Technical Training

PHYSICAL MEASUREMENT and CALIBRATION

PHYSICAL MEASUREMENT HANDBOOK

DECEMBER 2001

Electronic Warfare/Metrology Training Flight
332d Training Squadron
Keesler AFB, MS 39534-2480

OPR: 332 TRS/UNCD (MSgt Kwasny)

PHYSICAL MEASUREMENT HANDBOOK

This handout provides reference materials, formula, tables , charts, and definitions that apply to the study of physical measurements. Based on AETCI 36-2203, Operation Training Development, the information included in this book will aid you in performing numerous calculations and understanding a myriad of terms. This reference will used throughout your course of study.

TABLE OF CONTENTS

Reviewed By

J. Bartosik, GS-11

GENERAL INFORMATION

CONVERSION FACTORS

MASS and WEIGHT

1 centigram =

0.1543 grains

0.01 grams

1 grain =

6.480×10^{-2} grams

2.286×10^{-3} ounces

1 gram =

100 centigrams

980.7 dynes

15.43 grains

9.807×10^{-5} joules/cm

9.807×10^{-3} joules/meter (newtons)

1.0×10^{-3} kilograms

1,000 milligrams

0.03527 ounces

2.2046×10^{-3} pounds

1 kilogram =

980,665 dynes

1000 grams

9.807×10^{-2} joules/cm

9.807 joules/meter (newtons)

2.2046 pounds

9.842×10^{-4} tons (long)

1.102×10^{-3} tons (short)

1 ounce =

28.349527 grams

437.5 grains

16.0 drams

6.25×10^{-2} pounds

1 ounce (fluid)=

2.957×10^{-2} liters

1.805 cu. in.

1 pound =

0.4536 kilograms

7000 grains

453.5924 grams

256 drams

44.4823×10^{4} dynes

4.448×10^{-2} joules/cm

4.448 joules/meter (newtons)

16.0 ounces

5.0×10^{-4} tons (short)

LENGTH

1 angstrom =

1.0×10^{-8} centimeters

1.0×10^{-10} meters

3.9370×10^{-9} inches

1.0×10^{-4} microns

1 centimeter =

0.3937 inches

3.281×10^{-2} feet

$1.O94 \times 10^{-2}$ yards

6.214×10^{-6} miles

1 foot =

0.3333 yards

30.4801 centimeters

3.048×10^{-4} kilometers

.3048 meters

1.645×10^{-4} nautical miles

1.894×10^{-4} statute miles

1 inch =

2.540 centimeters

8.33×10^{-2} feet

2.778×10^{-2} yards

2.54×10^{-2} meters

25.40 millimeters

25,400 microns

1 kilometer =

0.6214 statute miles

3280.8399 feet

1,094.0 yards

3.937×10^{4} inches

1 knot =

1.0 nautical mile/hr

1 meter =

100 centimeters

39.37 inches

3.281 feet

1.094 yards

5.396×10^{-4} nautical miles

6.214×10^{-4} statue miles

1 micron =

1.0×10^{-4} centimeters

1.0×10^{-6} meters

3.937×10^{-5} inches

1 nautical mile =

6076.1155 feet

1852.0 meters

1.1508 statute miles

2,027 yards

1 statute mile =

5280 feet

1.6093 kilometers

1760 yards

1.609×10^{5} centimeters

6.336×10^{4} inches

.8684 nautical miles

1 yard =

0.9l44 meters

3 feet

36 inches

91.44 centimeters

9.144×10^{-4} kilometers

4.934×10^{-4} nautical miles

5.683×10^{-4} statute miles

VOLUME

in^3 =

16.3871 cm^3

5.787×10^{-4} ft^3

1.639×10^{-5} m^3

2.143×10^{-5} yd^3

4.329×10^{-3} gallons(US Liq)

1.639×10^{-2} liters

3.463×10^{-2} pints(US Liq)

1 ft^3 =

2.832×10^{-2} m^3

1728 in^3

28,320 cm^3

3.704×10^{-2} yd^3

7.48052 gallons(US Liq)

28.32 liters

59.84 pints(US Liq)

29.92 quarts(US Liq)

1 yd^3 =

0.7646 m^3

27 ft^3

7.646×10^{5} cm^3

46,656 in^3

202 gallons(US Liq)

764.5 liters

1615.9 pints(US Liq)

807.9 quarts(US Liq)

1 cm^3 =

6.102×10^{-2} in^3

3.5315×10^{-5} ft^3

1.0×10^{-6} m^3

1.308×10^{-6} yd^3

2.642×10^{-4} gallons(US Liq)

1.0×10^{-3} liters

2.113×10^{-3} pints(US Liq)

1.057×10^{-3} quarts(US Liq)

1 quart (US liquid) =

946.353 cm^3

57.75 in^3

3.342×10^{-2} ft^3

9.464×10^{-4} m^3

.25 gallons

.9463 liters

1 liter =

$1000\ cm^3$

$3.531 \times 10^{-2}\ ft^3$

$61.02\ in^3$

$1.308 \times 10^{-3}\ yd^3$

2.113 pints (US Liq)

1.0567 quarts (US Liq)

.2642 gallons (US Liq)

1 gallon liquid =

$231\ in^3$

$3785.4118\ cm^3$

$0.13368\ ft^3$

$3.7853 \times 10^{-3}\ m^3$

3.7853 liters

WEIGHT per VOLUME

1 gallon of water @4°C

8.33585 lbs of water

1 ft^3 of water =

62.426321 lbs of water @39.2°F

62.277354 lbs of water @60°F

POWER UNITS

1 joule =

1.0×10^7 ergs =

0.2390 calories/gram

1 erg =

1 dyne/cm

7.3756×10^{-8} ft-lbs

1 calorie/gram

4.184 joules

1 BTU =

1054.8 joules

1 horsepower =

745.7 watts

MATHEMATICAL SYMBOLS

+	Positive, Plus, or Add	$\perp$	Perpendicular to
-	Negative, Minus, or Subtract	$\parallel$	Parallel to
± or +/-	Positive or Negative Plus or Minus	π	Pi
X or ·	Multiply	$\in$	Base of natural log 2.718
÷ or /	Divide	$\sqrt{\ }$	Square root
= or ::	Equals	$\sqrt[3]{\ }$	Cube root
≡	Identical	$\sqrt[n]{\ }$	n^{th} root
≠	Not equal to	$\|n\|$	Absolute value of n
≅ or ≈	Approximately equal to	$n°$	n degrees
>	Greater than	n'	minutes of a degree feet or prime
<	Less than	n"	seconds of a degree inches or second
≥	Greater than or equal to	$\bar{n}$	Average value of n
≤	Less than or equal to	j	Square root of -1
::	Proportional to	%	Percentage
:	Ratio	n_l	Subscript of n
∴	Therefore	( )	Parentheses
∞	Infinity	[ ]	Brackets
Δ	Increment or change	{ }	Braces
∠	Angle	—	Vinculum

GREEK ALPHABET

NAME	UPPER CASE	COMMONLY DESIGNATES	LOWER CASE	COMMONLY DESIGNATES
Alpha	A		α	angles, area, absorption factor, atten. constant, I gain CB config.
Beta	B		β	angles, coefficients, phase constant, flux density, I gain CE config.
Gamma	Γ	complex propagation constant	γ	angles, specific gravity, elect. conductivity, propag'n constant
Delta	Δ	increment, determinant, permittivity, variation	δ	angles, density, increment
Epsilon	E		∊	base of natural logs, dielectric constant, electrical intensity
Zeta	Z	impedance	ζ	coordinates, coefficients
Eta	H		η	hysteresis, coordinates, efficiency intrinsic impedance
Theta	θ		θ	angular phase displacement, time constant, reluctance
Iota	I	current	ι	unit vector
Kappa	K		κ	coupling coefficient, susceptibility, dielectric constant
Lambda	Λ	permeance	λ	wavelength, attenuation constant
Mu	M		μ	prefix micro, amplification factor, permeability
Nu	N		ν	frequency, reluctivity
Xi	Ξ		ξ	coordinates, output coefficients
Omicron	O		ο	reference point
Pi	Π		π	3.1416
Rho	P		ρ	resistivity, volume charge density, coordinates
Sigma	Σ	summation	σ	electrical conductivity, leakage coefficient, complex propag'n constant
Tau	T		τ	time constant, time phase displacement, transmission factor, torque
Upsilon	Υ		υ	
Phi	Φ	sealar potential, magnetic flux, radiant flux	ϕ	phase angle
Chi	X		χ	angles, electrical susceptibility
Psi	Ψ		ψ	angles, coordinates, dielectric flux, phase difference
Omega	Ω	resistance in ohms	ω	angular velocity (2pf)

POWER OF TEN MULTIPLIER CHART

Multiple or Submultiple	Symbol	Prefix	Name
10^{12} = 1,000,000,000,000	T	Tera	Trillion
10^{9} = 1,000,000,000	G	Giga	Billion
10^{8} = 100,000,000			Hundred Million
10^{7} = 10,000,000			Ten Million
10^{6} = 1,000,000	M	Mega	Million
10^{5} = 100,000			Hundred Thousand
10^{4} = 10,000			Ten Thousand
10^{3} = 1,000	K	Kilo	Thousand
10^{2} = 100	H	Hecto	Hundred
10^{1} = 10	D	Deka	Ten
10^{0} = 1			One
10^{-1} = .1	d	Deci	One Tenth
10^{-2} = .01	c	Centi	One Hundredth
10^{-3} = .001	m	Milli	One Thousandth
10^{-4} = .0001			One Ten-Thousandth
10^{-5} = .00001			One Hundred-Thousandth
10^{-6} = .000001	μ	Micro	One Millionth
10^{-7} = .0000001			One Ten-Millionth
10^{-8} = .00000001			One Hundred-Millionth
10^{-9} = .000000001	n	Nano	One Billionth
10^{-12} = .000000000001	p	Pico	One Trillionth
10^{-15} = .000000000000001	f	Femto	One Quadrillionth
10^{-18} = .000000000000000001	a	Atto	One Quintillionth

POWER of TEN CONVERSION CHART

Move the decimal point the number of places and direction noted

To → / From ↓	tera	giga	mega	kilo	basic	deci	centi	milli	micro	nano	pico	femto	atto
Tera		3 →	6 →	9 →	12 →	13 →	14 →	15 →	18 →	21 →	24 →	27 →	30 →
Giga	3 ←		3 →	6 →	9 →	10 →	11 →	12 →	15 →	18 →	21 →	24 →	27 →
Mega	6 ←	3 ←		3 →	6 →	7 →	8 →	9 →	12 →	15 →	18 →	21 →	24 →
kilo	9 ←	6 ←	3 ←		3 →	4 →	5 →	6 →	9 →	12 →	15 →	18 →	21 →
basic	12 ←	9 ←	6 ←	3 ←		1 →	2 →	3 →	6 →	9 →	12 →	15 →	18 →
Deci	13 ←	10 ←	7 ←	4 ←	1 ←		1 →	2 →	5 →	8 →	11 →	14 →	17 →
Centi	14 ←	11 ←	8 ←	5 ←	2 ←	1 ←		1 →	4 →	7 →	10 →	13 →	16 →
Milli	15 ←	12 ←	9 ←	6 ←	3 ←	2 ←	1 ←		3 →	6 →	9 →	12 →	15 →
micro	18 ←	15 ←	12 ←	9 ←	6 ←	5 ←	4 ←	3 ←		3 →	6 →	9 →	12 →
Nano	21 ←	18 ←	15 ←	12 ←	9 ←	8 ←	7 ←	6 ←	3 ←		3 →	6 →	9 →
pico	24 ←	21 ←	18 ←	15 ←	12 ←	11 ←	10 ←	9 ←	6 ←	3 ←		3 →	6 →
Femto	27 ←	24 ←	21 ←	18 ←	15 ←	14 ←	13 ←	12 ←	9 ←	6 ←	3 ←		3 →
Atto	30 ←	27 ←	24 ←	21 ←	18 ←	17 ←	16 ←	15 ←	12 ←	9 ←	6 ←	3 ←	

BINARY CONVERSION

	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0	
	512	256	128	64	32	16	8	4	2	1	
EXAMPLE:	0	0	1	0	1	0	1	1	0	0	$= 172_{10}$

BINARY NUMBER	DECIMAL NUMBER
1	1
10	2
11	3
100	4
101	5
110	6
111	7
1000	8
1001	9
1010	10
110010	50
1100100	100

MATHEMATICS

SEQUENCE OF MATHEMATICAL OPERATIONS

Remember

Please Excuse My Dear Aunt Sally

Parentheses	(P)	Please
Exponents	(E)	Excuse
Multiply	(M)	My
Divide	(D)	Dear
Add	(A)	Aunt
Subtract	(S)	Sally

SIGNIFICANT FIGURES/SIGNIFICANT DIGITS

Figures arrived at by counting are often exact. On the other hand, figures arrived at by measuring areapproximate. Significant figures express the accuracy of the measurement.

When counting significant figures, all digits (including zeros) are counted **EXCEPT** those zeros that are to the left of the number.

Example:	4.3	contains 2 significant figures/digits
	0.0234	contains 3 significant figures/digits
	0.1100	contains 4 significant figures/digits

ROUNDING OFF NUMBERS

Rule 1: If the first digit to the right of the last significant digit is a 6, 7, 8, or 9 round up by increasing the last significant digit by one and dropping all the following digits. (Example rounded off to three significant digits to the right of the decimal)

45.784624 becomes 45.785

Rule 2: If the first digit to the right of the last significant digit is a 0, 1, 2, 3, or 4, round down by leaving the last significant digit unchanged, and dropping all the following digits. (Example rounded off to two significant digits to the right of the decimal)

45.784624 becomes 45.78

Rule 3: If the first digit to the right of the last significant digit is a 5, and there are additional digits other than 0, round up by increasing the last significant digit by one, and dropping all the following digits. (Example rounded off to two significant digits to the right of the decimal)

7.1450004 becomes 7.15

Rule 4: If the first digit to the right of the last significant digit is a 5, and there are no additional digits other than 0, round to the nearest even digit. This rule is also known as the odd-even rule for rounding off numbers. (Examples rounded off to two significant digits to the right of the decimal)

7.1450000 becomes 7.14
7.1550000 becomes 7.16

EXPONENTS

Zero exponent $a^{\circ} = 1$

Negative exponent $a^{-x} = \frac{1}{a^{x}}$

Multiplication $a^{x} \cdot a^{y} = a^{(x+y)}$

Division $a^{x} \div a^{y} = \frac{a^{x}}{a^{y}} = a^{(x-y)}$

Power of a product $(ab)^{x} = a^{x}b^{x}$

Power of a power $(a^{x})^{y} = a^{xy}$

Root of a power $\sqrt[y]{a^{x}} = a^{x/y}$

Fractional exponents $a^{1/4} = \sqrt[4]{a}$ $\quad \frac{x}{a^{y}} = \sqrt[y]{a^{x}}$

Radicals $\sqrt{\frac{a}{b}} = \frac{\sqrt{a}}{\sqrt{b}}$ $\quad \sqrt{ab} = \sqrt{a} * \sqrt{b}$

INTERPOLATION

To interpolate a value for any number in a given table

$$X = \left[\frac{(A_m - A_1)(B_2 - B_1)}{(A_2 - A_1)}\right] + B_1$$

Where:

X = unknown
A_m = measured amount
A_1 = lower of the two amounts bracketing the measured amount
A_2 = higher of the two amounts bracketing the measured amount
B_1 = value (from table) for A_1
B_2 = value (from table) for A_2

SCIENTIFIC NOTATION

A whole number between 1 and 10 times the proper power of ten, also called standard form.

