination at a point (A) on a surface which is one foot from and perpendicular to a uniform point source of one candle.**  **From the definition of a lumen it is obvious that one lumen uniformly distributed over one square foot of surface produces an illumination of one footcandle.**
Brightness **Luminous intensity in a given direction per unit of (projected) area.** **A surface or an object has *brightness* by reason of light emitted, reflected, or transmitted. Brightness is ordinarily independent of distance of observation.**	**B** **or** **B'**	**Candle per square inch ($c/in.^2$)** **or** **Footlambert (fL)**	**Brightness is expressed in two ways: in *candles* per unit area, or in *lumens* per unit area.** **A surface emitting or reflecting light in a given direction at the rate of one candle per square inch of projected area has a brightness in that direction of *one candle per square inch*.** **A surface which has a brightness equal to the uniform brightness of a perfectly diffusing surface emitting or reflecting one lumen per square foot has a brightness of *one footlambert*. The footlambert is also the average brightness of any surface emitting or reflecting light at the rate of one lumen per square foot.** **A *lambert* is the brightness of a surface emitting or reflecting one lumen per square centimeter; a *millilambert* is one-thousandth of a lambert.**

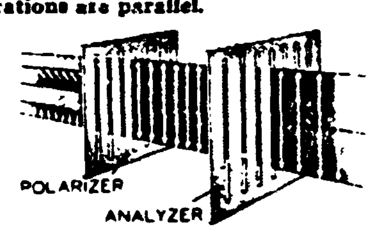
FUNDAMENTAL EQUATIONS	METHOD OF MEASUREMENT	PRINCIPAL USE
Inverse Square Law **Illumination decreases inversely as the square of the distance.**  **When light rays are perpendicular to the surface, the inverse square law as stated above applies:**  $E = \frac{I}{D^2}$ **E = Footcandles** **I = Candlepower** **D = Distance in feet** **When light rays are not perpendicular to the surface:**  $E_h = \frac{I \times \text{Cosine } \theta}{D^2}$  $E_v = \frac{I \times \text{Sine } \theta}{D^2}$ **Footcandles incident on a surface =** $\frac{\text{Lumens}}{\text{Area (sq. ft.)}}$	**Various models of direct-reading light-sensitive cell footcandle meters and visual photometers are available. A discussion of these instruments and their use is found in the following section entitled Field Measurements.**	**Footcandle readings are used to indicate the illumination at a specific point, or the average illumination on a surface. The inverse square law is the basis of calculation in the Point-By-Point Method of lighting design.** **The inverse square law applies strictly only to a *point source*. With most types of interior lighting fixtures, however, it is safe to assume that the law operates with sufficient accuracy for all practical purposes if the distance at which the measurements are taken is at least five times the greatest dimension of the light source. For special considerations involving linear sources and parallel beams of light, see Chapter Six.**
FL = Footcandles x Reflection factor of surface $FL = \frac{\text{Lumens (incident)} \times \text{Reflection factor}}{\text{Area (sq. ft.) of surface}}$ **1 Candle per sq. in. = 452 Footlamberts** **If the surface under consideration departs widely from the properties of a perfect diffuser, the lumens emitted or reflected cannot safely be calculated on the basis of a single brightness reading taken from any one angle.** **1 Lambert = 929 Footlamberts = 2.054 Candles per sq.in.** **1 Millilambert = 0.929 Footlamberts = 0.002 Candles per sq. in.**	**Methods of making brightness measurements and the meters used for the purpose are described later in this Chapter under Field Measurements.**	**Relatively high brightnesses, such as those of light sources, are usually expressed in terms of candles per square inch. Since the average brightness of a surface in footlamberts can be calculated by multiplying the illumination in footcandles by the reflection factor (see Fundamental Equations), the footlambert is a very convenient unit in which to express the brightnesses of illuminated surfaces.**

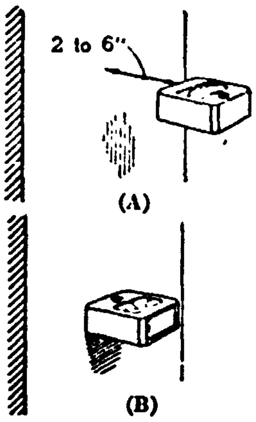
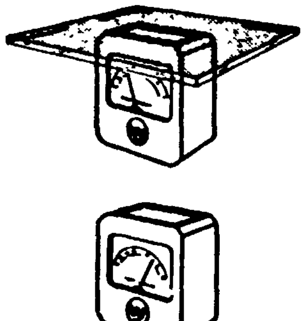
TYPE OF CONTROL	ILLUSTRATION	UNIT	METHOD OF MEASUREMENT
Reflection When a ray of light striking a surface is turned back, it is said to be ***reflected.*** Reflection may be of several types, the most common of which are ***specular*** (regular), ***diffuse, spread,*** and ***mixed.***	 SPECULAR REFLECTION DIFFUSE REFLECTION SPREAD REFLECTION MIXED REFLECTION	**Reflection Factor** The ratio of the light reflected from a surface to that incident upon it. The reflection factor of a given surface may vary considerably according to the direction and nature of the incident light. Specular reflection increases with angle of incidence, almost total reflection being obtainable at grazing angles. With colored surfaces the reflection factor may be quite different for different colors of light.	Place light meter cell against surface. Withdraw meter from surface slowly until constant reading is obtained (2 to 6 inches). (A) Place meter against surface with cell facing out (B) and note reading. Reflection factor = $\frac{\text{Reading (A)}}{\text{Reading (B)}}$
Transmission Light rays passing through transparent or translucent materials are said to be ***transmitted.*** The degree of diffusion of the transmitted light depends upon the type and density of the material.	 CLEAR GLASS DIFFUSING GLASS	**Transmission Factor** The ratio of the light transmitted by a material to that incident upon it. Transmission depends to some extent upon the direction and quality of the light.	Place material to be tested over cell of light meter. Note reading (A). Remove material. Note reading (B). Transmission factor = $\frac{\text{Reading (A)}}{\text{Reading (B)}}$
Refraction A light ray bent by passing obliquely from one transparent medium to another in which its velocity is different (as from air into glass) is said to be ***refracted.***	 AIR GLASS AIR	**Index of Refraction** The ratio of the speed of light in free space to the speed of light in the medium in question.	By special laboratory apparatus only.

Polarization

Light in which the waves vibrate in one plane only is said to be ***polarized.*** The vibrations which make the wave motion in a ray of light are at right angles to the direction in which the light is traveling, and in a beam of ordinary light these vibrations take place in all possible directions in that plane. By passing light through a material with a crystalline structure such that it transmits only waves vibrating in a certain direction, it is possible to produce polarized light, all of whose vibrations are parallel.





INSTRUMENT	MATERIALS	USE
	Reflecting Surface — Per Cent Light Reflected Magnesium Carbonate .... 97–98 Polished Silver .... 90 White Plaster .... 85–90 Mirrored Glass .... 80–90 Alzak Aluminum .... 80–85 White Blotting Paper .... 80–85 Porcelain Enamel .... 77–82 White Paint .... 75–85 Polished Chromium .... 65 Polished Aluminum .... 60–70 Polished Nickel .... 65 Aluminum Paint .... 50–75 Black Paint 3–5	In *specular*, or *regular*, reflection (mirrors, highly polished metals) the angle of incidence is equal to the angle of reflection (see Illustration: Angle X = Angle Y). In *diffuse* reflection (matte surfaces like white blotting paper, fresh snow) the maximum intensity is perpendicular to the surface, regardless of the angle of the incident beam. *Spread* reflection, as in sanded glass, is intermediate between specular and diffuse. Diffusing surfaces with a glazed superficial coat, like porcelain enamel, exhibit *mixed* reflection, a combination of specular and diffuse.
	Type of Glass — Per Cent Light Transmitted Clear .... 80–90 Frosted .... 75–85 Figured or Ribbed Crystal .... 70–85 Light-Density Diffusing .... 55–70 Heavy-Density Diffusing 10–45	In *regular* transmission (clear glass and plastics) the direction of the incident light is not changed. Diffusing media, such as dense opal glass, scatter the transmitted light so that its maximum intensity is normal to the surface. As in reflection, between the two extremes of regular transmission and perfectly diffuse transmission are to be found all degrees of diffusion.
	Index of Refraction for Various Materials Water .... 1.33 Alcohol .... 1.36 Turpentine .... 1.47 Crown Glass .... 1.53 Flint Glass .... 1.67 Diamond 2.47	The principle of *refraction* is utilized to control the direction of light by means of prismatic or ribbed glass plates, or in lens systems. It has wide application in certain types of general lighting systems, as well as in signal lighting and street lighting.
Two polarizing screens are ordinarily used in a system that involves polarization. The first, called the *polarizer*, produces the polarization, and the second, called the *analyzer*, selects or rejects the polarized light, according to the position in which it is placed.	Crystals of Iceland spar, calcite, and tourmaline; Polaroid, (a cellophane-like material available commercially). Reflection from specular or polished surfaces partially polarizes light.	The principle of *polarization* is used in certain kinds of laboratory equipment, and in testing for stress and strain in transparent materials; in producing third-dimension effects in motion pictures; in sun glasses and automobile visors to reduce reflected glare from road surfaces and water; in photographic filters. Experimental work on the control of automobile headlight glare by means of polarizing material is under way.

Nomograph for Intensity of Reflected Light

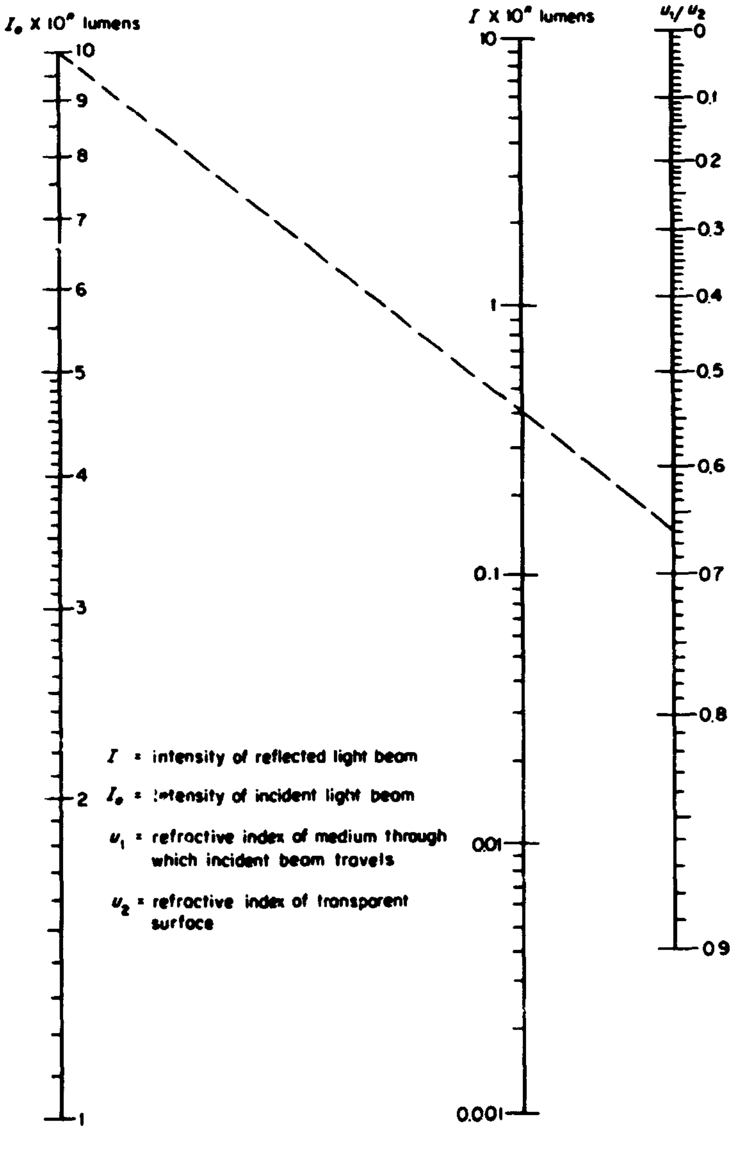
REFLECTED LIGHT from a transparent substance depends upon the refractive indices of the substance and the medium through which the incident light travels and upon the angle of incidence. The accompanying nomograph permits the determination of the intensity of reflected light at the medium-surface boundary when the incident light is perpendicular to the surface. At other incident angles, intensity values should be adjusted by trigonometric techniques for equivalent intensities at perpendicular incidence. The basic equation for the nomograph is

$$Iu_2^2 + 2Iu_2u_1 + Iu_1^2 - I_ou_2^2 + 2I_ou_1u_2 - I_ou_1^2 = 0$$

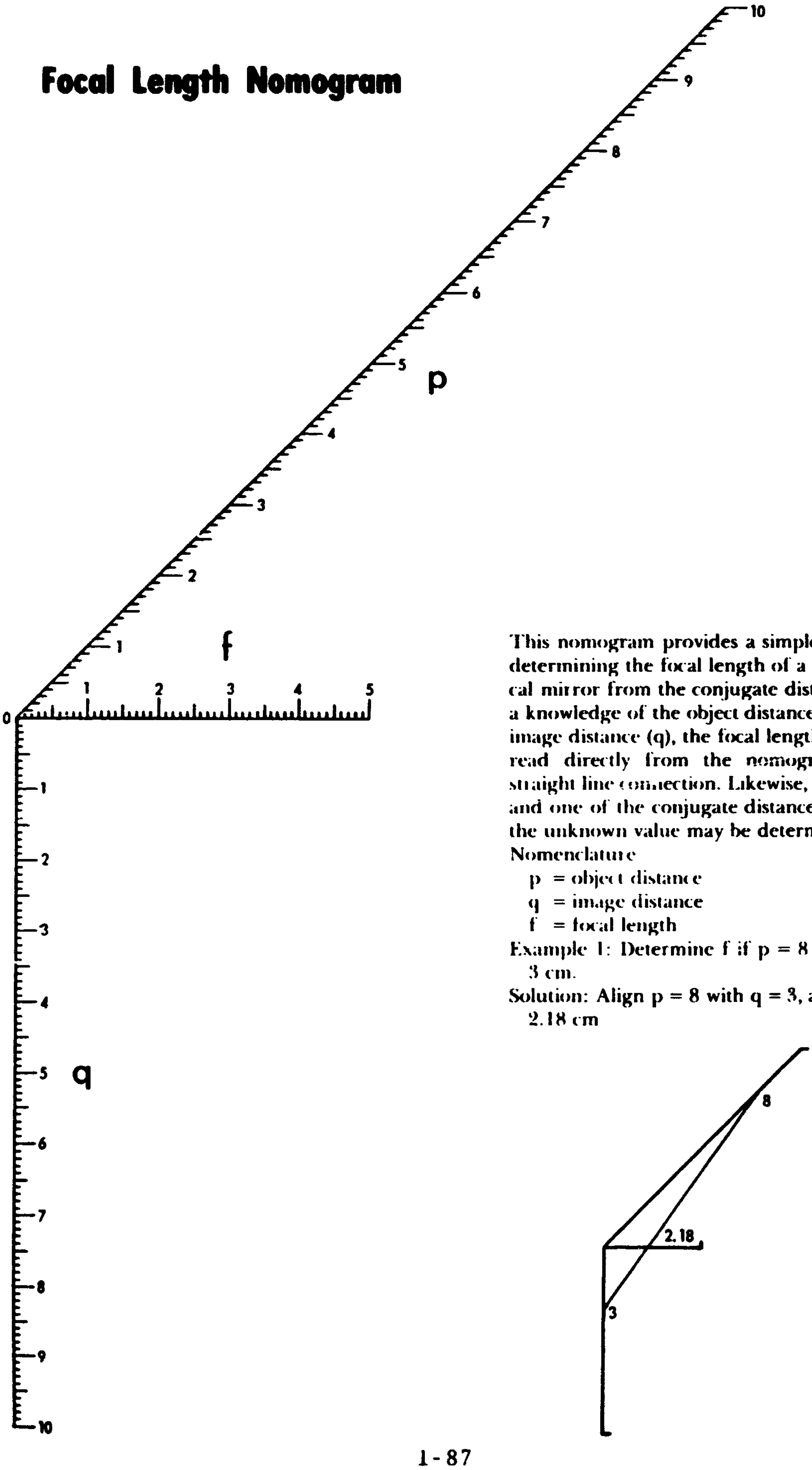
In using the nomograph a factor of 10^n must be extracted from the incident intensity and then must be returned to the resulting reflected intensity. For instance, an incident intensity of 800 lumens would be entered as 8; and if the results were 3, the actual reflected intensity would be 300 lumens. The procedure for using the nomograph is as follows:

1. Select the intensity of the incident light on the left line.
2. Select the ratio of the refractive indices u_1/u_2 on the right line.
3. Connect these values with a straight line to intersect the reflected intensity value on the center line.

The dashed line on the nomograph is an example. The incident light beam has a 1000-lumen intensity and is perpendicular to an air-glass boundary. The air-glass refractive index ratio is 1/1.5. The intensity of reflected light is found to be 40 lumens. ▲



Focal Length Nomogram



This nomogram provides a simple method of determining the focal length of a lens or optical mirror from the conjugate distances. With a knowledge of the object distance (p) and the image distance (q), the focal length (f) may be read directly from the nomogram with a straight line connection. Likewise, if f is known and one of the conjugate distances unknown, the unknown value may be determined.

Nomenclature

p = object distance
q = image distance
f = focal length

Example 1: Determine f if p = 8 cm and q = 3 cm.

Solution: Align p = 8 with q = 3, and read f = 2.18 cm

Optics: Refraction and Reflection at Plane Surfaces

Refraction and Dispersion

The index of refraction of an optical material occupies a position of central importance in geometrical optics. The index of refraction of a substance (n) at a specific wavelength is defined as the ratio of the velocity of light in a vacuum (c) to the velocity of light at that wavelength in the substance (v):

$$n = c/v \qquad (1)$$

The velocity of light in a vacuum is the same at all wavelengths. The velocity of light in material substances, however, is observed to vary with wavelength. Hence, index of refraction of an optical substance is a function of wavelength. To provide the convenience of a single measure, the index of refraction is usually specified at the particular wavelength of 5893 Angstrom Units, the average of the wavelengths of the two notable D-lines of the sodium spectrum.

Letter	Color	Source	Wavelength
C	Red	H	6563 Å
D	Yellow	Na	5893 Å
e	Green	Hg	5461 Å
F	Blue	H	4861 Å
G'	Violet	H	4341 Å
h	Violet	Hg	4047 Å

One Angstrom Unit is equal to 10^{-8} centimeters. The "D", and the other letters C, e, F G' and h used as subscripts in Table 1, are prevalent designations of certain prominent spectral lines of common chemical elements observed in the solar spectrum, and by association also refer to the wavelengths of these lines.

The index of refraction for air at standard conditions for red light of wavelength 6563 Angstrom Units is 1.0002914. and for violet light of wavelength 4359 Angstrom Units it is 1.0002957. It follows, then, that for most purposes, n for air may be taken as unity.

To conveniently signify with a single number the extent to which the index of refraction of a material substance varies with different wavelengths of light, the following ratio is often used:

$$V = \frac{n_D - 1}{n_F - n_C} \qquad (2)$$

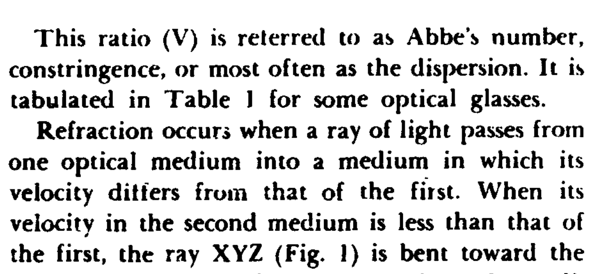


FIG. 1 REFRACTION OF LIGHT

This ratio (V) is referred to as Abbe's number, constringence, or most often as the dispersion. It is tabulated in Table 1 for some optical glasses.

Refraction occurs when a ray of light passes from one optical medium into a medium in which its velocity differs from that of the first. When its velocity in the second medium is less than that of the first, the ray XYZ (Fig. 1) is bent toward the normal NYO. When the ray travels from the medium of lesser velocity to the medium of greater velocity, it is bent away from the normal NYO. The law governing refraction is Snell's law:

$$n \sin I = n' \sin I' \qquad (3)$$

Where: n = index of refraction of first medium
n' = index of refraction of second medium
I = angle of incidence of first medium
I' = angle of incidence of second medium

For the special case of refraction at an air-glass boundary, the following equation is derived from

Snell's law:

$$n \sin r = \sin i \qquad (3a)$$

Where: n = index of refraction of glass
i = angle of incidence
r = angle of refraction

The ratio of the real depth to the apparent depth for any medium when viewed in air in a direction normal to the separating surface is

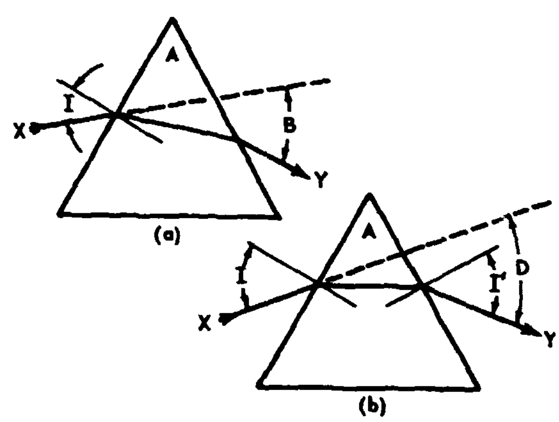


FIG. 2 REFRACTION BY A PRISM

given by:

$$n = \frac{\text{real depth}}{\text{apparent depth}} \qquad (4)$$

A light ray XY (Fig. 2a) passing from air through a glass prism and re-entering air is bent toward the thicker part of the prism. Minimum deviation, D, occurs when the ray passes through the prism symmetrically (parallel to the base)

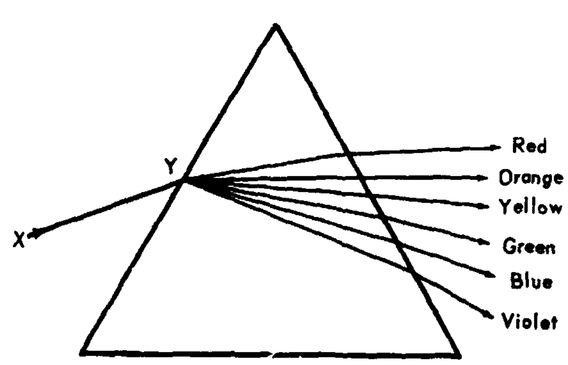


FIG. 3 DISPERSION BY A PRISM

thus making the angle I equal to angle I' (Fig. 2b). For minimum deviation:

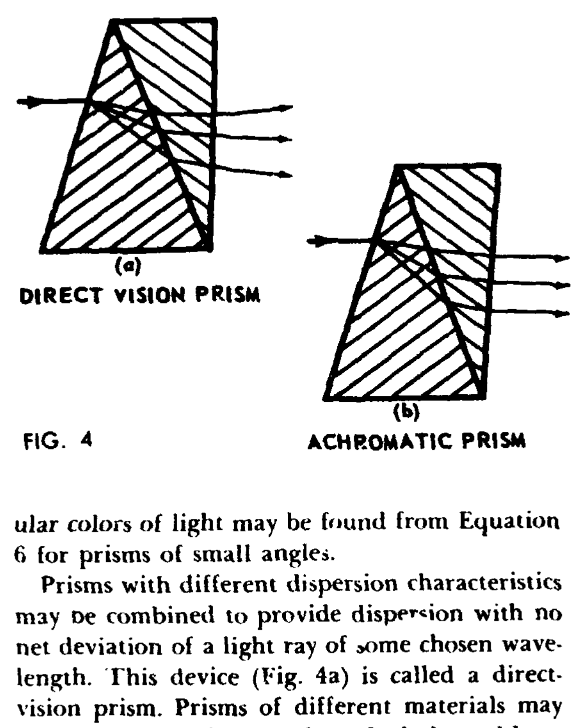
$$n = \frac{\sin \frac{1}{2}(A + D)}{\sin \frac{1}{2}A} \qquad (5)$$

Where: n = index of refraction of the prism
A = prism angle

When A is small, the sines of the angles in Equation 5 may be set equal to the angles (in radians):

$$D = A(n - 1) \qquad (6)$$

Most light beams are polychromatic; that is, they consist of light of different wavelengths. Monochromatic light consists of a single wavelength. Since the index of refraction varies with wavelength and velocity, a substance in which the velocity varies with wavelength will exhibit dispersion. Dispersion curves for various glasses are shown in Fig. 6. Consider Fig. 3 which shows a polychromatic light ray XY incident on a prism in air. Deviation caused by a prism increases as the index of refraction increases; hence, violet light is deviated the most and red the least. Dispersion from wavelength to wavelength of partic-



(a) DIRECT VISION PRISM

(b) ACHROMATIC PRISM

FIG. 4

ular colors of light may be found from Equation 6 for prisms of small angles.

Prisms with different dispersion characteristics may be combined to provide dispersion with no net deviation of a light ray of some chosen wavelength. This device (Fig. 4a) is called a direct-vision prism. Prisms of different materials may also be combined to produce deviation without dispersion. This device (Fig. 4b) is called an achromatic prism.

Reflection

When a ray of light is reflected from a plane surface, the angle of reflection is equal to the angle of incidence. Also, the reflected ray, the incident ray and the normal to the surface at the point of incidence are co-planar. A light ray XYZ (Fig. 5a) passing from glass into air is refracted in the amount given by Snell's law:

$$n \sin I = n' \sin I' \qquad (7)$$

Since n', the index of refraction of air (in this case) can be taken as unity, n/n′ is greater than unity. Hence, sin I′ is always larger numerically than sin I, and therefore is equal to unity for some angle (I) less than 90 deg. This is shown in Fig. 5b, where angle I has been increased to the point where angle I′ is equal to 90 deg. It can easily be seen that:

$$n \sin I = n' \sin 90^\circ = n' \qquad (8)$$

which means,

$$n \sin I = 1 \qquad (9)$$

or,

$$\sin I = 1/n \qquad (10)$$

If we increase angle I beyond this point as indicated in Fig. 5c, the ray XYZ no longer passes

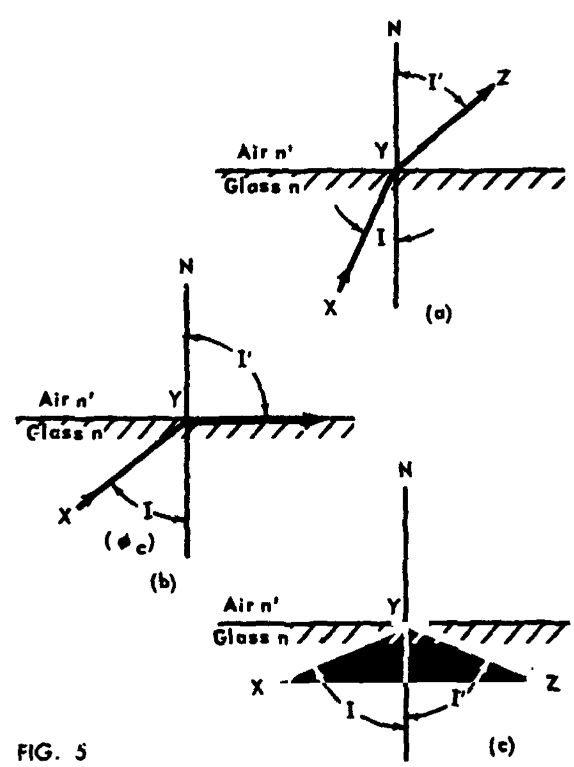


FIG. 5

through the air-glass boundary, but it is reflected back into the glass. The ray is thus totally internally reflected at the air-glass boundary. The phenomenon of total internal reflection can occur when, and only when, a ray is incident on the surface of a medium whose index is smaller than the index of the medium in which the ray is traveling. The angle at which total internal reflection begins is called the critical angle. This angle (ϕ_c) is shown in Table I for glasses of various indices of refraction.

The critical angle formula may be derived (for two given substances) by algebraic substitution in Snell's law, and may be stated as:

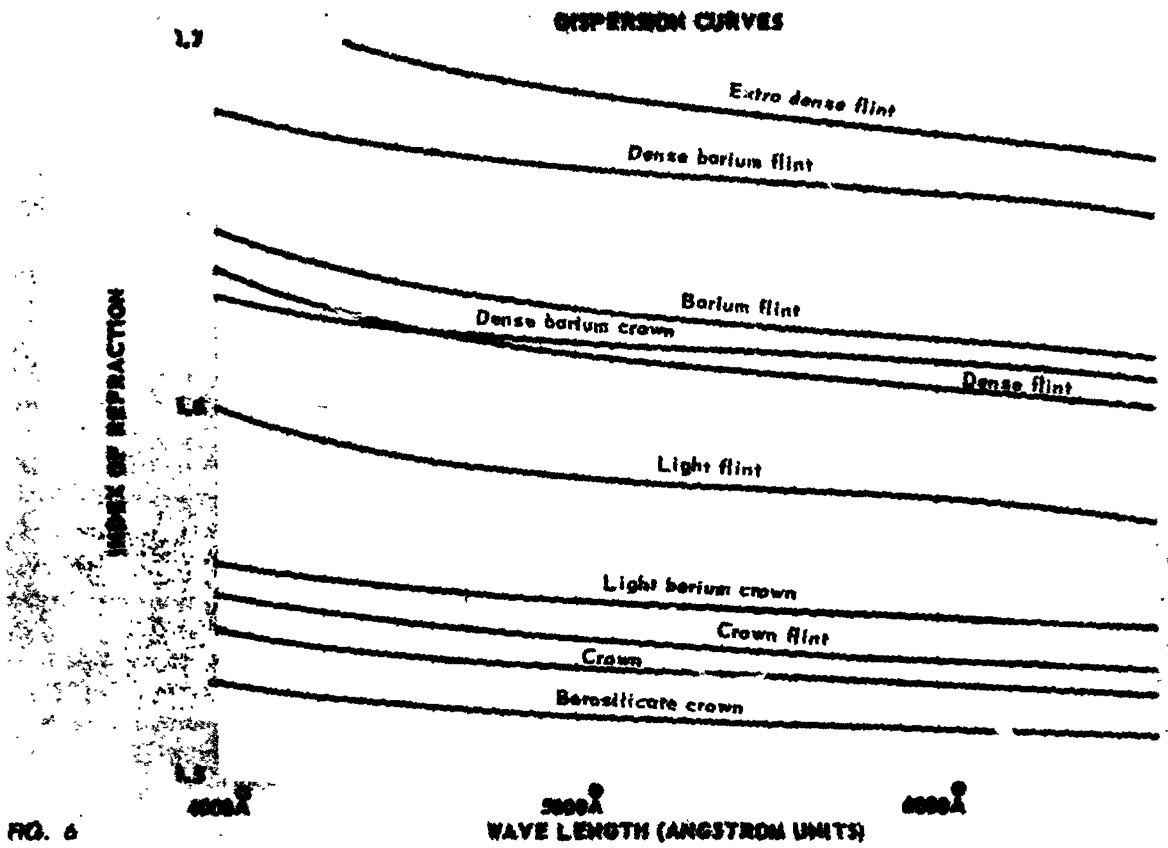


FIG. 6

Table I	INDICES OF REFRACTION								
	5893Å n_D	n_F-n_C	V	6563Å n_C	5461Å n_e	4861Å n_F	4341Å $n_{G'}$	4047Å n_h	Critical angle at 5893Å ϕ_c
Borosilicate Crown	1.51100 1.51700 1.50500	0.00804 0.00802 0.00760	63.5 64.5 66.5	1.50860 1.51462 1.50272	1.51300 1.51901 1.50688	1.51664 1.52264 1.51032	1.52112 1.52712 1.51455	1.52450 1.53047 1.51771	41 deg 26 min 41 deg 14 min 41 deg 38 min
Crown	1.52300 1.51300 1.50800	0.00895 0.00846 0.00832	58.5 60.5 61.0	1.52035 1.51050 1.50551	1.52521 1.51509 1.51005	1.52930 1.51897 1.51382	1.53437 1.52375 1.51849	1.53822 1.52737 1.52201	41 deg 3 min 41 deg 22 min 41 deg 32 min
Light Barium Crown	1.54100 1.58800	0.00905 0.01102	59.8 53.3	1.53832 1.58477	1.54323 1.59071	1.54737 1.59579	1.55250 1.60214	1.55638 1.60698	40 deg 28 min 39 deg 2 min
Dense Barium Crown	1.61100 1.61300	0.01039 0.01030	58.8 59.5	1.60796 1.60999	1.61359 1.61557	1.61835 1.62029	1.62425 1.62614	1.62868 1.63053	38 deg 22 min 38 deg 19 min
Crown Flint	1.53000 1.50200	0.01022 0.00885	51.8 56.7	1.52702 1.49940	1.53251 1.50417	1.53724 1.50825	1.54316 1.51327	1.54770 1.51714	40 deg 49 min 41 deg 45 min
Light Flint	1.57300 1.54900	0.01345 0.01201	42.5 45.7	1.56912 1.54556	1.57631 1.55199	1.58257 1.55757	1.59059 1.56468	1.59686 1.57020	39 deg 28 min 40 deg 13 min
Dense Flint	1.65400	0.01925	34.0	1.64857	1.65872	1.66782	1.67967	1.68908	37 deg 12 min
Extra Dense Flint	1.72800	0.02572	29.3	1.72080	1.73430	1.74652	1.76276	1.77592	35 deg 22 min
Barium Flint	1.61700	0.01605	38.5	1.61240	1.62095	1.62845	1.63815	1.64578	38 deg 12 min
Dense Barium Flint	1.70000 1.65700	0.01709 0.01286	41.0 51.2	1.69509 1.65326	1.70421 1.66016	1.71218 1.66612	1.72246 1.67360	1.73054 1.67934	36 deg 21 min 37 deg 7 min

$$\sin \phi_c = n'/n \text{ (see Fig. 5b)} \qquad (11)$$

Where: n = index of refraction of first medium
n′ = index of refraction of second medium

A beam of light passing through a boundary of two media whose indices of refraction differ is reflected back by the interface instead of passing through. This phenomenon is known as Fresnel reflection. In the case where a light ray is incident normally at an air-glass boundary, the amount of reflection is given by:

$$R = \frac{(n - 1)^2}{(n + 1)^2} \qquad (12)$$

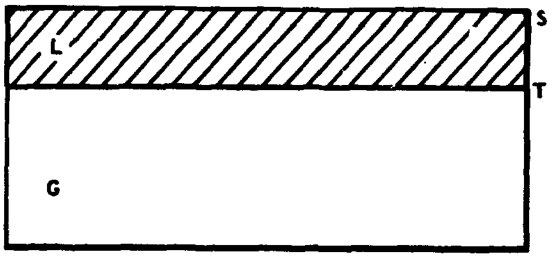


FIG. 7

Where: R = reflectance
n = index of refraction of the glass

Equation 12 refers to intensity, which is the square of the amplitude of the light rays. In a case of a single air-glass boundary, the reflectance R, for glass of index 1.5000, is 0.04. Thus, 4 percent of the incident light is reflected at the surface. There is a loss (generally negligible) as a result of absorption in the glass. In cemented lens or prism assemblies, reflectance loss at the cemented surface is generally minute because of the small index differential.

Low Reflectance Coatings

Consider Fig. 7 which shows a block of glass G coated with a thin layer L of some material which has a lower index than the glass. At surface S a certain amount of light is reflected back toward the source of light; since there exists an index differential, reflection also occurs at the interface of the coating and the glass (surface T). Let us assume that the index of refraction of the coating material L is such that equal amounts of light are reflected at surfaces S and T. As the thickness of this coating is increased, the two reflected components (being wave motions) will be alternately in and out of phase. If we make this thickness such that the two components will be out of phase, they will cancel by destructive interference. The energy cannot be destroyed. It appears, therefore, in the transmitted beam as an increase in transmission. In order to give equal reflectances at both surfaces, it has been observed that the index of the coating must be the geometrical mean of that of the air and glass. It can be seen, therefore, that the index (n_c) of the coating is given by:

$$n_c^2 = n_g n_a \qquad (13)$$

Where: n_g = index of refraction of the coated glass
n_a = index of refraction of air

Taking n_a as unity, we have:

$$n_c^2 = n_g \qquad (14)$$

The critical thickness which will cause destructive interference has been found to be ¼ of the wavelength of light chosen. This means, of course, that some reflection will occur at the contiguous wavelengths. The usual wavelength chosen for correction is 5550 Angstrom Units, which is approximately at the center of the visible spectrum.

Optical elements treated in this manner usually reflect a purplish haze because of the red and blue light reflected at the ends of the spectrum. The process usually used to apply low reflectance coatings to glass is evaporation of magnesium fluoride onto the glass in a vacuum. This material is generally acknowledged to be the best for use on exposed surfaces subject to handling.

Following are four nomograms which will simplify solution of basic equations appearing in this article.

Nomogram I solves Equation 3a:

$$n \sin r = \sin i$$

Nomogram II solves Equation 4:

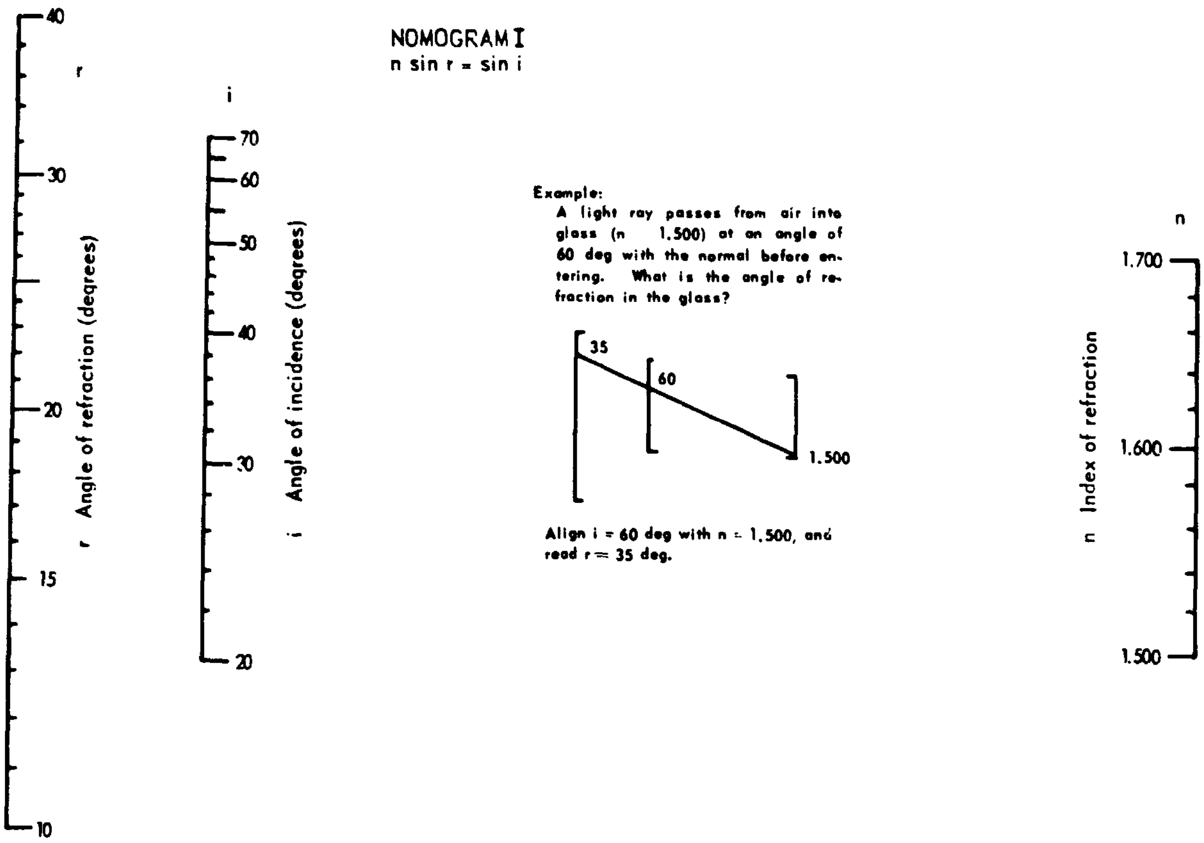
$$n = \frac{\text{real depth}}{\text{apparent depth}}$$

Nomogram III solves Equation 5:

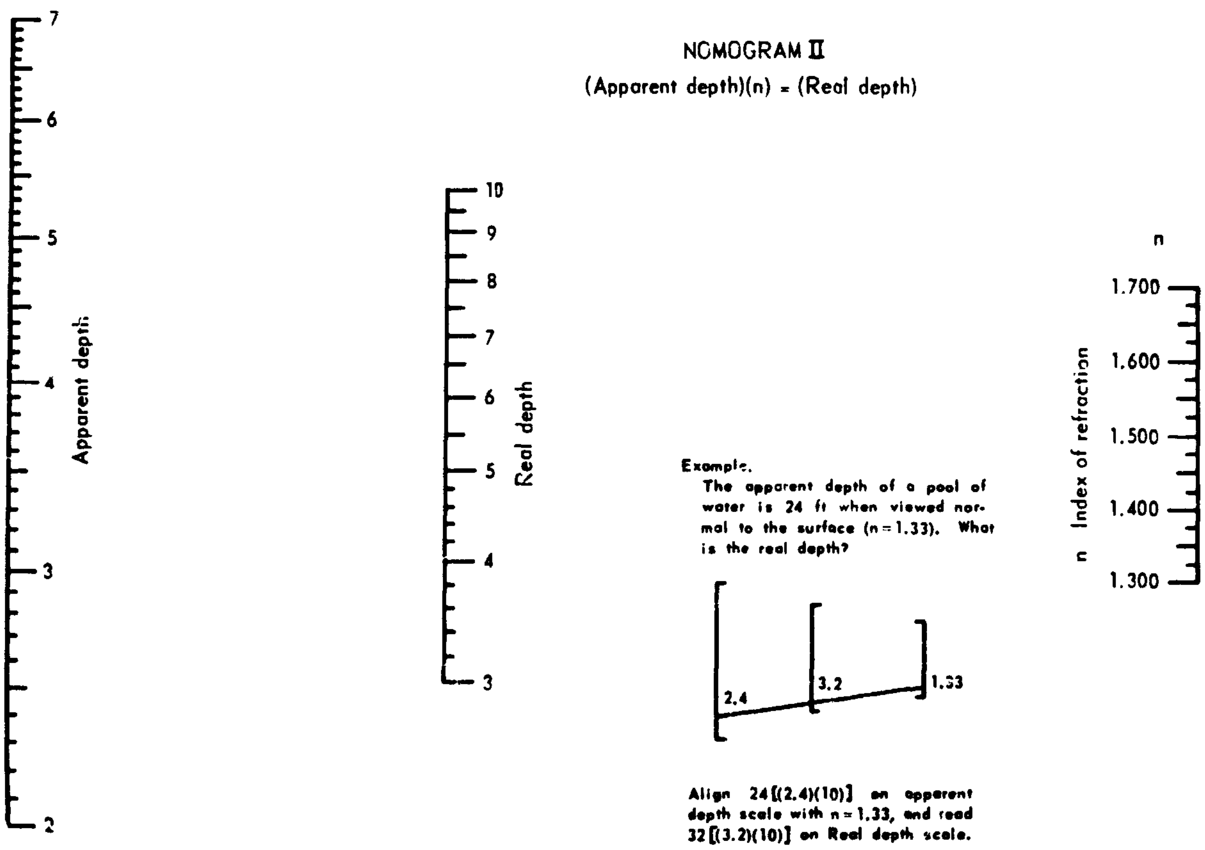
$$n = \frac{\sin \frac{1}{2}(A + D)}{\sin \frac{1}{2} A}$$

Nomogram IV solves Equation 6:

$$D = A(n - 1)$$



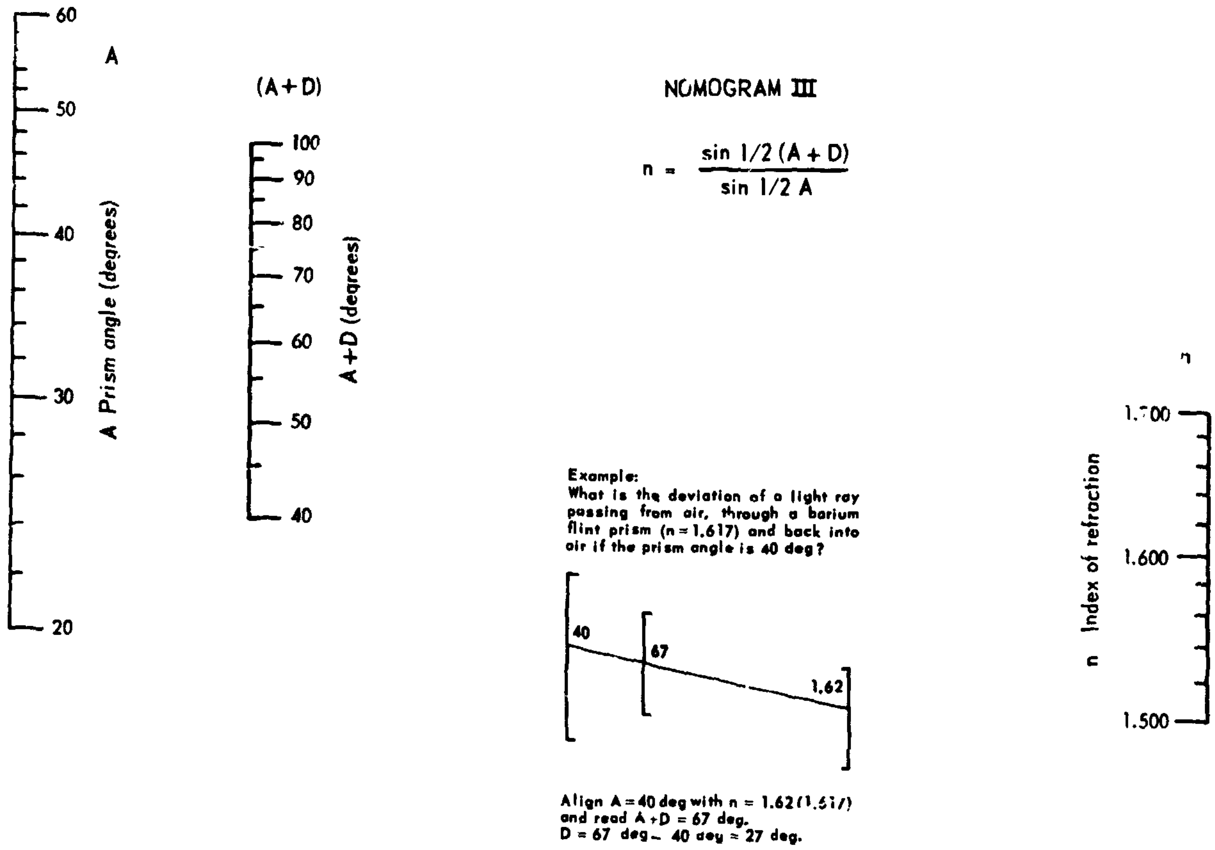
NOMOGRAM I
n sin r = sin i
r Angle of refraction (degrees)
40
30
20
15
10
i Angle of incidence (degrees)
70
60
50
40
30
20
Example:
A light ray passes from air into glass (n 1.500) at an angle of 60 deg with the normal before entering. What is the angle of refraction in the glass?
35
60
1.500
Align i = 60 deg with n = 1.500, and read r = 35 deg.
n Index of refraction
1.700
1.600
1.500



NOMOGRAM II
(Apparent depth)(n) = (Real depth)
Apparent depth
7
6
5
4
3
2
Real depth
10
9
8
7
6
5
4
3
Example.
The apparent depth of a pool of water is 24 ft when viewed normal to the surface (n = 1.33). What is the real depth?
2.4
3.2
1.33
Align 24 [(2.4)(10)] on apparent depth scale with n = 1.33, and read 32 [(3.2)(10)] on Real depth scale.
n Index of refraction
1.700
1.600
1.500
1.400
1.300

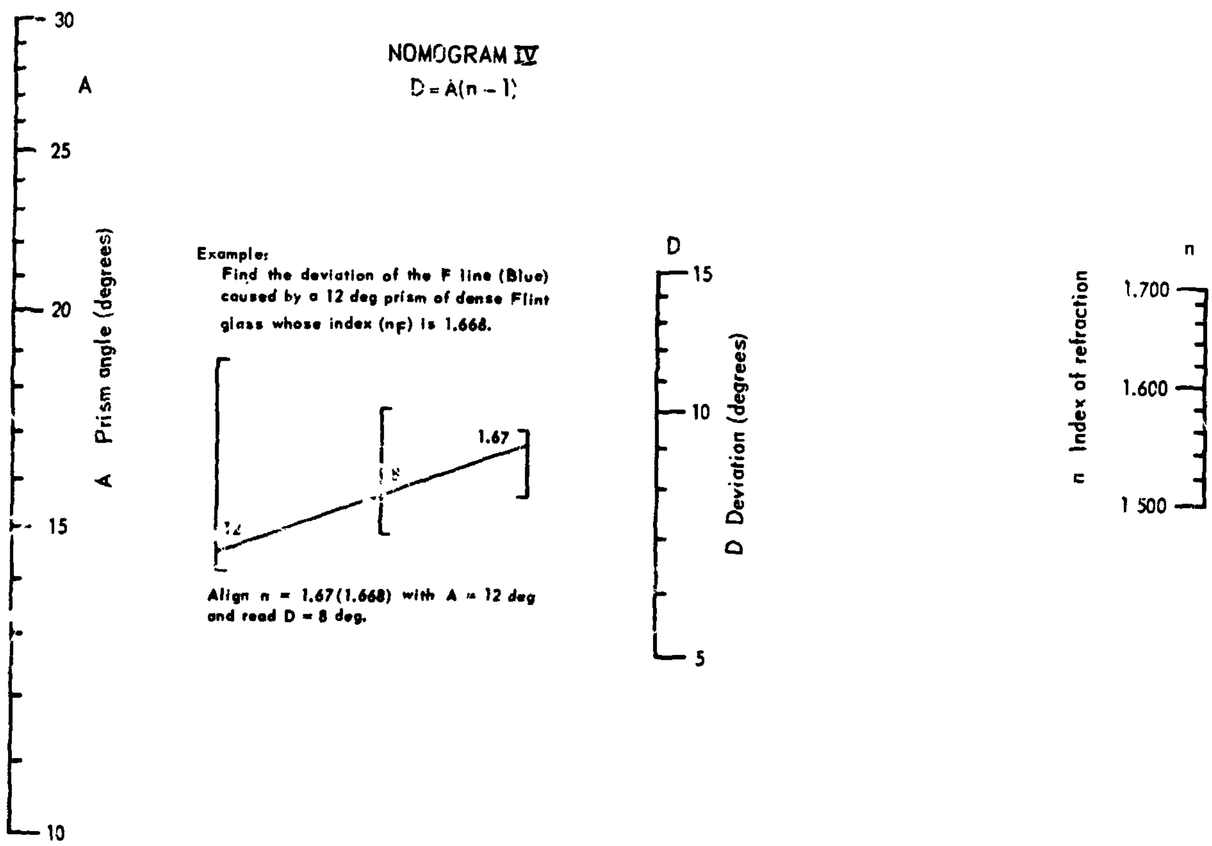
NOMOGRAM III

$$n = \frac{\sin 1/2\,(A + D)}{\sin 1/2\,A}$$



NOMOGRAM IV

$$D = A(n - 1)$$



PERIODIC TABLE OF THE ELEMENTS

KEY TO CHART: Atomic Number → 50; Symbol → Sn; Atomic Weight → 118.69; Oxidation States → +2 +4; Electron Configuration → -18-18-4

1a	2a	3b	4b	5b	6b	7b	8			1b	2b	3a	4a	5a	6a	7a	0	Orbit
1 H +1 -1 1.00797 1																	2 He 0 4.0026 2	K
3 Li +1 6.939 2-1	4 Be +2 9.0122 2-2											5 B +3 10.811 2-3	6 C +2 +4 -4 12.01115 2-4	7 N +1 +2 +3 +4 +5 -1 -2 -3 14.0067 2-5	8 O -2 15.9994 2-6	9 F -1 18.9984 2-7	10 Ne 0 20.183 2-8	K-L
11 Na +1 22.9898 2-8-1	12 Mg +2 24.312 2-8-2	Transition Elements								Transition Elements		13 Al +3 26.9815 2-8-3	14 Si +2 +4 -4 28.086 2-8-4	15 P +3 +5 -3 30.9738 2-8-5	16 S +4 +6 -2 32.064 2-8-6	17 Cl +1 +5 +7 -1 35.453 2-8-7	18 Ar 0 39.948 2-8-8	K-L-M
							Group 8											
19 K +1 39.102 -8-8-1	20 Ca +2 40.08 -8-8-2	21 Sc +3 44.956 -8-9-2	22 Ti +2 +3 +4 47.90 -8-10-2	23 V +2 +3 +4 +5 50.942 -8-11-2	24 Cr +2 +3 +6 51.996 -8-13-1	25 Mn +2 +3 +4 +7 54.9380 -8-13-2	26 Fe +2 +3 55.847 -8-14-2	27 Co +2 +3 58.9332 -8-15-2	28 Ni +2 +3 58.71 -8-16-2	29 Cu +1 +2 63.546 -8-18-1	30 Zn +2 65.37 -8-18-2	31 Ga +3 69.72 -8-18-3	32 Ge +2 +4 72.59 -8-18-4	33 As +3 +5 -3 74.9216 -8-18-5	34 Se +4 +6 -2 78.96 -8-18-6	35 Br +1 +5 -1 79.904 -8-18-7	36 Kr 0 83.80 -8-18-8	L-M-N
37 Rb +1 85.47 -18-8-1	38 Sr +2 87.62 -18-8-2	39 Y +3 88.905 -18-9-2	40 Zr +4 91.22 -18-10-2	41 Nb +3 +5 92.906 -18-12-1	42 Mo +6 95.94 -18-13-1	43 Tc +4 +6 +7 (97) -18-13-2	44 Ru +3 101.07 -18-15-1	45 Rh +3 102.905 -18-16-1	46 Pd +2 +4 106.4 18-18-0	47 Ag +1 107.868 -18-18-1	48 Cd +2 112.40 -18-18-2	49 In +3 114.82 -18-18-3	50 Sn +2 +4 118.69 -18-18-4	51 Sb +3 +5 -3 121.75 -18-18-5	52 Te +4 +6 -2 127.60 -18-18-6	53 I +1 +5 +7 -1 126.9044 -18-18-7	54 Xe 0 131.30 -18-18-8	M-N-O
55 Cs +1 132.905 -18-8-1	56 Ba +2 137.34 -18-8-2	57* La +3 138.91 -18-9-2	72 Hf +4 178.49 -32-10-2	73 Ta +5 180.948 -32-11-2	74 W +6 183.85 -32-12-2	75 Re +4 +6 +7 186.2 -32-13-2	76 Os +3 +4 190.2 -32-14-2	77 Ir +3 +4 192.2 -32-15-2	78 Pt +2 +4 195.09 -32-16-2	79 Au +1 +3 196.967 -32-18-1	80 Hg +1 +2 200.59 -32-18-2	81 Tl +1 +3 204.37 -32-18-3	82 Pb +2 +4 207.19 -32-18-4	83 Bi +3 +5 208.980 -32-18-5	84 Po +2 +4 (209) -32-18-6	85 At (210) -32-18-7	86 Rn 0 (222) -32-18-8	-N-O-P
87 Fr +1 (223) -18-8-1	88 Ra +2 (226) -18-8-2	89** Ac +3 -2																-O-P-Q

*Lanthanides	58 Ce +3 +4 140.12 -20-8-2	59 Pr +3 140.907 -21-8-2	60 Nd +3 144.24 -22-8-2	61 Pm +3 (145) -23-8-2	62 Sm +2 +3 150.35 -24-8-2	63 Eu +2 +3 151.96 -25-8-2	64 Gd +3 157.25 -25-9-2	65 Tb +3 158.924 -27-8-2	66 Dy +3 162.50 -28-8-2	67 Ho +3 164.930 -29-8-2	68 Er +3 167.26 -30-8-2	69 Tm +3 168.934 -31-8-2	70 Yb +2 +3 173.04 -32-8-2	71 Lu +3 174.97 -32-9-2		-N-O-P
**Actinides	90 Th +4 (232) -18-10-2	91 Pa +5 +4 (231) -20-9-2	92 U +3 +4 +5 +6 (238) -21-9-2	93 Np +3 +4 +5 +6 (237) -22-9-2	94 Pu +3 +4 +5 +6 (244) -24-8-2	95 Am +3 +4 +5 +6 (243) -25-8-2	96 Cm +3 (247) -25-9-2	97 Bk +3 +4 (247) -27-8-2	98 Cf +3 (251) -28-8-2	99 Es (254) -29-8-2	100 Fm (257) -30-8-2	101 Md (256) -31-8-2	102 No (254) -32-8-2	103 Lw -32-9-2	104 — -32-10-2	-O-P-Q

Numbers in parentheses are mass numbers of most stable isotope of that element.

International Atomic Weights

Element	Symbol	Atomic number	Atomic weight	Element	Symbol	Atomic number	Atomic weight
Actinium	Ac	89	227	Mercury	Hg	80	200.61
Aluminum	Al	13	26.98	Molybdenum	Mo	42	95.95
Americium	Am	95	[243]†	Neodymium	Nd	60	144.27
Antimony	Sb	51	121.76	Neon	Ne	10	20.183
Argon	Ar	18	39.944	Neptunium	Np	93	[237]
Arsenic	As	33	74.91	Nickel	Ni	28	58.71
Astatine	At	85	[210]	Niobium‡	Nb	41	92.91
Barium	Ba	56	137.36	Nitrogen	N	7	14.008
Berkelium	Bk	97	[249]	Nobelium	No	102	[ ]
Beryllium	Be	4	9.013	Osmium	Os	76	190.2
Bismuth	Bi	83	209.00	Oxygen	O	8	16
Boron	B	5	10.82	Palladium	Pd	46	106.4
Bromine	Br	35	79.916	Phosphorus	P	15	30.975
Cadmium	Cd	48	112.41	Platinum	Pt	78	195.09
Calcium	Ca	20	40.08	Plutonium	Pu	94	[242]
Californium	Cf	98	[249]	Polonium	Po	84	210
Carbon	C	6	12.011	Potassium	K	19	39.100
Cerium	Ce	58	140.13	Praseodymium	Pr	59	140.92
Cesium	Cs	55	132.91	Promethium	Pm	61	[145]
Chlorine	Cl	17	35.457	Protactinium	Pa	91	231
Chromium	Cr	24	52.01	Radium	Ra	88	226.05
Cobalt	Co	27	58.94	Radon	Rn	86	222
Copper	Cu	29	63.54	Rhenium	Re	75	186.22
Curium	Cm	96	[245]	Rhodium	Rh	45	102.91
Dysprosium	Dy	66	162.51	Rubidium	Rb	37	85.48
Einsteinium	Es	99	[ ]	Ruthenium	Ru	44	101.1
Erbium	Er	68	167.27	Samarium	Sm	62	150.35
Europium	Eu	63	152.0	Scandium	Sc	21	44.96
Fermium	Fm	100	[ ]	Selenium	Se	34	78.96
Fluorine	F	9	19.00	Silicon	Si	14	28.09
Francium	Fr	87	[223]	Silver	Ag	47	107.880
Gadolinium	Gd	64	157.26	Sodium	Na	11	22.991
Gallium	Ga	31	69.72	Strontium	Sr	38	87.63
Germanium	Ge	32	72.60	Sulfur	S	16	32.066
Gold	Au	79	197.0	Tantalum	Ta	73	180.95
Hafnium	Hf	72	178.50	Technetium	Tc	43	[99]
Helium	He	2	4.003	Tellurium	Te	52	127.61
Holmium	Ho	67	164.94	Terbium	Tb	65	158.93
Hydrogen	H	1	1.0080	Thallium	Tl	81	204.39
Indium	In	49	114.82	Thorium	Th	90	232.05
Iodine	I	53	126.91	Thulium	Tm	69	168.94
Iridium	Ir	77	192.2	Tin	Sn	50	118.70
Iron	Fe	26	55.85	Titanium	Ti	22	47.90
Krypton	Kr	36	83.80	Tungsten¶	W	74	183.86
Lanthanum	La	57	138.92	Uranium	U	92	238.07
Lead	Pb	82	207.21	Vanadium	V	23	50.95
Lithium	Li	3	6.940	Xenon	Xe	54	131.30
Lutetium	Lu	71	174.99	Ytterbium	Yb	70	173.04
Magnesium	Mg	12	24.32	Yttrium	Y	39	88.92
Manganese	Mn	25	54.94	Zinc	Zn	30	65.38
Mendelevium	Md	101	[256]	Zirconium	Zr	40	91.22

†Brackets denote mass number of isotope of longest known half-life.
‡Formerly known as columbium (symbol, Cb).
¶Also known as wolfram.

ELECTRONIC CONFIGURATION OF THE ELEMENTS

By Laurence S. Foster

References: F. H. Spedding and A. H. Daane, Editors, *The Rare Earths*, John Wiley and Sons, Inc. Publishers, New York, 1961. R. F. Gould, Editor, *Lanthanide–Actinide Chemistry*, Advances in Chemistry Series, No. 71, American Chemical Society, Washington, D.C., 1967: Paper No. 14, Mark Fred, *Electronic Structure of the Actinide Elements*.

Atomic No.	Element	K	L	M	N	O	P	Q
		1	2	3	4	5	6	7
		s	s p	s p d	s p d f	s p d f	s p d f	s p d f
1	H	1						
2	He	2						
3	Li	2	1					
4	Be	2	2					
5	B	2	2 1					
6	C	2	2 2					
7	N	2	2 3					
8	O	2	2 4					
9	F	2	2 5					
10	Ne	2	2 6					
11	Na	2	2 6	1				
12	Mg	2	2 6	2				
13	Al	2	2 6	2 1				
14	Si	2	2 6	2 2				
15	P	2	2 6	2 3				
16	S	2	2 6	2 4				
17	Cl	2	2 6	2 5				
18	Ar	2	2 6	2 6				
19	K	2	2 6	2 6 ..	1			
20	Ca	2	2 6	2 6 ..	2			
21	Sc	2	2 6	2 6 1	2			
22	Ti	2	2 6	2 6 2	2			
23	V	2	2 6	2 6 3	2			
24	Cr	2	2 6	2 6 5*	1			
25	Mn	2	2 6	2 6 5	2			
26	Fe	2	2 6	2 6 6	2			
27	Co	2	2 6	2 6 7	2			
28	Ni	2	2 6	2 6 8	2			
29	Cu	2	2 6	2 6 10*	1			
30	Zn	2	2 6	2 6 10	2			
31	Ga	2	2 6	2 6 10	2 1			
32	Ge	2	2 6	2 6 10	2 2			
33	As	2	2 6	2 6 10	2 3			
34	Se	2	2 6	2 6 10	2 4			
35	Br	2	2 6	2 6 10	2 5			
36	Kr	2	2 6	2 6 10	2 6			
37	Rb	2	2 6	2 6 10	2 6 ..	1		
38	Sr	2	2 6	2 6 10	2 6 ..	2		
39	Y	2	2 6	2 6 10	2 6 1	2		
40	Zr	2	2 6	2 6 10	2 6 2 ..	2		
41	Cb	2	2 6	2 6 10	2 6 4* ..	1		
42	Mo	2	2 6	2 6 10	2 6 5 ..	1		
43	Tc	2	2 6	2 6 10	2 6 6 ..	1		
44	Ru	2	2 6	2 6 10	2 6 7 ..	1		
45	Rh	2	2 6	2 6 10	2 6 8 ..	1		
46	Pd	2	2 6	2 6 10	2 6 10*	0		
47	Ag	2	2 6	2 6 10	2 6 10 ..	1		
48	Cd	2	2 6	2 6 10	2 6 10 ..	2		
49	In	2	2 6	2 6 10	2 6 10 ..	2 1		
50	Sn	2	2 6	2 6 10	2 6 10 ..	2 2		
51	Sb	2	2 6	2 6 10	2 6 10 ..	2 3		
52	Te	2	2 6	2 6 10	2 6 10 ..	2 4		
53	I	2	2 6	2 6 10	2 6 10 ..	2 5		
54	Xe	2	2 6	2 6 10	2 6 10 ..	2 6		
55	Cs	2	2 6	2 6 10	2 6 10 .	2 6	1	
56	Ba	2	2 6	2 6 10	2 6 10 ..	2 6	2	
57	La	2	2 6	2 6 10	2 6 10 ..	2 6 1 ..	2	
58	Ce	2	2 6	2 6 10	2 6 10 2*	2 6	2	
59	Pr	2	2 6	2 6 10	2 6 10 3	2 6	2	
60	Nd	2	2 6	2 6 10	2 6 10 4	2 6	2	
61	Pm	2	2 6	2 6 10	2 6 10 5	2 6	2	
62	Sm	2	2 6	2 6 10	2 6 10 6	2 6	2	
63	Eu	2	2 6	2 6 10	2 6 10 7	2 6	2	
64	Gd	2	2 6	2 6 10	2 6 10 7	2 6 1 ..	2	
65	Tb	2	2 6	2 6 10	2 6 10 9*	2 6	2	
66	Dy	2	2 6	2 6 10	2 6 10 10	2 6	2	
67	Ho	2	2 6	2 6 10	2 6 10 11	2 6	2	
68	Er	2	2 6	2 6 10	2 6 10 12	2 6	2	
69	Tm	2	2 6	2 6 10	2 6 10 13	2 6 ..	2	
70	Yb	2	2 6	2 6 10	2 6 10 14	2 6	2	
71	Lu	2	2 6	2 6 10	2 6 10 14	2 6 1 ..	2	
72	Hf	2	2 6	2 6 10	2 6 10 14	2 6 2 ..	2	
73	Ta	2	2 6	2 6 10	2 6 10 14	2 6 3 .	2	
74	W	2	2 6	2 6 10	2 6 10 14	2 6 4 ..	2	
75	Re	2	2 6	2 6 10	2 6 10 14	2 6 5 ..	2	
76	Os	2	2 6	2 6 10	2 6 10 14	2 6 6 ..	2	
77	Ir	2	2 6	2 6 10	2 6 10 14	2 6 9* ..	0	
78	Pt	2	2 6	2 6 10	2 6 10 14	2 6 9 ..	1	
79	Au	2	2 6	2 6 10	2 6 10 14	2 6 10 ..	1	
80	Hg	2	2 6	2 6 10	2 6 10 14	2 6 10 ..	2	
81	Tl	2	2 6	2 6 10	2 6 10 14	2 6 10 ..	2 1	
82	Pb	2	2 6	2 6 10	2 6 10 14	2 6 10 ..	2 2	
83	Bi	2	2 6	2 6 10	2 6 10 14	2 6 10 ..	2 3	
84	Po	2	2 6	2 6 10	2 6 10 14	2 6 10 ..	2 4	
85	At	2	2 6	2 6 10	2 6 10 14	2 6 10 ..	2 5	
86	Rn	2	2 6	2 6 10	2 6 10 14	2 6 10 ..	2 6	
87	Fr	2	2 6	2 6 10	2 6 10 14	2 6 10 .	2 6	1
88	Ra	2	2 6	2 6 10	2 6 10 14	2 6 10 ..	2 6	2
89	Ac	2	2 6	2 6 10	2 6 10 14	2 6 10 ..	2 6 1 ..	2
90	Th	2	2 6	2 6 10	2 6 10 14	2 6 10 ..	2 6 2 ..	2
91	Pa	2	2 6	2 6 10	2 6 10 14	2 6 10 2*	2 6 1 ..	2
92	U	2	2 6	2 6 10	2 6 10 14	2 6 10 3	2 6 1 ..	2
93	Np	2	2 6	2 6 10	2 6 10 14	2 6 10 4	2 6 1 ..	2
94	Pu		2 6	2 6 10	2 6 10 14	2 6 10 6	2 6 ..	2
95	Am	2	2 6	2 6 10	2 6 10 14	2 6 10 7	2 6	2
96	Cm	2	2 6	2 6 10	2 6 10 14	2 6 10 7	2 6 1 .	2
97	Bk	2	2 6	2 6 10	2 6 10 14	2 6 10 9*	2 6 .. .	2
98	Cf	2	2 6	2 6 10	2 6 10 14	2 6 10 10	2 6 .. .	2
99	Es	2	2 6	2 6 10	2 6 10 14	2 6 10 11	2 6	2
100	Fm	2	2 6	2 6 10	2 6 10 14	2 6 10 12	2 6	2
101	Md	2	2 6	2 6 10	2 6 10 14	2 6 10 13	2 6	
102	No	2	2 6	2 6 10	2 6 10 14	2 6 10 14	2 6	2
103	Lw	2	2 6	2 6 10	2 6 10 14	2 6 10 14	2 6 1 ..	2
104	—	2	2 6	2 6 10	2 6 10 14	2 6 10 14	2 6 2 ..	2

* Note irregularity.

Common Acids

HCl – Hydrochloric acid
H_2S – Hydrosulphonic acid (gas: hydrogen sulfide)
H_2SO_4 – Sulphuric acid
H_2SO_3 – Sulphurous acid
HNO_3 – Nitric acid
H_3PO_4 – Phosphoric acid
H_3PO_3 – Phosphorous acid
H_2CO_3 – Carbonic acid

Common Bases

NaOH – Sodium hydroxide
$Ca(OH)_2$ – Calcium hydroxide
NH_4OH – Ammonium hydroxide
Mg(OH)2– Magnesium hydroxide

Simple Hydrocarbons

Methane – CH_4

```
  H
  |
H-C-H
  |
  H
```

Ethane – C_2H_6

```
  H H
  | |
H-C-C-H
  | |
  H H
```

Alcohols

Methyl alcohol – CH_3 OH

```
  H
  |
H-C-OH
  |
  H
```

Ethyl alcohol – C_2H_5OH

```
  H H
  | |
H-C-C-OH
  | |
  H H
```

Common Compounds and Allotropes

Gases:	CO	–	Carbon monoxide
	CO_2	–	Carbon dioxide
	O_2	–	Oxygen (normal state)
	O_3	–	Ozone
	SO_2	–	Sulphur dioxide
	H_2S	–	Hydrogen sulfide
Compounds:	$NaCl$	–	Sodium chloride (table salt)
	Na_2O	–	Sodium oxide
	CaO	–	Calcium oxide (quicklime)

Statistical Definitions

Population	-	any finite or infinite collection of elements, that is, individuals, items, observations, etc., under consideration in a given problem.
Sample	-	part, or a subset, of a population.
Parameter	-	a constant describing a population (designated by Greek letters such as μ and σ).
Statistic	-	a quantity describing a sample, namely, a function of the observations (designated by Latin letters such as $\bar{X}$ and S).
Randomization		The process of arranging experimental conditions so that every possible order has a known probability of occurrence. Randomization is essential to the validity of most statistical analysis.
Model	-	a statement, usually in the form of a mathematical equation, of the assumptions made about individual observations.
Estimator	-	a rule, a method, or a formula for making a "best guess" about the value of a parameter. Thus, a sample mean $\bar{X}$ is frequently used as an estimator, or estimate, of a population mean.

Probability and Statistics

Operations

Σ : The sum of

$\Sigma X = X_1 + X_2 + \ldots + X_N$

$\Sigma X_1^2 = X_1^2 + X_2^2 + \ldots + X_N^2$

$(\Sigma X)^2 = (X_1 + X_2 + \ldots X_N)^2$

Π : The product of

$\Pi x = X_1 \cdot X_2 \ldots X_N$

Descriptive Statistics - Measures of central tendency (location, magnitide): average.

Sumbol:

Mo - Mode: most frequently occurring value(s).

Med - Median: 50^{th} percentile; point below which 50 percent of observations lie.

$\bar{X}$ - Mean (arithematic): $\frac{1}{N} \Sigma X$

Harmonic Mean: $\dfrac{N}{\Sigma \frac{1}{X}}$

Geometric Mean: $\sqrt[N]{\Pi X}$ (N^{th} root of the product of observed values).

Measures of Variability (spread, dispersion).

R - Range: [illegible] observed value minus smallest observed value.

Inter[illegible]es: Range for symmetric percentiles. [illegible] 97^{th} percentile minus 3rd percentile, [illegible]s 5^{th} percentile and 75^{th} percentile [illegible]e (interquartile range).

Q - Semi[illegible]ge: $\frac{1}{2}(Q_3 - Q_1)$; half the inter[illegible]nge.

AD - Average Deviation: $\frac{1}{N}\sum\left|X-\bar{X}\right|$; average of absolute value of deviation of observed values from their mean.

S^2 - Variance: $\frac{1}{N}\sum(X-\bar{X})^2$; average squared deviation of observed values from their mean.

MS - Mean Square: same as Variance.

S(SD) - Standard Deviation: Square root of variance.

RMS - Root Mean Square: Same as standard deviation.

PE - Probable Error: .67455

$S_{\bar{X}}$ - Standard Error of the Mean: $\frac{S}{\sqrt{N}}$

When used in inference (estimation, hypothesis testing) N-1 should be used in place of N in the formula for S^2

S^2 - Estimate of population variance: $\frac{1}{N-1}\sum(X-\bar{X})^2$

S - $\sqrt{S^2}$

$S_{\bar{X}}$ - $\frac{S}{\sqrt{N}}$

<u>Measures of relationship</u> between paired observations S + Y

S_{XY} - Covariance: $\frac{1}{N}\quad(X-\bar{X})\quad(Y-\bar{Y})$; average cross product of deviations of observed values from their respe ive means.

r - Product-Moment Correlation: $\frac{\sum(X-X)\quad(Y-Y)}{\sqrt{\sum(X-\bar{X})^2\sum(Y-\bar{Y})^2}}=\frac{S_{xy}}{S_xS_y}$

r_{bis} - Biserial Correlation

r_{Pb} - Point biserial

r_t - Tetrachoric

C - Contingency coefficient

y = a + bx - linear regression equation for predicting Y from X.

b - Slope constant: $\frac{S_{xy}}{S^2_{xy}} = r\frac{S_y}{S_x}$ (rate of change)

a - Intercept Constant: $\bar{Y} - b\bar{X}$; height of regression line at X = 0

Computational Formulas

SS - Sum of Squared Deviations (Sum of Squares):

$$\sum (X-\bar{X})^2 = \sum X^2 - \frac{(\sum X)^2}{N} = \frac{N \sum X^2 - (\sum X)^2}{N}$$

SP - Sum of Products: $\sum (X-\bar{X})(Y-\bar{Y}) = \sum XY - \frac{(\sum X)(\sum y)}{N} = \frac{N \sum XY - (\sum X)(\sum Y)}{N}$

S^2 - $\frac{1}{N}$ SS

s^2 - $\frac{1}{N-1}$ SS

r - $\frac{SP}{\sqrt{SS_X SS_Y}}$

b - $\frac{SP}{SS_X}$

Others

p - prop.

z - $\frac{X - \mu}{\sigma}$

t - $\frac{x - \mu}{s}$

F - $\frac{s_1^2}{s_2^2}$

$$\chi^2 - \frac{NS^2}{\sigma^2} = \sum \frac{(O-E)^2}{E}$$

Statistical Inference

π - Parameter: probability of occurrence of the event of interest ("success").

p - Estimator: proportion of "successes" in sample = $\frac{Y}{N}$

- One Sample Hypothesis (Null): is equal to some specific value ($\pi = \pi_o$)

- Exact Test: Compute $\sum \binom{N}{X} \pi_o^X (1 - \pi_o)^{N-X}$ for $0 \leq X \leq Y$ and $N - Y \leq X \leq N$ if $Y < \frac{N}{2}$ or $0 \leq X \leq N-Y$ and $Y \leq X \leq N$ if $Y > \frac{N}{2}$. If this sum is less than α, reject the hypothesis in favor of the alternative $\pi \neq \pi_o$

- Normal approximation Test: may be used if N 30 and $N(1 - \pi_o)$ and $N\pi_o$ both ≥ 5.

