HANDOUT

HO E3ABR2P0X1-0B1A

Technical Training

MEASUREMENT AND CALIBRATION HANDBOOK

Precision Measurement Equipment Laboratory Specialist Course

November 2005

81st TRAINING GROUP
332 Training Squadron
Keesler Air Force Base, Mississippi 39534-2480

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Designed for AETC Course Use

NOT INTENDED FOR USE ON THE JOB

Acknowledgment

The material contained in this handbook has been a combined effort of the staff of the Metrology Training Flight. This book is a combination of all the Metrology books that have come before. Special thanks goes to Mr. Thomas Daniels (Supplemental) and Mr. Floyd Parsons, 332 TRS/UNC (Physical Dimensional Course) for their concerted efforts.

Editorial Note

This guide has been established as a training aid for students attending all Metrology Courses. As technology changes, so must we. Should you encounter any additions, corrections, or deletions from this guide, please forward your suggestions to the following address :

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Table of Contents

Supersedes HO E3AQR2P031-000-1, February 2004, which may be used until exhausted

SECTION 1 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 centermeter
0.3937 inches
3.281×10^{-2} feet
1.094×10^{-2} yards
6.214×10^{-6} miles

1 foot
0.3333 yards
30.4801 centimeters
3.048×10^{-4} kilometers
0.3048 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
0.8684 nautical miles

1 yard =
0.9144 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

1 in^3 =

16.3871 cm^3
5.787 x 10^{-4} ft^3
1.639 x 10^{-5} m^3
2.143 x 10^{-5} yd^3
4.329 x 10^{-3} gallons(US Liq)
1.639 x 10^{-2} liters
3.463 x 10^{-2} pints(US Liq)

1 ft^3 =

2.832 x 10^{-2} m^3
1728 in^3
28,320 cm^3
3.704 x 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 x 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 x 10^{-2} in^3
3.5315 x 10^{-5} ft^3
1.0 x 10^{-6} m^3
1.308 x 10^{-6} yd^3
2.642 x 10^{-4} gallons(US Liq)
1.0 x 10^{-3} liters
2.113 x 10^{-3} pints(US Liq)
1.057 x 10^{-3} quarts(US Liq)

1 quart (US liquid) =

946.353 cm^3
57.75 in^3
3.342 x10^{-2} ft^3
9.464 x 10^{-4} m^3
0.25 gallons
0.9463 liters

1 liter =

1000 cm^3
61.02 in^3
1.308 x 10^{-3} yd^3
2.113 pints(US Liq)
1.0567 quarts(US Liq)
0.2642 gallons(US Liq)

1 gallon liquid =

231 in^3
3785.4118 cm^3
0.13368 ft^3
3.7853 x 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

PRESSURE

1 atmosphere @ 0°C and sea level =

14.696 PSIA
760 mmHg
29.9213 inHg

1 PSI (O°C) =

51.7149 mmhg
2.036 inhg
6.8947 x 10^4 dynes/cm^2
3.531 x 10^{-2} ft^3
49116 pounds/in^2 (PSI)
.03453 kilograms/cm^2

1 centimeter of mercury (O°C) =

13.5955 grams/cm^2
0.3937 inches of Hg

1 g =

388.58 in/sec^2

1 millibar =

0.02953 in Hg
0.0145 lbs/in^2
0.750062 mm Hg

1 foot of water =

0.4335 lbs/in^2
0.8826 in Hg
0.03048 kgs/cm^2

1 foot of sea water =

.4453 lbs/in

1 Torr =

1/760 atm.
1 mm
1000 microns

POWER, WORK and HEAT CONVERSION

1 BTU =

251.9958 calories/gram

777.649 ft-lbs

3.931×10^{-4}

horsepower-hrs

1,054.8 joules

1 watt =

44.2537 ft-lbs/minute

3.4144 BTU/hr

1 joule/sec

1 kilowatt =

1.3410 horsepower

1 horsepower =

745.7 watts

550 ft-lbs/sec

745.7 joules/sec

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

SECTION II MATHEMATICS

MATHEMATICAL SYMBOLS

$+$	Positive, Plus, or Add	$\perp$	Perpendicular to
$-$	Negative, Minus, or Subtract	$\parallel$	Parallel to
$\pm$ or $+/-$	Positive or Negative Plus or Minus	π	Pi
X or $\bullet$	Multiply	$\in$	Base of natural log 2.718
$\div$ or /	Divide	$\sqrt{\ }$	Square root
= or ::	Equals	$\sqrt[3]{\ }$	Cube root
$\equiv$	Identical	$\sqrt[n]{\ }$	n^{th} root
$\neq$	Not equal to	$\lvert n \rvert$	Absolute value of n
$\cong$ or $\approx$	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
$\geq$	Greater than or equal to	$\bar{n}$	Average value of n
$\leq$	Less than or equal to	j	Square root of -1
::	Proportional to	%	Percentage
:	Ratio	n_l	Subscript of n
$\therefore$	Therefore	( )	Parentheses
∞	Infinity	[ ]	Brackets
Δ	Increment or change	{ }	Braces
$\angle$	Angle	—	Vinculum

MATHEMATICAL CONSTANTS

Symbol	Number	Log_{10}	Symbol	Number	Log_{10}
π	3.1416	0.4971	$\frac{4}{\pi}$	1.2732	0.1049
π^2	9.8696	0.9943	$\frac{1}{2\pi}$	0.1592	9.2018^{-10}
2π	6.2832	0.7982	$\frac{1}{4\pi}$	0.0796	8.9008^{-10}
$2\pi^2$	19.7392	1.2953	$\frac{1}{6\pi}$	0.0531	8.7247^{-10}
3π	9.4248	09742	$\frac{1}{8\pi}$	0.0398	8.5998^{-10}
4π	12.5664	1.0992	$\frac{\pi}{180}$	0.0175	8.2419^{-10}
$4\pi^2$	39.4784	1.5964	$\frac{180}{\pi}$	57.2958	1.7581
8π	25.1327	1.4002	$\frac{1}{\pi^2}$	0.1013	9.0057^{-10}
$\frac{\pi}{2}$	1.5708	0.1961	$\frac{1}{2\pi^2}$	0.0507	8.7047^{-10}
$\frac{\pi}{3}$	1.0472	0.0200	$\frac{1}{4\pi^2}$	0.0253	8.4036^{-10}
$\frac{\pi}{4}$	0.7854	9.8951^{-10}	$\sqrt{\pi}$	1.7725	0.2486
$\frac{\pi}{6}$	0.5236	9.7190^{-10}	$\frac{\sqrt{\pi}}{2}$	0.8862	9.9475^{-10}
$\frac{\pi}{8}$	0.3927	9.5941^{-10}	$\frac{\sqrt{\pi}}{4}$	0.4431	9.6465^{-10}
$\frac{2\pi}{3}$	2.0944	0.3210	$\sqrt{\frac{\pi}{2}}$	1.25330	0.0980
$\frac{4\pi}{3}$	4.1888	0.6221	$\sqrt{\frac{2}{\pi}}$	0.7979	9.9019^{-10}
$\frac{1}{\pi}$	0.3183	9.5029^{-10}	π^3	31.0063	1.4914
$\frac{2}{\pi}$	0.6366	9.8039^{-10}	$\frac{1}{\pi^3}$	0.03225	8.5086^{-10}