Example: 4.30×10^4

NUMERICAL CONSTANTS (extended)

π or h = 3.14159 26535 89793 23846 26433 83279 50288 41971

ϵ or j = 2.71828 18284 59045 23536 02874 71352 66249 77572

TRIGONOMETRY AND GEOMETRY

Remember:

$$\text{Sin}\,\theta = \frac{\text{opposite}}{\text{hypotenuse}} \qquad \frac{\text{Oscar}}{\text{Had}} = \text{Sick} \qquad \frac{\text{O}}{\text{H}} = \text{S}$$

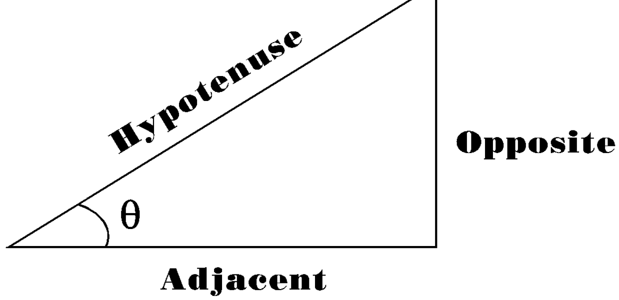
$$\text{Cos}\,\theta = \frac{\text{adjacent}}{\text{hypotenuse}} \qquad \frac{\text{A}}{\text{Heap}} = \text{Call} \qquad \frac{\text{A}}{\text{H}} = \text{C}$$

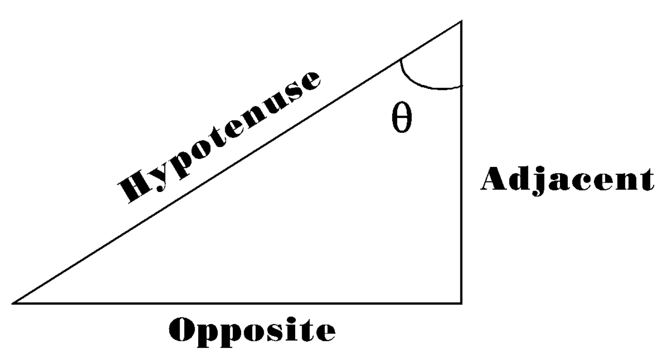
$$\text{Tan}\,\theta = \frac{\text{opposite}}{\text{adjacent}} \qquad \frac{\text{Of}}{\text{Apples}} = \text{Tomorrow} \qquad \frac{\text{O}}{\text{A}} = \text{T}$$

TRIGONOMETRIC RELATIONS

θ = angle between hypotenuse and adjacent side (base)

ϕ = angle between hypotenuse and the opposite side





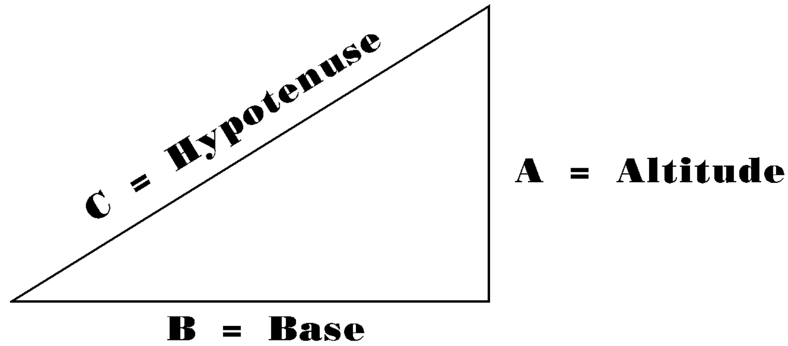
PYTHAGOREAN THEOREM

In a right triangle, the square of the hypotenuse is equal to the sum of the squares of the other two sides.

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

$a^2 = c^2 - b^2$

$b^2 = c^2 - a^2$

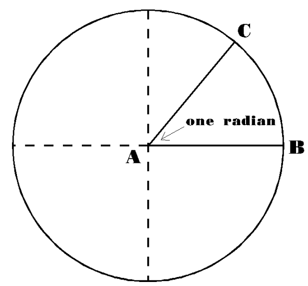


RADIAN MEASURE

The circular system of angular measurement is called radian measure.
A radian is an angle that intercepts an arc equal in length to the radius of a circle as illustrated below.

Length of arc BC = radius of circle

6.28 radians = 360°
2π radians = 360°
π radians = 180°
1 radian = 57.2958°
1 degree = 0.01745 radian

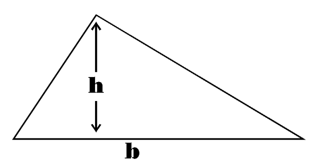


VARIOUS MEASUREMENTS

Plane figures bounded by straight lines.

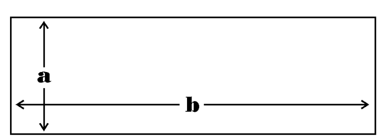
Area of a triangle whose base is (**b**) and altitude (**h**).

$$\text{Area} = \frac{bh}{2}$$



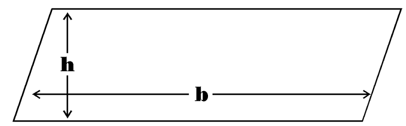
Area of a rectangle with sides (**a**) and (**b**).

Area = ab

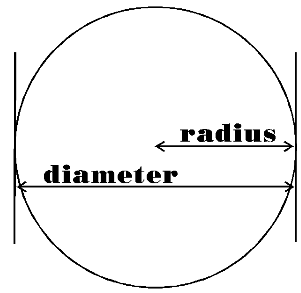


Area of a parallelogram with side **(b)** and perpendicular distance to the parallel side (**h**).

Area = bh



Plane figures bounded by curved lines.

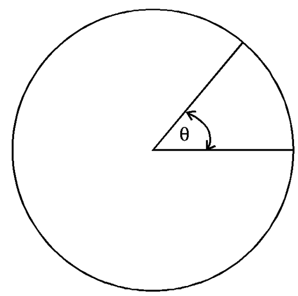


Circumference of a circle whose radius is (r) and diameter (d)

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

Area of a circle

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



Length of an arc of a circle for an arc of θ degrees.

Length of Arc = $\dfrac{\pi r\theta}{180}$

ERROR CALCULATIONS

E = N - A

C = A – N

Where:

E = Error

C = Correction

A = Actual value (as indicated by the standard or a value as determined through calculation)

N = Nominal value (as indicated by the TI)

Relative Error

$$e_r = \frac{\text{M - T}}{\text{T}}$$

Where:

e_r = relative error

M = measured value

T = true value

Percent Relative Error

$$e_r(\%) = \frac{\text{M - T}}{\text{T}} \times 100$$

Where:

e_r (%) = percent relative error

M = measured value

T = true value

a. The true value is usually replaced by the accepted or nominal value because the true value is never exactly known.

DIMENSIONAL ANALYSIS

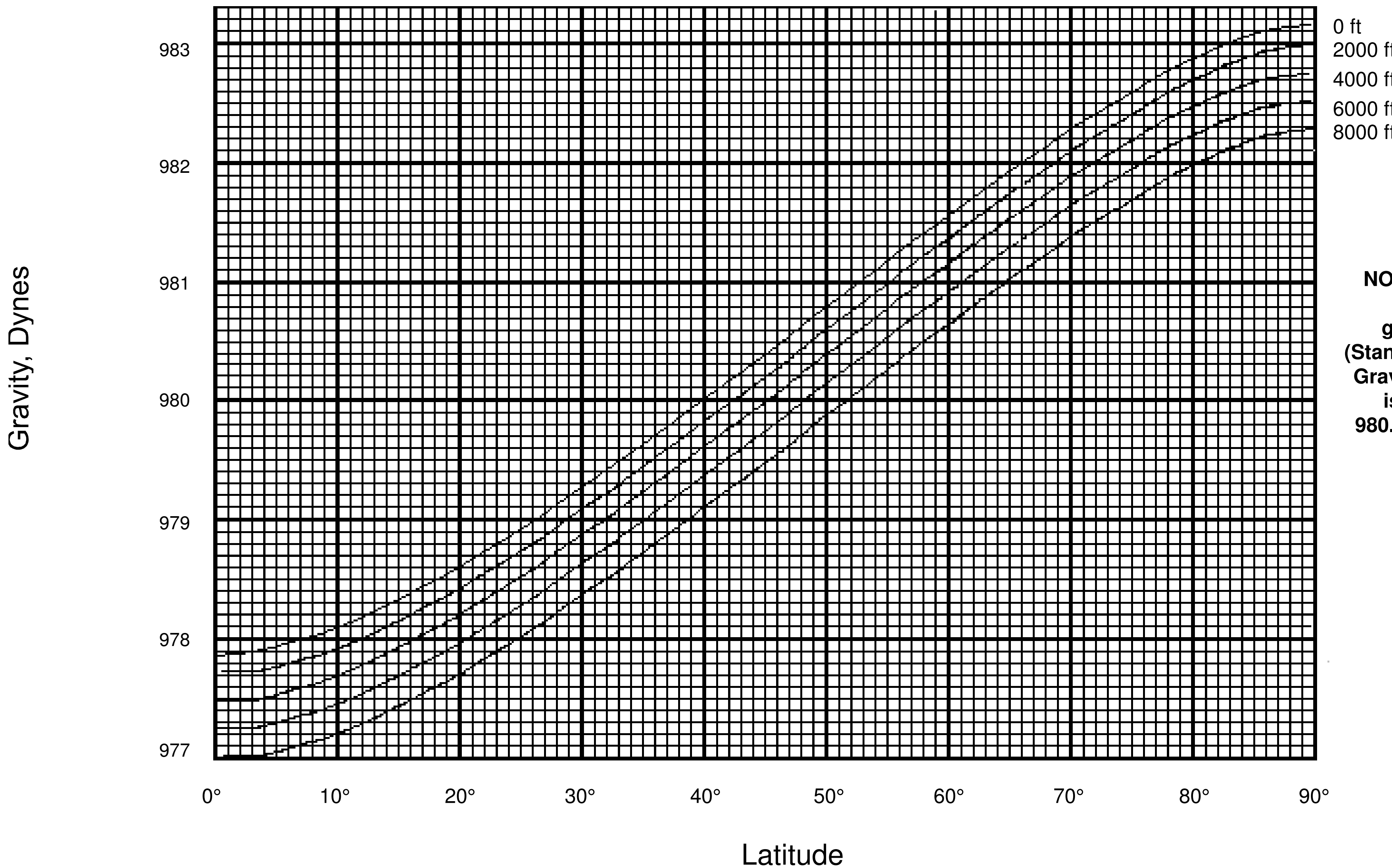
$$\frac{80\text{ ft}}{\text{sec}} = \frac{80\text{ ft}}{\text{sec}} \times \frac{12\text{ in}}{1\text{ ft}} \times \frac{2.54\text{ cm}}{1\text{ in}} \times \frac{1\text{ m}}{100\text{ cm}} \times \frac{1\text{ km}}{1000\text{ m}} \times \frac{60\text{ sec}}{1\text{ min}} \times \frac{60\text{ min}}{1\text{ hr}} = \frac{87.78\text{ km}}{\text{hr}}$$

DENSITIES OF VARIOUS SUBSTANCES

	ρ (grams/cm^3)	D (lbs/in^3)	Conditions
Acetone	0.792	0.02858778	20° C
Alcohol, ethyl	0.791	0.02858778	20° C
methyl	0.810	0.02922435	0° C
Carbon tetrachloride	1.595	0.05763852	20° C
Gasoline	0.66 - 0.69	0.0237267 - 0.0248841	
Kerosene	0.82	0.02962944	
Mercury	13.5955	.49116	
Milk	1.028 - 1.035	0.03715254 - 0.03738402	
Oils, Castor	0.969	0.03501135	15° C
Cotton seed	.926	0.03344886	16° C
Lubricating	.852 - .877	.0307 - .0318	15° C
Fuel	.928 - .979	.0336 - .0353	15° C
Seawater	1.025	0.037031013	15° C
Turpentine (spirits)	0.87	0.03142341	
Water	1.000	0.036127	4° C

Gravity vs. Latitude Elevation Chart

NOTE: Curves not drawn to scale



NOTE

g_o (Standard Gravity) is 980.655

LINEAR COEFFICIENTS OF EXPANSION, α

SUBSTANCE	$\frac{n \times 10^{-6}}{C^\circ}$	$\frac{n \times 10^{-6}}{F^\circ}$
Aluminum	25.0	13.89
Brass (Yellow)	18.9	10.5
Chromium Carbide	8.1	4.5
Copper	16.6	9.22
Iron (Cast)	12.0	6.67
Nickel	13	7.22
Platinum	9.0	5.0
Steel (Hardened)	11.5	6.4
Steel (Carbon)	11.3	6.30
Tungsten	4.50	2.50
Tungsten Carbide	5.40	3.0
Zinc	35.0	19.4

$$\mathbf{L_f = L_o (1 + \alpha\Delta t)} \qquad \mathbf{\Delta L = (L_o)(\alpha)(\Delta t)}$$

Where:

L_f = Length Final

L_o = Length Original

ΔL = Change in Length

α = Linear Coefficient of Expansion

t_1 = Original Temperature (68° F or 20° C)*

t_2 = Final Temperature

Δt = Change in Temperature (t_2 - t_1)

C°/F° = Diff in Temperatures (unit of measure)

*T.O. 00-20-14, Para 8.2.3.1.2 states that "by international agreement the true size and shape of an object is that which exists at a uniform temperature of 68ºF (20ºC)".