- Test Statistic: $Z = \frac{p - \pi_o}{\pi_o(1-\pi_o)} = \frac{Y - N\pi_o}{N\pi_o(1-\pi_o)}$

- Two Samples (both large, N_1 and $N_2 > 30$)

  parameters: π_1, π_2

  estimators: p_1, p_2 from statistics $Y_1 + Y_2$

  hypothesis: $\pi_1 = \pi_2$ $(\pi_1 - \pi_2 = 0)$

  test statistic: $Z = \frac{p_1 - p_2}{\hat{\pi}(1-\hat{\pi})}$ where $\hat{\pi} = \frac{Y_1 + Y_2}{N_1 + N_2}$

Normal Distribution

One Sample

μ - parameter: population mean

$\bar{X}$ - estimator

- hypothesis: equal to some specific value ($\mu = \mu_o$)
- test statistic: $t = \dfrac{\bar{X} - \mu_o}{S_{\bar{X}}}$ df = N-1

σ^2 - parameter: population variance

S^2 - estimator

- hypothesis: σ^2 equal to some specific value. ($\sigma^2 = \sigma_o^2$)
- test statistic: $\chi^2 = \dfrac{(N-1)S^2}{\sigma^2}$ df = N-1

Two Samples, independent

$\mu_1, \mu_2; \sigma_1^2, \sigma_2^2$ (assumed equal) - parameters
(note: refer to advanced test for techniques when this assumption questionable)

$\bar{X}_1, \bar{X}_2; S_1^2, S_2^2$ - estimators

- hypothesis: $\mu_1 = \mu_2$; ($\mu_1 - \mu_2 = 0$)
- test statistic: $t = \dfrac{\bar{X}_1 - \bar{X}_2}{S_{\bar{X}_1 - \bar{X}_2}}$ df = $N_1 + N_2 - 2$

where $(S_{\bar{X}_1 - \bar{X}_2})^2 = \dfrac{(N_1 - 1)S_1^2 + (N_2 - 1)S_2^2}{N_1 + N_2 - 2}\left(\dfrac{1}{N_1} + \dfrac{1}{N_2}\right) =$

$$\frac{SS_1 + SS_2}{N_1 + N_2 - 2}\left(\frac{1}{N_1} + \frac{1}{N_2}\right) = \frac{(N_1 + N_2)(SS_1 + SS_2)}{N_1 N_2 (N_1 + N_2 - 2)}$$

- hypothesis: $\sigma_1^2 = \sigma_2^2$
- test statistic: $F = \frac{S_1^2}{S_2^2}$ $df = N_1 - 1,\ N_2 - 1$

* two samples, correlated (match, paired observations; $N_1 = N_2 = N$)

μ_d - parameter(s): $\mu_d = \mu_1 - \mu_2$

$\bar{X}_d$ - estimator: mean of differences between matched observations

- hypothesis: $\mu_d = 0$
- test statistic: find N differences and treat as one sample with $\mu_o = 0$.

SOME METHODS OF PSYCHOPHYSICS

Method	Brief Characterization	Usual Statistical Index	Problems to which Most Applicable
1. Adjustment (average error)	Observer adjusts stimulus until it is subjectively equal to or in some desired relation to a criterion.	Average of settings (average error of settings measures precision).	Absolute threshold Equality Equal intervals Equal ratios
2. Minimal change (limits)	Experimenter varies stimulus upward and/or downward. Observer signals its apparent relation to a criterion.	Average value of stimulus at transition point of observer's judgment.	All thresholds Equality
3. Paired comparison	Stimuli are presented in pairs. Each stimulus is paired with each other stimulas. The observer indicates which of each pair is greater in respect of a given attribute.	Proportion of judgments calling one stimulus greater than another. (These proportions are sometimes translated into scale values via the assumption of a normal distribution of judgments.)	Order Equal intervals (under distribution assumption)
4. Constant stimuli	Several comparison stimuli are paired at random with a fixed standard. Observer says whether each comparison is greater or less than the standard. (A special case of paired comparisons.)	Size of difference limen equals stimulus distance between 50- and 75- percent points on psychometric function.	All thresholds Equality Equal intervals Equal ratios
5. Quantal	Various fixed increments are added to a standard, with no time interval between. Each increment is added several times in succession. Observer indicates apparent presence or absence of the increment.	Size of sensory quantum equals distance between intercepts of rectilinear psychometric function.	Differential thresholds
6. Order of merit	Group of stimuli, presented simultaneously, are set in apparent rank order by the observer.	Average or median rank assigned by observers.	Order
7. Rating scale	Each of a set of stimuli is given an "absolute" rating in terms of some attribute. Rating may be numerical or descriptive.	Average or median rating assigned by observers.	Order Equal intervals Stimulus rating

Section 2

METRICS AND CONVERSION DATA

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Section 2

METRICS AND CONVERSION DATA

The tables and nomograms included in this section contain what the authors consider a handy and frequently used collection of conversion factors relating to distances, weights, volumes, power, pressure, temperature, etc.

Although there are many formats in which such data may be presented, it is hoped that those selected will prove useful and convenient to the majority of users of this pocket databook.

It is difficult to refer the reader to other sources of conversion data since this kind of information usually is intermixed with other kinds of data. Manufacturers of technical and scientific products often prepare and distribute conversion tables of various kinds; textbooks of physics and chemistry invariably contain a great deal of conversion data; and the HANDBOOK OF CHEMISTRY AND PHYSICS is, of course, a prolific source of such information.

Our thanks, once again, to the Cahners Publishing Company for permission to reprint several nomograms which originally appeared in DESIGN NEWS.

acre	= 43,560 square feet = 4,840 square yards = 4,047 square meters = 1.562×10^{-3} square miles
ampere-hour	= 3.600×10^{3} coulombs = 3.731×10^{-2} faradays
Angstrom unit (A)	= 3.937×10^{-9} = 1×10^{-4} microns (mu) = 1×10^{-8} centimeters
astronomical unit (AU)	= 1.495×10^{8} kilometers
atmosphere	= 14.7 pounds/square inch = 76.0 cms of mercury = 29.92 inches of mercury = 3.39×10^{1} feet of water = 1.033 kilograms/square cm = 1.033×10^{4} kilograms/square meter = 1.058 tons/square foot
bar	= 9.869×10^{-1} atmospheres = 1×10^{6} dynes/square cm = 1.020×10^{4} kilograms/square meter = 2.089×10^{3} pounds/square foot = 1.45×10^{1} pounds/square inch
Btu	= 1.0409×10^{1} liter-atmosphere = 1.055×10^{10} ergs = 7.781×10^{2} foot-pounds = 2.520×10^{2} gram-calories = 3.927×10^{-4} horsepower-hours = 1.055×10^{3} joules = 1.0758×10^{2} kilogram-meters = 2.928×10^{-4} kilowatt-hours

Btu/hour	= 2.162×10^{-1} foot-pounds/second = 7.0×10^{-2} gram-calories/second = 3.929×10^{-4} horsepower = 2.931×10^{-1} watts
Btu/minute	= 1.296×10^{1} foot-pounds/second = 2.356×10^{-2} horsepower = 1.757×10^{1} watts
Btu/square foot/minute	= 1.22×10^{-1} watts/square inch
Candle/square cm	= 3.146 lamberts
Candle/square inch	= 4.870×10^{-1} lamberts
Centigrade (degrees)	= $(^{o}C \times \frac{9}{5}$ + 32 Fahrenheit (degrees) = ^{o}C + 273.18 Kelvin (degrees)
centimeter	= 3.281×10^{-2} feet = 3.937×10^{-1} inches = 1×10^{-5} kilometers = 6.214×10^{-6} miles = 3.937×10^{2} mils = 1.094×10^{-2} yards = 1×10^{4} microns = 1×10^{8} Angstrom units
centimeter-dyne	= 1.020×10^{-3} cm-grams = 1.020×10^{-8} meter-kgs = 7.375×10^{-8} pound-feet
centimeter-gram	= 9.807×10^{2} cm-dynes = 1×10^{-5} meter-kgs = 7.233×10^{-5} pound-feet
cm of mercury	= 4.461×10^{-1} feet of water = 2.785×10^{1} pounds/square foot = 1.934×10^{-1} pounds/square inch

centimeter/second	= 1.969 feet/minute = 3.281×10^{-2} feet/second = 3.6×10^{-2} kilometers/hour = 1.943×10^{-2} knots = 6.0×10^{-1} meters/minute = 2.237×10^{-2} miles/hour = 3.728×10^{-4} miles/minute
centimeter/sec/sec	= 3.281×10^{-2} feet/sec/sec = 3.6×10^{-2} kms/hour/sec = 2.237×10^{-2} miles/hour/sec
circumference	= 6.283 radians
coulomb	= 1.036×10^{-5} faradays
cubic centimeter	= 3.531×10^{-5} cubic feet = 6.102×10^{-2} cubic inches = 1.308×10^{-6} cubic yards = 2.642×10^{-4} gallons (U.S. liquid) = 1.057×10^{-3} quarts (U.S. liquid) = 2.113×10^{-3} pints (U.S. liquid) = 1×10^{-6} cubic meters = 1×10^{-3} liters
cubic foot	= 2.832×10^{4} cubic cms = 1.728×10^{3} cubic inches = 2.832×10^{-2} cubic meters = 3.704×10^{-2} cubic yards = 7.48052 gallons (U.S. liquid) = 2.832×10^{1} liters = 5.984×10^{1} pints (U.S. liquid) = 2.992×10^{1} quarts (U.S. liquid)
cubic foot/minute	= 4.72×10^{2} cubic cms/second = 1.247×10^{1} gallons/second = 4.720×10^{-1} liters/second = 6.243×10^{1} pounds water/minute = 6.46317×10^{-1} million gals/day = 4.48831×10^{2} gallons/minute

cubic inches	= 1.639×10^{1} cubic cms = 5.787×10^{-4} cubic feet = 1.639×10^{-5} cubic meters = 2.143×10^{-5} cubic yards = 4.329×10^{-3} gallons (U.S. liquid) = 1.639×10^{-2} liters = 3.463×10^{-2} pints (U.S. liquid) = 1.732×10^{-2} quarts (U.S. liquid)
cubic meter	= 1×10^{6} cubic cms = 3.531×10^{1} cubic feet = 6.1023×10^{4} cubic inches = 1.308 cubic yards = 2.642×10^{2} gallons (U.S. liquid) = 1×10^{3} liters = 2.113×10^{3} pints (U.S. liquid) = 1.057×10^{3} quarts (U.S. liquid)
cubic yard	= 7.646×10^{5} cubic cms = 2.7×10^{1} cubic feet = 4.6656×10^{4} cubic inches = 7.646×10^{-1} cubic meters = 2.02×10^{2} gallons (U.S. liquid) = 7.646×10^{2} liters = 1.6159×10^{3} pints (U.S. liquid) = 8.079×10^{2} quarts (U.S. liquid)
cubic yards/minute	= 4.5×10^{-1} cubic feet/second = 3.367 gallons/second = 1.274×10^{1} liters/second
day	= 8.64×10^{4} seconds = 1.44×10^{3} minutes
degrees (angle)	= 1.745×10^{-2} radians = 3.6×10^{3} seconds (angle)

degree/second	= 1.745×10^{-2} radians/second = 1.667×10^{-1} revolutions/minute = 2.778×10^{-3} revolutions/second
dram (apoth. or troy)	= 1.3714×10^{-1} ounces (avdp) = 1.25×10^{-1} ounces (troy)
dram (U.S. fluid or apoth)	= 3.6967 cubic cms
dram	= 1.7718 grams = 2.7344×10^{1} grains = 6.25×10^{-2} ounces
dynes/square cm	= 1×10^{-2} ergs/square mm = 9.869×10^{-7} atmospheres = 2.953 inches of mercury (at 0°C.) = 4.015×10^{-4} inches of water (at 4°C.)
dyne	= 1.020×10^{-3} grams = 1×10^{-7} joules/cm = 1×10^{-5} joules/meter (newtons) = 1.020×10^{-6} kilograms = 7.233×10^{-5} poundals = 2.248×10^{-6} pounds
dynes/square cm	= 1×10^{-6} bars
ell	= 1.143×10^{2} cms = 4.5×10^{1} inches
em, pica	= 1.67×10^{-1} inches = 4.233×10^{-1} cms
erg/second	= 1.0 dyne-cm/sec
erg	= 9.486×10^{-11} Btu = 1.0 dyne-centimeter = 7.376×10^{-8} foot-pounds = 2.389×10^{-8} gram-calories = 1.020×10^{-3} grams-cms = 3.725×10^{-14} horsepower-hours

erg	= 1.0×10^{-7} joules = 2.389×10^{-11} kilogram-calories = 1.020×10^{-8} kilogram-meters = 2.773×10^{-14} kilowatt-hours = 2.773×10^{-11} watt-hours
ergs/sec	= 5.668×10^{-9} Btu/minute = 4.426×10^{-6} ft-lbs/minute = 7.3756×10^{-8} ft-lbs/second = 1.341×10^{-10} horsepower = 1.433×10^{-9} kg-calories/minute = 1.0×10^{-10} kilowatts
faraday/second	= 9.65×10^{4} amperes(absolute)
faraday	= 2.68×10^{1} ampere-hours = 9.649×10^{4} coulombs
fathom	= 6.0 feet = 1.8288 meters
foot	= 3.048×10^{1} centimeters = 3.948×10^{-4} kilometers = 3.048×10^{-1} meters = 1.645×10^{-4} nautical miles = 1.894×10^{-4} statute miles = 1.2×10^{4} mils
foot of water	= 2.95×10^{-2} atmospheres = 8.826×10^{-1} inches of mercury = 3.048×10^{-2} kgs/square cm = 3.048×10^{2} kgs/square meter = 6.243×10^{1} pounds/square foot = 4.335×10^{-1} pounds/square inch
feet/minute	= 5.080×10^{-1} cms/second = 1.667×10^{-2} feet/second = 1.829×10^{-2} kms/hour = 3.048×10^{-1} meters/minute = 1.136×10^{-2} miles per hour

feet/second	= 3.048×10^{1} cms/second = 1.097 dms/hour = 5.921×10^{-1} knots = 1.829×10^{1} meters/minute = 6.818×10^{-1} miles/hour = 1.136×10^{-2} miles/minute
feet/sec/sec	= 3.048×10^{1} cms/sec/sec = 1.097 kms/hour/sec = 3.048×10^{-1} meters/sec/sec = 6.818×10^{-1} miles/hour/sec
feet/100 feet	= 1.0 per cent grade
foot-candle	= 1.0764×10^{1} lumen/square meter (lux)
foot-pound	= 1.286×10^{-3} Btu = 1.356×10^{7} ergs = 3.241×10^{-1} gram-calories = 5.050×10^{-7} horsepower-hours = 1.356 joules = 3.241×10^{-4} kg-calories = 1.383×10^{-1} kg-meters = 3.766×10^{-7} kilowatt-hours
foot-pounds/minute	= 1.286×10^{-3} Btu-minute = 1.667×10^{-2} foot-pounds/sec = 3.030×10^{-5} horsepower = 3.241×10^{-4} kg-calories/minute = 2.260×10^{-5} kilowatts
foot-pounds/second	= 4.6263 Btu-hour = 7.717×10^{-2} Btu-minute = 1.818×10^{-3} horsepower = 1.945×10^{-2} kg-calories/minute = 1.356×10^{-3} kilowatts

gallons	= 3.785×10^{3} cubic cms = 1.337×10^{-1} cubic feet = 2.31×10^{2} cubic inches = 3.785×10^{-3} cubic meters = 4.951×10^{-3} cubic yards = 3.785 liters
gallon (liquid, imperial)	= 1.20095 gallons (U.S. liquid)
gallon (U.S.)	= 8.3267×10^{-1} gallons (imperial)
gallon of water	= 8.337 pounds of water
gallon/minute	= 2.228×10^{-3} cubic feet/second = 6.308×10^{-2} liters/second = 8.0208 cubic feet/hour
grain	= 3.657×10^{-2} drams (avdp)
grains/U.S. gallon	= 1.7118×10^{1} parts/million = 1.4286×10^{2} pounds/million
grains/imperial gallon	= 1.4286×10^{1} parts/million
gram	= 9.807×10^{2} dynes = 3.527×10^{-2} ounces (avdp) = 3.215×10^{-2} ounces (troy) = 7.093×10^{-2} poundals = 2.205×10^{-3} pounds
grams/cm	= 5.6×10^{-3} pounds/inch
grams/cubic cm	= 6.243×10^{1} pounds/cubic feet = 3.613×10^{-2} pounds/cubic inch
gram-calories	= 3.9683×10^{-3} Btu = 4.184×10^{7} ergs = 3.086 foot-pounds = 1.5596×10^{-6} horsepower-hours = 1.162×10^{-6} kilowatt-hours = 1.162×10^{-3} watt-hours
gram-calories/second	= 1.4286×10^{1} Btu/hour

gram-centimeter	= 2.343×10^{-8} kg-calories
horsepower	= 4.244×10^{1} Btu/minute = 3.3×10^{4} foot-pounds/minute = 5.50×10^{2} foot-pounds/second = 1.068×10^{1} kg-calories/minute = 7.457×10^{-1} kilowatts = 7.457×10^{2} watts
horsepower (metric)	= 9.863×10^{-1} horsepower
horsepower	= 1.014 horsepower (metric)
horsepower-hours	= 2.547×10^{3} Btu = 2.6845×10^{13} ergs = 1.98×10^{6} foot-pounds = 6.4119×10^{5} gram-calories = 2.684×10^{6} joules = 6.417×10^{2} kg-calories = 2.737×10^{5} kg-meters
inch	= 2.540 centimeters = 1.578×10^{-5} miles = 2.54×10^{1} millimeters = 1×10^{3} mils = 2.778×10^{-2} yards = 2.54×10^{8} Angstrom units
inch of mercury	= 3.342×10^{-2} atmospheres = 1.133 feet of water = 3.453×10^{-2} kgs/square cm = 3.453×10^{2} kgs/square meter = 7.073×10^{1} pounds/square foot = 4.912×10^{-1} pounds/square inch
inch of water (at 4°C.)	= 2.458×10^{-3} atmospheres = 7.355×10^{-2} inches of mercury = 2.54×10^{-3} kgs/square cm = 5.781×10^{-1} ounces/square inch = 5.204 pounds/square foot = 3.613×10^{-2} pounds/square inch

joule	= 9.486×10^{-4} Btu = 1×10^{7} ergs = 7.736×10^{-1} foot-pounds = 2.389×10^{-4} kg-calories = 1.020×10^{-1} kg-meters = 2.778×10^{-4} watt-hours
joules/cm	= 1.020×10^{4} grams = 1×10^{7} dynes = 1.10^{2} joules/meter = 7.233×10^{2} poundals = 2.248×10^{1} pounds
kilogram	= 9.80665×10^{5} dynes = 7.093×10^{1} poundals = 2.2046 pounds = 3.5274×10^{1} ounces (avdp) = 9.842×10^{-4} tons (long = 1.102×10^{-3} tons (short)
kilogram/cubic meter	= 6.243×10^{-2} pounds/cubic foot = 3.613×10^{-5} pounds/cubic inch
kilogram/meter	= 6.72×10^{-1} pounds/foot
kilogram/square cm	= 9.80665×10^{5} dynes/square cm = 9.678×10^{-1} atmospheres = 3.281×10^{1} feet of water = 2.896×10^{1} inches of mercury = 2.048×10^{3} pounds/square foot = 1.422×10^{1} pounds/square inch
kilogram/square meter	= 9.679×10^{-5} atmospheres = 9.807×10^{-5} bars = 3.281×10^{-3} [illegible] water = 2.896 [illegible] of mercury = $2.048 \times 10^{[illegible]}$ pounds/square foot = 1.422×10^{-3} pounds/square inch

kilogram-calorie	= 3.968 Btu = 3.086×10^{3} foot-pounds = 1.558×10^{-3} horsepower-hours = 4.183×10^{3} joules = 1.163×10^{-3} kilowatt-hours
kilogram/calorie/minute	= 5.143×10^{1} foot-pounds/second = 9.351×10^{-2} horsepower = 6.972×10^{-2} kilowatts
kilogram-meter	= 9.296×10^{-3} Btu = 9.807×10^{7} ergs = 7.233 foot-pounds = 9.807 joules = 2.723×10^{-6} kilowatt-hours
kilometer	= 3.281×10^{3} feet = 3.937×10^{4} inches = 6.214×10^{-1} statute miles = 5.396×10^{-1} nautical miles = 1.0936×10^{3} yards
kilometer/hour	= 2.778×10^{1} cms/second = 5.468×10^{1} feet/minute = 9.113×10^{-1} feet/second = 5.396×10^{-1} knots = 1.667×10^{1} meters/minute = 6.214×10^{-1} miles/hour
kilometer/hour/second	= 2.778×10^{1} cms/sec/sec = 9.113×10^{-1} feet/sec/sec = 6.214×10^{-1} miles/hour/sec
kilowatt	= 5.692×10^{1} Btu/minute = 4.426×10^{4} foot-pounds/minute = 7.376×10^{2} foot-pounds/second = 1.341 horsepower = 1.434×10^{1} kg-calories/minute

kilowatt-hour	= 3.413×10^3 Btu = 3.6×10^{13} ergs = 2.655×10^6 foot-pounds = 8.5985×10^5 gram-calories = 1.341 horsepower-hours = 8.605×10^2 kg-calories
knot	= 6.080×10^3 feet-hour = 1.8532 kilometers/hour = 1.0 nautical miles/hour = 1.151 statute miles/hour = 2.027×10^3 yards/hour = 1.689 feet/second = 5.148×10^1 cms/second
lambert	= 3.183×10^{-1} candles/square cm = 2.054 candles/square inch
light year	= 5.9×10^{12} miles = 9.46091×10^{12} kilometers
liter	= 1×10^3 cubic cms = 3.531×10^{-2} cubic feet = 6.102×10^1 cubic inches = 1.308×10^{-3} cubic yards = 2.642×10^{-1} gallons (U.S. liquid) = 2.113 pints (U.S. liquid) = 1.057 quarts (U.S. liquid)
liter/minute	= 5.886×10^{-4} cubic feet/second
lumen	= 7.958×10^{-2} spherical candle power
lumen-square foot	= 1.0 foot-candles = 1.076×10^1 lumens/square meter
lux	= 9.29×10^{-2} foot-candles

meter	= 1×10^{10} Angstrom units = 5.4681×10^{-1} fathoms = 3.281 feet = 3.937×10^{1} inches = 5.396×10^{-4} nautical miles = 6.214×10^{-4} statute miles = 1.094 yards
meter/minute	= 1.667 cms/second = 3.281 feet/minute = 5.468×10^{-2} feet/second = 6.0×10^{-2} kms/hour = 3.238×10^{-2} knots = 3.728×10^{-2} miles/hour
meter/second	= 1.968×10^{2} feet/minute = 3.281 feet/second = 6.0×10^{-2} kilometers/minute = 2.237 miles/hour = 3.728×10^{-2} miles/minute
meter/second/second	= 3.281 feet/sec/sec = 3.6 kms/hour/sec = 2.237 miles/hour/sec
mile (nautical)	= 6.076×10^{3} feet = 1.853 kilometers = 1.853×10^{3} meters = 1.1516 statute miles = 2.0254×10^{3} yards
mile (statute)	= 5.280×10^{3} feet = 6.336×10^{4} inches = 1.609 kilometers = 8.684×10^{-1} nautical miles = 1.760×10^{3} yards = 1.69×10^{-13} light years

miles/hour	= 4.470×10^{1} cms/second = 8.8×10^{1} feet/minute = 1.467 feet/second = 1.6093 kms/hour = 2.862×10^{-2} kms/minute = 8.864×10^{-1} knots = 2.682×10^{1} meters/minute = 1.667×10^{-2} miles/minute
miles/hour/second	= 4.47×10^{1} cms/sec/sec = 1.467 feet/sec/sec = 1.6093 kms/hour/sec = 4.47×10^{-1} meters/sec/sec
miles/minute	= 2.682×10^{3} cms/second = 8.8×10^{1} feet/second = 1.6093 kms/minute = 8.684×10^{-1} knots/minute
millimeter	= 3.281×10^{-3} feet = 3.937×10^{-2} inches = 6.214×10^{-7} miles = 3.937×10^{1} mils = 1.094×10^{-3} yards
mil	= 2.54×10^{-3} centimeters = 8.333×10^{-5} feet = 1.0×10^{-3} inches = 2.54×10^{-8} kilometers = 2.778×10^{-5} yards
minute (angle)	= 1.667×10^{-2} degrees = 2.909×10^{-4} radians
minute (time)	= 9.9206×10^{-5} weeks = 6.944×10^{-4} days = 1.667×10^{-2} hours
newton	= 1.0×10^{5} dynes

ohm (international)	= 1.0005 ohm (absolute)
ounce	= 4.375×10^{2} grains = 2.8349×10^{1} grams = 6.25×10^{-2} pounds
ounce (fluid)	= 1.805 cubic inches = 2.957×10^{-2} liters
ounce (troy)	= 1.097 ounces (avdp)
ounce/square inch	= 4.309×10^{3} dynes/square cm = 6.25×10^{-2} pounds/square inch
parsec	= 1.9×10^{13} miles = 3.084×10^{13} kilometers
parts/million	= 5.84×10^{-2} grains/U.S. gallon = 7.016×10^{-2} grains/imperial gallon = 8.345 pounds/million gallons
pint (liquid)	= 4.732×10^{2} cubic cms = 1.671×10^{-2} cubic feet = 2.887×10^{1} cubic inches = 4.732×10^{-4} cubic meters = 6.189×10^{-4} cubic yards = 1.25×10^{-1} gallons = 4.732×10^{-1} liters
Planck's constant	= 6.6256×10^{-27} erg-seconds
pound (avdp)	= 1.4583×10^{1} ounces (troy)
pound (troy)	= 1.3166×10^{1} ounces (avdp)
pound	= 2.56×10^{2} drams = 4.448×10^{5} dynes = 7.0×10^{3} grains = 4.5359×10^{2} grams = 4.536×10^{-1} kilograms = 1.6×10^{1} ounces = 3.217×10^{1} poundals = 5.0×10^{-4} short tons

poundal	= 1.3826×10^{4} dynes = 1.41×10^{1} grams = 1.383×10^{-3} joules/cm = 1.383×10^{-1} joules/meter (newtons = 1.41×10^{-2} kilograms = 3.108×10^{-2} pounds
pound of water	= 1.602×10^{-2} cubic feet = 2.768×10^{1} cubic inches = 1.198×10^{-1} gallons
pounds of water/minute	= 2.670×10^{-4} cubic feet/second
pound-foot	= 1.356×10^{7} cm-dynes = 1.3825×10^{4} cm-grams = 1.383×10^{-1} meter-kgs
pounds/cubic foot	= 1.602×10^{-2} grams/cubic cm = 1.602×10^{1} kgs/cubic meter = 5.787×10^{-4} pounds/cubic inch
pounds/cubic inch	= 2.768×10^{1} grams/cubic cm = 1.728×10^{3} pounds/cubic foot
pounds/foot	= 1.488 kgs/meter
pounds per inch	= 1.786×10^{2} grams/cm
pounds/square foot	= 4.725×10^{-4} atmospheres = 1.602×10^{-2} feet of water = 1.414×10^{-2} inches of mercury = 4.882 kgs/square meter = 6.944×10^{-3} pounds/square inch
pounds/square inch	= 6.804×10^{-2} atmospheres = 2.307 feet of water = 2.036 inches of mercury = 7.031×10^{2} kgs/square meter = 1.44×10^{2} pounds/square foot = 7.2×10^{-2} short tons/square foot = 7.03×10^{-2} kgs/square meter

quadrant (angle)	= 9.0×10^{1} degrees = 5.4×10^{3} minutes = 1.571 radians = 3.24×10^{5} seconds
quart (dry)	= 6.72×10^{1} cubic inches
quart (liquid)	= 9.464×10^{2} cubic cms = 3.342×10^{-2} cubic feet = 5.775×10^{1} cubic inches = 9.464×10^{-4} cubic meters = 1.238×10^{-3} cubic yards = 2.5×10^{-1} gallons = 9.463×10^{-1} liters
radian	= 5.7296×10^{1} degrees = 3.438×10^{3} minutes = 6.366×10^{-1} quadrants = 2.063×10^{5} seconds
radian/second	= 5.7296×10^{1} degrees/second = 9.549 revolutions/minute = 1.592×10^{-1} revolutions/second
radians/sec/sec	= 5.7296×10^{2} revolutions/min/min = 9.549 revolutions/min/sec = 1.5492×10^{-1} revolutions/sec/sec
ream	= 500 sheets
revolutions/minute	= 6.0 degrees/second = 1.047×10^{-1} radians/second = 1.667×10^{-2} revolutions/second
revolutions/min/min	= 1.745×10^{-3} radians/sec/sec = 1.667×10^{-2} revolutions/min/sec = 2.778×10^{-4} revolutions/sec/sec
revolutions/second	= 3.6×10^{2} degrees/second = 6.283 radians/second = 60 revolutions/minute

revolutions/sec/sec	= 6.283 radians/sec/sec = $3.6x10^{3}$ revolutions/min/min = $6.0x10^{1}$ revolutions/min/sec
second (angle)	= $2.778x10^{-4}$ degrees = $1.667x10^{-2}$ minutes = $4.848x10^{-6}$ radians
slug	= $1.459x10^{1}$ kilograms = $3.217x10^{1}$ pounds
sphere (solid angle)	= $1.257x10^{1}$ steradians
square centimeter	= $1.973x10^{5}$ circular mils = $1.076x10^{-3}$ square feet = $1.550x10^{-1}$ square inches = $1.0x10^{-4}$ square meters = $3.861x10^{-11}$ square miles = $1.196x10^{-4}$ square yards
square foot	= $2.296x10^{-5}$ acres = $9.29x10^{2}$ square cms = $1.44x10^{2}$ square inches = $9.29x10^{-2}$ square meters = $3.587x10^{-8}$ square miles = $1.111x10^{-1}$ square yards
square inch	= $1.273x10^{6}$ circular mils = 6.452 square cms = $6.944x10^{-3}$ square feet = $6.452x10^{2}$ square millimeters = $7.716x10^{-4}$ square yards = $1.0x10^{6}$ square mils
square kilometer	= $1.076x10^{7}$ square feet = $1.550x10^{9}$ square inches = $1.0x10^{6}$ square meters = $3.861x10^{-1}$ square miles = $1.196x10^{6}$ square yards

square meter	$= 1.076\text{x}10^{1}$ square feet $= 1.55\text{x}10^{3}$ square inches $= 3.861\text{x}10^{-7}$ square miles $= 1.196$ square yards
square mile	$= 6.40\text{x}10^{2}$ acres $= 2.788\text{x}10^{7}$ square feet $= 2.590$ square kilometers $= 3.098\text{x}10^{6}$ square yards
square millimeter	$= 1.076\text{x}10^{-5}$ square feet $= 1.55\text{x}10^{-3}$ square inches
square yard	$= 2.066\text{x}10^{-4}$ acres $= 9.0$ square feet $= 1.296\text{x}10^{3}$ square inches $= 8.361\text{x}10^{-1}$ square meters $= 3.228\text{x}10^{-7}$ square miles
steradian	$= 7.958\text{x}10^{-2}$ spheres $= 1.592\text{x}10^{-1}$ hemispheres $= 6.366\text{x}10^{-1}$ spherical right angles $= 3.283\text{x}10^{3}$ square degrees
temperature (°C) + 273 temperature (°C) + 17.78 temperature (°F) + 460 temperature (°F) - 32	= 1.0 absolute temperature (°K) = 1.8 temperature (°F) = 1.0 absolute temperature (°R) = 5/9 temperature (°C)
ton (metric)	$= 2.205\text{x}10^{3}$ pounds
ton (long)	$= 2.24\text{x}10^{3}$ pounds
ton (short)	$= 2.0\text{x}10^{3}$ pounds $= 9.0718\text{x}10^{2}$ kilograms $= 3.2\text{x}10^{4}$ ounces $= 8.9287\text{x}10^{-1}$ tons (long) $= 9.078\text{x}10^{-1}$ tons (metric)

tons (short)/sq ft	= 9.765×10^{3} kgs/square meter = 1.389×10^{1} pounds/square inch
watt	= 3.4129 Btu/hour = 5.688×10^{-2} Btu/minute = 1.0×10^{7} ergs/second = 4.427×10^{1} foot-pounds/minute = 7.378×10^{-1} foot-pounds/second = 1.341×10^{-3} horsepower = 433×10^{-2} kg-calories/minute = 1.0×10^{-3} kilowatts
watt-hour	= 3.413 Btu = 3.6×10^{10} ergs = 2.656×10^{3} foot-pounds = 8.605×10^{2} gram-calories = 1.341×10^{-3} horsepower-hours = 8.605×10^{-1} kilogram-calories = 1.0×10^{-3} kilowatt-hours
watt (international)	= 1.000165 watts (absolute)
week	= 1.68×10^{2} hours = 1.008×10^{4} minutes = 6.048×10^{5} seconds
yard	= 9.144×10^{1} centimeters = 9.144×10^{-1} meters = 4.934×10^{-4} nautical miles = 5.682×10^{-4} statute miles
year	= 3.65256×10^{2} days (mean solar) = 8.7661×10^{3} hours (mean solar)

USEFUL PHYSICAL CONSTANTS

Acceleration of gravity (g)	= 32.17 ft/sec^2
	= 980.6 cm/sec^2
Velocity of sound in dry air @ 0°C and 1 atmos.	= 33,136 cm/second
	= 1,089 feet/second
Heat of fusion of water	= 79.7 calories/gram
	= 144 Btu/pound
Heat of vaporization of water @ 1.0 atmos.	= 540 calories/gram
	= 970 Btu/pound
Specific heat of air	= Cp = 0.238 cal/gram (°C)
Density of air @ 0°C and 760 mm	= 0.991293 grams/cubic cm
Velocity of light (c)	= 2.997902x10^{10} cm/sec
Avogadro's number (N)	= 6.061x10^{23} molecules/gram-mole
Pi	= 3.14159265
Naperian-logarithm base	= 2.71828133
Radiation absorbtion dose (rad)	= 1.0x10^2 ergs/gram
Roentgen	= 8.3x10^{-1} rads

International Standard Prefixes

Conversion Table

The accompanying table of International Standard Prefixes may be used to indicate decimal point movement and conversion of units.

Example 1:

Convert 10 microns to milli meters.

Solution:

Enter table at Micro in left-hand column, projecting horizontally to vertical Milli column. Move decimal point to left (direction of arrow) three figures. Ten microns equal 0.01 millimeter.

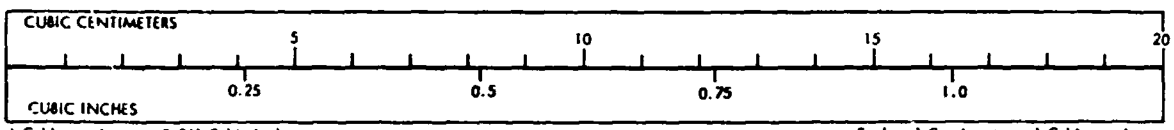
Example 2:

Convert 2 teraohms to megohms.

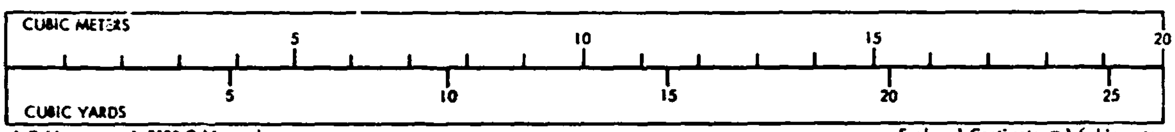
Solution:

Entering left-hand column at Tera, project to Mega column and note six. Two teraohms equal 2,000,000 megohms.

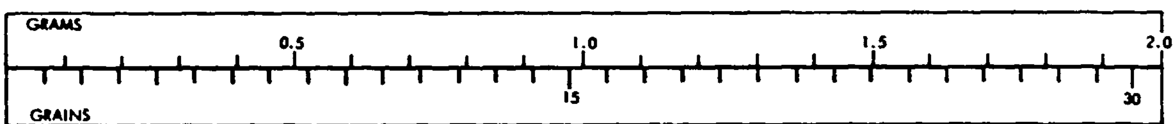
GIVEN	TO OBTAIN													
	Symbol	Tera	Giga	Mega	Kilo	Hecto	Deka	UNITY	Deci	Centi	Milli	Micro	Nano	Pico
Tera	T		3	6	9	10	11	12	13	14	15	18	21	24
Giga	G	3		3	6	7	8	9	10	11	12	15	18	21
Mega	M	6	3		3	4	5	6	7	8	9	12	15	18
Kilo	K	9	6	3		1	2	3			6	9	12	15
Hecto	h	10	7	4	1		1	2	3	4	5	8	11	14
Deka	dk	11	8	5	2	1		1	2	3	4	7	10	13
UNITY		12	9	6	3	2	1		1	2	3	6	9	12
Deci	d	13	10				2	1		1	2	5	8	11
Centi	c	14	11	8	5	4	3	2	1		1	4	7	10
Milli	m	15	12	9	6	5	4	3	2	1		3	6	9
Micro	μ	18	15	12	9	8	7	6	5	4	3		3	6
Nano	n	21	18	15	12	11	10	9	8			3		3
Pico	p	24	21	18	15	14	13	12	11	10	9	6	3	



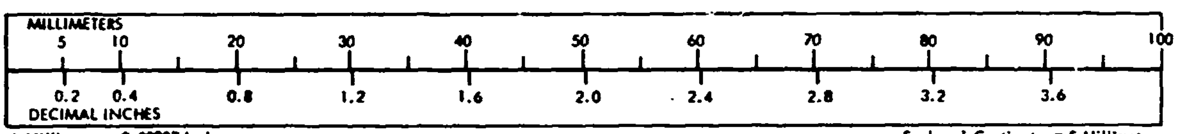
1 Cubic centimeter = 0.061 Cubic inch — Scale - 1 Centimenter = 1 Cubic centimeter



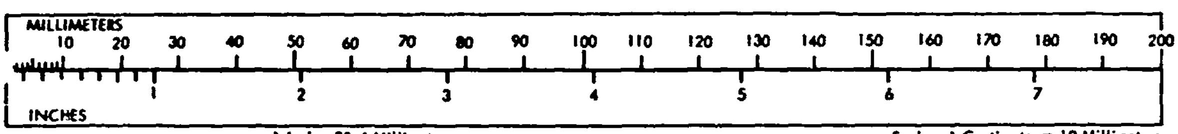
1 Cubic meter = 1.3080 Cubic yards — Scale - 1 Centimeter = 1 Cubic meter



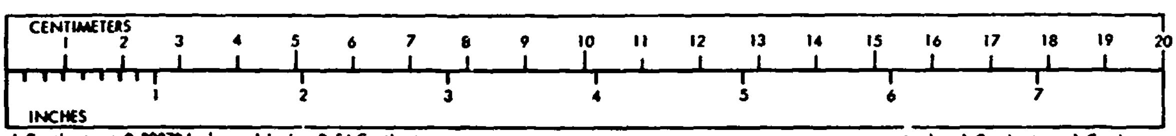
1 Gram = 15.4324 Grains — Scale - 1 Centimeter = 0.1 Gram



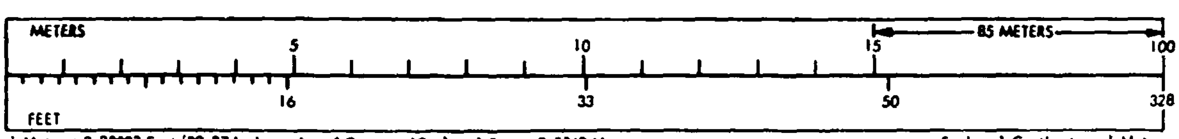
1 Millimeter = 0.03937 Inch — Scale - 1 Centimeter = 5 Millimeters



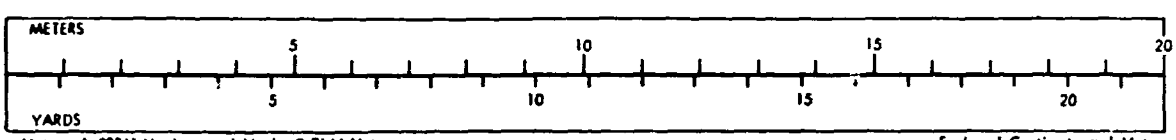
1 Inch = 25.4 Millimeters — Scale - 1 Centimeter = 10 Millimeters



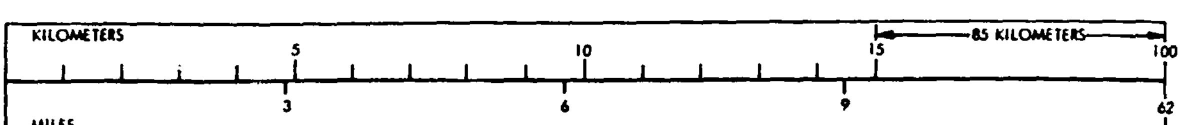
1 Centimeter = 0.39370 Inch — 1 Inch = 2.54 Centimeters — Scale - 1 Centimeter = 1 Centimeter



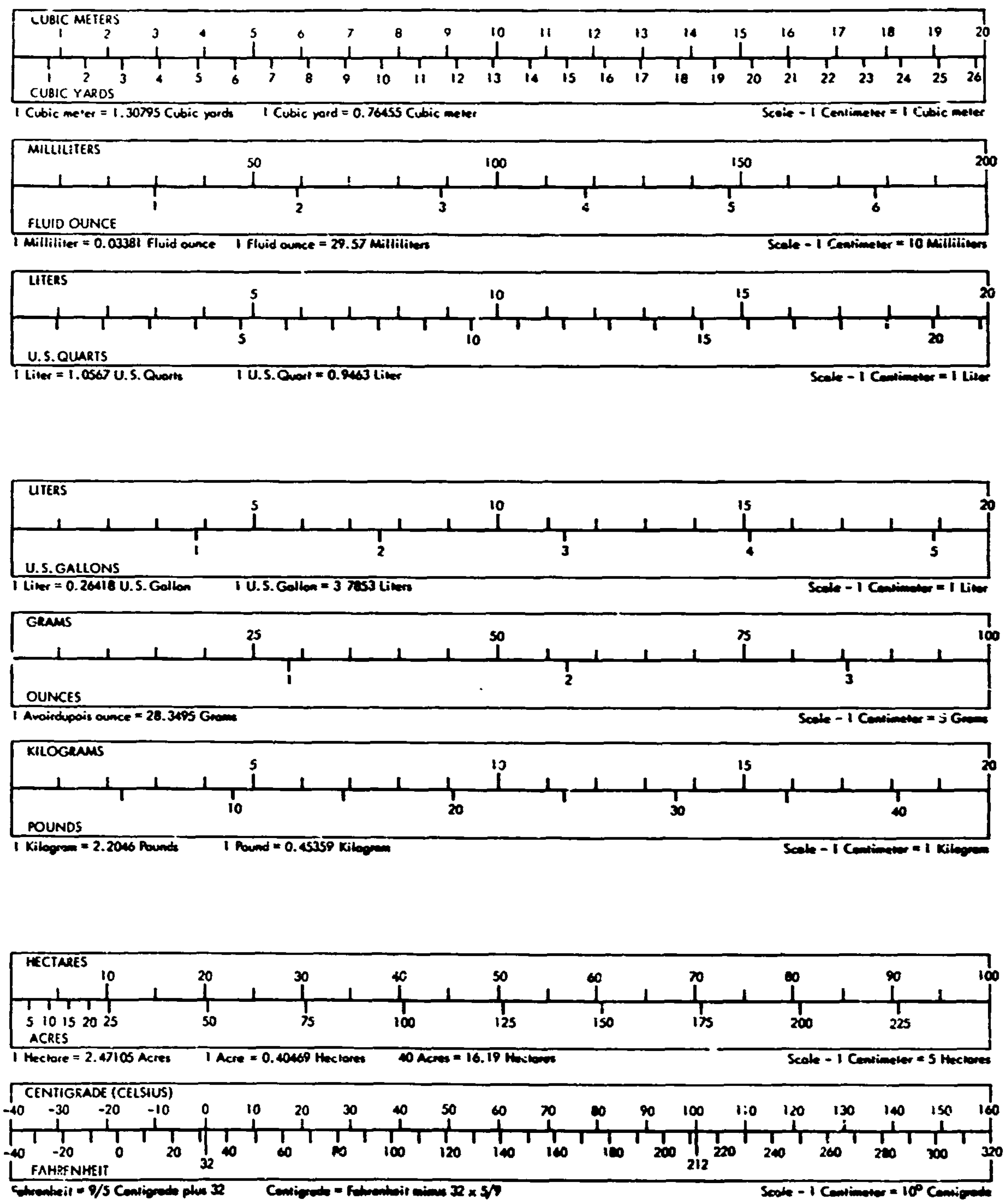
1 Meter = 3.28083 Feet (39.37 Inches - Act of Congress 1866) — 1 Foot = 0.3048 Meter — Scale - 1 Centimeter = 1 Meter



Meter = 1.09361 Yards — 1 Yard = 0.9144 Meter — Scale - 1 Centimeter = 1 Meter



1 Kilometer = 0.62137 Mile — 1 Mile = 1.6093 Kilometers — Scale - 1 Centimeter = 1 Kilometer

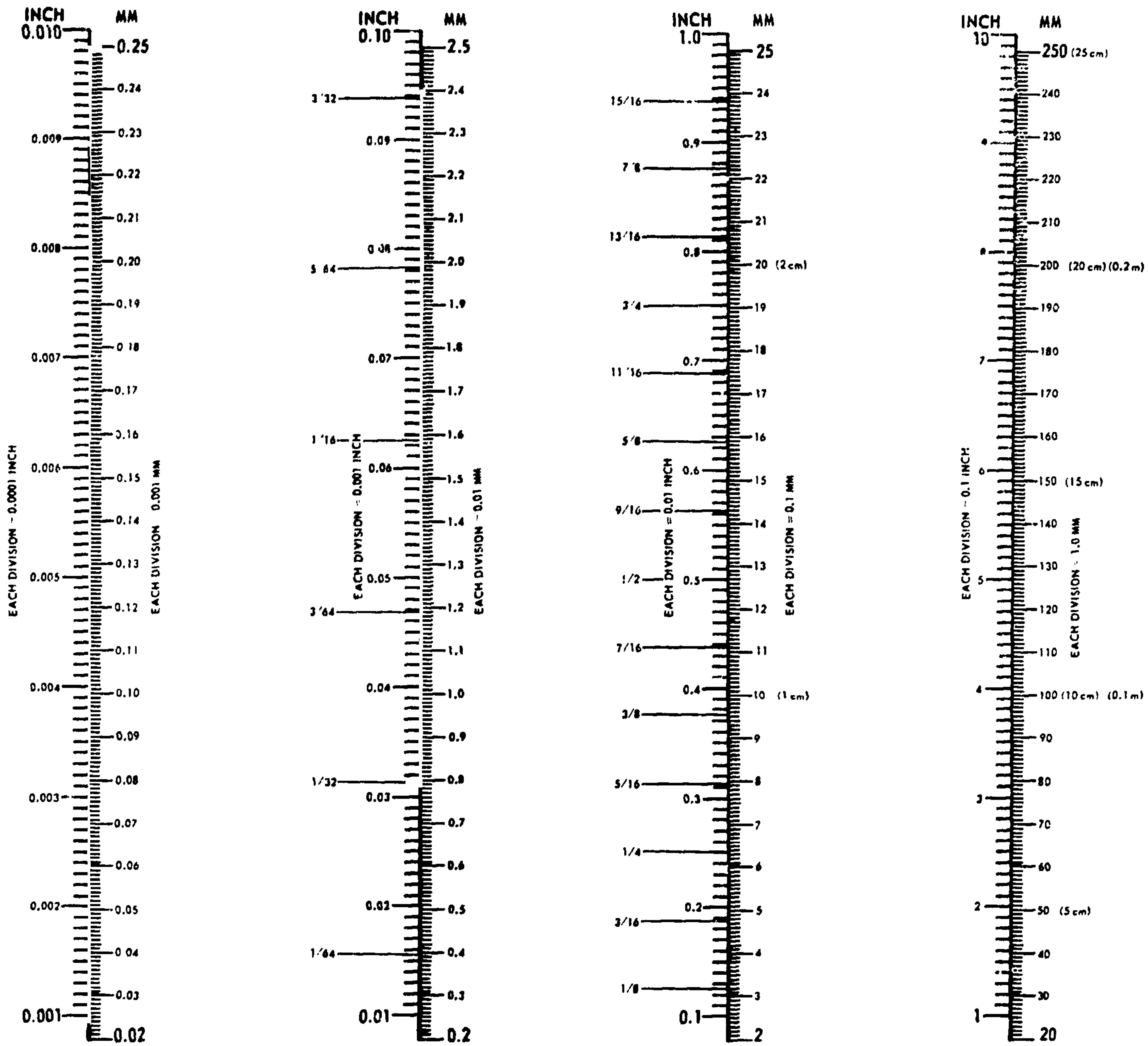


KELM MANUFACTURING CO.
ROUTE 2, COLOMA, MICHIGAN U.S.A.

Inches And Millimeters

Most of us visualize the inch and its various divisions with ease. Visualizing the millimeter is something different, and mentally relating the inch and millimeter takes lots of practice. Here is a simple reference guide, with inches compared to millimeters in four ranges, covering a total range from 0.001 to 10 inches.

As an example of how these line charts can be used, suppose a diameter is given as 2 mm. From the appropriate chart (0.2 to 2.5 mm) it can be seen that 5/64 is very close, in fact, smaller than 2 mm by less than a thousandth of an inch (each division on this scale is 0.001 inch). In many cases, this variation would be insignificant. Even closer would be 0.079 inch, and this is a standard size in many products.



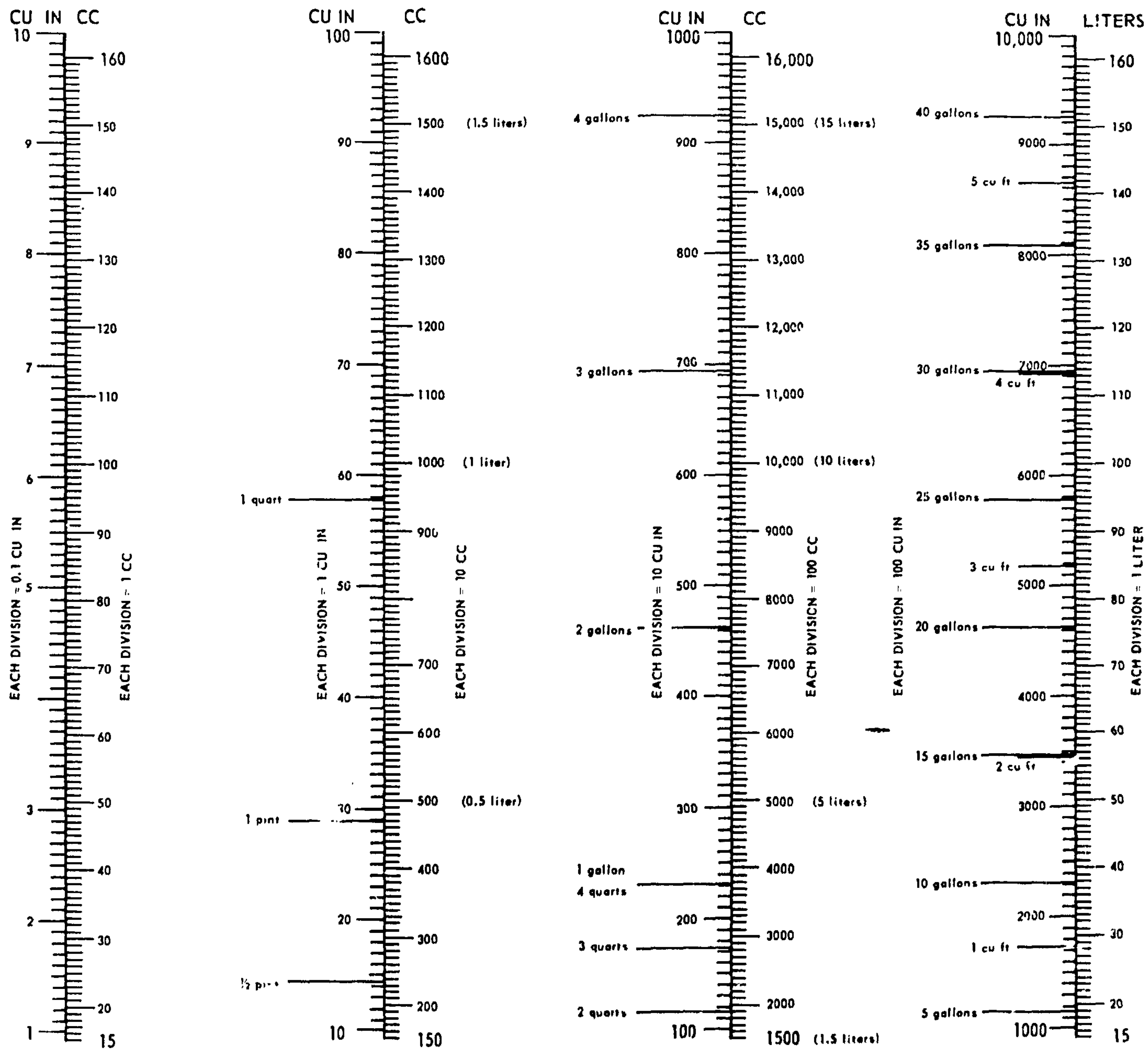
Cubic Inches And Cubic Centimeters

Previously, we related "Inches and Millimeters" and "Pounds and Grams" in useful line-chart form. Now we relate volume measure in terms of cubic inches and cubic centimeters. To make the scales more useful, common U.S. liquid units have been added. Note, however, that the pints, quarts and gallons shown are liquid measure, not dry measure.

Below are a few examples of how the charts can be used. Most of us remember that a quart and a liter are roughly equivalent. Most of us can't remember which is larger. A glance at the scale shows the liter is the larger (the quart being 947 cc, or 0.947 liter). The error of this quart-liter mental reference grows as the volume goes up. For example, 4 gals (16 quarts) is closer to 15 liters than 16 liters.

As another example, the displacement of an American-made engine might be 250 cu in. The equivalent, in metric units, is approximately 4100 cc, or 4.1 liters.

The chart to the far right may be useful for equating flow, if the time unit is kept the same. For example, a flow is given as 130 liters/min. The flow may be read in gal/min by reading the equivalent of 130 liters in gallons. Thus, 130 liters/min are almost 35 gal/min.



FRACTION/DECIMAL CONVERSION

FRACTION							FRACTION						
-/2	-/4	-/8	-/16	-/32	-/64	DECIMAL EQUIVALENT	-/2	-/4	-/8	-/16	-/32	-/64	DECIMAL EQUIVALENT
0	0	0	0	0	0	0.000000	1	2	4	8	16	32	0.500
					1	0.015625						33	0.515625
				1/32	2	0.03125					17/32	34	0.53125
					3	0.046875						35	0.546875
			1/16	2	4	0.0625				9/16	18	36	0.5625
					5	0.078125						37	0.578125
				3/32	6	0.09375					19/32	38	0.59375
					7	0.109375						39	0.609375
		1/8	2	4	8	0.125			5/8	10	20	40	0.625
					9	0.140625						41	0.640625
				5/32	10	0.15625					21/32	42	0.65625
					11	0.171875						43	0.671875
			3/16	6	12	0.1875				11/16	22	44	0.6875
					13	0.203125						45	0.703125
				7/32	14	0.21875					23/32	46	0.71875
					15	0.234375						47	0.734375
	1/4	2	4	8	16	0.250		3/4	6	12	24	48	0.750
					17	0.265625						49	0.765625
				9/32	18	0.28125					25/32	50	0.78125
					19	0.296875						51	0.796875
			5/16	10	20	0.3125				13/16	26	52	0.8125
					21	0.328125						53	0.828125
				11/32	22	0.34375					27/32	54	0.84375
					23	0.359375						55	0.859375
		3/8	6	12	24	0.375			7/8	14	28	56	0.875
					25	0.390625						57	0.890625
				13/32	26	0.40625					29/32	58	0.90625
					27	0.421875						59	0.921875
			7/16	14	28	0.4375				15/16	30	60	0.9375
					29	0.453125						61	0.953125
				15/32	30	0.46875					31/32	62	0.96875
					31	0.484375						63	0.984375
1	2	4	8	16	32	0.500	2	4	8	16	32	64	1.000000

TEMPERATURE CONVERSION

To use the table, look for the temperature reading you have in the middle column. If the reading you have is in degrees Centigrade, read the Fahrenheit equivalent in the right hand column. If the reading you have is in degrees Fahrenheit, read the Centigrade equivalent in the left hand column.

-80 to 34			35 to 77			78 to 290		
C		F	C		F	C		F
-62	-80	-112	1.7	35	95.0	25.6	78	172.4
-57	-70	- 94	2.2	36	96.8	26.1	79	174.2
-51	-60	- 76	2.8	37	98.6	26.7	80	176.0
-46	-50	- 58	3.3	38	100.4	27.2	81	177.8
-40	-40	- 40	3.9	39	102.2	27.8	82	179.6
-34	-30	- 22	4.4	40	104.0	28.3	83	181.4
-29	-20	- 4	5.0	41	105.8	28.9	84	183.2
-23	-10	14	5.6	42	107.6	29.4	85	185.0
-17.8	0	32	6.1	43	109.4	30.0	86	186.8
-17.2	1	33.8	6.7	44	111.2	30.6	87	188.6
-16.7	2	35.6	7.2	45	113.0	31.1	88	190.4
-16.1	3	37.4	7.8	46	114.8	31.7	89	192.2
-15.6	4	39.2	8.3	47	116.6	32.2	90	194.0
-15.0	5	41.0	8.9	48	118.4	32.8	91	195.8
-14.4	6	42.8	9.4	49	120.2	33.3	92	197.6
-13.9	7	44.6	10.0	50	122.0	33.9	93	199.4
-13.3	8	46.4	10.6	51	123.8	34.4	94	201.2
-12.8	9	48.2	11.1	52	125.6	35.0	95	203.0
-12.2	10	50.0	11.7	53	127.4	35.6	96	204.8
-11.7	11	51.8	12.2	54	129.2	36.1	97	206.6
-11.1	12	53.6	12.8	55	131.0	36.7	98	208.4
-10.6	13	55.4	13.3	56	132.8	37.2	99	210.2
-10.0	14	57.2	13.9	57	134.6	37.8	100	212.0
- 9.4	15	59.0	14.4	58	136.4	43	110	230
- 8.9	16	60.8	15.0	59	138.2	49	120	248
- 8.3	17	62.6	15.6	60	140.0	54	130	266
- 7.8	18	64.4	16.1	61	141.8	60	140	284
- 7.2	19	66.2	16.7	62	143.6	66	150	302
- 6.7	20	68.0	17.2	63	145.4	71	160	320
- 6.1	21	69.8	17.8	64	147.2	77	170	338
- 5.6	22	71.6	18.3	65	149.0	82	180	356
- 5.0	23	73.4	18.9	66	150.8	88	190	374
- 4.4	24	75.2	19.4	67	152.6	93	200	392
- 3.9	25	77.0	20.0	68	154.4	99	210	410
- 3.3	26	78.8	20.6	69	156.2	100	212	413.6
- 2.8	27	80.6	21.1	70	158.0	104	220	428
- 2.2	28	82.4	21.7	71	159.8	110	230	446
- 1.7	29	84.2	22.2	72	161.6	116	240	464
- 1.1	30	86.0	22.8	73	163.4	121	250	482
- 0.6	31	87.8	23.3	74	165.2	127	260	500
0.0	32	89.6	23.9	75	167.0	132	270	518
0.6	33	91.4	24.4	76	168.8	138	280	536
1.1	34	93.2	25.0	77	170.6	143	290	554

Formulas - C = 5/9 (F-32) or F= 9/5 C +32

Unknown Temp.	Known Temperature			
	°F	°C	°R	°K
°F	......	9/5°C + 32	°R − 459.68	9/5°K − 459.68
°C	5/9(°F − 32)	......	5/9°R − 273.16	°K − 273.16
°R	°F + 459.68	9/5°C + 491.68	......	9/5°K
°K	5/9(°F + 459.68)	°C + 273.16	5/9°R	......

High-Altitude and Space Pressure Environment

ALTITUDE			PRESSURE EQUIVALENTS				
FEET	MILES	KM	INCHES OF H_g	PSIA	MILLIMETERS OF H_g (Torr)	MICRONS	MEAN FREE PATH (FT)
0	0	0	29.930	14.700	760.222	760,222.0	2.176×10^{-7}
15,000	2.841	4.572	17.420	8.556	442.468	442,468.0	3.457
30,000	5.682	9.144	9.572	4.701	243.129	243,129.0	5.807
45,000	8.523	13.716	4.842	2.378	122.987	122,987.0	1.119×10^{-6}
60,000	11.364	18.288	2.277	1.118	57.836	57,835.8	2.293
70,000	13.258	21.336	1.396	0.686	35.458	35,458.4	3.716
75,000	14.205	22.860	1.099	0.540	27.915	27,914.6	4.740
80,000	15.152	24.384	0.869	0.427	22.065	22,065.0	6.035
85,000	16.099	25.908	0.689	0.338	17.493	17,493.0	7.670
90,000	17.046	27.432	0.548	0.269	13.914	13,914.1	9.732
95,000	17.992	28.956	0.437	0.215	11.102	11,102.3	1.233×10^{-5}
100,000	18.939	30.480	0.350	0.172	8.885	8,884.9	1.559
105,000	19.886	32.004	0.281	0.138	7.132	7,132.3	1.968
110,000	20.833	33.528	0.226	0.111	5.743	5,742.9	2.504
115,000	21.780	35.052	0.183	0.0897	4.638	4,638.0	3.175
120,000	22.727	36.576	0.148	0.0727	3.759	3,759.2	4.009
125,000	23.674	38.100	0.120	0.0591	3.056	3,055.6	5.042
130,000	24.621	39.624	0.0982	0.0482	2.493	2,493.0	6.315
135,000	25.568	41.148	0.0803	0.0394	2.039	2,039.4	7.879
140,000	26.515	42.672	0.0659	0.0323	1.673	1,672.8	9.793
145,000	27.462	44.196	0.0542	0.0266	1.376	1,376.2	1.213×10^{-4}
150,000	28.409	45.720	0.0447	0.0220	1.135	1,135.4	1.497
155,000	29.356	47.244	0.0370	0.0182	0.939	939.0	1.841
160,000	30.303	48.768	0.0306	0.0150	0.778	778.0	2.227
165,000	31.250	50.292	0.0254	0.0125	0.644	644.4	2.692
170,000	32.197	51.816	0.0210	0.0103	0.534	533.9	3.253
175,000	33.144	53.340	0.0174	0.00855	0.442	442.0	3.906
180,000	34.091	54.864	0.0144	0.00706	0.365	365.0	4.678
185,000	35.038	56.388	0.0118	0.00582	0.301	300.7	5.612
190,000	35.985	57.912	0.00773	0.00478	0.247	247.2	6.748
200,000	37.879	60.960	0.00653	0.00321	0.166	166.0	9.814
205,000	38.825	62.484	0.00532	0.00261	0.135	135.2	1.180×10^{-3}
210,000	39.773	64.008	0.00431	0.00212	0.110	109.6	1.417
215,000	40.720	65.532	0.00348	0.00171	0.0884	88.37	1.709
220,000	41.667	67.056	0.00279	0.00137	0.0709	70.89	2.071
225,000	42.614	68.580	0.00224	0.00109	0.0566	56.59	2.522
230,000	43.561	70.104	0.00177	0.000868	0.0449	44.91	3.088
235,000	44.508	71.628	0.00140	0.000685	0.0354	35.43	3.802
240,000	45.455	73.153	0.00109	0.000573	0.0278	27.76	4.707
245,000	46.402	74.676	0.000851	0.000418	0.0216	21.62	5.864
250,000	47.349	76.200	0.000658	0.000323	0.0167	16.72	7.353
255,000	48.296	77.724	0.0005[illegible]	0.000248	0.0128	12.83	9.284
260,000	49.242	79.248	0.000385	0.000189	0.00977	9.769	0.0118×10^{0}
265,000	50.189	80.772	0.000290	0.000143	0.00738	7.376	0.01538
270,000	51.136	82.296	0.000217	0.000107	0.00552	5.522	0.02036
275,000	52.083	83.820	0.000162	0.0000796	0.00412	4.117	0.02697
280,000	53.030	85.344	0.000121	0.0000593	0.00307	3.068	0.03570
285,000	53.977	86.868	0.0000901	0.0000443	0.00229	2.289	0.04727
290,000	54.924	88.392	0.0000672	0.0000330	0.00171	1.707	0.06257
295,000	55.871	89.916	0.0000502	0.0000246	0.00127	1.274	0.08281
300,000	56.818	91.440	0.0000375	0.0000184	0.000952	0.952	0.1118
350,000	66.288	106.680	0.335×10^{-5}	0.165×10^{-5}	0.0000852	0.0852	1.629
400,000	75.758	121.920	0.631×10^{-6}	0.310×10^{-6}	0.0000160	0.0160	13.81
450,000	85.227	137.160	0.248	0.122	0.631×10^{-5}	0.00631	60.32
500,000	94.697	152.400	0.138	0.678×10^{-7}	0.351	0.00351	151.3
550,000	104.167	167.640	0.879×10^{-7}	0.432	0.223	0.00223	278.7
600,000	113.636	182.880	0.592	0.291	0.150	0.00150	447.0
650,000	123.106	198.120	0.411	0.202	0.105	0.00105	675.9
700,000	132.576	213.360	0.292	0.144	0.742×10^{-6}	0.000742	986.1
750,000	142.046	228.600	0.212	0.104	0.537	0.000537	1408.0
800,000	151.515	243.840	0.156	0.764×10^{-8}	0.395	0.000395	1956.0
850,000	160.985	259.080	0.116	0.569	0.294	0.000294	2676.0
900,000	170.455	274.320	0.874×10^{-8}	0.429	0.222	0.000222	3611.0
950,000	179.924	289.560	0.666	0.324	0.169	0.000169	4811.0
1,000,000	189.394	304.800	0.513	0.252	0.130	0.000130	6325.0
1,100,000	208.333	335.280	0.312	0.153	0.792×10^{-7}	0.0000792	10,550.0
1,200,000	227.273	365.760	0.195	0.959×10^{-9}	0.496	0.0000496	17,040.0
1,300,000	246.212	396.240	0.126	0.616	0.319	0.0000319	26,760.0
1,400,000	265.152	426.720	0.825×10^{-9}	0.405	0.210	0.0000210	40,740.0
1,500,000	284.091	457.200	0.552	0.271	0.1[illegible]	0.0000140	60,930.0
1,600,000	303.030	487.680	0.376	0.185	0.956×10^{-8}	0.956×10^{-5}	89,830.0
1,700,000	321.970	518.160	0.260	0.128	0.661	0.661	130,000.0
1,800,000	340.909	548.640	0.182	0.893×10^{-10}	0.462	0.462	185,800.0
1,900,000	359.849	579.120	0.129	0.631	0.326	0.326	263,900.0
2,000,000	378.788	609.600	0.917×10^{-10}	0.450	0.233	0.233	371,100.0
2,100,000	397.727	640.080	0.659	0.324	0.167	0.167	516,200.0
2,200,000	416.667	670.560	0.478	0.235	0.121	0.121	713,300.0
2,300,000	435.606	701.040	0.348	0.171	0.884×10^{-9}	0.384×10^{-6}	978,400.0

0 TO 300,000 FEET
SOURCE: U.S. STANDARD ATMOSPHERE, 1966
CONDITION: 30°N, JULY DAY, GEOMETRIC ALTITUDE

OVER 300,000 FEET
SOURCE: U.S. STANDARD ATMOSPHERE, 1962

Line Chart Relates Hg Column to PSI

The height of a mercury column often is used to indicate pressure in pneumatic or hydraulic systems. Here is a line chart to convert column height to the system pressure in psi. The chart is based on the expression:

$$\frac{14.696 \text{ psi}}{29.921 \text{ (inches Hg)}} = 0.491$$

While only the range from zero to 50 inches of mercury is covered, larger or smaller values can be found by moving the decimal point a like number of places on both sides of the line. For instance, it is seen that 1.5 inches of mercury is equivalent to 0.73 psi. Moving the decimal point one place to the right gives 15 inches of mercury, which is seen to equal 7.36 psi. Moving one step further, 150 inches of mercury would equal 73.6 psi. The conversion chart should prove useful when checking fluidic device specifications. These often are rated in terms of inches of mercury.

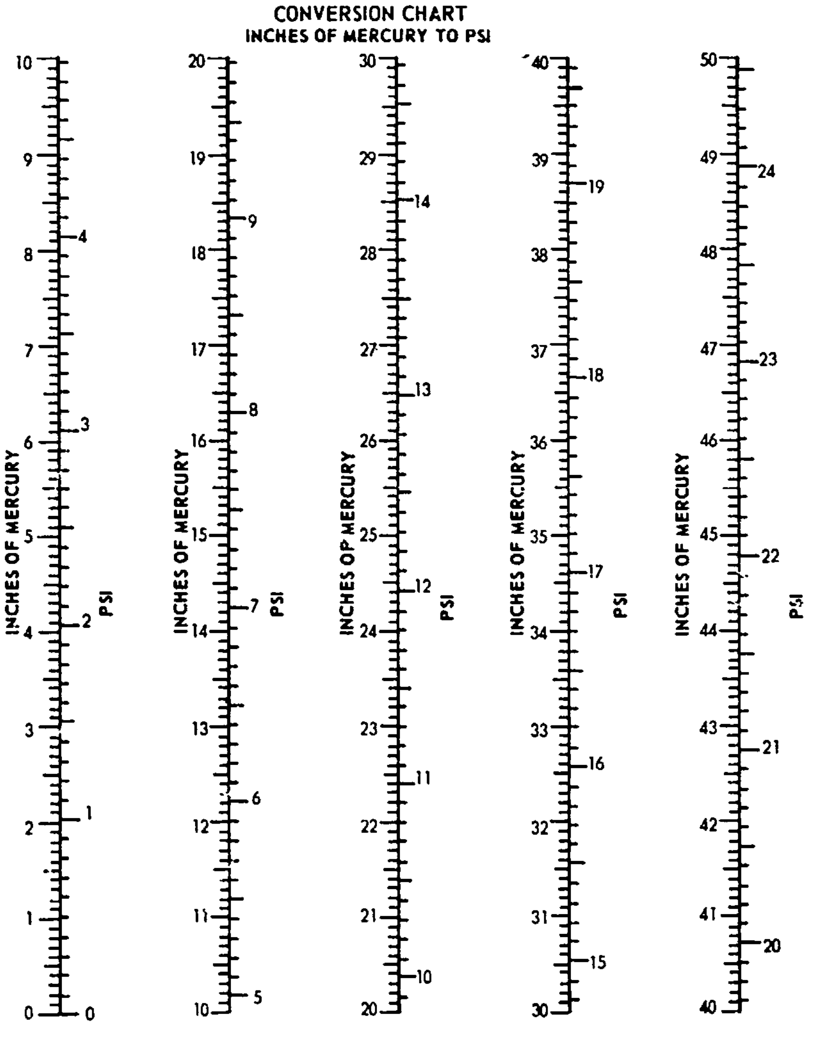


Table VI. Length of One Degree of Longitude at Different Latitudes

Latitude	*Statute Miles*	*Latitude*	*Statute Miles*
0°	69.171	45	48.995
1	69.162	46	48.135
2	69.130	47	47.261
3	69.078	48	46.372
4	69.005	49	45.469
5	68.911	50	44.552
6	68.796	51	43.621
7	68.660	52	42.676
8	68.503	53	41.719
9	68.326	54	40.749
10	68.128	55	39.766
11	67.909	56	38.771
12	67.670	57	37.764
13	67.411	58	36.745
14	67.131	59	35.715
15	66.830	60	34.674
16	66.510	61	33.622
17	66.169	62	32.560
18	65.808	63	31.488
19	65.427	64	30.406
20	65.026	65	29.315
21	64.606	66	28.215
22	64.166	67	27.106
23	63.706	68	25.988
24	63.227	69	24.862
25	62.729	70	23.729
26	62.212	71	22.589
27	61.676	72	21.441
28	61.121	73	20.287
29	60.548	74	19.126
30	59.956	75	17.960
31	59.345	76	16.788
32	58.717	77	15.611
33	58.071	78	14.428
34	57.407	79	13.242
35	56.726	80	12.051
36	56.027	81	10.857
37	55.311	82	9.659
38	54.578	83	8.458
39	53.829	84	7.255
40	53.063	85	6.049
41	52.281	86	4.841
42	51.483	87	3.632
43	50.669	88	2.422
44	49.840	89	1.211
45	48.995	90	0.000

Decimal to Binary Conversion Tables

The binary system of numbers is used wherever there is a need for "on-off", or plus-minus control. It is necessary in a number of automatic controls such as mechanical and electronic tape systems. These charts were developed particularly for use with the mechanical Binotrol system which positions a shaft to a fraction of a degree within any number of revolutions. However, they are equally applicable to any problem involving the use of binary numbers. They can be used to convert from decimal units up to 32,767 to binary units or to convert from 15-digit binary units to decimal units.

Decimal to Binary Conversion:

In Primary Table find decimal number either equal to or next less than the desired decimal number. Call this the Primary decimal number. The binary number opposite Primary decimal number represents the first eight digits of the Final binary number. (In the Table a square without a "1" is equivalent to zero.) Subtract the Primary decimal number from the desired decimal number. The difference will always be less than 128. Look up the difference in the Secondary Table. The binary number opposite the difference represents the last seven digits of the final binary number.

Example: Required to convert 20,125 to a binary number.

1. From Primary Table, Primary decimal number is 20,096.
2. The first eight digits of the binary number are 10011101.
3. Subtract 20,096 from 20,125 leaving 29.
4. Find 29 in Secondary Table. Last seven digits of binary number are 0011101.
5. Therefore the binary equivalent of 20,125 is 100111010011101.

Binary to Decimal Conversion

Find first eight digits of binary number in the Primary Table. Decimal number opposite this is the Primary decimal number. Find the last seven digits in the Secondary Table. This is the Secondary decimal number. Add Primary and Secondary decimal number to find the Final decimal.

Example: Required to reduce the binary number 100101101010110 to a decimal number.

1. Look up the first eight digits (10010110) in the Primary Table.
2. The Primary decimal number is 19,200.
3. Look up the last seven digits (1010110) in the Secondary Table.