NUMERICAL CONSTANTS (extended)

π or h = 3.14159 26535 89793 23846 26433 83279 50288 41971
$\in$ or j = 2.71828 18284 59045 23536 02874 71352 66249 77572

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		$\in$	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		o	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 ($2 \pi f$)

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

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

NOTES

POWERS OF TWO CHART

		2^n	n	2^{-n}								
		1	0	1.0								
		2	1	0.5								
		4	2	0.25								
		8	3	0.125								
		16	4	0.062	5							
		32	5	0.031	25							
		64	6	0.015	625							
		128	7	0.007	812	5						
		256	8	0.003	906	25						
		512	9	0.001	953	125						
	1	024	10	0.000	976	562	5					
	2	048	11	0.000	488	281	25					
	4	906	12	0.000	244	140	625					
	8	192	13	0.000	122	070	312	5				
	16	384	14	0.000	061	035	156	25				
	32	768	15	0.000	030	517	578	125				
	65	536	16	0.000	015	258	789	062	5			
	131	072	17	0.000	007	629	394	531	25			
	262	144	18	0.000	003	814	697	265	625			
	524	288	19	0.000	001	907	348	632	812	5		
1	048	576	20	0.000	000	953	647	316	406	25		
2	097	152	21	0.000	000	476	837	158	203	125		
4	194	304	22	0.000	000	238	418	579	101	562	5	
8	388	608	23	0.000	000	119	209	289	550	781	25	
16	777	216	24	0.000	000	059	604	644	775	390	625	
33	554	432	25	0.000	000	029	802	322	387	695	312	5

MATHEMATICS

SEQUENCE OF MATHEMATICAL OPERATIONS

Remember

Please Excuse My Dear Aunt Sally

Parentheses	(**P**)
Exponents	(**E**)
Multiply	(**M**)
Divide	(**D**)
Add	(**A**)
Subtract	(**S**)

SIGNIFICANT FIGURES/SIGNIFICANT DIGITS

Figures arrived at by counting are often exact. On the other hand, figures arrived at by measuring are approximate. 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. (Example rounded off to two significant digits to the right of the decimal) 7.1550000 becomes 7.16

EXPONENTS

Zero exponent	$a^{\circ} = 1$	Power of a power	$\left(a^x\right)^y = a^{xy}$
Negative exponent	$a^{-x} = \frac{1}{a^x}$	Root of a power	$\sqrt[y]{a^x} = a^{x},{}^{y}$
Multiplication	$a^x \bullet a^y = a^{(x+y)}$	Fractional exponents	$a^{1/4} = \sqrt[4]{a}$ $\quad \frac{x}{a^y} = \sqrt[y]{a^x}$
Division	$a^x \div a^y = \frac{a^x}{a^y} = a^{(x-y)}$	Radicals	$\sqrt{\frac{a}{b}} = \frac{\sqrt{a}}{\sqrt{b}}$ $\quad \sqrt{ab} = \sqrt{a} * \sqrt{b}$
Power of a product	$(ab)^x = a^x b^x$		

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

LOGARITHMS

The exponent of that power of a fixed number, called the base, which equals a given number.

$10^2 = 100$, therefore 2 = log of 100 to the base 10.

Exponential Form	Logarithmic Form
$2^4 = 16$	$4 = \log_2 16$
$10^2 = 100$	$2 = \log_{10} 100$
$10^3 = 1000$	$3 = \log_{10} 1000$
$a^b = c$	$b = \log_a c$

Multiplication	log (6*4) = log 6+log
Division	$\log \frac{3}{4} = \log 3 - \log 4$
Rasing to a power	$\log N^3 = 3 \log N$
Extracting roots	$\log \sqrt[3]{N} = \frac{\log N}{3}$
Common to natural	$\log_{10} N = 2.3026 \log_e N$
Natural to common	$\log_e N = 0.4343 \log_{10} N$

SCIENTIFIC NOTATION

A whole number between 1 and 10 times the proper power of ten, also called standard form.
Example: $4.30 \times 10^4 = 43000$

TRIGONOMETRY AND GEOMETRY

Remember:

$$\frac{\text{Oscar}}{\text{Had}} = \text{Sick} \qquad \frac{\text{O}}{\text{H}} = \text{S}$$

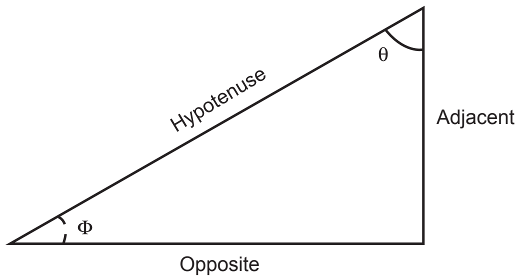
$$\frac{\text{A}}{\text{Heap}} = \text{Call} \qquad \frac{\text{A}}{\text{H}} = \text{C}$$

$$\frac{\text{Of}}{\text{Apples}} = \text{Tomorrow} \qquad \frac{\text{O}}{\text{A}} = \text{H}$$

H = Hypotenuse
A = Adjacent side
O = Opposite side

S = Sine
C = Cosine
T = Tangent

θ = angle between hypotenuse and adjacent side
ϕ = angle between hypotenuse and the opposite side