GAGE BLOCK CLASSIFICATION *(μ in)*

	Grade 0.5		Grade 1		Grade 2		Grade 3	
Nominal Size(in)	Length	Flatness & Parallelism	Length	Flatness & Parallelism	Length	Flatness & Parallelism	Length	Flatness & Parallelism
0 - 1	±1	1	±2	2	+4-2	4	+8-4	5
2	±2	1	±4	2	+8-4	4	+16-8	5
3	±3	1	±5	3	+10-5	4	+20-10	5
4	±4	1	±6	3	+12-6	4	+24-12	5
5			±7	3	+14-7	4	+28-14	5
6			±8	3	+16-8	4	+32-16	5
7			±9	3	+18-9	4	+36-18	5
8			±10	3	+20-10	4	+40-20	5
10			±12	4	+24-12	5	+48-24	6
12			±14	4	+28-14	5	+56-28	6
16			±18	4	+36-18	5	+72-36	6
20			±20	4	+40-20	5	+80-40	6

GAGE BLOCK SET NO. 481 (inches)

.050	.102	.114	.126	.138	.150	.750
.100	.103	.115	.127	.139	.200	.800
.1001	.104	.116	.128	.140	.250	.850
.1002	.105	.117	.129	.141	.300	.900
.1003	.106	.118	.130	.142	.350	.950
.1004	.107	.119	.131	.143	.400	1.000
.1005	.108	.120	.132	.144	.450	2.000
.1006	.109	.121	.133	.145	.500	3.000
.1007	.110	.122	.134	.146	.550	4.000
.1008	.111	.123	.135	.147	.600	
.1009	.112	.124	.136	.148	.650	
.101	.113	.125	.137	.149	.700	

Seven extra blocks used to make up an 88 Block set

.0625 = $1/16$	.078125 = $5/64$	.093750 = $3/32$	.109375 = $7/64$	.100025	.100050	.100075

ANGLE BLOCK SETS

Set No. 6	6 Blocks, 1 deg. smallest increment					
6 Blocks	1°	3°	5°	15°	30°	45°
Set No. 11	11 Blocks, 1 min. smallest increment					
6 Blocks	1°	3°	5°	15°	30°	45°
5 Blocks	1’	3’	5’	20’	30’	
Set No. 16	16 Blocks, 1 sec. smallest increment					
6 Blocks	1°	3°	5°	15°	30°	45°
5 Blocks	1’	3’	5’	20’	30’	
5 Blocks	1”	3”	5”	20”	30”	

TEMPERATURE

TEMPERATURE CONVERSION CHART

FROM	TO	FORMULA
FAHRENHEIT	CELSIUS	$(F - 32) \div 1.8$
	KELVIN	$(F + 459.67) \div 1.8$
	RANKINE	$F + 459.67$
RANKINE	KELVIN	$R \div 1.8$
	CELSIUS	$(R - 491.67) \div 1.8$
	FAHRENHEIT	$R - 459.67$
CELSIUS	FAHRENHEIT	$(1.8 \times C) + 32$
	RANKINE	$(1.8 \times C) + 491.67$
	KELVIN	$C + 273.15$
KELVIN	RANKINE	$1.8 \times K$
	FAHRENHEIT	$(1.8 \times K) - 459.67$
	CELSIUS	$K - 273.15$

STEM CORRECTIONS

$$C = KN(t_i - \overline{t_s})$$

Where:

C = Correction

K = Differential expansion coefficient between mercury and glass

$K = .00016/C°$ or $K = .00009/F°$

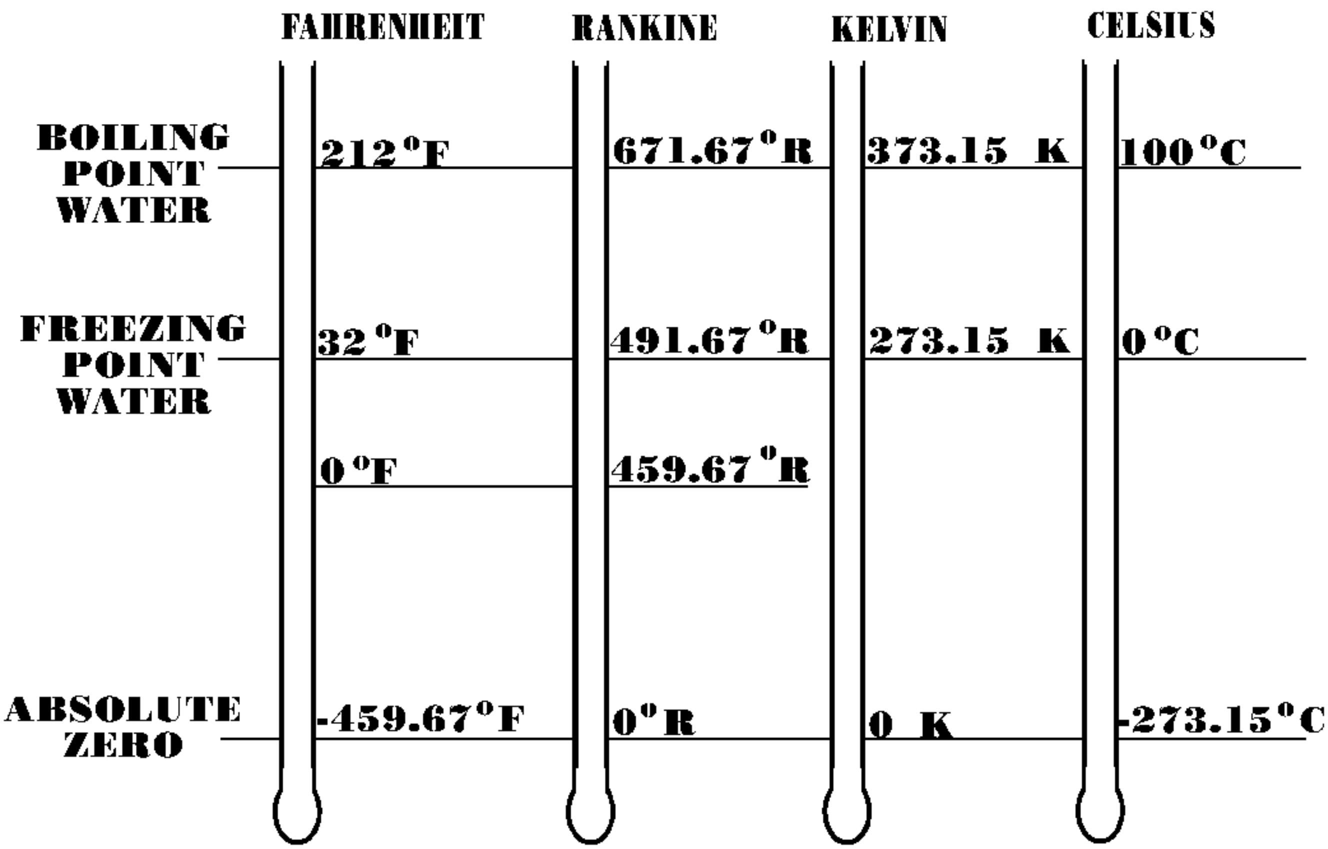
N = Number of thermometer scale degrees the mercury is out of the bath

t_i = Temperature of the thermometer bulb

$\overline{t_s}$ = <u>Average</u> temperature of the portion of the stem containing mercury which is out of the bath = $\frac{t_1 + t_2}{2}$

t_a = Actual temperature = $t_i + \left[K \times N \times \left(t_i - \overline{t_s}\right)\right]$

TEMPERATURE COMPARISON CHART



THERMOCOUPLES

$^{E}t = {}^{E}r + {}^{E}m$

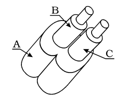
Where:

^{E}t = EMF value corresponding to the actual temperature at the Hot Junction

^{E}r = EMF output of the thermocouple if one junction were at 0°C and the other junction were at a temperature equal to the one being used as the reference under discussion.

^{E}m = Measured EMF output of the couple in its configuration of use (that is, reference junction not at 0°C).

THERMOCOUPLE IDENTIFICATION TABLE



ANSI Code	Alloy Combination		Color Coding						Magnetic Lead	Temperature Range	EMF (mv)	Limits of Error (Whichever is greater)	
	+ Lead	- Lead	Thermocouple Grade (TG)			Extension Grade (EG)						Standard	Special
			A	B (+)	C (-)	A	B (+)	C (-)					
J	IRON Fe	CONSTANTAN COPPER-NICKEL Cu-Ni	BRN	WHT	RED	BLK	WHT	RED	IRON (+)	TG 0 to 750℃ EG 0 to 200℃	0 to 42.283	2.2℃ or .75%	1.1℃ or .40%
K	CHROMEL NICKEL-CHROMIUM Ni-Cr	ALUMEL NICKEL-ALUMEL Ni-Al	BRN	YEL	RED	YEL	YEL	RED	ALUMEL (-)	TG -200 to 1250℃ EG 0 to 200℃	-5.973 to 50.633	2.2℃ or <0℃ .75% >0℃ 2.0%	1.1℃ or .40%
T	COPPER Cu	CONSTANTAN COPPER-NICKEL Cu-Ni	BRN	BLU	RED	BLU	BLU	RED	-	TG -200 to 350℃ EG -60 to 100℃	-5.602 to 17.816	1.0℃ or <0℃ .75% >0℃ 1.5%	0.5℃ or .40%
E	CHROMEL NICKEL-CHROMIUM Ni-Cr	CONSTANTAN COPPER-NICKEL Cu-Ni	BRN	PUR	RED	PUR	PUR	RED	-	TG -200 to 900℃ EG 0 to 200℃	-8.824 to 68.783	1.7℃ or <0℃ 0.5% >0℃ 1.0%	1.0℃ or .40%
N*	NICROSIL Ni-Cr-Si	NISIL Ni-Si-Mg	BRN	ORN	RED	ORN	ORN	RED	-	TG -270 to 1300℃ EG 0 to 200℃	-4.345 to 47.502	2.2℃ or <0℃ .75% >0℃ 2.0%	1.1℃ or .40%
R	PLATINUM-13% RHODIUM Pt-13% Rh	PLATINUM Pt	-	-	-	GRN	BLK	RED	-	TG 0 to 1450℃ EG 0 to 150℃	0 to 16.741	1.5℃ or .25%	.60℃ or .10%
S	PLATINUM-10% RHODIUM Pt-10% Rh	PLATINUM Pt	-	-	-	GRN	BLK	RED	-	TG 0 to 1450℃ EG 0 to 150℃	0 to 14.973	1.5℃ or .25%	.60℃ or .10%
B	PLATINUM-30% RHODIUM Pt-30% Rh	PLATINUM-6% RHODIUM Pt-6% Rh	-	-	-	GRY	GRY	RED	-	TG 0 to 1700℃ EG 0 to 100℃	0 to 12.426	<800℃ .50%	none est.
G*	TUNGSTEN W	TUNGSTEN-26% RHENIUM W-26% Re	-	-	-	WT/ BL	WHT	RED	-	TG 0 to 2320℃ EG 0 to 260℃	0 to 38.564	4.5-425℃ 1.0% - 2320℃	none est.
C*	TUNGSTEN-5% RHENIUM W-5% Re	TUNGSTEN-26% RHENIUM W-26% Re	-	-	-	WT/ RED	WHT	RED	-	TG 0 to 2320℃ EG 0 to 870℃	0 to 37.066	4.5-425℃ 1.0% - 2320℃	none est.
D*	TUNGSTEN-3% RHENIUM W-3% Re	TUNGSTEN-25% RHENIUM W-25% Re	-	-	-	WT/ YEL	WHT	RED	-	TG 0 to 2320℃ EG 0 to 260℃	0 to 39.506	4.5-425℃ 1.0% - 2320℃	none est.

* Not Official Symbol or Standard

THERMAL-SPECTRUM

Celsius <u>Scale</u>	Fahrenheit <u>Scale</u>	
1410	2570	Silicon Melts
1083.4	1982.12	Copper Melts
1064.43	1947.974	Freezing Point of Gold
937.4	1719.32	Germanium Melts
961.93	1763.474	Freezing Point of Silver
660.37	1220.666	Aluminum Melts
630.74	1167.332	Silver Solder Melts
630.74	1167.332	Antimony Melts
444.674	832.4132	Boiling Point of Sulfur
216	420	50/50 Lead/Tin Solder Melts
156.61	313.898	Indium Melts
100	212	Steam Point at Sea Level
57.8	136.04	Highest Recorded World Temperature
37	98.6	Human Body Temperature
4	39.2	Maximum Density of Water
0.010	32.018	Triple Point of Water
0	32	Ice Point
-38.87	-37.966	Mercury Freezes
-78.5	-109.3	Sublimation Point of CO
-88.3	-126.94	Lowest Recorded World Temperature
-182.962	-297.3361	Oxygen Boils
-273.15	-459.67	Absolute Zero

RESISTANCE THERMOMETER

$$RR = \frac{R_t}{R_o} \qquad ID = \frac{1}{RR_t - RR_{(t-1)}}$$

Where:

RR = Resistance Ratio Computed

RR_t = Resistance Ratio at a given temperature (t)

$RR_{(t-1)}$ = Resistance Ratio at temperature 1°C below (t)

$$t = t_2 + \left[(RR - RR_2) \times ID \right]$$

Where:

t = the measured temperature

t_2 = the lower of two(2) temperatures from the table which bracket the resistance ratio computed

RR_2 = Resistance Ratio at t_2

ID = Inverse difference for the temperature which has the resistance ratio which is just <u>greater</u> than RR

VOLUMETRIC COEFFICIENTS OF EXPANSION, β

SUBSTANCE	$\frac{n \times 10^{-4}}{C^\circ}$	$\frac{n \times 10^{-4}}{F^\circ}$
Alcohol, Ethyl	11.0	6.10
Benzene	13.9	7.70
Mercury	1.82	1.01
Petroleum (Pennsylvania)	9.0	5.0
Sulfuric Acid	5.56	3.10
Turpentine	9.70	5.40
Water	2.07	1.15

$V_f = V_o\,(1 + \beta\Delta t)$ $\Delta V = (V_o)\,(\beta)\,(\Delta t)$

Where:

V_f = Volume Final
V_o = Volume Original
ΔV = Change in Volume
β = Volumetric Coefficient of Expansion
Δt = Change in Temperature (t_2 - t_1)
t_2 = Final Temperature
t_1 = Original Temperature

BOYLES LAW

The relationship between volume and pressure. Remember that the law assumes the temperature to be constant.