PRIMARY TABLE

DECIMAL	1	2	3	4	5	6	7	8	DECIMAL	1	2	3	4	5	6	7	8
00000									08192		1						
00128								1	08320		1						1
00256							1		08448		1					1	
00384							1	1	08576		1					1	1
00512						1			08704		1				1		
00640						1		1	08832		1				1		1
00768						1	1		08960		1				1	1	
00896						1	1	1	09088		1				1	1	1
01024					1				09216		1			1			
01152					1			1	09344		1			1			1
01280					1		1		09472		1			1		1	
01408					1		1	1	09600		1			1		1	1
01536					1	1			09728		1			1	1		
01664					1	1		1	09856		1			1	1		1
01792					1	1	1		09984		1			1	1	1	
01920					1	1	1	1	10112		1			1	1	1	1
02048				1					10240		1		1				
02176				1				1	10368		1		1				1
02304				1			1		10496		1		1			1	
02432				1			1	1	10624		1		1			1	1
02560				1		1			10752		1		1		1		
02688				1		1		1	10880		1		1		1		1
02816				1		1	1		11008		1		1		1	1	
02944				1		1	1	1	11136		1		1		1	1	1
03072				1	1				11264		1		1	1			
03200				1	1			1	11392		1		1	1			1
03328				1	1		1		11520		1		1	1		1	
03456				1	1		1	1	11648		1		1	1		1	1
03584				1	1	1			11776		1		1	1	1		
03712				1	1	1		1	11904		1		1	1	1		1
03840				1	1	1	1		12032		1		1	1	1	1	
03968				1	1	1	1	1	12160		1		1	1	1	1	1
04096			1						12288		1	1					
04224			1					1	12416		1	1					1
04352			1				1		12544		1	1				1	
04480			1				1	1	12672		1	1				1	1
04608			1			1			12800		1	1			1		
04736			1			1		1	12928		1	1			1		1
04864			1			1	1		13056		1	1			1	1	
04992			1			1	1	1	13184		1	1			1	1	1
05120			1		1				13312		1	1		1			
05248			1		1			1	13440		1	1		1			1
05376			1		1		1		13568		1	1		1		1	
05504			1		1		1	1	13696		1	1		1		1	1
05632			1		1	1			13824		1	1		1	1		
05760			1		1	1		1	13952		1	1		1	1		1
05888			1		1	1	1		14080		1	1		1	1	1	
06016			1		1	1	1	1	14208		1	1		1	1	1	1
06144			1	1					14336		1	1	1				
06272			1	1				1	14464		1	1	1				1
06400			1	1			1		14592		1	1	1			1	
06528			1	1			1	1	14720		1	1	1			1	1
06656			1	1		1			14848		1	1	1		1		
06784			1	1		1		1	14976		1	1	1		1		1
06912			1	1		1	1		15104		1	1	1		1	1	
07040			1	1		1	1	1	15232		1	1	1		1	1	1
07168			1	1	1				15360		1	1	1	1			
07296			1	1	1			1	15488		1	1	1	1			1
07424			1	1	1		1		15616		1	1	1	1		1	
07552			1	1	1		1	1	15744		1	1	1	1		1	1
07680			1	1	1	1			15872		1	1	1	1	1		
07808			1	1	1	1		1	16000		1	1	1	1	1		1
07936			1	1	1	1	1		16128		1	1	1	1	1	1	
08064			1	1	1	1	1	1	16256		1	1	1	1	1	1	1

4. The Secondary decimal number is 86.
5. The final decimal number is 19,200 + 86 = 19,286
6. Therefore the decimal equivalent of 100101101010110 is 19,286.

Data Courtesy: Barnes Engineering Co., Stamford, Conn.

PRIMARY TABLE

DECIMAL	1	2	3	4	5	6	7	8	DECIMAL	1	2	3	4	5	6	7	8
16384	1								24576	1	1						
16512	1							1	24704	1	1						1
16640	1						1		24832	1	1					1	
16768	1						1	1	24960	1	1					1	1
16896	1					1			25088	1	1				1		
17024	1					1		1	25216	1	1				1		1
17152	1					1	1		25344	1	1				1	1	
17280	1					1	1	1	25472	1	1				1	1	1
17408	1				1				25600	1	1			1			
17536	1				1			1	25728	1	1			1			1
17664	1				1		1		25856	1	1			1		1	
17792	1				1		1	1	25984	1	1			1		1	1
17920	1				1	1			26112	1	1			1	1		
18048	1				1	1		1	26240	1	1			1	1		1
18176	1				1	1	1		26368	1	1			1	1	1	
18304	1				1	1	1	1	26496	1	1			1	1	1	1
18432	1			1					26624	1	1		1				
18560	1			1				1	26752	1	1		1				1
18688	1			1			1		26880	1	1		1			1	
18816	1			1			1	1	27008	1	1		1			1	1
18944	1			1		1			27136	1	1		1		1		
19072	1			1		1		1	27264	1	1		1		1		1
19200	1			1		1	1		27392	1	1		1		1	1	
19328	1			1		1	1	1	27520	1	1		1		1	1	1
19456	1			1	1				27648	1	1		1	1			
19584	1			1	1			1	27776	1	1		1	1			1
19712	1			1	1		1		27904	1	1		1	1		1	
19840	1			1	1		1	1	28032	1	1		1	1		1	1
19968	1			1	1	1			28160	1	1		1	1	1		
20096	1			1	1	1		1	28288	1	1		1	1	1		1
20224	1			1	1	1	1		28416	1	1		1	1	1	1	
20352	1			1	1	1	1	1	28544	1	1		1	1	1	1	1
20480	1		1						28672	1	1	1					
20608	1		1					1	28800	1	1	1					1
20736	1		1				1		28928	1	1	1				1	
20864	1		1				1	1	29056	1	1	1				1	1
20992	1		1			1			29184	1	1	1			1		
21120	1		1			1		1	29312	1	1	1			1		1
21248	1		1			1	1		29440	1	1	1			1	1	
21376	1		1			1	1	1	29568	1	1	1			1	1	1
21504	1		1		1				29696	1	1	1		1			
21632	1		1		1			1	29824	1	1	1		1			1
21760	1		1		1		1		29952	1	1	1		1		1	
21888	1		1		1		1	1	30080	1	1	1		1		1	1
22016	1		1		1	1			30208	1	1	1		1	1		
22144	1		1		1	1		1	30336	1	1	1		1	1		1
22272	1		1		1	1	1		30464	1	1	1		1	1	1	
22400	1		1		1	1	1	1	30592	1	1	1		1	1	1	1
22528	1		1	1					30720	1	1	1	1				
22656	1		1	1				1	30848	1	1	1	1				1
22784	1		1	1			1		30976	1	1	1	1			1	
22912	1		1	1			1	1	31104	1	1	1	1			1	1
23040	1		1	1		1			31232	1	1	1	1		1		
23168	1		1	1		1		1	31360	1	1	1	1		1		1
23296	1		1	1		1	1		31488	1	1	1	1		1	1	
23424	1		1	1		1	1	1	31616	1	1	1	1		1	1	1
23552	1		1	1	1				31744	1	1	1	1	1			
23680	1		1	1	1			1	31872	1	1	1	1	1			1
23808	1		1	1	1		1		32000	1	1	1	1	1		1	
23936	1		1	1	1		1	1	32128	1	1	1	1	1		1	1
24064	1		1	1	1	1			32256	1	1	1	1	1	1		
24192	1		1	1	1	1		1	32384	1	1	1	1	1	1		1
24320	1		1	1	1	1	1		32512	1	1	1	1	1	1	1	
24448	1		1	1	1	1	1	1	32640	1	1	1	1	1	1	1	1

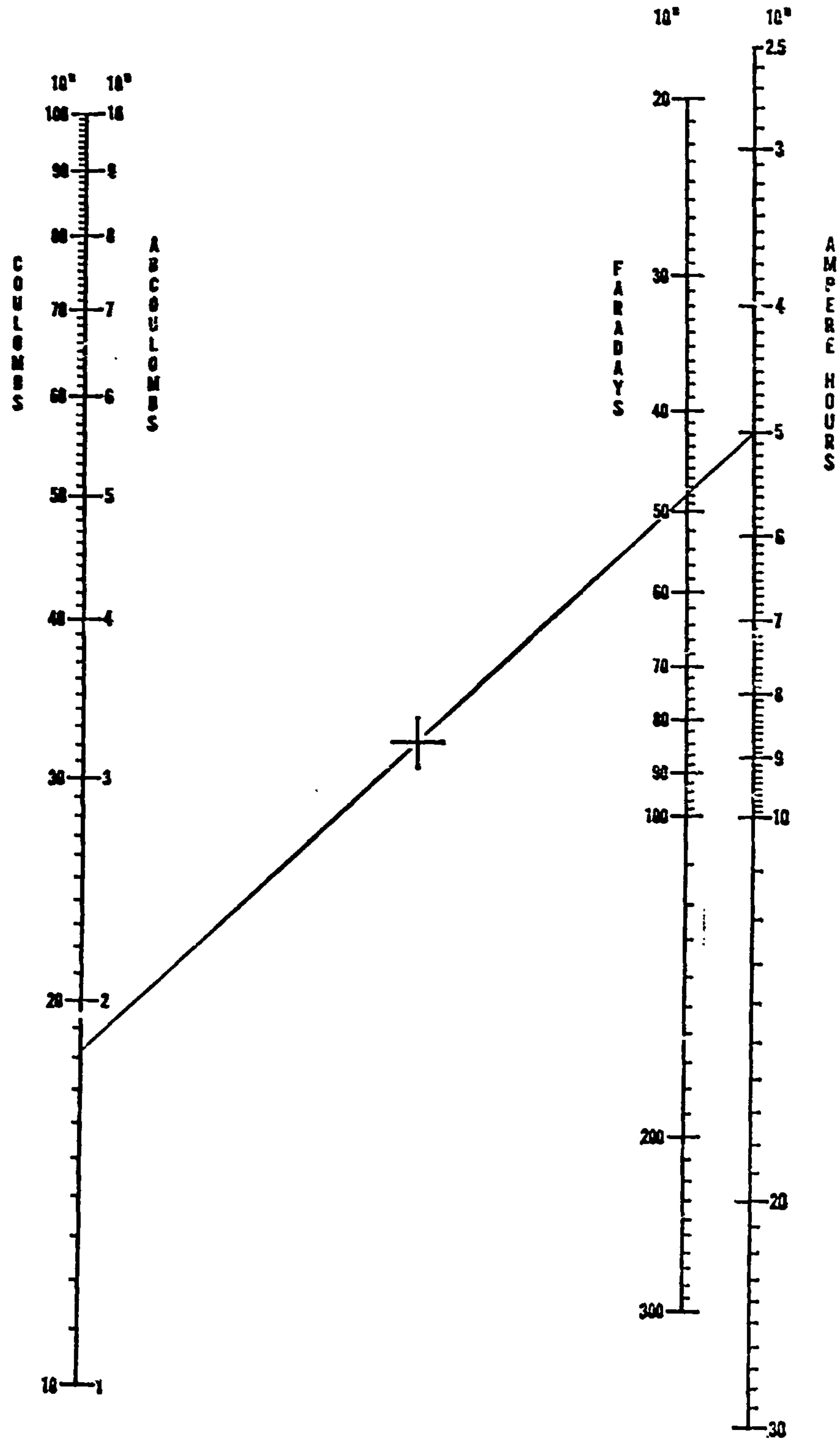
SECONDARY TABLE

DECIMAL	9	10	11	12	13	14	15	DECIMAL	9	10	11	12	13	14	15
000								064	1						
001							1	065	1						1
002						1		066	1					1	
003						1	1	067	1					1	1
004					1			068	1				1		
005					1		1	069	1				1		1
006					1	1		070	1				1	1	
007					1	1	1	071	1				1	1	1
008				1				072	1			1			
009				1			1	073	1			1			1
010				1		1		074	1			1		1	
011				1		1	1	075	1			1		1	1
012				1	1			076	1			1	1		
013				1	1		1	077	1			1	1		1
014				1	1	1		078	1			1	1	1	
015				1	1	1	1	079	1			1	1	1	1
016			1					080	1		1				
017			1				1	081	1		1				1
018			1			1		082	1		1			1	
019			1			1	1	083	1		1			1	1
020			1		1			084	1		1		1		
021			1		1		1	085	1		1		1		1
022			1		1	1		086	1		1		1	1	
023			1		1	1	1	087	1		1		1	1	1
024			1	1				088	1		1	1			
025			1	1			1	089	1		1	1			1
026			1	1		1		090	1		1	1		1	
027			1	1		1	1	091	1		1	1		1	1
028			1	1	1			092	1		1	1	1		
029			1	1	1		1	093	1		1	1	1		1
030			1	1	1	1		094	1		1	1	1	1	
031			1	1	1	1	1	095	1		1	1	1	1	1
032		1						096	1	1					
033		1					1	097	1	1					1
034		1				1		098	1	1				1	
035		1				1	1	099	1	1				1	1
036		1			1			100	1	1			1		
037		1			1		1	101	1	1			1		1
038		1			1	1		102	1	1			1	1	
039		1			1	1	1	103	1	1			1	1	1
040		1		1				104	1	1		1			
041		1		1			1	105	1	1		1			1
042		1		1		1		106	1	1		1		1	
043		1		1		1	1	107	1	1		1		1	1
044		1		1	1			108	1	1		1	1		
045		1		1	1		1	109	1	1		1	1		1
046		1		1	1	1		110	1	1		1	1	1	
047		1		1	1	1	1	111	1	1		1	1	1	1
048		1	1					112	1	1	1				
049		1	1				1	113	1	1	1				1
050		1	1			1		114	1	1	1			1	
051		1	1			1	1	115	1	1	1			1	1
052		1	1		1			116	1	1	1		1		
053		1	1		1		1	117	1	1	1		1		1
054		1	1		1	1		118	1	1	1		1	1	
055		1	1		1	1	1	119	1	1	1		1	1	1
056		1	1	1				120	1	1	1	1			
057		1	1	1			1	121	1	1	1	1			1
058		1	1	1		1		122	1	1	1	1		1	
059		1	1	1		1	1	123	1	1	1	1		1	1
060		1	1	1	1			124	1	1	1	1	1		
061		1	1	1	1		1	125	1	1	1	1	1		1
062		1	1	1	1	1		126	1	1	1	1	1	1	
063		1	1	1	1	1	1	127	1	1	1	1	1	1	1

Coulomb Conversion

This nomograph provides a simple method of conversion among the electrical quanti-·ᵉes: coulombs, abcoulombs, faradays and ampere-hours. It lessens the confusion that often arises in using these terms.

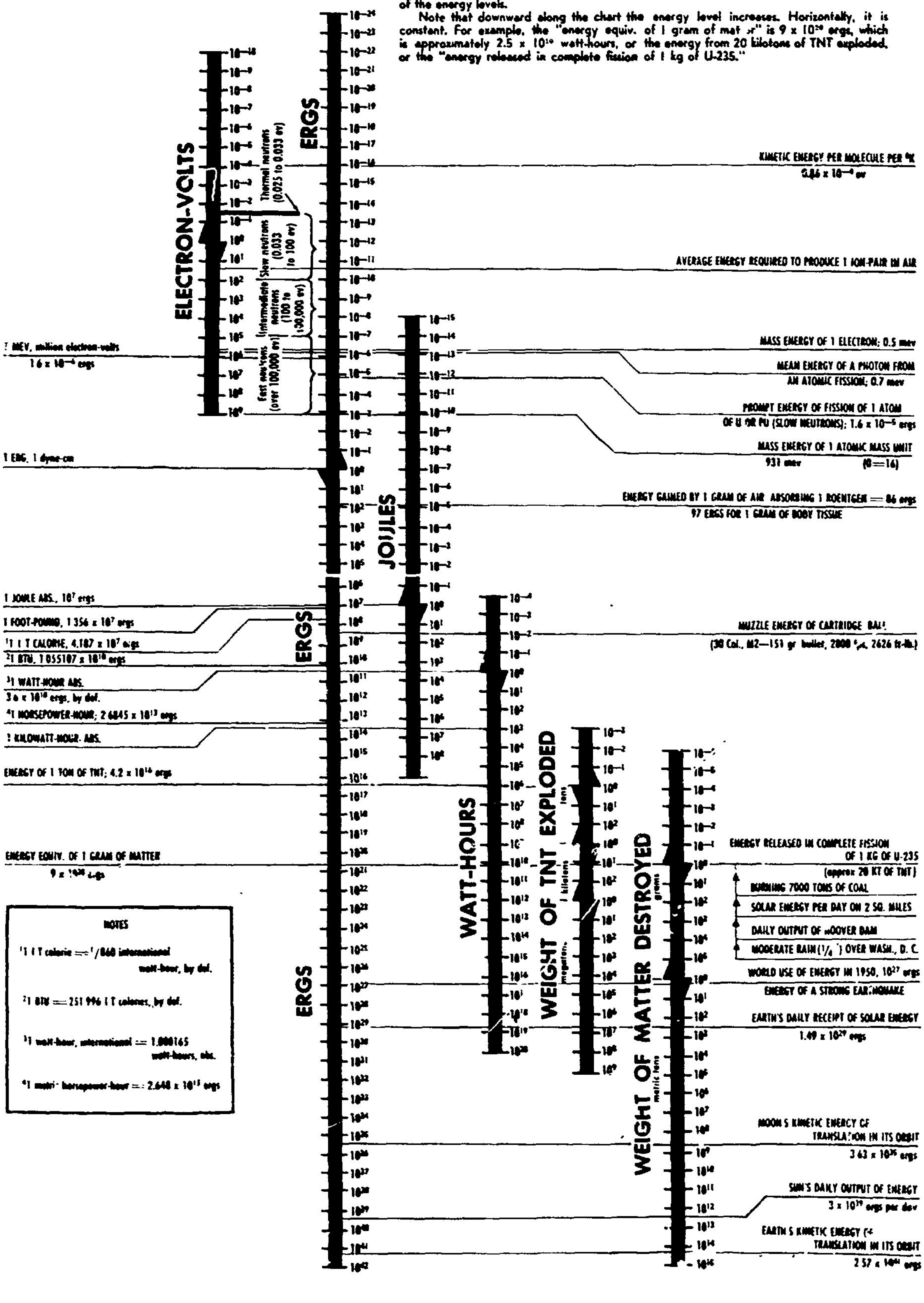
To use the nomograph, select the value in the known quantity, connect this with the pivot point to intersect other values. The decimal point should be adjusted (as indicated by the notation 10ⁿ) to allow entrance on the selected line. This value should be returned to the answer.



THE ENERGY LEVEL OF THINGS

OFTEN THE ENERGY UNITS used in one scientific field are not easily put into perspective by workers in another field. Thus, while certain units are utterly familiar to particular specialists, other units seem to exist only to confound. This chart has been designed to relate several commonly used units and to give "real life" benchmarks to a few of the energy levels.

Note that downward along the chart the energy level increases. Horizontally, it is constant. For example, the "energy equiv. of 1 gram of matter" is 9×10^{20} ergs, which is approximately 2.5×10^{10} watt-hours, or the energy from 20 kilotons of TNT exploded, or the "energy released in complete fission of 1 kg of U-235."



Energy Conversion Chart

In the design of systems where the engineer must deal with energy in several forms, it is necessary to be familiar with the various expressions of energy and their measurement. Energy sources must be well known, as well as their energy content. The accompanying chart, by presenting several energy forms and sources together, helps in this respect. Energy or power may be converted from one form to another by merely drawing a horizontal line between vertical columns. Conversion efficiencies may be taken into account by using the nomogram at the right.

Example:

Desired:—a gasoline-driven motor generator with an output of 2.5 kw.

How many horsepower will be required and how many gallons of gasoline will be consumed under full load conditions?

Assume that conversion efficiencies are:

1. Gasoline to mechanical = 15 percent
2. Mechanical to electrical = 85 percent

Solution: (Use chart with magazine turned sideways.)

Step 1. From 2.5 kw on curve 11, draw a horizontal line to the right intersecting curve 16 at about 3.4 hp.

Step 2. From 85 percent on curve 18, draw a line through 3.4 hp on curve 17, intersecting curve 16 at 3.8 hp. This is the required hp.

Step 3. From 15 percent on curve 18, draw a line through 3.8 on curve 17, intersecting curve 16 at 25.2 hp.

Step 4. From 25.2 on curve 16, draw a horizontal line to the left intersecting curve 9 at 0.5 gallons per hour.

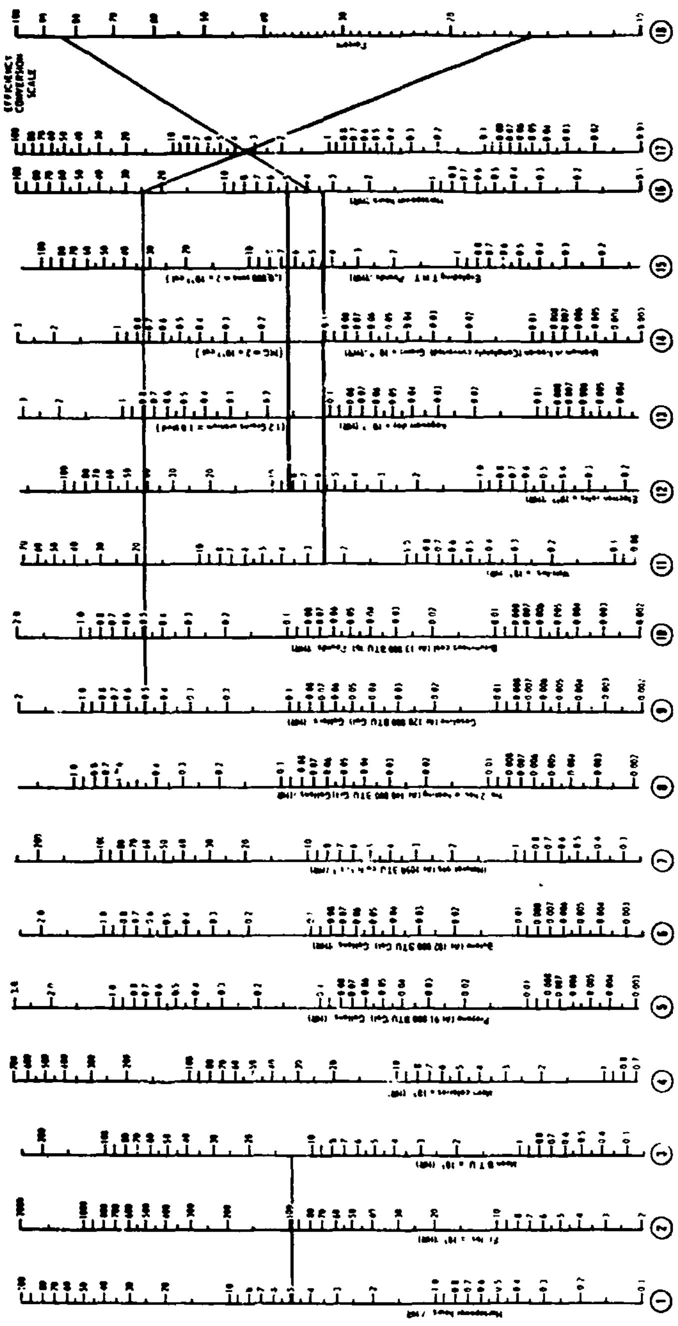
Desired: Equivalent of 5 hp in terms of electron volts: From 5 on curve 1 (or 16) proceed horizontally to intersect curve 12 at 8.3 (10[illegible]) electron volts.

Desired: 5 hp hours to Btu.

From 5 on curve 1 (or 16) proceed to 13 (10[illegible]) on curve 3.

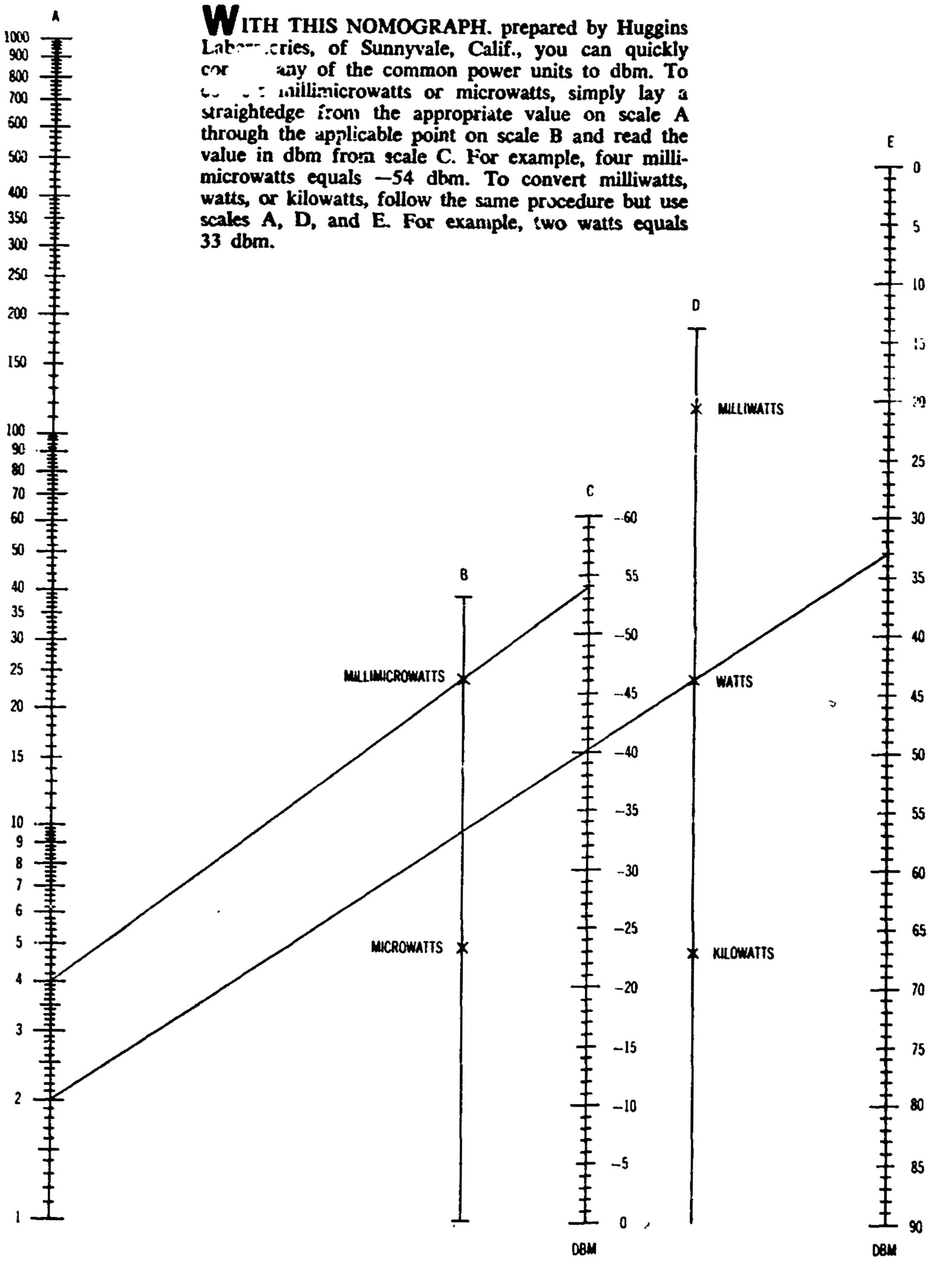
Note: Power is expressed in terms of energy notation per hour. To express energy, then, merely eliminate the "(hr)" notation.

The basic formula for each vertical column is indicated thereon. The information for columns 1, 2, 3, 4, and 11 was derived from standard physics texts. Information for the other columns was obtained from the Esso Standard Oil Company, Boston, Mass., the Boston Gas Company, the C. H. Sprague & Son Company, Boston, Mass., the "Smyth Report on Atomic Energy" published by Princeton University Press, from "Operations Research, Armament, Launching," by Merrill, Goldberg, Helmholz; published by D. Van Nostrand Company, and the Blaw-Knox Company, Inc., Pittsburgh, Pa. Nuclear energy is based on complete fission of uranium.



Power unit conversion

WITH THIS NOMOGRAPH, prepared by Huggins Laboratories, of Sunnyvale, Calif., you can quickly convert any of the common power units to dbm. To convert millimicrowatts or microwatts, simply lay a straightedge from the appropriate value on scale A through the applicable point on scale B and read the value in dbm from scale C. For example, four millimicrowatts equals —54 dbm. To convert milliwatts, watts, or kilowatts, follow the same procedure but use scales A, D, and E. For example, two watts equals 33 dbm.



Torque Conversion Charts

Here is a family of charts relating the various methods of measuring torque. It should prove especially valuable when having to convert from one system of units to another.

FOOT-POUNDS	INCH-OUNCES	INCH-GRAMS	INCH-POUNDS	CENTIMETER-KILOGRAMS	METER-KILOGRAMS
–	0.25	7.09	–	–	–
–	0.5	14.17	–	–	–
–	0.75	21.26	–	–	–
–	1.0	28.35	0.062	–	–
0.0208	4.0	113.40	0.25	–	–
0.0416	8.0	226.80	0.5	–	–
0.083	16.0	453.60	1.0	1.15	0.011
0.5	96.0	2721.60	6.0	6.91	0.069
1.0	192.00	5443.20	12.0	13.82	0.138
2.0	384.0	10886.40	24.0	27.65	0.276
3.0	576.0	16329.60	36.0	41.47	0.415
4.0	768.0	21772.80	48.0	55.30	0.553
5.0	960.0	27216.00	60.0	69.20	0.692
6.0	–	–	72.0	82.95	0.829
7.0	–	–	84.0	96.77	0.967
8.0	–	–	96.0	110.60	1.106
9.0	–	–	108.0	124.42	1.244
10.0	–	–	120.0	138.25	1.382

TO CONVERT: INCH-GRAMS

TO	MULTIPLY BY
Inch-ounces	0.03527
Inch-pounds	2.205(10^-3)
Foot-pounds	1.8376(10^-4)
Centimeter-kilograms	2.54(10^-3)
Meter-kilograms	2.54(10^-5)

TO CONVERT: INCH-OUNCES

TO	MULTIPLY BY
Inch-grams	28.3495
Inch-pounds	0.0625
Foot-pounds	5.2087(10^-3)
Centimeter-kilograms	72.808(10^-3)
Meter-kilograms	728.08(10^-6)

TO CONVERT: INCH-POUNDS

TO	MULTIPLY BY
Inch-grams	435.5924
Inch-ounces	16.0
Foot-pounds	0.08334
Centimeter-kilograms	1.152
Meter-kilograms	1.152(10^-2)

TO CONVERT: FOOT-POUNDS

TO	MULTIPLY BY
Inch-grams	5443.1088
Inch-ounces	192.0
Inch-pounds	12.0
Centimeter-kilograms	13.8257
Meter-kilograms	0.138257

TO CONVERT: CENTIMETER-KILOGRAMS

TO	MULTIPLY BY
Inch-grams	393.7
Inch-ounces	13.8858
Inch-pounds	85.8108(10^-2)
Foot-pounds	72.346(10^-3)
Meter-kilograms	0.01

TO CONVERT: METER-KILOGRAMS

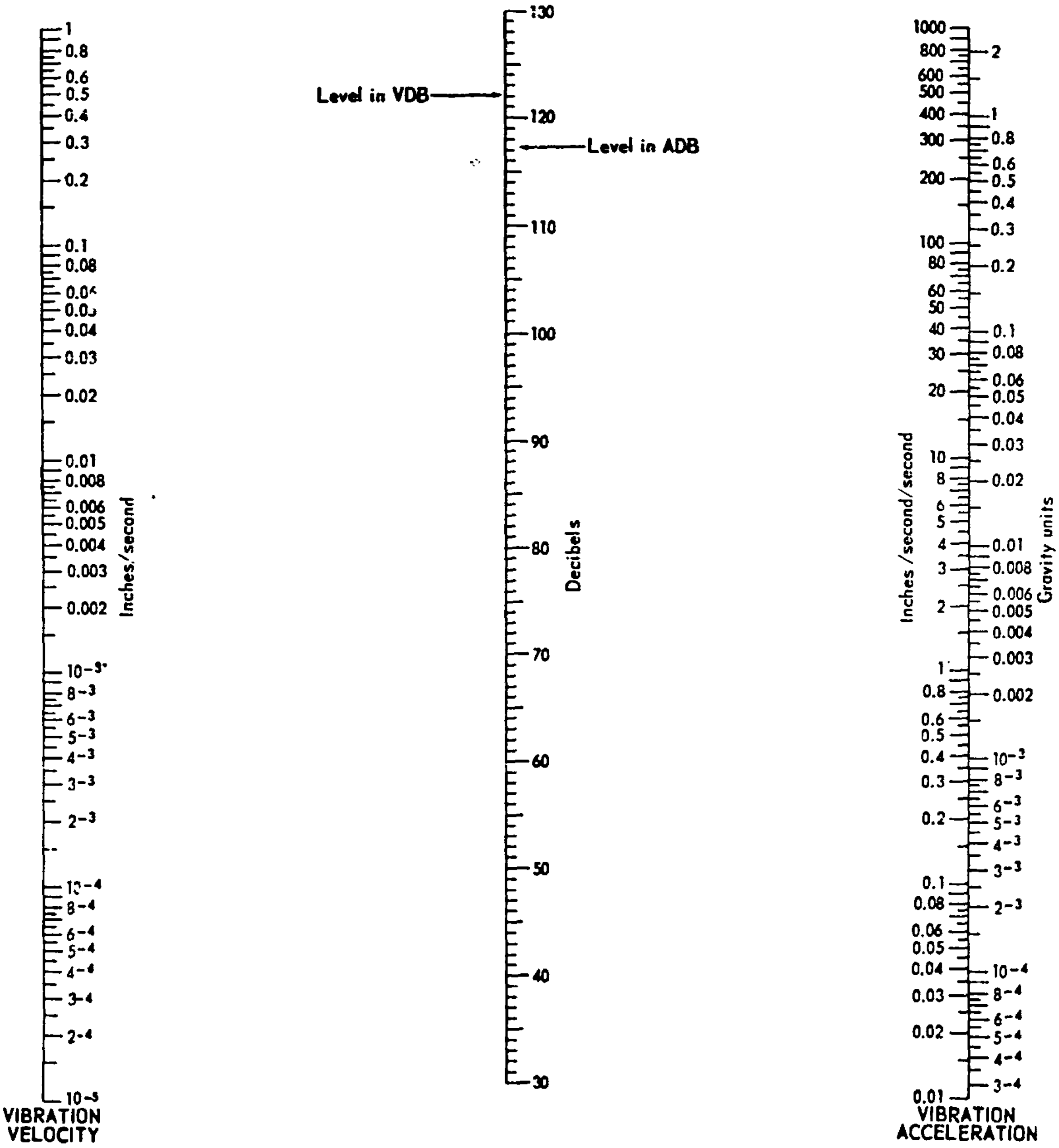
TO	MULTIPLY BY
Inch-grams	39370.0
Inch-ounces	1388.58
Inch-pounds	85.8108
Foot-pounds	7.2346
Centimeter-kilograms	100.0

Conversion Chart for Vibration Velocity Level And Vibration Acceleration Level

In the field of vibration (or structure-borne sound), it is in general practice to express and measure vibration levels in terms of the decibel. This quantity has always been employed in the field of air-borne sound. The standard expression for the measurement of air-borne sound is the sound pressure level (SPL) and is measured in "db".

Vibration velocity levels expressed in inches/second and vibration acceleration levels expressed in inches/second² are expressed conveniently as "vdb", velocity decibels (re 10^{-6} cm/sec), and "adb", acceleration decibels (re 10^{-3} cm/sec²), respectively.

The accompanying chart permits conversion of vibration level to either system.



CONVERSION TABLE - UNITS OF LUMINANCE

		Nit	Stilb	BOUGIE HECTOMÈTRE CARRÉ	Apostilb	Milli-apostilb	Micro-apostilb	Lambert	Milli-lambert	Micro-lambert	Foot-lambert	Candle Per Sq. ft.	Candle Per Sq. Inch
1 Nit = (nt)	$\frac{1\ \text{Candela}}{m^2}$ =	1	10^{-4}	10^{4}	3.14	3.14×10^{3}	3.14×10^{6}	3.14×10^{-4}	3.14×10^{-1}	3.14×10^{2}	2.919×10^{-1}	9.29×10^{-2}	6.452×10^{-4}
1 Stilb = (sb)	$\frac{1\ \text{Candela}}{cm^2}$ =	10^{4}	1	10^{8}	3.14×10^{4}	3.14×10^{7}	3.14×10^{10}	3.14	3.14×10^{3}	3.14×10^{6}	2.919×10^{3}	9.29×10^{2}	6.452
1 Bougie = Hectomètre Carré	$\frac{1\ \text{Candela}}{(100m)^2}$ =	10^{-4}	10^{-8}	1	3.14×10^{-4}	3.14×10^{-1}	3.14×10^{2}	3.14×10^{-8}	3.14×10^{-5}	3.14×10^{-2}	2.919×10^{-5}	9.29×10^{-6}	6.452×10^{-8}
1 Apostilb = (asb)	$\frac{1\ \text{Candela}}{\pi\times m^2}$ =	3.183×10^{-1}	3.183×10^{-5}	3.183×10^{3}	1	10^{3}	10^{6}	10^{-4}	10^{-1}	10^{2}	9.29×10^{-2}	2.957×10^{-2}	2.054×10^{-4}
1 Milli-apostilb = (masb)	$\frac{1\ \text{Candela}}{\pi\times1000\times m^2}$ =	3.183×10^{-4}	3.183×10^{-8}	3.183	10^{-3}	1	10^{3}	10^{-7}	10^{-4}	10^{-1}	9.29×10^{-5}	2.957×10^{-5}	2.054×10^{-7}
1 Micro-apostilb = (μ asb)	$\frac{1\ \text{Candela}}{\pi\times10^6\times m^2}$ =	3.183×10^{-7}	3.183×10^{-11}	3.183×10^{-3}	10^{-6}	10^{-3}	1	10^{-10}	10^{-7}	10^{-4}	9.29×10^{-8}	2.957×10^{-8}	2.054×10^{-10}
1 Lambert = (L)	$\frac{1\ \text{Candela}}{\pi\times cm^2}$ =	3.183×10^{3}	3.183×10^{-1}	3.183×10^{7}	10^{4}	10^{7}	10^{10}	1	10^{3}	10^{6}	9.29×10^{2}	2.957×10^{2}	2.054
1 Milli-lambert = (mL)	$\frac{1\ \text{Candela}}{\pi\times10^3\times cm^2}$ =	3.183	3.183×10^{-4}	3.183×10^{4}	10	10^{4}	10^{7}	10^{-3}	1	10^{3}	9.29×10^{-1}	2.957×10^{-1}	2.054×10^{-3}
1 Micro-lambert = (μL)	$\frac{1\ \text{Candela}}{\pi\times10^6\times cm^2}$ =	3.183×10^{-3}	3.183×10^{-7}	3.183×10	10^{-2}	10	10^{4}	10^{-6}	10^{-3}	1	9.29×10^{-4}	2.957×10^{-4}	2.054×10^{-6}
1 Foot-lambert = (ftL)	$\frac{1\ \text{Candela}}{\pi\times ft^2}$ =	3.426	3.426×10^{-4}	3.426×10^{4}	10.764	1.0764×10^{4}	1.0764×10^{7}	1.0764×10^{-3}	1.0764	1.0764×10^{3}	1	0.3183	2.14×10^{-3}
1 Candle Per Sq. ft. =	$\frac{1\ \text{Candela}}{ft^2}$ =	1.0764×10	1.0764×10^{-3}	1.0764×10^{5}	3.382×10	3.382×10^{4}	3.382×10^{7}	3.382×10^{-3}	3.382	3.382×10^{3}	3.14	1	6.944×10^{-3}
1 Candle Per Sq. Inch =	$\frac{1\ \text{Candela}}{inch^2}$ =	1.55×10^{3}	1.55×10^{-1}	1.55×10^{-5}	4.869×10^{3}	4.869×10^{6}	4.869×10^{9}	4.869×10^{-1}	4.869×10^{2}	4.869×10^{5}	4.524×10^{2}	1.44×10^{2}	1

Section 3

GRAPHIC SYMBOLS

Section 3

TECHNICAL AND GRAPHIC SYMBOLS

Included in this section are written and graphic symbols from such fields as mathematics, time-motion analysis, process analysis, functional analysis, computer processing and flow charting, electricity, air conditioning, architectural wiring symbology, and so forth.

Due to the practical impossibility of including the literally thousands of symbols used in the many related scientific and engineering disciplines with which the human factors engineer may have occasion to work, recommended standards from the USA Standards Institute's 1969 Catalog have been listed for the reader's reference. A quick comparison of several of these standards will convince the reader that the same notational symbols (principally the English and Greek alphabets with various subscripts and superscripts) are employed in several disciplines with unique meanings in each case. It is important, therefore, that such symbols be used in the proper context if their meanings are to be relevant to the subject being discussed.

Also, such graphic symbols as those used in the fields of electricity and electronics tend to vary slightly from source to source. Thus, electronic graphic symbols required by certain military specifications may not be exactly similar to those shown in the corresponding USA Standard, although these differences are tending to diminish as time passes. Nevertheless, the user should be alert to the need for selecting the proper reference source for the graphics required under any specific contract.

The USA Standards Catalog is available from:

USA Standards Institute
10 East 40th Street
New York, New York 10016

RECOMMENDED USA STANDARDS
(Available from USA Standards Institute)

Acoustics

S1.1-1960 - Acoustical Terminology
Y10.11-1953 - Acoustics, Letter Symbols for

Aeronautics

Y10.7-1954 - Aeronautical Sciences, Letter Symbols for

Colorimetry

Z58.1.2-1952 - Colorimetry, Nomenclature and Definitions in the Field of

Communications

C42.65-1957 - Communications

Drawings

Z32.13-1950 - Abbreviations for Use on Drawings

Electrical/Electronics

Y32.2-1967 - Graphic Symbols for Electrical/Electronics Diagrams
C83.37-1968 - Chassis Wiring, Color Coding of (EIA RS 336-April 1967)
Y10.5-1968 - Quantities Used in Electrical Science and Electrical Engineering, Letter Symbols for
Y10-19-1967 - Units Used in Electrical Science and Electrical Engineering, Symbols for

Engineering, General

Z10.1-1941 - Abbreviations for Scientific and Engineering Terms
Y10.17-1961 - Selecting Greek Letters Used as Letter Symbols for Engineering Mathematics, Guide for

Flow Charting

X3.5-1968 - Flowchart Symbols and Their Useage in Information Processing

Heat/Thermodynamics/Plumbing

A13.1-1956 - Identification of Piping Systems, Scheme for
Y10.4-1957 - Heat and Thermodynamics, Letter Symbols for

Hydraulics

Y10.2-1958	- Hydraulics, Letter Symbols for

Illumination

C42.55-1956	- Illuminating Engineering
D12.1-1963	- Roadway Lighting, Practice for
Y10.18-1967	- Letter Symbols for Illuminating Engineering
Z7.1-1967	- Illuminating Engineering, Nomenclature and Definitions for

Information Processing/Intelligibility

S3.2-1960	- Monosyllabic Word Intelligibility, Method for Measurement of
X3.12-1966	- Information Processing, Vocabulary for

Keyboards

X4.6-1966	- 10-Key Keyboard for Adding and Calculating Machines
X4.7-1966	- Typewriter Keyboards

Meteorology

Y10.10-1953	- Meteorology, Letter Symbols for

Physics

Z10.6-1948	- Physics, Letter Symbols for

Safety

Z2.1-1959	- Head, Eye and Respiratory Protection, Safety Code for
Z35.1-1968	- Accident Prevention Signs, Specifications for
Z53.1-1967	- Marking Physical Hazards and the Identification of Certain Equipment, Safety Color Code for

Traffic Control

D6.1-1961	- Manual on Uniform Traffic Control Devices for Streets and Highways

Transportation

C42.41-1956	- Transportation - Air
C42.42-1956	- Transportation - Land
C42.43-1956	- Transportation - Marine

MILITARY STANDARDS

AMRL-TR-66-115	-	Standardization of Symbols and Units for Environmental Research. W.C. Kaufman, August 1966, WPAFB, Ohio - AFSC Aerospace Medical Division
MIL-STF-12	-	Abbreviations for Use on Drawings and in Technical-Type Publications
MIL-STD-14	-	Architectural Symbols
MIL-STD-15	-	I Graphical Symbols for Electrical and Electronic Diagrams II Electrical Wiring Equipment Symbols for Ships Plans III Electrical Wiring Symbols for Architectural and Electrical Layout Drawings
MIL-STD-16	-	Electrical and Electronic Reference Designations
MIL-STD-17	-	Mechanical Symbols
MIL-STD-18	-	Structural Symbols
MIL-STD-23	-	Nondestructive Testing Symbols
MIL-STD-101	-	Color Code for Pipelines and for Compressed Gas Cylinders
MIL-STD-106	-	Mathematical Symbols
MIL-STD-783	-	Nomenclature and Abbreviations in Aircrew Stations
MIL-STD-1247	-	Identification of Pipe, Hose, and Tube Lines for Aircraft, Missile, and Space Systems
MS-33558	-	Numeral and Letter, Aircraft Instrument Dial, Standard Form of

ARITHMETIC AND ALGEBRA

GENERAL. By convention, the first few lower case letters of the Roman alphabet (a, b, c, . . .) are generally used to denote constant terms or coefficients and the last few letters of the Roman alphabet (. . . x, y, z) are generally used to indicate variables. Greek letters usually indicate specific constants except α, β, θ, and ϕ are commonly used to designate angles. To simplify complicated expressions containing numerous or often repeated terms, the substitution of a single capital Roman letter for a single factor is recommended; thus, the term (b^2-4ac) may be replaced by D where $D=b^2-4ac$.

$+$	Addition, positive value, underestimation, approach through positive values.
$-$	Subtraction, negative value, overestimation, approach through negative values.
$\pm$	Add or subtract plus or minus value.
$\mp$	Used where $\pm$ has appeared previously as in $(a\pm b)$ $(a^2\mp ab\pm b^2)=a^3\pm b^3$ upper signs are to be taken throughout or else lower signs.
$\cdot$	Multiplication (dot centered) ($\times$ used in arithmetic).
( )	Parenthesis; for grouping.
[ ]	Brackets; for grouping.
{ }	Braces; for grouping.
$\overline{\ }$ (superscript)	Vinculum; for grouping.
%	Percent; per hundred
/	Solidus; indicating division (preferred for running text).
—	Horizontal rule, indicating division; fraction line.
$\div$	Division sign; used chiefly in arithmetic (should be replaced by solidus when convenient).
:	Ratio (in proportion).
::	Equals (in proportion).
$=$	Equivalent sign; is equal to.
$\neq$	(IS) not equal (TO).
$\approx$	(IS) approximately equal (TO).
$\equiv$	(IS) identical with; (IS) identically equal (TO).
$\equiv_x$	Indicates identity with all values of x for which both terms are defined.
$<$	(IS) less than.
$\ll$	(IS) much less than.
$\leqq$ or $\leq$ or $\ngtr$	Equal to or less than; not greater than.

$>$	(IS) greater than.
$>>$	(IS) much greater than.
$\geqq$ or $\geq$	Greater than or equal to; not less than.
$\propto$	Varies directly as.
$N!$	Factorial; continued product of all integral numbers from 1 to N, where N is an integral number.
^{n} (superscript numbers or letters)	Exponent; raised to the power of degree n (exponent indicates number of iterations).
$\sqrt[n]{\ }$	Radical sign; superscript n indicates index of degree of root. Index omitted in case of square root.
$^{m/n}$ (superscript)	Fractional index; . . . raised to power of degree m/n.
$^{-n}$ (superscript)	Negative exponent; changes the term to its reciprocal.
$\exp f(x, y, \ldots)$	Functional symbol; exponential function.
$\exp u$	Functional symbol; exponential u.
i or j	Imaginary unit; j operator. $\sqrt{-1}$
$a \cdot 10^n$	Scientific notation; notation by powers of 10.
.	Decimal point (placed on line). Separates whole numbers from numerators of decimal fractions or is placed to the left of the numerator of a decimal fraction.
∞	Infinity symbol; algebraic number positively or negatively larger than any other number.
$\rightarrow$	Arrow, approaches as a limit.
$'$ (superscript)	Prime; notational method of distinguishing between differing variables and constants.
$''$ (superscript)	Double prime; notational method of distinguishing between differing variables and constants.
$'''$ (superscript)	Triple prime, notational method of distinguishing between differing variables and constants.
. . .	Three dots; dots of omission, meaning "and so forth."
$\log_a X$	Logarithm of X to base a.
$\log X$	Logarithm of X to base 10. (common system of logarithms).
$\ln X$	Logarithm of X to base e (Naperian system or Natural Logarithm).
e	Base of Naperian (natural) Logarithms (2.7182—).
$P(n, r)$	Permutations of n things taken r at a time.
$C(n, r)$	Combinations of n things taken r at a time.
$\vert\ \vert$	Vertical bars; indicates absolute value of the quantity inside the bars; vector magnitude; determinant.
$\Vert\ \Vert$	Double vertical bars; indicates a matrix; set of quantities written in specific order of rows and columns.
a_{ij}	Element in row i, column j of determinant or matrix.
$\det(a_{ij})$	Determinant with elements a_{ij} (or determinant of matrix (a_{ij})).
space or half-space	Used, instead of commas, to separate convenient groups of digits.
subscript number or letter	Notational method of indicating differing values in a set or series.

ELEMENTARY GEOMETRY

∠, ∡	Angle(s).
⊥, ⊥ₛ	Perpendicular(s); perpendicular to.
∥, ∥ₛ	Parallel(s), parallel to.
△, △ₛ	Triangle(s).
○, ○ₛ	Circle(s).
▱, ▱ₛ	Parallelogram(s).
□, □ₛ	Squares(s). Do not use symbols for any other types of polygon.
⏢, ⏢ₛ	Trapezoid(s).
$\cong$	(IS) congruent (TO).
$\sim$	(IS) similar (TO).
$\veebar$	(IS) equiangular.
$\therefore$	Three dots; hence therefore.
$\overline{AB}$	Vinculum; chord AB of a circle; length of line segment between A and B.
$\overleftarrow{AB}$	Directed segment B to A.
$\overset{\frown}{AB}$	Arc AB of a circle.
π	Pi; constant ratio of circumference of a circle to its diameter.

ANALYTIC GEOMETRY

x, y, z	Rectangular (Cartesian) coordinates of a point in space.
x, y	Rectangular coordinates of a point in a plane.
α	Alpha; indicates direction angle with x-axis.
l	Indicates directional cosine (with x axis).
β	Beta; indicates direction angle with y-axis.
m	Indicates directional cosine (with y-axis).
γ	Gamma; indicates direction angle with z-axis.
n	Indicates directional cosine (with z-axis).
r, θ, ϕ	Spherical coordinates of a point in space.
r, θ	Polar coordinates of a point in a plane.
ψ	Psi; indicates angle from radius vector to tangent of plane curve.
r, θ, z	Cylindrical coordinates of a point in space.
p, s	Indicates intrinsic coordinates.
e	Eccentricity of a conic.
p	Semi-latus rectum.
m	Slope of a curve or line.
C	Circumference of a circle.
r	Radius of a circle.
D	Diameter of a circle.
ρ	Radius of curvature.
d	Perpendicular distance from a point to a line (length of normal).

TRIGONOMETRY

$^\circ$ (superscript)	Indicates degree(s).
θ	Angle measured in radians.
$'$ (superscript)	Prime, indicates minutes.
$''$ (superscript)	Double prime; indicates seconds.
sin	Sine of angle.
cos	Cosine of angle.
tan	Tangent of angle.
cot	Cotangent of angle.
sec	Secant of angle.
csc	Cosecant of angle.
vers	Versed sine of angle. $1-\cos\theta$.
covers	Coversed sine of angle.
hav	Haversine of angle. $\frac{1}{2}(1-\cos\theta)$.
cis θ	$\cos\theta + 1 \sin\theta$.
arc sin or $\sin^{-1}$	Inverse sine (of); angle whose sine is.
arc cos or $\cos^{-1}$	Inverse cosine (of); angle whose cosine is.
$[\sin f(x)]^n$	The n^{th} power (of).

HYPERBOLIC FUNCTIONS

sinh	Hyperbolic sine.
cosh	Hyperbolic cosine, etc.
arc sinh or $\sinh^{-1}$	Inverse hyperbolic function (of); angle whose hyperbolic sine is.
arc cosh or $\cosh^{-1}$	Inverse hyperbolic function (of) angle whose hyperbolic cosine is etc.
$[\sinh f(x)]^n$	n^{th} power (of).
$[\cosh f(x)]^n$	n^{th} power (of) etc.

CALCULUS

d	Differential operator.
d^n	Differential operator of n^{th} order.
$\frac{d}{dx}$	Derivitive operator of first order.
$\frac{d^n}{dx}$	Derivitive operator of n^{th} order.
∂	Curly d; indicates partial differentiation.
D	Differential operator.
D^n	Differential operator of n^{th} order.
$\dot{x}, \ddot{x}$	Indicates first and second derivatives with respect to time (Newton's notation).
d^ny/dx^n	Derivitive of n^{th} order.
$''$ (superscript)	Double prime, order of differentiation.
$'''$ (superscript)	Triple prime; order of differentiation.

$\int, \int\int, \int\int\int$	Integral signs.
$\int_{i}^{}, \int_{a}^{b}, \int_{a}^{b}, \int_{a}^{b}$	Integral signs; indicating index and limits.
$\oint$	The integral around a closed path.
Δ	Delta; indicates increment.
$\sum_{i}$	Sigma; indicates summation; sum of terms of index i.

SPECIAL FUNCTIONS

$J_0(x)$, $J_1(x)$, $J_n(x)$.	Bessel F... the notation recommended is G. N. Watson's Treatise, 1922, as ... by E. P. Adams in the Smithsonia Tables, 1922.
$B_1, B_2, B_3, \ldots$ $B_1, B_2, B_3, \ldots$	Berno... and polynomials.
γ	Gamma: Euler's (Mascheronis) constant. (0.5772—)
$\Gamma(x) = \int_0^\infty x^{n-1} e^{-x}\,dx$	The Gamma function of the positive number n. Also called the factorial function
$B(m, n) = \int_0^1 x^{m-1} (1-x)^{n-1}\,dx$	The Beta function of any two positive numbers m and n.
$\Gamma x^{(n-1)} = \int_0^x x^n e^{-x}\,dx$	The incomplete Gamma function.
$B_x(m, n) = \int_0^x x^{m-1} (1-x)^{n-1}\,dx$	The incomplete Beta function.

VECTOR ANALYSIS

$\bar{i}, \bar{j}, \bar{k}$	Vectors of unit magnitude.
$\bar{A}\cdot\bar{B}$	Scalar product (dot product) of two vectors.
$\bar{A}\times\bar{B}$	The vector product (cross product) of two vectors.
$A\angle\theta$	Indicates the vector $\bar{A}=a\bar{i}+b\bar{j}$ (or) $\bar{i}a+\bar{j}b$, where $a=\lvert\bar{A}\rvert\cos\theta$, $b=\lvert\bar{A}\rvert\sin\theta$, $\theta=\arctan b/a$, and $\lvert\bar{A}\rvert=(a^2+b^2)^{\frac{1}{2}}$
∇	Del; differential operator. $\bar{i}\frac{\partial}{\partial_x}+\bar{j}\frac{\partial}{\partial_y}+\bar{k}\frac{\partial}{\partial_z}$

THERBLIGS					
SYMBOL	NAME	COLOR	SYMBOL	NAME	COLOR
	SEARCH	BLACK		INSPECT	BURNT OCHRE
	FIND	GREY		PRE-POSITION	SKY BLUE
	SELECT	LIGHT GREY		RELEASE LOAD	CARMINE RED
	GRASP	LAKE RED		TRANSPORT EMPTY	OLIVE GREEN
	TRANSPORT LOADED	GREEN		HOLD	GOLD OCHRE
9	POSITION	BLUE		REST FOR OVER-COMING FATIGUE	ORANGE
#	ASSEMBLE	VIOLET		UNAVOIDABLE DELAY	YELLOW OCHRE
U	USE	PURPLE		AVOIDABLE DELAY	LEMON YELLOW
	DISASSEMBLE	LIGHT VIOLET		PLAN	BROWN

Therblig symbols and colors.

ACTIVITIES DEFINED

Operation. An operation occurs when an object is intentionally changed in any of its physical or chemical characteristics, is assembled or disassembled from another object, or is arranged for another operation, transportation, inspection, or storage. An operation also occurs when information is given or received or when planning or calculating takes place.

Transportation. A transportation occurs when an object is moved from one place to another, except when such movements are a part of the operation or are caused by the operator at the work station during an operation or an inspection.

Inspection. An inspection occurs when an object is examined for identification or is verified for quality or quantity in any of its characteristics.

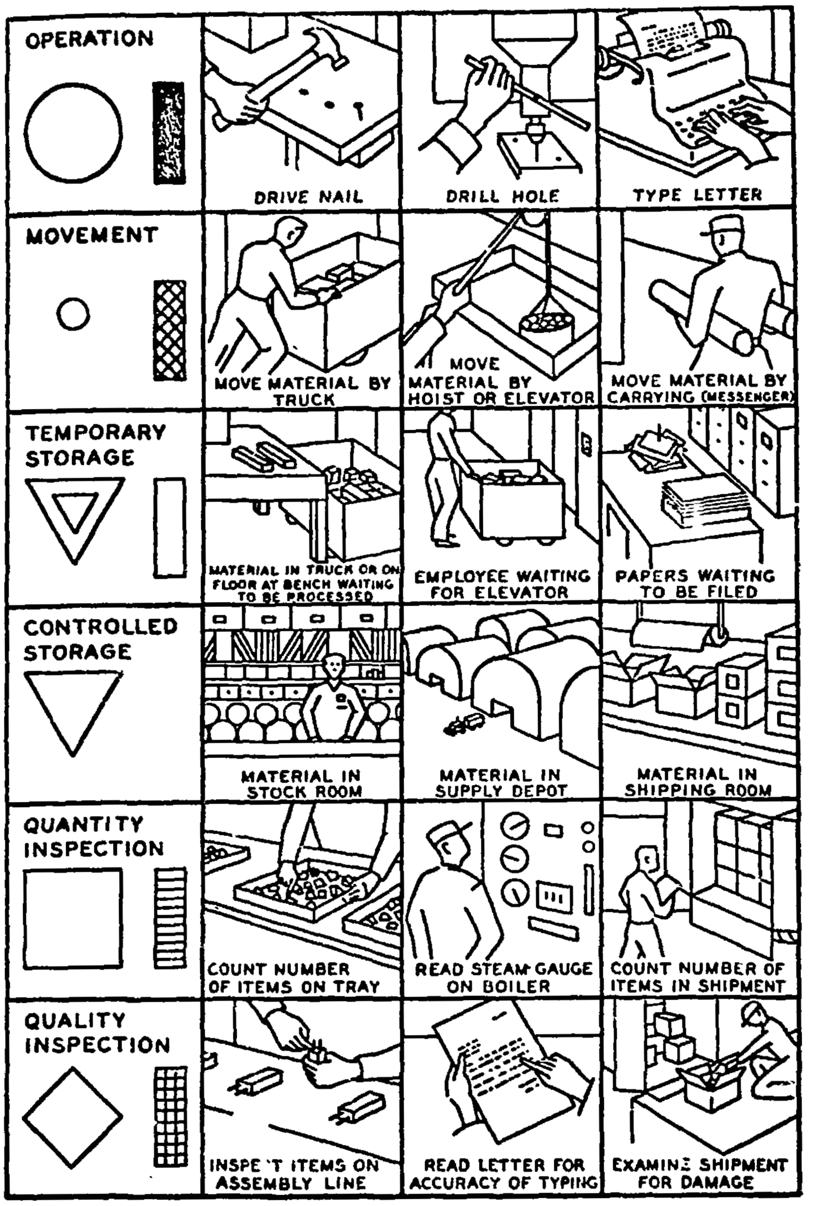
Delay. A delay occurs to an object when conditions, except those which intentionally change the physical or chemical characteristics of the object, do not permit or require immediate performance of the next planned action.

Storage. A storage occurs when an object is kept and protected against unauthorized removal.

Combined Activity. When it is desired to show activities performed either concurrently or by the same operator at the same work station, the symbols [illegible] those activities are combined, as shown by the circle placed within the [illegible] to represent a combined operation and inspection.

[illegible] outside the range of the definitions are encountered, the [illegible] summarized in the following tabulation will enable the analyst [illegible]ications.

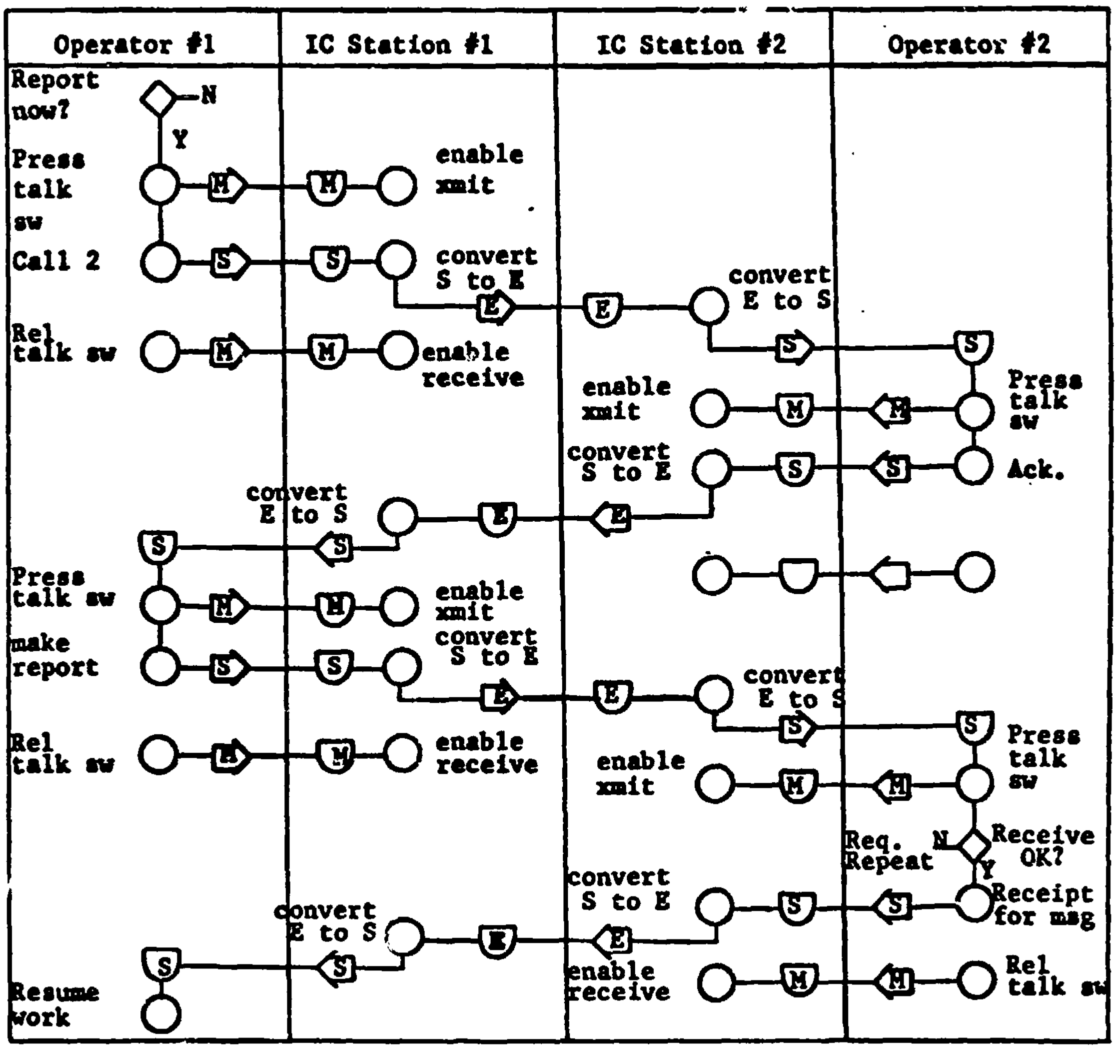
[illegible]	*Predominant Result*
[illegible]	Produces or accomplishes
[illegible]tion	Moves
[illegible]	Verifies
[illegible]	Interferes
[illegible]	Keeps



Process Analysis Basic Symbols

TYPICAL OPERATIONAL SEQUENCE DIAGRAM

MIL-H-46855



<u>**Notes on Operational Sequence Diagram**</u>

Symbols

- ◇ Decision
- ○ Operation
- Transmission
- Receipt
- D Delay
- □ Inspect, Monitor
- ▽ Store

Links

- M mechanical or manual
- E electrical
- V visual
- S sound

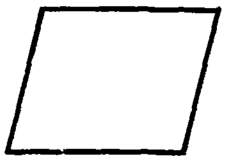
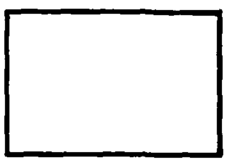
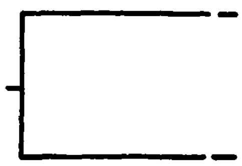
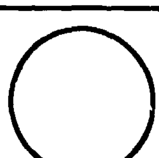
etc.

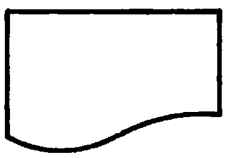
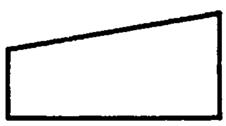
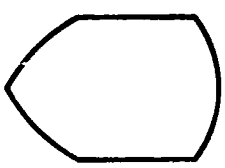
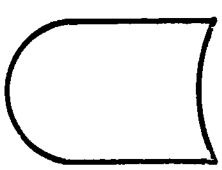
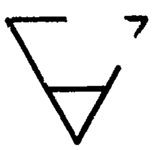
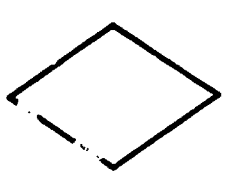
Stations or subsystems are shown by columns
Sequential time progresses down the page

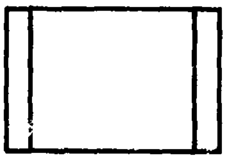
COMPUTER GRAPHICS AND NOTATIONS

NOTATIONS	MEANING
:	Is compared with
$=$	Equal to
$\neq$	Unequal
$>$	Is greater than
$<$	Is less than
$\geqslant$	Is greater than or equal to
$\leqslant$	Is less than or equal to
$+$	Plus
$-$	Minus
Σ	Sum of
Y	Yes
N	No

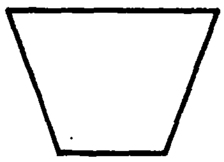
USASI STANDARD FLOW CHART SYMBOLS

SYMBOL	NAME	USE
	Input/Output	To represent the input/output function (I/O), i.e., the making available of information for processing (input), or the recording of processed information (output).
	Processing	To represent the processing function i.e., the process of executing a defined operation or group of operations resulting in a change in value, form, or location of information.
	Annotation	To represent the annotation function, i.e., the addition of descriptive comments or explanatory notes as clarification.
	Punch Card	To represent an I/O function in which the medium is punched cards, including mark sense cards. partial cards, stub cards, etc.
	Magnetic Tape	To represent an I/O function in which the medium is magnetic tape.
	Punched Tape	To represent an I/O function in which the medium is punched tape.

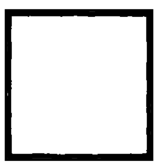
	Document	To represent an I/O function in which the medium is a document primarily intended for human use.
	Manual Input	To represent an I/O function in which the information is entered manually at the time of processing, by means of online keyboards, switch settings, push buttons, etc.
	Display	To represent an I/O function in which the information is displayed for human use at the time of processing by means of on-line indicators, video devices, console printers, plotters, etc.
	On-line Storage	To represent an I/O function utilizing auxiliary mass storage of information that can be accessed on-line; e.g., magnetic drums, magnetic disks, magnetic tape strips, automatic magnetic card systems, or automatic microfilm chip or strip systems.
	Off-line Storage	To represent any off-line storage of information, regardless of the medium on which the information is recorded.
	Decision	To represent a decision type operation that determines which of a number of alternate paths is to be followed.



Predefined Process — To represent a named process consisting of one or more operations or program steps that are specified elsewhere, e.g., subroutine.

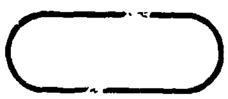


Manual Operation — To represent any off-line process geared to the speed of a human being.

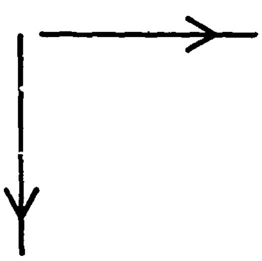


Auxiliary Operation — To represent an off-line operation performed on equipment not under direct control of the central processing unit.

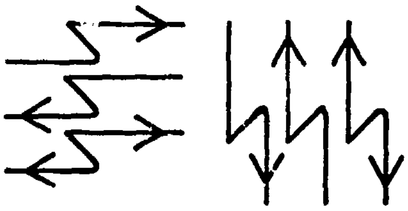
Connector — To represent a junction in a line of flow.



Terminal — To represent a terminal point in a system or communication network at which information can enter or leave; e.g., start, stop, halt, delay, or interrupt.



Flow Direction — To represent the flow direction function, i.e., the indication of the sequence of available information and executable operations. Normal direction flow is from left to right or top to bottom.



Communication Link — To represent an I/O function in which information is transmitted automatically from one location to another. The symbol indicates directional flow of Left to Right, Top to Bottom, Open arrowheads are necessary on symbol for which the flow opposes the above convention. An open arrow head may also be used on any line whenever increased clarity will result.

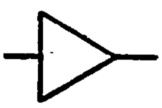
AMPLIFIER

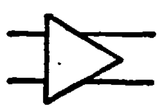
General

The triangle is pointed in the direction of transmission.

Amplifier type may be indicated in the triangle by words, standard abbreviations, or a letter combination from the following list.

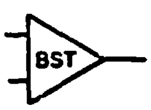
BDG	Bridging	MON	Monitoring
BST	Booster	PGM	Program
CMP	Compression	PRE	Preliminary
DC	Direct Current	PWR	Power
EXP	Expansion	TRQ	Torque
LIM	Limiting		

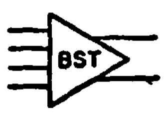




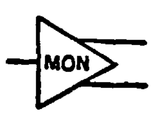
Applications

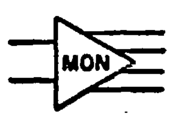
Booster amplifier with two inputs



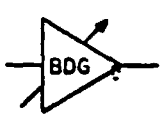


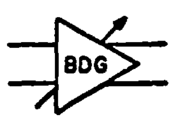
Monitoring amplifier with two outputs



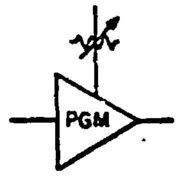


Bridging amplifier with adjustable gain

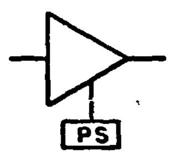


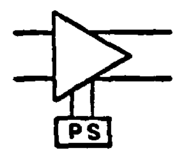


Program amplifier with associated attenuator

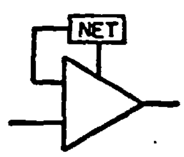


Amplifier with associated power supply





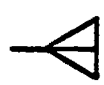
Amplifier with external feedback path



ANTENNA

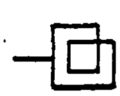
General

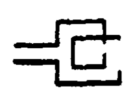
Types or functions may be indicated by words or abbreviations adjacent to the symbol.



Dipole

Loop



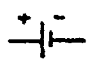


Counterpoise

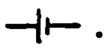
BATTERY

The long line is always positive, but polarity may be indicated in addition.

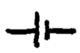
Example:



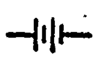
Generalized direct-current source



One cell

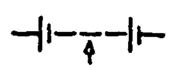


Multicell



Multicell battery with 3 taps

Multicell battery with adjustable tap



BREAKER, CIRCUIT

If it is desired to show the condition causing the breaker to trip, the relay-protective-function symbols in item 48.8 may be used alongside the breaker symbol.

General

Note 1—Use appropriate number of single-line diagram symbols.

SEE NOTE 1

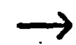
CONNECTOR

DISCONNECTING DEVICE

The connector symbol is not an arrowhead. It is larger and the lines are drawn at a 90-degree angle.

Female contact

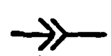
Male contact

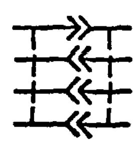


Separable connectors (engaged)

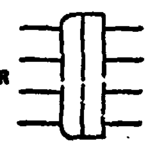
SEE NOTE 4 OR

Application: engaged 4-conductor connectors; the plug has 1 male and 3 female contacts





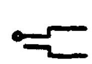
OR



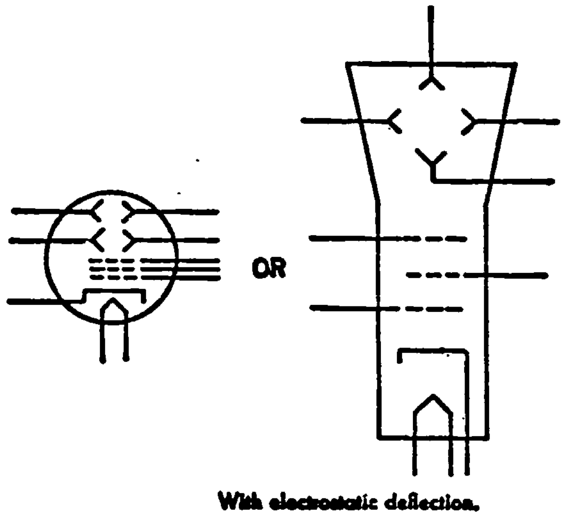
Communication switchboard-type connector

2-conductor (jack)

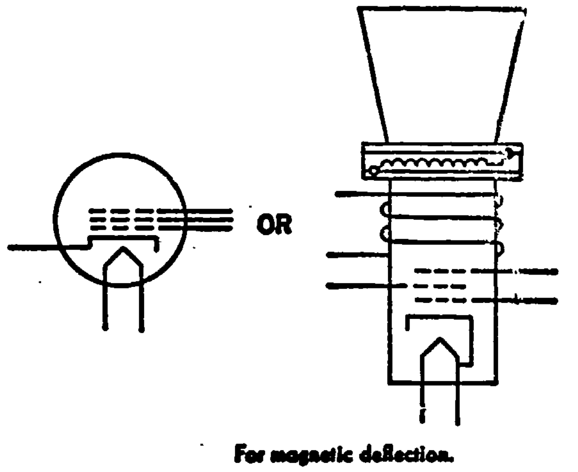
2-conductor (plug)



CATHODE RAY TUBES.



With electrostatic deflection.



For magnetic deflection.

DEVICE, AUDIBLE SIGNALING

Bell, general; telephone ringer

Note —If specific identification is required, the abbreviation AC or DC may be added within the square.

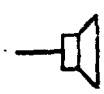
SEE NOTE

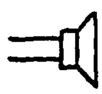
Buzzer

SEE NOTE

Horn; howler; loudspeaker; siren

General



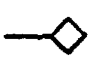


If specific identification of loudspeaker parts is required, the following letter combinations may be added. The * and ‡ are not part of the symbol.