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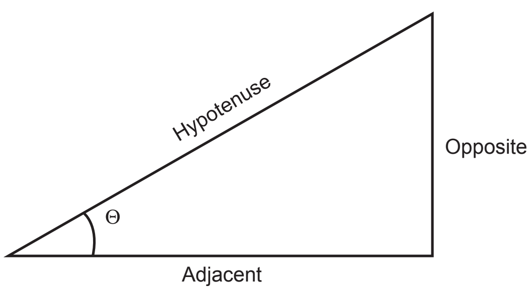
$$\sin\theta = \frac{O}{H} \qquad \cos ecant\theta = \frac{H}{O} \qquad \sin\theta = \cos\phi \qquad \cos ecant\theta = \sec\phi$$

$$\cos\theta = \frac{A}{H} \qquad \sec ant\theta = \frac{H}{A} \qquad \cos\theta = \sin\phi \qquad \sec\theta = \cos ecant\phi$$

$$\tan\theta = \frac{O}{A} \qquad \cot\theta = \frac{A}{O} \qquad \tan\theta = \cot\phi \qquad \cot angent\theta = \tan\phi$$

TRIGONOMETRIC RELATIONS



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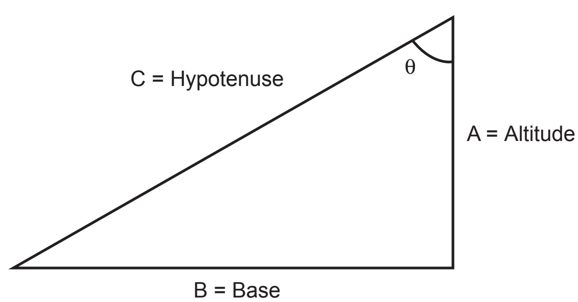
PYTHAGOREAN THEOREM

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

$c^2 = a^2 + b^2$ $\qquad a^2 = c^2 - b^2$ $\qquad b^2 = c^2 - a^2$



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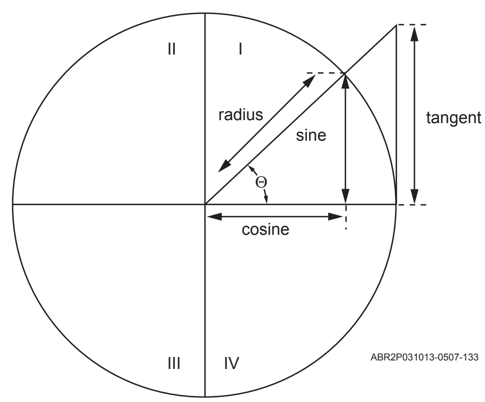
LENGTH of SIDES for RIGHT-ANGLE TRIANGLES

Length of Hypotenuse =	Side Opposite * Cosecant
	Side Opposite / Sine
	Side Adjacent * Secant
	Side Adjacent / Cosine
Length of Side Opposite =	
	Hypotenuse * Sine
	Hypotenuse / Cosecant
	Side Adjacent * Tangent
	Side Adjacent / Cotangent
Length of Side Adjacent =	
	Hypotenuse * Cosine
	Hypotenuse / Secant
	Side Opposite * Cotangent
	Side Opposite / Tangent

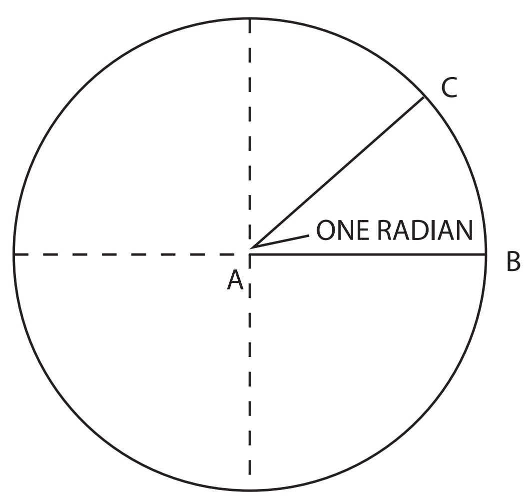
SIGNS OF THE FUNCTIONS

QUADRANT	$\sin\theta$	$\cos\theta$	$\tan\theta$
I	+	+	+
II	+	-	-
III	-	-	+
IV	-	+	-



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..
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



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To convert

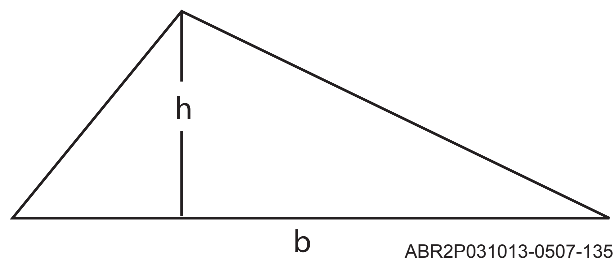
FROM → TO ↓	DEGREES (ANGLE)
QUADRANTS	.01111
RADIANS	.01745
SECONDS	3600

VARIOUS MEASUREMENTS

Plane figures bounded by straight lines.

Area of a triangle with base (b) and altitude (h).

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



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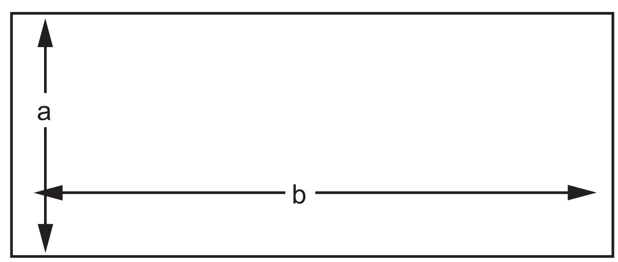
Area of a rectangle with sides (a) and (b).

area = ab



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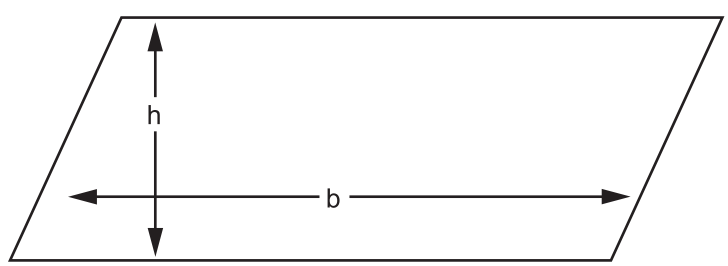
Area of a parallelogram

with side (b) and perpendicular distance to the parallel side (h).

area = bh



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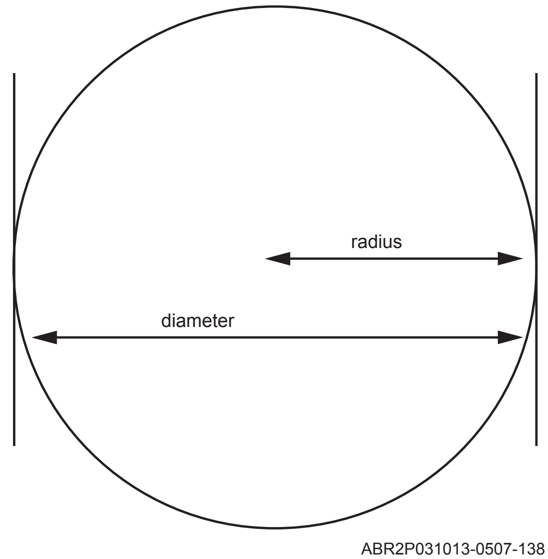
Plane figures bounded by curved lines.