$\frac{V_1}{V_2} = \frac{P_2}{P_1}$ or $V_1 P_1 = V_2 P_2$

Where:

V_1 = original volume
V_2 = new volume
P_1 = original pressure
P_2 = new pressure

CHARLES' LAW

The relationship between temperature and volume. Remember that the law assumes that the pressure remains constant.

$$\frac{V_1}{V_2} = \frac{T_2}{T_1} \qquad \text{or} \qquad \frac{V_1}{T_2} = \frac{V_2}{T_1}$$

Where:

V_1 = original volume
V_2 = new volume
T_1 = original absolute temperature
T_2 = new absolute temperature

IDEAL GAS LAW

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

Where:

P_1 = Initial Pressure
V_1= Initial Volume
T_1= Initial Temperature
P_2= Final Pressure
V_2= Final Volume
T_2= Final Temperature

HUMIDITY

DEW POINT

$$\%RH = \frac{P_s(t_{dew})}{P_s(t_a)} \times 100 \qquad P_s\ (+\,dew) = \frac{\%\,RH}{100}\ x\ P_s\ (t_a)$$

Where:

$P_s(t_a)$ = the saturation pressure of the gas from a reference table at temperature t_a
$P_s(t_{dew})$ = the saturation pressure of the gas from a reference table at temperature (t_{dew})

$$D = t_a - t_w$$

Where:

D = Wet bulb depression
t_a = Dry bulb temperature
t_w = Wet bulb temperature

HUMIDITY

$$\%RH = \frac{B}{C} \times 100 = \frac{P_v}{P_s} \times 100$$

Where:

B = P_v = Pressure of the water vapor
C = P_s = Saturation pressure
% RH = Percent relative humidity

FORCE

STRESS

$$\sigma(\text{sigma}) = \frac{F}{A}$$

Where:

F = the force
A = the area

STRAIN

$$\varepsilon\,(\text{epsilon}) = \frac{\Delta\ell}{\ell}$$

Where:

$\Delta\ell$ = change in length
ℓ = original length

YOUNG'S MODULUS

Stress divided by strain.

$$Y = \frac{\sigma}{\varepsilon} \qquad Y = \frac{F/A}{\Delta\ell/\ell} \qquad Y = \frac{F\ell}{A\Delta\ell} \qquad \Delta\ell = \frac{F\ell}{AY}$$

TRANSVERSE STRAIN

$$\varepsilon\ \text{transverse} = \frac{\Delta D}{D}$$

POISSON'S RATIO

Transverse strain to axial strain.

$$\mu = \frac{\varepsilon_{transverse}}{\varepsilon_{axial}} = \frac{\Delta D / D}{\Delta \ell / \ell}$$

$$\Delta D = \frac{\mu D \Delta \ell}{\ell}$$

HOOKE'S LAW

$$F = \frac{YA}{\ell} \times \Delta \ell = KX$$

$$K = \frac{YA}{\ell} = \text{force constant}$$

Where:

$X = \Delta \ell$ = elongation or change in length
F = force

LOAD CELLS

$$F\,(\text{lbs}) = \frac{E_0}{E_s\,(\text{sens})} \times C\,(\text{lbs})$$

Where:

E_s = source voltage across the bridge
Sen = sensitivity of the cell (mv/v)
E_o = output voltage of the bridge
C = range of the cell
F = force acting on the cell

TORQUE

TORQUE

$$T = F \times S$$

Where:

F = the force applied
S = the distance through which the force is acting
T = torque

COSINE ERROR

$$\text{Cos}\,\theta = \frac{\text{side adjacent}}{\text{hypotenuse}}$$

$$T = F \times S \times \text{Cos}\,\theta$$

MASS AND WEIGHT

$$E_M = T_M - F_B$$

$$T_M = E_M + F_B$$

$$F_b = \frac{M}{\rho_b} \times \rho_{air}$$

Where:

M = mass
E_m = effective mass
Tm = true mass
F_b = air displaced by mass
ρ_b = density of brass = 8.4 gm/cm^3
ρ_{ss} = density of stainless steel = 8.0 gm/cm^3
ρ_{air} = density of air = .0012 gm/cm^3

WEIGHING METHODS

R = Optical scale reading
RP = Rest point
M_{sen} = Sensitivity weight
IRP = initial rest point
FRP = final rest point
SRP = sensitivity rest point
m_x = unknown mass
m_s = known mass
Cr_s = correction of standard weight
Cr_x = correction of test weight
Δ = Difference **not** direction

Rest Points

$$RP = \frac{B + \frac{A+C}{2}}{2} \qquad\qquad RP = \frac{\frac{B+D}{2} + \frac{A+C+E}{3}}{2}$$

Where A,B,C,D,E are values recorded for consecutive turning points

Weighing Methods

1. **DIRECT WEIGHING** **Note: If FRP > IRP, the weight in left pan is heavier.**

$$SR = \left|\frac{Msen}{FRP - SRP}\right|$$

Where:

$\Delta RP = |FRP - IRP|$
$\Delta m = \Delta RP \times SR$
If m_s is heavier than m_x then $m_s - \Delta m$
If m_s is lighter than m_x then $m_s + \Delta m$

2. **SUBSTITUTION WEIGHING**

$$CR_x = SR \times (IRP - FRP) + CR_s$$

Note: Always add CR_X to the nominal value of M_X.

3. **TRANSPOSITION WEIGHING**

$$CR_x = SR \times \left(\frac{IRP - FRP}{2}\right) + CR_s$$

Note: Always add CR_X to the nominal value of M_X.

4. DIFFERENTIAL WEIGHING

$$CR_x = R - M_{sen}$$

DENSITY, VISCOSITY AND FLOW

SPECIFIC GRAVITY

$$sp.\,gr. = \frac{D_x}{D_w} \qquad sp.\,gr. = \frac{\rho_x}{\rho_w}$$

$$sp.\,gr. = \frac{W_a}{W_a - W_w} \qquad sp.\,gr. = \frac{m_a}{m_a - m_w}$$

$$sp.\,gr. = \frac{W_a - W_x}{W_a - W_w} \qquad sp.\,gr. = \frac{m_a - m_x}{m_a - m_w}$$

$$V = \frac{W_a - W_w}{D_w} \qquad V = \frac{m_a - m_w}{\rho_w}$$

Where:

ρ = Density in CGS system
D = Density in FPS system
W = Weight
V = Volume
x = unknown substance
w = water
a = air
m = mass
Mass density of water at 4°C = 1 gm/cm^3
Weight density of water at 39.2°F = .03612 lb/in^3
Weight density of water at 39.2°F = 62.426321 lb/ft^3
Weight density of water at 60°F = 62.277354 lb/ft^3

PICNOMETER

$$sp.\,gr. = \frac{W_a - W_p}{W_b - W_p}$$

Where:

W_p = weight of empty picnometer vessel
W_a = weight of picnometer vessel and test liquid
W_b = weight of picnometer vessel and water

SPECIFIC GRAVITY TABLES

SOLIDS			
Aluminum	2.7	Ice	0.917
Brass	8.2 - 8.7	Iron, Steel	7.6 - 7.8
Carbon	1.9 - 3.5	Lead	11.34
Copper	8.9	Oak	0.60 - 0.98
Gold	19.3	Pine	0.37 - 0.64
Human Body	1.07	Silver	10.5

GASES			
Air	1.000	Neon	0.696
Ammonia	0.596	Nitrogen	0.967
Carbine dioxide	1.529	Oxygen	1.105
Hydrogen	0.069		

LIQUIDS			
Water, Distilled @ 4℃	1.000	Mercury @ 0℃	13.5951
Alcohol, Ethyl	0.789	Milk	1.029
Carbon Tetrachloride	1.60	Oil, Linseed	0.942
Gasoline	0.66 - 0.69	Water, Sea	1.025
Kerosene	0.82		

VISCOSITY

Absolute

$$\eta = \frac{F/A}{\Delta V/\Delta L}$$

Where:

η = absolute viscosity
F = force
A = area
ΔV = change in velocity
ΔL = change in length (thickness)

Kinematic

$$\nu = \frac{\eta}{\rho}$$

Where:

η = absolute viscosity
ρ = density
ν = kinematic viscosity

$$\text{MKS}: \ \nu = \frac{\text{meter}^2}{\text{sec}} \qquad \text{FPS}: \ \nu = \frac{\text{ft}^2}{\text{sec}}$$

VISCOMETER

$$V_\theta = k_\theta t$$

Where:

V_θ = viscosity at temperature
k_θ = instrument constant at temperature
t = efflux time

FLOW

$$\frac{Q_s P_s}{Z_s T_s} = \frac{Q_a P_a}{Z_a T_a} \qquad \text{or} \qquad Q_s = \left(\frac{Z_s T_s P_a}{Z_a T_a P_s}\right) Q_a \qquad \text{or} \qquad Q_a = \left(\frac{Z_a T_a P_s}{Z_s T_s P_a}\right) Q_s$$

Where:

Q = a volume or volume rate
P = pressure (absolute)
T = temperature (absolute)
Z = compressibility factor (correction for non ideal gas behavior)
a = actual
s = standard

PRESSURE AND VACUUM

PRESSURE

$$P = \frac{F}{A}$$

Where:

P = Pressure (lbs/in^2, newtons/m^2, dynes/cm^2)

F = Force (lbs, newtons, dynes)

A = Area (in^2, m^2, cm^2)

$$P = \rho g h$$

Where:

P = Pressure (lbs/in^2, newtons/m^2, dynes/cm^2)

ρ = the density of the fluid

h = the vertical height of the fluid

g = gravitational acceleration

$$P = Dh$$

Where:

P = Pressure (lbs/in^2)

D = the weight density (lbs/in^3)

h = the vertical height of the fluid

True Pressure

$$P_t = \frac{M}{A_o}\left[\frac{\left(1-\frac{\rho_a}{\rho_b}\right)\left(\frac{g_l}{g_s}\right)}{(1+bP)\left[1+(\alpha_k+\alpha_c)(t_2-t_1)\right]}\right]$$

Where:

P_t = true pressure
M = mass
ρ_a = density of air
ρ_b = density of brass
g_L = local gravitational acceleration
g_S = standard gravitational acceleration
A_o = area of piston
b = pressure coefficient
P = nominal pressure
α_k = coefficient of thermal expansion of piston
α_c = coefficient of thermal expansion of cylinder
t_1 = reference temperature
t_2 = ambient temperature

PRESSURE CONVERSION CHART

From / To➔ ➔	psi	in H_2O	ft H_2O	in HG	ATM	gm/cm^2	kg/cm^2	cm H_2O	mm HG
1 psi	Multiply By	27.66	2.307	2.036	0.06805	70.31	0.07031	70.31	51.72
1 in H_2O (4℃)	0.03612		0.08333	0.07355	0.002458	2.540	0.002450	2.540	1.868
1 ft H_2O (4℃)	0.4335	12.00		0.8826	0.02950	30.45	0.03048	30.48	22.42
1 in HG (0℃)	0.49116	13.60	1.133		0.03342	34.53	0.03453	34.53	25.40
1 ATM	14.696	406.8	33.90	29.92		1033	1.033	1033	760
1 gm/cm^2	0.01422	0.3937	0.03281	0.02896	0.0009678		0.0010	1.000	0.7356
1 km/cm^2	14.22	393.7	32.81	28.96	0.9678	1000		1000	735.6111
1 cm H_2O (4℃)	0.01422	0.3937	0.03281	0.02896	0.0009678	1.000	0.0010		0.7355
1 mm HG (0℃)	0.01934	0.5353	0.04461	0.03937	0.001316	1.360	0.001360	0.001360	

Directions: To find the conversion factor, select the pressure unit you are converting FROM in the *left-most column*. Select the pressure unit you are converting TO from the *top row*. The block where the selected row and column intersect is your conversion factor. Multiply the conversion factor by your original pressure value. This is your converted pressure value in the new units.

ROTARY MOTION

$$\omega = \frac{\theta}{t}$$

Where:

ω = angular velocity (radians/second)
θ = angular displacement
t = elapsed time

VIBRATION

$$f = \frac{1}{t} \qquad f = \frac{Vave}{2 * D} \qquad f =. \frac{V}{D * \pi}$$

Where:

f = frequency
t = time (in seconds)
Vave = Average Velocity
V= Velocity
D= Displacement (in inches DA (double amplitude)

$$Sens_{OC} = Sens_{Loaded}\left(\frac{R_1 + R_2}{R_2}\right)$$

Where:

$Sens_{OC}$ = Open circuit sensitivity
$Sens_{Loaded}$ = Pickup sensitivity in the calibration load at frequency used
R_1 = Pickup impedance
R_2 = Calibration system load impedance

$$Sens_{Corr} = Sens_{OC}\left(\frac{R_3}{R_1 + R_3}\right)$$

Where:

$Sens_{Corr}$ = Sensitivity corrected to indicator impedance
$Sens_{OC}$ = Sensitivity into open circuit
R_1 = Pickup impedance
R_3 = Input impedance on readout device

$$\text{Sensitivity (mv)} = \frac{\sqrt{2} \times \text{mV (rms)}}{\pi f \times DA}$$

Where:

mV (rms) = meter reading
f = frequency in Hz
DA = peak-to-peak displacement

GLOSSARY

aberration

A broad term covering several types of image defects in a lens or lens system.

absolute pressure

Actual pressure on a confined gas, irrespective of the atmosphere on the outside. Absolute pressure = gage pressure + atmospheric pressure.

absolute system

A system of units in which a small number of units is chosen as fundamental and all other units are derived from this group.

absolute temperature

Temperature measured from absolute zero as in the Kelvin and Rankine scales.

absolute zero

(1) This is the temperature at which the volume of an ideal gas would become zero. The value calculated from the limited value of the coefficient of expansion of various real gases is -273.15°C.

(2) The temperature at which all thermal (molecular) motion ceases; zero point in absolute temperature scale equal to -273.15°C or -459.67°F. Absolute temperature T is given by the equation:

1/2 mv av 2 = 3/2 kT

absorption

(1) The loss of energy in traveling through a medium.

Examples: A yellow filter absorbs all wavelengths except yellow just as red paint will absorb all colors except red which is reflected.

(2) The internal taking up of one material by another.

(3) Transformation of radiant energy into other forms of energy when passing through a material substance.

acceleration

(1) A rate of change in velocity per unit time. Positive acceleration means an increase in velocity while negative acceleration means a decrease in velocity per unit time. Avoid the use of the term "deceleration."