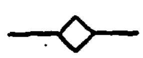
*HN Horn
*HW Howler
*LS Loudspeaker
*SN Siren

DEVICE, VISUAL SIGNALING

Annunciator, general

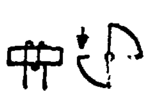


OR

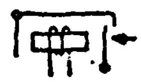


Annunciator drop or signal, shutter or grid type

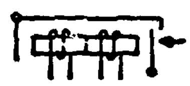
Annunciator drop or signal, ball type



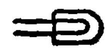
Manually restored drop



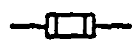
Electrically restored drop



Communication switchboard-type lamp



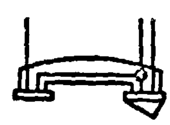
FUSE



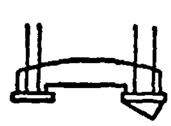
HANDSET
OPERATOR'S SET

General

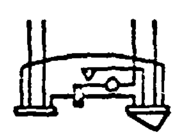
With push-to-talk switch



3-conductor.

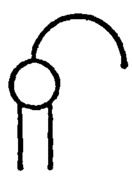


4-conductor.

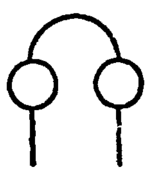


4-conductor with transmitter cut-out key.

Hand.



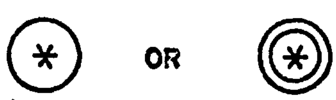
Single-head set.



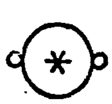
Double-head set.

MICROPHONE

LIGHT, INDICATING.



Basic.

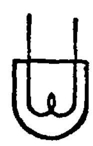


With terminals.

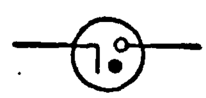
The following letter or letters in the symbol indicate color. In case of conflict with any other symbol, spell out.

A—Amber	G—Green	W—White
B—Blue	O—Orange	FL—Fluorescent
C—Clear	R—Red	OP—Opalescent

Illuminating.

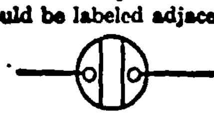


Pilot, switchboard.

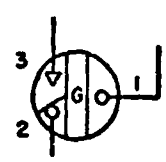


Gas filled (neon, etc.).

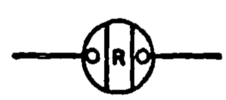
NOTE.—Lights used for ground indication, synchronizing, etc., should be labeled adjacent to the light.



Jeweled indicator or warning light.



Jeweled indicator or warning light with push to test circuit.



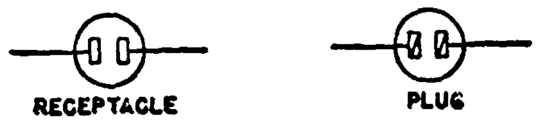
With terminals and red jeweled indicator.

METER
INSTRUMENT

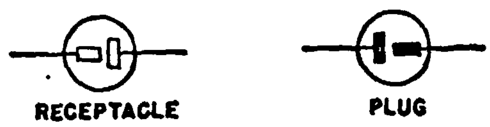
Note —The asterisk is not a part of the symbol. Always replace the asterisk by one of the following letter combinations, depending on the function of the meter or instrument, unless some other identification is provided in the circle and explained on the diagram.

A	Ammeter
AH	Ampere-hour meter
CMA	Contact-making (or breaking) ammeter
CMC	Contact-making (or breaking) clock
CMV	Contact-making (or breaking) voltmeter
CRO	Oscilloscope or cathode-ray oscillograph
D	Demand meter
DB	DB (decibel) meter
DBM	DBM (decibels referred to 1 milliwatt) meter
DTR	Demand-totalizing relay
F	Frequency meter
G	Galvanometer
GD	Ground detector
I	Indicating
M	Integrating
μA or UA	Microammeter
MA	Milliammeter
N	Noise meter
OHM	Ohmmeter
OP	Oil pressure
OSCG	Oscillograph, string
PH	Phase meter
PI	Position indicator
PF	Power-factor meter
RD	Recording demand meter
REC	Recording
RF	Reactive-factor meter
S	Synchroscope
TLM	Telemeter
T	Temperature meter
TT	Total time
VH	Varhour meter
V	Voltmeter
VA	Volt-ammeter
VAR	Varmeter
VI	Volume indicator
VU	Standard volume indicator
W	Wattmeter
WH	Watthour meter

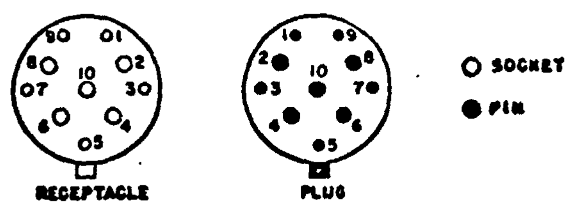
PLUGS, JACKS, RECEPTACLES.



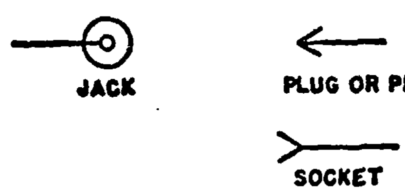
Nonpolarized, 2-pole.



Polarized.



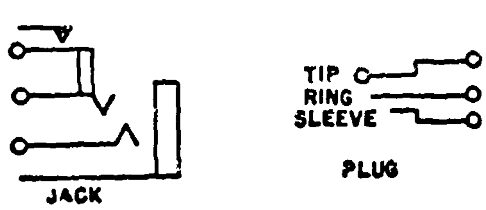
Multipole.



Pin type.

Pin type, coaxial.

2-conductor switchboard type.



3-conductor switchboard type (with auxiliary contacts).

SWITCH.

Centrifugal. See Governor Regulator.

Spring contact type.

Spring return.

Spring close.

Manual open or close (nonspring return).

Spring contact types.

NOTE.—The symbol ——▲ always indicates a spring return contact.

Typical rotary.

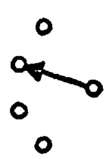
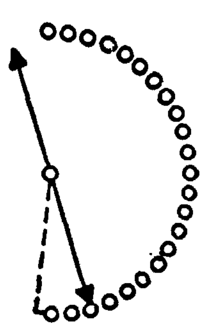


Figure 475. Single pole.

Selector type.



Typical.

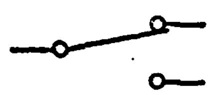
Pushbutton switch, break contact momentary, normally closed.

Pushbutton switch, momentary contact, normally open.

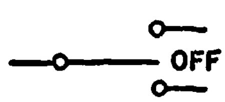
Toggle switch SPST—shown open.

Toggle switch SPST normally off, momentarily on.

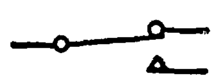
Toggle switch SPST normally on, momentarily off.



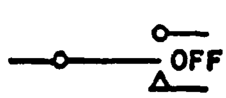
Toggle switch SPDT no off position.



Toggle switch SPDT with off position.



Toggle switch SPDT normally on, momentarily on.



Toggle switch SPDT on, off, momentarily on.

SYMBOLS FOR ELECTRICAL EQUIPMENT IN BUILDINGS AND BUILDING DISTRIBUTION SYSTEMS

ALARMS.

Fire-alarm box, wall type.


Fire-alarm box, pedestal type.

Fire-alarm bell.

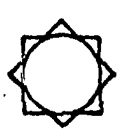
Fire-alarm central station.

Automatic fire-alarm device.


Fire-alarm printing register.


Fire-alarm siren.


Fire-alarm station, city.

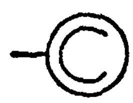

Fire-alarm transmitter.

CLOCKS.

Master, wall.

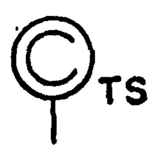
Secondary.


Single face, ceiling.


Single face, wall.

Double face, ceiling.

Double face, wall.



Time stamp.

DISTRIBUTION.

Lighting panel.

Power panel.

Branch circuit, concealed in ceiling or wall.

Branch circuit, concealed in floor.

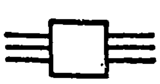
Branch circuit, exposed.

Home run to panel board. Indicate number of circuits by number of arrows.

NOTE.—Any circuit without further designation indicates a two-wire circuit. For a greater number of wires indicate as follows: (3 wires) (4 wires), etc.

Feeders.

NOTE.—Use heavy lines and designate by number corresponding to listing in feeder schedule.



Underfloor duct and junction box. Triple system.

NOTE.—For double or single systems eliminate one or two lines. This symbol is equally adaptable to auxiliary system layouts.

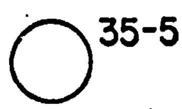
Motor.

Instrument.

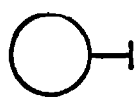
Power transformer (or draw to scale).

Controller.

Electrical distribution, aerial.



Pole, length, and class as indicated.



Pole with down guy, anchor length, class of pole, and strength of guy in pounds as indicated.

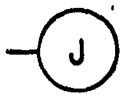
Electrical distribution underground.

Manhole, type as indicated.

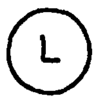
Transformer vault.

Street-lighting standard.

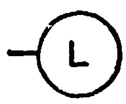
Junction box, ceiling.



Junction box, wall.

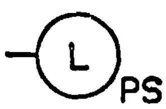


Lampholder, ceiling.



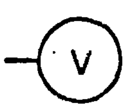
Lampholder, wall.

Lampholder with pull switch, ceiling.



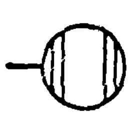
Lampholder with pull switch, wall.

Lamp, vapor-discharge, ceiling.



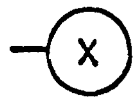
Lamp, vapor-discharge, wall.

Light, night, ceiling.



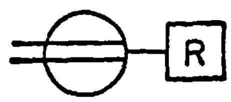
Light, night, wall.

Light, exit, ceiling.

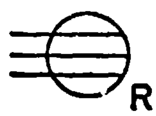


Light, exit, wall.

Radio.



Radio and convenience.

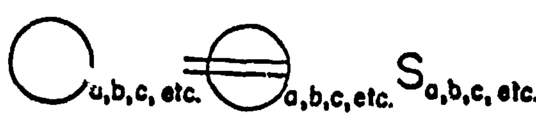


Range.

Special purpose (describe with note on drawing).

Special purpose.

Any standard symbol as shown in 605, with the addition of a lower case subscript letter may be used to designate some special variation of standard equipment of particular interest in a specific set of architectural plans. When used as shown on figure 697 they shall be listed in the key of symbols on each drawing and, if necessary, further described in the specifications.



Special purpose.

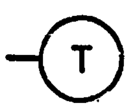
TELEPHONE OUTLETS.

Outside.

Interconnecting.

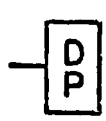
Telephone switchboard.

THERMOSTAT.



Thermostat.

SIGNALS.



Doctors' paging station, wall.

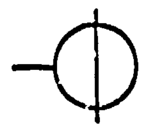
Control station doctors' paging system.

Doctors' paging station, ceiling.

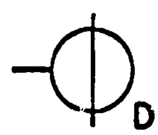
Nurses' signal plug.

Nurses' call dome light.

NOTE.—Number indicates number of lights when more than one is required.



Nurses' call station and radio outlet, single combination.



Nurses' call station and radio outlet, double combination.

Signal central station.

Watchman's station.

Watchman's central station.

SWITCHES.

Pushbutton.

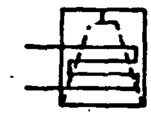
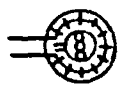
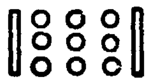
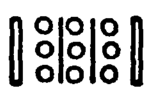
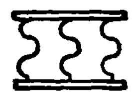
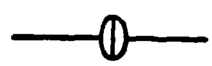
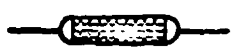
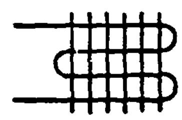
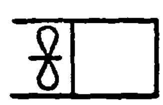
S

Single-pole.

S_2

Double-pole.

GRAPHICAL SYMBOLS FOR AIR CONDITIONING

EVAPORATIVE CONDENSER	
EVAPORATOR, CIRCULAR, CEILING TYPE, FINNED	
EVAPORATOR, MANIFOLDED, BARE TUBE, GRAVITY AIR	
EVAPORATOR, MANIFOLDED, FINNED, FORCED AIR	
EVAPORATOR, MANIFOLDED, FINNED, GRAVITY AIR	
EVAPORATOR, PLATE COILS, HEADERED OR MANIFOLD	
FILTER, LINE	
FILTER & STRAINER, LINE	
FINNED TYPE COOLING UNIT, NATURAL CONVECTION	
FORCED CONVECTION COOLING UNIT	
GAUGE	
HIGH SIDE FLOAT	
IMMERSION COOLING UNIT	

STANDARD WIRING SYMBOLS

GENERAL OUTLETS

Ceiling | Wall

- Outlet.
- Blanked Outlet.
- Drop Cord.
- Electrical Outlet; for use only when circle used alone might be confused with columns, plumbing symbols, etc.
- Fan Outlet.
- Junction Box.
- Lamp Holder.
- Lamp Holder with Pull Switch.
- Pull Switch.
- Outlet for Vapor Discharge Lamp.
- Exit Light Outlet.
- Clock Outlet. (Specify Voltage)

CONVENIENCE OUTLETS

- Duplex Convenience Outlet.
- Convenience Outlet other than Duplex. 1 = Single, 3 = Triplex, etc.
- Weatherproof Convenience Outlet.
- Range Outlet.
- Switch and Convenience Outlet.
- Radio and Convenience Outlet.
- Special Purpose Outlet. (Des. in Spec.)
- Floor Outlet.

SWITCH OUTLETS

S	Single Pole Switch.
S_2	Double Pole Switch.
S_3	Three Way Switch.
S_4	Four Way Switch.
S_D	Automatic Door Switch.
S_E	Electrolier Switch.
S_K	Key Operated Switch.
S_P	Switch and Pilot Lamp.
S_{CB}	Circuit Breaker.
S_{WCB}	Weatherproof Circuit Breaker.
S_{MC}	Momentary Contact Switch.
S_{RC}	Remote Control Switch.
S_{WP}	Weatherproof Switch.
S_F	Fused Switch.
S_{WF}	Weatherproof Fused Switch.

PANELS, CIRCUITS, AND MISCELLANEOUS

- Lighting Panel.
- Power Panel.
- Branch Circuit; Concealed in Ceiling or Wall.
- Branch Circuit; Concealed in Floor.
- Branch Circuit; Exposed.
- *Home Run to Panel Board. Indicate number of Circuits by number of arrows.
- Feeders.
- **Underfloor Duct and Junction Box.
- Battery.
- Generator.
- Motor.
- Instrument.
- Power Transformer. (Or draw to scale.)
- Controller.
- Isolating Switch.

AUXILIARY SYSTEMS

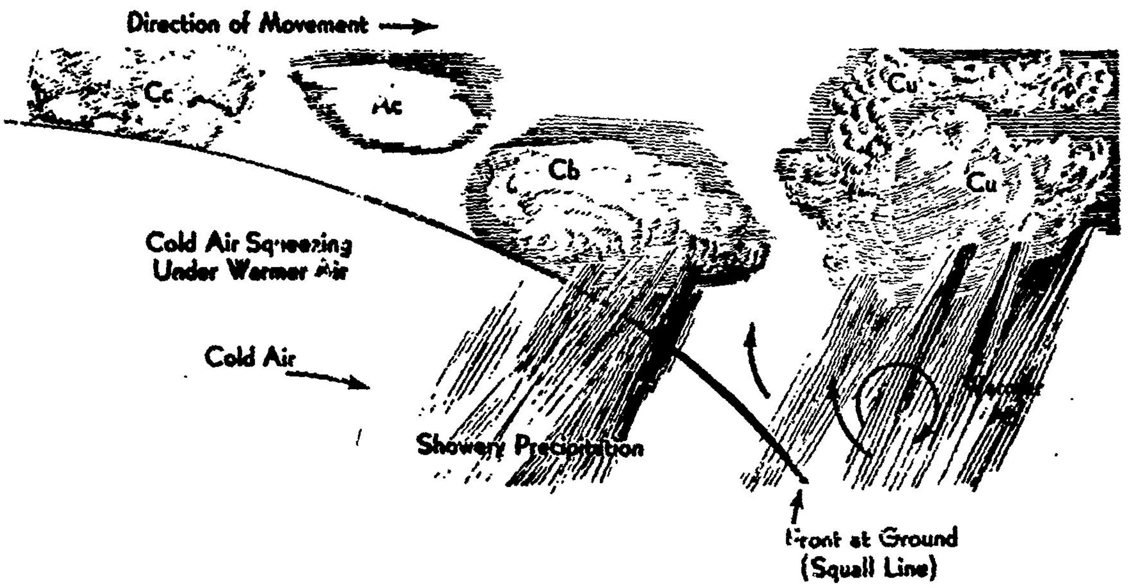
- Push Button.
- Buzzer.
- Bell.
- Annunciator.
- Outside Telephone.
- Interconnecting Telephone.
- Telephone Switchboard.
- Bell Ringing Transformer.
- Electric Door Opener.
- Fire Alarm Bell.
- Fire Alarm Station.
- City Fire Alarm Station.
- Fire Alarm Central Station.
- Automatic Fire Alarm Device.
- Watchman's Station.
- Watchman's Central Station.
- Horn.
- Nurse's Signal Plug.
- Maid's Signal Plug.
- Radio Outlet.
- Signal Central Station.
- Interconnection Box.

*Any circuit without further designation indicates a two-wire circuit. For a greater number of wires indicate as follows: -///- (3 wires) -////- (4 wires), etc.

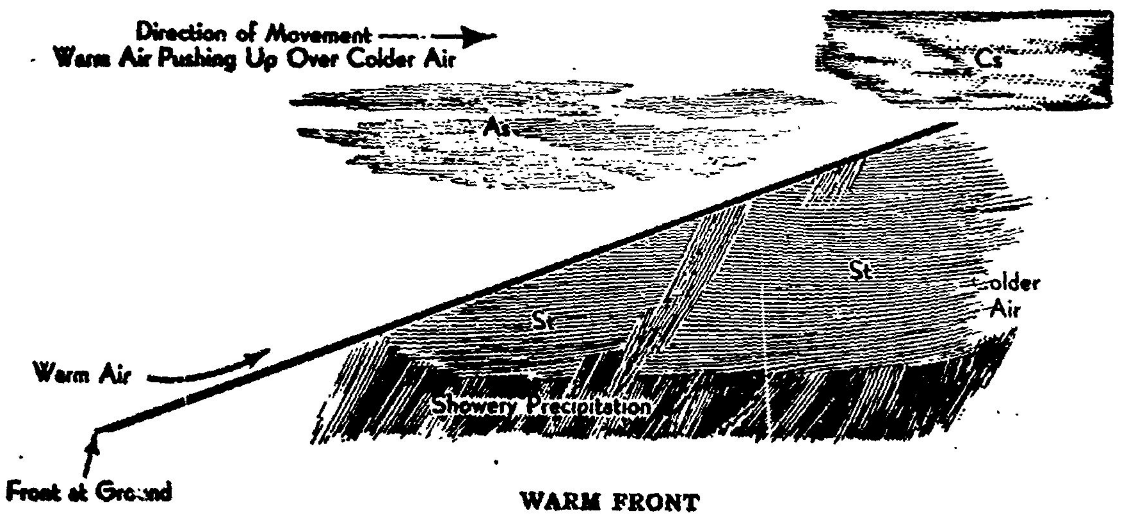
**For double or single systems eliminate one or two lines. This symbol is equally adaptable to auxiliary system layouts.

ALPHABET TABLE

Greek letter	Greek name	English equivalent	RUSSIAN letter	English equivalent
Α α	Alpha	(ä)	А а	(ä)
Β β	Beta	(b)	Б б	(b)
Γ γ	Gamma	(g)	В в	(v)
Δ δ	Delta	(d)	Г г	(g)
Ε ε	Epsilon	(e)	Д д	(d)
Ζ ζ	Zeta	(z)	Е е	(ye)
Η η	Eta	(ā)	Ж ж	(zh)
Θ θ	Theta	(th)	З з	(z)
Ι ι	Iota	(ē)	И и	(i, ē)
Κ κ	Kappa	(k)	Й й	(ē) '
Λ λ	Lambda	(l)	К к	(k)
Μ μ	Mu	(m)	Л л	(l)
Ν ν	Nu	(n)	М м	(m)
Ξ ξ	Xi	(ks)	Н н	(n)
Ο ο	Omicron	(o)	О о	(ō, o)
Π π	Pi	(p)	П п	(p)
Ρ ρ	Rho	(r)	Р р	(r)
Σ σ s	Sigma	(s)	С с	(s)
Τ τ	Tau	(t)	Т т	(t)
Υ υ	Upsilon	(ü, ōō)	У у	(ōō)
Φ φ	Phi	(f)	Ф ф	(f)
Χ χ	Chi	(H)	Х х	(kh)
Ψ ψ	Psi	(ps)	Ц ц	(ts)
Ω ω	Omega	(ō)	Ч ч	(ch)
			Ш ш	(sh)
			Щ щ	(shch)
			Ъ ъ	"
			Ы ы	(ĭ)
			Ь ь	'
			Э э	(e)
			Ю ю	(ū)
			Я я	(yä)



COLD FRONT



WARM FRONT

HIGH CLOUDS (CH) MEAN LOWER LEVEL 20,000 FEET	
1. Cirrus (Ci) 2. Cirro-cumulus (Cc) 3. Cirro-stratus (Cs)	Thin and Featherlike Thin—Cotton or Flakelike Very Thin—High Sheet Cloud
MIDDLE CLOUDS (CM) MEAN LEVELS 6500 TO 20,000 FEET	
4. Alto-cumulus (Ac) 5. Alto-stratus (As)	Puffy—Sheep Back Medium High—Uniform Sheet Cloud
LOW CLOUDS (CL) MEAN LEVELS CLOSE TO SURFACE TO 6500 FEET	
6. Strato-cumulus (Sc) 7. Stratus (St) 8. Nimbo-stratus (Ns)	Globular Masses or Rolls Low Uniform Sheet Cloud Low Amorphous and Rainy Layer
VERTICAL CLOUDS (CL) MEAN LEVELS 1600 TO 20,000 FEET	
9. Cumulus (Cu) 10. Cumulo-nimbus (Cb)	Dense—Dome-shaped and Puffy Towering Cauliflower—Anvil Top

CLOUD FAMILIES

Section 4

DEFINITIONS

Section 4

DEFINITIONS

The definitions included in the following pages were selected from a much more comprehensive list developed from many sources, the principal of which are identified below. In order to make the present list practical from the standpoint of a pocket data book it was necessary to be very selective. The following criteria were used to guide the selection process:

a. The definition is known to be used frequently in human engineering work.

b. The definition is needed because there has been confusion as to the meaning of the word in the past.

c. The definition, although common to some disciplines, is not well known to others.

d. Multiple interpretations of meaning require that the word be defined according to a specific technical category.

The following references proved to be extremely helpful in compiling the definitions which follow and are recommended to the reader seeking terms that do not appear herein:

Thesaurus of Engineering and Scientific Terms - U.S. Department of Defense, ONR Project LEX, 1967; Defense Documentation Center, Cameron Station, Alexandria, Virginia

Dictionary of Technical Terms for Aerospace Use - Allen, W.H.(Ed), Scientific and Technical Information Division, NASA SP-7, Washington, D.C., 1965

Aeronautical Dictionary - Adams, F.D. (Ed), NASA, U.S. Government Printing Office, Washington, D.C.

Navigation Dictionary - U.S. Navy Hydrographic Office, U.S. Government Printing Office, Washington, D.C.

A Glossary of Ocean Science and Undersea Technology Terms - Hunt, L.M. & Groves, D.C.(Eds), Compass Publications, Inc., 1111 N. 19th Street, Arlington, Va. 22209, 1965.

Aberration - In optics, a specific deviation from perfect imagery, for example:

a. Spherical - Due to spherical form of lens or mirror, central and marginal rays from a point source on the axis, converge to different foci.
b. Chromatic - Due to variation of refractive material, each wavelength of energy has a distinct focus.
c. Astigmatism - Rays from a point source off the axis coverged by a lens or mirror in planes at right angles to each other are brought to different foci.
d. Coma - Central and marginal rays from a point source not on the axis converge to different foci.

Ablation - The removal of surface material from a body by vaporization, melting, chipping, or other erosive process; specifically, the intentional removal of material from a nose cone or spacecraft during high-speed movement through a planetary atmosphere to provide thermal protection to the underlying structure.

Absolute system of units - 1. A system of units in which a small number of units are chosen as fundamental, and all other units are derived from them. 2. Specifically, a system of electrical units put into effect by international agreement on 1 January 1948.

Absolute zero - The theoretical temperature at which molecular motion vanishes and a body would have no heat energy; the zero point of the Kelvin and Rankine temperature scales.

Absorption - The process by which radiant energy is absorbed and converted into other forms of energy. See attenuation. Absorption takes place only after the radiant flux enters a medium and thus acts only on the entering flux, not on the incident flux, some of which may be reflected at the surface of the medium. A substance which absorbs energy may also be a medium of refraction, diffraction or scattering; these processes, however, involve no energy retention or transformation and are to be clearly differentiated from absorption.

Accelerometer - A transducer which measures acceleration or gravitational forces capable of imparting acceleration. An accelerometer usually uses a concentrated mass (seismic mass) which resists movement because of its inertia. The displacement of the seismic mass relative to its supporting frame or container is used as a measure of acceleration.

Accessibility - A quality of design that permits ready and adequate access for testing, fault detection, and repair or replacement.

Acclimatization - The adjustments of a human body or other organism to a new environment; the bodily changes which tend to increase efficiency and reduce energy loss.

Accommodation - 1. The process by which the lens of the eye adjusts to objects at different distances by changing its curvature so that the image is focused on the retina. 2. Support facility for personnel (e.g., housing, work area, etc.).

Accumulator - 1. A device or apparatus that accumulates or stores up, as: fluid under pressure. 2. In computer technology, a device which stores a number and upon receipt of another number adds to and stores the sum. See counter.

Achromatic - Lacking in hue and saturation and therefore falling in a series of colors which varies only in lightness or brightness.

Acoustic dispersion - Acoustic dispersion is the change of speed of sound with frequency.

Acoustic impedance - The acoustic impedance of a given surface area of an acoustic medium perpendicular, at every point, to the direction of propagation of sinusoidal acoustic waves of given frequency, and having equal acoustic pressures and equal volume velocities per unit area at every point of the surface at any instance; the quotient obtained by dividing (1) the phasor corresponding to the acoustic pressure by (2) the phasor corresponding to the volume velocity.

Acoustic intensity - The limit approached by the quotient obtained by dividing the power of the acoustic energy being transmitted at a given time, through a given area, by the magnitude of this area, as the magnitude of this area approaches zero.

Acoustic interferometer - An acoustic interferometer is an instrument for making physical observations upon standing waves. It may be used, for example, to measure velocity, wave length, absorption, or impedance.

Acoustic memory - A memory which uses a sonic delay line.

Acoustic ohms - Acoustic impedance is measured in acoustic ohms. One acoustic ohm is equal to one gm/cm^4 sec, or to one dyne sec/cm^5.

Acoustic radiometer - An acoustic radiometer is an instrument for measuring acoustic radiation pressure by determining the unidirectional steady-state force resulting from reflection or absorption of a sound wave at its boundaries.

Acoustic refraction - Acoustic refraction is the process by which the direction of sound propagation is changed due to variations in the speed of sound in the medium from point to point. Refraction then is due to a nonuniformity of the medium itself.

Acoustics - Acoustics is the science of sound, including its production, transmission, and effects.

Acoustic scattering - Acoustic scattering is the irregular reflection, refraction, or diffraction of a sound in many directions.

Acoustic sounding - The indirect evaluation of water depth, using the principle of measuring the length of time necessary for a sound wave to travel to the bottom, reflect and travel back to the water surface.

Acoustic spectrograph - An instrument used to analyze the acoustic transmittive and reflective powers of marine life and thermal layers in terms of their effects on particular acoustic frequencies.

Acoustic theodolite - An instrument designed to provide a continuous vertical profile of ocean currents, from the bottom to the surface, in a specific location.

Actinometry - The science of measurement of radiant energy, particularly that of the sun, in thermal, chemical, and luminous aspects.

Active maintenance time - The time during which preventive and corrective maintenance work is actually being done on the item.

Active repair time - The time during which one or more technicians are working on the item to effect a repair.

Active sonar - Active sonar is the method or equipment by which information concerning a distant object is obtained by evaluation of sound generated by the equipment.

Active technician time - That time expanded by the technician(s) in active performance of a maintenance task. Expressed in manhours, not calendar time.

Active transducer - A transducer whose output is dependent upon sources of power, apart from that supplied by any of the actuating signals, which power is controlled by one or more of these signals.

Acuity, visual - The ability of the eye to perceive form and detail in a plane perpendicular to the line of sight.

Adaptation level - Adaptation luminance.

Adaptation luminance - The average luminance (or brightness) of those objects and surfaces in the immediate vicinity of an observer. Also called adaptation brightness, adaptation level, adaptation illuminance. High adaptation luminance tends to produce a high threshold contrast, thus reducing the estimated visual range. This effect of the adaptation luminance is to be distinguished from the influence of background luminance.

Adaptive control system - A control system which continuously monitors the dynamic response of the controlled system and automatically adjusts critical system parameters to satisfy preassigned response criteria, thus producing the same response over a wide range of environmental conditions.

Additive color mixture - Type of color mixing in which the colors that are mixed all stimulate the same retinal elements. This can be accomplished by viewing overlapping light beams projected on the same surface.

Address - A label that identifies a specific location in the computer memory or register, or an input/output device.

ADF bearing indicator - An instrument used with a radio direction finder to indicate automatically the relative, magnetic, or true bearing (or reciprocal) of a transmitter. A manual type of such an instrument is called an MDF bearing indicator.

Adiabatic - Without gain or loss of heat.

Adiabatic process - A thermodynamic change of state of a system in which there is no transfer of heat or mass across the boundaries of the system. In an adiabatic process, compression always results in warming, expansion in cooling. In meteorology the adiabatic process is often also taken to be a reversible process.

Adiabatic temperature gradient - The adiabatic temperature change on a vertical distance of 1000 meters.

A-display - In radar, a display in which targets appear as vertical deflections from a line representing a time base. A-scan or A-scope.

Adjustment and calibration time - That element of Active Maintenance Time required to make the adjustment and/or calibrations necessary to place the item in specified condition.

Administrative time - That portion of Nonactive Maintenance Time that is not included in Supply Time.

Adsorption - The adhesion of a thin film of liquid or gas to the surface of a solid substance. The solid does not combine chemically with the adsorbed substance.

Aerobiology - The study of the distribution of living organisms freely suspended in the atmosphere.

Aerodynamic force - The force exerted by a moving gaseous fluid upon a body completely immersed in it.

Aeroembolism - 1. The formation or liberation of gases in the blood vessels of the body, as brought on by a too-rapid change from a high, or relatively high, atmospheric pressure to a lower one. 2. The disease or condition caused by the formation of gas bubbles (mostly nitrogen) in the body fluids. The disease is characterized principally by neuralgic pains, cramps, and swelling, and sometimes results in death. Also called decompression sickness.

Aeropause - A region of indeterminate limits in the upper atmosphere, considered as a boundary or transition region between the denser portion of the atmosphere and space.

Afterbody - 1. A companion body that trails a satellite. 2. A section or piece of a rocket or spacecraft that enters the atmosphere unprotected behind the nose cone or other body that is protected for entry. 3. The afterpart of a vehicle.

Afterburner - A device for augmenting the thrust of a jet engine by burning additional fuel in the uncombined oxygen in the gases from the turbine.

Agravic illusion - An apparent movement of a target in the visual field due to otolith response in zerogravity. Also called oculoagravic illusion.

Air - The mixture of gases comprising the earth's atmosphere. The percent by volume of those gases found in relatively constant amount in dry air near sea level is very nearly as follows:

	%
nitrogen (N_2)	78.084
oxygen (O_2)	20.9476
argon (A)	0.934
carbon dioxide (CO_2)	0.0314 (variable)
neon (Ne)	0.001818
helium (He)	0.000524
methane (CH_4)	0.0002 (variable)
krypton (Kr)	0.000114
hydrohen (H_2)	0.00005
nitrous oxide (N_2O)	0.00005
zenon (Xe)	0.0000087

Airborne equipment - Material designed to be transported by aircraft, as distinguished from weapons and equipment installed in and remaining a part of the aircraft.

Aircraft flight simulators - Synthetic flight trainers, capable of simulating complete flight of a specified aircraft from cockpit checkout and ground runup through an actual cross-country flight under total instrument conditions.

Airfoil - A structure or body designed to obtain a useful reaction on itself in its motion through the air.

Air position indicator - An airborne computing system which presents a continuous indication of the aircraft position on the basis of aircraft heading, airspeed, and elapsed time.

Airspace - Specifically, the atmosphere above a particular portion of the earth, usually defined by the boundaries of an area on the surface projected upward.

Airstart - An act or instance of starting an aircraft's engine while in flight, especially a jet engine after flameout.

Albedo - The ratio of the amount of electromagnetic radiation reflected by a body to the amount incident upon it, commonly expressed as a percentage. The albedo is to be distinguished from the reflectivity, which refers to one specific wavelength (monochromatic radiation).

Alga (plural, algae) - Any plants of a group of unicellular and multicellular primitive organisms that include the Chlorella, Scenedesmus, and other genera. The green algae and blue-green algae, for example, provide a possible means of photosynthesis in a closed ecological system, also a source of food.

Algorithm - A special mathematical procedure for solving a particular type of problem.

Alpha particle - A positively charged particle emitted from the nuclei of certain atoms during radioactive disintegration. The alpha particle has an atomic weight of 4 and a positive charge equal in magnitude to 2 electronic charges; hence it is essentially a helium nucleus (helium atom stripped of its two planetary electrons).

Altimeter - An instrument for measuring height above a reference datum; specifically an instrument similar to an aneroid barometer that utilizes the change of atmospheric pressure with altitude to indicate the approximate elevation above a given point or plane used as reference.

Altitude (symbol h) - In astronomy, angular displacement above the horizon; the arc of a vertical circle between the horizon and a point on the celestial sphere, measured upward from the horizon.

Altitude acclimatization - A physiological adaptation to reduced atmospheric and oxygen pressure.

Alveolar oxygen pressure - The oxygen pressure in the alveoli. The value is about 105 millimeters of mercury.

Alveoli - The terminal air sacs deep within the lungs.

Ambient - Encompassing on all sides; the environment surrounding a body but undisturbed or unaffected by it. For example, ambient noise is the composite noise from all sources in a given environment excluding the desired signal and noise inherent in the measuring equipment and platform.

Ambient noise - The pervasive noise associated with a given environment, being usually a composite of sounds from sources both near and distant.

Ambinocular field - The total area that can be seen by either eye; it is not limited to the binocular field but includes, in addition, monocular regions visible to the right eye but not to the left, and vice versa.

Amblyopia - Dimness of vision for which no organic defect in the refractive system of the eye has been discovered. (Found in total color blindness, in albinism, in toxic conditions, and associated with excessive use of tobacco and various drugs.)

Ametropia - A general term embracing any sort of regular refractive defect in the eye.

Ampere - The unit of electric current; the constant current which, if maintained in two straight, parallel conductors of infinite length, of negligible circular sections, and placed 1 meter apart in a vacuum will produce between these conductors a force equal to 2×10^{-7} newtons per meter of length.

Amplifier - A device which enables an input signal to control a source of power, and thus is capable of delivering at its output an enlarged reproduction of the essential characteristics of the signal. Typical amplifying elements are electron tubes, transistors, and magnetic circuits.

Amplitude - The maximum value of the displacement of a wave or other periodic phenomenon from a reference position.

Amplitude modulation - 1. In general, modulation in which the amplitude of a wave is the characteristic subject to variation. 2. Specifically, in telemetry those systems of modulation in which each component frequency f of the transmitted intelligence produces a pair of sideband frequencies at carrier frequency plus f and carrier minus f .

Anacoustic zone - The region above an altitude of about 100 miles where the distance between the air molecules is greater than the wavelength of sound, and sound waves can no longer be propagated.

Analog - A similar thing, representation or model of an idea, object or physical system (see analog computer, analog display).

Analog computer - A computing machine working on the principle of measuring, as distinguished from counting, in which the input data is analogous to a measurement continuum, such as linear lengths, voltages, resistances, etc., which can be manipulated by the computer.

Analog display - A visual display which presents a picture analogous to a real world scene.

Analog output - Transducer output in which the amplitude is continuously proportional to a function of the stimulus. Distinguished from digital output.

Analog to digital conversion - A process by which a sample of analog information is transformed into a digital code.

Analog to digital converter - A device which will convert an analog voltage sample to an equivalent digital code of some finite resolution. Also called digitizer, encoder.

Analysis of variance - A method for analyzing the total variance in a set of measurements into its component variances or parts which may be attributed to varying experimental factors.

AND - In Boolean algebra, the operation of intersection.

AND gate, and gate - A circuit or device used in computers whose output is energized only when every input is in its prescribed state. It performs the logical function of the AND, the Boolean operation of intersection. Also called intersector, AND circuit.

Anemometer - The general name for instruments designed to measure the speed (or force) of the wind. These instruments may be classified according to the means of transduction employed: those used in meteorology include the rotation anemometer, pressure plate anemometer, pressure-tube anemometer, bridled cup anemometer, contact anemometer, cooling-power anemometer, and sonic anemometer.

Aneroid - A thin, disk-shaped box or capsule, usually metallic, partially evacuated of air and sealed, which expands and contracts with changes in atmospheric or gaseous pressure.

Angel - A radar echo caused by a physical phenomenon not discernible to the eye.

Angle - The inclination to each other of two intersecting lines, measured by the arc of a circle intercepted between the two lines forming the angle, the center of the circle being the point of intersection.

Angle of attack - The angle between a reference line fixed with respect to an airframe and a line in the direction of movement of the body.

Angle of climb - The angle between the flight path of a climbing vehicle and the local horizontal.

Angle of descent - The angle between the flight path of a descending vehicle and the local horizontal.

Angle of deviation - The angle through which a ray is bent in refraction.

Angle of elevation - The angle in a vertical plane between the local horizontal and an ascending line, as from an observer to an object. Also called elevation angle. A negative angle of elevation is usually called an angle of depression.

Angle of incidence - The angle at which a ray of energy impinges upon a surface, usually measured between the direction of propagation of energy and a perpendicular to the surface at the point of impingement, or incidence.

Angle of reflection - The angle at which a reflected ray of energy leaves a reflecting surface, measured between the direction of the outgoing ray and a perpendicular to the surface at the point of reflection. Compare angle of incidence.

Angle of refraction - The angle at which a refracted ray of energy leaves the interface at which the refraction occurred, measured between the direction of the refracted ray and a perpendicular to the interface at the point of refraction.

Angle of roll - The angle that the lateral body axis of an aircraft or similar body makes with a chosen reference plane in rolling; usually, the angle between the lateral axis and a horizontal plane. The angle of roll is considered positive if the roll is to starboard.

Angle of yaw - The angle, as seen from above, between the longitudinal body axis of an aircraft, rocket, or the like and a chosen reference direction. This angle is positive when the forward part of the longitudinal axis is directed to starboard. Also called yaw angle.

Ångstrom - A unit of length, used chiefly in expressing short wavelengths. It equals 10^{-10} meters or 10^{-8} centimeters.

Angular acceleration - The rate of change of angular velocity.

Angular resolution - Specifically, the ability of a radar to distinguish between two targets solely by the measurement of angles.

Angular velocity - The change of angle per unit time; specifically, in celestial mechanics, the change in angle of the radius vector per unit time.

Animated panels - Training aids used in teaching nomenclature, principles, and theory of operation of various components and systems. A device designed to illustrate system functional changes or process flow by means of moving mechanical elements or illuminated symbols.

Anisometropia - Unequal refractive power in the two eyes.

Anode - The positive pole or electrode of any electron emitter, such as an electron tube or an electric cell. The negative pole or electrode is called a cathode.

Anomalistic period - The interval between two successive perigee passages of a satellite in orbit about a primary. Also called perigee-to-perigee period.

Anomalous propagation - In sonar, pronounced and rapid variations in echo strength caused by large and rapid local fluctuations in propagation conditions.

Anomalous trichromatism - Form of trichromatism in which some of the proportions of colorimetric primaries required to match various colors are beyond normal limits. Anomalous trichromatism may be either protanomaly, deuteranomaly, tritanomaly or some irregular form.

Anomaly - 1. In general, a deviation from the norm. 2. In geodesy, a deviation of an observed value from a theoretical value, due to an abnormality in the observed quantity. 3. In celestial mechanics, the angle between the radius vector to an orbiting body from its primary (the focus of the orbital ellipse) and the line of apsides of the orbit, measured in the direction of travel, from the point of closest approach to the primary (perifocus).

Anoxia - A complete lack of oxygen available for physiological use within the body. Compare hypoxia. Anoxia is popularly used as a synonym for hypoxia. This usage should be avoided.

Anthropometry - The science of measuring the human body and its parts and functional capacities.

Antinode - 1. Either of the two points on an orbit where a line in the orbit plane, perpendicular to the line of nodes, and passing through the focus, intersects the orbit. 2. A point, line, or surface in a standing wave where some characteristic of the wave field has maximum amplitude.

Aphelion - That point in a solar orbit which is most distant from the sun. The point nearest the sun is called perihelion.

Apogee - That point in a geocentric orbit which is most distant from the earth. That orbital point nearest the earth is called perigee.

Apostilb - A unit of luminance equal to 1/ X 10^{-4} international candles per square centimeter. Compare stilb.

Apparent motion - Motion relative to a specific or implied reference point which may itself be in motion. Also called relative motion.

Apparent time - Time based upon the rotation of the earth relative to the apparent or true sun. This is the time shown by a sundial.

Area rule - A prescribed method of design for obtaining minimum zero-lift drag for a given aerodynamic configuration, such as a wing-body configuration, at a given speed.

Arithmetic word - That portion of the computer word devoted to the performance of arithmetic operations; in NAREC, binary digits 0 through 44.

Artificial gravity - A simulated gravity established within a space vehicle by rotation or acceleration.

Artificial horizon - 1. A gyro-operated flight instrument that shows the pitching and banking attitudes of an aircraft or spacecraft with respect to a reference line horizon, within limited degrees of movement, by means of the relative position of lines or marks on the face of the instrument representing the aircraft and the horizon. 2. A device, such as a spirit level, pendulum, etc., that establishes a horizontal reference in a navigation instrument.

Ascendent - The negative of the gradient. The ascendent of a function is a vector with magnitude equal to the maximum spatial rate of change of that function at a given point at a given time.

Ascending node - That point at which a planet, planetoid, or comet crosses to the north side of the ecliptic; that point at which a satellite crosses to the north side of the equatorial plane of its primary. Also called northbound node. The opposite is descending node or southbound node.

A-scope - A radarscope that presents the target range by a vertical deflection of the time base, or, in certain modified versions, by a horizontal deflection.

Aspect - The angle made by a target with the line joining it to the observation point is known as the aspect of the target.

Aspect ratio - The ratio of the square of the span of an airfoil to the total airfoil area, or the ratio of its span to its mean chord.

Aspheric - Not spherical; an optical element having one or more surfaces which are other than spherical.

Asteroid - One of the many small celestial bodies revolving around the sun, most of the orbits being between those of Mars and Jupiter. Also called planetoid, minor planet.

Astigmatism - Defect of the eye. Two types are recognized: regular, in which the error is due to a greater curvature of a refractive surface (chiefly the cornea) in one meridian, and which may be corrected by a cylindrical lens; and irregular, in which the refraction is irregularly unequal within the pupillary area and which is not correctable except by contact lenses.

Astrobiology - The study of living organisms on celestial bodies other than the earth.

Astrodynamics - The practical application of celestial mechanics, astroballistics, propulsion theory, and allied fields to the problem of planning and directing the trajectories of space vehicles.

Astronomical constants - 1. The elements of the orbits of the bodies of the solar system, their masses relative to the sun, their size, shape, orientation, rotation, and inner constitution, and the velocity of light. 2. System of astronomical constants.

Astronomical unit - A unit of length, usually defined as the distance from the earth to the sun, 149,599,000 kilometers.

Astrophysics - A branch of astronomy that treats of the physical properties of celestial bodies, such as luminosity, size, mass, density, temperature, and chemical composition.

Asynchronous computer - An automatic computer in which succeeding operations are started by signals indicating the completion of the previous operation, rather than by signals from a master synchronizer. Contrast to synchronous computer.

Atelectasis - Collapsed or airless state of all or part of a lung. Also called apneumatosis.

Atmosphere - Term used in diving to describe pressure exerted by sea water. 1 ATM = 14.7 PSI.

Atmospheric entry - The penetration of a planetary atmosphere by any object from outer space; specifically, the penetration of the earth's atmosphere by a manned or unmanned capsule or spacecraft.

Atmospheric optics - The study of the optical characteristics of the atmosphere and of the optical phenomena produced by the atmosphere's suspensoids and hydrometeors. It embraces the study of refraction, reflection, diffraction, scattering, and polarization of light, but is not commonly regarded as including the study of any other kinds of radiation. Also called meteorological optics.

Atmospheric pressure - The pressure at any point in an atmosphere due solely to the weight of the atmospheric gases above the point concerned. (Refer to Section IV, Table .).

Atmospheric refraction - Refraction resulting when a ray of radiant energy passes obliquely through an atmosphere.

Atomic number - An integer that expresses the positive charge of the nucleus in multiples of the electronic charge e. It is the number of electrons outside the nucleus of a neutral (unionized) atom and, according to widely accepted theory, the number of protons in the nucleus.

Atomic particle - One of the particles of which an atom is constituted, as an electron, neutron, or a positively charged nuclear particle.

Atomic weight - The weight of an atom according to a scale of atomic weight units, awu, valued as one-twelfth the mass of the carbon atom (C^{12} = 12.00000).

Attenuation - Reduction in intensity.

Attitude - 1. The position or orientation of an aircraft, spacecraft, etc., either in motion or at rest, as determined by the relationship between its axes and some reference line or plane or some fixed system of reference axes. 2. An attribute of human behavior characterized by a persons feelings towards other persons, objects, processes, situations - classifiable as positive, negative, passive, aggressive.

Attitude control - 1. The regulation of the attitude of an aircraft, spacecraft, etc. 2. A device or system that automatically regulates and corrects attitude, especially of a pilotless vehicle.

Attitude gyro - 1. A gyro-operated flight instrument that indicates the attitude of an aircraft or spacecraft with respect to a reference coordinate system throughout 360° of rotation about each axis of the craft. 2. Broadly, any gyro-operated instrument that indicates attitude.

Attributes of color - The chromatic colors have the attributes of hue saturation, and brightness or lightness; but the achromatic colors do not have those of hue and saturation. All colors do have the general attributes of duration and extent, but these are rarely mentioned. (Syn. Dimensions of color)

Attributes of sensation - The fundamental, intrinsic characteristics of simple sensory response, generally recognized as quality, intensity, duration, and extensity; clearness or attensity sometimes also being included. (Syn. Dimensions of sensation.)

Audible sound - Sound containing frequency components lying between about 15 to 20,000 cycles per second.

Audio - Pertaining to the audiofrequency (audible to the human ear) range. The word audio may be used as a modifier to indicate a device or system intended to operate at audiofrequencies, e.g., audioamplifier.

Auditory sensation area - In acoustics, the frequency region enclosed by the curves defining the threshold of pain and the threshold of audibility.

Aural signal - A signal which must be heard by the ear and be interpreted without benefit of visual instruments.

Autocorrelation - In statistics the simple linear internal correlation of members of a time series (ordered in time or other domains).

Autokinetic illusion - The illusion of a fixed object or light moving when gazed at steadily.

Automatic coding - A type of automatic programming in which some of the coding is taken over by the computer.

Automatic direction finder - A radio direction finder which automatically and continuously provides a measure of the direction of arrival of the received signal. Data are usually displayed visually.

Automatic frequency control - An arrangement whereby the frequency of an oscillator is automatically maintained within specified limits.

Automatic gain control - A process by which gain is automatically adjusted as a function of input or other specified parameter.

Automatic pilot - Equipment which automatically stabilizes the attitude of a vehicle about its pitch, roll, and yaw axes. Also called autopilot.

Automatic tracking - Tracking in which a servomechanism automatically follows some characteristic of the signal; specifically a process by which tracking or data acquisition systems are enabled to keep their antennas continually directed by a moving target without manual operation.

Avogadro number, Avogadro constant - The number of molecules in 1 mole of gas (6.02252×10^{22} per mole).

Axis (plural axes) - 1. A straight line about which a body rotates, or along which its center of gravity moves (axis of translation). 2. A straight line around which a plane figure may rotate to produce a solid; a line of symmetry. 3. One of a set of reference lines for a coordinate system.

Azimuth - 1. Horizontal direction or bearing. 2. In navigation, the horizontal direction of a celestial point from a terrestrial point, expressed as the angular distance from a reference direction, usually measured from 0° at the reference direction clockwise through 360°. 3. In astronomy, the direction of a celestial point from a terrestrial point measured clockwise from the north or the south point of the meridian plane. 4. In surveying, the horizontal direction of an object measured clockwise from the south point of the meridian plane.

Azimuth angle - Azimuth measured from 0° at the north or south reference direction clockwise or counterclockwise through 90° or 180°.

Azimuth error - An error in the indicated azimuth of a target detected by radar, resulting from horizontal refraction.

Azimuth marker - 1. A scale encircling the plan position indicator (PPI) scope of a radar on which the azimuth of a target from the radar may be measured. 2. Reference limits inserted electronically at 10° or 15° intervals which extend radially from the relative position of the radar on an offcenter PPI scope. These are employed for target azimuth determination when the radar position is not at the center of the PPI scope and hence the fixed azimuth scale on the edge of the scope cannot be employed.

Background luminance - In visual-range theory, the luminance (brightness) of the background against which a target is viewed. (See Section II - Units of Luminance).

Backlash - Dead space or unwanted movement in a control system.

Backscatter (in illumination) - Dispersion of luminant energy such that ambient visual conditions are either enhanced or degraded, i.e., backscatter from fog may cause glare; from a uniform surface, effective brightness control.

Ballistic body - A body free to move, behave, and be modified in appearance, contour, or texture by ambient conditions, substances, or forces as the pressure of gasses in a gun, by rifling in a barrel, by gravity, by temperature, or by air particles.

Ballistic missile - A missile designed to operate primarily in accordance with the laws of ballistics; i.e., it is guided during only a portion of its flight, thereafter it acts in a way similar to an artillery shell.

Bandwidth - 1. In an antenna, the range of frequencies within which its performance, in respect to some characteristic, conforms to a specified standard. 2. In a wave, the least frequency interval outside of which the power spectrum of a time-varying quantity is everywhere less than some specified fraction of its value at a reference frequency. 3. The number of cycles per second between the limits of a frequency band.

Bang-bang control - Flicker control, especially as applied to rockets. A control which provides a single, prescribed or finite, metered thrust burst (e.g., non-continuous).

Baralyme - A compressed pill consisting of a blended mixture of barium octohydrate and calcium hydroxide. It is used as a carbon dioxide absorbent in rebreathing (diving) systems.

Barany chair - (After Robert Barany, 1876-1936, Swedish physician.) A kind of chair in which a person is revolved to test his susceptibility to vertigo.

Baromil - The unit length used in graduating a mercury barometer in the centimeter-gram-second system.

Baroswitch (from barometric switch) - 1. Specifically, a pressure-operated switching device used in a radiosonde. 2. Any switch operated by a change in atmospheric pressure.

Barotrauma - A generic term for injury caused by pressure.

Barotropy - The state of a fluid in which surfaces of constant density (or temperature) are coincident with surfaces of constant pressure.

Barrier, acoustic - Structure and/or materials placed between a sound source and the listener to reduce the sound level reaching the listener's ear. (as opposed to sound absorption).

Barycenter - The center of mass of a system of masses, as the barycenter of the earth-moon system.

Baseline - Any datum that serves as a basis for either objective or subjective comparisons.

Base-timing sequencing - The control of the time sharing of a single transponder between several ground transmitters through the use of suitable coded timing signals.

Bathymetry - The art or science of determining depths of water.

B-display - In radar, a rectangular display in which targets appear as blips with bearing indicated by the horizontal coordinate and distance by the vertical coordinate. Also called B-scan or B-scope.

Beam - 1. A ray or rays of radiated energy as in light or radar beams. 2. Extreme width of a ship at its widest part.

Beam splitter - A partially reflecting mirror which permits some incident light to pass through and reflects the remainder.

Beam width - A measure of the concentration of power of a directional antenna. It is the angle in degrees subtended at the antenna by arbitrary power-level points across the axis of the beam. This power level is usually the point where the power density is one-half that which is present in the axis of the beam at the same distance from the antenna (half-power points). Also called beam angle.

Bearing - The horizontal direction of an object or point, usually measured clockwise from a reference line or direction through 360°.

Beat frequency - The frequency obtained when two simple harmonic quantities of different frequencies f_1 and f_2 are superimposed. The beat frequency equals $f_1 - f_2$.

Beaufort Wind Scale - A scale (0 through 12) for showing the strength of wind, devised by Sir Francis Beaufort (see Table 1).

Bel - The bel is a unit of level when the base of the logarithm is 10. Use of the bel is restricted to level of quantities proportional to power.

Bends - 1. Pains in the extremities, abdomen, and chest caused by aeroemphysema and in some instances by aeroembolism resulting from the reduction of ambient air pressure. 2. Popularly used as synonymous with aeroembolism (sense 2).

Bernoulli law or Bernoulli theorem - (After Daniel Bernoulli, 1700-1782, Swiss scientist.) In aeronautics, a law or theorem stating that in a flow of incompressible fluid the sum of the static pressure and the dynamic pressure along a streamline is constant if gravity and frictional effects are disregarded.

Bias error - A measurement error that remains constant in magnitude for all observations. A kind of systematic error.

Billet - A military term referring to (a) living quarters or (b) work or job assignment.

Binary - 1. Involving the integer two (2). See binary notation. 2. = binary cell. 3. = binary star.

Binary counter - A counter with two distinguishable states.

Binary notation - A system of positional notation in which the digits are coefficients of powers of the base 2 in the same way as the digits in the conventional decimal system are coefficients of powers of the base 10. (See Section I - Binary numbers).

Binocular field - The field of vision of the two eyes acting conjointly. (Vol. I, Section I - Anthropometry)

Binocular fusion - The combination of two images, falling upon the two retinas, into a single visual impression. The images may be alike, or may differ to some degree in form and color.

Binocular vision - Vision with the two eyes operating conjointly, usually with fixation of both on the same objective point. In general, characterized by a single perception of the objects fixated, but in certain conditions by doubling or by rivalry. An important factor in perception of space, giving projection and relief. Contrast with monocular.

Bioastronautics - The study of biological, behavioral, and medical problems pertaining to astronautics. This includes systems functioning in the environments expected to be found in space, vehicles designed to travel in space, and the conditions on celestial bodies other than on earth.

Biochemistry - Chemistry dealing with the chemical processes and compounds of living organisms.

Bioclimatology - The study of the relations of climate and life, especially the effects of climate on the health and activity of human beings (human bioclimatology) and on animals and plants.

Table 1 - The Beaufort Wind Scale

Beaufort No.	Seaman's description of wind	Deep sea signs	Mode of estimating for average sized sailing trawler	Miles per hour (statute)†	Miles per hour (nautical)	Meters per second	Equivalent pressure in millibars* (10^3 dynes per cm^2)	Terms used in U. S. Weather Bureau forecasts
0	Calm	Sea smooth as a mirror	No headway	Less than 1	Less than 1	Less than 0.3	Less than 0.005	
1	Light air	Small waveletlike scales; no foam crests	Sufficient to give good steerage way to fishing smacks, with "wind free."	1-3	1-3	0.3-1.5	0.005-0.03	Light.
2	Light breeze	Waves short; crests begin to break	Fishing smacks with topsails and light canvas, "full and by," make up to 2 knots.	4-7	4-6	1.6-3.3	0.03-0.1	
3	Gentle breeze	Foam has glassy appearance, not yet white	Smacks begin to heel over slightly under topsails and light canvas, make up to 3 knots, "full and by."	8-12	7-10	3.4-5.4	0.1-0.2	Gentle.
4	Moderate breeze	Waves now longer; many white horses	Good working breeze; smacks heel over considerably on a wind under all sail.	13-18	11-16	5.5-8.0	0.2-0.5	Moderate.
5	Fresh breeze	Waves pronounced and long; white foam crests	Smacks shorten sail	19-24	17-21	8.1-10.7	0.5-1.0	Fresh.
6	Strong breeze	Larger waves form; white foam crests all over	Smacks double-reef gaff mainsail	25-31	22-27	10.8-13.8	1-1.5	Strong.
7	Moderate gale	Sea heaps up; wind blows foam in streaks	Smacks remain in harbor, and those at sea lie to.	32-38	28-33	13.9-17.1	1.5-2	
8	Fresh gale	Height of waves and crests increasing	Smacks take shelter if possible	39-46	34-40	17.2-20.7	2-3	Gale.
9	Strong gale	Foam is blown in dense streaks		47-54	41-47	20.8-24.4	3-4.5	
10	Whole gale	High waves with long overhanging crests; large foam patches.		55-63	48-55	24.5-28.3	4.5-6	Whole gale.
11	Storm	High waves; ships in sight hidden in troughs		64-75	56-65	28.4-33.5	6-8	
12	Hurricane	Sea covered with streaky foam; air filled with spray.		Above 75	Above 65	33.6 or above	Above 8	Hurricane.

* 1 millibar equals approximately 10 kilograms per square meter or 2 pounds per square foot.
† Approximate velocity equivalents at a height of 33 feet above sea level. Values deduced from observations made at British coastal stations.

Biodynamics - The study of the effects of dynamic processes (motion, acceleration, weightlessness, etc.) on living organisms.

Bioluminescence - The emission of light by living organisms.

Bionics - The study of systems, particularly electronic systems, which function after the manner of, or in a manner characteristic of, or resembling, living systems.

Biosatellite - An artificial satellite which is specifically designed to contain and support man, animals, or other living material in a reasonably normal manner for an adequate period of time and which, particularly for man and animals, possesses the proper means for safe return to the earth. See ecological system.

Biosensor - A sensor used to provide information about a life process.

Biotechnology - The application of engineering and technological principles to the life sciences.

Biotelemetry - The remote measuring and evaluation of life functions, as, e.g., in spacecraft and artificial satellites.

Bit - 1. An abbreviation of binary digit. 2. A single character of a language employing only two distinct kinds of characters. 3. A quantity of intelligence which is carried by an identifiable entity and which can exist in either of two states. 4. A unit of storage capacity; the capacity of bits of a storage device is the logarithm to the base two of the number of possible states of the device. 5. A quantum of information. 6. Loosely, a mark.

Bit rate - The frequency derived from the period of time required to transmit one bit.

Black - An achromatic color of minimum lightness (maximum darkness) which represents one limit of the series of grays, and which is the complement or antagonist of white, the other extreme of the gray series. Though typically a response to zero or minimal stimulation, black appears always to depend upon surrounding contrast.

Black body, blackbody - An ideal emitter which radiates energy at the maximum possible rate per unit area at each wavelength for any given temperature. A black body also absorbs all the radiant energy in the near visible spectrum incident upon it.

Black body radiation - The electromagnetic radiation emitted by an ideal black body; it is the theoretical maximum amount of radiant energy of all wavelengths which can be emitted by a body at a given temperature.

Blackout - A condition in which vision is temproarily obscured by a blackness, accompanied by a dullness of certain of the other senses, brought on by decreased blood pressure in the eye and a consequent lack of oxygen, as may occur, e.g., in pulling out of a high-speed dive in an airplane. Compare grayout, redout.

Bleed off - To take off a part or all of a fluid from a tank or line, normally through an escape valve or outlet, as in to bleed off excess oxygen from a tank.

Blind spot - A small area in the retina, where the optic nerve leaves the eyeball. This area is not sensitive to light stimulation.

Blink - 1. A glare on the underside of extensive cloud areas created by light reflected from snow or ice covered surfaces; also observable in a clear sky. Blink caused by ice surfaces is usually yellowish-white in contrast to the whitish, brighter glare caused by snow surfaces. This distinction is sometimes difficult to perceive. In contrast to snowblink and iceblink, the sky is dark above bare land or open water surfaces. 2. The act of closing one's eyelid momentarily.

Blip - A spot of light or deflection of the trace on a radarscope, loran indicator, or the like, caused by the received signal, as from a reflecting object. Also called a pip or echo.

Boltzmann constant - The ratio of the universal gas constant to Avogadro number; equal to 1.38054×10^{-16} erg/°K. Sometimes called gas constant per molecule, Boltzmann universal conversion factor.

Boolean algebra - The study of the manipulation of symbols representing operations according to the rules of logic. Boolean algebra corresponds to an algebra using only the numbers 0 and 1, therefore can be used in programming digital computers which operate on the binary principle.

Boresighting - The process of aligning a directional antenna or weapon system by an optical procedure.

Boundary conditions - A set of mathematical conditions to be satisfied, in the solution of a differential equation, at the edges or physical boundaries (including fluid boundaries) of the region in which the solution is sought. The nature of these conditions usually is determined by the physical nature of the problem.

Bow - Forward part of a ship.

Bow and beam bearings - Successive relative bearings (right or left) of 45° and 90° taken on a fixed object to obtain a running fix. The length of the run between such bearings is equal to the distance of the craft from the object at the time the object is broad on the beam, neglecting current. The 45° bearing is also called a four-point bearing.

Bow wave - A shock wave in front of a body such as an airfoil, or apparently attached to the forward tip of the body.

Brake parachute - Deceleration parachute; also drogue parachute.

Branch - 1. In an electrical circuit, a portion of a network consisting of one or more two-terminal elements in series. 2. The point in a computer program at which the machine will proceed with one of two or more possible routines according to existing conditions and instructions.

Breadboard - 1. An assembly of preliminary circuits or parts used to prove the feasibility of a device, circuit, system, or principle without regard to the final configuration or packaging of the parts. 2. To prepare a breadboard (sense 1).

Breakoff phenomenon - The feeling which sometimes occurs during high-altitude flight of being totally separated and detached from the earth and human society. Also called the breakaway phenomenon.

Breakwater - A structure protecting a shore area, harbor, anchorage or basin from waves.

Bremsstahlung effect - The emission of electromagnetic radiation as a consequence of the acceleration of charged elementary particles, such as electrons, under the influence of the attractive or repulsive force fields of atomic nuclei near which the charged particle moves.

Brightness - 1. Attribute of visual sensation determined by intensity of light radiation reaching the eye. Sometimes called lightness, tint, or value. Refers to variations along the achromatic scale of black to white. 2. Photometric measure of light emission per unit area of a luminous body or of a translucent or reflective surface, i.e., candlepower per unit area. 3. = luminance.

Brightness contrast - The relative difference in brightness between two objects, expressed as the ratio of the absolute brightness difference to the greater brightness.

Brightness level - Adaptation luminance.

Brightness ratio - Ratio of illumination on the object being viewed to the illumination of the surrounding area.

Brightness threshold, absolute - The intensity of the least visual stimulus (of any specified wave-length composition) sufficient to evoke a brightness in excess of that of the adjacent unstimulated visual field. The value is determined after complete dark adaptation but does not exclude the effect of processes normally active in the sense-organ.

Brilliance - That attribute of any color or visual sense-quality in respect to which it may be classed as equivalent to some member of a series of grays ranging from black to white. Distinguish from brightness, which has reference solely to stimulus-magnitude.

British candle - International candle.

British thermal unit - The amount of heat required to raise 1 pound of water at 60° F, 1° F.

Broken ice - Ice that covers from five-tenths to eight-tenths of the sea surface. Also called loose ice, loose pack ice, open ice, open pack ice, slack ice.

B-scan - B-display.

B-scope - A cathode-ray indicator in which a signal appears as a spot with bearing as the horizontal coordinate and distance as the vertical coordinate. Also called B-display.

B-trace - The second trace of an oscilloscope having more than one, as the lower trace of a loran indicator.

Buddy breathing - In scuba, the sharing by two or more divers of the same breathing tank. See buddy system.

Buddy system - In scuba diving, divers with few exceptions should work in pairs. This is probably the greatest single aid toward scuba safety, especially under unfavorable conditions. The divers should remain in sight of each other. In poor visibility, they should use a buddy line 6-10 feet long.

Buffer - In computers: 1. An isolating circuit used to avoid reaction of a driven circuit on the corresponding driving circuit. 2. A storage device used to compensate for a difference in rate of flow of information or time or occurrence of events when transmitting information from one device to another.

Burnout - 1. An act or instance of fuel or oxidant depletion or, ideally, the simultaneous depletion of both; the time at which this occurs. 2. An act or instance of something burning out or of overheating; specifically, an act or instance of a rocket combustion chamber, nozzle, or other part overheating so as to result in damage or destruction.

Cable - A nautical unit of horizontal distance, equal to 600 feet (100 fathoms) and approximately one-tenth of a nautical mile.

Caging - The process of orienting and mechanically locking the spin axis of a gyro to an internal reference position.

Calendar day - The period from midnight to midnight. The calendar day is 24 hours of mean solar time in length and coincides with the civil day unless a time change occurs during the day.

Calendar life - That period of time expressed in days, months or years, which an item may remain installed in an operation environment as serviceable, and be expected to perform satisfactorily and reliably, but which should be removed at the expiration of designated time and returned for repair, overhaul or other maintenance action.

Calendar time - The total number of calendar days or hours in a designated period of observation.

Calorie - A unit of heat originally defined as the amount of heat required to raise the temperature of 1 gram of water through 1° C (the gram-calorie or small calorie).

Canard - Pertaining to an aerodynamic vehicle in which horizontal surfaces used for trim and control are forward of the main lifting surface; the horizontal trim and control surfaces in such an arrangement.

Candela - The unit of luminous intensity in the International System of Units, 1960; equal to one-sixtieth of the luminous intensity from 1 square centimeter of a black body at 2046°K (the temperature of solidification of platinum). Also called candle.

Candle - 1. Unit of light intensity. At a distance of one foot, one candle produces an illumination of one foot-candle (equivalent to one lumen per square foot) upon a surface normal to the beam. 2. = candela.

Canonical time unit - For geocentric orbits, the time required by a hypothetical satellite to move one radian in a circular orbit of the earth's equatorial radius; 13.447052 minutes.

Capacity - In computer operations, a) the largest quantity which can be stored, processed, or transferred; b) the largest number of digits or characters which may regularly be processed; c) the upper and lower limits of the quantities which may be processed.

Capsule - 1. A boxlike component or unit, often sealed. 2. A small, sealed, pressurized cabin with an internal environment which will support life in a man or animal during extremely high altitude flight, space flight, or emergency escape.

Capture - Of a central force field, as of a planet; to overcome by gravitational force the velocity of a passing body and bring the body under the control of the central force field, in some cases absorbing its mass.

Carbon dioxide excess - In diving CO_2 excess is a possibility wherever carbon dioxide absorbing canisters are used or where, because apparatus design does not reduce apparatus deadspace, some carbon dioxide is re-inhaled. The chief symptoms, which furnish ample warning to trained men, are increased effort of breathing, a sense of breathlessness and headache.

Carbon monoxide poisoning - In diving, this type of accident usually occurs as a result of contamination of the diver's air supply by exhaust gases from an internal combustion engine.

Cardiovascular - Pertaining to the heart and the blood vessels.

Carrier - 1. In a semiconductor, a mobile conduction electron or hole. 2. In modulation of a signal, a wave suitable for being modulated as a sine wave, a recurring series of pulses, or a direct current.

Carrier wave - A wave generated at a point in the transmitting system and modulated by the signal.

Carry time - In computer operations, the time required for a binary chain to complete its response to an input pulse.

Cartesian coordinates - A coordinate system in which the locations of points in space are expressed by reference to three planes, called coordinate planes, no two of which are parallel.

Cassegrain telescope - A reflecting telescope in which a small hyperboloidal mirror reflects the convergent beam from the paraboloidal primary mirror through a hole in the primary mirror to an eyepiece in back of the primary mirror. Also called Cassegrainian telescope, Cassegrain.

Catheter - A hollow tube of metal, glass, hard or soft rubber, rubberized silk, etc., for introduction into a body cavity through a narrow canal, for the purpose of discharging the fluid contents of a cavity or for establishing that the canal is unobstructed.

Cathode - In an electron tube, an electrode through which a primary stream of electrons enters the interelectrode space.

Cathode-ray oscilloscope - An instrument which displays visually on the face of a cathode-ray tube instantaneous voltages of electrical signals. Either the intensity or the displacement of the trace may be controlled by the signal voltage. More commonly called oscilloscope. Also called cathode-ray oscillograph. See radarscope.

Cathode-ray tube - A vacuum tube consisting essentially of an electron gun producing a concentrated electron beam (or cathode ray) which impinges on a phosphorescent coating on the back of a viewing face (or screen). See Scope.

Cauchy number - A nondimensional number arising in the study of the elastic properties of a fluid. It may be written U^2p/E, where U is a characteristic velocity; p is the density; and E the modulus of elasticity of the fluid. It is the square of the Mach number.

Caution light - An indicator light located on a control panel which denotes existence of a system malfunction and that the operator should be prepared to take corrective action. An amber color is generally prescribed for caution lights.

Cavitation - The formation of bubbles in a liquid, occurring whenever the static pressure at any point in the fluid flow becomes less than the fluid vapor pressure.

Cavitation noise - Cavitation noise is the noise produced in a liquid by the collapse of bubbles that have been created by cavitation.

C-band - A radar frequency band.

C-display - In radar, a rectangular display in which targets appear as blips with bearing indicated by the horizontal coordinate and angles of elevation by the vertical coordinate. Also called C-scan and C-scope.

Celestial coordinates - Any set of coordinates, measured in degrees, used to define a point on the celestial sphere, e.g., right ascension and declination.

Celestial guidance - The process of directing movements of an aircraft or spacecraft by reference to celestial bodies. Also called automatic celestial navigation.

Celestial-inertial guidance - The process of directing the movements of an aircraft or spacecraft by the measurement of inertial forces and reference to celestial bodies.

Celestial observation - In navigation, the measurement of the altitude and/or azimuth of a celestial body.

Celestial pole - Either of the two points of intersection of the celestial sphere and the extended axis of the earth, labeled N or S to indicate whether the north celestial pole or the south celestial pole.

Cell - Storage space for one bit of information in a digital computer.

Cent - In acoustics, the interval between two sounds whose basic frequency ratio is the twelve-hundredth root of 2.

Center frequency - The assigned carrier frequency of a frequency-modulation (FM) station; the unmodulated frequency of an FM system.

Center of buoyancy - The center of buoyancy is the center of gravity of the displaced water or the location of the upward or buoyant force. It is the geometric center of volume of the displaced water. The center of buoyancy should not be confused with the center of gravity of the immersed or floating body. The center of gravity is the effective center of all the weights in a ship. The total weight acts downward on the ship as if it were concentrated at the center of gravity.

Center of mass - That point in a given body, or in a system of two or more bodies that act together in respect to another body, which represents the mean position of the matter in the body or bodies.

Centigrade temperature scale - A temperature scale with the ice point at 0° and the boiling point of water at 100°. Now called Celsius temperature scale.

Centimeter - One-hundredth of a meter; approximately 0.3937 U.S. inch, exactly 1/2.54 inch.

Centimeter-gram-second system - A system of units based on the centimeter as the unit of length, the gram as the unit of mass, and the second as the unit of time.

Central tendency, measure of - Measure of a statistic calculated from a set of distinct and independent observations or measurements of a certain item or entity, and intended to typify those observations.

Centrifugal force - The apparent force in a rotating system, deflecting masses radially outward from the axis of rotation, with magnitude per unit mass ω^2R, where ω is the angular speed of rotation; and R is the radius of curvature of the path. This magnitude may also be written as V^2/R, in terms of the linear speed V. This force (per unit mass) is equal and opposite to the centripetal acceleration. Also called centrifugal acceleration.

Centripetal acceleration - The acceleration on a particle moving in a curved path, directed toward the instantaneous center of curvature of the path, with magnitude V^2/R, where V is the speed of the particle and R the radius of curvature of the path. This acceleration is equal and opposite to the centrifugal force per unit mass.

Chain radar beacon - A radar beacon with a very fast recovery time.

Channel capacity (information theory) - The maximum transmission of information that a channel can provide. It is measured in bits by $\log_2 c$, where c is the number of classes of input messages that can be discriminated by the channel.

Charactron - A cathode ray tube which is capable of displaying alphanumeric characters and other symbols.

Charles-Gay-Lussac law - An empirical generalization that in a gaseous system at constant pressure, the temperature increase and the relative volume increase stand in approximately the same proportion for all so-called perfect gases. Mathematically, $t - t_0 = 1/c$ $(v - v_0)/v_0$ where t is temperature; v is volume; and c is a coefficient of thermal expansion independent of the particular gas.

If the centigrade temperature scale is used and v_0 is the volume at 0° C, then the value of the constant c is approximately 1/273. Also called Charles law, Gay-Lussac law.

Charpentier's bands - A series of alternating light and dark bands which follow a moving slit-shaped stimulus presented against a dark visual field and which are due to fluctuations of visual excitation similar to those which give rise to after-images.

Check-reading instruments - Displays which present dichotamous information, e.g., good-bad, yes-no, rather than quantative information.

Chemiluminescence - Any luminescence produced by chemical action.

Chest-to-back acceleration - See physiological acceleration, Vol. I, Section 2.

Chi-square test - A statistical significance test based on frequency of occurrence; it is applicable both to qualitative attributes and quantitative variables. Among its many uses, the most common are tests of hypothesized probabilities or probability distributions (goodness of fit), statistical dependence or independence (association), and common population (homogeneity).

Chlorella - A genus of unicellular green algae, considered to be adapted to converting carbon dioxide into oxygen in a closed ecological system. See closed ecological system.

Chlorophyll - The green pigment, located in the chloroplasts, which is necessary to the process of photosynthesis.

Chloroplast - A specialized body in the cytoplasm which contains chlorophyll.

Chord - 1. A straight line intersecting a circle or other curve, or a straight line connecting the ends of an arc. 2. (symbol c). In aeronautics, a straight line intersecting or touching an airfoil profile at two points; specifically, that part of such a line between two points of intersection.

Chord length - The length of the chord of an airfoil section between the extremities of the section.

Chroma - The characterization of a color quality without reference to its brilliance or hue (saturation only).

Chromatic aberration - In an optical system, the failure of rays of light from a given point to come to a focus at a point, owing to the fact that light from different parts of the spectrum is refracted unequally.

Chromatic color - A color, or visual quality, which manifests hue and saturation, and therefore cannot be placed in an achromatic series.

Chromatic contrast - A change in hue saturation (or both), in a given area of the visual field, due to the concomitant state of chromatic stimulation of an adjoining or neighboring area, or of the given area or its neighborhood at a closely preceding time.

Chromatic flicker - A pulsating or flicker phenomenon, due to differences in either dominant wave-length or purity, or both, between stimuli or equal luminance, which are alternately applied to the same retinal area. Distinguished from flicker in general, which may involve also pulsations in brightness.

Chromaticity - The aspect of the color stimulus which is specified by dominant wave-length and purity (alternatively, complementary wave-length and purity) taken together.

Chromaticity diagram - A plane diagram, each point in which represents a different combination of dominant wave-length and purity, and which is usually constructed in some form of triangle with colorimetric primaries represented at the corners. The ICI standard chromaticity diagram is essentially a right triangle representing hypothetical primaries and the complete chromaticity gamut of the ICI standard observer. (See Figure 1).

CIE color system - The Commission Internationale de l'Eclairage color system which designates colors in terms of mixtures of theoretical colored lights. Based on the fact that all colors can be reproduced by proper combinations of the three primary colors of light, viz., red, green and blue. (See Table).

Circle of equal probability - A measure of the accuracy with which a rocket or missile can be guided; the radius of the circle at a specific distance in which 50 percent of the reliable shots land. Also called circular error probable, circle of probable error.