<u>Circumference of a circle</u>

whose radius is (r) and diameter (d)

$$\text{circumference} = 2\pi r = \pi d$$



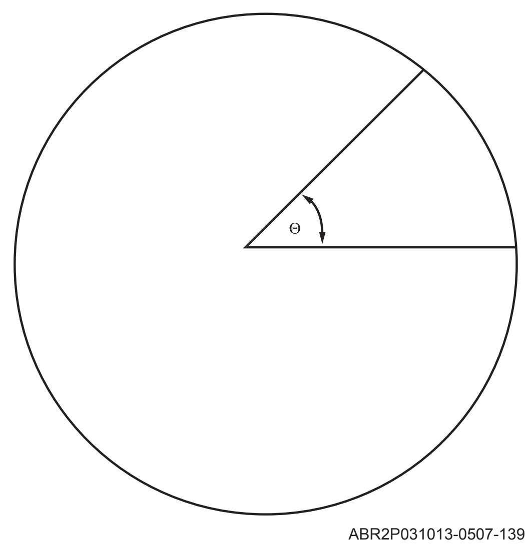
<u>Area of a circle</u>

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

<u>Length of an arc</u>

of a circle for an arc of θ degrees.

$$\text{length of arc} = \frac{\pi r \theta}{180}$$



ERROR CALCULATIONS

Relative Error

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

Where:

e_r= relative error
M= measured value
T= True value

$$e_r = N - A$$

Where:

e_r = Error
N = Nominal
A = Actual

Percent Relative Error

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

Where

$e_r(\%)$ = percent relative error
M = measured value
T= true value

Correction

C = A-N

Where

C = Correction
N = Nominal
A = Actual

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

Correction Factor (%)

$$CF\% = \frac{A - N}{N} x100$$

Correction Factor (PPM)

$$CF_{ppm} = \frac{A - N}{N} x10^6$$

WHERE :

CF = Correction Factor (in Percent or Parts-Per-Million)
A = Actual Value
N = Nominal value

(1)To convert from Percent(%) to Parts-Per-Million, move the decimal place 4 places to the right.
(2)To convert from Parts-Per-Million to Percent(%), move the decimal place 4 places to the left.

Calculation of Acceptable Limits

____________% of Range (FULL SCALE) ____________Where any of these quantities are
____________% of Reading(INPUT/OUTPUT) ____________given, cross multiply the values across,
____________#of Digits(RESOLUTION) ____________and then add to fill the total block. This
TOTAL = ± _______________value is then applied to the %READING

EXAMPLE : 930V applied, 1200 Volt Range, 8 1/2 digit display,tolerance ±(.015% input + .01% range + 5 digits)

.01% Range * 1200 = .12
.015% Input * 930 = .1395
8 1/2 digits 1 2 0 0.0 0 0 0 5 (NOTE : ELIMINATE #'s LEFT OF DECIMAL)
TOTAL = ±.25955 WHICH IS THEN APPLIED TO 930v FOR LIMITS OF 929.74045 to 930.25955

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	0.036128241	4° C

METRIC CONVERSION: ft to N•m

The chart below can be used to convert pound foot to newton meter. The left hand column lists pound foot in multiplie of 10 and the numbers at the top of the columns list the second digit. Thus 36 pound foot is found by following the 30 pound foot line to the right to the "6" and the conversion is 49 N•m.

lb ft	**0** N•m	**1** N•m	**2** N•m	**3** N•m	**4** N•m	**5** N•m	**6** N•m	**7** N•m	**8** N•m	**9** N•m
0	0	1.36	2.7	4.1	5.4	6.8	8.1	9.5	10.9	12.2
10	13.6	14.9	16.3	17.6	19.0	20.3	21.7	23.1	24.4	25.8
20*	27	28	30	31	33	34	35	37	38	39
30	41	42	43	45	46	47	49	50	52	53
40	54	56	57	58	60	61	62	64	65	66
50	68	69	71	72	73	75	76	77	79	80
60	81	83	84	85	87	88	90	91	92	94
70	95	96	98	99	100	102	103	104	106	107
80	109	110	111	113	114	115	117	118	119	121
90	122	123	125	126	127	129	130	132	133	134
100	136	137	138	140	141	142	144	145	146	148

* Above 20 lb. ft the converted N•m readings are rounded to the nearest N•m

METRIC CONVERSION: kg cm to N•m										
The chart below can be used to convert kilograms centimeter to newton meter. The left hand column lists kg•cm in multiplie of 10 and the numbers at the top of the columns list the second digit. Thus 72 kg•cm is found by following the 70 kg•cm line to the right to the "2" and the conversion is 7.1 N•m.										
kg cm	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
	N•m	**N•m**	**N•m**	**N•m**	**N•m**	**N•m**	**N•m**	**N•m**	**N•m**	**N•m**
0	0	.098	.20	.29	.39	.49	.59	.69	.78	.88
10	.98	1.08	1.18	1.27	1.37	1.47	1.57	1.67	1.76	1.86
20*	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9
30	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8
40	3.9	4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8
50	4.9	5.0	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8
60	5.9	6.0	6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8
70	6.9	7.0	7.1	7.2	7.3	7.4	7.5	7.6	7.7	7.8
80	7.9	7.9	8.0	8.1	8.2	8.3	8.4	8.5	8.6	8.7
90	8.8	8.9	9.0	9.1	9.2	9.3	9.4	9.5	9.6	9.7
100	9.8	9.9	10.0	10.1	10.2	10.3	10.4	10.5	10.6	10.7
* Above 20 kg•cm the converted N•m readings are rounded to the nearest N•m										