(2) The time rate of change of velocity in either magnitude or direction. CGS Unit: cm/sec .

acceleration due to gravity (g)

The acceleration of a freely falling body in a vacuum, 980.665 cm/sec or 32.174 ft/sec at sea level and 45° latitude.

accommodation

Changes in focus of the crystalline lens to adjust the eye for various object distances.

accuracy

The term accuracy refers to how close we are to the nominal value. In the past we have used this term to indicate error in a measurement device. For instance, the accuracy of a standard cell is plus or minus 0.01 percent. Use of the word accuracy in this sense is incorrect because what we mean is the inaccuracy or error is plus or minus 0.01 percent. However, this is still a common method of describing accuracies. To remedy this practice, the National Bureau of Standards has dropped the term accuracy, when used in this respect, and uses instead the term "uncertainty."

achromat

A lens doublet, to two lenses combined to eliminate chromatic aberration.

achromatic

Free from hue

activation energy

The energy necessary to start a particular reaction.

actual value (true value)

It is not possible to determine a completely true value of a quantity as there is always some error in every measurement. Theoretically we could say the "true" value of a measured quantity can be derived by taking the average of an infinite number of measurements assuming that the conditions contributing to deviations act is a completely free and random manner.

acuity

Visual acuity is the resolving power of the eye, normally taken as 1 minute arc. Vernier acuity is the ability of the eye to make coincidence settings.

adsorption

The adhesion of one substance to the surface of another.

algebra

A continuation of arithmetic in which letters and symbols are used to represent definite quantities whose actual values may or may not be known.

algorithm

Step-by-step procedure for the solution to a problem. First the problem is stated and the algorithm is devised for its solution.

alignment telescope

A telescope specifically designed to be mounted and used in conjunction with an end target in order to form a fixed line of sight. Can also be used to measure linear displacement (alignment of a rail for straightness) by using the optical micrometers.

alloy

A mixture of two or more metals, such as brass (zinc and copper), bronze (copper and tin), and manganin (nickel, manganese, and copper).

alnico

An alloy consisting chiefly of aluminum, nickel, and cobalt. It has high retentivity and is used to make powerful small-size permanent magnets which hold their magnetism indefinitely.

alphanumeric

Set of all alphabetic and numeric characters.

alternation

One half of a complete cycle, consisting of a complete rise and fall of voltage or current in one direction. There are 120 alternations per second in 60 Hz alternating current.

altimeter

An aircraft instrument that indicates the elevation in respect to a reference. The aneroid altimeter is referenced to sea level, while an electronic altimeter uses the radar method. See barometer.

ambient temperature

The temperature of the air in the immediate vicinity.

ambiguity

The quality of having more than one meaning.

amici prism

Direct vision prism; beam of light is dispersed into a spectrum without mean deviation.

ammeter

An instrument used for measuring the amount of current in amperes. A meter that indicates the current value in milli-amperes is a milli-ammeter, and one that indicates values in micro-amperes is a micro-ammeter.

amplitude

The extent of a vibratory movement measured from the mean position to an extreme.

amplification

As a related to detection instruments, the process (either gas, electronic, or both) by which ionization effects are magnified to a degree suitable for their measurement.

angle of incidence

The angle formed by the line of an incident ray and a perpendicular line arising from the point of incidence.

angle of lag

The angle with which one alternating electrical quantity lags behind another quantity in time, expressed in degrees (1 cycle equals 360°) or in radians (1 cycle equals 2 radians).

angle of reflection

The angle formed by the line of a reflected ray and a perpendicular line arising from the point of incidence.

angle of refraction

The angle formed between the line of a refracted ray and a perpendicular line drawn through the point of refraction.

angular acceleration

The time rate of change of angular velocity either in angular speed or in the direction of the axis of rotation. CGS unit: radians/sec .

angular velocity

(1) The speed of a rotating object measured in radians per second and generally designated by the lower case Greek letter omega. In the case of a periodic quantity, such as alternating current, the angular velocity is equal to a 2 f.

(2) The time rate of angular displacement about an axis; CGS unit: radians/sec. If the angle described in time is θm the angular velocity is $\theta = \frac{w}{t}$, where θ is in radians, t is in seconds, and w is in radians per second.

angstrom unit

10 cm, a convenient unit for measuring wavelength of light. Abbreviation: A.

antilogarithm

Number from which the log was derived. Obtained as a result of using the inverse procedure of obtaining a log. It is often written as "antilog."

aperture

An opening or gap. In optics, the effective aperture is the portion of an objective lens that is actually used.

aplantic lens

A lens that is corrected for spherical, coma, and chromatic aberrations.

apses

The point at which an orbiting body is the greatest or least distance from the center of attraction. The greatest distance is called the higher apses and the least distance is called the lower apses.

arc

A portion of the circumference of a circle.

Archimedes' principle

When a body is placed in a fluid, it is buoyed up by a force equal to the weight of the displaced fluid.

astigmatism

(1) A visual aberration caused by lack of sphericity of the cornea.

(2) A blurring of the trace of an oscilloscope.

atom

Smallest particle of an element that can enter into combination with other elements.

atomic number

(1) The number of protons in the nucleus, hence the number of positive charges on the nucleus.

(2) The number of protons in the nucleus, hence the number of positive charges on the nucleus. It is also the number of electrons outside the nucleus of a neutral atom. Symbol: Z.

atomic weight

The relative weight of the atom of an element based on an atomic weight of 16 for the oxygen atom as the usual chemical standard. The sum of protons plus neutrons is the approximate atomic weight of an atom.

attached method(optics)

A method of measuring when all test equipment and standards are physically located on the same reference plane.

Autocollimation

A process in which collimated rays of light emanating from an instrument, and carrying the image of a reticle, are aimed at a reflective surface. The reticle image is reflected back into the focal place of the telescope for comparison with the actual reticle as a measure of relative tilt, between the optical axis and the reflective surface. An instrument used for this purpose is called an Autocollimator.

Autocollimator

A telescope provided with both an eyepiece and a focal plane target. The basic operating principle is to align a plane with a reflective capability at right angles to the autocollimator axis and/or measure the out-of-squareness of a plane to the autocollimator axis.

autoreflection

A process in which the reflected image of a target surrounding the front end of a telescope is compared with the telescope reticle as a measure of relative tilt. (The focal length is twice the dimension from the instrument to reflective surface.)

average value

(1) The value obtained by dividing the sum of a number of quantities by the number of quantities represented.

(2) The average of many instantaneous amplitude values taken at equal intervals of time during an alternation (half-cycle). The average value of an alternation of a pure sine wave is 0.637 times its maximum or peak amplitude value.

Avogadro's law

The hypothesis that equal volumes of all gases at the same pressure and temperature contain equal numbers of molecules. Hence the number of molecules contained in 1 cm^3 of any gas under standard conditions is a universal constant.

Avogadro's number

The number of molecules in a gram-molecular weight of any substance (6.03×10^{23} molecules); also, the number of atoms in a gram-atomic weight of any element.

axis

A straight line, real or imaginary, passing through a body, on which the body rotates.

axis, optical

A line formed by the coinciding principal axis of a series of optical elements.
*** Note *** optical axis as described on pg. 4-6 of OM 3&2 is stated wrong, the glossary is correct.

axis, principal

A line through the centers of curvature of a refracting lens.

azimuth

Horizontal direction or bearing of one object with respect to another, expressed as an angle measured in a horizontal plane and in a clockwise direction from the north (true north, unless otherwise indicated).

backlash

A form of mechanical hysterysis (lag) in which there is a lag between the application of a driving force and the response of the driven object.

barometer

An instrument for measuring atmospheric pressure. There is a direct relationship between atmospheric pressure and altitude and many barometers are equipped with an altitude scale. Two types of barometers are "mercury" and "aneroid." The aneroid barometer with an altitude scale is an altimeter.

beam

A beam of light can be regarded as the path traced by a small section of an advancing wave front, which is comprised of an infinite number of light rays.

Bernoulli's principle

With a fluid in motion, if the velocity is low, the pressure is high and vice versa.

bifilar winding

A method of winding transformers in which the wires are placed side by side, and wound together.

bilateral

Having, or arranged upon, two sides.

bimetallic element

Two strips of dissimilar metal bonded together so that a change in temperature will be reflected in the bending of the element, as a result of differential expansion. Used in thermostats, dial thermometers, and temperature compensating devices in the better pressure gages.

boiling

Rapid vaporization which disturbs a liquid, and which occurs when the vapor pressure within a liquid is equal to the pressure on its surface.

bonded strain gage

A thin metallic resistance element, usually of wire or foil, chemically cemented to a device being subject to loading or stress. As the load (stress) changes, the electrical resistance of the strain gage changes. Thus, for a fixed value of applied voltage, the output voltage from the strain gage varies in proportion to the strain and provides an indication proportional to the load causing the stress and resultant strain.

bourdon element

A curved, hollow tube sealed at one end. When fluid under pressure is forced in the tube it has a tendency to straighten out. With a pointer attached to the sealed end and allowed to move across a scale it becomes a bourdon gage.

Boyle's Law

If the temperature of a gas is kept constant, then the volume of the gas will be inversely proportional to the pressure.

bridge circuit

An electrical network that is basically composed of four branches connected in the form of a square. One pair of diagonally opposite junctions is connected to the input, and the other pair is connected to the output circuit which contains an indicating device.

bridge rectifier

A full-wave rectifier with four elements connected as in a bridge circuit. Alternating voltage is applied to one pair of junctions.

British Thermal Unit (BTU)

The amount of heat that will raise the temperature of 1 pound of water 1° Fahrenheit from 62°F to 63°F.

bucking-in

To place an instrument so that its line of sight passes through two given points or fulfills two requirements simultaneously. Usually the first operation in setting up control is to establish a width plane.

buoyancy

The power to float or rise in a fluid.

buoyant force

The upward force which any fluid exerts on a body placed in it.

calibrate

To determine by measurement or comparison the correct value of each scale reading on a meter or other device being calibrated. To determine the settings of a control that corresponds to particular values of voltage, current, frequency, or some other characteristic.

calorie

The amount of heat required to raise the temperature of 1 gram of water 1° Celsius at 15° Celsius.

candela

Unit of luminous intensity. It is of such a value that the luminous intensity of a full radiator at the freezing temperature of platinum (1773°C) is 60 candela per centimeter squared. Candela was formerly termed candlepower, or simply candle.

capillarity

The characteristic of a liquid to be raised or depressed in a tube or small bore. This action is caused by a combination of cohesive, adhesive, and surface tension forces.

celestial

Of the sky or the heavens. A celestial telescope is one in which the image appears inverted, as in astronomical telescopes with no erector.

Celsius temperature scale

A temperature scale based on mercury in glass thermometer with the freezing point of water defined at 0°C and the boiling point of water defined at 100°C, both under conditions of normal atmospheric pressure. Formerly called the Centigrade scale.

center of instrument

In optics, the intersect point of the vertical, horizontal, and optical axis of a transit or similar instrument when perfectly calibrated.

certify

To attest a being true or as represented, or to meet a certain standard.

centripetal force

The force required to keep moving mass traveling in a circular path. The force is directed toward the axis of the circular path.

cgs system

The common metric system of units (centimeter-gram-second).

chain reaction

Any chemical or nuclear process in which some of the products of the process are instrumental in the continuation of magnification of the process.

Charles Law

The volume of a gas is directly proportional to its absolute temperature, providing the pressure is constant.

chemical compound

A pure substance composed of two or more elements combined in a fixed and definite proportion by weight.

chromatic aberration

A property of lenses that causes the various colors in a beam of light to be focused at various points, this causing a spectrum to appear.

clinometer

The clinometer is, in principle, a level mounted on a rotatable member, whose angle of inclination relative to its base can be measured by a circular drum scale.

coefficient of linear expansion

The change in unit length in a solid when its temperature is changed 1°.

coefficient of volume expansion

The change in unit volume of a solid when its temperature is changed 1°.

cohesion

The force that causes molecules which are brought close together, as in liquids and solids, to stick together. This force is especially strong in solids when the distance between molecules is very small.

coincidence

Exact correspondence; aligning two lines; placing one beside the other. In optics, a coincidence bubble is equipped with a prismatic or mirror arrangement for simultaneously viewing both ends of the bubble for more precise adjustment.

collimate

To render parallel.

collimation

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

collimator

An instrument designed to produce collimated (parallel) rays of light, usually equipped with displacement and tilt graticules.

collinear

Lying on or passing through the same straight line

complex number

The expression resulting when a real number is united with an imaginary number by a plus or minus sign.

complex vibration

The combination of two or more sinusoidal vibrations existing simultaneously.

compound

Two or more substances combined in definite proportions by weight and united chemically.

concave

A lens that is thicker at the ends than the middle. A concave lens diverges (spreads) rays of light.

concentricity

Having a common center, as circles or spheres one within another.

condensation

The change of state from a gas or vapor to a liquid.

conservation of energy

The principle that energy can neither be created nor destroyed, and therefore the total amount of energy in the universe is constant. This law of classical physics is modified for certain nuclear reactions. (See Conservation-of-Mass-Energy.)

conservation of mass-energy

The principle that energy and mass are interchangeable in accordance with the equation $E = mc^2$; where E is energy, m is mass, and c is velocity of light.

correction

The correction is the value in proportional parts, that must be algebraically added to the nominal value to obtain the certified value. The correction is equal in absolute magnitude but opposite in sign to the error. Correction is what must be done to the nominal to reach the actual.

cosmic rays

Rays of higher frequency than radioactive gamma rays; highly penetrating, of unknown origin, traversing interplanetary space.

coulomb

Unit of quantity of electricity. The quantity of electricity transported in 1 second by a current of 1 ampere, or a movement of 6.28×10^{18} electrons past a given point in 1 second.

Coulomb's law of electrostatic charges

The force of attraction or repulsion exerted between two electrostatic charges, Q_1 and Q_2, a distance, s, apart separated by a medium of dielectric value, Î, is given by the equation:

$$F = \frac{Q_1 Q_2}{4\pi \in r^2}$$

Converge

Tend to meet at a point.

convex lens

A lens that is thicker in the middle than the ends. A convex lens converges rays of light.

creep

The long term change in dimensional characteristics of a body under load, in an elastic force measurement device. This term refers to the change in reading which occurs when a constant load is applied for a period of time.

critical angle

The angle between and at which there is neither refraction or internal reflection.

critical size

For fissionable material, the minimum amount of a material which will support a chain reaction.

cross section (Nuclear)

The area subtended by an atom or molecule for the probability of a reaction; that is, the reaction probability measured in units of area.

cryogenic

The science of refrigeration pertaining to the methods for producing and measuring very low temperatures.

cycle

(1) The complete sequence of instantaneous values of a periodic event that occurs during one period.

(2) In electricity, one complete positive alternation and one complete negative alternation of an alternating current.

damping

(1) The prevention of free swinging or vibration by some means, usually friction or resistance.

(2) The dissipation of energy with motion or time.

decade box

In measurement work, a special device containing two or more sections. Each section is divided into 10 equal parts and has a value of 10 times the value of the preceding section. Switching arrangements permit selection of any desired value in its range.

decay

The disintegration of the nucleus of an unstable element by the spontaneous emission of charged particles and/or photons.

decay time

The time required for the trailing edge of a pulse to decrease from 90 percent to 10 percent of its maximum amplitude. Also referred to as fall time.

deionization potential

The potential at which the ionization of the gas within a gas-filled tube ceases and conduction stops.

density

The mass per unit volume. CGS unit: gm/cm .

detached method

A very flexible method of optical tooling. The instruments are mounted on stands or on optical tooling bars which are free of the actual work.

deuterium

A heavy isotope of hydrogen having 1 proton and 1 neutron in the nucleus. Symbol: D or $_{1}$H2 .

deuteron

The nucleus of a deuterium atom containing 1 proton and 1 neutron.

dew point

The temperature at which the water vapor in the air begins to condense. At this temperature the relative humidity is 100 percent.

dial indicator

This is a mechanical lever system used for amplifying small displacements and measuring it be means of a pointer which transverses a graduated dial.

differential voltmeter

A voltmeter that operates on the potentiometric principle. The unknown voltage is compared to an adjustable calibrated voltage developed within the differential voltmeter.

differentiating circuit

A circuit in which the output voltage is proportional to the rate of change of the input voltage. In an RC circuit the output is taken across the resistor, and in an RL circuit it is taken across the inductor.

diffraction

The bending of waves, light, sound, or radio, as they pass an obstruction or pass through a small aperture.

diffusion

(1) The penetration of one type of particle into a mass consisting of a second type of particle.