Circuit - A network providing one or more closed paths.

Circular area - Of a circle, the square of the diameter. Circular area = 1.2733 x true area. True area = 0.785398 x circular area.

Circular error probable - Circle of equal probability.

Cislunar - Of or pertaining to space between the Earth and the orbit of the Moon, or to a sphere of space centered on the Earth with a radius equal to the distance between the Earth and the Moon.

Clear - To restore a storage or memory device to a prescribed state, usually that denoting zero. See reset.

Climatization - All measures taken to provide for the satisfactory operation, packaging, transportation, and storage of ground equipment regardless of climatic conditions.

Clinometer - A device for measuring the amount of roll aboard ship.

Clo - The amount of insulation which will maintain normal skin temperature of the human body when heat production is 50 kilogram-calorie per meter squared per hour, air temperature is 70° F, and the air is still.

Closed circuit scuba - An underwater swimmer breathing system in which the rate of oxygen utilization is determined by the diver's metabolic consumption of oxygen rather than by the larger volume of gas required for ventilation as in the open circuit type.

Closed ecological system - A system that provides for the maintainance of life in an isolated living chamber through complete re-utilization of the material available, in particular, by means of a cycle wherein exhaled carbon dioxide, urine, and other waste matter are converted chemically or by photosynthesis into oxygen, water, and food.

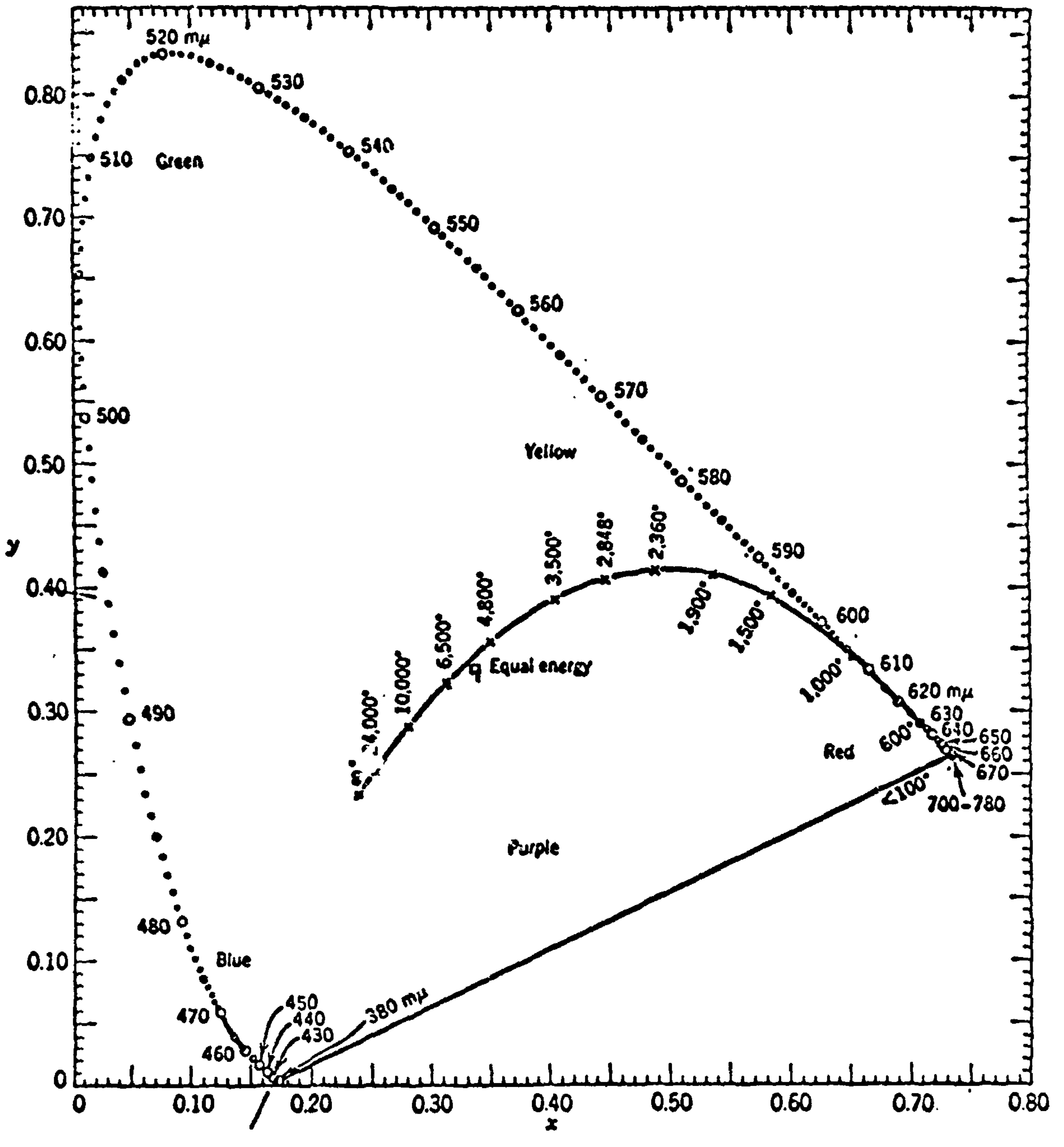


FIG. 1 The (x, y)-chromaticity diagram of the ICI system. The abscissa is the ratio of the tristimulus value X to the sum of all three $(X + Y + Z)$. The ordinate is the ratio of Y to this sum. The parts of the spectrum locus are identified by wavelength in millimicrons. The region bounded by this locus and the straight line (purple border) joining its extremes represents all chromaticities producible by actual stimuli. The central curved line represents the chromaticities of the complete radiator and is called the Planckian locus. Points on this locus are identified by the temperature of the radiator expressed on the Kelvin scale.

Table 2. Chromaticity Coordinates (x, y, z) of the Spectrum Colors

Wavelength, mμ	Chromaticity Coordinates			Wavelength, mμ	Chromaticity Coordinates		
	x	y	z		x	y	z
380	0.1741	0.0050	0.8209	550	0.3014	0.6923	0.0061
385	0.1740	0.0050	0.8210	555	0.3373	0.6589	0.0038
390	0.1738	0.0049	0.8213	560	0.3731	0.6245	0.0024
395	0.1736	0.0049	0.8215	565	0.4087	0.5896	0.0017
				570	0.4441	0.5547	0.0012
400	0.1733	0.0048	0.8219				
405	0.1730	0.0048	0.8222	575	0.4788	0.5202	0.0010
410	0.1726	0.0048	0.8226	580	0.5125	0.4866	0.0009
415	0.1721	0.0048	0.8231	585	0.5448	0.4544	0.0008
420	0.1714	0.0051	0.8235	590	0.5752	9.4242	0.0006
				595	0.6029	0.3965	0.0006
425	0.1703	0.0058	0.8239				
430	0.1689	0.0069	0.8242	600	0.6270	0.3725	0.0005
435	0.1669	0.0086	0.8245	605	0.6482	0.3514	0.0004
440	0.1644	0.0109	0.8247	610	0.6658	0.3340	0.0002
445	0.1611	0.0138	0.8251	615	0.6801	0.3197	0.0002
				620	0.6915	0.3083	0.0002
450	0.1566	0.0177	0.8257				
455	0.1510	0.0227	0.8263	625	0.7006	0.2993	0.0001
460	0.1440	0.0297	0.8263	630	0.7079	0.2920	0.0001
465	0.1355	0.0399	0.8246	635	0.7140	0.2859	0.0001
470	0.1241	0.0578	0.8181	640	0.7190	0.2809	0.0001
				645	0.7230	0.2770	0.0000
475	0.1096	0.0868	0.8036				
480	0.0913	0.1327	0.7760	650	0.7260	0.2740	0.0000
485	0.0687	0.2007	0.7306	655	0.7283	0.2717	0.0000
490	0.0454	0.2950	0.6596	660	0.7300	0.2700	0.0000
495	0.0235	0.4127	0.5638	665	0.7311	0.2689	0.0000
				670	0.7320	0.2680	0.0000
500	0.0082	0.5384	0.4534				
505	0.0039	0.6548	0.3413	675	0.7327	0.2673	0.0000
510	0.0139	0.7502	0.2359	680	0.7334	0.2666	0.0000
515	0.0389	0.8120	0.1491	685	0.7340	0.2660	0.0000
520	0.0743	0.8338	0.0919	690	0.7344	0.2656	0.0000
				695	0.7346	0.2654	0.0000
525	0.1142	0.8262	0.0596				
530	0.1547	0.8059	0.0394	700	0.7347	0.2653	0.0000
535	0.1929	0.7816	0.0255	705	0.7347	0.2653	0.0000
540	0.2296	0.7543	0.0161	710	0.7347	0.2653	0.0000
545	0.2658	0.7243	0.0099	715	0.7347	0.2653	0.0000

Closed-loop system - A system in which the output is used to control the input.

Closed respiratory gas system - A completely self-contained system within a sealed cabin, capsule, or spacecraft that will provide adequate oxygen for breathing, maintain adequate cabin pressure, and absorb the exhaled carbon dioxide and water vapor.

Closing rate - The speed at which two bodies approach each other.

Clutter - Atmospheric noise, extraneous signals, etc., which tend to obscure the reception of a desired signal in a radio receiver, radarscope, etc.

Coated optics - Optical elements (lenses, prisms, etc.) which have their surfaces covered with a thin transparent film to minimize reflection and loss of light in the system.

Coaxial cable - A transmission line consisting of one conductor, usually a small copper tube or wire, within and insulated from another conductor of larger diameter, usually copper tubing braid. The outer conductor may or may not be grounded. Radiation from this type of line is practically zero. Coaxial cable is sometimes called concentric line.

Cockpit procedure trainers - Trainers used to provide cockpit familiarization and orientation.

Coding, control-display - The application of color, shape, location or other features which enable an operator to identify a control or display more quickly.

Coefficient of thermal expansion - The ratio of the change of length per unit length (linear), or change of volume per unit volume (voluminal), to the change of temperature.

Coherent radar - A type of radar that employs circuitry which permits comparison of the phase of successive received target signals.

Collector - Any lens or mirror which collects or converges radiation.

Collimate - 1. To render parallel, as rays of light. 2. To adjust the line of sight of an optical instrument, such as a theodolite, in proper relation to other parts of the instrument.

Collimator - 1. Optical system for rendering convergent or divergent radiation parallel. 2. An optical device which renders rays of light parallel.

Color - Visual sensation determined by interaction of wavelength, intensity, and mixture of wavelengths of light. The corresponding attributes of color are hue, brightness, and saturation.

Color attribute - (See Attributes of Color).

Color blindness - Inability to distinguish colors on the part of a person able to see shapes and forms.

Color code - A technique for simplifying the identification of electrical components and wiring, warning and caution displays, etc., based on color cues.

Color constancy - The relative independence of object colors of changes in illumination or of other viewing conditions.

Color deficient - A general term for relative inability to discriminate chromaticity or hue--as contrasted with color blindness.

Color discrimination - Ability to see and determine differences between color spectrum wavelengths of light. Physiological process attributed to cones of retina.

Color mixture - The presentation of two or more color stimuli to the same area of the retina effectively at the same time for the purpose of eliciting their combined effect. Mixture may be accomplished in various ways such as simultaneous projection, rapid alternation, or diffusive combination of the several stimuli concerned.

Color sensation - Any elementary visual experience of a chromatic or achromatic nature which results from stimulation of the regina, as distinguished from the physical considerations descriptive of the stimulus. More narrowly, those elementary visual experiences which exhibit hue.

Color shades - Colors of brightnesses or lightnesses which are darker than median gray. Contrast with tint.

Color stimulus - Radiant energy of any degree, wavelength, or composition within the ranges which are capable of adequate stimulation of retinal receptors. The term is sometimes limited to adequate stimuli for hueful responses. Color stimuli are sometimes specified in the psychophysical terms of luminance, dominant wavelength, and purity.

Color temperature - The temperature of a blackbody or complete radiator at which it yields a color matching that of a given sample or radiant energy. The blackbody colors form a single series of relatively unsaturated visual qualities, ranging from red, through orange, white, pale blues, and violets, as the temperature is increased. The temperature is measured on the absolute or Kelvin scale.

Color tints - Colors of brightnesses or lightnesses which are lighter than median gray. Contrast with shade.

Color triangle - (See Chromaticity diagram).

Color weakness - A defect in color vision marked by diminished color sensitivity rather than actual loss of any hue. Also called anomalous trichromatism.

Color zones - Regions of the retina which have different characteristics as to chromatic response. For most individuals and usual conditions, the central portions shows full chromatic response, while red and green responses disappear at a moderately peripheral position, and blue and yellow fail toward the extreme periphery. The exact boundaries of any zone depend upon the extent, intensity, and chromatic power of the stimulus used; they vary also with the individual, and with the technique employed. Also called retinal zones.

Coma - 1. The gaseous envelope that surrounds the nucleus of a comet. 2. In an optical system, a result of spherical aberration in which a point source of light, not on the axis, has a blurred, comet-shaped image.

Command - A signal which initiates or triggers an action in the device which receives the signal. In computer operations also called instruction.

Command control - The acquisition process ng, and dissemination of information required by a commander in planning, directing, and controlling operations.

Command destruct - A command control system that destroys a flight-borne test rocket, actuated on command of the range safety officer whenever the rocket performance indicates a safety hazard.

Command guidance - The guidance of a spacecraft or rocket by means of electronic signals sent to receiving devices in the vehicle.

Common item - An item of supply used in two or more systems, subsystems, or pieces of support equipment, cluding related components and spares.

Communication links - Those links through which information is transmitted from one unit to another. They may be from man to man, from equipment to man, from equipment to equipment and from man to equipment.

Commutation - Sequential sampling, on a repetitive timesharing basis of multiple data sources for transmitting or recording, or both, c a single channel.

Compass - An instrument used in determining the azimuth or direction of a body relative to the meridian of a place. There are two principal kinds of compass in use, namely, the magnetic compass which is actuated by the earth's magnetism, and the gyro-compass which is actuated by a rapidly spinning rotor which tends to place its axis of rotation parallel to the earth's axis of rotation. The first is subject to certain errors, known as variation and deviation, and may also be affected by other local attractions. The gyrocompass is free from these disturbances and indicates direction relative to the true meridian of the earth.

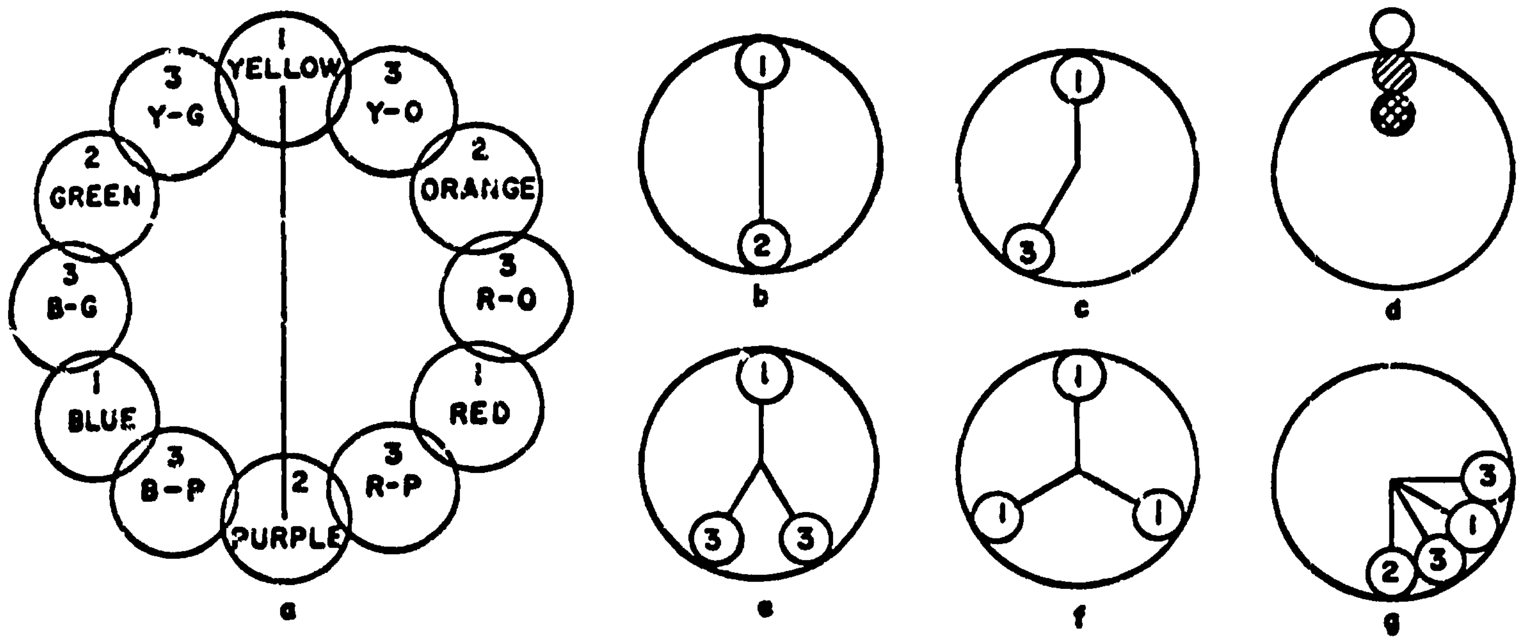
Compass direction - Direction as indicated by a compass without any allowances for compass error. The direction indicated by a magnetic compass may differ by a considerable amount from the true direction referred to a meridian of the earth.

Compass error - The amount by which a compass direction differs from the true direction due to the effects of magnetic deviation and variation.

Compatibility (man-machine) - A characteristic ascribed to the interface between an operator and the equipment he uses; indicates how well the interface matches human physical and mental capabilities and limitations.

Compile - In computer terminology, to assemble the necessary subroutines into a main routine for a specific problem.

Complementary color - 1. The wavelength of light energy of a single frequency which matches the color of a reference standard when combined in suitable proportion with the light. 2. Color pigment, colors opposite one another on a standard color wheel (see Fig. 2).



INTERIOR

FIG. 2 *a.* Color wheel (1-primaries, 2-secondaries, 3-tertiaries). *b.* Complementary colors. *c.* Adjacent complementary colors. *d.* Monochromatic. *e.* Split complementary. *f.* Triad. *g.* Analogous colors.

Complementary wavelength - (See Complementary color).

Complementation - In Boolean algebra, an operation in which items are described by stating that they do not belong to a particular class or classes. See Not circuit.

Component - A combination of parts, subassemblies, or assemblies, usually self-contained, which performs a distinctive function in the operation of the overall equipment.

Concave - Curved inward (as a cave).

Condensation trail - A visible trail of condensed water vapor or ice particles left behind an aircraft, an airfoil, etc. in motion through the air. Also called a contrail or vapor trail.

Cones - Sensory elements found in the retina of the eye that constitute specific receptors for vision at high levels of illumination and for color vision.

Confidence factor - In statistics, the percentage figure that expresses confidence level, or proportion of times the statement should be correct that the estimated population parameter lies within the given confidence interval.

Confidence interval - In statistics, a range of values which is believed to include, with a preassigned degree of confidence (confidence level), the true characteristic of the lot or universe a given percentage of the time.

Confidence level - In statistics, the degree of desired trust or assurance in a given result.

Configuration - 1. Relative position or disposition of various things, or the figure or pattern so formed. 2. A geometric figure, usually consisting principally of points and connecting lines. 3. = planetary configuration. 4. A particular type of a specific aircraft, rocket, etc., which differs from others of the same model by virtue of the arrangement of its components or by the addition or omission of auxiliary equipment as long-range configuration, cargo configuration.

Conical beam - The radar beam produced by conical scanning methods.

Conical scanning - Scanning in which the direction of maximum radiation generates a cone whose vertex angle is of the order of the beam width. Such scanning may be either rotating or nutating, according as the direction of polarization rotates or remains unchanged.

Conjunction - The situation of two celestial bodies having either the same celestial longitude or the same sidereal hour angle.

Console - Panels or cabinets upon which are mounted dials, switches and other apparatus used in centrally controlling electrical or mechanical devices.

Conspicuity - Degree of conspicuousness.

Constancy - The phenomenon that perceptual objects retain to a greater or lesser degree normal appearance in relative (though not in absolute) independence of the local stimulus conditions. Applied to the following properties: color, preservation of normal hue, saturation, and brightness under different illumination; form-persistence of the shape of an object when, from geometrical optics, a change might be expected; magnitude-preservation of apparent size in spite of differences in the retinal image.

Continuous-flow system - An oxygen system in which the oxygen flows during both inspiration and expiration by the individual

Continuous-pressure breathing - A kind of pressure breathing in which a minimum amount of pressure variation exists inside the mask.

Continuous-wave radar - A general species of radar transmitting continuous waves, either modulated or unmodulated. The simplest form transmits a single frequency and detects only moving targets by the Doppler effect. This type of radar determines direction but usually not range. Also called CW radar.

Continuum - Something which is continuous, which has no discrete parts, as the continuum of real numbers as opposed to the sequence of discrete integers, as the background continuum of a spectrogram due to thermal radiation.

Contrail - Condensation trail.

Contrast - Difference in brightness between two portions of visual field, usually expressed in experimental procedure as:

$$C = \frac{B\ (\text{background}) - B\ (\text{test field})}{B\ (\text{background})} \times 100\%$$

Contrast flicker - Flicker which is induced into a physically constant field by a neighboring flicker.

Control - 1. Device by which direction, regulation, or restraint is exercised over something. 2. An activity or organization that directs or regulates an activity.

Control-display compatibility - The naturalness of the control used as it relates to the response made. For example, a clockwise turn of a rotary control is associated with an increase in values.

Control-display ratio - The ratio of the control movement of the control to the movement of the display indicator. The ratio may be in distance, as for levers, or revolutions as for rotary devices.

Control feel - The impression of the stability and control of an aircraft that a pilot receives through the cockpit controls, either from the aerodynamic forces acting on the control surfaces or from forces simulating these aerodynamic forces.

Controlled environment - The environment of any object, such as an instrument, a man, or an unlaunched rocket, in which effects such as humidity, pressure, temperature, etc., are maintained at predetermined levels.

Convergence - The turning of the two eyes toward each other so that their respective lines of sight meet at a point in space. Thus, the image is formed at corresponding regions of the two retinas.

Convex - Curved outward.

Coordinate system - Any scheme for the unique identification of each point of a given continuum. The geometry of the system is a matter of convenience determined by the boundaries of the continuum or by other considerations. Also called reference frame.

Coriolis effects - The physiological effects (nausea, vertigo, dizziness, etc.) felt by a person moving radially in a rotating system, as a rotating space station.

Coriolis force - An inertial force on a moving body, or particles, produced by the movement of the masses involved, perpendicular to the axis of the primary rotating system. Also called compound centrifugal force, deflecting force.

Corona - 1. The outer visible envelope of the sun. Also called solar corona. 2. The extremely tenuous outer atmosphere of the sun now known to extend beyond the earth's orbit. 3. A set of one or more prismatically colored rings of small radii, concentrically surrounding the disk of the sun, moon, or other luminary when veiled by a thin cloud.

Corona discharge - A luminous, and often audible, electric discharge that is intermediate in nature between a spark discharge (with, usually, its single discharge channel) and a point discharge (with its diffuse, quiescent, and nonluminous character). Also called brush discharge, St. Elmo's fire, corposant.

Corrective maintenance - That maintenance performed to restore an item to a satisfactory condition by providing correction of a malfunction which has caused degradation of the item below the specified performance.

Corrective maintenance time - The time that begins with the observance of a malfunction of an item and ends when the item is restored to a satisfactory operating condition. It may be subdivided into Active Maintenance Time and Nonactive Maintenance Time. Does not necessarily contribute to equipment or system downtime in cases of alternate modes of operation or redundancy.

Correlation - 1. In statistics, a relationship between two occurrences which is expressed as a number between minus one (-1) and plus one (+1). 2. When used without further qualification, the statistical term correlation usually refers to simple, linear correlation between two variables, x and y, and is measured by the product-moment coefficient of correlation p or its sample estimate r.

Correlation detection - A method of detection in which a signal is compared, point-to-point, with an internally generated reference. Also called cross correlation detection.

Correlation tracking and ranging (Cotar) - A nonambiguous trajectory-measuring system using short-baseline, single-station, continuous-wave phase-comparison measure in two direction cosines and a slant range.

Correlation tracking and triangulation (Cotat) - A trajectory measuring system composed of several antenna baselines, each separated by large distances, used to measure direction cosines to an object. From these measurements its space position is computed by triangulation.

Cosine law of illumination - A purely geometric relationship between the illuminance of a surface and the angle of incidence of the illuminating rays. Mathematically, the illuminance I of the surface illuminated by a beam of flux density F incident at angle θ is $I = F \cos \theta$.

Coulomb - The unit of quantity of electricity; the quantity of electricity transported in 1 second by a current of 1 ampere.

Counter, digital readout - A numerical readout device which presents absolute numerical values on a mechanical drum, screen projection, solid state or other display.

Counterclockwise, control motion - Refers to movement of a rotary control knob to the left.

Course - 1. A predetermined or intended route or direction to be followed, measured with respect to a geographic reference direction; a line on a chart representing a course. 2. A line of flight taken by an aircraft, rocket, etc. 3. A radio beam in a radio range.

Critical - In reactor theory, capable of sustaining a chain reaction.

Critical damping - Critical damping is the minimum viscous damping that will allow a displaced system to return to its initial position without oscillation.

Critical flicker frequency - The minimum number of alternations per second of two different visual stimuli (or the frequency of any periodically variable stimulus) upon the same retinal area which will permit a constant effect in visual experience, as if from an invariable stimulus, i.e., which will result in the elimination of flicker. Cf. flicker.

Critical incidence (or angle) - The least angle of incidence at which total reflection takes place.

Criticality - The effect of a malfunction of an item on the performance of a system.

Critical speed - A speed of a rotating system that corresponds to a resonance frequency of the system.

Cross coupli[illegible] - Unintentional control inputs introduced by an operator [illegible] associated with integrated control such as a joystick.

Crosstalk [illegible] ances in a communication channel as a result [illegible] communication channels.

Cryogenic [illegible] The [illegible] etals and alloys which are usable in structur[illegible] y low temperature, and usually possess improved [illegible] operties at these temperatures.

Cryogenics - 1. The study of the methods of producing very low temperatures. 2. The study of the behavior of materials and processes at cryogenic temperatures.

C-scan - C-display.

C-scope - C-display.

Curie - The unit of the rate of radioactive decay; the quantity of any radioactive nuclide which undergoes 3.70×10^{10} disintegrations per second.

Current - 1. The flow of electrons in an electrical conductor. 2. A horizontal movement of the water.

Cursor - A device used with an instrument to provide a movable reference, as the runner of a slide rule or a rotatable plastic disk with inscribed crosslines, used in reading bearings on a plan position indicator.

Curve of regression - A realistic curve having a least-squares fit to the data points.

Curvilinear coordinates - Any linear coordinates which are not Cartesian coordinates. Examples of frequently used curvilinear coordinates are polar coordinates and cylindrical coordinates.

Cutaneous sense - Any of the senses whose receptors lie in the skin or immediately beneath it (or in the external mucous membranes): contact, pressure, warmth, cold, pain, and perhaps others.

Cybernetics - The study of methods of control and communication which are common to living organisms and machines.

Cycle - 1. The complete sequence of values of a periodic quantity that occur during a period. 2. One complete wave, a frequency of 1 wave per second. 3. Any repetitive series of operations or events.

Dalton's law - States that the total pressure exerted by a mixture of gases may be considered to be the sum of the pressures that would be exerted by each of the gases if it alone were present and occupied the total volume.

Damping - The suppression of oscillations or disturbances; the dissipation of energy with time.

Dark adaptation - The process by which the iris and retina of the eye adjust to allow maximum vision in dim illumination, following exposure of the eye to a relatively brighter illumination. (See Vol. I Section

Dark-adapted eye - An eye whose condition has been so modified by the withdrawal of general light stimulation that faint stimulation has become more effective. Contrast with light-adapted eye.

Dark trace tube - A cathode-ray tube, on which the face is bright, and signals are displayed as dark traces or dark blips.

Dash - Term to describe a phase of an aircraft mission, usually the final run prior to release of a weapon.

Data link - Any communications channel or circuit used to transmit data from a sensor to a computer, a readout device, or a storage device.

Data point - A unit of fundamental information obtained through the processing of raw data.

Data processing - Application of procedures, mechanical, electrical, computational, or other, whereby data are changed from one form into another.

Data reduction - Transformation of observed values into useful, ordered, or simplified information.

Data smoothing - The mathematical process of fitting a smooth curve to dispersed data points.

Datum - Any numerical or geometrical quantity or set of such quantities which can serve as a reference or a base for measurement of other quantities.

Datum line - Any line which can serve as a reference or base for the measurement of other quantities.

Datum plane - A plane from which angular or linear measurements are reckoned. Also called reference plane.

Datum point - Any point which can serve as a reference or base for the measurement of other quantities.

Dazzle - An expression used to describe extreme brightness characteristics of direct or reflected light; causes difficulty in seeing.

D-display - In radar, a C-display in which the blips extend vertically to give a rough estimate of distance.

Dead band - An arrangement incorporated in a guidance system which prevents an error from being corrected until that error exceeds a specified magnitude.

Dead man controls - Devices for shutting off or rendering mechanisms safe in case of accident or illness of the operator.

Dead reckoning - In navigation, determination of position by advancing a previous known position for courses and distances.

Debug - 1. To isolate and remove malfunctions from a device, or mistakes from a routine or program. 2. Specifically, in electronic manufacturing, to operate equipment under specified environmental and test conditions in order to eliminate early failures and to stabilize equipment prior to actual use. Also called burn-in.

Decay time - 1. In computer operations, the time required for a pulse to fall to one-tenth of its peak value. 2. In charge-storage tubes, the time interval during which the magnitude of the stored charge decreases to a stated fraction of its initial value. 3. Approximately the lifetime of an orbiting object in a nonstable orbit. Decay time is usually applied only to objects with short orbit lifetimes caused by atmospheric drag.

Deceleration parachute - A parachute attached to a craft and deployed to slow the craft, especially during landing. Also called a brake parachute, drogue parachute, parabrake.

Decibel - 1. A dimensionless measure of the ratio of two powers, equal to 10 times the logarithm to the base 10 of the ratio of two powers P_1/P_2. 2. One-tenth of a bel.

Decimal-to-binary conversion - The mathematical process of converting a quantity from decimal notation to the equivalent binary notation. For example: 1 = 1; 7 = 111; 23 = 10111, etc. See binary notation.

Decision element - In computer operations, any device which as the result of the input of data issues one of two or more possible instructions.

Declination - Angular distance north or south of the celestial equator.

Decoder - 1. A device for translating electrical signals into predetermined functions. 2. In computer operations, a network or device in which one of two or more possible outputs results from a prescribed combination of inputs.

Decompression sickness - A disorder experienced by deep sea divers and aviators caused by reduced atmospheric pressure and evolved gas bubbles in the body, marked by pain in the extremities, pain in the chest (chokes), occasionally leading to severe central nervous symptoms and neurocirculatory collapse. See bends, dysbarism.

Deep scattering layer - Term applied to widespread strata in the ocean which scatter or return vertically directed sound such as in the case of echo sounding. These layers, which are evidently of biological origin, are located in depths ranging from 150 to 200 fathoms during the day with most of them migrating to or near the surface during the night.

Deep water - Water of depth such that surface waves are little affected by conditions on the ocean bottom. It is customary to consider water deeper than one-half the surface wave length as deep water.

Definition - The clarity, fidelity, sharpness, resolution and briliancy of an image, as a photographic image.

Degaussing - Slang for demagnetize.

Degree of freedom - 1. A mode of motion, either angular or linear, with respect to a coordinate system, independent of any other mode. 2. Specifically, of a gyro the number of orthogonal axes about which the spin axis is free to rotate. 3. In an unconstrained dynamic or other system, the number of independent variables required to specify completely the state of the system at a given moment. 4. Of a mechanical system, the minimum number of independent generalized coordinates required to define completely the positions of all parts of the system at any instant of time.

Delayed reaction - In a reaction-time experiment, reactions believed to depend upon higher cortical centers: discrimination reactions, choice reactions, etc.

Demand oxygen system - An oxygen system in which oxygen flows to the user during inspiration only.

Demodulation - The process of recovering the modulating wave from a modulated carrier.

Denitrogenation - The removal of nitrogen dissolved in the blood and body tissues, usually by breathing of pure oxygen for an extended period of time in order to prevent aeroembolism at high altitudes.

Dependent variable - Any variable considered as a function of other variables, the latter being called independent. Compare parameter. Whether a given quantity is best treated as a dependent or independent variable depends upon the particular problem.

Depot Maintenance - Maintenance performed on material requiring a major overhaul or a complete rebuilding of parts, subassemblies, assemblies, and end items.

Depth angle - The angle between the horizontal and the bearing of the submerged target as seen from own ship.

Depth perception - The ability to estimate depth or distance between points in the field of vision.

Descending node - That point at which a planet, planetoid, or comet crosses to the south side of the ecliptic; that point at which a satellite crosses to the south side of the equatorial plane of its primary. Also called southbound node. The opposite is ascending node or northbound node.

Design gross weight - The gross weight at take-off that an aircraft, rocket, etc, is expected to have, used in design calculations.

Destruct - The deliberate action of destroying a rocket vehicle after it has been launched, but before it has completed its course.

Detection - See recognition.

Deuteranomalous Trichromat - An individual having deuteranomalous vision, viz., deuteranomaly.

Deuteranomaly - Form of trichromatism in which the luminosity function is within normal limits, but in which an abnormally large proportion of stimulus green is required in a red-green stimulus mixture in order to match a given yellow.

Deuteranope - Individual having deuteranopic vision.

Deuteranopia - Form of dichromatism in which green and purplish red stimuli are confused, but a normal proportion suffices to match a given yellow, and the luminosity function also is within normal limits. Sometimes called green blindness.

Deuterium - A heavy isotope of hydrogen having one proton and one neutron in the nucleus.

Deviation - 1. In statistics, the difference between two numbers. Also called departure. Commonly applied to the difference of a variable from its mean, or to the difference of an observed value from a theoretical value. 2. = magnetic deviation. 3. In radio transmission the apparent variation of frequency above and below the unmodulated or center frequency.

Dewpoint - The temperature to which a given parcel of air must be cooled at constant pressure and constant water-vapor content in order for saturation to occur; the temperature at which the saturation vapor pressure of the parcel is equal to the actual vapor pressure of the contained water vapor. Any further cooling usually results in the formation of dew or frost. Also called dewpoint temperature.

Diastolic blood pressure - The pressure exerted by the blood during periods between cardiac contraction.

Dichromat - Individual having dichromatic vision.

Dichromatism - Form of vision yielding colors which require in general two independently adjustable primaries (such as red and green, or blue and yellow) for their duplication by stimulus mixture. Dichromatism may be either protanopia, deuteranopia, tritanopia, or some irregular form such as tetartanopia.

Difference limen - The small amount of difference between two compared stimuli which gives rise (statistically) to a perceived difference as often as it does not. The difference limen is the same as the average just noticeable difference. Also called differential threshold, threshold of difference.

Differential analyzer - An analog computer designed and used primarily for solving differential equations.

Differential pressure - The pressure difference between two systems or volumes.

Differential sensitivity - The 50 percent detectable ratio between the sum of echo strength and background noise and the background noise.

Differentiator - 1. In computer operations, a device whose output is proportional to the derivative of an input signal. 2. In electronics, a transducer whose output waveform is the time derivative of its input waveform.

Diffraction - 1. A modification which light undergoes, as in passing by the edges of opaque bodies or through narrow slits, in which the rays appear to be deflected, producing fringes or parallel light and dark or colored bands. 2. The name given to that process which allows sound waves to bend around obstacles that are in their path.

Diffuse sky radiation - Solar radiation reaching the earth's surface after having been scattered from the direct solar beam by molecules or suspensoids in the atmosphere. Also called skylight, diffuse skylight, sky radiation.

Diffuse sound - Sound energy for which energy is uniform in the region considered and when all directions of energy flux at all parts of the region are equally probable.

Digit - 1. A single symbol or character representing an integral quality. 2. Any one of the symbols used in positional notation as coefficients of each power, or order, of the base.

Digital - Using discrete expressions to represent variables.

Digital computer - A computer which operates with information, numerical or otherwise, represented in a digital form.

Digital output - Transducer output that represents the magnitude of the stimulus in the form of a series of discrete quantities coded to represent digits in a system of notation. Compare analog output.

Digitize - Changing an analog measurement into a number expressed in digits.

Diopter - Measurement of the focusing power of a lens according to the reciprocal of the focal length of the lens. A lens of one diopter focuses parallel rays at 1 meter.

Dioptric light - A light concentrated into a collimated beam by means of refracting lenses or prisms.

Diplopia - Any condition of the ocular mechanism in which a single external object is seen double.

Dipole - 1. A system composed of two, separated, equal electric or magnetic charges of opposite sign. 2. = dipole antenna.

Dipole antenna - A straight radiator, usually fed in the center, and producing a maximum of radiation in the plane normal to its axis. The length specified is the overall length.

Directional gyro - 1. A two-degree-of-freedom gyro with a provision for maintaining its spin axis approximately horizontal. 2. A flight instrument incorporating a gyro that holds its position in azimuth and thus can be used as a directional reference.

Directional stability - The property of an aircraft, rocket, etc., enabling it to restore itself from a yawing or sideslipping condition. Also called weathercock stability.

Direction finder - Radio direction finder.

Direct motion - Eastward or counterclockwise motion of a planet or other object as seen from the North Pole (motion in the direction of increasing right ascension).

Discrete - Composed of distinct or discontinuous elements.

Discrete variable - A quantity that may assume any one of a number of individually distinct or separate values.

Dish - A parabolic reflector type of radio or radar antenna.

Dispersion - 1. In rocketry, (a) deviation from a prescribed flight path, (b) specifically, circular dispersion. 2. A measure of the scatter of data points around a mean value or around a regression curve. 3. The process in which radiation is separated into its component wavelengths.

Displacement - A vector quantity that specifies the change of position of a body or particle usually measured from the mean position or position of rest.

Display - The presentation of the output data of any device or system in a form suitable for human perception and interpretation.

Distance measuring equipment - A radio aid to navigation which provides distance information by measuring total round-trip time of transmission from an interrogator to a transponder and return.

Distortion - 1. An undesired change in waveform. 2. In a system used for transmission or reproduction of sound, a failure by the system to transmit or reproduce a received waveform with exactness.

Distribution-free statistics - A branch of statistics making no assumptions about the distribution.

Diurnal - Having a period of, occurring in, or related to a day.

Diurnal aberration - Aberration caused by the rotation of the earth. The value of diurnal aberration varies with the latitude of the observer and ranges from zero at the poles to 0.31 second of arc.

Divergence - 1. The expansion or spreading out of a vector field; also a precise measure thereof. 2. A static instability of a lifting surface or of a body on a vehicle wherein the aerodynamic loads tending to deform the surface or body are greater than the elastic restoring forces.

Docking - The act of coupling two or more orbiting objects; the operation of mechanically connecting together, or in some manner bringing together, orbital payloads.

Dogleg - A directional turn made in the launch trajectory to produce a more favorable orbit inclination.

Doppler effect - The change in frequency with which energy reaches a receiver when the receiver and the energy source are in motion relative to each other. Also called Doppler shift.

Doppler navigation - Dead reckoning performed automatically by a device which gives a continuous indication of position by integrating the speed derived from measurement of the Doppler effect of echoes from directed beams of radiant energy transmitted from the craft. See Doppler radar.

Doppler radar - A radar which detects and interprets the Doppler effect in terms of the radial velocity of a target.

Doppler shift - 1. = Doppler effect. 2. The magnitude of the Doppler effect, measured in cycles per second.

Dorsal - Toward or pertaining to the back, or upper surface.

Dosimeter - 1. An instrument for measuring the ultraviolet in solar and sky radiation. Compare actinometer. 2. A device, worn by persons working around radioactive material, which indicates the dose of radiation to which they have been exposed.

Double-dabble - A technique for binary to decimal conversion. Starting with the most significant bit, proceed, bit-by-bit, as follows: if the next bit is 0, double what you have (double); if the next bit is 1, double what you have and add 1 (dabble). Thus, 111 (binary) = 7 (decimal); 10111 (binary) = 23 (decimal).

Double stars - Stars which appear as single points of light to the eye but which can be resolved into two points by a telescope.

Down range - The airspace extending downstream on a given rocket test range.

Downtime - A period (calender time) during which equipment is not operating correctly because of machine failure.

Draft - The depth to which a vessel is submerged. Draft is customarily indicated by numerals called draft marks at the bow and stern. It may also be determined by means of a draft gauge.

Drag - A retarding force acting upon a body in motion through a fluid, parallel to the direction of motion of the body. It is a component of the total fluid forces acting on the body. See aerodynamic force.

Drag coefficient - A coefficient representing the drag on a given airfoil or other body, or a coefficient representing a particular element of drag.

Drag parachute - 1. = drogue parachute. 2. Any of various types of parachutes attached to high-performance aircraft that can be deployed, usually during landings, to decrease speed and also, under certain flight conditions, to control and stabilize the aircraft.

Drift - 1. The lateral divergence from the prescribed flight path of an aircraft, a rocket, or the like, due primarily to the effect of a crosswind. 2. A slow movement in one direction of an instrument pointer or other marker. 3. A slow change in frequency of a radio transmitter. 4. The angular deviation of the spin axis of a gyro from a fixed reference in space. 5. In semiconductors, the movement of carriers in an electric field.

Drift rate - The amount of drift, in any of its several senses, per unit time (e.g., straying from normal position, course or operating level).

Drogue - 1. A device, usually shaped like a funnel or cone, dragged or towed behind something and used, e.g., as a sea anchor. 2. A funnel-shaped part at the end of the hose of a tanker aircraft, used in air refueling to drag the hose out and stabilize it and to receive the probe of the receiving aircraft. 3. = drogue parachute.

Drogue parachute - 1. A type of parachute attached to a body used to slow it down; also called deceleration parachute or drag parachute. 2. A parachute used specifically to pull something, usually a larger parachute, out of stowage, as, a drogue parachute deploys a drag parachute.

Drogue recovery - A type of recovery system for space vehicles or space capsules after initial reentry into the atmosphere using deployment of one or more small parachutes to diminish speed, to reduce aerodynamic heating, and to stabilize the vehicle so that larger recovery parachutes can be safely deployed at lower altitudes without too great an opening shock.

Drone - A remotely controlled aircraft.

Dry weight - The weight of a rocket vehicle without its fuel.

Ducted-fan engine - An aircraft engine incorporating a fan or propeller enclosed in a duct; especially, a jet engine in which an enclosed fan or propeller is used to ingest ambient air to augment the gases of combustion in the jetstream.

Duplexer - A device which permits a single antenna system to be used for both transmitting and receiving. Duplexer should not be confused with diplexer, a device permitting an antenna system to be used simultaneously or separately by two transmitters.

Dust - In meteor terminology, finely divided solid matter, with particle sizes in general smaller than micrometeorities, as meteoric dust, meteroritic dust.

Dye marker - A substance which, when placed in water, spreads out and colors the water immediately surrounding so as to make a spot readily visible from the air.

Dynamic balance - The condition which exists in a rotating body when the axis about which it is forced to rotate, or to which reference is made, is parallel with a principal axis of inertia. No products of inertia about the center of gravity of the body exist in relation to the selected rotational axis.

Dynamic load - A load imposed by dynamic action, as distinguished from a static load. Specifically, with respect to aircraft, rockets, or spacecraft, a load due to an acceleration of craft, as imposed by gusts, by maneuvering, by landing, by firing rockets, etc.

Dynamic pressure - The pressure of a fluid resulting from its motion, equal to one-half the fluid density times the fluid velocity square ($\frac{1}{2}\rho V^2$). In incompressible flow, dynamic pressure is the difference between total pressure and static pressure. Also called kinetic pressure. Compare impact pressure.

Dynamic storage - Storage in which information is moving in time, and not always available instantaneously.

Dynamometer - An instrument for measuring power or force; specifically, an instrument for measuring the power, torque, or thrust of an aircraft engine or rocket.

Dyne - That unbalanced force which acting for 1 second on a body of 1 gram mass produces a velocity change of 1 centimeter per second. The dyne is the unit of force in the CGS system.

Dysbarism - A condition of the body resulting from the existence of a pressure differential between the total ambient pressure and the total pressure of dissolved and free gases within the body tissues, fluids, and cavities.

Dyspnea - Shortness of breath, difficult or labored respiration.

Earthlight - The illumination of the dark part of the moon's disk produced by sunlight reflected onto the moon from the earth's surface and atmosphere. Also called earthshine.

Ebb tide - A non-technical term referring to that period of the tide between a high water and the succeeding low water; falling tide.

Ebullism - The formation of bubbles, with particular reference to water vapor bubbles in biological fluids caused by reduced ambient pressure; the boiling of body fluids.

Eccentricity (symbol e) - 1. Of any conic, the ratio of the length of the radius vector through a point on the conic to the distance of the point from the directrix. 2. Of an ellipse, the ratio of the distance between the center and focus of an ellipse to its semimajor axis. Also called numerical eccentricity. 3. Of an ellipse, the distance between the center and the focus. Also called linar eccentricity.

Echo - 1. A wave that has been reflected or otherwise returned with sufficient magnitude and delay to be detected as a wave distinct from that directly transmitted. 2. In radar, a pulse of reflected radiofrequency energy; the appearance on a radar indicator of the energy returned from a target. Also called blip.

Ecliptic - The apparent annual path of the sun among the stars; the intersection of the plane of the earth's orbit with the celestial sphere.

Ecological system - A habitable environment, either created artifically, as in a manned space vehicle, or occurring naturally, such as the environment on the surface of the earth, in which man, animals, or other organisms can live in mutual relationship with one another and the environment.

Ecology - The study of the environmental relations of organisms.

Ecosphere - 1. = biosphere. 2. A volume of space surrounding the Sun, extending from the orbit of Venus past the orbit of Mars, in which some biologists believe conditions are favorable for the development and maintenance of life.

E-display - In radar, a rectangular display in which targets appear as blips with distance indicated by the horizontal coordinate and evaluation by the vertical coordinate. Also called E-scan and E-scope.

Effective acoustic center - The effective acoustic center of an acoustic generator is the point from which the spherically divergent sound waves, observable at remote points, appear to diverge.

Effective temperature - In physiology, the temperature at which motionless, saturated air would induce, in a sedentary worker wearing ordinary indoor clothing, the same sensation of comfort as that induced by the actual conditions of temperature, humidity, and air movement.

Efficiency - 1. Of a device with respect to a physical quantity which may be stored, transferred, or transformed by the device, the ratio of the useful output of the quantity to its total input. Unless specifically stated otherwise, the term efficiency means efficiency with respect to power. 2. (Human performance) the effectiveness of work output relative to specified task objectives.

Egress - Pertains to access for departing from an operating or passenger station within a vehicle or work area.

Eight ball - Common name given to a flight attitude indicator.

Ejection capsule - 1. In an aircraft or manned spacecraft, a detachable compartment serving as a cockpit or cabin, which may be ejected as a unit and parachuted to the ground. 2. A satellite, probe, or unmanned spacecraft, a box-like unit, usually containing recording instruments or records of observed data, which may be ejected and returned to earth by a parachute or other deceleration device.

Elastomers - Rubber-like compounds.

E-layer - A division of the ionosphere, usually found at an altitude between 100 and 120 kilometers in the E-region. It exhibits one or more distinct maximums and sharp gradients of free electron density. It is most promounced in the daytime but does not entirely disappear at night. Also called E_1-layer, Kennelly-Heaviside layer, Heaviside layer.

Electrode - A terminal at which electricity passes from one medium into another. The positive electrode is called anode; the negative electrode is called cathode.

Electroluminescence - Emission of light caused by an application of electric fields to solids or gases.

Electromagnetic radiation - Energy propagated through space or through material media in the form of an advancing disturbance in electric and magnetic fields existing in space or in the media. The term radiation, alone, is used commonly for this type of energy, although it actually has a broader meaning. Also called electromagnetic energy or simply radiation.

Electromyogram - A record of the response of a muscle to an electric stimulation.

Electronic data processing - The use of electronic devices and systems in the processing of data so as to interpret the data and put them into usable form.

Electroluminescent display - A solid state display based on the principles of electroluminescence.

Embolism - Large amounts of air in the blood stream which, reaching the heart, cause it to fail; small amounts are resorbed and cause no symptoms.

Emittance - 1. The radiant flux per unit area emitted by a body. 2. The ratio of the emitted radiant flux per unit area of a sample to that of a black body radiator at the same temperature and under the same conditions.

Emphysema - Refers to a swelling or inflation due to abnormal presence of air in the tissues. Subcutaneous emphysema is the presence of air in the tissues just under the skin. Mediastinal emphysema is the presence of air in the tissues in the vicinity of the heart and large blood vessels in the middle of the chest. Unless extreme, neither of these conditions is likely to cause serious difficulty.

Empty field myopia - Involuntary accommodation of the eyes in the absence of visual objects on which to focus; often occurs with pilots at high altitudes and results in temporary nearsightedness.

End item - A final combination of end products, component parts, and/or materials that is ready for its intended use; e.g., a missile, a mobile guidance unit, a launcher.

Endoskeleton - An internal supporting framework or structure.

Energy management - In rocketry the monitoring of the expenditure of fuel for flight control and navigation.

Entry corridor - Depth of the region between two trajectories which define the design limits of a vehicle which will enter a planetary atmosphere.

Envelope - 1. Of a variable, a curve which bounds the values which the variable can assume, but does not consider possible simultaneous occurrences or correlations between different values. 2. The bounds within which a certain system can operate, as a flight envelope, especially a graphic representation of these bounds showing interrelationships of operational parameters.

Ephemeris time - The uniform measure of time defined by the laws of dynamics and determined in principle from the orbital motions of the planets, specifically the orbital motion of the earth as represented by Newcomb's Tables of the Sun.

Epicenter - In seismology, the point of the earth's surface directly over the focus or theoretical point of origin of an earthquake.

Episcotister - A disk with adjustable open and closed sectors together with a mechanism for rotating it. Used for adjusting or equating luminances and for the short exposure of visual material, especially in the study of flicker.

Equinoctial - Celestial equator.

Equinoctial system of coordinates - Celestial equator system of coordinates.

Equinox - One of the two points of intersection of the ecliptic and the celestial equator, occupied by the sun when its declination is 0°.

Equivalent foot-candle - foot-lambert.

Erg - The unit of energy or work in the centimeter-gram-second system; the work performed by a force of 1 dyne acting through a distance of 1 centimeter.

E-scan - E-display.

Escape velocity - The radial speed which a particle or larger body must attain in order to escape from the gravitational field of a planet or star. When friction is neglected, the escape velocity is $\sqrt{2Gm/r}$ where G is the universal gravitational constant (see gravitation); m is the mass of the planet or star; and r is the radial distance from the center of the planet or star. Also called escape speed.

Eulerian angles - A system of three angles which uniquely define with reference to one coordinate system (e.g., earth axes), the orientation of a second coordinate system (e.g., body axes). Any orientation of the second system is obtainable from that of the first by rotation through each of the three angles in turn, the sequence of which is important.

Eulerian coordinates - Any system of coordinates in which properties of a fluid are assigned to points in space at each given time, without attempt to identify individual fluid parcels from one time to the next. Eulerian coordinates are to be distinguished from Lagrangian coordinates. The particular coordinate system used to identify points in space is quite independent of whether the representation is Eulerian or Lagrangian.

Euphotic zone - For the purpose of biological investigations, the sea is divided vertically into three zones with respect to the amount of light present. These are: 1. The euphotic zone, 2. the disphotic zone, and 3. the aphotic zone. The euphotic zone is supplied with sufficient light for the photosynthetic processes of plants. It extends from the surface to 80 or more meters.

Exobiology - That field of biology which deals with the effects of extraterrestrial environments on living organisms and with the search for extraterrestrial life.

Exoskeleton - 1. An external supporting structure or covering. 2. A recently developed device worn and operated by man to provide increased manual force capability.

Exosphere - The outermost, or topmost, portion of the atmosphere. Its lower boundary is the critical level of escape, variously estimated at 500 to 1000 kilometers above the earth's surface. Also called region of escape.

Expiratory reserve - The volume of air that can be expelled from the lungs after a normal expiration.

Explosive decompression - A very rapid reduction of air pressure inside a cabin, coming to a new static condition of balance with the external pressure.

Exposure suit - A suit designed to protect a person from a harmful natural environment, such as cold water.

Extinction coefficient - In meteorology, a measure of the space rate of diminution, or extinction, of any transmitted light; thus, it is the attenuation coefficient applied to visible radiation.

Extragalactic - Outside our galaxy, which is the Milky Way.

Extraspectrum hue - A hue which is not characteristically evoked by any color stimulus in the spectrum. Extraspectrum hues range from the extreme violet through the series of purples and magentas, and include the psychologically primary red itself.

Extraterrestrial life - Life forms evolved and existing outside the terrestrial biosphere.

Extraterrestrial radiation - In general, solar radiation received just outside the earth's atmosphere.

Extremely high frequency - See frequency band.

Extremely low frequency - See frequency band.

Extreme value - In statistics, the upper or lower bound of the random variable which is not expected to be exceeded by a specified percentage of the population within a given confidence interval.

Eyeballs in, eyeballs out, eyeballs down, eyeballs up, eyeballs left, eyeballs right - Expressions used to indicate effect of acceleration on human operators. Eyeballs-in associated with forward acceleration, etc.

Facsimile (transmission) - In electrical communications, the process, or the result of the process, by which fixed graphic material including pictures or images in scanned and the information converted into signals which are used either locally or remotely to produce in record form a likeness (facsimile) of the subject copy.

Fahrenheit temperature scale - A temperature scale with the ice point at 32° and the boiling point of water at 212°.

Fail-safe design - Design considerations to prevent probable equipment failures or malfunctions which may injure the operator or damage the equipment.

Failure modes and effects analysis - An analytic procedure which defines the possible ways in which a particular system might fail, including an estimate of probable effects of each failure on system performance.

Farad - The unit of electrical capacitance, the capacitance of a condenser between the plates of which there is a difference of potential of 1 volt when it is charged by a quantity of electricity equal to 1 coulomb.

Fathom - The common unit of depth in the ocean, equal to six feet (or 1.83 meters). It is also sometimes used in expressing horizontal distances, in which case 100 fathoms make one cable or very nearly one-tenth nautical mile.

Fatigue - 1. A weakening or deterioration of metal or other material occurring under load, especially under repeated cyclic, or continued loading. 2. State of the human organism after exposure to any type of physical or psychological stress (e.g., pilot fatigue).

Fatigue, retinal - Depletion of the capacity of the retina to respond to light and color stimuli. Postulated to explain negative afterimage, successive contrast, etc.

Fatigue, visual - Decreased ability of visual performance and/or characteristic sensations or feeling resulting from prolonged visual work.

Fault correction time - That element of Active Repair Time required under a specified maintenance philosophy to correct the malfunction. It may consist of correcting the malfunction with the faulty item in place, removing and replacing the item with a like serviceable item, or removing the item for corrective maintenance and reinstalling the same item.

Fault location time - That element of Active Repair Time required for testing and analyzing an item to isolate a malfunction.

F-display - In radar a rectangular display in which a target appears as a centralized blip when the radar antenna is aimed at it. Horizontal and vertical aiming errors are respectively indicated by the horizontal and vertical displacement of the blip. Also called F-scan, F-scope, F-indicator.

Fechner's law - The intensity of the sensory response is proportional to the logarithm of the stimulus intensity. The logarithmic relation fails to hold experimentally, but a general principle of diminishing returns seems characteristic of all sensory response.

Feedback - 1. The return of a portion of the output of a device to the input; positive feedback adds to the input, negative feedback subtracts from the input. 2. Information, as to progress, results, etc., returned to an originating source. 3. In aeronautics, the transmittal of forces initiated by aerodynamic action on a control surfaces or rotor blades to the cockpit controls; the forces so transmitted.

Feedback control loop - A closed transmission path (loop), which includes an active transducer and which consists of a forward path, a feedback path, and one or more mixing points arranged to maintain a prescribed relationship between the loop input signal and the loop output signal.

Feedback control system - A control system, comprising one or more feedback control loops, which combines functions of the controlled signals with functions of the commands to tend to maintain prescribed relationships between the commands and the controlled signals.

Feel - The sensation or impression that a pilot has or receives as to his, or his craft's, attitude, orientation, speed, direction of movement or acceleration, or proximity to nearby objects, or, as most often used, as to the aircraft's stability and responsiveness to control. See control feel.

Fermi - A unit of length equal to 10^{-13} centimeters.

Fidelity - The accuracy to which an electrical system, such as a radio, reproduces at its output the essential characteristics of its input signal.

Fiducial mark - An internally generated identification mark on a film; two or more of these are generally used for orienting a film for reading, and for determining the geometric center of the film.

Field lens - Lens used to effect transfer of the image formed by an optical system.

Field luminance - Adaptation luminance.

Field maintenance - Maintenance performed by designated maintenance activities in direct support of using organizations.

Field strength - 1. For any physical field, the flux density, intensity, or gradient of the field at the point in question. Also called field intensity. 2. = signal strength, in radar. 3. = electric field strength.

Figure - Any group of visual impressions which is perceived as a unit pattern or object.

Filtering - 1. The decomposition of a signal into its harmonic components. 2. The separation of a wanted component of a time series from any unwanted residue (noise).

Fin - 1. A fixed or adjustable airfoil or vane attached longitudinally to an aircraft, rocket, or similar body to provide a stabilizing effect. 2. A projecting flat plate or structure, as a cooling fin.

Fineness ratio - The ratio of the length of a body to its maximum diameter, or, sometimes, to some equivalent dimension -- said especially of a body such as an airship hull or rocket.

Fix - In navigation, a relatively accurate position determined without reference to any former position. It may be classed as visual, sonic, celestial, electronic, radio, hyperbolic, Loran, radar, etc., depending upon the means of establishing it.

Fixation point - Point in the visual field at which the observer is looking directly. It is the point whose image falls on the center of the fovea.

Fixed satellite - A satellite that orbits the earth from west to east at such a speed as to remain fixed over a given place on the earth's equator at approximately 35,900 kilometers altitude.

Flameout - The extinguishment of the flame in a jet engine from cause other than deliberate shutoff.

Flare - 1. A bright eruption from the sun's chromosphere. Compare prominence. 2. Pyrotechnic devices used for signalling or to provide illumination. 3. An expansion at the end of a cylindrical body as at the base of a rocket.

Flashpoint - The temperature at which a substance, as fuel oil, will give off a vapor that will flash or burn momentarily when ignited.

Flicker, flicker phenomenon - A rapid periodic change perceived in a visual impression, due to a corresponding rapid periodic change in the intensity or some other character of the stimulus. Flicker disappears when the frequency of the stimulus-change exceeds a rate called the critical flicker frequency, which is about 25 to 30 cycles per second, when each cycle consists of a moderately bright and a wholly dark half-period; the critical rate is somewhat higher at higher intensity-levels and somewhat lower for lower intensities; the rate is lowered with decrease in the intensity-difference between parts of the period.

Flicker photometry - A method of photometry in which two different color stimuli are alternately presented to the eye at a suitable rate; the stimuli are considered equal in luminance when the flicker is at a minimum.

Flicker, visual - A rapid periodic change in a visual impression, due to a corresponding rapid cyclic change in the intensity or some other characteristic of the stimulus.

Flight attitude - The aspect that an aircraft, rocket, etc., presents at any given moment, as determined by its inclinations about its three axes.

Flightpath angle - The angle between the horizontal and a tangent to the flightpath at a point.

Flight simulator - A training device or apparatus that simulates certain conditions of actual flight or of flight operations.

Flip-flop - 1. A device having two stable states and two input terminals (or types of input signals) each of which corresponds with one of the two states. The circuit remains in either state until caused to change to the other state by application of the corresponding signal. 2. A similar bistable device with an input which allows it to act as a single-stage binary counter.

Flow chart - A graphical representation of a mission or a sequence of operations using symbols to represent the operations (see Section 3).

Flourescence - Emission of light or other radiant energy as a result of and only during absorption of radiation of a different wavelength from some other source. Also called photoluminescence. See luminescence. Compare phosphorescence.

Flutter - An aeroelastic self-excited vibration in which the external source of energy is the airstream and which depends on the elastic, inertial and dissipative forces of the system in addition to the aerodynamic forces.

Flux density - The flux (rate of flow) of any quantity, usually a form of energy, through a unit area of specified surface. (Note that this is not a volumetric density like radiant density.)

Flyby - An interplanetary mission in which the vehicle passes close to the target planet but does not impact it or go into orbit around it.

Flying spot - A rapidly moving spot of light, usually generated by a cathode-ray tube and used to scan a surface containing visual information.

F/number (relative aperture) - Ratio of diameter to focal length of a lens or mirror.

Focal length - The distance between the optical center of a lens, or the surface of a mirror, and its focus.

Focal plane - A plane parallel to the plane of a lens or mirror and passing through the focus.

Focal point - The point at which a lens or mirror will focus parallel incident radiation. Also called focus.

Focus (plural focuses) - 1. That point at which parallel rays of light meet after being refracted by a lens or reflected by a mirror. Also called focal point. 2. A point having specific significance relative to a geometrical figure.

Foot - The foot (international) is exactly 0.3048 meter.

Foot-candle - A unit of illuminance, incident light, or illumination equal to 1 lumen per square foot. This is the illuminance provided by a light source of one candle at a distance of 1 foot, hence the name. Compare lux, phot. (See also Vol. I, Section 2).

Foot-lambert - A unit of luminance (or brightness) equal to $1/\pi$ candle per square foot, or 1 lumen per square foot. In Great Britian this is also called the equivalent foot-candle.

Foot-to-head acceleration - See physiological acceleration.

Force - The cause of the acceleration of material bodies measured by the rate of change of momentum produced on a free body.

Fortran - A commonly-used computer programming language for scientific and engineering applications.

Fovea - A small depression in the central region of the retina, containing only cone .

Foveal vision - Vision in which the eye is so oriented toward the pertinent light source as to have the light fall upon that central portion of the retina called the fovea.

Free ascent - An emergency ascent by a diver accomplished by floating to the surface by means of natural or assisted buoyancy.

Free atmosphere - That portion of the earth's atmosphere, above the planetary boundary layer, in which the effect of the earth's surface friction on the air motion is negligible, and in which the air is usually treated (dynamically) as an ideal fluid.

Freeboard - The additional height of a marine structure above the design high water level to prevent overflow. On a ship, the distance from the water line to main deck or gunwale.

Free fall - 1. The fall or drop of a body, such as a rocket, not guided, not under thrust, and not retarded by a parachute or other braking device. 2. The free and unhampered motion of a body along a Keplerian trajectory, in which the force of gravity is counterbalanced by the force of inertia. See weightlessness.

Free flight - Unconstrained or unassisted flight, as: (a) the flight of a rocket after consumption of its propellant or after motor shutoff; (b) the flight of an unguided projectile; (c) the flight in certain kinds of wind tunnel of an unmounted model.

Free gyro - 1. A two-degree-of-freedom gyro whose spin axis may be oriented in any specified attitud 2. A gyro not provided with an erection system, i.e., a gyro free to move about its axes.

Frequency - The number of cycles occurring [illegible] ven unit of time.

Frequency band - A continuous range of f[illegible]s extending between two limiting frequencies. (See Table [illegible] 3b).

Frequency modulation - Angle modulation of a sine-wave carrier in which the instantaneous frequency of the modulated wave differs from the carrier frequency by an amount proportional to the instantaneous value of the modulating wave.

Table 3a - Frequency Bands

Frequency band	Approximate frequency range, gigacycles	Approximate wavelength range centimeters
P-band..........	0.225 to 0.39	140 to 76.9
L-band..........	0.39 to 1.55	76.9 to 19.3
S-band..........	1.55 to 5.20	19.3 to 5.77
X-band..........	5.20 to 10.90	5.77 to 2.75
K-band..........	10.90 to 36.00	2.75 to 0.834
Q-band..........	36.00 to 46.00	0.834 to 0.652
V-band..........	46.00 to 56.00	0.652 to 0.536

Table 3b - Frequency Bands

Band number	Frequency range	Metric sub-division waves	Atlantic City frequency subdivision	
4	3- 30	Myriametric	Very-low	VLF
5	30- 300	Kilometric	Low	LF
6	300- 3,000	Hectometric	Medium	MF
7	3,000- 30,000	Decametric	High	HF
8	30- 300	Metric	Very-high	VHF
9	300- 3,000	Decimetric	Ultra-high	UHF
10	3,000- 30,000	Centimetric	Super-high	SHF
11	30,000- 300,000	Millimetric	Extremely high	EHF
12	300,000-3,000,000	Decimillimetric	----	---

Frequency response - 1. The portion of the frequency spectrum which can be sensed by a device within specified limits of amplitude error. 2. Response of a system as a function of the frequency of excitation.

Fresnel lens - A lens which utilizes the refractive properties of a multiprism surface to control light emission direction (e.g., concentrates light rays into a narrow beam, as in a spotlight).

Frustration threshold - The point at which an aggressive attitude is generated due to interference with normal goal-seeking activity. Generally considered that stage at which a barrier to goal-seeking cannot be circumvented and irrational responses are exhibited.

Fuel cell - 1. A fuel tank, especially one of a number of fuel tanks, as in an airplane's wing; also, a compartment within a fuel tank. 2. A device which converts chemical energy directly into electrical energy but differing from a storage battery in that the reacting chemicals are supplied continuously as needed to meet output requirements.

Full pressure suit - A suit which completely encloses the body and in which a gas pressure sufficiently above ambient pressure for maintenance of function, may be sustained.

Function - 1. A magnitude so related to another magnitude that for any value of one there is a corresponding value of the other. 2. Term used to describe an operational requirement, the performance of which may be done by man or machine (See Function Analysis).

Functional reserves - The ability of the body to accomplish additional muscular or other activity and useful work beyond the normal level of activity of an individual.

Function analysis - A technique for identifying the human and/or equipment requirements for adequately meeting system/operational needs. Man-machine function analyses (or allocations) are primarily conducted to determine whether functions will be performed by man, by machine, or by a combination of both.

Fundamental frequency - 1. Of a periodic quantity, the lowest component frequency of a sinusoidal quantity which has the same period as the periodic quantity. 2. Of an oscillating system, the lowest natural frequency. The normal mode of vibration associated with this frequency is known as the fundamental mode. 3. The reciprocal of the period of a wave.

Fundamental response curves - The set of three spectral sensitivity or mixture curves (usually plotted with relative luminosity as a function of wave-length) which represent the actual sensitivities according to trireceptor theories of color vision. The maxima of these response curves are believed to be about 450, 540, and 590 millimicrons, respectively.

G or g - An acceleration equal to the acceleration of gravity, 980.665 centimeter-second-squared, approximately 32.2 feet per second per second at sea level; used as a unit of stress measurement for bodies undergoing acceleration. See gravity.

Gage pressure - In engineering literature, a term used to indicate the difference between atmospheric pressure and absolute pressure, as read from a differential manometer.

Gain - 1. A general term used to denote an increase in signal power in transmission from one point to another. Gain is usually expressed in decibels and is widely used to denote transducer gain. 2. An increase or amplification.

Galaxy - A vast assemblage of stars, nebulae, etc., composing an island universe separated from other such assemblages by great distances.

Gale - Wind of a force exceeding a specified value, usually 30 miles per hour. In the United States, winds of force 7,8,9 and 10 on the Beaufort scale (32-63 miles per hour or 29-55 knots) are classed as gales. Wind of force 7 (32-38 miles per hour or 28-33 knots) is classified as a moderate gale; wind of force 8 (39-46 miles per hour or 34-40 knots) as a fresh gale; wind of force 9 (47-54 miles per hour or 41-47 knots) as a strong gale; and wind of force 10 (55-63 miles per hour or 48-55 knots) as a whole gale.

Gals - Measurements of gravity are expressed in gals (for Galileo) and milligals. One gal is equal to an acceleration of one centimeter per second per second. Values of gravity on the earth's surface range approximately between 978.0490 gals at the equator to 983.2213 gals at the poles (± 5200 milligals). A one foot change in elevation is equivalent to a .094 milligal change in gravity on land or a .068 milligal change under water.

Gamma ray - A quantum of electromagnetic radiation emitted by a nucleus, each such photon being emitted as the result of a quantum transition between two energy levels of the nucleus. Gamma rays have energies usually between 10 thousand electron volts and 10 million electron volts with correspondingly short wavelengths and high frequencies. Also called gamma radiation.

Gantry - A frame structure that spans over something, as an elevated platform that runs astride a work area, supported by wheels on each side; short for gantry crane or gantry scaffold.

Gate - 1. To control passage of a signal as in the circuits of a computer. 2. A circuit having an output and inputs so designed that the output is energized only when a definite set of input conditions are met. In computers, called AND-gate.

Gauss - A unit of magnetic induction (or magnetic flux density) equal to 1 dyne per unit cgs magnetic pole.

Gaussian distribution - Normal distribution.

Geocentric - Relative to the earth as a center; measured from the center of the earth.

Geodesic line - The shortest line on a mathematically derived surface, between two points on the surface. Also called geodesic.

Geodesy - The science which deals mathematically with the size and shape of the earth, and the earth's external gravity field, and with surveys of such precision that overall size and shape of the earth must be taken into consideration.

Geodetic line - A geodesic line on the spheriodal earth. Also called geodesic. Compare geodesic line.

Geodetic survey - 1. A survey which takes into account the size and shape of the earth. 2. An organization engaged in making geodetic surveys, sense 1.

Geographical mile - The length of 1 minute of arc of the equator, or 6089.08 feet.

Geographical position - 1. That point on the earth at which a given celestial body is in the zenith of a specified time. 2. Any position on the earth defined by means of its geographic coordinates, either astronomical or geodetic.

Geographic coordinates - Coordinates defining a point on the surface of the earth, usually latitude and longitude. Also called terrestrial coordinates, geographical coordinates.

Geomagnetism - 1. The magnetic phenomena, collectively considered, exhibited by the earth and its atmosphere and, by extension, the magnetic phenomena in interplanetary space. 2. The study of the magnetic field of the earth. Also called terrestrial magnetism.

Geometric mean - A measure of central position. The geometric mean of n quantities equals the n^{th} root of the product of the quantities.

Geophysics - The study of the physical characteristics and properties of the Earth.

Geopotential - The potential energy of a unit mass relative to sea level, numerically equal to the work that would be done in lifting the unit mass from sea level to the height at which the mass is located; commonly expressed in terms of dynamic height or geopotential height.

Gimbal - 1. A device with two mutually perpendicular and intersecting axes of rotation, thus giving free angular movement in two directions, on which an engine or other object may be mounted. 2. In a gyro, a support which provides the spin axis with a degree of freedom. 3. To move a reaction engine about on a gimbal so as to obtain pitching and yawing correction moments. 4. To mount something on a gimbal.

Gimbal lock - A condition of a two-degree-of-freedom gyro wherein the alinement of the spin axis with an axis of freedom deprives the gyro of a degree of freedom, and therefore of its useful properties.

Glide path - 1. The flight path of an aeronautical vehicle in a glide, seen from the side. 2. The path used by an aircraft or spacecraft in approach procedure and which is generated by an instrument-landing facility.

Glide slope - 1. An inclined surface which includes a glide path and which is generated by an instrument-landing facility. 2. = slope angle. 3. = gliding angle.

Glitter - The spots of light reflected from a point source by the surface of the sea. Statistical analysis of glitter patterns has revealed relationships from which the roughness of the sea can be determined by the study of photographs of the glitter.

Glossiness - An attribute of the surface mode of appearance which ranges from matt to maximum. Low glossiness is characteristically evoked by reflection from rough diffusing surfaces and high gloss from smooth surfaces. (See Figure 3).

G-meter - A meter that indicates acceleration.

Go, No-go display - A visual display which provides only two alternate choices of information (e.g., ON-OFF, START-STOP, etc.).

Gox - Gaseous oxygen.

Gradient - 1. The space rate of decrease of a function. 2. Often loosely used to denote the magnitude of the gradient or ascendant. 3. Either the rate of change of a quantity (as temperature, pressure, etc.) or a diagram or curve representing this.

Gram - The standard of mass in the metric system.

Gram-centimeter - The CGS (gram-centimeter-second) gravitation unit of work.

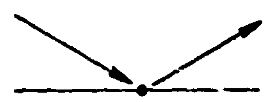
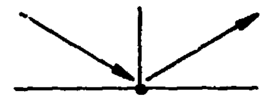
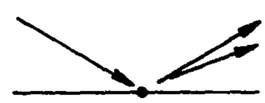
Kind of Glossiness	Correlate in Terms of Luminous Directional Reflectance	Diagram of the Angular Conditions
Specular	Ratio of $R_{60,-60}$ for the specimen to that of a perfect mirror.	
Sheen	Ratio of $R_{85,-85}$ for the specimen to that of a perfect mirror.	
Contrast	Ratio of $R_{60,-60}$ (specular) to $R_{60,0}$ (diffuse).	
Distinctness of image	Rate of change of $R_{i,-\theta}$ with angle of incidence, i, where the angle of view $-\theta$ differs by a few minutes of arc from that of mirror reflection, $-i$.	
Absence of bloom	Ratio of $R_{i,-i}$ to $R_{i,-\theta}$, where the angle of view $-\theta$ differs from the angle of mirror reflection $-i$ by a few degrees.	

Figure 3 - Various Kinds of Glossiness and Their Correlates

Gram-molecule - The mass in grams of a substance numerically equal to its molecular weight.

Graph - A diagram indicating the relationship between two or more variables.

Grass - 1. Sharp, closely spaced discontinuities in the trace of a cathode-ray tube, produced by random interference; so named because of their resemblance to blades of lawn grass. 2. In radar, a descriptive colloquialism used to refer to the indication of noise on an 'A' or similar type of display.

Graticule - 1. The network of lines representing parallels and meridians on a map, chart, or plotting sheet. 2. A scale at the focal plane of an optical instrument to aid in the measurement of objects. See reticle.

Gravireceptors - Highly specialized nerve endings and receptor organs located in skeletal muscles, tendons, joints, and in the inner ear which furnish information to the brain with respect to body position, equilibrium, and the direction of gravitational forces. See gravitation.

Gravitation - The acceleration produced by the mutual attraction of two masses, directed along the line joining their centers of masses, and of magnitude inversely proportional to the square of the distance between the two centers of mass.

Gravitational constant - The coefficient of proportionality in Newton law of gravitation: $G = 6.670 \pm 0.005 \times 10^{-8}$ dyne-centimeter squared per gram squared. Also called constant of gravitation, Newtonian universal constant of gravitation.

Gravity - 1. Viewed from a frame of reference fixed in the earth, force imparted by the earth to a mass which is at rest relative to the earth. Since the earth is rotating, the force observed as gravity is the resultant of the force of gravitation and the centrifugal force arising from this rotation and the use of an earthbound rotating frame of reference. It is directed normal to sea level and to its geopotential surfaces. 2. = acceleration of gravity. 3. By extension, the attraction of any heavenly body of any mass; as Martian gravity.

Gravity potential - The work required or gained in moving a unit mass from sea level to a point above or below sea level. The unit in m.t.s. system is one dynamic decimeter.

Gray - An achromatic color of any lightness intermediate between the extremes of black and white. Gray is typically a response to an achromatic stimulus situation involving contrast.

Grayout - A temporary condition in which vision is hazy, restricted, or otherwise impaired, owing to insufficient oxygen. Compare blackout.