One oz. in = 28.35 gms. in

One lb. in = 1.152 kg•cm

One lb. ft. = kg•m

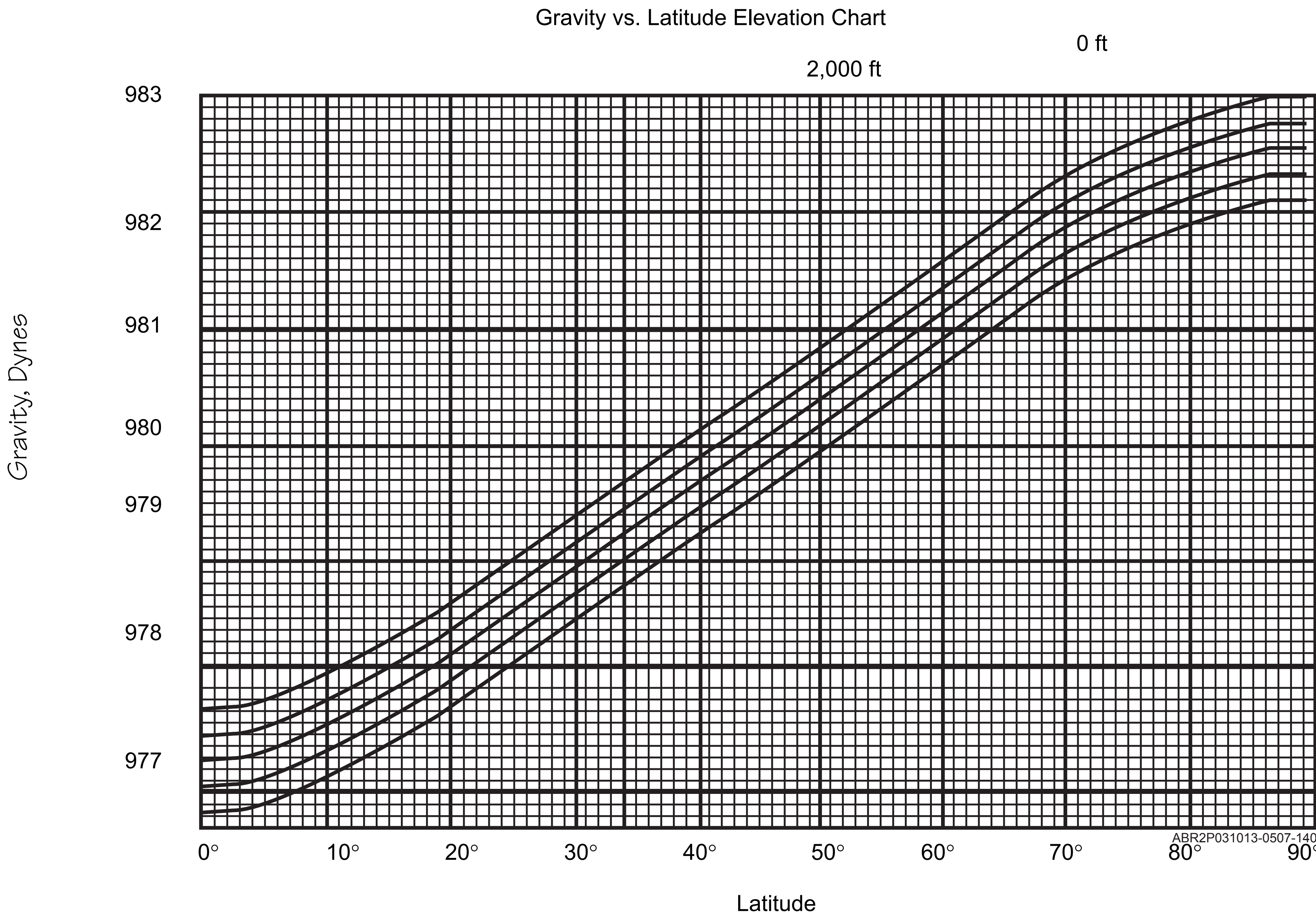
One kg•cm = 8679 lb. in.

One kg•cm = 7.233 ;b. ft.

One N•cm = .0885 lb. in.

One N•m = .7375 lb. ft.

CONVERSION OF VARIOUS UNITS OF TORQUE					
Convert from	**To**	**Multiply**	**Convert from**	**To**	**Multiply**
lb.in	oz.in.	16	oz.in.	lb.in	.0625
lb.in	lb.ft.	.08333	lb.ft.	lb.in	12
lb.in	kg.cm.	1.1519	kg.cm.	lb.in	.8681
lb.in	kg.m	.011519	kg.m	lb.in	86.81
lb.in	N.m	.113	N.m	lb.in	8.85
lb.in	dN.m	1.13	dN.m	lb.in	.885
lb.ft	kg.m	.1382	kg.m	lb.ft	7.236
lb.ft	N.m	1.356	N.m	lb.ft	.7376
N•m	dN.m	10	dN.m	N•m	.10
N•m	kg.cm	10.2	kg.cm	N•m	.09807
N•m	kg.m	.102	kg.m	N•m	9.807



NOTE
g_s (Standard Gravity) is 980.665

LINEAR COEFFICIENTS OF EXPANSION α

SUBSTANCE	$\frac{n \times 10^{-6}}{C°}$	$\frac{n \times 10^{-6}}{F°}$
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

$L_f = L_o (1 + \alpha \Delta t)$

Where:

L_f = Length Final

ΔL = Change in Length

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

Δt = Change in Temperature ($t_2 - t_1$)

$\Delta L = (L_o)(\alpha)(\Delta t)$

Where:

L_o = Length Original

α = Linear Coefficient of Expansion

t_2 = Final Temperature

Cº/Fº = 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 an uniform temperature of 68ºF (20ºC)"

GAGE BLOCK CLASSIFICATION

	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	±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. 4-88 (Inch system)						
.050	.1006	.109375	.122	.135	.148	.700
.0625	.1007	.110	.123	.136	.149	.750
.078125	.1008	.111	.124	.137	.150	.800
.093750	.1009	.112	.125	.138	.200	.850
.100	.101	.113	.126	.139	.250	.900
.100025	.102	.114	.127	.140	.300	.950
.100050	.103	.115	.128	.141	.350	1.000
.100075	.104	.116	.129	.142	.400	2.000
.1001	.105	.117	.130	.143	.450	3.000
.1002	.106	.118	.131	.144	.500	4.000
.1003	.107	.119	.132	.145	.550	
.1004	.108	.120	.133	.146	.600	
.1005	.109	.121	.134	.147	.650	