(2) To spread out in all directions.

digit

Sign or symbol used to convey a specific quantity of information either by itself or with other numbers of its set; 2, 3, 4, and 5 are digits. The base or radix must be specified and each digit's value assigned.

digital voltmeter

An automatic electronic measuring instrument which displays its measurements directly in the decimal system. It is an automatic potentiometric measurement.

dimensional analysis

A process whereby the metrologist separates a quantity into its constituent parts to facilitate the solution to a problem.

diopter

The unit of lens power, is usually denoted by D and is the power of a lens of 1 meter focal length.

displacement

(1) The amount of change in position from a reference.

(2) Misalignment from a line of sight, usually measured vertically and horizontally.

displacement graticule

A graduated reticle used in Collimators measuring vertical and horizontal displacement. Generally in terms of linear displacement.

distortion

Any deviation from the desired waveform.

diverge

To spread out, as in the effect of a concave or negative lens. Diverges away from the focal point.

dove

A prism which inverts the image without displacement. Also called a rotating prism.

dyne

That unit of force which, when acting upon a mass of 1 gm, will produce an acceleration of 1 cm/sec/sec.

Edison effect

The emission of electrons from hot bodies. The rate of emission increases rapidly with temperature. Also known as thermionic emission.

effective mass

The mass of a body which is being acted upon by the buoyant forces of air. The effective mass of a weight is its true mass minus the buoyant force of air displaced by the weight.

effective value (RMS)

The alternating current value that will produce the same amount of heat in a resistance as the corresponding direct current value. All alternating current meters, unless otherwise marked, indicate effective values of voltage or current. The effective value is also called RMS (root-mean-square) value.

efficiency

The ratio of useful output energy to input energy, usually expressed as a percentage. A perfect electrical device would have an efficiency of 100 percent.

elasticity

The property of material to return to its original shape after stress is removed.

elastic limit

The maximum unit stress which can be obtained in a structural material without causing permanent deformation.

E Layer

An ionized layer in the E region of the ionosphere. This layer occurs during daylight hours; its ionization depends on the angles of the sun.

electric field intensity

The magnitude of the intensity of an electric field at a particular point, equal to the force which would be exerted upon a unit positive charge placed in the field at that point. The direction of the electric field is the direction of this force.

electron

(1) A subatomic particle possessing a unit negative charge.

(2) A negatively charge particle which is a constituent of every atom. A unit of negative electricity equal to 4.80×10^{-10} esu. Its mass is 0.00548 mu.

electronics

That branch of physics which relates to the emission behavior and effects of electron conduction through a vacuum, gaseous media or semiconductors.

electronic switch

An electronic circuit designed to cause a start and stop action or a switching action.

electrostatic field

The region surrounding an electric charge in which another electric charge experiences a force.

electrostatic unit of charge (Statcoulomb)

That quantity of electric charge which, when placed in a vacuum 1 cm distant from an equal and like charge, will repel it with a force of 1 dyne. Abbreviation: esu.

element

(1) In chemistry, one of the 100-odd primary substances that cannot be divided into simpler substances by chemical means.

(2) A pure substance consisting of atoms of the same atomic number, which cannot be subdivided by ordinary chemical means.

elevation

The vertical distance above a reference level, usually sea level, to a point or object on the surface of the Earth, as distinguished from altitude, which refers to points above the Earth's surface.

empirical

Based on actual measurement, observation, or experience without regard to science and theory.

endoergic reaction

A reaction which absorbs energy.

energy

Capacity for performing work. Energy due to the motion of a piece of matter is called kinetic energy. Energy due to the position of a piece of matter is called potential energy.

equilibrium

A condition in which all forces processes or tendencies present are exactly counterbalanced by equal and opposite forces, processes, or tendencies.

erect

Not inverted, the normal position.

erector lens

Additional optics fitted to the eyepiece lens system enabling the image to be viewed in the normal (erect) position.

erg

The unit of work done by a force of 1 dyne acting through a distance of 1 cm. The unit of energy which can exert a force of 1 dyne through a distance of 1 cm. CGS units: dyne-cm, or $gm\text{-}cm^2/sec^2$.

error

The error is the difference between an observed value or calculated value and the true or actual value.

evaporization

The change of state from a liquid to a gas.

exoergic reaction

The reaction which liberates energy.

exponent

Power of ten by which a number is multiplied, used in floating point representation. For example, the exponent in the decimal number 0.9873×10^7 is 7.

exponential

Pertaining to varying exponents or to an expression having varying exponents. Any constant base affected with an exponent is exponential.

eyepiece

An essential component of a telescope which receives a real image in its focal plane and forms a magnified virtual image.

Fahrenheit scale

A thermometric scale on which the freezing point of water is 32° and boiling point 212°, both at standard pressure.

field of view

Expressed as an angle and representing the arc through which observations are possible through a telescope. The field angle is controlled by the aperture of the eye lens and decreases as magnification increases.

filar

Also known as: cross hair, reticle. In optics, a superimposed reference line. For two parallel lines, the term bifilar is used. See reticle also.

fission products

The elements and/or particles produced by fission.

fixed point

The point where all heat energy applied or removed is used to change the state of a substance.

flux

(1) A material used to promote fusion or joining of metals in soldering, welding, or smelting. Rosin is widely used as a flux in electric soldering.

(2) A general term used to designate collectively all the electric or magnetic lines of force in a region.

focal length

The distance from the optical center of a lens to the point where light rays converge.

focal plane

A plane that is perpendicular to the optical axis at the focal point. All light coming from infinity will focus somewhere on the focal plane.

focal point

The point at which light rays converge after passing through a convex (positive) lens.

focus

Correct adjustment of a lens to produce a clear image.

force

A push or pull. That which produces or prevents motion or has a tendency to do so.

force measurement device

Refers to any device by which a quantitative determination of an applied force can be made.

forced vibration

Motion caused by some mechanical excitation.

foot-candle

The amount of illumination which a standard source of 1 candle (candlepower) will throw upon a surface placed 1 foot away and at right angles to the rays of light.

free vibration

Vibration that occurs without forcing, as after a tuning fork is struck.

frequency

The number of recurrences of a periodic phenomenon in a unit of time. In specifying electrical frequency, the unit of time is the second.

frequency meter

An instrument for measuring the frequency of an AC signal.

fundamental mode of vibration

The lowest natural frequency.

fusion (heat)

The change of state from a solid to a liquid.

gage

An instrument for measuring or testing; a device for determining whether specific dimensions are within specified limits.

gage block

A block of alloy steel, usually rectangular, with two gaging surfaces. The standard length as nominally represented on the side is in inches between the two gaging surfaces with an uncertainty in the neighborhood of 6 microinches.

Galilean telescope

Devised and constructed by Gailieo in 1609. The device consists of a positive objective lens and a negative eyepiece with their focal points in coincidence. The system is suitable for two or three power magnification and produces an erect image.

galvanometer

A D'Arsonval laboratory instrument usually of the suspension type capable of measuring very small electrical currents. It is usually used to indicate a null. Since the galvanometer is used in this application, to indicate whether or not a current is present, and not necessarily the actual magnitude of the current, the primary requirement of the galvanometer is to show a readable deflection for the smallest current that is significant for a particular measurement.

gamma ray

Radiant energy of extremely short wavelength emitted spontaneously by a radioactive substance.

gas

The state of matter that has no definite shape or volume. The molecules of a gas have almost no cohesive forces, hence the expansion of a gas in free space is almost unlimited.

gauss

Unit of magnetic induction (also called magnetic flux). One gauss represents one line of flux per square centimeter.

geometry

Study of the properties, measurement, and relations between lines, angles, surfaces, and solids.

Go and No-go gages

These are gages that do not measure actual size but merely determine whether parts are within specified limits.

grain

A measure of mass in the English gravitational system equal to one seven-thousandth (1/7000th) pound.

gram

Metric unit of mass or weight. One pound is equal to 453.59 grams.

gram-atomic weight

The relative atomic weight of an element, expressed in grams.

gram-molecular weight (Gram-Mole)

The relative molecular weight of a compound, expressed in grams.

graph

A pictorial presentation of the relation between two or more variable quantities.

graticule

A scale on a transparent material in the focal plane of an optical instrument for the location and measurement of objects.

gravity

Any two bodies in the universe attract each other with a force that is directly proportionate to the product of their mass and inversely proportionate to the square of their distance apart.

gravitational acceleration

The acceleration due to the force of gravity.

gravitational units or "G" units

The usual way of expressing acceleration intensity, in terms of gravitational constant, is equal to the acceleration in inches/sec/sec divided by 386.087 inches/sec/sec.

gross error

A gross error is simply a mistake.

ground

A reference point in an electrical circuit which is usually a connection between an electrical circuit and the Earth or some conducting body serving in place of the Earth.

group velocity

The axial velocity at which a signal travels through a waveguide. Group velocity is always less than the velocity of a signal in open air.

half life

The length of time during which half of a given number of atoms of a radioactive element will disintegrate.

half thickness

The thickness of absorbing material necessary to reduce the intensity of radiation by one-half.

hardness

The internal resistance of an object to having its molecules forced further apart or closer together.

harmonic

A sinusoidal component of a periodic wave or quantity having a frequency that is an integral multiple of the fundamental frequency. Thus, a component whose frequency is twice the fundamental frequency is called the second harmonic.

heat

The energy of molecular motion measured in terms of the effect on some material substance.

heat of fusion

The amount of heat needed to melt a unit mass or weight of a substance at its normal melting point.

heat of vaporization

Heat required to vaporize a unit mass or weight of a liquid at its normal boiling point.

heavy water

The popular name for water which is composed of 2 atoms of deuterium and 1 atom of oxygen.

Hertz

A unit of frequency equal to 1 cycle per second.

Hooke's Law

Within the limits of perfect elasticity, stress is directly proportional to strain.

hunting

Refers to a tendency of a mechanical system to oscillate about a normal condition, or about the point of alignment.

humidity

See relative humidity.

hydrogen atom

The atom of lightest mass and simplest atomic and nuclear structure, consisting of 1 proton with 1 orbital electron. Its mass is 1.008123 mu.

hydrometer

An instrument used to determine the specific gravity of liquids.

hydraulics

The study of liquids in motion.

hydrostatics

The study of liquids at rest.

hygrometer

Any of several instruments for measuring the humidity of the atmosphere.

hygroscopic

Readily absorbing and retaining moisture, often reflecting this absorption by changing physical appearance and shape.

hysteresis

(1) The word hysteresis means "lag." One example is the lagging of the magnetic flux, in a magnetic material, behind the magnetizing force which is producing it. Another example is the lag of a standard cell in returning to its initial voltage following a change in temperature.

(2) In force measurement, hysteresis may refer to the difference in indication for two identical loads, one obtained by reducing from a larger load and the other built up from a lesser value.

ice point

0.01°C below the triple point of water.

illumination

To supply or brighten with light.

image

(1) A virtual image is the impression of an object as viewed by an observer. Rays do not pass through, but only appear to come from the image.

(2) A real image is one through which rays actually pass and can be projected onto a screen.

incident ray

A ray of light entering into a lens or mirror.

inclination

Refers to a difference between the slope of the line or place in question and some other reference line or plane.

increment

Adding the value one to the contents of a register or memory location.

index of refraction

The ratio of the speed of light in a vacuum to its speed in a given substance.

inertia

That property of mass which resists a change in motion.

infinite

Subject to no limitation or external determination, extending indefinitely.

infinite line

A transmission line having characteristics corresponding to those which would be obtained with an ordinary line that is infinitely long.

infinity (optical)

An infinite distance from which collimated or parallel light rays are assumed to emanate (approximately 2000 yards).

initialization

Setting a system to a known state.

instability

An undesired change over a period of time, which change is unrelated to input, operating conditions, or load.

intensity of radiation

The amount of radiant energy emitted in a specific direction per unit time and per unit surface area.

interface

In optics, a boundary between two media in which light travels with different velocities.

interference

In optics, when two sets of light waves of equal wave length and amplitude from the same source meet, so that the crests of one coincide with the troughs of another, they cancel out. Similarly, if two sets of light waves meet when the crests of one coincide with the crests of the other they reinforce each other.

interferometer

An instrument that is used to measure minute linear displacement through the phenomena of light interference.

interferometry

The use of light interference patterns for measurements with apparatuses such as the optical flat.

interpolation

The process of estimating in a transmission line due to power dissipation.

inversion

The condition that exists when both axes of an image are reversed.

inverter

Any mechanical or electrical device for converting direct current into alternating current.

ion

An atomic particle, atom, or chemical radical (group of chemically combined atoms) bearing an electrical charge, either positive or negative, caused by an excess or deficiency of electrons.

ionization

The process by which molecules of a gas are converted into positive ions by loss of electrons, or into negative ions by gain of electrons. Ionization can be produced in a number of ways, by collisions of ions with electrons, by the action of ultraviolet light or other radiations.

ionization potential

The potential necessary to separate 1 electron from an atom.

ionizing event

An event in which an ion is produced.

isobars

Elements having the same mass number but different atomic numbers.

isotope

One of two or more forms of an element having the same atomic number (nuclear charge) and hence occupying the same position in the periodic table. All isotopes are identical in chemical behavior, but are distinguishable by small differences in atomic weight. The nuclei of all isotopes of a given element have the same number of protons but have different numbers of neutrons.

ionosphere

That region of the atmosphere, 70 to 250 miles above the surface of the Earth, containing layers of highly ionized air that are capable of bending or reflecting radio waves back to Earth. Reflection from the ionosphere makes possible long distance reception of radio waves.

jitter

Small, rapid variations in a waveform due to mechanical disturbances.

joule

Unit of energy. The work done when the point of application of 1 newton is displaced a distance of 1 meter in the direction of the force.

K

Symbol for 1000 (10^3). When referring to bits or words, K=1024 (2^{10}).