Great circle - The intersection of a sphere and a plane through its center. Also called orthodrome.

Greenhouse effect - The heating effect exerted by the atmosphere upon the earth by virtue of the fact that the atmosphere (mainly, its water vapor) absorbs and reemits infrared radiation. In detail: the shorter wavelengths of insolation are transmitted rather freely through the atmosphere to be absorbed at the earth's surface. The earth then reemits this as long-wave (infrared) terrestrial radiation, a portion of which is absorbed by the atmosphere and again emitted. Some of this is emitted downward back to the earth's surface (counterradiation).

Greenwich civil time = Greenwich mean time. (United States terminology from 1925 through 1952.)

Greenwich hour angle - Angular distance west of the Greenwich celestial meridian; the arc of the celestial equator, or the angle at the celestial pole, between the upper branch of the Greenwich celestial meridian and the hour circle of a point on the celestial sphere, measured westward from the Greenwich celestial meridian through 360°; local hour angle at the Greenwich meridian.

Greenwich mean time - Local mean time at the Greenwich meridian; the arc of the celestial equator, or the angle at the celestial pole, between the lower branch of the Greenwich celestial meridian and the hour circle of the mean sun, measured westward from the lower branch of the Greenwich celestial meridian through 24 hours; Greenwich hour angle of the mean sun, expressed in time units, plus 12 hours. Called Greenwich civil time in U.S. terminology from 1925 through 1952. Also called universal time, Z-time.

Greenwich meridian - The meridian through Greenwich, England, serving as the reference for Greenwich time.

Ground - 1. The unfocused surroundings and interstices of a figure or object, perceived as lying beyond and not belonging to the figure or object, e.g., the background in a painting. Figure and ground are sometimes reversible, as when an interwoven black-white pattern may appear either as a white figure on a black background, or vice versa; electrical - low potential current return path.

Ground-controlled approach (GCA) - A ground radar system providing information by which aircraft approaches may be directed via radio communications. Also attributively, as in GCA controller, GCA equipment, GCA landing, GCA weather, etc.

Ground-controlled intercept - A radar system by means of which a controller may direct an aircraft to make an interception of another aircraft.

Ground-effect machine - A machine that hovers or moves just above the ground by creating a cushion of supporting air between it and ground surface and by varying the thrust vector and magnitude to regulate direction and rate of motion.

Ground-handling equipment - Equipment on the ground used to move, lift, or transport a space vehicle, a rocket, or component parts.

Ground return - Radar echoes reflected from the terrain. Also called ground clutter, land return.

Ground servicing equipment - This includes aircraft tow bars, chocks, cradles, dollies, hoists, jacks, ladders, scaffolds, stands, supports, and similar items.

Ground-support equipment - That equipment on the ground, including all implements, tools, and devices (mobile or fixed), required to inspect, test, adjust, calibrate, appraise, gage, measure, repair, overhaul, assemble, disassemble, transport, safeguard, record, store, or otherwise function in support of a rocket, space vehicle, or the like, either in the research and development phase or in an operational phase, or in support of the guidance system used with the missile, vehicle, or the like.

Ground wave - A radio wave that is propagated over the earth and is ordinarily affected by the presence of the earth's surface and the troposphere. The ground wave includes all components of a radio wave over the earth except ionospheric and tropospheric waves. Compare sky wave.

G-scan - Display of g-force information.

G-suit or g-suit - A suit that exerts pressure on the abdomen and lower parts of the body to prevent or retard the collection of blood below the chest under positive acceleration. Compare pressure suit.

G-tolerance - A tolerance in a person or other animal, or in a piece of equipment, to an acceleration of a particular value and direction with respect to the object.

Guided missile - Broadly, any missile that is subject to, or capable of, some degree of guidance or direction after having been launched, fired, or otherwise set in motion.

Gyro - 1. A device which utilizes the angular momentum of a spinning mass (rotor) to sense angular motion of its base about one or two axes orthogonal to the spin axis. Also called gyroscope. 2. Short for direction gyro, gyrocompass, etc.

Gyrocompass - A compass that is actuated by a rapidly spinning rotor which tends to place its axis of rotation parallel to the earth's axis of rotation. It indicates direction relative to the true north.

Gyro horizon - 1. An artificial horizon or an attitude gyro. 2. A flight indicator.

Half-life - The average time required for one half the atoms in a sample of a radioactive element to decay.

Halo - A narrow bright band which is observed surrounding the dark after-image of a bright stimulus.

Hard landing - An impact landing of a spacecraft on the surface of a planet or natural satellite destroying all equipment except possibly a very rugged package.

Harmonic - 1. An integral multiple or submultiple of a given frequency; a sinusoidal component of a periodic wave. 2. A signal having a frequency which is a harmonic (sense 1) of the fundamental frequency.

Harmonic motion - The projection of circular motion on a diameter of the circle of such motion.

H-display - In radar, a B-display modified to include indication of angle of elevation. The target appears as two closely spaced blips which approximate a short bright line, the slope of which is in proportion to the sine of the angle of elevation. Also called H-scan, H-scope, H-indicator.

Heading - The horizontal direction in which a craft is pointed, expressed as angular distance from a reference direction, usually from 0° at the reference direction clockwise through 360°.

Head-to-foot acceleration - See physiological acceleration.

Heat barrier - Thermal barrier.

Heat exchanger - A device for transferring heat from one fluid to another without intermixing the fluids, as (a) a regenerator and, (b) an apparatus for cooling or heating the air in a wind tunnel. See radiator, sense 2.

Heat shield - 1. Any device that protects something from heat. 2. Specifically, the protective structure necessary to protect a reentry body from aerodynamic heating. See heat sink.

Heat sink - A contrivance for the absorption or transfer of heat away from a critical element or part.

Heaviside layer - E-layer.

Hedgehogs - Groups of relatively small projectiles which land in the water in mixed patterns, sink and explode upon contact with a submarine.

Henry - The unit of electrical inductance; the inductance of a closed circuit in which an electromotive force of 1 volt is produced when the electric current in the circuit varies uniformly at the rate of 1 ampere per second.

Hertz - The unit of frequency, cycles per second.

Heterodyne - To mix two radio signals of different frequencies to produce a third signal which is of lower frequency; i.e., to produce beating.

Heterosphere - The upper portion of a two-part division of the atmosphere; the layer above the homosphere.

Heuristic program - A set of instructions that imitates the behavior of human operations (i.e., response modification based on previous current and anticipated conditions which are not pre-planned).

Hibernating spacecraft - A spacecraft maintaining an orbit without using propellant power and without maintaining orientation within the orbit, but with inherent power capability.

High frequency - See frequency bands.

High-pass filter - A wave filter having a single transmission band extending from some critical or cutoff frequency, not zero, up to infinite frequency.

H-indicator - H-display.

Hohmann orbit - A minimum energy transfer orbit.

Holddown test - The testing of some system or subsystem in a rocket while the rocket is firing but restrained in a test stand.

Homing - The following of a path of energy waves to or toward their source or point of reflection.

Homing beacon - A beacon providing homing guidance. Also called homer.

Homosphere - The lower portion of a two-part division of the atmosphere according to the general homogeniety of atmospheric composition; opposed to the heterosphere. The region in which there is no gross change in atmospheric composition, that is, all the atmosphere from the earth's surface to about [illegible] kilometers.

Hookah - In free diving an apparatus consisting of a demand regulator worn by the diver and a hose connected to a compressed air supply at the surface.

Horizon - That great circle of the celestial sphere midway between the zenith and nadir, or a line resembling or approximating such a circle.

Horopter - The locus of all points in the binocular field of vision, the images of which fall upon identical points on the two retinas, viz., the images of which are normally seen as single.

Hour angle - Angular distance west of a celestial meridian or hour circle; the arc of the celestial equator, or the angle at the celestial pole, between the upper branch of a celestial meridian or hour circle and the hour circle of a celestial body or the vernal equinox, measured westward through 360°.

Hovercraft and ground effect machines - Ships designed to hover above water and supported by air trapped between the bottom of the ship and the water. The supporting air cushion is augmented at high speeds (i.e., 100 knots) by the forward motion of the craft. (Note: Various types of ground effect machines are: Air Curtain, Plenum, Ram Wing, Diffuser-Recirculation, Water Curtain, and Skegs.)

Hue - The attribute of color determined primarily by the wavelength of light entering the eye. Spectral hues range from red through orange, yellow, green, and blue to violet.

Human engineering (human factors engineering) - The activity or science of designing, building, or equipping mechanical devices or artificial environments to the anthropometric, physiological, or psychological requirements of the men who will use them.

Human factors - The study of psychophysical, psychological, and physiological variables which affect man's performance in an operational system. See human engineering.

Human-induced failures - Those failures and malfunctions of equipment components directly attributable to some act or omission by a human operator. Examples of human-induced failure events include: activation of the wrong control, rough handling, and incorrect wiring. Sources of human-induced failures may include: poor design, incorrect process or test procedures, improper inspection, and inadequate training or supervision.

Human operator - A person who participates in some aspect of operation or support of a space system and its associated equipment and facilities. (Generally refers to one who operates equipment as opposed to one who maintains the equipment).

Human-performance assurance - A method or approach for reducing and eliminating sources of human-induced failures by implementing an adequate human engineering and serviceability effort during the project life cycle of space systems.

Human engineering research - Research and development necessary to obtain the scientific knowledge required to accomplish the Human Engineering Program. This includes consideration of the following basic human characterisitcs: a) Sensory capacities, b) Mobility and muscle strength, c) Information-handling and decision-making, d) Common skills and capacity for learning new skills, e) Capacity for team or group effort, f) Body dimensions, and g) Effects of working environments upon human physical and mental performance.

Humidity - 1. The amount of water vapor in the air. 2. Specifically, relative humidity.

Hunting - An attempt by a computer control system to seek-out a condition of equilibrium.

Hurricane force - Winds with a force above 75 miles per hour.

Hydrodynamics - The study of fluid motion.

Hydrography - The science which deals with the measurement of the physical features of the oceans, seas, lakes, rivers, and other waters, and their marginal land areas, with special reference to the elements that affect safe navigation, and the publication of such information in a suitable form for use by navigators.

Hydrology - The scientific study of the waters of the earth, especially with relation to the effects of precipitation and evaporation upon the occurrence and character of water in streams, lakes and on or below the land surface. In terms of the hydrologic cycle, the scope of hydrology may be defined as that portion of the cycle from precipitation to re-evaporation or return of the water to the seas.

Hydrosphere - The water portion of the earth as distinguished from the solid part, called the lithosphere, and from the gaseous outer envelope, called the atmosphere.

Hyperbarism - Disturbances in the body resulting from an excess of ambient pressure over that within the body fluids, tissues, and cavities.

Hyperbola - An open curve with two branches, all points of which have a constant difference in distance from two fixed points called focuses.

Hyperbolic navigation - Radio navigation in which a hyperbolic line of position is established by signals received from two stations at a constant time difference.

Hypergolic propellants - Rocket propellants that ignite spontaneously when mixed with each other.

Hyperopia - Synonym for farsightedness; a defect of the eye such that, with accommodation relaxed, parallel rays of light focus behind the retina.

Hyperpnea - Abnormally rapid or deep breathing.

Hypersonic glider - An unpowered vehicle, specifically a reentry vehicle, designed to fly at hypersonic speeds.

Hyperventilation - A term applied to breathing more than is necessary to keep the body's carbon dioxide tensions at the proper level. If carried to an extreme, hyperventilation can be dangerous.

Hyperbarism - Disturbances resulting from a decrease of ambient pressure to less than that within the body fluids, tissues, and cavities.

Hypocapnia - Deficiency of carbon dioxide in the blood and body tissues, which may result in dizziness, confusion, and muscular cramps.

Hypoventilation - A respiratory-minute volume, or pulmonary ventilation that is less than normal. Also called underbreathing.

Hypoxia - Oxygen deficiency in the body tissues.

Hysteresis - 1. Any of several effects resembling a kind of internal friction, accompanied by the generation of heat within the substance affected. 2. The delay of an indicator in registering a change in a parameter being measured.

I-display - In radar, a display in which a target appears as a complete circle when the radar antenna is correctly pointed at it and in which the radius of the circle is proportional to target distance. When not correctly pointing at the target, the circle reduces to a segment of a circle, the segment length being reciprocal to the direction of pointing error. Also called I-scan, I-scope, I-indicator.

Illuminance - The total luminous flux received on a unit area of a given real or imaginary surface, expressed in such units as the foot-candle, lux, or phot. Illuminance is analogous to irradiance, but is to be distinguished from the latter in that illuminance refers only to light and contains the luminous efficiency weighting factor necessitated by the nonlinear wavelength-response of the human eye. Compare luminous intensity.

Illuminant color - Color seen as glowing, luminous, or belonging to an illuminant, viz., in the illuminant mode of appearance. Commonly referred to a comparatively small area of high brightness, viz., brighter than white under similar conditions of viewing. Examples: color of perceived flame, tungsten lamp, neon sign, flourescent fabric. Also called glow, glowing color.

Illumination color - Color seen as belonging to illumination distributed in space, viz., color in the illumination mode of appearance. Examples: color of sunlight in a room, red light flooding a stage, etc.

Illumination flicker - Flicker seen as belonging to the illumination of the illuminated space rather than to the surfaces or objects seen in it.

Illumination, Law of - The principle that the illuminance of a surface varies directly as the luminous intensity of the light-source, inversely as the square of its distance, and directly as the cosine of the angle made by the light-rays with the perpendicular to the surface.

Illusion - A misinterpretation of certain elements in a given experience, so that the experience does not represent the objective situation.

Image, optical - The picture or reproduction of an object produced by a lens, reflector, or optical system, as a result of the focusing in the light emanating from each point in the object.

Image, reginal - The optical image of external objects formed upon the retina by the refracting surfaces of the eye.

Impact acceleration - The acceleration generated by very sudden starts or stops of a vehicle. The term is usually applied in the context of physiological acceleration.

Impact pressure - That pressure of a moving fluid brought to rest which is in excess of the pressure the fluid has when it does not flow, i.e., total pressure less static pressure.

Impedance - 1. The apparent opposition in an electrical circuit to the flow of an alternating current that is analogous to the actual electrical resistance to a direct current and that is the ratio of effective electromotive force to the effective current; 2. the ratio of the pressure to the volume displacement at a given surface in a sound transmittive medium.

Impeller - 1. A device that imparts motion to a fluid; specifically, in a centrifugal compressor, a rotary disk which, faced on one or both sides with radial vanes, accelerates the incoming fluid outward into a diffuser. Also called impeller wheel. 2. That part of a centrifugal compressor comprising this disk and its housing.

Implosion - The rapid inward collapsing of the walls of a vacuum system or device as the result of failure of the walls to sustain the ambient pressure.

Impulse - 1. The product of a force and the time during which the force is applied. 2. Psychology; human response which is generally devoid of orderly thought processes.

Impulse noise - Noise generated in discrete energy bursts, not of random nature, which has a characteristic wave shape of its own.

Incandescence - Emission of light due to high temperature of the emitting material. Any other emission of light is called luminescence.

Inch - Exactly 2.540 centimeters.

Incidence - 1. Partial coincidence, as a circle and a tangent line. 2. The impingement of a ray on a surface. See angle of incidence.

Incipient failure - A degradation failure which is just beginning to exist or appear.

Increment - A change in the value of a variable. A negative increment is also called decrement.

Independent variable - Any of those variables of a problem, chosen according to convenience, which may arbitrarily be specified, and which then determine the other or dependent variables of the problem.

Index level - The index level of a sound is defined as the level which that sound would have at a point one yard from the point of its apparent origin, assuming such a point to exist, if it were generated at this apparent source point but produced the same effects at distant points as the effects it actually does produce.

Index of refraction - The ratio of the velocity of light in a vacuum to the velocity of light in a refractive material for a particular wavelength of light.

Indicator - A visual readout device or instrument which provides information about system conditions which cannot readily be determined directly by an operator. Generally refers to an instrument which has no provision for storing information.

Induced color - A color or change in color which appears in a given portion of the subjective visual field, due not to direct stimulation of the corresponding portion of the retina, but to concomitant stimulation of other portions.

Induced failure - A failure basically caused by a physical condition or phenomenon external to the failed item.

Inert gas - Any one of six gases, helium, neon, argon, krypton, xenon, and radon, all of whose shells of planetary electrons contain stable numbers of electrons so that the atoms are almost completely chemically inactive. Also called rare gas.

Inertia - Resistance to acceleration.

Inertial coordinate system - A system in which the (vector) momentum of a particle is conserved in the absence of external forces. Thus, only in an inertial system can Newton laws of motion be appropriately applied.

Inertial force - A force is a given coordinate system arising from the inertia of a parcel moving with respect to another coordinate system. The inertial force is proportional and directionally opposite to the accelerating force. Also called inertia force.

Inertial guidance - Guidance by means of accelerations measured and integrated within the craft.

Inertial navigation - Dead reckoning performed automatically by a device which gives a continuous indication of position by integration of accelerations since leaving a starting point.

Inertial orbit - The type of orbit described by all celestial bodies, in conformance with Kepler laws of celestial motion.

Inertial space - A stationary frame of reference, or set of coordinates, for calculating trajectories.

Inferior conjunction - The conjunction of an inferior planet and the sun when the planet is between the earth and the sun.

Inferior planets - The planets with orbits smaller than that of the earth: Mercury and Venus.

Inflection - 1. Reversal of direction of curvature. 2. Special emphasis given to a word or group of words in speaking by changing the pitch, loudness or other characteristics of vocalization.

Infrared radiation - Electromagnetic radiation lying in the wavelength interval from about 75 microns to an indefinite upper boundary sometimes arbitrarily set at 1000 microns (0.01 centimeter). Also called longwave radiation.

Infrasonic frequency - A frequency below the audiofrequency range.

Ingress - Pertains to access for entering an operating or passenger station within a vehicle or work area.

In phase - The condition of two or more cyclic motions which are at the same part of their cycles at the same instant. Also called in step.

Input - 1. The path through which information is applied to any device. 2. The means for supplying information to a machine. See input equipment. 3. Information or energy entering into a system. Compare output. 4. The quantity to be measured, or otherwise operated upon, which is received by an instrument. Also called input signal.

Input equipment - Specifically, the hardware through which information is fed into a computer.

Input section - That portion of machine hardware through which information passes into the computer.

Insolation (contracted from incoming solar radiation) - 1. In general, solar radiation received at the earth's surface. 2. The rate at which direct solar radiation is incident upon a unit horizontal surface at any point on or above the surface of the earth.

Instability - 1. The condition of a body if, when displaced from a state of equilibrium, it continues, or tends to continue, to depart from the original condition. Compare stability. 2. Combustion instability.

Instruction code - An artificial language for describing or expressing the instructions which can be carried out by a digital computer.

Instrumentation - 1. The installation and use of electronic, gyroscopic, and other instruments for the purpose of detecting, measuring, recording, telemetering, processing, or analyzing different values or quantities as encountered in the flight of a rocket or spacecraft. 2. The assemblage of such instruments in a rocket, spacecraft, or the like. 3. A special field of engineering concerned with the design, composition, and arrangement of such instruments.

Instrument flight trainers - Synthetic flight trainers capable of approximating engine runup and flight control of a general type of aircraft. These trainers are used to familiarize the basic student in the employment and use of aircraft instruments and their functions.

Instrument landing system - A system which provides, in the aircraft, a display of the lateral, longitudinal, and vertical references necessary for a landing.

Integer - A whole number; a number that is not a fraction.

Integral - 1. Of or pertaining to an integer. 2. Serving to form a whole or a part of a whole, as an integral tank. 3. The result of a mathematical integration.

Integrated circuitry - A fabricated part which serves all or a portion of a function and which is constructed by etching, diffusing, doping, etc. of a single piece of material. Sections of this material may be joined by the use of jumper wires or printed circuitry.

Integrated controller - A control device which combines more than one aspect of an operation (e.g., control of steering, acceleration and braking in a single joystick).

Integraged display - A visual display which combines related information outputs or multiple physical parameters in a format that can be interpreted as a single function for purposes of response simplification (as opposed to a combined display which merely locates several pieces of information within a single display package).

Integrator - 1. In digital computers, a device for accomplishing a numeric approximation of the mathematical process of integration. 2. A device whose output is proportional to the integral of an input signal.

Integration - 1. Coordination of mental processes into a normal effective personality as with the individual's environment. 2. The operation of finding a function whose differential is known; the operation of solving a differential equation.

Intensity - 1. The quantitative expression of the physical level of light or sound (e.g., the amount of light expressed in foot-candles, or the level of noise expressed in decibels above a reference level). 2. The qualtative expression of a behavioral response which describes the level of mental effort such as concentration on a task or attention paid to a given activity. 3. The qualitative and/or quantitative expression of a physical environment such as heat, cold, electromagnetic radiation, etc.

Intensity level - In acoustics, ten times the logarithm to the base 10 of the ratio of the intensity I of the sound measured to the reference intensity I_0. The reference intensity I_0 must be stated.

Intensity-modulated indicator - One of two general classes of radar indicators, in which echoes from targets are presented as spots or areas of light whose intensity or brilliance is normally a function of the power of the echo signal.

Intensity modulation - The change of the brilliance (or intensity) of the trace on the screen of a cathode-ray tube in accordance with the strength of the applied signal.

Interaction - The effects from two or more items of such functional and physical characteristics as to be equivalent in performance and durability and capable of being exchanged one for the other without alteration of the items themselves or of adjoining items except for adjustment, and without selection for fit or performance.

Interchangeability - Interchangeability does not mean identity, but requires that a substitution of such like assemblies, subassemblies, and replaceable parts be easily effected without physical or electrical modifications to any part of the system or assemblies, including cabling, wiring, and mounting, and without resorting to component or part selection.

Interface - 1. A common boundary between two parts of a system, whether material or non-material. 2. Specifically, in a rocket vehicle or other mechanical assembly, a common boundary between two components. 3. Specifically, in fluid dynamics, a surface separating two fluids across which there is a discontinuity of some fluid property such as density or velocity or fo some derivative of these properties in a direction normal to the interface. 4. The input-output or other direct physical boundary between an operator and the equipment he uses e.g., control, display, seat, etc.

Interference - 1. Extraneous signals, noises, etc. that hinder proper reception of the desired signal in electronic equipment. 2. The mutual effect of two or more meeting waves or vibrations of any kind. Sometimes called wave interference.

Intermediate frequency - The beat frequency used in heterodyne receivers, usually the difference between the received radio-frequency signal and a locally generated signal.

Intermittent pressure breathing - Pressure breathing in which different pressures are used at different points in the respiratory cycle, usually with a high pressure during inspiration and lower pressure during expiration.

International candle - The unit of luminous intensity formerly used as the international standard. On January 1, 1948, it was replaced with the candela, which is equal to 58.9/60 or 0.98 international candle. Also called English candle, British candle.

Interrogation - Transmission of a radio signal or combination of signals intended to trigger a transponder or group of transponders.

Interrogator-responsor - A radio transmitter and receiver combined to interrogate a transponder and display the resulting replies. Often shortened to interrogator and sometimes called challenger.

Intersection - In Boolean algebra, the operation in which concepts are described by stating that they have all the characteristics of the classes involved. Intersection is expressed as AND.

Intervalometer - Any device that may be set so as to accomplish automatically a series of like actions, such as the taking of photographs, or the closure of electrical circuits, at constant predetermined intervals.

Invariable hues - The invariable hues are those which are independent of the Bezold-Brucke phenomenon, i.e., those hues which do not change with change in luminance of the stimulus. Purdy's average values for the spectrum stimuli to the invariables are: 474, 506, and 571 millimicrons, respectively.

Inverse-square law - A relation between physical quantities of the formula: x proportional to $1/y^2$; where y is usually a distance; and x terms are of two kinds, forces and/or fluxes. For example, illumination varies inversely as the square of the distance of receiving plane from point source: $E = I/d^2$ where E = illumination in foot-candles; I = source intensity in candles; and d = distance in feet.

Inverter - 1. A device for changing direct current to alternating current. 2. In computers, a device or circuit which inverts the polarity of a pulse. Also called NOT circuit.

Ion - 1. A charged atom or molecularly bound group of atoms; sometimes also a free electron or other charged subatomic particle. 2. In atmospheric electricity, any of several types of electrically charged submicroscopic particles normally found in the atmosphere. 3. In chemistry, atoms or specific groupings of atoms which have gained or lost one or more electrons, as the chloride ion or ammonium ion. Such ions exist in aqueous solutions and in certain crystal structures.

Ion engine - A reaction engine in which ions, accelerated in an electrostatic field, are used as propellant. Also called electrostatic engine.

Ionization - The process by which neutral atoms or groups of atoms become electrically charged, either positively or negatively, by the loss or gain of electrons; or the state of a substance whose atoms or groups of atoms have become thus charged.

Ionizing radiation - Any electromagnetic or particulate radiation capable of producing ions, directly or indirectly, in its passage through matter.

Ionosphere - The atmospheric shell characterized by a high ion density. Its base is at about 70 or 80 kilometers and it extends to an indefinite height.

Iris (Physiological) - A flat, ring-shaped structure situated within the eyeball immediately in front of the lens, containing unstriped muscle-fibers whose contraction and relaxation regulate the amount of light admitted through the pupil.

Irradiation - The apparent excess in size of a visual stimulus of relatively high intensity, e.g., of a white stimulus figure on a black ground, as compared with an equal black stimulus figure on white.

Isabnormal - A line connecting points having the same difference from normal, usually temperature, or indicating the same difference between actual and calculated values at different parallels.

Isallobar - A line connecting points having the same change of atmospheric pressure in a specified period.

Isallotherm - A line connecting points having the same change of temperature in a specified period.

Isanomal - A line connecting points having the same anomalies of temperature, pressure, etc.

I-scan - I-display

Isobar - A line of equal or constant pressure, specifically, such a line in a weather map.

Isobath - Depth contour.

Isobathic - Having equal depth.

Isobathytherm - A line or surface showing the depths in oceans or lakes at which points have the same temperature. Isobathytherms are usually drawn to show cross sections of the water-mass.

Isoclinic line - A line through points on the earth's surface having the same magnetic dip. Compare isogonic line.

Isogonic line - A line through points on the earth's surface having the same magnetic variation. Compare isoclinic line.

Isolation - 1. In vibration studies, a reduction in the capacity of a system to respond to an excitation, attained by the use of a resilient support. 2. Perceptual isolation, referring to the lack of normal input to an operator through his sensory organs, resulting in lack of motivation, reduced attention and possible emotional trauma.

Isotherm - A line of equal or constant temperature. A distinction is made, infrequently, between a line representing equal temperature in space, choroisotherm, and one representing constant temperature in time, chronoisotherm.

Isotope - 1. One of several nuclides having the same number of protons in their nuclei, and hence belonging to the same element, but differing in the number of neutrons and therefore in mass number A, or in energy content (isomers). Small quantitative differences in chemical properties exist between isotopes. 2. A radionuclide or a preparation of an element with special isotopic composition (allobar) as an article of commerce, so called because of the principal use of such materials as radioactive tracers. 3. In common usage, a synonym for nuclide (not recommended).

Jamming - Intentional transmission or reradiation of radio signals in such a way as to interfere with reception of desired signals by the intended receiver.

J-display - In radar, a modified A-display in which the time base is a circle. The target signal appears as a radial deflection from the time base. Also called J-scan, J-scope, J-indicator.

Jerk - A vector that specifies the time rate of change of the acceleration; the third derivative of displacement with respect to time.

Jet-assisted take-off (JATO, Jato, or jato) - 1. A take-off utilizing an auxiliary jet-producing unit or units, usually rockets, for additional thrust. Hence JATO bottle, Jato unit, etc.; a rocket or unit so used. Where rockets are the auxiliary units, RATO is the more specific term. 2. A JATO bottle or unit; the complete auxiliary power system used for assisted take-off.

Jetsam - See jettison.

Jet stream - A strong band of wind or winds in the upper troposphere or in the stratosphere, moving in a general direction from west to east and often reaching velocities of hundreds of miles an hour.

Jettison - The throwing overboard of objects, especially to lighten a craft in distress. Jettisoned objects that float are termed flotsam; objects that sink, jetsam; and heavy articles that are buoyed for future recovery lagan.

Jezebel - A submarine detection and classification system.

Jitter - 1. Instability of the signal or trace of a cathode-ray tube. 2. Small rapid variations in a waveform due to deliberate or accidental electrical or mechanical disturbances or to changes in the supply voltages, in the characteristic of components, etc.

Joule - A unit of energy or work in the MKS system; the work done when the point of application of 1 newton is displaced a distance of 1 meter in the direction of the force. 1 joule = 10^7 ergs = 1 watt second.

Joule constant - The ratio between heat and work units from experiments based on the first law of thermodynamics: 4.1858×10^7 ergs per 15° calorie. Also called mechanical equivalent of heat.

J-scan - J-display.

J-scope - J-display.

Julie - An active aircorne submarine localization system which uses the explosive echo ranging technique or E^2R.

Jumper - A direct electrical connection, which is not a portion of the conductive pattern, between two points in a printed circuit.

Jury rig - Any temporary or makeshift device, rig, or piece of equipment.

Just noticeable difference - The least amount of a stimulus which, added to or subtracted from a standard stimulus, produces a just noticeably different experience. Also called just perceptible difference, least noticeable difference, minimal change.

K-band - A frequency band used in radar extending approximately from 10.9 gigacycles per second to 36 gigacycles per second.

K-display - In radar, a modified A-display in which a target appears as a pair of vertical deflections or blips instead of a single deflection. When the radar antenna is correctly pointed at the target in azimuth, the blips are of equal height. When not correctly pointed, the difference in blip height is an indication of direction and magnitude of azimuth pointing error. Also called K-scan, K-scope, K-indicator.

Kelvin temperature scale - An absolute temperature scale independent of the thermometric properties of the working substance. On this scale, the difference between two temperatures T_1 and T_2 is proportional to the heat converted into mechanical work by a Carnot engine operating between the isotherms and adiabats through T_1 and T_2. Also called absolute temperature scale, thermodynamic temperature scale.

Kennelly-Heaviside layer - E-layer.

Keplerian - Pertaining to motion in conformance with Kepler laws, as Keplerian trajectory, Keplerian ellipse.

Kepler laws - The three empirical laws governing the motions of planets in their orbits, discovered by Johannes Kepler (1571-1630). These are: (a) the orbits of the planets are ellipses, with the sun at a common focus; (b) as a planet moves in its orbit, the line joining the planet and sun sweeps over equal areas in equal intervals of time (also called law of equal areas); (c) the squares of the periods of revolution of any two planets are proportional to the cubes of their mean distances from the sun.

Kev - In nuclear physics: A unit of energy: 1 Kev = 1.6×10^{-9} ergs. A unit of temperature: 1 Kev = 11.6×10^{6} °K.

Kill - The achievement of the desired destructive effect against a target; term relates to military weapon systems.

Kill radius - The distance from the center of detonation to the point on a spherical surface where there is a 50% probability of destroying specific targets.

Kilo - Prefix meaning multiplied by 10^3.

Kilocycle - One thousand cycles or 1000 cycles per second; KHz.

Kilogram - The unit of mass in the metric system; the mass of the International Prototype Kilogram, a cylinder of platinumiridium alloy, stored at Seures, France, by the International Bureau of Weights and Measures.

Kilometer - A unit of distance in the metric system. One kilometer = 3280.8 feet = 1093.6 yards = 1000 meters = 0.62137 statute miles = 0.53996 nautical miles.

K-indicator - K-display.

Kinematics - The branch of mechanics dealing with the description of the motion of bodies or fluids without reference to the forces producing the motion.

Kinestheses - A sense mediated by end organs located in muscles, tendons and joints and stimulated by bodily movements and tensions.

Kinesthetic feedback - Sensory information obtained from disturbance of end organs within muscles, tendons and joints.

Kinetic energy - The energy which a body possesses as a consequence of its motion, defined as one-half the product of its mass m and the square of its speed v, $\frac{1}{2}mv^2$.

Kinetic theory - The derivation of the bulk properties of fluids from the properties of their constituent molecules, their motions, and interactions.

Kirchhoff's law - In any branching network of wires the algebraic sum of currents in all the wires that meet at a point is zero.

Klystron - An electron tube for converting direct-current energy into radio frequency energy by alternately speeding up and slowing down the electrons.

Knot - The unit of speed used in navigation. It is equal to 1 nautical mile per hour or 1.1508 statute miles per hour.

K-scan - K-display.

K-scope - K-display.

Latitude - Angular distance on the earth's surface measured north and south of the equator from 0° to 90°.

Launch complex - The site, facilities, and equipment used to launch a rocket vehicle.

Launch vehicle - The part of the space vehicle which furnishes the propulsion and guidance during the initial part of the trajectory to provide the prescribed velocity, position, and attitude required for injection into the desired trajectory.

Launch window - The mission conditions which impose launch time limitations on the launch vehicle for any given trajectory, such as relative position of Earth and Moon or planets, mid-course propulsion capabilities, guidance limits, etc.

Law of equal areas - Kepler second law.

Layer depth - In oceanography, the thickness of the mixed layer; or the depth of the top of the thermocline.

Layer effect - Reduction in the echo and listening ranges on a target located within or beneath a thermocline.

Layer of no motion - A layer, assumed to be at rest, at some depth in the ocean. This implies that the isobaric surfaces within the layer are level, and hence they may be used as reference surfaces for the conputation of absolute gradient currents.

L-display - In radar, a display in which a target appears as two horizontal blips, one extending to the right and one to the left, from a central vertical time base. Also called L-scan, L-scope, L-indicator.

League - A unit of distance of indefinite value, varying from 2.4 to 4.6 miles. In the U.S. it is approximately 3 miles, either statute or nautical.

Least squares - Any statistical procedure that involves minimizing the sum of squared differences.

Leeward - The direction toward which the wind is blowing; the direction toward which the waves are traveling.

Labyrinthine - Referring to the labyrinth of the inner ear which acts as an acceleration sensor.

Lag - 1. The delay between change of conditions and the indication of the change on an instrument. 2. Delay in human reaction. 3. The amount one cyclic motion is behind another, expressed in degrees. The opposite is lead.

Lambert - A unit of luminance (or brightness) equal to 1/π candle per square centimeter. Physically, the lambert is the luminance of a perfectly diffusing white surface receiving an illuminance of 1 lumen per square centimeter.

Landolt ring - A ring with a small gap at one point, used to test visual acuity by having observer report orientation of the gap.

Lapse rate - The decrease of an atmospheric variable with height, the variable being temperature, unless otherwise specified.

Laser - A device for producing intense narrow-band, highly directional light by emission of energy stored in a molecular or atomic system when stimulated by an input signal.

Latent heat - The unit quantity of heat required for isothermal change in state of a unit mass of matter.

Lateral - 1. Of or pertaining to the side; directed or moving toward the side. 2. Of or pertaining to the lateral axis; directed, moving, or located along, or parallel to, the lateral axis.

Lens - The transparent body, convex on its front and back surfaces, situated just behind the iris and pupil of the eye; it serves through changes in its shape brought about by the action of the ciliary muscles, to focus the eye for different distances.

Lens shapes -

a. Plano-convex - One convex side, one flat side.
b. Double convex (bi-convex) - Both sides convex.
c. Plano-concave - One concave side, one flat side.
d. Double concave (bi-concave) - Both sides concave.
e. Meniscus - One convex side, one concave side.

Level - In acoustics, the logarithm of the ratio of that quantity to a reference quantity of the same kind. The base of the logarithm, the reference quantity, and the kind of level must be specified.

Library - In computer operations, a collection of programs, routines, and subroutines by which problems (and parts of problems) of many types can be solved.

Life sciences - The field of scientific disciplines encompassing biology, physiology, psychology, medicine, sociology, and other related areas.

Lift - 1. That component of the total aerodynamic force acting on a body perpendicular to the undisturbed airflow relative to the body. 2. To lift off, to take off in a vertical ascent. Said of a rocket vehicle.

Lift coefficient - A coefficient representing the lift of a given airfoil or other body.

Lift-drag ratio - The ratio of lift to drag obtained by dividing the lift by the drag, or the lift coefficient by the drag coefficient. Also called L/D ratio.

Light - Visible radiation (about 0.4 to 0.7 micron in wavelength) considered in terms of its luminous efficiency, i.e., evaluated in proportion to its ability to stimulate the sense of sight.

Light-adapted eye - An eye which has been exposed to light stimuli of relatively high intensity and has so become relatively insensitive to lower intensities. Cf. adaptation.

Light energy - Luminous energy. (See Table 4).

Light intensity - Luminous intensity.

Lightness - That attribute of most object colors by reference to which they can be classed as equivalent to members of the achromatic series ranging from black to white.

Lightening holes - Holes cut out of a structural material to reduce its weight.

Light sensation - A kind of sensation whose adequate stimulus is light and whose receptor is the eye.

Light-year - A unit of length used in expressing stellar distances equal to the distance electro-magnetic radiation travels in 1 year. 1 light-year = 9.460×10^{12} kilometers = 63,280 astronomical units = 0.3068 parsecs.

Limb - The edge of the apparent disk of a celestial body, as of the sun.

Limen - Threshold; a psychophysical concept denoting the lowest detectable intensity of any sensory stimulus.

Limiter - A device whose output is constant for all inputs above a predetermined value.

L-indicator - L-display.

Table 4 - General Characteristics of Light Sources

	Luminance, ft-lamberts	Spatial Distribution	Life, hours	Color	Efficiency lumens w	Note
Electroluminescent	3-65	Cosine (area source)	3000-50,000	Any visual color	3	
Fluorescent	3000-12,000	Cylindrical	5000-15,000	White (warm to blue)	50-80	
Mercury Arc	100,000	Spherical (approx.)	20,000	Blue green, little red (except coated bulbs)	45	3-minute warm-up
Metalarc	150,000	Spherical (approx.)	7500	White	8C-100	3-minute warm-up
Incandescent	4,000,000 to 6,000,000	Spherical	100-600	White with little blue	20-16	
Incandescent	8,500,000	Spherical	100-600	White with little blue	25-20	
Quartz Tungsten						
Halogen	5,500,000					
High-Pressure Arc	100,000,000	Spherical	300	White	40	Needs costly ballasts

	Luminance, ft lamberts	Spatial Distribution	Life, hours	Color	Efficiency, lumens w	Choice
Inte or Flooding	Low	Cylindrical	Short	White but warm	High	Fluorescent
Instrument Display	High enough for daytime vision	Area	Long	Specified colors	Low	Electroluminescent
Exterior Signals	High	Spherical	Reliable to 600	White with filters	Low	Reliable incandescent
Forward	Very high	Spherical	Reliable to 200	White	Medium	Quartz tungsten-halogen

Linear - 1. Of or pertaining to a line. 2. Having a relation such that a change in one quantity is accompanied by an exactly proportional change in a related quantity, such as input and output of electronic equipment.

Linear array - An antenna array whose elements are equally spaced along a straight line.

Linear integer programming - Considers linear programming models where only integer solutions are admissible. A special case for integer programming is selective programming. In this case the variables in the solution can take only one of the preselected values.

Line of position - In navigation, a line representing all possible locations of a craft at a given instant.

Line of sight - 1. The straight line between the eye of an observer and the observed object or point. Also called optical path. 2. Any straight line between one point and another, or extending out from a particular point. 3. In radio, a direct propagation path that does not go below the radio horizon.

Line printer - A printer, often used in conjunction with a computer, which is capable of printing an entire line of characters at one time.

Link analysis - An analysis of the visual, auditory, and tactual links between man and machine or between one man and another involved in an operation. Primary objectives are determination of the importance of links, frequency of their use, and their adequacy.

Litre - A unit of volume equal to the space occupied by 1 kilogram of water.

Local civil time - See local mean time.

Localization, auditory - The capability of an observer to identify the position of a sound source with reference to himself.

Local mean time - Local hour angle of the mean sun, expressed in time units, plus 12 hours. Mean time reckoned from the upper branch of the local meridian is called local astronomical time.

Local meridian - The meridian through any particular place or observer, serving as the reference for local time, in contrast with Greenwich meridian.

Local time - Time based upon the local meridian as reference, as contrasted with that based upon a zone meridian, or the meridian of Greenwich.

Logarithm - The power to which a fixed number, called the base, usually 10 or e (2.7182818), must be raised to produce the value to which the logarithm corresponds.

Logarithmic scale - A scale graduated in the logarithms of uniformly spaced consecutive numbers.

Logical element - In a computer or data-processing system, the smallest building blocks which can be represented by operators in an appropriate system of symbolic logic. Typical logical elements are the AND gate and the flip-flop, which can be represented as operators in a suitable symbolic logic.

Longitude - Angular distance on the earth's surface measured east and west of the Greenwich meridian from 0° to 180°.

Longitudinal axis - The fore-and-aft line through the center of gravity of a craft.

Look angles - The elevation and azimuth at which a particular satellite is predicted to be found at a specified time. Look angles are used in satellite tracking and data acquisition to minimize the amount of searching needed to acquire the satellite in the telescope field of view or the antenna beam.

Loran (long range navigation) - An electronic navigational system in which hyperbolic lines of position are determined by measuring the difference in the time of reception of synchronized pulse signals from two fixed transmitters.

Loudness - The intensive attribute of an auditory sensation, in terms of which sounds may be ordered on a scale extending from soft to loud. Loudness is measured in sones.

Lower branch - That half of a meridian or celestial meridian from pole to pole which passes through the antipode or nadir of a place.

Low frequency - See frequency bands.

Low-pass filter - A wave filter having a single transmission band extending from zero frequency up to some critical or bounding frequency, not infinite.

Low vacuum - The condition in a gas-filled space at pressures less than 760 torr and greater than some lower limit.

Lox - Liquid oxygen.

L-scan - L-display.

L-scope - L-display.

Lubber's line - A reference line on any direction-indicating instrument, marking the reading which coincides with the heading.

Lumen - A unit of luminous flux equal to the luminous flux radiated into a unit solid angle (steradian) from a point source having a luminous intensity of 1 candela.

Luminance - In photometry, a measure of the intrinsic luminous intensity emitted by a source in a given direction; the illuminance produced by light from the source upon a unit surface area oriented normal to the line of sight at any distance from the source, divided by the solid angle subtended by the source at the receiving surface. Also called brightness, but luminance is preferred.

Luminescence - Light emission by a process in which kinetic heat energy is not essential for the mechanism of excitation.

Luminosity - Luminous efficiency.

Luminosity coefficients - The coefficients by which the color mixture data for any color need to be multiplied so that the sum of the three products is the luminance of the color sample to be specified.

Luminous - 1. In general, pertaining to the emission of visible radiation. 2. In photometry, a modifier used to denote that a given physical quantity, such as luminous emittance, is weighted according to the manner in which the response of the human eye varies with the wavelength of the light.

Luminous flux - Luminous energy per unit time; the flux of visible radiation, so weighted as to account for the manner in which the response of the human eye varies with the wavelength of radiation. See luminous efficiency.

Luminous intensity - Flux per unit solid angle, usually expressed in candles. Also called candlepower, light intensity. Compare luminance, illuminance.

Lunar day - The duration of one rotation of the earth on its axis, with respect to the moon (about 24 hours 50 minutes of mean solar time).

Lunar gravity - Approximately 1/6 of the earth's gravity.

Lux - A photometric unit of illuminance or illumination equal to 1 lumen per square meter. Compare foot-candle, phot.

Mach - Mach number. (See Section 1 for Mach/speed equivalents).

Machine language - 1. A language, occurring within a computer, ordinarily not perceptible or intelligible to persons without special equipment or training. 2. A translation or transliteration of sense 1 into more conventional characters but frequently still not intelligible to persons without special training.

Machmeter - An instrument that measures and indicates speed relative to the speed of sound, i.e., that indicates the Mach number. Also called Mach indicator.

Mach number - The ratio of the speed of a body or of a point on a body with respect to the surrounding air or other fluid, or the speed of a flow, to the speed of sound in the medium; the speed represented by this number.

Macroscopic - Large enough to be visible to the naked eye or under low order of magnification.

Macula, Macula Lutea - A yellow pigmented area situated centrally about the fovea of the retina. Also called yellow spit.

Magnetic anomaly detector - A system which detects local changes in the earth's magnetic field.

Magnetic deviation - The angle between the magnetic meridian and the axis of a compass card, expressed in degrees east or west.

Magnetic dip - The angle between the horizontal and the direction of a line of force of the earth's magnetic field at any point.

Magnetic drum - A memory device used in computers, a rotating cylinder on which information may be stored as magnetically polarized areas, usually along several parallel tracks around the periphery.

Magnetic lines of force - Imaginary lines so drawn in a region containing a magnetic field to be everywhere tangent to the magnetic field intensity vector if in vacuum or non-magnetic material, or parallel to the magnetic induction vector if in a magnetic medium.

Magnetic north - That point on the earth's surface in the vicinity of the north geographic pole where the earth's magnetic field appears to converge.

Magnetic poles - In geomagnetism, either of the two points on the earth's surface at which the magnetic meridians converge, i.e., where the magnetic field is vertical. The exact locations of these two magnetic poles shift in complex fashion.

Magnetic storage - In computer terminology, any device which makes use of the magnetic properties of materials for the storage of information.

Magnetic tape - A ribbon of paper, metal, or plastic, coated or impregnated with magnetic material on which information may be stored in the form of magnetically polarized areas.

Maintainability - A quality of the combined features and characteristics of equipment design which permits or enhances the accomplishment of maintenance by personnel of average skill, under the natural environmental conditions in which it will operate.

Maintainability index - A quantitative figure of merit which relates the maintainability of an item to a standard reference.

Maintenance - The function of retaining material in or restoring it to a serviceable condition.

Maintenance task - Any action(s) required to preclude the occurrence of a malfunction or restore an equipment to satisfactory operating condition.

Maintainer - A maintenance technician trained to inspect, service, repair, test and/or adjust a specific equipment.

Man-machine system - A system in which the functions of the man and the machine are interrelated and necessary for the operation of the system.

Manned - Of a vehicle occupied by one or more persons who normally have control over the movements of the vehicle, as in a manned aircraft or spacecraft, or who perform some useful function while in the vehicle. As opposed to non-vehicle systems which are also manned for operation and/or maintenance.

Man-rated - A manned vehicle which meets pre-specified safety-of-flight criteria.

Maser - An amplifier utilizing the principle of microwave amplification by stimulated emission of radiation. Emission of energy stored in a molecular or atomic system by a microwave power supply is stimulated by the input signal.

Matrix - 1. Any rectangular array of elements composed of rows and columns; specifically, such an array consisting of numbers or mathematical symbols which can be manipulated according to certain rules. 2. In electronic computers, any logical network whose configuration is a rectangular array of intersections of its input-output leads, with elements connected at some of these intersections. The network usually functions as an encoder or decoder. Loosely, any encoder, decoder, or translator.

M-display - In radar, a display in which target distance is determined by moving an adjustable blip along the baseline until it coincides with the horizontal position of the target signal deflections. The control which moves the blip is calibrated in distance. Also called M-scan, M-scope, M-indicator.

Mean - Arithmetic mean.

Mean error - Root-mean-square error.

Mean square - Referring to the arithmetic mean of the squares of the values under consideration, as mean-square amplitude, mean-square error.

Mean-square error - The quantity whose square is equal to the sum of the squares of the individual errors divided by the number of those errors.

Mean sun - A fictitious sun conceived to move eastward along the celestial equator at a rate that provides a uniform measure of time equal to the average apparent time; the reference for reckoning mean time, zone time, etc.

Mean time - Time based upon the rotation of the earth relative to the mean sun.

Mean-time-between-failure - The limit of the ratio of item operating time to the number of observed failures (r) as the number of failures approaches infinity.

Mean-time-to-failure - The average of mean life of an irreparable device.

Mechanoreceptor - A nerve ending that reacts to mechanical stimuli, as touch, tension, and acceleration.

Median - The middle term of a series, or the interpolated value of the two middle terms if the number of terms is even. Compare mean.

Medium frequency - See Frequency bands.

Megacycle - One million cycles; one thousand kilocycles.

Mel - A unit of acoustic pitch - By definition, a simple tone of frequency 1000 cycles per second, 40 decibels above a listener's threshold, produces a pitch of 1000 mels. The pitch of any sound that is judged by the listener to be n times that of a 1-mel tone is n mels.

Memory - 1. Recall and recognition of anything previously learned or experienced. 2. The component of a computer, control system, guidance system, instrumented satellite, or the like, designed to provide ready access to data or instructions previously recorded so as to make them bear upon an immediate problem, such as the guidance of a physical object, or the analysis and reduction of data.

Meridian - A north-south reference line, particularly a great circle through the geographical poles of the earth. The term usually refers to the upper branch, that half, from pole to pole, which passes through a given place, the other half being called the lower branch.

Mesopic vision - Vision intermediate between photopic and scotopic vision, and consequently attributed to the combined functioning of the rods and cones.

Metabolic reserves - The energy source stored in chemical form, such as carbohydrates, that can be efficiently mobilized and utilized by the body, particularly for muscular activity and work beyond the normal level of activity of an individual.

Metabolism - The utilization of oxygen by all cells of the body for the production of energy and heat. In this process carbon dioxide is produced.

Metamers, metameric colors - Color stimuli which have different spectrophotometric characteristics but which elicit identical colors under favorable conditions of comparison.

Meter - 1. The basic unit of length of the metric system. 2. A device for measuring, and usually indicating, some quantity.

Method of attributes - In reliability testing, measurement of quality by noting the presence or absence of some characteristic (attribute) in each of the units in the group under consideration and counting how many do or do not possess it.

Method of average error - The psychophysical method in which the subject manipulates the variable stimulus until he judges it to match the standard. The error is then measured.

Method of constant stimuli - Psychophysical method in which the frequency with which a sensation occurs is measured as a function of the variation in magnitude of the stimulus. A few discrete stimuli are used and each is presented many times.

Method of limits - Method of investigation which proceeds by gradually decreasing the value of a given stimulus (or the difference between two stimuli) until it is no longer noticeable; and also by increasing the stimulus value (or the difference between two stimuli) from a definitely imperceptible value until it becomes just noticeable.

Method of paired comparison - Method in which each member of a series is compared with every other member with respect to a given characteristic.

Micrometeorite penetration - Penetration of the thin outer shell (skin) of space vehicles by small particles travelling in space at high velocities.

Micron - A unit of length equal to one-millionth of a meter or one-thousandth of a millimeter.

Midcourse guidance - Guidance of a rocket from the end of the launching phase to some arbitrary point or at some arbitrary time when terminal guidance begins. Also called incourse guidance.

Mil - 1. One-thousandth of an inch. 2. A unit of angular measurement, 1/6400 of a circle.

Millimeter - One-thousandth of a meter; one-tenth of a centimeter; 0.039370 U.S. inch.

Millimeter of mercury - A unit of pressure corresponding to a column of mercury exactly 1 millimeter high at 0° C under standard acceleration of gravity of 980.665 centimeters per second squared.

Minimum separable acuity - Smallest space between two lines that can be discriminated as a gap. It is measured in terms of the angle subtended by the gap, measured at the eye.

Minimum visible acuity - Least area of a uniform brightness that can activate the eye. It is measured in terms of the angle subtended by the area, measured at the eye.

Minute - 1. The sixtieth part of an hour. 2. The sixtieth part of a degree of arc.

Mission profile - A time-sequence description of the events required, as well as the necessary locations and conditions of their occurrence, in order to accomplish the objectives of the mission.

Mission task - The specified purpose for which a device must perform.

Mobile training units - Training aids representing major aircraft components and related airborne and supporting equipment representative of a specific type and model of aircraft.

Mockup - A full-sized replica or dummy of something, such as a spacecraft, often made of some substitute material such as wood, and sometimes incorporating actual functioning pieces of equipment such as engines controls, displays, etc.

Mode - 1. A functioning position or arrangement that allows for the performance of a given task. 2. A measure of central tendency; the score occurring in the largest number of cases.

Moment - A tendency to cause rotation about a point or axis, as of a control surface about its hinge or of an airplane about its center of gravity; the measure of this tendency, equal to the product of the force and the perpendicular distance between the point of axis of rotation and the line of action of the force.

Moment of inertia - Of a body about an axis, $\sum mr^2$, where m is the mass of a particle of the body and r is its distance from the axis.

Momentum - Quantity of motion, the measure of resistance of a moving body to a change in direction.

Monitor - To observe, listen in on, keep track of, or exercise surveillance over by any appropriate means, as, to monitor radio signals; to monitor the flight of a rocket by radar; to monitor a landing approach.

Monochromatic - Pertaining to a single wavelength or, more commonly, to a narrow band of wavelengths.

Monochromatism - Form of visual deficiency in which the colors can be matched with a single adjustable primary.

Monocular field - Field of vision with one eye alone.

Monte Carlo method - A technique that permits computer simulation of a brute-force empirical approach. This empirical approach involves the mathematical construction of a number of possible models under study from constituents selected at random from representative populations.

Motion parallax - The apparent difference in rate of movement of two objects actually moving at the same velocity but at different distances from the observer.

Motion study (time and motion study) - An analysis technique which examines task elements according to the time required to perform each element.

M-scan - M-display.

M-scope - M-display.

Multiplexer - A mechanical or electrical device for time sharing of a circuit.

Munsell color notation - A system of letters and numbers of which the Munsell color samples are notated or specified with respect to hue, value, and chroma. Unspecified surface colors can be specified by comparison with the Munsell samples and assignment of the appropriate notation.

Munsell colors - A series of about 1000 standard samples of chromatic and achromatic surfaces, each specified by a letter-number system of notation with respect to Munsell hue, value, and chroma (analogues of hue, lightness, and saturation).

Musculo-skeletal - Pertaining to the human muscle and skeletal systems.

Nautical mile - A unit of distance used principally in navigation; defined as the length of one minute of arc along any great circle on the earth's surface. Since this actual distance varies slightly with latitude, a nautical mile by international agreement is defined as 1852 meters (6076.103 feet or 1.1508 statute miles).

N-display - In radar, a display similar to the K-display in which the target appears as a pair of vertical deflections or blips from the horisontal time base. Direction is indicated by the relative amplitude of the vertical deflections; target distance is determined by moving an adjustable signal along the baseline until it coincides with the horizontal position of the vertical deflections. The horizontal control is calibrated in distance. Also called N-scan, N-scope, N-indicator.

Negative acceleration - Deceleration.

Negative feedback - Feedback which results in decreasing the amplification.

Negative g - In designating the direction of acceleration on a body, the opposite of positive g, for example, the effect of flying an outside loop in the upright seated position. See physiological acceleration.

Neuromuscular - Pertaining jointly to nerves and muscles, as neuromuscular junction.

Nitrogen narcosis - The narcotic effect related to the partial pressure of inspired nitrogen; a function of depth of diving and the percentage of nigrogen in the respired gas.

Nodal point - The point in the eye through which all straight lines pass which join points in the stimulus field with their respective retinal images.

Node - 1. One of the two points of intersection of the orbit of a planet, planetoid, or comet with the ecliptic, or of the orbit of a satellite with the plane of the orbit of its primary. Also called nodal point. 2. A point, line, or surface in a standing wave where some characteristic of the wave field has essentially zero amplitude. 3. A terminal of any branch of a network or a terminal common to two or more branches of a network. Also called junction point, branch point, or vertex.

Noise - Noise is any undesired sound. By extension, noise is any unwanted disturbance within a useful frequency band, such as undesired electric waves in a transmission channel or device. Also used to describe unwanted or interfering characteristics of visual or other sensory input systems.

Noise level - The transmission level of interference computed from its equivalent plane wave intensity is usually spoken of as the noise level.

Non-parametric statistics - A branch of statistics making no assumptions about the nature of the distribution.

Normal - 1. Equivalent to usual, regular, rational or standard conditions. 2. Perpendicular, e.g., the line normal to a surface or to another line, normal line of sight, etc.

NOR circuit - A circuit that has an output only when all inputs are out.

Normal distribution - The fundamental frequency distribution of statistical analysis. Also called Gaussian distribution.

Normalize - 1. To change in scale so that the sum of squares, or the integral of the squares of the transformed quantity is unity. 2. To transform a random variable so that the resulting random variable has a normal distribution. 3. In computer operations, to adjust the exponent and coefficient of a floating-point result so that the coefficient is in the prescribed normal range. Also called standardize.

NOT circuit - In computers, a device or circuit which inverts the polarity of a pulse. Also called inverter.

NTDS - Navy Tactical Data System. Under this system, computer-fed consoles display a schematic picture of enemy targets, their type and movements, as well as the defensive and offensive position of friendly ships and aircraft.

Nystagmus - An involuntary oscillation of the eyeballs, especially occurring as a result of eye fixations and stimulations of the inner ear during rotation of the body.

Object color - Color seen as belonging to an object. This includes surface and volume colors to the extent that surfaces and volumes are perceived as objects or parts of objects. Object colors are relatively insensitive to changes in viewing conditions, viz., they exhibit the phenomenon of constancy.

Objective - The lens or combination of lenses which receives light rays from an object and refracts them to form an image in the focal plane of the eyepiece of an optical instrument, such as a telescope. Also called object glass.

Oculogyral illusion - The apparent movement of an image in space in the same direction as that in which one seems to be turning when the semicircular canals are stimulated.

Omnibearing - A bearing toward an omni-directional radio-range station, as given to an aircraft by the omnidirectional radio range.

Omnirange - A radio navigation system providing a direct indication of the bearing of the omnirange facility from the vehicle. Usually used in combination with distance-measuring equipment. Also called omnidirectional range.

Opacity - Of an optical path, the reciprocal of transmission. See transmittance.

Open circuit scuba - A swimmer underwater breathing system in which expired gases are vented overboard.

Open loop - A system operating without feedback, or with only partial feedback. See closed loop system.

Open system - A system that provides for the body's metabolism in an aircraft or spacecraft cabin by removal of respiratory products and of waste from the cabin and by use of stored food and oxygen. Compare closed ecological system.

Operand - In computer operations, a word on which an operation is to be performed.

Operational ground equipment - Ground equipment required in direct support of operation, as opposed to maintenance of an aerospace vehicle.

Operative temperature - In the study of human bioclimatology, one of several parameters devised to measure the air's cooling effect upon a human body. It is equal to the temperature at which a specified hypothetical environment would support the same heat loss from an unclothed, reclining human body as the actual environment. In the hypothetical environment, the wall and air temperatures are equal and the air movement is 7.6 centimeters per second From experiment it has been found that the operative temperature

$$T_o = 0.48t_r + 0.19\left[\sqrt{vt_a} - (\sqrt{v} - 2.76)t_s\right]$$

where t_r is the mean radiant temperature: t_a is the mean air temperature; t_s is the mean skin temperature (all in °C); and v is the airspeed in centimeters per second.

Operator task - A group of related activities required in performing (with other tasks) a more comprehensive system functional activity.

Optical axis - Of an antenna, a line parallel to, but offset from, the electrical axis of an ant .

Optical line of sight - The generally curved path of visible light through the atmosphere.

Optical systems, primary types -

a. Refractive - Uses refractive elements (lenses to collect and focus radiation).

b. Reflective - Uses reflective elements (mirrors) to collect and focus radiation.

c. Cathioptric - Uses combination of refractive and reflective elements to collect and focus radiation.

  1. Maksutov System (also called Bouwers or concentric system - A thick meniscus lens having spherical surfaces is used to minimize the spherical aberrations of a spherical primary mirror.

  2. Schmidt System - The aberrations of a spherical mirror are corrected by the use of refractive corrector element having aspheric surfaces.

Optic disc - A small, low eminence on the inner surface of the retina, within the eyeball, formed by the nerve-fibers of the retina, as they collect just before emerging from the eyeball to form the optic nerve.

Optic nerve - The second cranial nerve, which connects the retina of the eye with the visual center .

Optimal - 1. Pertaining to a trajectory, path, or control motion, one that minimizes or maximizes some quantity or combination of quantities such as fuel, time, energy, distance, heat transfer, etc. This optimum condition, or path, is commonly calculated by a type of mathematics known as calculus of variations. 2. Refers also to "best fit" for man-machine system design or procedure.

OR - 1. The logical operator which has the property that A or B is true if either A is true or B is true. 2. In Boolean algebra, the operation of union.

Orbital elements - A set of seven parameters defining the orbit of a body attracted by a central, inverse-square force. Several different sets of parameters have been used. For artificial satellites the elements usually given are: longitude of the ascending node, Ω; inclination of the orbit plane, i; argument of perigee, ω; eccentricity, e; semimajor axis, a; mean anomaly, M; and epoch, t_o.

Orbital velocity - The average velocity at which an earth satellite or other orbiting body travels around its primary.

Order of magnitude - A factor of 10.

Organizational maintenance - Maintenance performed by a using organization on its assigned equipment.

OR-gate - A gate whose output is energized when any one or more of the inputs is in its prescribed state. An OR-gate performs the function of the logical inclusive-OR, of Boolean algebra.

Oscilloscope - 1. An instrument for producing a visual representation of oscillations or changes in an electric current. 2. Specifically, a cathode-ray oscilloscope.

Ostwald colors - A series of several hundred chromatic and achromatic samples, each corresponding to a certain theoretical pigment combination of "full color content, white content, and black content"; and designated in an arbitrary letter-number system of notation.

Otolith organs - Structures of the inner ear (utricle and saccule) which respond to linear acceleration and tilting.

Outgassing - The evolution of gas from a material in a vacuum.

Out of phase - The condition of two or more cyclic motions which are not at the same part of their cycles at the same instant. Also called out of step. Compare in phase.

Oxidizer - Specifically, a substance (not necessarily containing oxygen) that supports the combustion of a fuel or propellant.

Packaging - Expression applied to design of equipment enclosures, chassis and control-display panels.

Parabola - An open curve all points of which are equidistant from a fixed point, called the focus, and a straight line.

Parabolic reflector - A reflecting surface having the cross section along the axis in the shape of a parabola.

Paraboloid - A surface of revolution generated by revolving a section of a parabola about its major axis.

Parabrake - Deceleration parachute.

Paracentral vision - Vision mediated by the zone of the retina immediately surrounding the fovea centralis.

Parafoveal vision - Vision in which the eye is so oriented toward the pertinent light source as to have the light fall upon some portion of the retina surrounding the fovea. Also called scotopic vision. See foveal vision.

Parallax - The difference in the apparent direction or position of an object when viewed from different points expressed as an angle.

Parameter - 1. In general, any quantity of a problem that is not an independent variable. More specifically, the term is often used to distinguish, from dependent variables, quantities which may be assigned more or less arbitrary values for purposes of the problem at hand. 2. In statistical terminology, any numerical constant derived from a population or a probability distribution. Specifically, it is an arbitrary constant in the mathematical expression of a probability distribution.

Parametric equations - A set of equations in which the independent variables or coordinates are each expressed in terms of a parameter. For example, instead of investigating $y = f(x)$ or $F(x,y) = 0$, it is often advantageous to express both x and y in terms of a parameter u: $x = g(u)$; $y = G(u)$. The parameter may or may not have a useful geometric or physical interpretation.

Parking orbit - An orbit of a spacecraft around a celestial body, used for assembly of components or to wait for conditions favorable for departure from the orbit.

Parsec - A unit of length equal to the distance from the sun to a point having a heliocentric parallax of 1 second (1"), used as a measure of stellar distance. The name parsec is derived from the words parallax second.

Part - 1. One of the constituents into which a thing may be divided. Applicable to a major assembly, subassembly, or the smallest individual piece in a given thing. 2. Restrictive. The least subdivision of a thing; a piece that functions in interaction with other elements but is itself not ordinarily subject to disassembly.

Partial derivative - The ordinary derivative of a function of two or more variables with respect to one of the variables, the others being considered constants. If the variables are x and y, the partial derivatives of $f(x,y)$ are written $\partial f/\partial x$ and $\partial f/\partial y$, or $D_x f$ and $D_y f$, or f_x and f_y. The partial derivative of a variable with respect to time is known as the local derivative.

Partial pressure - The pressure exerted by a designated component or components of a gaseous mixture.

Partial pressure suit - A skintight suit which does not completely enclose the body but which is capable of exerting pressure on the major portion of the body in order to counteract an increased oxygen pressure in the lungs.

Passive sonar - Passive sonar is the method or equipment by which information concerning a distant object is obtained by evaluation of sound generated by the object.

Peak sound pressure - For any specified time interval, the maximum absolute value of the instantaneous sound pressure in that interval.

Pelorus - An instrument used on a boat in connection with a log line to obtain the direction of current. In its simplest form, it is a disk about 8 inches in diameter and graduated clockwise for every 5° or 10°. It is mounted rigidly on the boat, usually with the 0° mark forward and the diameter through this mark parallel with the keel of the boat.

Pencil beam - Emission, from an antenna, having the form of a narrow conical beam.

Perception - The awareness of external objects, qualities, or relations, which ensues directly upon sensory processes.

Pericynthian - That point in the trajectory of a vehicle which is closest to the moon.

Perigee - That orbital point nearest the earth when the earth is the center of attraction.

Perihelion - That point in a solar orbit which is nearest the sun.

Perimeter - An instrument for mapping the sensibility of the retinal field; it consists typically of a quadrant rotating about one of its limiting radii as an axis so that on every point of this arm, and at every angle (corresponding to some point on the retina) a stimulus can be given and the visual impression recorded on a chart, the eye being placed at the center of the quadrant and fixated upon its center of rotation. Sometimes a semi-circular arm is used rotating about its middle radius.

Period - 1. The interval needed to complete a cycle. 2. = orbital period. 3. Specifically, the interval between passages at a fixed point of a given phase of a simple harmonic wave; the reciprocal of frequency.

Periphery of retina - The region of the retina remote from the center of vision, as distinguished from the central region. Defines peripheral visual limits.

Permanent memory - In computer terminology, storage of information which remains intact when the power is turned off. Also called nonvolatile storage.

Personnel subsystem - Those aspects of a system which relate to the operational and support personnel required. Includes man-machine interface design and trained personnel requirements for effective system performance. (See PSS/Hardware development interaction Figure 4).

Phase angle - 1. The phase difference of two periodically recurring phenomena of the same frequency, expressed in angular measure. 2. The angle at the celestial body between the sun and earth.

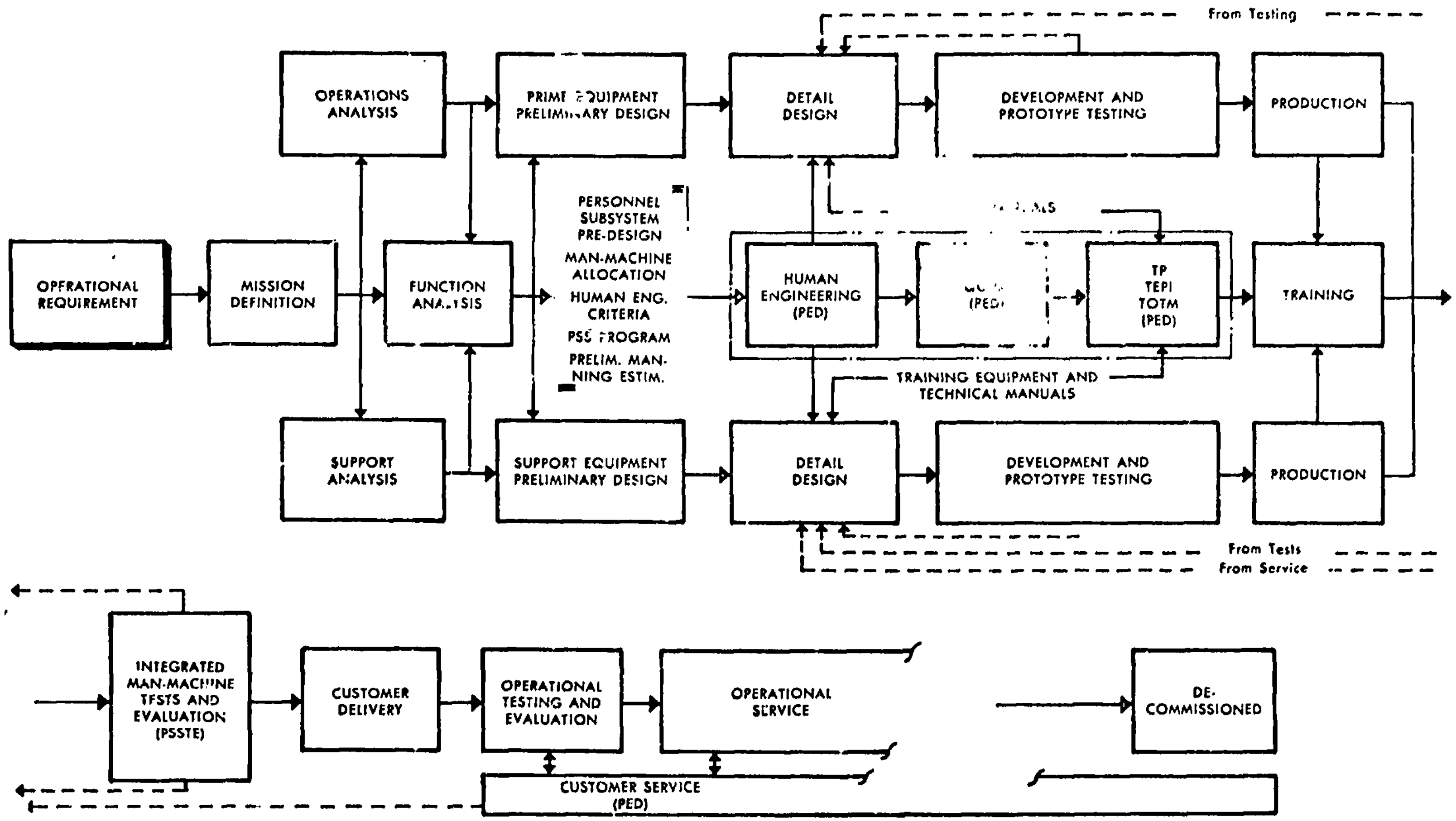


Figure 4 - A TYPICAL MANNED WEAPON-SYSTEM DEVELOPMENT MODEL SHOWING THE PSS-CONCEPT INTERACTION WITH EQUIPMENT DEVELOPMENT

Phase modulation - Angle modulation in which the angle of a sine-wave carrier is caused to depart from the carrier angle by an amount proportional to the instantaneous value of the modulating wave.

Phon - The unit of loudness level of sound, numerically equal to the sound pressure level in decibels, relative to 0.0002 microbar, of a simple 1000 cycle per second tone judged by listeners to be equivalent in loudness. Compare sone.

Phosphorescence - Emission of light which continues after the exciting mechanism has creased. See luminescence. Compare flourescence.

Phot - A photometric unit of illuminance or illumination equal to 1 lumen per square centimeter. Compare foot-candle, lux.

Photochromatic interval - The range of visual stimulus-intensity, for a chromatic stimulus, between the absolute threshold or limen for light-perception, and the threshold for hue. There is said to be no photochromatic interval for long wave light, i.e., in the red end of the spectrum. Also called colorless interval.

Photochromic display - A large screen display which retains a trace when exposed to ultra violet light.

Photogrammetry - The art or science of obtaining reliable measurements by means of photog aphy.

Photoluminescence - Flourescence. See luminescence.

Photopic vision - Vision associated with levels of illumination 0.01 foot-lambert or higher, characterized by the ability to distinguish colors and small detail. Also called foveal vision. Compare scotopic vision.

Photopic adaptation - The decreased visual sensitivity to light, sometimes manifest by decreased brightness of a fixed stimulus, which is dependent on relatively intense light stimulation.

Photoreceptor - The visual receptor, the adequate stimulus for which is the luminous energy of the spectrum in the human; cones and rods.

Photosynthesis - A process operating in green plants in which carbohydrates are formed from carbon dioxide and water in the presence of chlorophyll, using light energy and releasing oxygen.

Physiological acceleration - The acceleration experienced by a human or animal test subject in an accelerating vehicle. (See Volume I, Section 3).

Pickoff - A s[illegible] device that responds to angular movement to create a signal [illegible] some type of control, as a pickoff on a gyro in an aut[illegible]

P-indic[illegible] [illegible] indicator (PPI).

Ping - [illegible] projected by an echo-ranging transducer.

Pip - [illegible] on the oscilloscope screen of an electronic instrum[illegible] short, sharply peaked pulse of voltage. Also ca[illegible]

Pipper - A small hole in the reticle of an optical sight or computing sight; a pipper image.

Pitch - 1. Of a vehicle, an angular displacement about an axis parallel to the lateral axis of the vehicle. 2. In acoustics, that attribute of auditory sensation in terms of which sounds may be ordered on a scale extending from low to high.

Pitch attitude - The attitude of an aircraft, rocket, etc., referred to the relationship between the longitudinal body axis and a chosen reference line or plane as seen from the side.

Pitch axis - A lateral axis through an aircraft, missile, or similar body, about which the body pitches. It may be a body, wind, or stability axis. Also called a pitching axis.

Pitching moment - A moment about a lateral axis of an aircraft, rocket, airfoil, etc.

Pitchover - 1. The programmed turn from the vertical that a rocket takes as it describes an arc and points in a direction other than vertical. 2. The point-in-space of this action.

Pitot-static tube - A device consisting essentially of a unit combination of a pitot tube and a static tube arranged coaxially or otherwise parallel to one another, used principally in measuring impact and static pressures; also called pitot-static head.

Plan position indicator - 1. A cathode-ray indicator in which a signal appears on a radial line. Distance is indicated radially, and bearing as an angle. 2. In radar technique, a cathode-ray indicator on which blips produced by signals from reflecting objects and transponders are shown in plan position, thus forming a maplike display. Also called P-indicator, P-scan, P-scope.

Poisson distribution - A one-parameter discrete frequency distribution giving the probability that n points (or events) will be (or occur) in an interval (or time) x, provided that these points are individually independent and that the number occurring in a subinterval does not influence the number occurring in any other nonoverlapping subinterval. It has the form: $f(n,x) = e^{-\sigma}(\sigma x)^n/n!$ The mean and variance are σx, and σ is the average density (or rate) with which the events occur. When σx is large, the Poisson distribution approaches the normal distribution. The binomial distribution approaches the Poisson when the number of events n becomes large and the probability of success P becomes small in such a way that $nP \rightarrow \sigma x$.

Population - In statistical usage, any definite class of individuals or objects. Also called universe. Compare sample.

Port - Left side of a ship (looking forward) - opposite of starboard.

Positive acceleration - 1. Acceleration such that speed increases. 2. Accelerating force in an upward sense or direction, e.g., from bottom to top, seat to head, etc.; acceleration in the direction that this force is applied. See physiological acceleration.

Pound - 1. A unit of mass equal in the United States to 0.45359237 kilogram, exactly. 2. Specifically, a unit of measurement of the thrust or force of a reaction engine representing the weight the engine can move, as an engine with 100,000 pounds of thrust. See poundal, pound mass. 3. The force exerted on 1 pound mass by the standard acceleration of gravity. See gravity, sense 2.

Poundal - A unit of force; that unbalanced force which, acting on a body of 1 pound mass, produces an acceleration of 1 foot per second squared. See pound, pound mass.

Pound mass - 1. A mass equal of 0.45359237 kilogram. 2. A unit of measure of the inertial property equal to the mass of a body weighing 1 pound at the standard acceleration of gravity (980.665 centimeters per second squared).

Power - 1. Rate of doing work. 2. Luminous intensity. 3. The number of times an object is magnified by an optical system, such as a telescope. Usually called magnifying power. 4. The result of multiplying a number by itself a given number of times, as the third power of a number is its cube; the superscript which indicates this process as in $2^3 = 2x2x2$.

Precession - Change in the direction of the axis of rotation of a spinning body, as a gyro, when acted upon by a torque.