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

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”	

SECTION III PHYSICAL-DIMENSIONAL

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

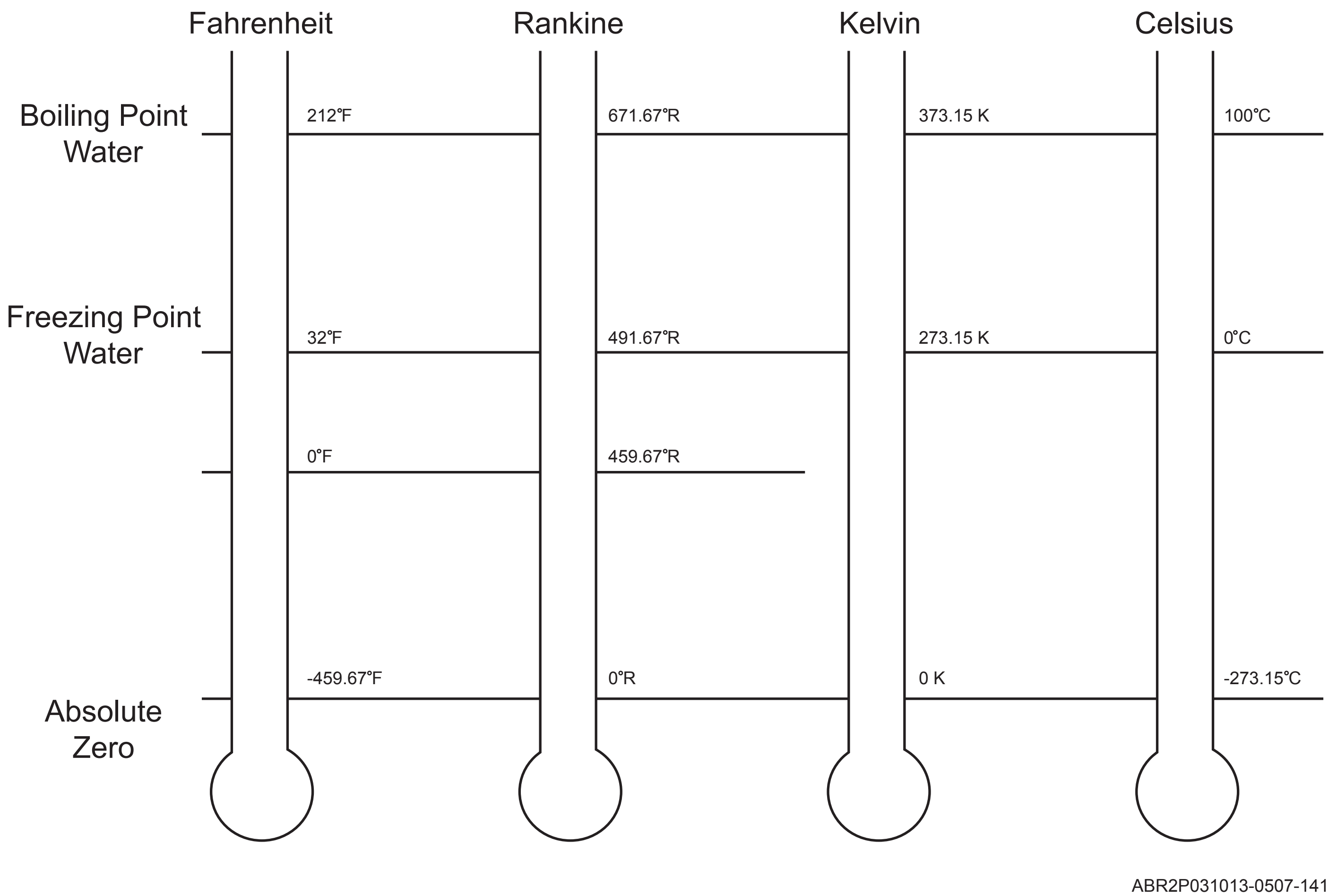
t_i = Temperature of the thermometer bulb

$\overline{t_s}$ = Average temperature of the portion of the stem containing mercury which is out of the bath

t_a = Actual temperature

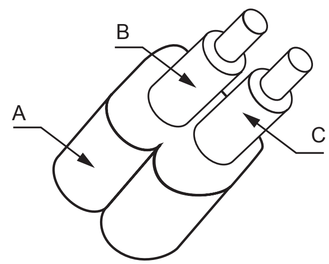
$$\overline{t_s} = \frac{t_1 + t_2}{2} \qquad t_a = t_i + \left[K \times N \times \left(t_i - \overline{t_s} \right) \right]$$

TEMPERATURE COMPARISON CHART



THERMOCOUPLE'S
$^{E}t = {}^{E}r + {}^{E}m$
^{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



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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	CONSTANT AN COPPER-NICKEL Cu-Ni	BRN	WHT	RED	BLK	WHT	RED	IRON (+)	TG 0 to 750°C EG 0 to 200°C	0 to 42.283	2.2°C or .75%	1.1°C or .40%
K	CHROMEL NICKEL-CHROMIUM Ni-Cr	ALUMEL NICKEL-ALUMEL Ni-Al	BRN	YEL	RED	YEL	YEL	RED	ALUMEL (-)	TG -200 to 1250°C EG 0 to 200°C	-5.973 to 50.633	2.2°C or <0°C .75% >0°C 2.0%	1.1°C or .40%
T	COPPER Cu	CONSTANT AN COPPER-NICKEL Cu-Ni	BRN	BLU	RED	BLU	BLU	RED	-	TG -200 to 350°C EG -60 to 100°C	-5.602 to 17.816	1.0°C or <0°C .75% >0°C 1.5%	0.5°C or .40%