Kelvin temperature scale

The absolute temperature scale in the CGS system. Kelvin is equal to degrees Celsius plus 273.15.

kilogram

Unit of mass. The mass of a particular cylinder of platinum-iridium alloy, called the International Prototype Kilogram, which is preserved in a vault at Sevres, France, by the International Bureau of Weights and Measures.

kinetic energy

Energy due to motion.

lapping

A smoothing or polishing operation.

laser

An optical cavity capable of oscillating in the visible and nonvisible light spectrum. The laser is a true light amplifier because light energy is used for excitation.

lateral

From the side. Usually refers to movement of a given reference made from left to right to left.

lens

A body of glass or similar material ground to fine limits, used to either converge or diverge rays of light by refraction.

level

Perpendicular to the force of gravity. Also, a device for determining true level by means of a gravity seeking level.

light

A narrow band of radiation which is the visual section of the electromagnetic spectrum. It consists of wavelengths of 15.7 to 27.5 microinches.

line of sight

A straight line that passes through the cross hairs and the principal point of lens is called the line of sight or the line of collimation; it always strikes the object where the cross hairs appear to fall. Accordingly, the cross hairs and the principal point of the lens are said to define the line of sight.

linear

A relation such that any change in one of two related quantities is accompanied by an exactly proportional change in the other.

liquid

The state of matter which has definite volume but no definite shape.

load cell

A type of force transducer designed primarily for the measurement of load or weight. Electric load cells usually employ bonded strain gage resistance elements to provide an electrical output signal proportional to the load. Hydraulic and pneumatic load cells generally make use of a bourdon-type device, such as a Heise gage.

loading effects

An error of measurement resulting in a change of the system under test caused by insertion of the test instrument.

logarithm

The logarithm of a number is the power to which a second number, called the base, must be raised in order to yield the original number. Bases in common use are 10 and 2.718.

lumen

Unit of luminous flux. It is the luminous flux emitted in a solid angle, 1 steradian, by a uniform point source having an intensity of 1 candela.

magnet

Any object which has the property of attracting iron, nickel, or cobalt objects with forces which are much greater than those of gravitation and which do not depend on the presence of electric charges on either body.

magnetic deflection

Method of bending electrons in a CRT by means of the magnetic field produced by coils placed outside the tube.

magnification

The value of magnification is the apparent size of an object viewed through a telescope divided by the size it appears to the unaided eye from the same distance.

malleability

The property of a metal which allows it to be hammered or rolled into sheets.

mantissa

Fractional value used as part of a floating point number. For example, the mantissa in the number 0.9873×10^7 is 0.9873.

mass

The measure of the quantity of matter that a body contains.

mass density (ρ)

Mass per unit volume.

mass number

The number of nucleons in the nucleus of an atom. Symbol: A.

mass unit

A unit of mass based upon 1/16 the weight of an oxygen atom taken as 16.00000. Abbreviation: mu, or atomic mass unit, amu.

master flat

A surface plate, usually round rather than square with a high degree of surface flatness.

matter

Anything which has weight and occupies space.

Mcleod gage

A primary instrument for the measurement of pressure in a vacuum system. The gage consists of a glass bulb with a vertical capillary tube at the top.

mean free path

The average distance a particle moves between collisions. Abbreviation: mfp, symbol, I.

mean solar day

The average of all apparent solar days in a given year.

measurement

The overall process that a person goes through in reaching a decision as to the magnitude of some quantity.

mechanical axis

The true centerline of the mechanical components within the telescope. For a perfectly calibrated instrument the mechanical axis would be coincident with the optical axis.

meniscus

The curved upper surface of a column of liquid which is concave when the walls of the container are wet and convex when the walls of the container are dry.

mercury

A heavy, silver-colored metal which is liquid at ordinary room temperatures.

meson

A short-lived particle carrying a positive, negative, or zero charge, and having a variable mass in multiples of the mass of the electron. Also called mesotron.

metastable state

An excited state of nucleus which returns to the ground state by the emission of a gamma ray over a measurable half life.

meter

Unit of length. The length of exactly 1,650,763.73 wavelengths of the radiation in vacuum corresponding to the unperturbed transition between the levels 2p10 and 5d of the atom of Krypton 86, the orange-red line.

metrology

The science of measurement.

mev

The abbreviation for million electron volts. See Electron-Volt.

micron

A unit of length equal to one-millionth of a meter.

minute

A minute is 1/60th of a degree. This is more correctly described as a "minute of arc."

MKS system

The meter-kilogram-second system.

molecule

The smallest particle of any substance which can exist free and still exhibit all properties of the substance.

molecular weight

The sum of the atomic weights of all the atoms in a molecule.

moment arm

The length of a torque wrench from the center of pivot to the point where force is applied.

momentum

The product of the mass of a body and its velocity. CGS unit: gm-cm/sec.

monochromatic light

Light of only one wavelength or color.

nadir

The point of the celestial sphere that is directly opposite the zenith and vertically downward from the observer.

National Institute of Science and Technology (NIST)

Formerly the National Bureau of Standard (NBS). An independent agency of the U.S. Department of Commerce charged with the improvement and maintenance of all kinds of standards. The bureau operates radio stations WWV, WWVH, WWVB, and WWVL which broadcast accurate frequency and time standards.

negative lens

A concave lens, thicker at the edges than the center, which diverges or spreads rays of light through refraction.

negative mirror

A convex mirror curved out. Produces reflected diverging light rays away from the focal point.

neon

An inert element which is a gas at room temperature. When ionized by current flow it produces a bright orange-red glow.

neutron

An elementary nuclear particle with a mass approximately the same as that of a hydrogen atom and electrically neutral; a constituent of the atomic nucleus. Its mass is 1.00893 mu.

neutrino

A particle with zero rest mass and zero charge, emitted to preserve spin, momentum, and energy in decay and other processes.

newton

Unit of force. That force which gives to a mass of 1 kilogram an acceleration of 1 meter per second. One newton equals 100,000 dynes.

Newtonian fluid

A fluid whose absolute viscosity is the same for all values of shear stress.

nominal value

This is normally the value indicated by the manufacturer. Also the indicated value of an instrument under test.

nomograph

A chart or diagram with which equations can be solved graphically by placing a straightedge on the two known values and reading the answer where the straightedge crosses the scale of the unknown values.

nonsinusodial wave

Any waveform that differs from that of a sine wave.

normal

Perpendicular to a tangent at a point of tangency.

nuclear fission

A special type of nuclear transformation characterized by the splitting of a nucleus into at least two other nuclei and the release of a relatively large amount of energy.

nuclear fusion

The act of coalescing two or more nuclei.

nucleon

The common name for the constituent parts of the nucleus. At present applied to protons and neutrons, but will include any other particle that is found to exist in the nucleus.

nucleus

The heavy central part of an atom in which most of the mass and the total positive electric charge are concentrated. The charge of the nucleus, an integral multiple Z of the charge of the proton, is the essential factor which distinguishes one element from another. Z is the atomic number.

nuclide

A general term referring to all nuclear species--both stable (about 270) and unstable (about 500)-- of the chemical elements, as distinguished from the two or more nuclear species of a single chemical element which are called isotopes.

null method

Any method of measurement in which the reading is taken at zero. Galvanometers, sensitive voltmeters, oscilloscopes, and earphones are used as null detectors.

objective lens

The objective lens of a telescope optical system causes a real image to be formed which, when adjusted to lie within the focal plane of the eyepiece lens can be magnified as a virtual image.

ohm

Unit of electrical resistance. The electric resistance between two points of a conductor when a constant difference of potential of 1 volt, applied between these two points, produces in this conductor a current of 1 ampere, this conductor not being the source of any electromotive force.

ohmmeter

An instrument for measuring resistance.

Ohm's Law

A fundamental electrical law which expresses the relationship between voltage, current, and resistance in a DC circuit, or the relationship between voltage, current, and impedance in an AC circuit.

opaque

Neither reflecting nor emitting light.

optical axis

Centers of curvature of a lens define a line called the axis of the lens. When several lenses combine to form an optical system, the line defined as these axis' is called the optical axis.

optical flat

A piece of glass or quartz which is accurately flat to within one-tenth of a wave length on one or both surfaces, used as a reference (proof plane) for comparison of flatness.

optical infinity

A section of a wave front which has advanced a great distance from its source and assumed essentially a zero curvature. In optics approximately 2000 yards

optical pyrometer

An instrument designed to estimate the temperature of glowing surfaces.

optical tooling

The geometric method of optically establishing a precise line and/or reference plane.

optics

The branch of physics which deals with the phenomena of light.

optimum

The most favorable degree or condition.

out of phase

Having waveforms that are of the same frequency but not passing through corresponding values at the same instants.

out-of-round

The high and low spots in a true circle. It is also the ovality or lobing effect which causes a change of true roundness of cylindrical objects.

overload

A load that is greater than the device is designed to handle.

overshoot

The initial transient response to an unidirectional change in input which exceeds the steady state response.

oxide

An element combined with oxygen. Rust is an oxide of iron.

packing fraction

The difference between the atomic weight in mass units and the mass number of an element divided by the mass number and multiplied by 10,000. It indicates nuclear stability. The smaller the packing fraction, the more stable the element.

pair production

The description of an electron leaving the valence band to enter the conduction band due to absorption of energy (usually heat). This provides a free electron carrier and a free hole carrier at the same time.

parallax

The apparent displacement of the position of an object caused by a shift in the point of observation. Thus, the pointer of a meter will appear to be at different positions on the scale depending on the angle from which the meter is read. To eliminate errors in meter reading due to parallax, the line of sight should be perpendicular to the pointer.

parallel (optical)

A piece of glass with one side parallel to the other side. An optical parallel gives linear displacement.

parameter

(1) In mathematics, one of the constants entering into a functional equation and corresponding to some characteristic property, or dimension.

(2) In an electronic circuit, a characteristic element or constant factor, such as: resistance, capacitance, or inductance values.

Pascal's Law

The pressure applied on a confined fluid is transmitted undiminished in every direction.

peak-to-peak amplitude

The amplitude of an alternating quantity measured from positive to negative peak. This is the value indicated on an oscilloscope.

peak-to-peak value

The algebraic difference between extreme values (as DA or double amplitude is twice the single amplitude).

pentaprism

A five-sided prism which deviates rays of light by 90° without reversing or inverting the image.

pentavalent impurity

Any impure atom that has five electrons in its valence band.

period

The time corresponding to one cycle of a periodic phenomenon. The period of a galvanometer is the elapsed time between consecutive passages of the pointer in the same direction through its zero point.

perpendicular

Being at right angles to a given line or plane.

photoelectric effect

The electrical effect of light or other radiation. This effect can be emission of electrodes, penetration of voltage, or a change in electrical resistance upon exposure to light.

photometry

The measurement of luminous intensity from a light source by comparison to a known standard.

photon

Small particles of light energy according to the quantum theory of light.

photon generator

A light source.

physics

The physical science which deals with matter and energy and with the transformations of energy.

physi-optics

Physi-optical practices combine the use of specific physical measuring standards with optical instruments and physical indicating apparatus.

Planck's constant

A natural constant of proportionality h relating the frequency of a quantum of energy to the total energy of the quantum;

plunge

To rotate the telescope of a Theodolite 180° about the trunnion axis of the instrument.

pointer

The needle-shaped rod that moves over the scale of a meter or dial.

polarized light

Light in which vibrations occur in a single plane perpendicular to the ray.

polyethylene

A tough, flexible, plastic compound that has excellent insulating properties, even at the ultra high frequencies. It is widely used as the insulating material in coaxial cable.

polystyrene

A clear thermoplastic material having very desirable dielectric properties. Many standard capacitors use polystyrene as dielectric.

porosity

Small openings or spaces between particles of matter.

porro prism

A prism which causes an image to be rotated 180°, or reflected. The image is reversed in the plane in which the reflection takes place.

positive lens

A convex lens, thicker at the center than at the edges, which converges rays of light through refraction.

positive mirror

A concave mirror that is curved toward the middle, which converges rays of light through refraction.

positron

A nuclear particle equal in mass to the electron and having an equal but opposite charge. Its mass is 0.000548 mu.

potential

The amount of voltage or charge between a point and a zero reference point. Bodies with an excess of electrons have a negative potential. Bodies with a deficiency of electrons have a positive potential. The electric potential at any point in an electric field is equal to the work done on a unit charge to bring the charge to that point from a place where the potential is zero.

potential difference

The difference in potential between any two points in a circuit; the work required to carry a unit positive charge from one point to another.

potential energy

Energy due to position.

potentiometer (pot)

A variable resistance unit having a rotating contact arm that can be set at any desired point along a resistance element. The voltage source is connected to the end terminals of the resistance element, and the output circuit is connected between one end terminal and the moveable contact to give a voltage dividing action.

potentiometric measurement

DC voltage can be most accurately measured using the potentiometric method. It consists of comparing the unknown voltage with a known voltage from a calibrated potentiometer.

precision

The term precision can best be defined as repeatability. If a measurement is made a number of times and nearly the same value is read each time, it is a precise measurement, the readings may be all wrong. Care should be taken not to confuse precision with accuracy.

pressure

(1) Force per unit area (closed system).

(2) Height times density (open system).

primary colors

Colors in terms of which all colors may be described or from which all colors may be evolved by mixtures.

primary electron

The electron ejected from an atom by an initial ionizing event, as caused by an photon or beta particle.

primary standard

A unit established by some authority or developed through practical exact application of a formula. Secondary standards are calibrated against the primary standard.

principal focus

A point to which rays parallel to the principal axis converge, or from which they diverge after reflection.

principal quantum number

The number, $n = 1, 2, 3, \ldots$ which describes the basic state of atomic system in quantum theory.

prism

A transparent body bounded in part by two plane faces that are not parallel, used to deviate or disperse a beam of light.

probability

The likelihood of the occurrence of any particular form of an event, figured as the ratio of the number of ways in which that form might occur to the whole number of ways in which the event might occur in any form.

proving ring

An elastic ring in which the deflection of the ring, when loaded along a diameter, is measured by means of a micrometer screw and a vibrating reed. Note that all ring-type elastic force measuring devices are not proving rings, and such devices which do not make use of a micrometer screw and vibrating reed should not be called proving rings.

proving ring deflection

The difference between the reading for a given load and the reading for no load.

proton

A positively charged particle occupying the nucleus of an atom that has a charge equal to that of an electron.

psychrometer

An instrument for measuring relative humidity.

pyrometer

A device for measuring high temperatures.

quadrant

One of the four sections in which a plane is divided by two perpendicular lines.

quantum

One of the very small parts into which many forms of energy are subdivided.

quantum level

An energy level of an electron or of any atomic system, distinct from any other of its energy levels by discrete quantities dependent upon Planck's constant.

quantum mechanics

The science of description of atomic systems in terms of discrete quantum states.

quantum number

One of a set of integral or half-integral numbers, one for each degree of freedom, which determines the state of an atomic system in terms of the constants of nature.

quantum state

A term defining the way in which an atomic system exists at any specific time. This state is often described by means of a complex mathematical function called quanta.

quantum theory

The transfer of light and matter occurs only in discrete quantities proportional to the frequency of the energy transferred.

radian

The angle for which the arc length is equal to the radius. There are 2p radians in 1 revolution (360°). A radian represents an angle of approximately 57.3°.

radiant energy

Energy in the form of electromagnetic radiation such as radio waves, heat waves, light waves, ultra violet rays or X-rays.

radiation

A method of transmission of energy. Specifically:

1. Any electromagnetic wave (quantum).
2. Any moving electron or nuclear particle, charged or uncharged, emitted by a radioactive substance.

radioactivity

The process whereby certain nuclides undergo spontaneous atomic disintegration in which energy is liberated, generally resulting in the formation of new nuclides. The process is accompanied by the emission of one or more types of radiation, such as alpha particles, beta particles, and gamma radiation.

radius

The shortest distance from the center of a circle or arc, to a point on the circumference.

random error

Random errors are sometimes called "accidental" errors because they are as likely to occur in one direction as the other. They are the error left when all gross errors and systematic errors have been corrected.

range

(1) Extent of coverage of effectiveness.
(2) Measure of distance.