Preparation time - That element of Active Repair Time required to obtain necessary test equipment and maintenance manuals, and to set up necessary equipment in preparation for fault location.

Presbyopia - A condition of the eye characterized by ability to see distant objects clearly and inability to obtain a clear picture of nearby objects, due to inelasticity of the lens, with consequent reduction of accommodation, which develops with advancing age.

Pressure altitude - 1. Altitude in the earth's atmosphere above the standard datum plane, standard sea level pressure, measured by a pressure altimeter. 2. The altitude in a standard atmosphere corresponding to atmospheric pressure encountered in a real atmosphere. 3. The simulated altitude created in an altitude chamber.

Pressure breathing - The breathing of oxygen or of a suitable mixture of gases at a pressure higher than the surrounding pressure.

Pressure-breathing system - An oxygen system in which oxygen is injected inside the respiratory ducts through a pressure higher than the surrounding pressure.

Pressure-demand oxygen system - A demand oxygen system that furnishes oxygen at a pressure higher than atmospheric pressure above a certain altitude.

Pressure suit - A garment designed to provide pressure upon the body so that respiratory and circulatory functions may continue normally, or nearly so, under low-pressure conditions, such as occur at high altitudes or in space without benefit of a pressurized cabin.

Preventive maintenance - That maintenance performed to retain an item in satisfactory operational condition by providing systematic inspection, detection, and prevention of incipient failures.

Primary colors - Three colors whose normal stimuli, when mixed additively in proper proportions, are capable of yielding colors of all hues (within a wide range of saturations) and the gray series. This usage relates especially to theories of color vision of the tri-receptor type. (For mixing paint pigment, primaries are red, yellow, blue; for light, they are red, blue, green).

Primary hues - The four psychologically simple or unique hues of normal trichromats. A primary hue is unmixed, viz., it does not partake of the specific nature of any one of the other three; thus a primary red is neither bluish nor yellowish nor greenish, the primary yellow is neither reddish nor greenish nor bluish, etc. Also called psychological primaries, principal hues, unitary hues.

Prime meridian - 1. The meridian of longitude 0°, used as the origin for measurement of longitude. The meridian of Greenwich, England, is almost universally used for this purpose. 2. Any meridian in any coordinate system used as an origin for measurement of longitude.

Probability - The chance that a prescribed event will occur, represented as a pure number P in the range $0 \leq P \leq 1$. The probability of an impossible event is zero and that of an inevitable event is unity.

Probable error - In statistics, that value e_p for which there exists an even probability (0.5) that the actual error exceeds e_p. The probable error e_p is 0.6745 times the standard deviation σ.

Program - 1. In computer operations, a plan for the solution of a problem. 2. To create a plan for the solution of a problem.

Proportional control - Control of an aircraft, rocket, etc., in which control-surface deflection is proportional to the movement of the remote controls.

Proportional navigation - The control of the angular rate of the velocity vector of a vehicle in proportion to the apparent relative angular velocity of its moving target.

Proprioceptive stimulation - Stimulation originating within the deeper structures of the body (muscles, tendons, joints, etc.) for sense of body position and movement and by which muscular movements can be adjusted with a great degree of accuracy and equilibrium can be maintained.

Protanomaly - Form of trichromatism in which the luminosity curve is abnormally low at the long-wave end, and an abnormally large proportion of stimulus red is required in a red-green stimulus mixture in order to match a given yellow.

Protanope - Individual having protanopic vision.

Protanopia - Form of dichromatism in which red and blue-green stimuli are confused and the luminosity is abnormally low at the long-wave end; but a normal proportion of red and green stimuli suffices to match a given yellow. Sometimes called red blindness.

Prototype - 1. A production model of a system suitable for complete evaluation of mechanical and electrical form, design, and performance. 2. The first of a series of similar devices. 3. A physical standard to which replicas are compared, as the prototype kilogram.

Pseudo-isochromatic charts - Charts for testing color deficiency, comprised of colored spots which yield a recognizable pattern (number, letter, irregular line) to a normal observer, but yield a different or not recognizable pattern to an abnormal observer.

Psychomotor ability - Of or pertaining to muscular action ensuing directly from a mental process, as in the coordinated manipulation of aircraft or spacecraft controls.

Psychophysical methods - Standardized procedures for presenting stimulus material to subject for judging and for recording his results. Originally developed for determining functional relations between physical stimuli and correlated sensory responses, but now used more widely.

Psychophysical quantity - A physical measurement, as a threshold, dependent on human attributes or perception.

Pulmonary - Pertaining to, or affecting, the lungs or any component of the lungs.

Pulse radar - A type of radar, designed to facilitate range measurement, in which the transmitted energy is emitted in periodic short pulses. Also called pulsed radar. Compare continuous-wave radar.

Pupil - The circular opening in the iris, which forms the diaphragm of the optical system of the eye, regulating the amount of light admitted to the eye by contracting as the light increases, or the reverse.

Purge - To rid a line or tank of residual fluid, especially of fuel or oxygen in the tanks or lines of a rocket after a test firing or simulated test firing.

Purity - A measure of the degree to which a color stimulus approaches the condition required for maximum saturation. There are various measures of purity, but all of them are based on the ratio of the spectrum and achromatic components of the stimulus mixture.

Purkinje after-image - The second positive visual after-sensation which appears most plainly in the hue complementary to that of the primary sensation.

Purkinje effect - The response of the human eye which makes it less sensitive to lights of longer wavelengths under conditions of decreased illumination, e.g., red appears darker at night than blue having the same brightness under photopic conditions.

Purkinje phenomenon - A phenomenon concerning the perceived brightness of different color stimuli, namely, that as the spectrum is darkened, the long-wave end darkens more rapidly than the short-wave end, e.g., red brightens in an intense general illumination, blue in faint illumination. Concomitant dark adaptation is required, since the effect rests upon the transition from cone to rod vision.

Q - Dynamic pressure.

Quality control - A management function to control the quality of articles to conform to quality standards.

Quality factor - A measure of the sharpness of resonance or frequency selectivity of a resonant vibratory system having a single degree of freedom, either mechanical or electrical. In a mechanical system, this quantity is very nearly equal to one-half the reciprocal of the damping ratio. When used with reference to a lightly damped system, it is also approximately equal to the following: (1) transmissibility at resonance; (2) π / δ where δ is the logarithmic decrement; (3) $2\pi W/\Delta W$ where W is the stored energy and ΔW the energy dissipation per cycle; and (4) $f_r/\Delta f$ where f_r is the resonance frequency and Δf is the bandwidth between the half-power points. Historically the letter Q was an arbitrarily chosen symbol to designate the ratio of reactance to resistance of a circuit element. The name quality factor was introduced later.

Quantitative display - A display which provides numerical values (as opposed to one in which only qualitative information is provided).

Quiet sun - The sun when it is free from unusual radio wave or thermal radiation such as that associated with sun spots.

Quiet - 1. (Acoustics) generally devoid of or free from loud or disturbing sound. 2. (Physics) generally devoid of motion. 3. (Physiological) state of rest or minimum activity.

Radar - The name is derived from the words, Radio Detection and Ranging. Radar is a system of determining the distance of an object by measuring the interval of time between transmission of a radio signal and reception of a signal returned as an echo, or by a transmitter triggered by the outgoing signal.

Radar altitude - The altitude of an aircraft or spacecraft as determined by a radio altimeter; thus, the actual distance from the nearest terrain feature.

Radar beacon - A beacon transmitting a characteristic signal on radar frequency, permitting a craft to determine the bearing and sometimes the range of the beacon.

Radar horizon - The angle of elevation at which the beam from a radar antenna is intercepted by the earth's horizon.

Radar indicator - Radarscope.

Radar mile - A time unit of 10.75 microseconds duration; the time it takes for the signal emitted by a radar to travel from the radar to a target one mile distant and return to the radar.

Radar range - 1. The distance from a radar to a target as measured by the radar. 2. The maximum distance at which a radar set is effective in detecting targets.

Radar scan - 1. The searching motion of a radar beam in any of various path configurations; the pattern of the motion of a radar beam. 2. Radar scanning.

Radarscope - The cathode-ray tube or oscilloscope in a radar set, which displays the received signal in such a manner as to indicate range, bearing, etc. Sometimes called a radar indicator.

Radarscope display - The visual presentation or picture displayed on a radar screen.

Radar screen - 1. A radar network. 2. A cathode-ray screen in a radar set.

Radial - Motion along a radius.

Radial velocity - In radar, that vector component of the velocity of a moving target that is directed away from or toward the ground station.

Radian - The angle subtended at the center of a circle by an arc equal in length to a radius of the circle. It is equal to $360°/2\pi$ or approximately 57 degrees 17 minutes 44.8 seconds.

Radiant energy - Quanta of energy travelling through space in the form of electromagnetic waves of various lengths.

Radiation - 1. The process by which electromagnetic energy is propagated through free space by virtue of joint undulatory variations in the electric and magnetic fields in space. This concept is to be distinguished from conduction and convection. 2. The process by which energy is propagated through any medium by virtue of the wave motion of that medium, as in the propagation of sound waves through the atmosphere, or ocean waves along the water surface. 3. = radiant energy. 4. = electromagnetic radiation, specifically, high-energy radiation such as gamma rays and X-rays. 5. Corpuscular emissions, such as α or β radiation. 6. = nuclear radiation. 7. = radioactivity.

Radiation dose - The amount of radiation absorbed by a material, system, or tissue in a given amount of time; usually measured in one of the commonly accepted units as roentgen, roentgen-equivalent-man, roentgen-equivalent-physical, etc.

Radiation shield - 1. A device used on certain types of instruments to prevent unwanted radiation from biasing the measurement of a quantity. 2. A device used to protect human beings from the harmful effects of nuclear radiation, cosmic radiation, or the like. 3. = heat shield.

Radiation sickness - A syndrome following intense acute exposure to ionizing radiations. It is characterized by nausea and vomiting a few hours after exposure. Further symptoms include bloody diarrhea, hemorrhage under the skin (and internally), epilation (hair falling), and a decrease in blood-cell level.

Radiator - 1. Any source of radiant energy, especially electromagnetic radiation. 2. A device that dissipates the heat from something, as from water or oil, not necessarily by radiation only.

Radioactive - Exhibiting or pertaining to radioactivity.

Radioactivity - Spontaneous disintegration of atomic nuclei with emission of corpuscular or electromagnetic radiations.

Radio altimeter - A device that measures the altitude of a craft above the terrain by measuring the elapsed time between transmission of radio waves from the craft and the reception of the same waves reflected from the terrain. Also called radar altimeter.

Radio astronomy - The study of celestial objects through observation of radiofrequency waves emitted or reflected by these objects.

Radiobiology - The study of the effects produced on living organisms by radiation.

Radio direction finder - A radio-receiving set, together with its associated equipment, used to determine the direction from which a radio signal is transmitted.

Radio energy - Electromagnetic radiation of greater wavelength (lower frequency) than infrared radiation, that is, of wavelength greater than about 1000 microns (0.01 centimeter). The high-frequency end of the radio-energy spectrum is known as microwave radiation.

Radiofrequency - 1. A frequency at which coherent electromagnetic radiation of energy is useful for communication purposes. 2. Specifically, the frequency of a given radio carrier wave.

Radiosonde - An instrument, usually balloon-borne, for the simultaneous measurement and transmission of meteorological data while moving vertically through the atmosphere.

Radius vector - A straight line connecting a fixed reference point or center with a second point, which may be moving; specifically, in astronomy, the straight line connecting the center of a celestial body with the center of a body which revolves around it, as the radius vector of the moon.

Radome - (From radar dome. Pronounced raydome.) A dielectric housing for an antenna.

Ram air - Air entering an airscoop or air inlet as a result of the high-speed forward movement of a vehicle.

Ramjet engine - A type of jet engine with no mechanical compressor consisting of a specially shaped tube or duct open at both ends, the air necessary for combustion being shoved into the duct and compressed by the forward motion of the engine, where the air passes through a diffuser and is mixed with fuel and burned, the exhaust gases issuing in a jet from the rear opening. The ramjet engine cannot operate under static conditions. Often called a ramjet. Also called Lorin tube.

Random - Eluding precise prediction, completely irregular. Compare stochastic.

Random access - Equal access time to all memory locations, independent of the location of the previous memory reference.

Random error - Errors that are not systematic, are not erratic, and are not mistakes.

Random noise - An oscillation whose instantaneous amplitudes occur, as a function of time, according to a normal (Gaussian curve). Also called Gaussian noise, random Gaussian noise.

Random number - An expression formed by a set of digits selected from a sequence of digits in which each successive digit is equally likely to be any of the digits.

Random sample - A sample taken at random from a population.

Range - 1. The difference between the maximum and minimum of a given set of numbers; in a periodic process it is twice the amplitude, i.e., the wave height. 2. The distance between two objects, usually an observation point and an object under observation. 3. A maximum distance attributable to some process, as in visual range or the range of a rocket. 4. An area in and over which rockets are fired for testing, as Atlantic Missile Range. 5. = radar range.

Range error - The error in radar range measurement due to the propagation of radio energy through a nonhomogeneous atmosphere. This error is due to the fact that the velocity of radio-wave propagation varies with the index of refraction and that ray travel is not in straight lines through actual atmospheres. The resulting range error is generally insignificant. Compare azimuth error.

Range gating - The use of circuits in radar to suppress signals from all targets falling outside selected range limits.

Range-height-indicator scope - A type of radar indicator (radar-scope); an intensity-modulated indicator on which echoes are displayed in coordinates of slant range and elevation angle, simulating, thereby, a vertical cross section of the atmosphere along some azimuth from the radar.

Range marker - The index marks displayed on radar indicators to establish the scale or facilitate determination of the distance of a target from the radar. On the plan-position-indicator scope, for example, range markers take the form of concentric circles with the position of the radar at the center. Also called distance marker.

Range rate - The rate at which the distance from the measuring equipment to the target or signal source being tracked is changing with respect to time.

Range ring - A circle on a plan-position-indicator, particularly one with an adjustable diameter, to indicate distance from the antenna.

Rankine temperature scale - A temperature scale with the degree-interval of the Fahrenheit temperature scale and the zero point at absolute zero. The ice point is thus 401.69 degrees Rankine and the boiling point of water is 671.69 degrees Rankine.

Raster - The pattern followed by the electron-beam exploring element scanning the screen of a television transmitter or receiver.

Rate gyro - A single-degree-of-freedom gyro having primarily elastic restraint of its spin axis about the output axis. In this gyro an output signal is produced by gimbal angular displacement, relative to the base, which is proportional to the angular rate of the base about the input axis.

Rate of decay - 1. Of a sound, the time rate at which the sound pressure level (or other stated characteristic) decreases at a given point and at a given time. A commonly used unit is the decibel per second. 2. Of a radioactive nuclide, the number of nuclei of that nuclide changing (or disintegrating) per unit time. It is usually expressed as the instantaneous rate of decay by $-dN/dt$ where N is the total number of the state nuclides present at the given time t.

Ray - 1. An elemental path of radiated energy; or the energy following this path. It is perpendicular to the phase fronts of the radiation. 2. One of a series of lines diverging from a common point, as radii from the center of a circle. 3. A long, narrow, light-colored streak on the lunar surface originating from a crater. Rays range in length to over 150 kilometers and usually several radiate from the same crater, like spokes of a wheel.

Reaction engine - An engine that develops thrust by its reaction to a substance ejected from it; specifically, such an engine that ejects a jet or stream of gases created by the burning of fuel within the engine.

Reaction motor - Reaction engine.

Reaction time - In human engineering, the interval between an input signal (physiological) or a stimulus (psycho-physiological) and the response elicited by the signal. (See Vol. I, Section 6).

Read in - In computer operations, to introduce information into storage.

Readout - 1. The action of a radio transmitter transmitting data either instantaneously with the acquisition of the data or by playing a magnetic tape upon which the data have been recorded. 2. The data transmitted by the action described in sense 1. 3. In computer operations, to extract information from storage.

Readout indicators - Any type of indicating instrument from which meaningful information and data can be directly obtained and used.

Real time - Time in which reporting or events or recording of events is simultaneous with the events.

Real-time data - Data presented in usable form at essentially the same time the event occurs.

Rearward acceleration - See physiological acceleration.

Rebreather - An oxygen system with a circuit closed to the atmosphere, to which oxygen is added to meet the user's needs; carbon dioxide and water vapor are removed from the expired gas.

Receiver - 1. The initial component or sensing element of a measuring system. For example, the receiver of a thermo-electric thermometer is the measuring thermocouple. 2. An instrument used to detect the presence of and to determine the information carried by electromagnetic radiation. A receiver includes circuits designed to detect amplify, rectify, and shape the incoming radio-frequency signals received at the antenna in such a manner that the information-containing component of this received energy can be delivered to the desired indicating or recording equipment.

Receptor - A sensory nerve ending or organ in a living organism that is sensitive to physical or chemical stimuli.

Reciprocating engine - An engine, especially an internal-combustion engine, in which a piston or pistons moving back and forth work upon a crankshaft or other device to create rotational movement.

Recognition - The psychological process in which an observer so interprets the visual stimuli he receives from a distant object that he forms a correct conclusion as to the exact nature of that object.

Recoverable - Of a rocket vehicle or one of its parts, so designed or equipped as to be located after flight and recovered with or without damage.

Recovery capsule - A capsule designed to be recovered after reentry vehicle.

Recovery gear - The devices and equipment used to mark and locate a nose cone or other part of a rocket vehicle after impact.

Recovery package - A package attached to a reentry or other body designed for recovery, containing devices intended to locate the body after impact.

Rectifier - A static device having an asymmetrical conduction characteristic which is used to convert attending current into direct current.

Recurrent image - A visual, auditory, or other image which persistently returns.

Recurrent vision - A succession of positive and negative after-images or after-sensations.

Red-green blindness - A common form of partial color blindness, or dichromatism, in which red and green stimuli are confused because they are seen as various saturations and brightnesses of yellow, blue, or gray. Cf. Protanopia and deuteranopia.

Redout - The condition occurring under negative g in which objects appear to have a red coloration due to uncertain causes, possible venous congestion of engorged eyelids. Compare blackout.

Redundancy - 1. In information theory: of a source, the amount by which the logarithm of the number of symbols available at the source exceeds the average information content per symbol of the source. 2. The existence of more than one means of accomplishing a given task, where all means must fail before there is an overall failure to the system; e.g., that design which makes additional electrical paths available to a function.

Reentry - The event occurring when a spacecraft or other object comes back into the sensible atmosphere after being rocketed to higher altitudes; the action involved in this event.

Reentry vehicle - Any payload carrying vehicle designed to leave the sensible atmosphere and then return through it to earth.

Reflectance - The ratio of the radiant flux reflected by a body to that incident upon it. Also called reflection factor.

Reflection - The process whereby a surface of discontinuity turns back a portion of the incident radiation into the medium through which the radiation approached.

Reflectivity - A measure of the fraction of radiation reflected by a given surface; defined as the ratio of the radiant energy reflected to the total that is incident upon that surface.

Refraction - A change in the angle of propagation of a wave in passing from one medium to another of different density or elasticity.

Refractive index - A numerical expression indicating the degree to which the path of light or radiant energy is bent in passing from one transparent medium into another.

Refactory - A material, usually ceramic, that resists the action of heat, does not fuse at high temperatures, and is very difficult to break down.

Regenerative cooling - The cooling of a part of an engine by the fuel or propellant being delivered to the combustion chamber; specifically, the cooling of a rocket-engine combustion chamber or nozzle by circulating the fuel or oxidizer, or both, around the part to be cooled.

Register - A device capable of retaining information, often that contained in a small subset (e.g., one word) of the aggregate information in a digital computer. See storage.

Regression - The statistical counterpart or analog of the functional expression, in ordinary mathematics, of one variable in terms of others. Thus, regression curve, regression coefficient.

Relative - Of angle measurements in navigation, measured from the heading of a craft, as relative bearing.

Relative coordinate system - Any coordinate system which is moving with respect to an inertial coordinate system.

Relative humidity - The (dimensionless) ratio of the actual vapor pressure of the air to the saturation vapor pressure. The corresponding ratios of specific humidity or of mixing ratio give approximations of sufficient accuracy for many purposes in meteorology. The relative humidity is usually expressed in percent. Also called humidity. See dewpoint. The ratio of mixing ratio to saturation mixing ratio is preferred as a definition of relative humidity by the International Meteorological Organization.

Relative motion - Motion of one object or body measured relative to another. Usually called apparent motion when applied to the change of position of a celestial body as observed from the earth. See also apparent motion.

Reliability - The probability that system, subsystem, component, or part will perform its intended functions under defined conditions at a designated time and for a specified operating period.

Rem - Abbreviation for roentgen-equivalent-man.

Remote control - Control of an operation from a distance, especially by means of electricity or electronics; a controlling switch, lever, or other device used in this kind of control; as in remote-control armament, remote-control switch, etc.

Remote indicating - Of an instrument, displaying indications at a point remote from its sensing element, often by electrical or electronic means.

Rendezvous - 1. The event of two or more objects meeting with zero relative velocity at a preconceived time and place. 2. The point in space at which such an event takes place, or is to take place.

Rep - Abbreviation for roentgen-equivalent-physical.

Repair - The process of returning an item to a specified condition including Preparation, Fault Location, Item Procurement, Fault Correction, Adjustment and Calibration, and Final Test.

Reparability - The probability that, when the actual repair begins, the system will be repaired in a given period of time with a given manpower expenditure.

Reset - 1. To restore a storage device to a prescribed state. 2. To place a binary cell in the initial or zero state. See clear.

Resistance - 1. In electricity, the factor by which the square of the instantaneous conduction current must be multiplied to obtain the power lost by heat dissipation or other permanent radiation of energy away from the electrical current. 2. In mechanics, the opposition by frictional effects to forces tending to produce motion.

Resolution - 1. The ability of a film, a lens, a combination of both, or a vidicon system to render barely distinguishable a standard pattern of black and white lines. 2. In radar, the minimum angular separation at the antenna at which two targets can be distinguished (a function of beamwidth); or the minimum range at which two targets at the same azimuth can be separated (equal to one-half the pulse length). 3. Of a gyro, a measure of response to small changes in input; the maximum value of the minimum input change that will cause a detectable change in the output for inputs greater than the threshold, expressed as a percent of one-half the input range.

Resonance - The phenomenon of amplification of a free wave or oscillation of a system by a forced wave or oscillation of exactly equal period. The forced wave may arise from an impressed force upon the system or from a boundary condition. The growth of the resonant amplitude is characteristically linear in time.

Resonance frequency - A frequency at which resonance exists. Also called resonant frequency.

Resonator - In radio and radar applications, a circuit which will resonate at a given frequency, or over a range of frequencies, when properly excited.

Respiration - The interchange of gases of living organisms and the gases of the medium in which they live. Respiration applies to the interchange by any channel as pulmonary respiration, cutaneous respiration, etc.

Respiratory rate (frequency) - Indicates the number of complete respiratory cycles that take place in 1 minute. At rest, a normal adult will have a respiratory rate somewhere between 10 and 20 "breaths" per minute. The rate normally increases during work.

Responder - 1. In general, an instrument that indicates reception of an electric or electromagnetic signal. 2. = transponder.

Response - The muscular contraction, glandular secretion, or any other activity of an organism which results from stimulation.

Resultant - The sum of two or more vectors.

Reticle - A system of lines, wires, etc., placed in the focal plane of an optical instrument to serve as a reference. Also called reticule.

Reticule - Reticle.

Retina - Inner coating of the eyeball, which receives the image formed by refraction of light rays at the cornea and lens; it is made up of rods and cones, the receptor cells for vision.

Retinal disparity - The difference which exists between the images formed in the right and left eyes when a solid object is viewed binocularly.

Retinal field - The extended mosaic of the rod and cone receptor elements of the retina, which forms something of an anatomical correlate of the stimulus field.

Retinal illuminance - The illuminance of the retina, the usual units being the troland and the lux.

Retinal rivalry - Alternation of sensations first from one eye and then from the other, when the two eyes are simultaneously stimulated by different colors or figures. Also called binocular rivalry. Contrast with binocular fusion, in which the two impressions are fused into a single impression.

Retrofire - To ignite a retrorocket.

Retrograde motion - 1. Motion in an orbit opposite to the usual orbital direction of celestial bodies within a given system. Specifically, of a satellite, motion in a direction opposite to the direction of rotation of the primary. 2. The apparent motion of a planet westward among the stars. Also called retrogression.

Retrorocket - A rocket fitted on or in a spacecraft, satellite, or the like to produce thrust opposed to forward motion.

Retrothrust - Thrust used for a braking maneuver; reverse thrust.

Reverberation - 1. The persistence of sound in an enclosed space, as a result of multiple reflections after the sound source has stopped. 2. The sound that persists in an enclosed space, as a result of repeated reflection or scattering, after the source of the sound has stopped.

Revolution - 1. Motion of a celestial body in its orbit; circular motion about an axis usually external to the body. 2. One complete cycle of the movement of a celestial body in its orbit, or of a body about an external axis, as a revolution of the earth about the sun.

Revolve - To move in a path about an axis, usually external to the body accomplishing the motion, as in the planets revolve about the sun. Hence revolution. See rotate.

Rhodopsin - A substance found in the rods of the dark-adapted eye, which bleaches rapidly on exposure to light, and is believed to be the substance underlying scotopic or twilight vision.

Rho-theta system - 1. Any electronic navigation system in which position is defined in terms of distance, or radius ρ and bearing θ with respect to a transmitting station. Also called an R-theta system. 2. Specifically, a polar-coordinate navigation system providing data with sufficient accuracy to permit the use of a computer which will provide arbitrary course lines anywhere within the coverage area of the system.

Ribbon parachute - A type of parachute having a canopy consisting of an arrangement of closely spaced tapes. This parachute has high porosity with attendant stability and slight opening shock.

Right ascension - Angular distance east of the vernal equinox; the arc of the celestial equator, or the angle at the celestial pole, between the hour circle of the vernal equinox and the hour circle of a point on the celestial sphere, measured eastward from the hour circle of the vernal equinox through 24 hours.

Rocket engine - A reaction engine that contains within itself, or carries along with itself, all the substances necessary for its operation or for the consumption or combustion of its fuel, not requiring intake of any outside substance and hence capable of operation in outer space. Also called rocket motor.

Rod - A type of photoreceptive cell in the retina of the mammalian eye. Rods are involved in detection of movement and scotopic vision (night vision).

Rod threshold - The dimmest illumination in which the rods of the retina can function.

Roentgen - A unit of radiation, that quantity of X-rays or gamma rays which will produce, as a consequence of ionization, 1 electrostatic unit of electricity in 1 cubic centimeter of dry air measured at 0° C and standard atmospheric pressure.

Roentgen-equivalent-man - A unit of radiation which when absorbed by a human being, produces the same effect as the absorption of 1 roentgen of high-voltage X-rays. See rem.

Roentgen-equivalent-physical - A unit measuring a purely physical effect of radiation by the number of ion pairs produced per unit volume of target material per time unit. One rep is equivalent to the absorption of 93 ergs per gram of tissue. See rep.

Roll - 1. The act of rolling; rotational or oscillatory movement of an aircraft or similar body about a longitudinal axis through the body--called roll for any degree of such rotation. 2. The amount of this movement, i.e., the angle of roll.

Roll axis - A longtudinal axis through an aircraft, rocket, or similar body, about which the body rolls.

Rolling moment - A moment that tends to rotate an aircraft, a rocket, etc., about a longitudinal axis. This moment is considered positive when it tends to depress the starboard side of the body.

Root-mean-square error - In statistics, the square root of the arithmetic mean of the squares of the deviations of the various items from the arithmetic mean of the whole. Also termed standard deviation.

Rotate - To turn about an internal axis. Said especially of celestial bodies. Hence rotation. Compare revolve.

Rotational speed - Revolutions per unit time.

Rubber suit - A partial or complete diving suit designed primarily for the purpose of insulation (preservation) of body heat. The suits are classified as "wet" and "dry".

Saccadic movements - Sudden movement of the eyes from one fixation point to another.

Sagittal - Pertaining to the median plane of the human body or any plane parallel thereto.

Sample - In statistics, a group of observations selected from a statistical population by a set procedure. See random sample.

Sandwich construction - A type of construction in which two sheets, sides, or plates are separated by a core of stiffening material, generally lightweight.

Satellite - 1. An attendant body that revolves about another body, the primary; especially in the solar system, a secondary body, or moon, that revolves about a planet. 2. A manmade object that revolves about a spatial body, such as Explorer I orbiting about the earth. 3. Such a body intended and designed for orbiting, as distinguished from a companion body that may incidentally also orbit, as in "the observer actually saw the orbiting rocket rather than the satellite." 4. An object not yet placed in orbit, but designed or expected to be launched into an orbit.

Saturation - Extent to which a chromatic color differs from a gray of the same brightness, measured on an arbitrary scale from 0% to 100% (where 0% is gray).

Saturation diving - A diving technique in which the diver stays at depths for a period long enough to permit his body cells to become totally saturated with inert gas, at this point decompression requirements do not change regardless of how long the diver stays at that depth.

Saturation vapor pressure - The vapor pressure of a system, at a given temperature, wherein the vapor of a substance is in equilibrium with a plane surface of the pure liquid of solid phase of that substance; that is, the vapor pressure of a system that has attained saturation but not supersaturation.

Scalar - Any physical quantity whose field can be described by a single numerical value at each point in space.

Scalar product - A scalar equal to the product of the magnitudes of any two vectors and the cosine of the angular θ between their positive directions. Also called dot product, direct product, inner product. See vector product.

Scan converter - A double-ended cathode-ray tube for converting from one mode of display scan to another (e.g., polar to raster).

Scanning - In radar, the motion of the radar antenna assembly when searching for targets.

Scanning sonar - Echo-ranging system in which the ping is transmitted simultaneously throughout the entire angle to be searched, and a rapidly rotating narrow beam scans for the returning echoes.

Scatter - 1. = scattering. 2. The relative dispersion of points on a graph, especially with respect to a mean value, or any curve used to represent the points. See dispersion. 3. To accomplish scattering.

Scintillation - 1. Generic term for rapid variations in apparent position, brightness, or color of a distant luminous object viewed through the atmosphere. 2. A flash of light produced in a phosphor by an ionizing event. 3. On a radar display, a rapid apparent displacement of the target from its mean position. Also called target glint or wander. This includes but is not limited to shift of effective reflection point on the target.

Scope - (Short for cathode ray scope) generally applied to radar and sonar displays. See Figure 5 for methods for displaying parameters. Sometimes called radarscope.

Scotoma - A blind or partially blind area in the visual field.

Scotopic adaptation - Like dark adaptation, but more explicit reference to the part played by the rod-system of the retina.

Scotopic vision - Vision which occurs in faint light, or after dark adaptation. Sometimes called twilight or night vision. Hues and saturations cannot be distinguished. Compare photopic vision.

Sealed cabin - The occupied space of an aircraft or spacecraft characterized by walls which do not allow any gaseous exchange between the inner atmosphere and its surrounding atmosphere and containing its own mechanisms for maintenance of the inside atmosphere.

Search radar - A radar designed for the approximate location of (usually airborne) objects. Search radar beams are usually wide, wider in the vertical than in the horizontal, making it possible to scan large volumes of space quickly.

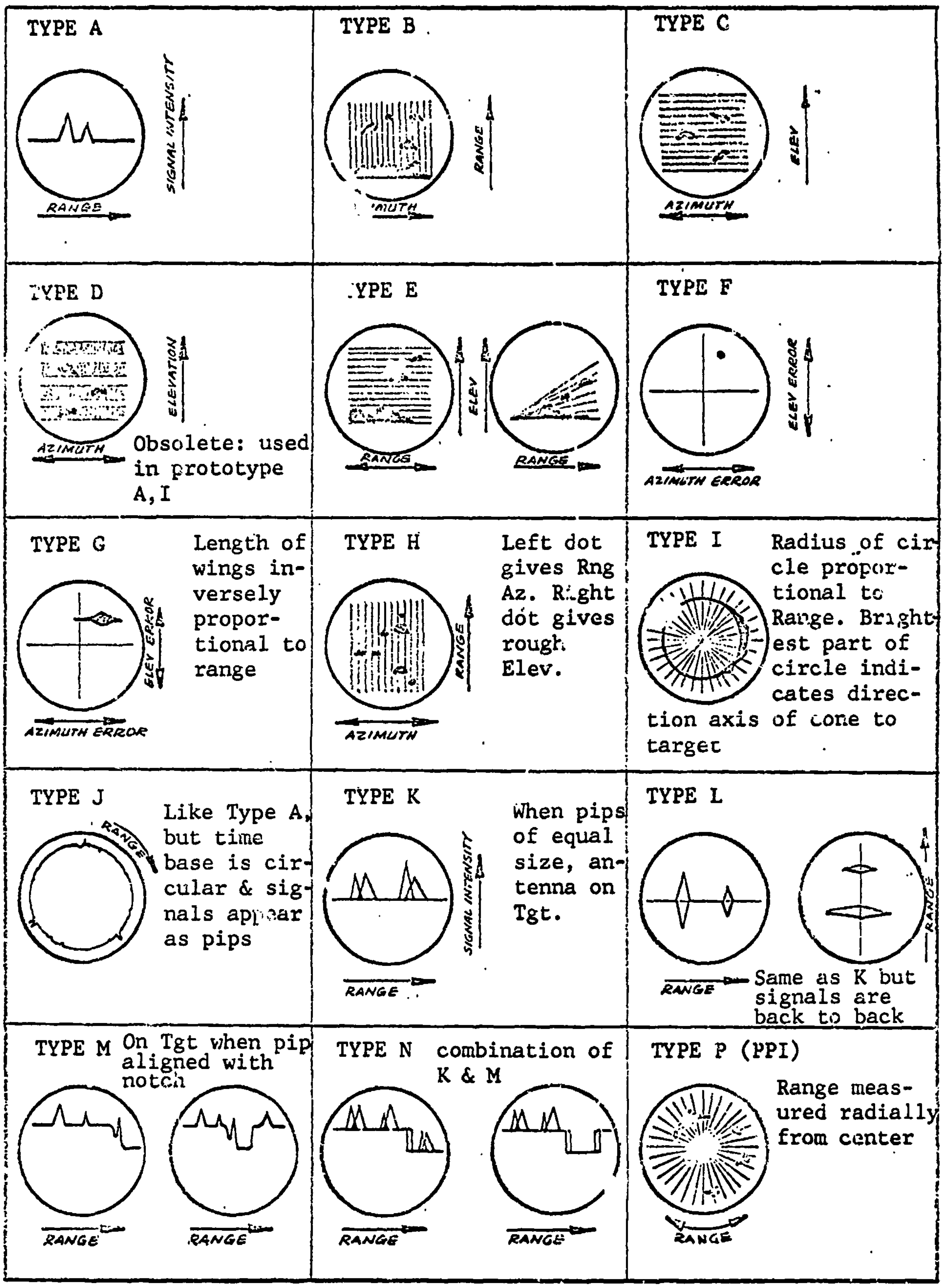


Figure 5 - Scope Types

Sea state - The numerical or written description of ocean surface roughness. For more precise usage sea state may be defined as the average height of the highest one-third of the waves observed in a wave train, referred to a numerical code which covers an increasing range of such heights as indicated by the table below:

Code	Wave Height (feet)
0	0
1	0 - 1/3
2	1/3 - 1 2/3
3	1 2/3 - 4
4	4 - 8
5	8 - 13
6	13 - 20
7	20 - 30
8	30 - 45
9	over 45

Seat-to-head acceleration - See physiological acceleration.

Secchi disk - A white disk which, when submerged to varying depths, aids in determining the color and depth of light penetration in the sea.

Secondary - Refers to human operator functions, displays, controls, etc., as opposed to primary.

Selective absorption - Absorption which varies with the wavelength of radiation incident upon the absorbing substance.

Selective scattering - Scattering which varies with the wavelength of radiation incident upon the scattering particles.

Selectivity - The capability to differentiate.

Self-adaptive control system - A particular type of stability augmentation system which changes the response of a given control input by constantly sampling response and adjusting its gain, rather than having a fixed or selective gain system.

Semicircular canals - Structures of the inner ear, the primary function of which is to register movement of the body in space. They respond to change in the rate of movement.

Semiconductor - An electronic conductor, with resistivity in the range between metals and insulators, in which the electrical charge carrier concentration increases with increasing temperature over some temperature range. Certain semiconductors possess two types of carriers, namely, negative electrons and positive holes.

Sensation - Subjective response or any exp... aroused by stimulation of a sense organ.

Sensation level - The level of psycho-physiologic stimulation above the threshold.

Sensibility - In measurements, the smallest change that is reliably detectable.

Sensible atmosphere - That part of the atmosphere that offers resistance to a body passing through it.

Sensible temperature - The temperature at which average indoor air of moderate humidity would induce, in a lightly clothed person, the same sensation of comfort as that induced by the actual environment. Compare effective temperature.

Sensitivity - 1. The ability of electronic equipment to amplify a signal, measured by the minimum strength of signal input capable of causing a desired value of output. The lower the input signal for a given output, the higher the sensitivity. 2. In measurements, the derivative representing the change in instrument indication produced by a change in the variable being measured. 3. (Physiological) degree to which human receptors accept or respond to energy inputs.

Sensor - 1. The component of an instrument that converts an input signal into a quantity which is measured by another part of the instrument. Also called sensing element. 2. The nerve endings or sense organs which receive information from the environment, from the organism, or from both.

Sequential control - Control by completion of a series of one or more events in a pre-specified order.

Serviceability - Equipment design, configuration, installation, and operation that minimize maintenance, inspection, and servicing. Serviceability analyses are performed to determine what must be accomplished to achieve this objective.

Servo system - Control system with feedback. The behavior of a servo is governed, not by the input signal alone, but by the difference between the input and some function of the output.

Servicing - The performance of any act (other than preventive or corrective maintenance) required to keep an item of equipment in operating condition, such as lubricating, fueling, oiling, cleaning, etc., but does not include periodic replacement of parts or any corrective maintenance tasks.

Set - 1. (Material set) the act of becoming rigid or assuming a change in form which becomes essentially permanent. 2. (Mental set) inclination to think or act in a certain way. 3. (Mathematical) a number of things of the same kind that belong or are used together. 4. (Hardware) an apparatus of electronic components assembled so as to function as a unit.

Shade - Any color darker, i.e., of lower lightness, than median gray.

Shadow zone - Region in which refraction effects cause exclusion of echo-ranging signals (sound).

Shallow-water blackout - A carbon dioxide accumulation or excess in a breathing system which causes the diver to lose consciousness without the usual warning of dyspnea or other symptoms such as headache, nausea, dizziness or weakness.

Shear strength - In materials, the stress required to produce fracture in the plane of cross section, the conditions of loading being such that the directions of force and of resistance are parallel and opposite although their paths are offset a specified minimum amount.

Shelf life - The length of time an item can be stored under specified conditions and still meet specifications.

Shoran (from short-range navigation) - A precision electronic position fixing system using a pulse transmitter and receiver and two transponder beacons at fixed points.

Sideband - 1. Either of the two frequency bands on both sides of the carrier frequency within which fall frequencies of the wave produced by the process of modulation. 2. The wave components lying within such a band.

Sidereal - Of or pertaining to the stars.

Sigma - Standard deviation.

Signal-to-noise ratio - A ratio which measures the comprehensibility of a data source or transmission link, usually expressed as the root-mean-square signal amplitude divided by the root-mean-square noise amplitude.

Simple harmonic motion - A motion such that the displacement is a sinusoidal function of time.

Simulation - A set of test conditions designed to duplicate field operating and usage environments.

Simulator - Any machine or apparatus that simulates a desired condition or set of conditions, such as a flight simulator.

Sine wave - A wave which can be expressed as the sine of a linear function of time, or space, or both.

Single-degree-of-freedom system - A mechanical system for which only one coordinate is required to define completely the configuration of the system at any instant. See degree of freedom.

Single-sideband transmission - That method of operation in which one sideband is transmitted and the other sideband is suppressed. The carrier wave may be either transmitted or suppressed.

Sink - 1. In the mathematical representation of fluid flow, a hypothetical point or place at which the fluid is absorbed. 2. A heat sink.

Sinus - A hollow or cavity; a recess or pocket. Specifically, sinuses: air cavities lined by mucous membrane which communicate with the nasal cavity; the ethmoidal, frontal, sphenoidal, and maxillary sinuses.

Sinusoidal - Having the form of a sine wave.

Skew - The conditions which combine to cause some degree of nonsynchronism of supposedly parallel bits when bit-coded characters are read from magnetic tape.

Skewness - A statistical measure of the asymmetry in a distribution.

Skin diving - Diving without the use of scuba or artificial breathing apparatus.

Sky wave - In radio, radio energy that is received after having been reflected by the ionosphere.

Slant range - The line-of-sight range of a radar or radio. See range.

Slave station - In a hyperbolic navigation system, a station whose transmissions are controlled by a master station. Often shortened to slave. See hyperbolic navigation.

Slaving - Of a gyro, the use of a torquer to maintain the orientation of the spin axis relative to an external reference such as a pendulum or magnetic compass.

Slew - To change the position of an antenna or range gear assembly by injecting a synthetic error signal into the positioning servo-amplifier.

Slug - A unit of mass; the mass of a free body which if acted upon by a force of 1 pound would experience an acceleration of 1 foot per square second; thus approximately 32.17 pounds.

Sniffer - Gear designed to detect ionization traces in the atmosphere left by a snorkeling submarine.

Snorkel - A tube used by skin divers which permits breathing without raising the nose or mouth out of the water when swimming face down on the surface of the water. One end of the tube is held in the mouth of the swimmer while the other end protrudes above the surface.

Snow-blindness - A temporary abnormality of the color sense, in which all objects are tinged with red. Caused by long-continued exposure to very bright light, as in Arctic exploration, on glaciers, in telescopic observation of the sun, watching welding operations, etc.

Sofar - A system of navigation providing hyperbolic lines of position determined by shore listening stations which receive sound signals produced by depth charges dropped at sea and exploding in a sound channel which is at a considerable depth in most areas.

Soft landing - The act of landing on the surface of a planet without damage to any portion of the vehicle or payload except possibly the landing gear.

Solar cycle - The periodic increase and decrease in the number of sunspots. The cycle has a period of about 11 years.

Solar day - 1. The duration of one rotation of the earth on its axis, with respect to the sun. This may be either a mean solar day, or an apparent solar day, as the reference is the mean or apparent sun, respectively. 2. The duration of one rotation of the sun on its axis.

Solar time - Time based upon the rotation of the earth relative to the sun.

Solid angle - A portion of the whole of space about a given point, bounded by a conical surface with its vertex at that point and measured by the area cut by the bounding surface from the surface of a sphere of unit radius centered at that point. See steradian.

Solid propellant - Specifically, a rocket propellant in solid form, usually containing both fuel and oxidizer combined or mixed, and formed into a monolithic (not powered or granulated) grain.

Solid-state devices - Devices which utilize the electric, magnetic, and photic properties of solid materials, e.g., binary magnetic cores, transistors, etc.

Solstice - 1. One of the two points of the ecliptic farthest from the celestial equator; one of the two points on the celestial sphere occupied by the sun at maximum declination. 2. That instant at which the sun reaches one of the solstices, about June 21 (summer solstice) or December 22 (winter solstice).

Sonar - An acronym derived from the expression "SOund NAvigation and Ranging". The method or equipment for determining, by underwater sound, the presence, location, or nature of objects in the sea. Active Sonar (echo-ranging sonar) is the method or equipment by which information concerning a distant object is obtained by evaluation of sound generated by the equipment. Passive Sonar (listening sonar) is the method or equipment by which information concerning a distant object is obtained by evaluation of sound generated by the object itself.

Sone - A unit of loudness. A simple tone of frequency 1000 cycles per second, 40 decibels above a listener's threshold, produces a loudness of 1 sone.

Sonic - 1. In aerodynamics, of or pertaining to the speed of sound; that which moves at acoustic velocity as in sonic flow; designed to operate or perform at the speed of sound, as in sonic leading edge. 2. Of or pertaining to sound, as in sonic amplifier.

Sonic barrier - A popular term for the large increase in drag that acts upon an aircraft approaching acoustic velocity; the point at which the speed of sound is attained and existing subsonic and supersonic flow theories are rather indefinite. Also called sound barrier.

Sonic boom - A noise caused by a shock wave that emanates from an aircraft or other object traveling at or above sonic velocity.

Sonic speed - Acoustic velocity; by extension, the speed of a body traveling at a Mach number of 1.

Sound barrier - Sonic barrier.

Sound energy - The sound energy of a given part of a medium is the total energy in this part of the medium minus the energy which would exist in the same part of the medium with no sound waves present.

Sound-energy flux - The sound-energy flux is the average rate of flow of sound energy for one period through any specified area.

Sound intensity - In a specified direction at a point, the average rate of sound energy transmitted in the specified direction through a unit area normal to this direction at the point considered. Also called sound energy flux density, sound power density.

Sound level - Specifically, a weighted sound pressure level, obtained by the use of metering characteristics and the weightings A, B, or C specified in American Standard Publication Z24.3-1944: Sound Level Meters for Measurement of Noise and Other Sounds. The weighting employed must always be stated. The reference pressure is 0.0002 microbar or dynes per cm^2.

Sound pressure - At a point, the total instantaneous pressure at that point in the presence of a sound wave minus the static pressure at that point.

Sound pressure level - In decibels, 20 times the logarithm to the base 10 of the ratio of the sound pressure to the reference pressure. The reference pressure must be explicitly stated.

Space suit - A pressure suit for wear in space or at very low ambient pressures within the atmosphere, designed to permit the wearer to leave the protection of a pressurized cabin.

Span - 1. The dimension of a craft measured between lateral extremities; the measure of this dimension. 2. Specifically, the dimension of an airfoil from tip to tip measured in a straight line. 3. Anthropometric description of distance between human body elements, e.g., arm span, etc.

Sparkle, glitter - Changes of limited extent in color, especially in brightness, and involving movement.

Special weapons trainers - Training devices for special weapons type munitions for the training of personnel on the munition system, test, and preflight check, ground handling operations and in-flight monitoring procedures.

Specific impulse - A performance parameter of a rocket propellant, expressed in seconds, equal to the thrust F in pounds divided by the weight flow rate $\dot{w}$ in pounds per second: $I_{sp} = F/\dot{w}$.

Spectral - 1. Of or pertaining to a spectrum. 2. Referring to thermal radiation properties, for ratios such as emittance, reflectance, and transmittance, at a specified wavelength; for powers, such as emissive power, within a narrow wavelength band centered on a specified wavelength.

Spectral line - A bright, or dark, line found in the spectrum of some radiant source. Bright lines indicate emission, dark lines indicate absorption.

Spectrum - 1. In physics, any series of energies arranged according to wavelength (or frequency). 2. The series of images produced when a beam of radiant energy is subject to dispersion. 3. Short for electromagnetic spectrum or for any part of it used for a specific purpose, as the radio spectrum (10 kilocycles to 300,000 megacycles). 4. In mathematics, = function. 5. In acoustics, the distribution of effective sound pressures or intensities measured as a function of frequency in specified frequency bands.

Spectrum colors - The series of saturated colors normally evoked by photopic stimulation of the retina with radiant energy of continuously differing single wavelengths through the visible range. Purple is not a spectrum color.

Spectrum line - Any one of the narrow lines, each representing light or a definite wavelength, which are observed in the solar and other spectra, certain groups of lines being characteristic of specific chemical elements. These lines are characteristic of substances in the gaseous state, and appear bright when due to emission from these, or dark when due to absorption by them.

Specular reflection - Reflection in which the reflected radiation is not diffused; reflection as from a mirror. Also called regular reflection, simple reflection.

Speed of light - The speed of propagation of electromagnetic radiation through a perfect vacuum; a universal dimensional constant equal to 299,792.5 $\pm$ 0.4 kilometers per second. Also called velocity of light.

Spherical coordinates - A system of coordinates defining a point on a sphere or spheriod by its angular distances from a primary great circle and from a reference secondary great circle, as latitude and longitude.

Spin axis - The axis of rotation of the rotor of a gyro.

Spin stabilization - Directional stability of a spacecraft obtained by the action of gyroscopic forces which result from spinning the body about its axis of symmetry.

Spin table - A flat round platform on which human and animal subjects can be placed in various positions and rapidly rotated, much as on a phonograph record, in order to simulate and study the effects of prolonged tumbling at high rates.

Spoiler - A plate, series of plates, comb, tube, bar, or other device that projects into the airstream about a body to break up or spoil the smoothness of the flow, especially such a device that projects from the upper surface of an airfoil, giving an increased drag and a decreased lift.

Square wave - 1. An oscillation, the amplitude of which shows periodic discontinuities between two values, remaining constant between jumps. 2. Specifically, in radar a pulse initiated by a rapid rise to peak power, maintained at a constant peak power over the finite pulse length, and terminated by rapid decrease from peak power.

Squeeze - Squeeze in diving is due to the effect of increasing external pressure upon the ears and sinuses, the face plate or the swim suit, uncompensated by an equal increase in pressure from within.

Squib - 1. Any of various small explosive devices. 2. An explosive device used in the ignition of a rocket. Usually called an igniter.

Stability - 1. The property of a body, as an aircraft or rocket, to maintain its attitude or to resist displacement, and, if displaced, to develop forces and moments tending to restore the original condition. 2. Of a fuel, the capability of a fuel to retain its characteristics in an adverse environment, e.g., extreme temperature.

Stability augmentation system - An auxiliary system to the basic manual vehicle control system whereby response of the control surfaces to inputs by the pilot can be adjusted to give a preselected vehicle response by selection of certain fixed gains in a standard feedback loop on control-surface output.

Stable platforms - A gyroscopic device so designed as to maintain a plane of reference in space regardless of the movement of the vehicle carrying the stable platform.

Stadimeter - An instrument for determining the distance to an object of known dimension by measuring the angle subtended at the observer by the object. The instrument is graduated directly in distance.

Stage - 1. A self-propelled separable element of a rocket vehicle. 2. A strip or process through which a fluid passes, especially in compression or expansion. 3. A set of stator blades and a set of rotor blades in an axial-flow compressor or in a turbine; an impeller wheel in a radial-flow compressor.

Staging - The process or operation during the flight of a rocket vehicle whereby a full stage or half stage is disengaged from the remaining body and made free to decelerate or be propelled along its own flightpath.

Stagnation point - A point in a field of flow about a body where the fluid particles have zero velocity with respect to the body.

Standard air - Air having a density of 0.07651 pounds per cubic foot at 59.6 degrees F.

Standard artillery atmosphere - A set of values describing atmospheric conditions on which ballistic computations are based: namely, no wind, a surface temperature of 15° C, a surface pressure of 1000 millibars, a surface relative humidity of 78 percent, and a lapse rate which yields a prescribed density-altitude relation.

Standard atmosphere - A hypothetical vertical distribution of atmospheric temperature, pressure, and density which, by international agreement, is taken to be representative of the atmosphere for purposes of pressure altimeter calibrations, aircraft performance calculation, aircraft and rocket design, ballistic tables, etc.

Standard deviation - Statistical term used to indicate the variability of scores or measurements.

Standard observer - An hypothetical observer with a visual response mechanism possessing the colorimetric properties defined by the 1931 ICI tables of the distribution coefficients, $\bar{x}$, $\bar{y}$, $\bar{z}$, and the trichromatic coefficients, x, y, z, of the equal energy spectrum. The $\bar{y}$ coefficients of the equal energy spectrum are the relative luminosity values defining the standard observer for photometry.

Standard operating procedure - Formal operating procedure documented for guidance and compliance by system personnel.

Standard pressure - 1. In meteorology, usually a pressure of 1000 millibars, but other pressures may be used as standard for specific purposes. 2. In physics, a pressure of 1 standard atmosphere.

Standing wave - A periodic wave having a fixed distribution in space which is the result of interference of progressive waves of the same frequency and kind. Such waves are characterized by the existence of nodes or partial nodes and antinodes that are fixed in space.

Star - A self-luminous celestial body exclusive of nebulas, comets, and meteors; any one of the suns seen in the heavens. Distinguished from planets or planet satellites that shine by reflected light.

Starboard - The right side of a craft, facing forward. The opposite is port.

Static - 1. Involving no variation with time. 2. Involving no movement, as in static test. 3. Any radio interference detectable as noise in the audio stage of a receiver.

Static pressure - 1. The pressure with respect to a stationary surface tangent to the mass-flow velocity vector. 2. The pressure with respect to a surface at rest in relation to the surrounding fluid.

Static testing - The testing of a rocket or other device in a stationary or hold-down position, either to verify structural design criteria structural integrity, and the effects of limit loads or to measure the thrust of a rocket engine.

Stationary orbit - An orbit in which the satellite revolves about the primary at the angular rate at which the primary rotates on its axis. From the primary, the satellite thus appears to be stationary over a point on the primary. A stationary orbit with respect to the earth is commonly called a 24-hour orbit.

Station keeping - 1. The sequence of maneuvers that maintains a vehicle in a predetermined orbit. 2. The collection of monitoring and control tasks essential to keep a station operational.

Statistically significant difference - A difference in the results obtained under two experimental conditions which can legitimately be concluded not to be due to chance; usually significant differences are arbitrarily considered to be differences that would be expected to occur by chance no more than 1% (or 5%) of the time.

Stator - In machinery, a part or assembly that remains stationary with respect to a rotating or moving part or assembly such as the field frame of an electric motor or generator, or the stationary casing and blades surrounding an axial-flow-compressor rotor or turbine wheel; a stator blade.

Statute mile - 5280 feet = 106093 kilometers = 0.869 nautical mile. Also called land mile.

Steady state - The condition of a substance or system whose local physical and chemical properties do not vary with time.

Stellar guidance - Celestial guidance.

Stellar inertial guidance - The guidance of a flight-borne vehicle by a combination of celestial and inertial guidance; the equipment which accomplishes the guidance.

Stern - Aft part of a ship.

Steradian - A unit of measure of solid angles. It is the solid angle subtended at the center of the sphere by a portion of the surface whose area is equal to the square of the radius of the sphere.

Stilb - A unit of luminance (or brightness) equal to 1 international candle per square centimeter. Compare apostilb.

Stimulus - Energy, external or internal, which excites a receptor.

Stimulus field - The extended totality of visual stimuli which act upon the unmoving eye at a given moment.

Stochastic - Conjectural; in statistical analysis = random.

Stochastic process - An ordered set of observations in one or more dimensions, each being considered as a sample of one item from a probability distribution.

Storage - 1. The act of storing information. See store. 2. Any device in which information can be stored. Also called a memory device. 3. In a computer, a section used primarily for storing information. Such a section is sometimes called a memory or a store. 4. Refers to location or facility for storing material (temporary or long-term).

Storage capacity - The amount of information, usually expressed in bits (i.e., the $\log_2$ of the number of distinguishable states in which the storage can exist), that can be retained in storage. Also called memory capacity.

Store - 1. To retain information in a device from which it can later be withdrawn. 2. To introduce information into such a device. 3. A container, rocket, bomb, or vehicle carried externally in a craft.

Stratosphere - See atmospheric shell.

Stress - 1. The force per unit area of a body that tends to produce a deformation. 2. The effect of a physiological, psychological, or mental load on a biological organism which causes fatigue and tends to degrade proficiency.

Strong color - A color of high saturation.

Subassembly - Two or more parts which form a portion of an assembly or a unit replaceable as a whole, but having a part or parts which are individually replaceable.

Subaudio frequency - A frequency below the audiofrequency range, below about 15 cycles per second.

Subharmonic - A subharmonic is a sinusoidal quantity having a frequency that is an integral submultiple of the fundamental frequency of a periodic quantity to which it is related.

Sublimation - The transition of a substance directly from the solid state to the vapor state, or vice versa, without passing through the intermediate liquid state.

Subroutine - A set of instructions necessary to direct a computer to carry out a well-defined mathematical or logical operation; a sub-unit of a routine, usually coded in such a manner that it can be treated as a black box by the routine using it.

Subsonic - In aerodynamics, of or pertaining to, or dealing with speeds less than acoustic velocity, as in subsonic aerodynamics.

Subsystem - A major functional sub-assembly or group of items or equipment which is essential to operational completeness of a system.

Subtend - To be opposite, as an arc of a circle subtends an angle at the center of the circle, the angle being formed by the radii joining the ends of the arc with the center.

Subtractive color mixture - Method of color mixture in which a beam of light is passed through two or more transparent colored filters in succession. Only those wavelengths which are common to both or all will be transmitted. By this method, white light passing through broad band yellow and blue filters gives green.

Superior conjunction - The conjunction of a planet and the sun when the sun is between the earth and the other planet.

Supersonic - Of or pertaining to, or dealing with, speeds greater than the acoustic velocity.

Sweep - The motion of the visible dot across the face of a cathode-ray tube, as a result of deflections of the electron beam.

Switch indicator - A push-button switch device which serves also as an indicator (generally internally-illuminated).

Symbiosis - The living together of two or more organisms in an association which is mutually advantageous.

Synchronous - Coincident in time, phase, rate, etc.

Synchronous computer - A computer in which the starting time of every ordinary operational cycle is controlled by signals which occur at regular intervals. Contrast with asynchronous computer.

Synergism - Cooperative action of discrete units such that the total effect attained is greater than the sum of the independent effects.

System - A composite of equipment, skills, and techniques (including all related facilities, equipment, materiel, services, and personnel) that is capable of performing and/or supporting an operational role. (AFR 375-1).

Systematic error - An error that is always a function of the magnitude of the quantity observed. When the error is constant it is called a bias error. Systematic errors are often caused by false elements in an instrument. An example is an eccentrically mounted azimuth circle or an azimuth circle with graduation errors.

Target - 1. Any object, point, etc., toward which something is directed. 2. An object which reflects a sufficient amount of a radiated signal to produce an echo signal on detection equipment.

Target acquisition - The process of optically, manually, mechanically, or electronically orienting a tracking system in direction and range to lock on a target.

Target discrimination - 1. Resolution of a radar. 2. The act of perceiving a desired signal within a background of noise.

Target signal - The radar energy returned to a radar by a target. Also called echo signal, video signal.

Target strength - Measure of reflecting power of the target. Ratio, in decibels, of the target echo to the echo from a six-foot diameter perfectly reflecting sphere at the same range and depth.

Task analysis - An analytical process employed to determine the specific behaviors required of human components in a man-machine system. It involves determining, on a time basis, the detailed performance required of a man and machine, the nature and extent of their interactions, and the effects of environmental conditions and malfunctions. Within each task, behavioral steps are isolated in terms of perceptions, decisions, memory storage, and motor outputs required, as well as the errors which may be expected. The data are used to establish equipment design criteria, personnel, training requirements, etc.

Telemetry - The science of measuring a quantity or quantities, transmitting the results to a distant station, and there interpreting, indicating, and/or recording the quantities measured.

Terminal - 1. A point at which any element in a circuit may be directly connected to one or more other elements. 2. Pertaining to a final condition or the last division of something, as terminal ballistics.

Terminal guidance - Guidance from an arbitrary point, at which midcourse guidance ends, to the destination.

Terminal velocity - The maximum velocity attainable, especially by a freely falling body, under given conditions.

Terminator - The line separating illuminated and dark portions of a celestial body, as the moon, which is not self luminous.

Tesla - The unit of magnetic flux density, one weber per square meter.

Theodolite - An optical instrument which consists of a sighting telescope, mounted so that it is free to rotate around horizontal and vertical axes, and graduated scales so that the angle of rotation may be measured. The telescope is usually fitted with a right-angle prism so that the observer continues to look horizontally into the eyepiece, whatever the variation of the elevation angle.

Thermal - 1. Of or pertaining to heat or temperature. 2. A vertical air current caused by differential heating of the terrain.

Thermal barrier - A popular term for speed limitations within an atmosphere imposed by aerodynamic heating. Also called the heat barrier.

Thermal emission - The process by which a body emits electromagnetic radiation as a consequence of its temperature only.

Thermionic emission - Direct ejection of electrons as the result of heating the material, which raises electron energy beyond the binding energy that holds the electron in the material.

Thermocline - That region in oceans where maximum temperature changes occur with increased depth. Layer of water whose temperature is different than water above or below it.

Thermocouple - A device which converts thermal energy directly into electrical. In its basic form it consists of two dissimilar metallic electrical conductors connected in a closed loop. Each junction forms a thermocouple.

Thermonuclear - Pertaining to a nuclear reaction which is triggered by particles of high thermal energy.

Thermopile - 1. A transducer for converting thermal energy directly into electrical energy, composed of pairs of thermocouples which are connected either in series or in parallel.

Therblig (Time and Motion Study) - Term applied to movement elements of a work task. (See Section 3, pages 10,11 and Table 5, this section.)

Three-body problem - That problem in classical celestial mechanics which treats the motion of a small body, usually of negligible mass, relative to and under the gravitational influence of two other finite point masses.

Threshold - Generally, the minimum value of a signal that can be detected by the system or sensor under consideration (including human perception).

Threshold contrast - The smallest contrast of luminance (or brightness) that is perceptible to the human eye under specified conditions of adaptation luminance and target visual angle. Also called contrast threshold, liminal contrast. Compare threshold illuminance. Psychophysically, the existence of a threshold contrast is merely a special case of the general rule that for every sensory process there is a corresponding lowest detectable intensity of stimulus, i.e., a limen.

Threshold illuminance - The lowest value of illuminance which the eye is capable of detecting under specified conditions of background luminance and degree of dark adaptation of the eye. Also called flux-density threshold. Compare threshold contrast.

Threshold of audibility - For a specified signal t[illegible] minimum effective sound pressure level of the signal that is cap[illegible] of evoking an auditory sensation in a specified fraction of trails. The characteristics of the signal, the manner in which it is presented to the listener, and the point at which the sound pressure level is measured must be [illegible]cified. Also called threshold of detectability.

Threshold of detectability - Threshold of audibility.

Threshold of discomfort - In acoustics, for a specified signal, the minimum effective sound pressure level of that signal which, in a specified fraction of the trials, will stimulate the ear to a point at which the sensation of feeling becomes uncomfortable. The term applies similarly for other senses.

Threshold of feeling - In acoustics, for a specified signal, the minimum sound pressure level at the entrance to the external auditory canal which, in a specified fraction of the trials, will stimulate the ear to a point at which there is a sensation of feeling that is different from the sensation of hearing. Also called tickle.

Threshold of pain - In acoustics, for a specified signal, the minimum effective sound pressure level of that signal which, in a specified fraction of the trials, will stimulate the ear to a point at which the discomfort gives way to definite pain that is distinct from mere non-noxious feeling of discomfort. The term applies similarly for other senses.

Thrust - 1. The pushing or pulling force developed by an aircraft engine or a rocket engine. 2. The force exerted in any direction by a fluid jet or by a powered screw, as, the thrust of an antitorque rotor. 3. Specifically, in rocketry, $F = mv$ where m is propellant mass flow and v is exhaust velocity relative to the vehicle. Also called momentum thrust.

Thrust reverser - A device or apparatus for reversing thrust, especially of a jet engine.

Tickle - Threshold of feeling.

Timbre - That attribute of auditory sensation by which a listener discriminates between two sounds of similar loudness and pitch, but of different tonal quality.

Time - A measure of duration; interval between two events; a particular moment, hour, day, or year as fixed by a timepiece, calender or some other arbitrary reckoning system.

Time and motion study - A method for analyzing task elements in terms of "time to perform" (see Table 5).

Time-line analysis - Reducing or charting a function on a time base. The analysis can be performed first at the broader functional levels and then be repeated with successively greater precision at successively narrower levels of function.

Time of useful consciousness - The period between loss of oxygen supply (at altitude) and the inability of the individual to function efficiently.

Time signal - 1. An accurate signal marking a specified time or time interval. It is used primarily for determining errors of timepieces. Such signals are usually sent from an observatory by radio or telegraph. 2. In photography, a time indication registered on the film to serve as a time reference for interpretation of the date recorded on the film.

Abbreviation	Therblig	Definition
TL	Transport Loaded	The act of moving a Transportation Means with a load or against a resistance
TE	Transport Empty	The act of moving a Transportation Means without a load or to a point from which it can be moved against a resistance
D	Direct	The act of guiding actions with sensory movements
G	Grasp	The act of gaining complete managing control
H	Hold	The act of maintaining complete managing control
RL	Release Load	The act of completely relinquishing managing control
UD	Unavoidable Delay	The delay in the operation which is beyond the control of the operator
AD	Avoidable Delay	The delay in the operation which is under the control of the operator
BD	Balance Delay	The delay in the operation caused by the nervous limitations of the human body.
R	Rest	The delay in the operation which permits elimination of fatigue
PP	Pre-position	The act of rearranging Transportation Means, the part being transported, or any other part to have them in readiness for continuing the main operation
P	Position	The act of bringing two parts to an exact and pre-determined relationship with each other after the transportation is complete
SE	Select	The act of making a choice between two or more pieces which are in a known location
S	Search	The act of determining the location of anything
I	Inspect	The act of examining the characteristics of anything
PL	Plan	The act of determining a method for accomplishing anything
U	Use	The act of performing a mechanical or chemical operation

Table 5 - Basic Motions of Motion-Time-Analysis

Time tick - A time signal consisting of one or more short audible sounds or beats.

Time to unconsciousness - The period between loss of oxygen supply (at altitude) and the onset of unconsciousness.

Time zone - See zone time.

Tint - Any color lighter, i.e., of higher lightness, than median gray. May imply weak saturation as well as relatively high lightness.

Tolerance - The allowable variation in measurements within which the dimensions of an item are judged acceptable.

Topocentric - Of measurements or coordinates, referred to the position of the observer on the earth as the origin.

Topography - The general configuration of the land surface (or the ocean bottom); the sum total of the results of erosion and deposition on the physiographic features of a region.

Torque - The product of a force and the distance of its line of action from the axis.

Torquing - Tightening of a rotary fastener, usually to a predetermined value.

Torr - Provisional international standard term to replace the English term millimeter of mercury and its abbreviation mm of Hg (or the French mm de Hg).

Trace - The line appearing on the face of a cathode-ray tube when the visible dot repeatedly sweeps across the face of the tube as a result of deflections of the electron beam.

Track - 1. The path or actual line of movement of an aircraft, rocket, etc., over the surface of the earth. 2. To observe or plot the path of something moving.

Traffic pattern - 1. An officially prescribed pattern which regulates the approach and departure of aircraft about an air terminal or control center. 2. Designated or natural flow of personnel among work stations and facilities or vehicular traffic within a road network.

Train - 1. Anything, such as luminous gas or ionized particles, left along the trajectory of a meteor after the head of the meteor has passed. 2. To point, as in tracking a target.

Transceiver - A combination transmitter and receiver in a single housing, with some components being used by both units. See transponder.

Transducer - A device capable of being actuated by energy from one or more transmission systems or media and of supplying related energy to one or more other transmission systems or media, as a microphone, a thermocouple, etc.

Transfer orbit - In interplanetary travel, an elliptical trajectory tangent to the orbits of both the departure planet and the target planet. Also called transfer ellipse.

Transillumination - The passing of light through media or material for purposes of increasing its "readability," an organ of the body for medical examination.

Transistor - An active semiconductor device with three or more electrodes.

Transit - 1. The passage of a celestial body across a celestial meridian, usually called meridian transit. 2. The apparent passage of a celestial body across the face of another celestial body or across any point, area, or line. 3. An instrument used by an astronomer to determine the exact instant of meridian transit of a celestial body. 4. A reversing instrument used by surveyors for accurately measuring horizontal and vertical angles; a theodolite which can be reversed in its supports without being lifted from them.

Translation - Movement in a straight line without rotation.

Transmission level - The intensity level of the audio signal in a communications system.

Transmission loss - The reduction in the magnitude of some characteristic of a signal between two stated points in a transmission system. Also called loss.

Transmittance - Ratio of tranmitted to incident luminous flux (expressed as percent).

Transmitter - A device used for the generation of signals of any type and form which are to be transmitted. See receiver.

Transonic - Pertaining to that which occurs or is occurring within the range of speed in which flow patterns change from subsonic to supersonic or vice versa, about Mach 0.8 to 1.2, as in transonic flight, transonic flutter; that operates within this regime, as in transonic aircraft, transonic flow or transonic speed, as in transonic region, transonic zone.

Transpiration - The passage of gas or liquid through a porous solid (usually under conditions of molecular flow).

Transponder - An automated receiver/transmitter for transmitting signals when triggered by an interrogating signal.

Transverse acceleration - (viz. physiol.) Perpendicular to long axis of human body.

Transverse vibration - Vibration in which the direction of motion of the particles is perpendicular to the direction of advance of the vibratory motion, in contrast with longitudinal vibration, in which the direction of motion is the same as that of advance.

Trianomaly - Rare type of trichromatism in which an abnormally large proportion of blue stimulus is required in a blue-green mixture to match a given cyan.

Trichromatic theory - A color theory based upon the facts of trichromatic mixture, namely that all hues may be derived from the mixture of two or more of three primaries.

Trichromatism -Form of vision yielding colors which require in general three independently adjustable primaries (such as red, green, and blue) for their duplication by stimulus mixture. Trichromatism may be either anomalous trichromatism or normal color vision.

Triplexer - A dual-duplexer which permits the use of two receivers simultaneously and independently in a radar system by disconnecting the receivers during the transmitted pulse.

Tritanope - Individual with tritanopic vision.

Tritanopia - Form of dichromatism in which reddish blue and greenish yellow stimuli are confused. Tritanopia is a common result of retinal disease, but in rare cases may be inherited. Sometimes called blue blindness.

Troland - Unit of retinal illuminance equal to that produced by viewing a surface whose luminance is 1 candle per square meter through an artificial pupil whose area is 1 square millimeter centered on the natural pupil.

Tropopause - The boundary between the troposphere and stratosphere.

Troposphere - The lower layer of the earth's atmosphere, extending from the surface of the earth to an altitude of ten miles.

Troubleshooting - Locating and diagnosing malfunctions or breakdowns in equipment by means of systematic checking or analysis.

True altitude - Instrument (barometric) altitude corrected for atmospheric temperature and pressure.

True north - The direction from any point on the earth's surface toward the geographic North Pole.

Trunk - Human body torso.

T-time - Any specific time, minus or plus as referenced to zero or launch time, during a countdown sequence that is intended to result in the firing of a rocket propulsion unit that launches a rocket vehicle.

Tumble - 1. To rotate end over end--said of a rocket, of an ejection capsule, etc. 2. Of a gyro, to precess suddenly and to an extreme extent as a result of exceeding its operation limits of bank or pitch.

Turbidity - The state or condition of having the transparence or translucence disturbed, as when sediment in water is stirred up, or when dust, haze, clouds, etc., appear in the atmosphere because of wind or vertical currents.

Turbofan - A turbojet engine in which additional propulsive thrust is gained by extending a portion of the compressor or turbine blades outside the inner engine case.

Turbojet engine - A jet engine incorporating a turbine-driven air compressor to take in and compress the air for the combustion of fuel (or for heating by a nuclear reactor), the gases of combustion (or the heated air) being used both to rotate the turbine and to create a thrust-producing jet. Often called a turbojet.

Turbulence - 1. A state of fluid flow in which the instantaneous velocities exhibit irregular and apparently random fluctuations so that in practice only statistical properties can be recognized and subjected to analysis. Compare laminar flow.

Turn error - Any error in gyro output due to cross-coupling and acceleration encountered during vehicle turns.

Ultrasonic - In acoustics, of or pertaining to frequencies above those that affect the human ear, i.e., more than 20,000 vibrations per second.

Ultra-violet - Radiant energy of wavelengths shorter than the extreme violet and lying beyond the ordinarily visible spectrum. Usually assigned to vibrations below 400 or 390 millimicrons.

Ultraviolet radiation - Electromagnetic radiation of shorter wavelength than visible radiation; roughly radiation in the wavelength interval from 100 to 4000 angstroms. Also called ultra-violet. See X-ray.

Umbilical cord - Any of the servicing electrical, gaseous, or fluid lines between the ground or a tower and an uprighted rocket vehicle before the launch or between an astronaut or aquanaut and their source of supply (e.g., life support, communications, etc.). Often shortened to umbilical.

Umbra - 1. The darkest part of a shadow in which light is completely cut off by an intervening object. A lighter part surrounding the umbra, in which the light is only partly cut off, is called the penumbra. 2. The darker central portion of a sun spot, surrounded by the light pénumbra.

Undamped natural frequency - Of a mechanical system, the frequency of free vibration resulting from only elastic and inertial forces of the system.

Union - In Boolean algebra, the operation in which concepts are described by stating that they have the characteristics of one or more of the classes involved. Union is expressed as OR.

Universe - 1. In statistical terminology, = population. 2. (Celestial) composite of all the stars and planets.

Universal gravitational constant - See gravitation.

Up Doppler - When a target is moving toward a transducer the echo will be of higher frequency than the reverberation regardless of whether the range is opening or closing.

Upper branch - That half of a meridian or celestial meridian from pole to pole which passes through a place or its zenith.

Upper stage - A second or later stage in a multistage rocket.

Upper transit - Transit of the upper branch of the celestial meridian. Also called superior transit, upper culmination. Transit of the lower branch is called lower transit.

Vacuum - A given space filled with gas at pressures below atmospheric pressure. Various approximate ranges are:

low vacuum, torr....................	760 to 25
medium vacuum, torr.................	25 to 10^{-3}
high vacuum, torr...................	10^{-3} to 10^{-6}
very high vacuum, torr..............	10^{-6} to 10^{-9}
ultrahigh vacuum, torr..............	10^{-9} and below

Value - 1. The dimension of the Munsell system of color which corresponds most closely to lightness. 2. Numerical quantity. 3. Worth, as in value engineering.

Van Allen belt, Van Allen radiation belt - (For James A. Van Allen, 1915.) The zone of high-intensity particulate radiation surrounding the earth beginning at altitudes of approximately 1000 kilometers.

Vapor train (Vapor Trail) - Condensation trail.

Variance - In statistics, a measure of variability (or spread); the mean-square deviation from the mean, that is, the mean of the squares of the differences between individual values of x and the mean value μ .

Variation - The angle between the magnetic and geographical meridians at any place, expressed in degrees east or west to indicate the direction of magnetic north from true north.

Vector -Any quantity, such as a force, velocity, or acceleration, which has both magnitude and direction at each point in space, as opposed to a scalar which has magnitude only. Such a quantity may be represented geometrically by an arrow of length proportional to its magnitude, pointing in the assigned direction.

Vector product - A vector whose magnitude is equal to the product of the magnitudes of any two given vectors and the sine of the angle between their positive directions. Also called cross product, outer product. See scalar product.

Vector quantity - Vector.

Vector steering - A steering method for rockets and spacecraft wherein one or more thrust chambers are gimbal mounted so that the direction of the thrust force (thrust vector) may be tilted in relation to the center of gravity of the vehicle to produce a turning movement.

Vehicle control system - A system, incorporating control surfaces or other devices, which adjusts and maintains the altitude and heading, and sometimes speed, of a vehicle in accordance with signals received from a guidance system.

Velocity - A vector quantity equal to speed in a given direction.

Ventilation - The systematic exchange of air (e.g., as in the human respiratory system or in an air conditioning system) for the purpose of sustaining life, removing toxic gases and/or providing a comfortable work environment.

Ventilation garment - A lightweight, specially designed garment that is integrated with the pressure suit for providing adequate evaporation and heat dissipation from the surface of the body, by circulating dry air through the porous material.

Ventral - Pertaining to the belly, or the underside of a vehicle, as ventral camera.

Venturi tube - A short tube of smaller diameter in the middle than at the ends. When a fluid flows through such a tube, the pressure decreases as the diameter becomes smaller, the amount of the decrease being proportional to the speed of flow and the amount of restriction.

Vernal equinox - That point on the ecliptic where the sun changes from southerly to northerly declination. Marks the beginning of spring and summer in the northern hemisphere.

Vernier - A scale or control used for fine adjustment to obtain a more precise reading of an instrument or closer adjustment of any equipment.

Vernier engine - A rocket engine of small thrust used primarily to obtain a fine adjustment in the velocity and trajectory of a rocket vehicle just after the thrust cutoff of the last sustainer engine, and used secondarily to add thrust to a booster or sustainer engine. Also called vernier rocket.

Vertex - 1. The highest point of a trajectory or other curve, as the vertexes of a great circle, the points nearest the poles. 2. Node, sense 3.

Vertical circle - A great circle of the celestial sphere, through the zenith and nadir. Vertical circles are perpendicular to the horizon.

Vertigo - The sensation that the outer world is revolving about the subject (objective vertigo) or that he himself is moving in space (subjective vertigo).

Video - Pertaining to the picture signals in a television system or to the information-carrying signals which are eventually presented on the cathode-ray tubes of a radar.

Vidicon - A television pickup tube utilizing a photoconductor as the sensing element. In conjunction with a telescope this is known as a vidicon telescope.

Virtual image - An image that cannot be shown on a surface but is visible, as in a mirror.

Viscosity - That molecular property of a fluid which enables it to support tangential stresses for a finite time and thus to resist deformation; the ratio of shear stress divided by shearing strain.

Viscous damping - The dissipation of energy that occurs when a particle in a vibrating system is resisted by a force that has a magnitude proportional to the magnitude of the velocity of the particle and direction opposite to the direction of the particle.

Visibility - The capacity of radiant energy, within a certain range of wave-lengths, to excite a visual receptor process and thereby evoke the phenomenon of brightness.

Vision - The sense whose receptive organ is the eye, whose normal stimulus is radiant energy, and whose response is color (See Figure 6).

Vision, foveal - Visual sensations or perceptions due to stimulation of the fovea centralis, or center of the retina. Contrast with peripheral vision.

Vision, peripheral - Visual sensations or perceptions due to stimulation of the outlying protions of the retina. Contrast with foveal vision.

Vision, persistence of - The tendency of visual excitation to outlast the stimulus, or more generally the tendency of changes in visual sensory response to lag behind changes in the stimulus.

Visual acuity - A more concentrated form of visibility; it is the resolving ability of the eye to discern fine details.

Visual adaptation - Adjustive change in visual sensitivity due to continued visual stimulation. Three recognized types are: (1) scotopic or dark adaptation, (2) photopic or light adaptation, and (3) chromatic or color adaptation.

Visual angle - The angle subtended by an object of vision at the nodal point of the eye. The magnitude of this angle determines the size of the corresponding retinal image, irrespective of the size or distance of the object.

Visual field - That part of space that can be seen when head and eyes are motionless, (or) the totality of visual stimuli which act upon the unmoving eye at a given moment.

Visual photometry - A subjective approach to the problem of photometry, wherein the human eye is used as the sensing element; to be distinguished from photoelectric photometry.

Visual range - The distance, under daylight conditions, at which the apparent contrast between a specified type of target and its background becomes just equal to the threshold contrast of an observer; to be distinguished from the night visual range. Also called daytime visual range.

Visual space - This term, like visual field, refers to the extended world as perceived by means of the eyes but is commonly used in a more generic and abstract way in discussions of the perception of distance and length, of depth or distance away from the retina, and of form or figure in two and three dimensions.

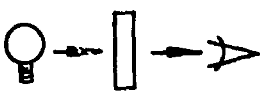
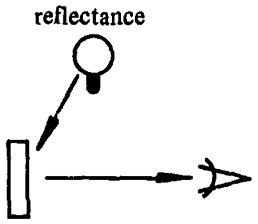
Radiometric	Photometric and Colorimetric	Perceptual
Spectral radiance	Luminance	Brightness (dim to bright)
	Dominant wavelength and purity, or chromaticity coordinates	Hue and saturation, or red-green, blue-yellow
Spectral transmittance	Luminous transmittance	Lightness (dark to clear)
	Dominant wavelength and purity, or chromaticity coordinates	Hue and saturation, or red-green, blue-yellow
Spectral directional reflectance	Luminous directional reflectance	Lightness (black to white)
	Dominant wavelength and purity, or chromaticity coordinates,	Hue and saturation, or red-green, blue-yellow
	or Munsell value	Lightness (black to white)
	Munsell hue	Hue red-green
	Munsell chroma	Saturation blue-yellow

Figure 6 - Summary of Stimulus Correlates for the Perception of Color by a Daylight-Adapted Observer

Volt - The unit of electric potential difference and electromotive force, equal to the difference of electric potential between two points of a conductor carrying a constant current of 1 ampere when the power dissipated between these points equals 1 watt.

Volume level - In an electric circuit, the level, as measured on a standard volume indicator, of a complex wave such as produced by speech or music. Often shortened to volume.

Walk-around bottle - A personal supply of oxygen for the use of crew members when temporarily disconnected from the craft's system.

Warmup time - Time measured from the application of power to an operable system to the instant when the system is capable of functioning in its intended manner.

Warning light - A red indicator light used to indicate a requirement for immediate attention or action by the observer.

Water suit - A liquid-filled pressure garment.

Watt - The unit of power in the MKSA system; that power which produces energy at the rate of 1 joule per second.

Weak color - A color of low saturation.

Weapon system - An instrument of combat such as an air vehicle together with all functioning equipment, the skills necessary to operate the equipment, and the supporting facilities and services required to enable the instrument of combat to be a single unit of striking power in its operational environment.

Weber-Fechner law - An approximate psychophysical law relating the degree of response or sensation of a sense organ and the intensity of the stimulus.

Weight - 1. The force with which a body is attracted toward the earth. 2. The product of the mass of a body and the acceleration acting on a body.

Weightlessness - 1. A condition in which no acceleration, whether of gravity or other force, can be detected by an observer within the system in question. 2. A condition in which gravitational and other external forces acting on a body produce no effect, either internal or external, on the body.

Wet suit - See rubber suit.

White - An achromatic color of maximum lightness which represents one limit of the series of grays, and which is the complement or antagonist of black, the other extreme of the gray series. White is typically evoked by any mixture of wavelengths from a high-reflectance matt surface, which approximates average daylight or the equivalent color temperature; but white depends also upon surrounding contrast.

White body - A hypothetical body whose surface absorbs no electromagnetic radiation of any wavelength, i.e., one which exhibits zero absorptivity for all wavelengths; an idealization exactly opposite to that of the black body.

White noise - A sound or electromagnetic wave whose spectrum is continuous and uniform as a function of frequency.

Whiteout - An atmospheric and surface condition in the arctic in which no object casts a shadow, the horizon being indiscernible, and only very dark objects being seen. Also called "milky weather." (This condition is brought on when snow cover is complete and the clouds so thick and uniform that light reflected by the snow is of about the same intensity as the light of the sun after passing through the clouds.)

White room - A clean and dust-free room used for assembly and repair of precise mechanisms such as gyros.

Window - 1. Any device introduced into the atmosphere for producing an appreciable radar echo, usually for tracking some airborne device or as a tracer of wind. 2. Any gap in a linear continuum, as atmospheric windows, ranges of wavelengths in the electromagnetic spectrum to which the atmosphere is transparent, or firing windows, intervals of time during which conditions are favorable for launching a spacecraft on a specific mission. 3. Aperture for viewing by human operator.

Windscreen - A windshield.

Windshield - Anything that serves to shield against wind (usually transparent) allowing forward vision.

Work - 1. Energy resulting from the motion of a system against a force and existing only during the process of energy conversion. 2. Expression for human effort (often measured in ergs, or specific output results in terms of parts/unit time); general description of task, i.e., "his work involves production of piece parts."

Work space layout - A design of a work area of work station to include provisions for seating, physical movement of human operators, operational maintenance, and other factors permitting adequate person-to-person contact and man-machine interaction.

Work Study - Objective, systematic, analytical, and critical examination of work methods, techniques, and procedures.

Write - In computer terminology, record.

X-band - A frequency band used in radar extending approximately from 5.2 to 10.9 kilomegacycles per second.

X-ray - Nonnuclear electromagnetic radiation of very short wavelength, lying within the interval of 0.1 to 100 angstroms (between gamma rays and ultraviolet radiation). Also called X-radiation, Roentgen ray.

Yard (international) - Exactly 0.9144 meter. The U.S. yard before 1 July 1959 was 0.91440183 meter.

Yaw - 1. The rotational or oscillatory movement of an aircraft, rocket, or the like about a vertical axis. 2. The amount of this movement, i.e., the angle of yaw. 3. To cause to rotate about a vertical axis. 4. To rotate or oscillate about a vertical axis.

Yaw angle - Angle of yaw.

Yaw axis - A vertical axis through an aircraft, rocket, or similar body, about which the body yaws. It may be a body, wind, or stability axis. Also called a yawing axis.

Yawing moment - A moment that tends to rotate an aircraft, an air- a rocket, etc., about a vertical axis. This moment is considered positive when it rotates clockwise.

Zenith - That point of the celestial sphere vertically overhead. The point 180° from the zenith is called the nadir.

Zero-g - Weightlessness.

Zero gravity - Weightlessness.

Zone time - A world-wide time-keeping system based on the division of the earth's surface into 24 time zones 15° in width within which all inhabited areas use the local civil time of the central meridian.

Z-time - Greenwich mean time. Also referred to as Zulu time.

GLOSSARY OF ACCEPTABLE TASK ANALYSIS ACTION VERBS IN THE HUMAN FACTORS CONTEXT

A

Activate - Provide the initial force or action to begin an operation of some equipment configuration.

Adjust - Manipulate controls, levers, linkages and other equipment items to return equipment from an out-of tolerance condition to an in-tolerance condition.

Affect - Influence or produce an effect (it presupposes a stimulus powerful enough to elicit a response or reaction).

Agree - Ascertain if the actual relationship between specified components is in accord with a prescribed relationship.

Alert - Inform designated persons that a certain condition exists in order to bring them up to a watchful state in which a quick reaction is possible.

Align - Adjust controls to match visual indicators, such as pointers, line of sight, wave forms, or aural signals, until coincidence is achieved.

Apply - Utilize sufficient force, manual (as opposed to automatic functions) or mechanical, to accomplish a desired objective.

Assemble - Perform the various manual operations necessary to place, align, fit, or secure together two or more equipment items to complete a subunitary or unitary complex.

Attach - Fasten one object onto another; in general, it will be a smaller object onto a larger object (e.g., to attach a lock on a door).

Attain - Achieve or accomplish a desired goal or condition.

Attempt - Endeavor to accomplish a task or goal, but with the realization that failure is a possibility.

C

Calibrate - Determine accuracy, deviation, or variation by special measurement or by comparison with a standard.

Change - Choose an alternate or different method of operation, unit of equipment, etc., of some component in the present configuration.

Check - Examine to determine if a given action produces a specified result; to determine that a presupposed condition actually exists, or to confirm or determine measurements by the use of visual, auditory, tactile, or mechanical means.

Checkout - Perform routine procedures, which are discrete, ordered, stepwise actions designed to determine the status or assess the performance of an item of equipment or a unit--Typical examples of these routine procedures are the procedures used to checkout the performance level of a vacuum tube, and aircraft preflight checkout procedures.

Clean - Wash, sweep, decontaminate, etc., equipment units and areas.

Close - Perform the operation of blocking direct access to an enclosure (e.g., close door; close lid on box).

Code - Convert a message, document, etc., from ordinary language to a coded system of letters, words, numbers, or symbols.

Communicate - Perform the operation of transmitting, emitting, or receiving signals, signs, writing, images, sounds, or intelligence of any nature by wire, radio, visual, or other electromagnetic systems.

Compare - Examine the characteristics of two or more items to determine their similarities and differences.

Complete - Finish an entire task, operation, or mission, or to finish a clearly defined step in a task, operation, or mission.

Compose - Make up of component parts (e.g., a task or unit of equipment).

Connect - Couple or join prepositioned, keyed, or matched equipment units in a permanent, semipermanent or temporary union.

Continue - Proceed in the performance of some action, procedure, etc., or to remain on the same course or direction (e.g., continue to check the temperature fluctuations; continue to adjust the controls; and continue on the same heading).

Coordinate - Bring two or more separate items into a common action or condition.

Count - Determine by numerical methods the number of units in a collection.

D

Deactivate - Remove the force so that an equipment configuration ceases operation.

Decode - Convert a message, document, etc., from a system of letters, words, numbers, or symbols to ordinary language.

Delay - Wait a brief period of time before taking a certain action or making a response.

Depress - Apply manual (as opposed to automatic) pressure to activate or initiate an action, or to cause an item of equipment to function or cease to function.

Determine - Find, discover, or detect a condition (e.g., determine degree of angle.)

Disassemble - Perform the various manual operations (as opposed to automatic) necessary to take a hardware item apart to its next smaller unit or down to all removal parts.

Discard - Remove, separate, or dispose of something that originally was of use but which is no longer functional or may have salvage value (e.g., a faulty part, an obsolete procedure).

Disconnect - Separate keyed or matched equipment units in a routine nondestructive manner.

Disengage - Change or make a setting in a routine nondestructive manner on some form of positioning, holding or power transfer device so that it no longer restricts movement, or permits the transfer of power (e.g., positioning device, guide pins; holding device, cotterpins; power transfer device, clutch).

E

Enable - Bring to a state of readiness.

Engage - Make a setting in a routine nondestructive manner on some form of positioning, holding or power transfer device so that it restricts movement, or permits the transfer of power (e.g., to cause the teeth of one gear wheel to engage those of another).

Establish - Set up initial condition or procedure.

Evaluate - Judge or appraise the worth or amount, of a unit of equipment, operational procedure or condition (e.g., evaluate status of life support systems).

Execute - Carry out a direct order, which most often is a part of an existing plan.

Extend - Stretch, draw out, or move out from an enclosure (e.g., to extend a flap).

F

Fill - Pour or put into a receptacle (e.g., fill an aircraft's tanks with fuel).

Fly - Move a manned or unmanned aircraft or spacecraft through the air or space after it is airborne.

Follow - Proceed along or succeed in order or time.

G

Gain - Increase an advantage or control, over the previous condition (e.g., gain an altitude advantage over a hostile aircraft; gain increased control through manual operations.

H

Handle - Move, turn, raise, lower, lift, etc. objects and equipment items manually or with equipment, such as hoists.

I

Identify - Determine by some rational systematic manner what something is and its precise characteristics.

Illuminate - Light an area or display surface.

Include - Add a constituent, component, or subordinate part of a task, operation, or equipment unit.

Inform - Pass on information in some appropriate manner to one or more persons about a condition, event, etc., of which they should be aware.

Initiate - Give a start to a plan, idea, request, or some form of human action (e.g., initiate a new safety procedure).

Input - Provide instructions and data to a machine by electro/mechanical means (e.g., counter, gauge, switches, dials, punched tapes, and magnetic tapes).

Insert - Place, put, or thrust something within an existing context (e.g., insert a part in the equipment, insert a request in the compute.).

Inspect - Perform critical visual examination of operating equipment units for a specific condition and determine whether the equipment should continue in operation, or determine whether new or restored equipment requires any repairs before being checked out, tested, or placed in operation--also, examine particular parts after disassembly for wear, deterioration or defects.

Install - Perform the manual (as opposed to automatic) operations necessary to attach or connect (mount) an equipment unit in the next larger assembly or system.

Instruct - Impart information in an organized, systematic manner to one or more persons.

Insure - Make certain by some direct act or observation that a desired or necessary action, task, operation, etc., has been performed or accomplished.

Interrogate - Examine, or query a system regarding the status or conditions of its components.

Isolate - Locate the cause of an equipment malfunction.

L

Land - Bring an aircraft down, and stop it upon a surface, either ground, snow, ice, water, or other surface or platform such as carrier deck (excludes taxiing).

Launch - Start the flight of a missile or rocket.

Listen - Give attention to particular verbal or other audible sounds.

Load - Provide inputs to a system, component, or assembly.

Loosen - Reduce a force in order to release some type of holding device (e.g., loosen a screwclamp).

Lower - Move an object in a downward direction, attitude, or angle.

M

Maintain - Keep a unit of equipment operational or in commission (e.g., an aircraft).

Monitor - Observe continually or periodically visual displays, or listen for or to audio displays, or vibrations in order to determine equipment condition or operating status.

O

Observe - Note the presence of mechanical motion, the condition of an indicator, or audio display, or other sources of movement or audible sounds on a nonperiodic basis.

Open - Perform the operation of providing direct access to an enclosure (e.g., open door, open lid on box).

Operate - Control equipment mechanically, electrically, manually, etc., in order to accomplish a specified predetermined purpose.

Order - Issue a command to carry out a certain procedure, operation, or directive.

Overhaul - Disassemble equipment units down to all removable parts, clean, inspect critically, repair, restore, and replace where necessary; assemble, adjust, align, recalibrate, and verify operational readiness by test or checkout, and package for transportation or storage.

P

Package - Make a protective cover for an item with some type of material (paper, wood, metal, and plastic) to protect it and facilitate its transportation to a new location or to put in a protected and convenient form for storage.

Park - Stop and keep a vehicle stationary for a period of time on a roadway or runway.

Pass - Meet a specified level of acceptability.

Perform - Carry out some action from preparation to completion (It is understood that some special skill or knowledge is required to successfully accomplish the action.)

Persist - Continue an operation or task in spite of difficulties that may arise from undesirable working conditions.

Place - Transport an object to an exact location.

Playback - Run a tape or record of some desired information for instruction or to check certain information.

Plug - Insert a fitting into a receptacle or establish some type of electrical circuit.

Position - Turn, slide, rotate, or otherwise move a switch, lever, valve handle, or similar control device to a selected orientation about some fixed reference point.

Prepare - Perform initial actions, such as check, connect, refill, etc., which precede the accomplishment of a specific job operation or which ready equipment for subsequent use.

Present - Cause presence of some form of foreseeable information on a standard display surface, such as a CRT, dial, and gauge.

Proceed - Move, pass, or go forward or advance, in an orderly or regulated manner.

Provide - Furnish in advance the materials, supplies, facilities, information, etc., for which a need can be foreseen.

Pull - Exert a force on an object in such a manner that the object will move or tend to move in the direction of the force.

Push - Exert a force on an object in such a manner that the object will move or tend to move away from the origin of the force.

R

Raise - Move an object in an upward direction, attitude, or angle.

Read - Use ones eyes to comprehend some standardized form of visual symbols (e.g., sign, gauge, or chart).

Receive - Acquire the status of equipment or action in progress by visual or auditory means (e.g., receive message from air traffic control).

Record - Make a permanent account of the results of some action, test, event, etc., so that the authentic evidence will be available for subsequent examination.

Refer - Make use of source material or prescribed routines for verification or when some procedure or step in an operation does not check out correctly.

Release - Remove the manual application of pressure to stop an action, or activate or deactivate an item of equipment.

Remain - Stay within prescribed limit constraints (e.g., time, space, cost, etc.).

Remove - Perform the various manual operations necessary to take an equipment item out of the next larger assembly or system.

Repair - Restore or replace damaged, worn-out, or malfunctioning equipment so that it is serviceable, usable, or in operational condition.

Repeat - Perform the same series of tests, operations, etc., over again, or perform an identical series of tasks, tests, operations, etc.

Replace - Return an item of equipment to its normal operational location.

Report - Order specified persons to contact, or to report at a specified location; usually the time is specified or it is understood that the interested persons are aware of the time limitations.

Request - Ask for something in a formalized routine manner, which is in line with set procedures.

Require - Demand that a condition(s) be met in order that a desired objective can be accomplished.

Respond - Answer an inquiry or react to a verbal, visual, auditory, tactile, or olfactory stimulus.

Resume - Restart an operation or procedure at the point where its progress was halted or interrupted.

Retract - Withdraw an item of equipment into a large equipment unit (e.g., retract an aircraft's landing gear).

Return - Go or come back again to a place, person, or condition.

Review - Examine work performed or documents produced to determine its adequacy, correctness, preciseness, etc.

Revise - Make a new, improved, or up-to-date version of a document, procedure, regulation, or the like.

Rotate - Apply manual torque to cause a multiple position rotary switch or a constantly varying device like a handwheel, thumbwheel, or potentiometer to move in a clockwise or counterclockwise manner.

S

Secure - Fasten, tie, clamp, or in some other manner, restrict the movement of a unit of equipment, or cargo, so that movements of the transporting device (e.g., truck, aircraft, or ship), or the base it is on, will not result in its shifting position or being damaged.

Select - Choose, or be commanded to choose, and alternative from among a series of similar choices (e.g., select a proper transmission frequency).

Service - Perform cleanup, lubrication, and replenishment of such necessities as fuel, in order to prepare a vehicle, or a unit of equipment (e.g., aerospace ground equipment, rifles, or drill-presses) for operation.

position.

Setup - Perform those discontinuous or procedural actions necessary to prepare an end-item or an item of support equipment for a maintenance activity, such as checkout (The term is similar to "Prepare," but is more specific in that it relates only to those preparatory actions associated with a single item of equipment.)

Steer - Direct the course of a vehicle by mechanical means.

Stop - Halt some action currently in progress.

Store - Deposit parts, equipment, or other material in a warehouse, container, etc., for use at some future time.

T

Take - Acquire temporary possession or control of an operational system or a supporting facility, or have exclusive use of the operational system or support facility for a limited period of time (e.g., direct that a co-pilot take control of an aircraft--direct that an aircraft take over exclusive use of a runway for takeoff).

Taxi - Travel along the ground under an aircraft's own power or on the water, if a seaplane, when picking out a starting place for a takeoff, after coming in for a landing, or when changing locations on the ground.

Test - Conduct a formalized program such as Personnel Subsystem Test and Evaluation (PSTE) that generates data* used by the government and contractors during the developmental and operational stages to evaluate the performance of a system or any part thereof against certain standards.

Throw - Change manually the setting of a toggle switch from one position to another.

Tighten - Apply a force to secure some type of fastner (e.g., tighten a screwclamp).

Transfer - Change from one form of operation to another, or move an item of equipment from one complex to another so that the mode of operation is changed.

Transmit - Send out a signal by means of radio waves.

Transport - Move one or more items from one location to another.

Troubleshoot - Examine and analyze failure reports, equipment readouts, test equipment meter valves, failure symptoms, etc., to isolate the source of the malfunction.

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* Data consist of any representation such as characters or analog quantities to which meaning may be assigned. Data may be expressed in digital, graphic, or symbolic forms, such as writings, sound, recordings, pictoral reproductions and drawings. Information is the meaning assigned to data by known conventions.

Tune - Adjust an item of equipment to a prescribed operating condition.

U

Use - Utilize some unit of equipment or operational procedure.

W

Wait - Stay or remain in a state of readiness to perform a given action.

Walk - Use ones own legs to move a restricted distance from one location or position to another location or position.

Section 5

ACRONYMS AND ABBREVIATIONS

Section 5

ACRONYMS & ABBREVIATIONS

The terms listed on the following pages were selected from a much more extensive list developed from many sources. In order to make the present list practical from the standpoint of a pocket data book it was necessary to be highly selective.

The following criteria were used in the selection process:

a. The item was known to be used frequently with reference to human engineering activities.

b. The item appears to be relatively permanent and not subject to early obsolescence.

c. It has been common pratice for a number of years to use the acronym or abbreviation in correspondence or reports in place of the full word or phrase.

d. Multiple interpretations require that the term be defined according to a specific technical category.

The only distinction made herein between an acronym and an abbreviation is the one commonly made, namely, that although both are comprised of the initial letters or parts of several words, acronyms are those combinations of letters that can be conveniently pronounced as a word.

A

AADS - Army Air Defense System (formerly FABMDS)
AAE - Aerospace ancillary equipment
AAM - Air-to-air missile
AAP - Apollo Applications Program
AASR - Airport and airways surveillance radar
AATRI - Army air traffic regulation and identification
AAW - Anti-air warfare
ABC - Advanced biomedical capsule
ABLE - Activity balance line evaluation (PERT)
ABM - Anti-ballistic missile
ABMA - Army Ballistic Missile Agency
ABRES - Advanced ballistic re-entry system
ABSAP - Airborne search and attack plotter
ACBWS - Automatic chemical biological warning system
ACIC - Aeronautical Chart and Information Center (USAF)
ACRE - Automatic checkout and readiness equipment
ADC - Air Defense Command
ADF - Automatic direction finder
ADP - Automatic data processing
ADPS - Automatic data processing system
AEC - Atomic Energy Commission
AEDC - Arnold Engineering Development Center
A/E ratio - Absorbtivity-emissivity ratio
AEV - Aerothermodynamic elastic vehicle
AEW - Airborne early warning
AFC - Automatic frequency control
AFCE - Automatic flight control equipment
AFLC - Air Force Logistics Command
AFR - Air Force regulation
AFSC - Air Force Systems Command
AGACS - Automatic ground-to-air communications system
AGC - Automatic gain control
AJ - Anti-jam
ALBM - Air launched ballistic missile
ALGOL - Algorithmic language
AMC - Army Materiel Command
AMD - Aerospace Medical Division
AMPS - Automatic message processing system
AMR - Atlantic Missile Range
AMRL - Aerospace Medical Research Laboratory
ANIP - Army-Navy Instrumentation Program
API - Air-position indicator
APOTA - Automatic positioning telemetering antenna
APU - Auxiliary power unit
ARIS - Advanced range instrumentation ship
ARO - Army Research Office
ASDEFLORANT - Antisubmarine Defense Force, Atlantic Fleet. U.S. Naval Base, Norfolk, Virginia
ASDIC - British echo-ranging equipment (derived from: Anti-Submarine Development Investigation Committee)

ASIRC	-	Aquatic Sciences Information Retrieval Center
ASM	-	Air-to-surface missile
ASPR	-	Armed Services Procurement Regulation (AFR 70-1)
ASR	-	Air-sea rescue operations
ASROC	-	Anti-submarine rocket
ASTIA	-	Armed Services Technical Information Administration (now called Defense Documentation Center - DDC)
ASTOR	-	A nuclear torpedo
ASW	-	Anti-submarine warfare
ASWEPS	-	Anti-submarine warfare environmental prediction system
ASWTNS	-	ASW tactical navigation system
ATC	-	Air Training Command
ATDS	-	Airborne tactical data system
ATS	-	Air transportable sonar
AUDIT	-	Automatic unattended detection inspection transmitter
AUM	-	Air-to-underwater missile
AUTEC	-	Atlantic Underwater Test and Evaluation Center
AVE	-	Aerospace vehicle equipment
AWACS	-	Airborne warning and control system
AWS	-	Air Weather Service (meteorology)

B

BAMBI	-	Ballistic missile boost intercept
BDI	-	Bearing deviation indicator (on ASW gear)
BECO	-	Booster engine cut-off
BEMA	-	Business Equipment Manufacturers Association
BFO	-	Beat frequency oscillator
BOSS	-	Bio-astronautic orbiting space station
BUDOCKS	-	Bureau of Yards and Docks (USN)
BUMED	-	Bureau of Medicine and Surgery
BUPERS	-	Bureau of Naval Personnel
BUSANDA	-	Bureau of Supply and Accounts
BUSHIPS	-	Bureau of Ships
BUSTDS	-	National Bureau of Standards
BUWEPS	-	Bureau of Naval Weapons

C

CAB	-	Civil Aeronautics Board
CADPO	-	Communications and data processing operation
CAVU	-	Ceiling and visibility unlimited
CB	-	Center of bouyancy
CCTV	-	Closed circuit television
CCM	-	Counter, counter-measures
CCN	-	Contract change notice
CD	-	Contract definition
CDR	-	Critical design review
CEI	-	Contract end item
CELESCOPE	-	Celestial telescope
CEP	-	Circle of equal probability

CERC	-	Coastal Engineering Research Center (formerly Beach Erosion Board)
CF	-	Concept formulation
CG	-	Center of gravity
CGOU	-	Coast Guard Oceanographic Unit
CGRS	-	Central gyro reference system
CGS	-	Coast and Geodetic Survey
CIA	-	Central Intelligence Agency
CIC	-	Combat information center
CINCLANT	-	Commander-in-Chief, Atlantic (USN/Allies)
CINCLANTFLT	-	Commander-in-Chief, Atlantic Fleet (USN)
CINCNELM	-	Commander-in-Chief, Naval Forces, Easter Atlantic and Mediterranean
CINCPAC	-	Commander-in-Chief, Pacific (USN/USA/USAF)
CINCPACFLT	-	Commander-in-Chief, Pacific Fleet (USN)
CM	-	Command module
CNM	-	Chief of Navy Materiel
CNR	-	Chief of Naval Research
CNO	-	Chief of Naval Operations
CO	-	Commanding officer
COHO	-	Coherent oscillator
COLIDAR	-	Coherent light detection and ranging
COMASWFORPAC	-	Commander Antisubmarine Warfare Force, Pacific Fleet
COMASWFORLANT	-	Commander Antisubmarine Warfare Force, Atlantic
COMINT	-	Communications intelligence
COMOPTEVFOR	-	Commander Operational Test and Evaluation Force
ConAC	-	Continental Air Command
ConAD	-	Continental Air Defense Command (USN/USA/USAF)
CONUS	-	Continental U.S.
COSAR	-	Compression scanning array radar
COZI	-	Communications zone indicator
CPM	-	Critical path method (PERT)
CPO	-	Chief Petty Officer
CRT	-	Cathode-ray tube

D

DA	-	Department of the Army
DASH	-	Drone anti-submarine helicopter
DCA	-	Defense Communications Agency (DoD)
DCA	-	Digital Computer Association
DCAA	-	Defense Contract Audit Agency
DCAS	-	Data collection and analysis system (NASA); also, Defense Contract Administration Services
DDC	-	Defense Documentation Center
DDI	-	Depth deviation indicator
DDP	-	Digital data processor
DEI	-	Development engineering inspection
DESLANT	-	Destroyer Forces, Atlantic
DF	-	Direction finder
DLRV	-	Dual-mode lunar roving vehicle

DME	-	Distance measuring equipment
DoD	-	Department of Defense
DON	-	Department of the Navy
DOT	-	Department of Transportation; also, Department of the Treasury
DR	-	Dead reckoning
DRA	-	Dead reckoning analyzer
DRAI	-	Dead reckoning analog indicator
DRSC	-	Direct radar scope camera
DRT	-	Dead reckoning tracer
DRV	-	Deep research vehicle
DSB	-	Double sideband
DSIF	-	Deep space instrumentation facility (worldwide network of tracking stations operated for the NASA by the Jet Propulsion Laboratory)
DSL	-	Deep scattering layer
DSRV	-	Deep submergence rescue vehicle
DSSP	-	Deep submergence systems project
DSSRG	-	Deep submergence systems review group
DSSV	-	Deep submergence search vehicle
DTMS	-	Department of Mines and Technical Surveys

E

ECM	-	Electronic Countermeasure Mission
ECP	-	Engineering change proposal
ECS	-	Environmental control system
EDP	-	Electronic data processing
EEG	-	Electro-encephalogram
EER	-	Explosive echo ranging
EHF	-	Extremely high frequency
EKG	-	Electrocardiogram
EL	-	Electroluminescence
ELF	-	Extremely low frequency
ELINT	-	Electromagnetic intelligence
EM	-	Enlisted man
EMR	-	Electromagnetic radiation
EMU	-	Extravehicular mobility unit
EOD	-	Explosive ordnance disposal
ERTS	-	Earth resources technology satellite
ESHP	-	Equivalent shaft horsepower
ET	-	Ephemeris time
ETA	-	Estimated time of arrival
ETD	-	Estimated time of departure
EVA	-	Extravehicular activity
EW	-	Electronic warfare

F

FAA	-	Federal Aviation Agency
FACI	-	First article configuration inspection
FCC	-	Federal Communications Commission

FFDS - Fleet flag data system
FLIP - Floating instrument platform
FM - Frequency modulation
FMO - Frequency modulated oscillator
FRAM - Fleet rehabilitation and modernization program
FRESH - Foil research hydrofoil
FTD - Foreign Technology Division

G

GCA - Ground controlled approach
GCI - Ground controlled interception
GCT - Greenwich civil time
GEM - Ground effects machine; also, guidance evaluation missile
GFE - Government furnished equipment
GFP - Government furnished property
GLOTRAC - Global tracking network
GMT - Greenwich mean time
GOR - General operational requirement
GPI - Ground position indicator
GQ - General quarters (battle conditions)
GSE - Ground-support equipment
GSS - Global surveillance system

H

HF - High frequency
HIAD - Handbook of Instructions for Aircraft Design
HIAGED - Handbook of Instructions for Aerospace Ground Equipment Design
HIAPSD - Handbook of Instructions for Aerospace Personnel Subsystems Design
HIAVED - Handbook of Instructions for Aerospace Vehicle Equipment Design
HIMSD - Handbook of Instructions for Missile System Design
HO - Hydrographic Office (now Navy Oceanographic Office)
HOBS - High orbital bombardment system
HP - High pass
HST - Hypersonic transport
HUFF-DUFF - High-frequency direction finder
HUK - Hunter-killer Naval force or unit
HumRRO - [illegible] Resources Research Office
HYDRO - [illegible] Office (now Navy Oceanographic Office)

I

IAC - [illegible], assembly and checkout
IC - [illegible]unication
ICAO - [illegible] Civil Aviation Organization ([illegible]ounced as a word)

ICI	-	International Chromaticity Index
ICW	-	Interrupted continuous wave
IDA	-	Institute for Defense Analysis
IF	-	Intermediate frequency
IFF	-	Identification, friend or foe
ILAS	-	Instrument low approach system
ILS	-	Instrument landing system
IMBLMS	-	Integrated Medical/Behavioral Laboratory Measurement System
IMI	-	Intermediate manned interceptor
IMP	-	Inflatable micrometeroid paraglide
IMPACT	-	Implementation planning and control technique
IMU	-	Inertial measurement unit
IPS	-	Interpretative programming system
IR	-	Interrogator-Responder; also Infra-red
ISA	-	Instrument Society of America
ISO	-	International Standardization Organization

J

JAN	-	Joint Army-Navy
Jnd	-	Just noticeable difference
JPL	-	Jet Propulsion Laboratory

L

LAAR	-	Liquid air accumulator rocket
LADAR	-	Laser detection and ranging
LASER	-	Light amplification by stimulated emission of radiation
LAW	-	Light anti-tank weapon
LRV	-	Lunar roving vehicle

M

MDSS	-	Micrometeoroid deep space satellite
MEW	-	Microwave early warning
MF	-	Medium frequency
MGE	-	Maintenance ground equipment
MIDAS	-	Missile defense alarm satellite
MINPAC	-	Mine Warfare Forces, Pacific (USN)
MMRBM	-	Mobile, mid-range ballistic missile (Air Force)
MODEM	-	Modulator/Demodulator
MOL	-	Manned orbiting laboratory
MOLAB	-	Mobile (lunar) laboratory
MOPAR	-	Master oscillator power amplifier radar
MPE	-	Maximum permissible exposure (radiation)
MRBM	-	Medium-range ballistic missile
MSTS	-	Military sea transport service

MTBF	-	Mean time between failures
MTBM	-	Mean time between maintenance actions
MTD	-	Mobile training detachment
MTDS	-	Marine tactical data system
MTI	-	Moving target indicator
MTU	-	Mobile training unit
MTTR	-	Mean time to repair
MX	-	Multiplex

N

NADC	-	Naval Air Development Center
NAFEC	-	National Aviation Facilities Experimental Center (FAA)
NAMC	-	Naval Air Material Center
NAS	-	Naval Air Station; also, National Academy of Sciences
NASA	-	National Aeronautics and Space Administration
NAS/NRC	-	National Academy of Sciences-National Research Council
NASL	-	Naval Applied Sciences Laboratory
NATO	-	North Atlantic Treaty Organization
NAVAIRLANT	-	Naval Air Forces, Atlantic
NAVAIRPAC	-	Naval Air Forces, Pacific
NAVOCEANO	-	U.S. Naval Oceanographis Office
NAVSAT	-	Navigational satellite
NAVUWSEC	-	Naval Underwater Weapons Systems Engineering
NBS	-	National Bureau of Standards
NCEL	-	Naval Civil Engineering Laboratory, Port Hueneme, California
NEES	-	Naval Engineering Experimental Station, Annapolis, Maryland
NELC	-	Navy Electronics Laboratory Center, San Diego, California
NERVA	-	Nuclear engine for rocket vehicle application
NMDL	-	Navy Mine Defense Laboratory, Panama City, Florida
NODC	-	National Oceanographic Data Center, Washington, D.C.
NOL	-	Naval Ordnance Laboratory, White Oak, Maryland
NOL CORONA	-	Naval Ordnance Laboratory, Corona, California
NOMAD	-	Navy Oceanographic and Meteorological Automatic Device
NOO	-	Navy Oceanographic Office
NORAD	-	North American Air Defense Command
NORC	-	National Oceanographic Research Center
NOTS	-	Naval Ordnance Test Station, Chine Lake, California
NPO	-	Navy Purchasing Office
NPRA	-	Naval Personnel Research Activity
NRC	-	National Research Council
NRL	-	Naval Research Laboratory
NSF	-	National Science Foundation
NSIA	-	National Security Industrial Association
NTDC	-	Naval Training Device Center
NTDS	-	Naval Tactical Data System
NUC	-	Naval Undersea Research and Development Center
NUOS	-	Naval Underwater Ordnance Station

NUSL - Navy Underwater Sound Laboratory, New London, Connecticut

NWL - Naval Weapons Laboratory, Dahlgren, Virginia

O

OAO - Orbiting astronomical observatory

OAR - Office of Aerospace Research

OGE - Operating ground equipment

OGO - Orbiting geophysical observatory

OJT - On-the-job training

ONR - Office of Naval Research

OOD - Officer of the deck

OPAL - Optical platform alighment linkage

OPTEVFOR - Operational test and evaluation force

ORT - Operational readiness training

OS - Ocean station

OSO - Orbiting solar observatory

OSR - Operational support requirement

OST - Office of Science and Technology

OSTE - Operational support test and evaluation

P

PADAR - Passive airborne detection and ranging

PAM - Pulse amplitude modulation

PAR - Precision approach radar; also, Peactime Air Reconnaisance

PDR - Precision depth recorder

PE - Probable error

PED - Personnel-equipment data

PEP - Program evaluation procedure (former Air Force designation for PERT)

PERT - Performance evaluation and review technique

PFM - Pulse frequency modulation

PGR - Precision graphic recorder

PHIBLANT - Amphibious Forces, Atlantic

PHIBPAC - Amphibious Forces, Pacific

PLSS - Portable life support system

PM - Phase modulation

PMR - Pacific Missile Range

PNL - Pacific Naval Laboratory

PPI - Plan position indicator

PPS - Pulses per second

PREAMP - Preamplifier

PRISM - Program reliability information system (Navy)

PSAC - President's Scientific Advisory Committee

PSPP - Proposed system package plan

PSS - Personnel subsystem

PSTE - Personnel subsystem test and evaluation

PTDP - Preliminary technical development plan

Q

QQPRI	-	Qualitative and quantitative personnel requirements information

R

RADC	-	Rome Air Development Center
RADCM	-	Radar countermeasures and deception
RADIST	-	Radar distance indicator
RAPCON	-	Radar approach control center
RAS	-	Requirements allocation sheet
RAT	-	Rocket-assisted torpedo
RATAN	-	Radar and television aid to navigation
RATCC	-	Radar air traffic control center
RATO	-	Rocket-assisted take-off
RATT	-	Radio teletype
RCM	-	Radar countermeasures; also radio countermeasure
REM	-	Roentgen-equivalent man
REMAD	-	Remote magnetic anomoly detection
REP	-	Roentgen-equivalent physical
RF	-	Radio frequency
RFI	-	Radio frequency interference
RFP	-	Request for proposal
RHI	-	Range-height indicator
RM	-	Range marks
RMI	-	Radio magnetic indicator
RMS	-	Root mean square
RMU	-	Remote maneuvering unit
RPIE	-	Real-property installed equipment
RPU	-	Remote phone unit
RUM	-	Remote underwater manipulator
RTG	-	Radioisotopic thermal generator
R/V	-	Research Vehicle

S

SAC	-	Strategic Air Command
SAGE	-	Semi-automatic ground environment
SAM	-	Surface-to-air missile
SATCOM	-	Army Satellite Communications Agency
SCN	-	Specification change notice
SCORE	-	Signal communications by orbiting relay equipment
SCUBA	-	Self-contained underwater breathing apparatus
SEIS	-	Submarine emergency identification signal
SERVLANT	-	Service Forces, Atlantic
SERVPAC	-	Service Forces, Pacific
SHF	-	Super high frequency

SHORAN - Short-range aid to navigation
SINS - Ships internal navigation system; also, stellar-inertial navigation system
SISS - Submarine integrated sonar system
SLAM - Supersonic low-altitude missile
SM - Strategic missile
SNAP - System for nuclear auxiliary power
SNR - Signal-to-noise ratio
SOFAR - Sound fixing and ranging
SONAR - Sound navigation and ranging
SOP - Standard operation procedure
SOR - Specific operational requirement
SPADATS - Space detection and tracking system
SPAR - Seagoing platform for acoustic research
SPASUR - Space surveillance
SPD - System program director
SPO - System program office
SR - Study requirement
SRA - Specialized repair activity
SRBM - Short-range ballistic missile
SS - Navy designation for a submarine
SSB - Single sideband
SSM - System support manager; also, surface-to-surface missile
SST - Supersonic transport
STRAC - Strategic Army Corps
SUBIC - Submarine integrated control system
SUM - Surface-to-underwater missile
SURIC - Surface ship integrated control system
SYN - Synchronizing

T

TAC - Tactical Air Command
TACAN - Tactical air navigation
TACS - Tactical air control system
TCTO - Time compliance technical order
TDP - Technical development plan
TEA - Task-equipment analysis
TEPI - Training equipment planning information
TM - Technical Manual
TO - Technical Order
T/O - Table of organization
TRACALS - Traffic control, approach and landing system

U

UDT - Underwater demolition team
UHF - Ultra-high frequency
UNACOM - Universal Army communication system
UNICOM - Universal integrated communication system
UNREP - Underway replenishment

URV	-	Underseas research vehicle
USAFA	-	U.S. Air Force Academy
USCG	-	United States Coast Guard
USC&GS	-	United States Coast & Geodetic Survey
(US)GS	-	Geological survey (Department of the Interior)
USN	-	United States Navy
(USN)HO	-	Hydrographic Office (although now officially the U.S. Naval Oceanographic Office, H.O. is still used in referring to charts and publications)
USNUSL	-	U.S. Navy Underwater Sound Lab
USSTRICOM	-	U.S. Strike Command
UST	-	Undersea technology
USWB	-	U.S. Weather Bureau
UTS	-	Underwater telephone system
UV	-	Ultraviolet radiation

V

VAR	-	Visual-aural radio range; also, volt-ampere reactive
VDS	-	Variable-depth sonar
VF	-	Voice frequency
VFR	-	Visual flight rules
VHF	-	Very-high frequency
VID	-	Video
VLF	-	Very-low frequency
VLR	-	Very long range
VODAT	-	Voice-operated device for automatic transmission
VOR	-	VHF omnidirectional radio range
V/STOL	-	Vertical/short take-off and landing (aircraft)
VTOL	-	Vertical take-off and landing (aircraft)

W

W/D	-	Weight/displacement ratio
WO	-	Warrant officer
WWMCS	-	Worldwide Military Command System

X

XO	-	Executive officer

U.S. Navy Ship Designations

A

ACM	-	Minelayer, Auxiliary Ship
AD	-	Destroyer Tender
AE	-	Ammunition Ship
AF	-	Store Ship
AFS	-	Combat Store Ship
AG	-	Miscellaneous Auxiliary
AGB	-	Icebreaker
AGC	-	Amphibious Force Flagship
AGDE	-	Escort Research Ship
AGEH	-	Hydrofoil Research
AGM	-	Missile Range Instrumentation Ship
AGOR	-	Auxiliary General Oceanographic Research Ship
AGR	-	Radar Picket Ship
AGS	-	Auxiliary General Survey (Hydrographic) Ship
AGSC	-	Auxiliary General Survey Coastal Ship
AGSL	-	Satellite Launching Ship
AG(SS)	-	Auxiliary Submarine
AH	-	Hospital Ship
AM	-	Minesweeper
AMS	-	Minesweeper, Coastal
AN	-	Net Laying Ship
AO	-	Oiler
AOE	-	Fast Combat Support Ship
AOG	-	Gasoline Tanker
AOR	-	Replenishment Fleet Tanker
AO(SS)	-	Submarine Oiler
AP	-	Transport
APA	-	Attack Transport Ship
APB	-	Self-Propelled Barracks Ship
APC	-	Small Coastal Transport
APD	-	High Transport Ship
AP(SS)	-	Transport Submarine
AR	-	Repair Ship
ARB	-	Battle Damage Repair Ship
ARC	-	Cable Repairing or Laying Ship
ARD	-	Floating Drydock
ARG	-	Internal Combustion Engine Repair Ship
ARL	-	Landing Craft Repair Ship
ARS	-	Salvage Ship
ARSD	-	Salvage Lifting Vessel
ARST	-	Salvage Craft Tender
ARV	-	Aircraft Repair Ship
ARVA	-	Aircraft Repair Ship (Aircraft)
ARVE	-	Aircraft Repair Ship (Engine)
AS	-	Submarine Tender
ASR	-	Submarine Rescue Vessel
ASSA	-	Cargo Submarine
ASSP	-	Transport Submarine
ATA	-	Auxiliary Ocean Tug
ATF	-	Fleet Ocean Tug

AV - Seaplane Tender
AVB - Advanced Aviation Base Ship
AVM - Guided Missile Ship
AVP - Small Seaplane Tender
AVS - Aviation Supply Ship
AVT - Auxiliary Aircraft Transport
AW - Distilling Ship

B

BB - Battleship

C

CAG - Guided Missile Heavy Cruiser
CB - Large Cruiser
CC - Command Ship
CG - Guided Missile Cruiser
CGC - Coast Guard Cutter
CL - Light Cruiser
CLAA - Anti-Aircraft Light Cruiser
CLC - Tactical Command Ship
CLG - Guided Missile Light Cruiser
CLK - Hunter Killer Ship
CV - Aircraft Carrier
CVA - Attack Aircraft Carrier
CVB - Large Aircraft Carrier
CVE - Escort Aircraft Carrier
CVHA - Helicopter Assault Ship
CVL - Small Aircraft Carrier
CVS - ASW Support Aircraft Carrier

D

DD - Destroyer
DDE - Escort Destroyer
DDG - Guided Missile Destroyer
DDK - Hunter-Killer Destroyer
DDR - Radar Picket Destroyer
DE - Escort Vessel
DEC - Control Escort Vessel
DEG - Guided Missile Escort
DER - Radar Picket Escort Vessel
DL - Frigate
DLG - Guided Missile Frigate
DM - Minelayer, Destroyer
DMS - Minesweeper, Destroyer

I

IFS - Inshore Fire Support Ship

L

LPD	-	Amphibious Transport, Dock
LPH	-	Amphibious Assault Ship
LS	-	Light-Ship
LSD	-	Dock Landing Ship
LSM	-	Medium Landing Ship
LSMR	-	Medium Landing Ship (Rocket)
LST	-	Tank Landing Ship
LSV	-	Vehicle Landing Ship

M

MCS	-	Mine Warfare Command and Support Ship
MHA	-	Mine Hunter, Auxiliary
MHC	-	Mine Hunter, Coastal
MMA	-	Minelayer, Auxiliary
MMF	-	Minelayer, Fleet
MSA	-	Minesweeper, Auxiliary
MSC	-	Minesweeper, Coastal
MSC(O)	-	Minesweeper, Coastal (Old)
MSF	-	Minesweeper, Fleet (Steel Hulled)
MSI	-	Minesweeper, Inshore
MSO	-	Minesweeper, Ocean (Nonmagnetic)
MSS	-	Minesweeper, Special

P

PC	-	Sub Chaser
PCE	-	Escort Sub Chaser
PCER	-	Rescue Escort
PCH	-	Sub Chaser, Hydrofoil
PCS	-	Sub Chaser
PF	-	Patrol Escort
PGM	-	Motor Gunboat
PT	-	Motor Torpedo Boat
PTC	-	Motor Sub Chaser
PTF	-	Fast Patrol Boat
PY	-	Yacht

S

SS	-	Submarine
SSB	-	Fleet Ballistic Missile Submarine
SSG	-	Guided Missile Submarine
SSK	-	Killer Submarine
SSO	-	Oiler
SSR	-	Radar Picket Submarine
SST	-	Target Submarine

MILITARY AIRCRAFT MODEL DESIGNATIONS

BASIC MISSION AND TYPE SYMBOLS

Letter	Type
A	Attack
B	Bomber
C	Cargo/Transport
E	Special Electronic Installation
F	Fighter
*H	Helicopter
K	Tanker
O	Observation
P	Patrol
S	Antisubmarine
T	Trainer
U	Utility
*V	VTOL and STOL
X	Research
*Z	Airship

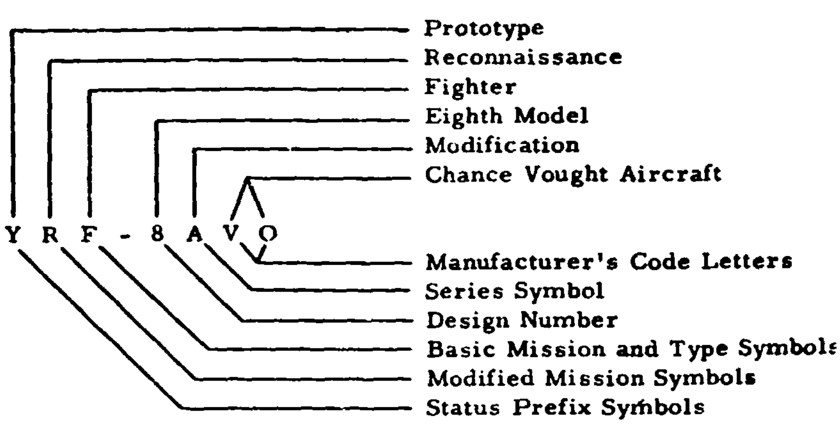
* Type Symbols

MODIFIED MISSION SYMBOLS
(Prefix Letters)

Letter	Title
A	Attack
C	Cargo/Transport
D	Director
E	Special Electronic Installation
H	Search/Rescue
K	Tanker
L	Cold Weather
M	Missile Carrier
Q	Drone
R	Reconnaissance
S	Antisubmarine
T	Trainer
U	Utility
V	Staff
W	Weather

EXAMPLE

YRF-8AVO



"AN" NOMENCLATURE SYSTEM FOR ELECTRONIC EQUIPMENT

INSTALLATION	TYPE OF EQUIPMENT	PURPOSE
A. Airborne	A. Invisible Light, Heat	A. Auxiliary Assemblies
B. Underwater Mobile, Submarine	B. Pigeon	B. Bombing
C. Air Transportable (Inactivated)	C. Carrier	C. Communications
D. Pilotless Carrier	D. Radiac	D. Direction Finder
F. Fixed	E. Nupac	E. Ejection
G. Ground	F. Photographic	G. Fire Control or Searchlight Directing
K. Amphibious	G. Telegraph, Telephone	H. Recording, Reproducing
M. Ground Mobile*	I. Interphone, or P.A.	L. Searchlight (inactivated)
P. Pack or Portable	J. Electro-mechanical	M. Maintenance
S. Water, Surface Craft	K. Telemetering	N. Navigation Aids
T. Ground Transportable	L. Countermeasures	P. Reproducing (inactivated).
U. General Utility, Ship	M. Meterological	Q. Special Purpose
V. Ground Vehicular	N. Sound in air	R. Receiving
W. Water Surface & Underwater	P. Radar	S. Detecting Range and Bearing
	Q. Sonar	T. Transmitting
	R. Radio	W. Control
	S. Special type magnetic	X. Identification and recognition.
	T. Telephone	
	V. Visual	
	W. Armament	
	X. Facsimile, T.V.	

*Vehicles only function is transporting the gear.

ABBREVIATIONS AND SYMBOLS

Abbreviations

The following list of abbreviations is intended to cover those in common use in chemistry and physics. Symbols are presented in a separate list following the abbreviations.

A.	Acre
Å	Ångström unit
a	Are
a.	Acid
abs.	Absolute
abt.	About
a.c.	Alternating current
acet.	Acetone
acet. a.	Acetic acid
al.	Alcohol
alk.	Alkali
alt.	Altitude
amal.	Amalgam; amalgamated
amor. or amorph.	Amorphous
amp.	Ampere
anh.	Anhydrous
antilog	Antilogarithm
ap.	Apothecaries'
appr.	Approximately
aq.	Aqua; aqueous; water
aq. reg.	Aqua regia
asym.	Asymmetrical
atm. or atmos.	Atmosphere (atmospheric)
At. No.	Atomic number
At. Wt.	Atomic weight
aux.	Auxiliary
Av.	Average
av. or avoir.	Avoirdupois
bar.	Barometer
bbl.	Barrel
bd.	Board
Bé	Beaumé (degrees)
B.G.	Birmingham gauge (hoop and sheet)
b.h.p.	Brake horse power
bl.	Blue
blk.	Black
B.M.	Board measure
b.p.	Boiling point
br.	Brown
BTU	British thermal unit
bu.	Bushel
B.W.G.	Birmingham wire gauge
bz.	Benzene
C	Centigrade
c	Carat; centi-
c.	Cold
cd	Candle
ca.	Circa, about; approximately
cal.	Calorie (gram)
cc. or c.c.	Cubic centimeter
cd.	Cord
c. cm	Cubic centimeter
Cent.	Centigrade
centi-	Prefix meaning 1/100
cf.	*Confer*, compare
c.f.m.	Cubic foot per minute
cgs	Centimeter-gram-second system of units
cgse	Cgs electrostatic system
cgsm	Cgs electromagnetic system
ch.	Chain
chl.	Chloroform
cir.	Circular
circum.	Cirumference
cl	Centiliter
cm	Centimeter
cm^2	Square centimeter
cm^3	Cubic centimeter
c.m.	Circular mil
coef.	Coefficient
colog	Cologarithm
colorl.	Colorless
comm'l	Commercial
conc.	Concentrated
cond.	Condensing
const.	Constant
cos	Cosine
cos^{-1}	Arc or angle whose cosine is...; arc-cosine of; inverse cosine of
cosec	Cosecant
cosh	Hyperbolic cosine
$cosh^{-1}$	Inverse hyperbolic cosine
cot	Cotangent
cot^{-1}	Arc or angle whose cotangent is . . .
coth	Hyperbolic cotangent
$coth^{-1}$	Inverse hyperbolic cotangent
covers	Coversed sine
c.p.	Candle power; circular pitch; center of pressure
cry. or cryst.	Crystalline; crystals
csc	Cosecant
csc^{-1}	Arc or angle whose cosecant is...
csch	Hyperbolic cosecant
$csch^{-1}$	Inverse hyperbolic cosecant
CTU	Centigrade thermal unit
cu.	Cubic
cu. cm	Cubic centimeter
cu. ft.	Cubic foot
cu. in.	Cubic inch
cu. m	Cubic meter
cu. yd.	Cubic yard
cwt.	Hundredweight
cyl.	Cylinder
d	Derivative; deci-
d.	Decomposes; day
d.	Dextrorotary
d.c.	Direct current
dec.	Decomposes
deci-	Prefix meaning 1/10
def.	Definition (s)
deg	Thermometric degree; absolute C unless contrary is indicated
deka-	Prefix meaning 10
deliq.	Deliquescent
den. or dens.	Density
dg	Decigram
diam.	Diameter
dil.	Dilute
dissd.	Dissolved
dk	Deka-
dk.	Dark
dkg.	Dekagram
dkl	Dekaliter
dkm	Dekameter
dkm^2	Square dekameter
dkm^3	Cubic dekameter
dks	Dekastere
dl	Deciliter
dm	Decimeter
dm^2	Square decimeter
dm^3	Cubic decimeter
d.p.	Diametral pitch; double pole
dr.	Dram
dr. ap. or ʒ ap.	Dram, apothecaries'
dr. av. or ʒ av.	Dram, avoirdupois
dr. fl. or ʒ fl.	Dram, fluid
dr. t. or ʒ t.	Dram, troy
ds	Decistere
dwt.	Pennyweight
efflor.	Efflorescent
e.g.	*Exempli gratia*, for example
e.h.p.	Effective horse power
E.L.	Elastic limit
em	Cgsm unit of quantity of electricity
emf or e.m.f.	Electromotive force
es	Electrostatic or cgse unit of quantity of electricity
etc.	*Et cetera*, and so forth
eth.	Ether
eth. acet.	Ethyl acetate
et. seq.	*Et sequentes*, and the following
evap.	Evaporation
ex.	Excess
exp	Exponential function
exp.	Explodes
exsec	Exterior secant
F	Fahrenheit
f.	From
fahr.	Fahrenheit
fath.	Fathom
feath.	Feathery
f.h.p.	Friction horse power
fir.	Firkin
fl.	Fluid
fl. dr.	Dram, fluid
fl. oz.	Ounce, fluid
fluores.	Fluorescent
fps	Foot-pound-second system of units
fpse	Foot-pound-second electrostatic system
fpsm	Foot-pound-second electromagnetic system
F.S.	Factor of safety
ft.	Foot
$ft.^2$	Square foot
$ft.^3$	Cubic foot
ft.-lb.	Foot-pound
fur.	Furlong
G	Gravitation constant
g	Gram
g-cal. or g.-cal.	Gram calorie
gal.	Gallon
gel.	Gelatinous
gi.	Gill
glac.	Glacial
glit.	Glittering
glyc.	Glycerine
gm.	Gram
gr.	Gray; grain
grn.	Green
gyr.	Gyration
h	Hecto-
h.	Hot; hour
ha	Hectare
hecto-	Prefix meaning 100
hex.	Hexagonal
hg	Hectogram
hhd.	Hogshead
hl	Hectoliter
hm	Hectometer
hm^2	Square hectometer
hm^3	Cubic hectometer
hor. or horiz.	Horizontal
h.-p.	High-Pressure
HP or h.p.	Horse power
h.p.-hr.	Horse power-hour
hr.	Hour
hyg.	Hygroscopic
i.	Insoluble
ibid.	*Ibidem*, in the same place
i.e.	*id est*, that is
ign.	Ignites
i.h.p.	Indicated horse power
in.	Indigo; inch
$in.^2$	Square inch
$in.^3$	Cubic inch
inc.	Inclusive
in.-lb.	Inch-pound
insol.	Insoluble
Int.	International
iso.	Isotropic
isom.	Isometric
isoth.	Isothermal
k	Kilo-
kg	Kilogram
kg-cal.	Kilogram-calorie
kg-m	Kilogram-meter
kilo-	Prefix meaning 1,000
kl	Kiloliter
km	Kilometer
km^2	Square kilometer
km^3	Cubic kilometer
kva.	Kilovolt-ampere
kw.	Kilowatt
kw.-hr.	Kilowatt-hour
l	Liter
l.	Long
l	Laevorotary
lat.	Latitude
lb.	Pound
lb. ap.	Pound, apothecaries'
lb. av.	Pound, avoirdupois
lb. t.	Pound, troy
leaf.	Leaflets
lgr.	Ligroin
li.	Link
lin.	Linear
liq.	Liquid
lim.	Limit
ln	Natural hyperbolic or Napierian logarithm
log or log.	Logarithm
log_e	Logarithm to the base e; natural, hyperbolic or Napierian logarithm
log_{10}	Common logarithm; logarithm to the base 10
long.	Longitude
lng.	Long
l.-p.	Low-pressure
lt.	Light
lust.	Lustrous
♏	Minim or drop
m	Meter; milli-
m^2	Square meter
m^3	Cubic meter
m.	Minute
m.	Meta-
max.	Maximum
med.	Medium
meth.	Methyl
meth. al.	Methyl alcohol
m.e.p.	Mean effective pressure
met.	Metallic
mg	Milligram
m.h.c.p.	Mean horizontal candle power
mi.	Mile
mic.	Microscopic
micro-	Prefix meaning 1/1,000,000 or 10^{-6}
micro-micro	Prefix meaning 10^{-12}
milli-	Prefix meaning 1/1,000
milli-micro-	Prefix meaning 10^{-9}
min or min.	Minute
min.	Minim; minimum; mineral
ml	Milliliter
m.l.h.c.p.	Mean lower hemispherical candle power
mm	Millimeter
mm^2	Square millimeter
mm^3	Cubic millimeter
mmf or m.m.f.	Magnetomotive force
mol.	Molecule
Mol. Wt.	Molecular weight
monocl.	Monoclinic
m.p.	Melting point
m.s.c.p.	Mean spherical candle power
myria-	Prefix meaning 10,000 or 10^4
$m\mu$	Millimicron; millimicro-
N	Numeric; number (in mathematical tables)
n.	Normal
n	Refractive index
need.	Needles
o	Ortho-
Obs.	Observer
octahdr.	Octahedral
oil turp.	Oil of turpentine
or.	Orange
oz.	Ounce
oz. ap. or ℥ ap.	Ounce, apothecaries'
oz. av. or ℥ av.	Ounce, avoirdupois
oz. fl. or ℥ fl.	Ounce, fluid
oz. t. or ℥ t.	Ounce, troy
p	Para-
pa.	Pale
p. ct.	Per cent
perp.	Perpendicular
p.f.	Power factor
pk.	Peck
pl.	Plates
powd.	Powder
pr.	Prisms
precip. or p'p't'd	Precipitated
p. sol.	Partly soluble
pt.	Point; pint
purp.	Purple
pyr.	Pyridine
Q	Quantity
q	Quintal
qt.	Quart
q.v.	*Quod vide*, which see
R	Réaumur; radioactive mineral
rac	Racemic
rad	Radian, measure of angle
rad.	Radius
rd.	Rod
reg.	Regular
rev.	Revolution
rhbdr.	Rhombohedral
rhomb.	Rhombic or orthorhombic
R.M.S.	Square root of mean square
r.p.m.	Revolutions per minute
s	Stere
s.	Scruple; soluble; second
s. ap. or ℈	Scruple, apothecaries'
sat. or sat'd	Saturated
sc.	Scales
S.E.	Siemens unit
sec or sec.	Second (mean solar unless contrary is stated)
sec	Secant
sec^{-1}	Arc or angle whose secant is . . .
sech	Hyperbolic secant
$sech^{-1}$	Inverse hyperbolic secant
segm.	Segment
sh.	Short
sin	Sine
sin^{-1}	Arc or angle whose sine is . . .
sinh	Hyperbolic sine
$sinh^{-1}$	Inverse hyperbolic sine
sl.	Slightly
sm.	Small
sol.	Solution; soluble
soln.	Solution
sp.	Specific
specif.	Specification
sp. gr.	Specific gravity
sq.	Square
sq. ch.	Square chain
sq. ft.	Square foot
sq. in.	Square inch
sq. mi.	Square mile
sq. rd.	Square rod
sq. yd.	Square yard
std.	Standard
subl.	Sublimes
sym.	Symmetrical
t	Metric ton
t.	Troy
tab. or tabl.	Tablets
tan	Tangent
tan^{-1}	Arc or angle whose tangent is . . .
tanh	Hyperbolic tangent
$tanh^{-1}$	Inverse hyperbolic tangent
temp.	Temperature
tetr. or tetrag.	Tetragonal
tn.	Ton
tr.	Transition
tricl.	Triclinic
trig.	Trigonal
trim.	Trimetric
T.S.	Tensile strength
turp.	Turpentine
Tw.°	Degrees Twaddell, hydrometer scale
ult.	Ultimate
uns.	Unsymmetrical
U.S.	United States of America; universal system of lens apertures
v.	Very
v.	*Vide*, see
vel. or veloc.	Velocity
vers	Versed sine
vert	Vertical
visc.	Viscous
vol.	*Volume*
volt.	Volatilizes
w.	Water
wh.	White
wt.	Weight
yd.	Yard
yel.	Yellow
yr.	Year
μ	Micron; micro-
$\mu\mu$	Micromicron; micromicro-

SPELLING AND SYMBOLS FOR UNITS

From "Units of Weight and Measure"
L. B. Chisholm, National Bureau of Standards
Miscellaneous Publication 286 (May, 1967)

The spelling of the names of units as adopted by the National Bureau of Standards is that given in the list below. The spelling of the metric units is in accordance with that given in the law of July 28, 1866, legalizing the Metric System in the United States.

Following the name of each unit in the list below is given the symbol that the Bureau has adopted. Attention is particularly called to the following principles:

1. No period is used with symbols for units. Whenever "in" for inch might be confused with the preposition "in", "inch" should be spelled out.

2. The exponents "^{2}" and "^{3}" are used to signify "square" and "cubic," respectively, instead of the symbols "sq" or "cu," which are, however, frequently used in technical literature for the U. S. Customary units.

3. The same symbol is used for both singular and plural.

Some Units and Their Symbols

Unit	Symbol	Unit	Symbol	Unit	Symbol
acre	acre	fathom	fath	millimeter	mm
are	a	foot	ft	minim	minim
barrel	bbl	furlong	furlong	ounce	oz
board foot	fbm	gallon	gal	ounce, avoirdupois	oz avdp
bushel	bu	grain	grain	ounce, liquid	liq oz
carat	c	gram	g	ounce, troy	oz tr
Celsius, degree	°C	hectare	ha	peck	peck
centare	ca	hectogram	hg	pennyweight	dwt
centigram	cg	hectoliter	hl	pint, liquid	liq pt
centiliter	cl	hectometer	hm	pound	lb
centimeter	cm	hogshead	hhd	pound, avoirdupois	lb avdp
chain	ch	hundredweight	cwt	pound, troy	lb tr
cubic centimeter	cm^3	inch	in	quart, liquid	liq qt
cubic decimeter	dm^3	International		rod	rod
cubic dekameter	dam^3	Nautical Mile	INM	second	s
cubic foot	ft^3	Kelvin, degree	°K	square centimeter	cm^2
cubic hectometer	hm^3	kilogram	kg	square decimeter	dm^2
cubic inch	in^3	kiloliter	kl	square dekameter	dam^2
cubic kilometer	km^3	kilometer	km	square foot	ft^2
cubic meter	m^3	link	link	square hectometer	hm^2
cubic mile	mi^3	liquid	liq	square inch	in^2
cubic millimeter	mm^3	liter	liter	square kilometer	km^2
cubic yard	yd^3	meter	m	square meter	m^2
decigram	dg	microgram	μg	square mile	mi^2
deciliter	dl	microinch	μin	square millimeter	mm^2
decimeter	dm	microliter	μl	square yard	yd^2
dekagram	dag	micron	μm	stere	stere
dekaliter	dal	mile	mi	ton, long	long ton
dekameter	dam	milligram	mg	ton, metric	t
dram, avoirdupois	dr avdp	milliliter	ml	ton, short	short ton
				yard	yd

PRACTICAL ELECTRICAL UNITS

Quantity	Sym	Equation (cgs)	Practical unit
Current	I, i	$I = E/R$; $I = E/Z$ $I = Q/t$	Amp
Charge	Q, q	$Q = it$; $Q = CE$	Coulomb
Electromotive force	E, e	$E = IR$; $E = W/Q$	Volt
Resistance	R, r	$R = E/I$; $R = \rho l/A$	Ohm
Resistivity	ρ	$\rho = RA/l$	Ohm-cm
Conductance	G, g	$G = \gamma A/l$	Mho, siemens
Conductivity	γ	$\gamma = 1/\rho = l/RA$	Mho per cm
Capacitance	C	$C = Q/E$	Farad
Capacitivity (dielectric constant)	ϵ_r	Numeric	....
Self-inductance	L	$L = -N\dfrac{d\phi}{di}$	Henry
Mutual inductance	M	$M = K\sqrt{L_1L_2}$	Henry
Energy	W	$W = eit$	Joule
	whr	whr $= eiT$	Watthour
	kwh	kwh $= eiT/1{,}000$	Kilowatt-hour
Apparent power	.....	$P = EI$	Volt-amp
Active power	P, p	$P = \dfrac{dw}{dt} = ei$ $P = EI\cos\theta$	Watt
Reactive power	jQ	$Q = EI\sin\theta$	Var
Power factor	pf	pf $= \dfrac{P}{EI}$ $= \dfrac{P}{\sqrt{P^2 + Q^2}}$	....
Time constant	.....	L/R or RC	Sec
Frequency	f	$f = 1/T$	Cycles per sec
Period	T	$T = 1/f$	Sec
Angular velocity	ω	$\omega = 2\pi f$	....
Reactance, inductive	X_L	$X_L = 2\pi fL$	Ohm
Reactance, capacitive	X_C	$X_C = 1/(2\pi fC)$	Ohm
Impedance	Z	$Z = E/I$ $= \sqrt{R^2 + (X_L - X_C)^2}$	Ohm
Conductance	G	$G = R/Z^2$	Mho
Susceptance	B	$B = X/Z^2$	Mho
Admittance	Y	$Y = I/E$ $= \sqrt{G^2 + B^2}$	Mho

Section 6

REFERENCE SOURCES

Section 6

BASIC REFERENCE SOURCES

Since the number of reference sources related to the many scientific and engineering disciplines with which the human factors engineer may come in contact is almost limitless, only a few, carefully selected basic reference documents are included here. However, these in turn will lead the reader to many others.

Two lists are included. The first consists primarily of commercial or trade publications. The second list is comprised of military standards, reports, regulations and specifications relating to applied human factors in the development of military systems.

It is recognized that every experienced human engineering practitioner will have his own favorite reference texts, and the omission of any such documents from these lists is not in any way intended to minimize their value. Rather it is an attempt to provide the less experienced practitioner with a list of those publications which the great majority of human factors engineers consider essential.

Experience will provide the background for making personal selections and building individual libraries and reference files.

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AFSC DH 1-6	System Safety. Air Force Systems Command/ NASA Design Handbook Series 1-0. Space & Missile Systems, Andrews AFB, Washington, D.C., 20331.
AFSC 80-3	Handbook of Instructions for Aerospace Personnel Subsystem Design. Headquarters, Air Force Systems Command, Andrews AFB, Washington, D.C.
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AFM 35-99	Human Reliability Program, Chapter 6, Attachment 3.
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HEL STD S-2-64	Human Factors Engineering design Standard for Vehicle Fighting Compartments. US Army Human Engineering Laboratories, Aberdeen, Md.
HEL STD S-3-65	Human Factors Engineering Design Standard for Missile Systems and Related Equipment. US Army Human Engineering Laboratories, Aberdeen Proving Ground, Md.
HEL STD S-4-65	Human Factors Engineering Requirements for the Development of US Army Materiel. US Army Human Engineering Laboratories, Aberdeen Proving Ground, Md.
HEL STD S-6-66	Human Factors Engineering Design Standard for Wheeled Vehicles. US Army Human Engineering Laboratories, Aberdeen Proving Ground, Md.

MIL-A- 8806	Acoustical Noise Level in Aircraft, General Specification for
MIL-H- 8810	Handles, Control, Aircraft
MIL-E- 16400	Electronic Equipment, Naval Ship and Shore, General Specification
MIL-K- 25049	Knob, Control, Equipment, Aircraft
MIL-C- 25050	Color, Aeronautical Lights and Lighting Equipment, General Requirements For
MIL-H- 25095	Handbook, Field Maintenance Instructions (for Airborne Electric Equipment) (supersedes MIL-H-7490)
MIL-D-26239	Data, Qualitative and Quantitative Personnel Requirements Information (QQPRI)
MIL-L-27160	Lighting, Instrument, Integral, White, General Specification for
MIL-S-38130	Safety Engineering of Systems and Associated Subsystems and Equipment, General Requirements for
MIL-H-46819	Human Factors Engineering in Development of Missile Systems
MIL-H-46855	Human Engineering Requirements for Military Systems, Equipment and Facilities
MIL-STD- 12	Abbreviations for Use on Drawings and in Technical-Type Publications
MIL-STD-101	Color Code for Pipelines and for Compressed Gas Cylinders
MIL-STD-203	Aircrew Station Controls and Displays for Fixed Wing Aircraft
MIL-STD-250	Cockpit Controls Location and Actuation of, for Helicopters
MIL-STD-411	Aircrew Station Signals
MIL-STD-470	Maintainability Program Requirements for Systems and Equipment
MIL-STD-721	Definitions of Effectiveness Terms for Reliability, Maintainability, Human Factors, and Safety
MIL-STD-740	Airborne and Structureborne Noise Measurement and Acceptance Criteria of Shipboard Equipment
MIL-STD-783	Nomenclature and Abbreviations in Aircrew Stations

MIL-STD-795	Color
MIL-STD-850	Aircrew Station Vision Requirements for Military Aircraft
MIL-STD-1247	Identification of Pipe, Hose, and Tube Lines for Aircraft, Missile, and Space Systems
MIL-STD-1472	Human Engineering Design Criteria for Military Systems, Equipment and Facilities
MS-33558	Numeral and Letter, Aircraft Instrument Dial, Standard Form of
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AR 385-16	Safety for Systems, Associated Subsystems and Equipment
AR 746-5	Color and Marking of Army Materiel
AMCR 70-1	Application of Human Factors Engineering
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AFBSD 62-41	System Safety Engineering, General Specification for Development of Ballistic Missile Systems
AFBSD 62-53	WS-133B Maintainability Design Criteria
AFBSD 62-79	Life Support Subsystem Criteria (WS-133B)
AFBSD 62-101	System Analysis; Procedures for System Definition
AFBSD 61-94	Personnel Planning Information for Space System Research and Development Test Sites
AFBSD 62-44	Human Engineering for Air Force Satellite Control System
BSD 65-10	Personnel Subsystem Test and Evaluation
BSD 65-14	Personnel Subsystem Definition and Development
AFM 11-1	Air Force Glossary of Standardized Terms and Definitions

AFM 11-2	Air Force Manual of Abbreviations
AFM 32-3	Ground Safety - Accident Prevention Handbook
AFM 127-201	Missile Safety Handbook
AFSCM 80-1 (HIAD)	Handbook of Instructions for Aircraft Designers Vol. I - Piloted Aircraft Vol. II - Guided Missiles Vol. III - Aircraft Design Control Drawings
AFSCM 80-5 (HIGED)	Handbook of Instructions for Ground Equipment Designers
AFSCM 80-6 (HIAGSED)	Handbook of Instructions for Ground Support Equipment Designers
AFSCM 80-7 (HIAVED)	Handbook of Instructions for Aerospace Vehicle Equipment Designers
AFSCM 80-8 (HIMD)	Handbook of Instructions for Missile Designers
AFSCM 80-9 (HIASD)	Handbook of Instructions for Aerospace System Designers
AFSCM 122-1	The Nuclear Weapons Safety Program
AFSCM 375-5	System Engineering Management Manual
NAVSHIPS 94324	Maintainability Design Criteria Handbook for Designers of Shipboard Electronic Equipment
MIL-HDBK-220	Glossary of Training Device Terms
ANA 261	Abbreviations and Contractions, Approvedth List of
NAVSHIPS 94324	Human Engineering Guidelines for Maintainability
WADC TR 52-204	Handbook of Acoustic Noise Control (AD 18206)
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AFSWC TR 59-11	Human Factors Handbook for Design of Transporting, Positioning, and Lifting Ground Support Equipment
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NOTE:

A useful compendium of military documents relating to the various aspects of human factors is the following:

> "Regulatory and Advisory Documents Applicable to Human Factors, Personnel, and Training Requirements," Third Edition, published by Man Factors, Inc., 4433 Convoy St., San Diego, Calif. 92111, 1969.