Rankine temperature scale

A temperature scale which corresponds to the Kelvin scale, but is based on the absolute zero of the Fahrenheit system, so that 0° Fahrenheit = 459.67° Rankine.

ratio bridge

A bridge circuit that uses a calibrated resistive or calibrated inductive voltage divider for one side of the bridge. Precision resistors, inductors, and capacitors are measured with ratio bridge circuits.

ratio transformer

A precisely wound auto transformer used as an AC voltage divider.

ray of light

Can be considered as the path traced by a point on an advancing wave front.

reaction

Any process involving a chemical or nuclear change.

real image

A real image is one through which light rays actually pass and can be projected onto a screen.

reference line

A line from which all other measurements are taken.

reference plane

A reference line that has been rotated through 360 degrees.

reflection

The change in direction of waves after striking a surface.

refraction

The bending of a ray of light, heat, sound, or a radio wave passing obliquely from one medium into another in which the velocity of propagation is different from the first medium.

relative humidity

The ratio of the amount of water vapor in the air at a given temperature to the maximum water vapor (capacity of the air) at the same temperature.

repulsion

A force tending to separate objects or particles having like electrical charges or magnetic polarities.

resilience

The resilience of a body measures the extent to which energy may be stored in it by elastic deformation.

resolution

(1) The term resolution pertains to the scale of an instrument. It is the smallest readout at calibrated points. Resolution is sometimes referred to as "least count."

(2) When uncalibrated adjustments are made, resolution is the smallest change which can be obtained by manipulation of the instrument controls. Resolution can be increased by use of vernier scales.

resonance

The frequency whereby any system responds with maximum amplitude to an applied force having a frequency equal or nearly equal to its own.

resultant

An entity or quantity obtained by means of, or as a result of, a given process.

restoring force

The constant mechanical force provided.

rest point

The equilibrium point or the point at which the pointer of the balance would come to rest once it has been set into oscillation.

reticle

Cross lines found in the telescope of sight levels, transits, and theodolites. Initially in the form of a fine hair. They are now produced by engraving glass with a diamond point to achieve a line of 2.5 to 3 seconds thickness. Also known as; cross hair, filar, (For two parallel lines called); bifilar

reverse

In optics, to rotate a Theodolite 180° about the vertical axis.

rho

The magnitude of the reflection coefficient.,

rhomboid prism

A prism which displaces the axis of a beam without introducing and without reverting the image.

right angle prism

A simple prism used when deviations of 90° are required. Reversion of the image takes place.

roentgen

The quantity of X or   radiation which produces 1 esu of positive or negative electricity/cm^3 of air at standard temperature and pressure or 2.083 x 10^9 ion pairs/cm of dry air.

rosin-core solder

Solder made up in tubular form with the inner space containing rosin flux for effective soldering.

rotary motion

Motion in which every particle of a body moves in a circle and all the circles have their centers on the same straight line.

rotor

(1) A rotating member such as the armature of a motor, generator, or synchro.

(2) The rotating plates of a variable capacitor.

saturation

The point in operation where an increase in a given quantity will have a negligible effect on the output or end result.

scale

(1) Something graduated when used as a measure or rule. A series of spaces marked by lines to indicate the magnitude of some quantity.

(2) A weighing device.

schematic diagram

A diagram which shows all of the electronic parts by means of symbols.

scintillation counter

A device used for the detection of radioactivity.

second (ephemeris second)

Unit of time. Exactly 1/31,556,925.9747 of the tropical year of 1900, January, 0 days and 12 hours ephemeris time.

secondary emission

Electron emission that is the direct result of the impact of electrons against a surface.

Seeback effect

The EMF produced in a circuit containing two contacting conductors of different metals having two junctions at different temperatures.

sensitivity

(1) The degree of response of a circuit to signals of the frequency to which it is tuned.

(2) An indication of the gain of a receiver.

(3) A measure of the minimum signal to which a device shows a measurable response.

(4) The ratio of a small change in instrument reading to the change in the measured quantity required to produce it.

(5) Ratio between electrical output to mechanical output.

servo system

An electromechanical system which is used for positioning one element of a system in relation to another, for example, a PPI sweep in relation to the antenna. The change in position of one element of the system results in the reproduction of an error voltage that is used indirectly to cause a motor to drive the other element of the system to the point where the error voltage no longer exists.

shear

An action or stress from applied forces that causes two contacting parts of a body, to slide relative to each other, in a direction parallel to their place of contact.

shell

One of a series of concentric spheres, called signals, which are designated in the order of increasing distance from the nucleus of an atom, as K, L, M, N, O, P, and Q shells. The number of electrons contained in each shell is limited.

sinusoidal vibration

A simplified back and forth motion of a constrained object which varies sinusoidally with time.

Snell's Law

(Index of refraction) x (sine of incident angle) = (index of refraction) x (sine of refracted angle).

solder

An alloy of lead and tin which melts at a fairly low temperature (about 500°F) and is used for making permanent electrical connections in electrical circuits.

solder bridge

Glob of excess solder that shorts two conductors. A common problem on production PC boards.

solid

The state of matter which has a definite shape and definite volume.

solid state physics

That branch of physics which deals with the structure and properties of solids. In electronics, solid state refers to those devices which can control current without the use of moving parts, heated filaments or vacuum gaps.

sonar

Sound navigation and ranging. Electronic equipment used for underwater detection of objects and determination of their range.

sound

A vibration of a body which can be heard by human ears. The extreme limits of human hearing is 20 Hz to 20 kHz. Sound can travel through any medium which possesses the ability to vibrate; the vibrations are called sound waves.

space charge

The negative charge produced by the cloud of electrons existing in the space between the cathode and plate of a thermionic vacuum tube; formed by electrons emitted from the cathode in excess of those immediately attracted to the plate.

specific gravity

The ratio of the density of a substance to the density of a standard (distilled water).

specific heat

The ratio of the heat capacity of a body to its mass or weight.

spectrum

(1) The entire range of wavelengths within which electromagnetic radiations occur.

(2) A segment of wavelengths which has a special function or possesses special properties.

spherical aberration

The failure of parallel rays to meet at a single point after reflection, causing a blurred image.

spin

The inherent, intrinsic angular momentum of an atomic particle; a quantum number in modern atomic theory.

spindle axis

An axis found on theodolites and transits that goes directly through the center of the instrument.

stadia lines

Lines or marks on a reticle used to determine distances to objects of a known height or width by using trigonometric principles.

standard

Anything taken as a basis of comparison. An authorized weight or measure having recognized excellence. It is desirable that the standard have an uncertainty that is one-tenth or less than the equipment being calibrated. A standard is a physical embodiment of a unit. In general it is not independent of physical condition, and it is a true embodiment of the unit only under specified conditions, for example, a yard standard has a length of one yard when at some definite temperature and supported in a certain manner.

standard deviation

The square root of the sum of the squares of the deviations from the arithmetic mean of a frequency distribution. The deviations from the arithmetic mean are squared and added, and the square root of this sum is the standard deviation.

standard pressure

The pressure exerted by a column of mercury exactly 760 mm high.

standard temperature

The temperature of melting ice.

steradian

One-fourth of the solid angle around a point.

Stoke's Law

The basis of kinematic viscosity which states that the terminal velocity of a sphere (or any object) falling freely through a fluid is controlled by the density of the sphere and the absolute viscosity of the fluid.

strain

Deformation of a material body under the action of applied forces (stress).

straightness

This is the uniformity of direction throughout the extent of that feature, such as the freedom from bend, warp, or twist of a shaft.

stress

Mutual force between contacting surfaces of bodies caused by an external force, such as tension or shear.

stress testing

Introducing mechanical, electrical, or thermal stress on electrical devices so as to modify their operation and allow intermittent problems to be observed.

stroboscope

An instrument used to determine the speed of a rotating body. It creates the optical illusion of slowing down or stopping the motion of an object by illuminating it with flashes of intense light at regular intervals.

sublimation

The change of state from a solid to a vapor or gas without going through the liquid state.

summer solstice

Longest day of the year. It usually falls on June 21st in the northern hemisphere. The sun casts its shortest shadows in the summer solstice.

surface tension

The tendency of the surface of a liquid to contract.

synchro

The universal term applied to any of the various synchronous devices such as the "selsyn," "autosyn," "motor-torque generator," "magslip," and "siemens." The standard signal and control synchro today has two-pole single-phase rotor field and a delta or Y-wound single-phase variable-voltage stator.

systematic error

Systematic errors tend to bias all the measurements in one direction. The same error is occurring in measurement after measurement. Systematic errors can usually be blamed for trends, jumps, or drifts in a reading. They are also called persistent errors.

table

Collection of data in a form suitable for ready reference, frequently stored in sequential memory locations.

table look-up

Obtaining a value from a table of values stored in the computer.

tachometer

An instrument for measuring rotational speed in revolutions per minute (rpm).

telescope

An instrument for making objects appear nearer and larger. The telescope forms the basis upon which physi-optical instruments are designed, such as the transit and Theodolite.

temperature

The quantitative measure of the relative hotness or coldness of an object.

temperature coefficient

A numerical value that indicates the relation between a temperature change and the resulting change in another property. The numerical value can be either negative or positive.

tensile strength

The force required to break a rod or wire of unit cross-sectional area.

terminal Linearity

Ratio of the actual error voltage in the output to the total input voltage. This will vary with the setting of the ratio voltage divider.

terrestrial

Relating to earthly matters. A terrestrial telescope is one in which the image appears normal, not reversed or inverted.

termination

The load connected to the output end of a circuit or transmission line.

testing machine

A machine for applying forces to specimens of steel and other material to determine the applied force which the test specimen will withstand.

test instrument

The device which is being compared with the calibration standard. The test instrument is the instrument whose accuracy is being tested.

test set

A combination of instruments needed for making a particular combination of tests, or for servicing a particular type of equipment.

Theodolite

An optical instrument used for measuring horizontal or vertical angles.

thermal agitation

Random movement of free electrons in a circuit due to the presence of heat.

thermal energy

The potential and kinetic energy of the particles of a body which can be evolved as heat.

thermal runaway

A result of a regenerative increase in collector current and junction temperature.

thermal capacity

The amount of heat required to produce a unit temperature change. Water has the highest thermal capacity of any common substance.

thermistor

A resistor whose value varies with temperature in a definite desired manner, used in circuits to compensate for temperature variations in other parts. It may have either a negative or a positive temperature coefficient. One type is made from a semiconducting material such as uranium oxide or silver sulfide, having a relatively large negative temperature coefficient of resistance. The name is a contraction of thermal resistor.

thermocouple

Two dissimilar metals joined at one end. When a difference of temperature exists between the ends, and EMF is generated across the thermocouple. This DC voltage is proportional to the heat applied to the thermocouple junction.

threshold sensitivity

Refers to the smallest fractional load which will cause a pressure system to indicate that a load is starting to be applied.

tilt graticule

A graduate reticule used in Collimators for measuring vertical and horizontal tilt, or angular deviation.

time

The period during which an action or process continues; measurement of duration.

torque

The cause of rotary motion. Torque is equal to the applied force multiplied by the distance from the center of rotation. (lb/ft, oz/in, etc..)

torque wrench

A wrench with which the mechanic can apply specific amounts of torque, usually as indicated by the setting of the handle.

torr

1/760 of an atmosphere - 1 mm Hg.

total force

The force acting against the entire area of a particular surface.

transient

The instantaneous surge of voltage or current that occurs as the result of a change from one steady-state condition to another.

transient vibration

Abrupt changes or shocks in the levels of other motion.

transit

Similar to a Theodolite; can only make measurements with the use of accessories. Readings are linear deviation.

transmutation

A change in the identity of a nucleus because of a change in its number of protons.

transparent

Having the property of transmitting light without appreciable scattering so that bodies lying beyond are entirely visible.

trivalent impurity

Any impure atom that has three electrons in its valence band.

troubleshoot

To seek the cause of a malfunction or erroneous program behavior in order to remove the malfunction.

troubleshooting tree

Flow diagram consisting of tests and measurements used to diagnose and locate faults in a product.

tropical year

The time between two successive vernal equinoxes. Our calendar is based on the tropical year. It is equal to 365 days, 5 hours, 48 minutes, and 49.7 seconds.

true mass

Mass as measured in a vacuum.

true value

The value of a physical quantity that would be attributable to a material object or physical system if that value could be determined without error.

twisted pair

A cable composed of two insulated conductors twisted together either with or without a common covering.

ultraviolet

A range of invisible radiation frequencies beyond the visible spectrum at the high frequency end, and extending into the region of low frequency X-rays.

unifilar

Having or using one fiber, wire or thread.

unit

A value, quantity, or magnitude in terms of which other values, quantities, or magnitudes are expressed. In general, a unit is fixed by definition and is independent of such physical conditions as temperature.

Examples: yard, pound, gallon, meter, liter, gram.

vacuum

Any pressure below atmospheric. In gage pressure measurement, 5 psig vacuum means 5 psi below atmospheric pressure. In absolute pressure measurements, any pressure from zero psia (perfect vacuum) up to atmospheric pressure.

valence

The number representing the combining or displacing power of an atom; number of electrons lost, gained, or shared by an atom in a compound; the number of hydrogen atoms with which an atom will combine, or the number it will displace.

valence band

The outermost orbit of an atom that will contain electrons at absolute zero.

valence electrons

Electrons which are gained, lost, or shared in chemical reactions.

vaporization

The production of a vapor or gas from matter in another physical state.

velocity

The time rate of change of position.

velocity constant

The ratio of the velocity of propagation in a transmission line to the velocity of light.

vernal (spring) equinox

First day of spring in the northern hemisphere. It usually falls on March 21st in the northern hemisphere. There are about 12 hours of light and 12 hours of darkness every place on the Earth during an equinox.

vernier

An auxiliary scale made to work in conjunction with the divisions of a graduated instrument for indicating parts of a division.

vertically polarized wave

An electromagnetic wave in which the electric field (E) is perpendicular to the horizon and the magnetic field (H) is horizontal (parallel to the Earth's surface).

vertical

Perpendicular to the horizontal plane. The direction of gravity.

vertical axis

The axis about which the telescope rotates when sweeping a horizontal plane.

vibration

Mechanical oscillations or motion about a reference point or equilibrium.

virtual image

The impression of an object as viewed by the observer. Light rays do not pass through, but only appear to come from the image.

viscosity

The internal friction of a fluid. Also a quantitative measure of a fluid's lubricity.

VLSI

Very Large Scale Integration.

volatile

Readily vaporizable at a relatively low temperature.

volume

The amount of space which matter occupies.

wave front

A surface composed at any instant of all the points just reached by a vibrational disturbance in its propagation through a medium.

wedge

A weak prism, used when very small deviations of a beam are required. The wedge is also used in conjunction with penta and other prisms for corrective purposes.

weight

The force of gravity acting on an object.

winter solstice

Shortest day of the year. It usually falls on December 21st in the northern hemisphere. The sun casts its longest shadows in the winter solstice.

work

That which is accomplished when a force acts on matter and moves it. (ft/lb, in/oz, etc...)

zenith

The point of the celestial sphere that is directly opposite the nadir and vertically above the observer.