E	CHROMEL NICKEL-CHROMIUM Ni-Cr	CONSTANTAN COPPER-NICKEL Cu-Ni	BRN	PUR	RED	PUR	PUR	RED	-	TG -200 to 900°C EG 0 to 200°C	-8.824 to 68.783	1.7°C or <0°C 0.5% >0°C 1.0%	1.0°C or .40%
N*	NICROSIL Ni-Cr-Si	NISIL Ni-Si-Mg	BRN	ORN	RED	ORN	ORN	RED	-	TG -270 to 1300°C EG 0 to 200°C	-4.345 to 47.502	2.2°C or <0°C .75% >0°C 2.0%	1.1°C or .40%
R	PLATINUM-13% RHODIUM Pt-13% Rh	PLATINUM Pt	-	-	-	GRN	BLK	RED	-	TG 0 to 1450°C EG 0 to 150°C	0 to 16.741	1.5°C or .25%	.60°C or .10%
S	PLATINUM-10% RHODIUM Pt-10% Rh	PLATINUM Pt	-	-	-	GRN	BLK	RED	-	TG 0 to 1450°C EG 0 to 150°C	0 to 14.973	1.5°C or .25%	.60°C or .10%
B	PLATINUM-30% RHODIUM Pt-30% Rh	PLATINUM-6% RHODIUM Pt-6% Rh	-	-	-	GRY	GRY	RED	-	TG 0 to 1700°C EG 0 to 100°C	0 to 12.426	<800°C .50%	none est.
G*	TUNGSTEN W	TUNGSTEN-26% RHENIUM W-26% Re	-	-	-	WT/ BL	WHT	RED	-	TG 0 to 2320°C EG 0 to 260°C	0 to 38.564	4.5-425°C 1.0% - 2320°C	none est.
C*	TUNGSTEN - 5% RHENIUM W-5% Re	TUNGSTEN-26% RHENIUM W-26% Re	-	-	-	WT/ RED	WHT	RED	-	TG 0 to 2320°C EG 0 to 870°C	0 to 37.066	4.5-425°C 1.0% - 2320°C	none est.
D*	TUNGSTEN - 3% RHENIUM W-3% Re	TUNGSTEN-25% RHENIUM W-25% Re	-	-	-	WT/ YEL	WHT	RED	-	TG 0 to 2320°C EG 0 to 260°C	0 to 39.506	4.5-425°C 1.0% - 2320°C	none est.

* Not Official Symbol or Standard

THERMAL-SPECTRUM

Celsius Scale	Fahrenheit Scale	Results
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

$$R_t = R_o\left(1 + A_t + B_t^2\right)$$

Where:

R_t = the resistance at some temperature (°C)

R_o = the resistance at 0°C

t = the temperature in °C

A & B = constants for a particular element which best describe its behavior with temperature

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

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)

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

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 greater 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.

$$\frac{V_1}{V_2} = \frac{P_2}{P_1} \quad \text{or} \quad V_1P_1 = V_2P_2$$

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

$$\%\mathrm{RH} = \frac{\mathrm{P_s}(\mathrm{t_{dew}})}{\mathrm{P_s}(\mathrm{t_a})} \times 100 \qquad P_S(\mathrm{t}_{dew}) = \frac{\%RH}{100} * P_S(\mathrm{t}_a)$$

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})

$$\mathrm{D} = \mathrm{t_a} - \mathrm{t_w}$$

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

$D\ell$ = 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

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

Transverse strain to axial strain.

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

HOOKE'S LAW

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

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

$X = \Delta\ell$ = 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

$$T = F \times S$$

Where:

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

COSINE ERROR

$$COS = \frac{\text{side adjacent}}{\text{hypotenuse}}$$

$$T = F \times S \times COS$$

MASS and WEIGHT

$$m_E = m_T - F_b \qquad m_T = m_E + F_b \qquad F_b = \frac{m}{P_b} * P_{air}$$

Where

m = Mass
m_E = Effective Mass
m_T = 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

Three Turning Point Method

$$RP = \frac{B + \frac{A+C}{2}}{2}$$

Five Turning Point Method

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

A, B, C, D, E = Values recorded for consective turning points.

DIRECT WEIGHING

$$\Delta \mathrm{m} = \Delta \mathrm{RP} \times \mathrm{SR}$$

$$\mathrm{SR} = \left| \frac{\mathrm{m_{sen}}}{\mathrm{FRP - SRP}} \right|$$

$$\Delta \mathrm{RP} = \left| \mathrm{FRP - IRP} \right|$$

$$\mathrm{m_x > m_s : m_x = m_s + \Delta m}$$

$$\mathrm{m_x < m_s : m_x = m_s - \Delta m}$$

SUBSTITUTION WEIGHING

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

ALWAYS ADD CR_X TO THE NOMINAL VALUE OF m_X.

$Cr_s = m_s$ – Nominal Value of m_s

TRANSPOSITION WEIGHING

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

ALWAYS ADD CR_X TO THE NOMINAL VALUE OF m_X.

$Cr_s = m_s$ – Nominal Value of m_s

DIFFERENTIAL WEIGHING

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

DENSITY, VISCOSITY AND FLOW

SPECIFIC GRAVITY

ρ = Density in CGS system	x = unknown substance
D = Density in FPS system	w = water
W = Weight	m = mass
V = Volume	a = air

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

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

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

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

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

PYCNOMETER

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

Where:

- W_p = weight of empty pycnometer vessel
- W_a = weight of pycnometer vessel and test liquid
- W_b = weight of pycnometer 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°C	1.000	Mercury @ 0°C	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

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

VISCOMETER

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

Where:

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

FLOW

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

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

<u>**PRESSURE AND VACUUM**</u>

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

TO → FROM ↓	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°C)	0.03612		0.08333	0.07355	0.002458	2.540	0.002450	2.540	1.868
1 ft H_2O (4°C)	0.4335	12.00		0.8826	0.02950	30.45	0.03048	30.48	22.42
1 in Hg (0°C)	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°C)	0.01422	0.3937	0.03281	0.02896	0.0009678	1.000	0.0010		0.7355
1 mm Hg (0°C)	0.01934	0.5353	0.04461	0.03937	0.001316	1.360	0.001360	0.001360	

ROTARY MOTION

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

Where:

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

VIBRATION

$$f = \frac{1}{t} = \frac{V_{av}}{2DA} \qquad f = \frac{V}{D\pi} \qquad g = .0512\ f^2\ DA$$

Where:

V_{av} = average velocity(in/sec)
T = time in seconds
DA = double amplitude
f = frequency in hertz
g = acceleration in "g" units
V = Velocity (in/sec pk

$$\mathrm{Sens}_{OC} = \mathrm{Sens}_{Loaded}\left(\frac{R_1 + R_2}{R_2}\right)$$

Where:

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

$$\mathrm{Sens}_{Corr} = \mathrm{Sens}_{OC}\left(\frac{R_3}{R_1 + R_3}\right)$$

Where:

Sens_{Corr} = Sensitivity into open circuit
Sens_{OC} = Sensitivity corrected for loading effect
R_1 = Pickup impedance
R_3 = Input impedance on readout device

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

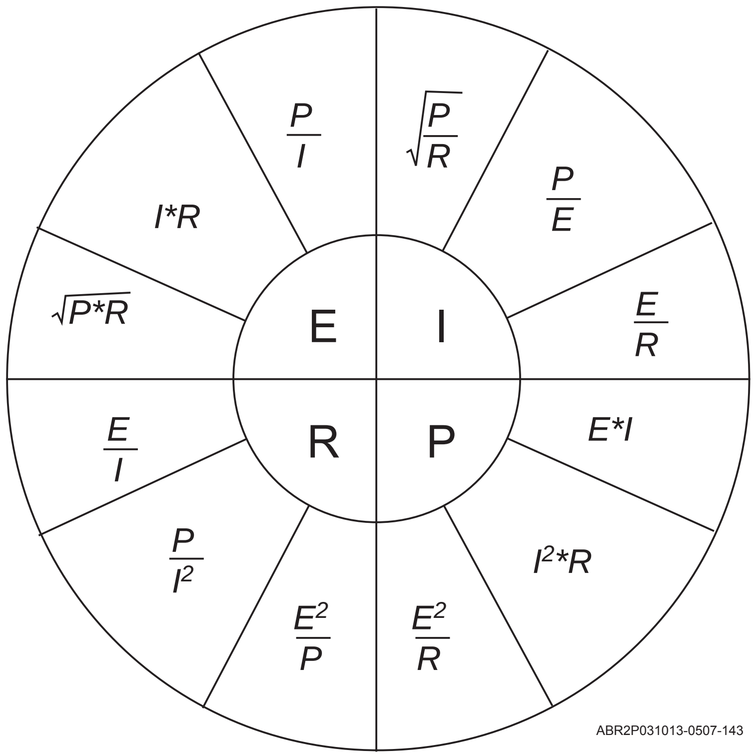
Where:

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

SECTION IV ELECTRONIC PRINCIPLES

VOLTAGE, CURRENT, POWER, and RESISTANCE RELATIONSHIP CHART

Voltage, Resistance, Current, and Power Wheel



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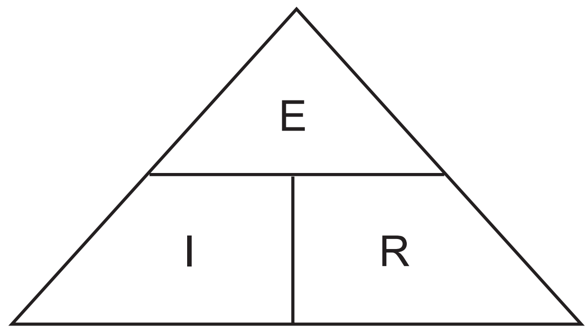
OHM'S Traingle



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DECIBELS and POWER RATIOS

The ratio betweeen any two amounts of electrical power is usually expressed in units on a logarithmic scale. The decibel is a logarithmic unit for expressing a power ratio.

$$PR_{(db)} = 10 \log \frac{P_2}{P_1}$$

Where : PR = power ratio in db

P_1 = power in (small)

P_2 = power out (large)

When the output of a circuit is larger than the input, the device is an AMPLIFIER and there is a GAIN. When the output of a circuit is less than the input, the device is an ATTENUATOR and there is a LOSS. In the last example , use the same formula as above and place the larger power over the smaller power, and put a minus sign in front of the PR to indicate a power loss or attenuation.

Basically, the decibel is a measure of the ratio of two powers. Since voltage and current are related to power by impedance, the decibek can be used to express voltage and current ratios, provided the input and output impedances are taken in to account.

Equal Impedances : db = 20 log $\frac{E_2}{E_1}$ db = 20 log $\frac{I_2}{I_1}$

Where : E_1 = input voltage I_1 = input current

E_2 = output voltage I_2 = output current

Unequal Impedances : db = 20 log $\frac{E_2\sqrt{R_1}}{E_1\sqrt{R_2}}$ db = 20 log $\frac{I_2\sqrt{R_2}}{I_1\sqrt{R_1}}$

Where :R_1 = impedance of the input in ohms R_2 = impedance of the output in ohms

E_1 = voltage of the input in volts E_2 = voltage of the output in volts

I_1 = current of the input in amperes I_2 = current of the output in amperes

db,Power, Voltage, Current Ratio Relationships

Decrease(-) Voltage and Current Ratio	Decrease (-) Power Ratio	Number of db's	Increase(+) Voltage and Current Ratio	Increase (+) Power Ratio
1.0000	1.0000	0	1.0000	1.0000
.9886	.9772	.1	1.0120	1.0230
.9772	.9550	.2	1.0230	1.0470
.9661	.9330	.3	1.0350	1.0720
.9550	.9120	.4	1.0470	1.0960
.9441	.8913	.5	1.0590	1.2220
.9333	.8710	.6	1.0720	1.1480
.9226	.8511	.7	1.0840	1.1750
.9120	.8318	.8	1.0960	1.2020
.9016	.8128	.9	1.1090	1.2300
.8913	.7943	1	1.1220	1.2590
.7943	.6310	2	1.2590	1.5850
.7079	.5012	3	1.4130	1.9950
.6310	.3981	4	1.5850	2.5120
.5623	.3162	5	1.7780	3.1620
.5012	.2512	6	1.9950	3.9810
.4467	.1995	7	2.2390	5.0120
.3981	.1585	8	2.5120	6.3100
.3548	.1259	9	2.8180	7.9430
.3162	.1000	10	3.1620	10.0000
.1000	.01000	20	10.0000	100.000
.03162	.0010	30	31.6200	1000.00
.0100	.0001	40	100.000	10000.0
.00316	.00001	50	316.20	1×10^5
.0010	1×10^{-6}	60	1000.0	1×10^6
.000316	1×10^{-7}	70	3162.0	1×10^7

dbm

The decibel does not represent actual power,but only a measure of power ratios. It is desireable to have a logarithmic expression that represents actual power. The dbm is such an expression and it represents power levels above and below one milliwatt.

The dbm indicates an arbitrary power level with a base of one milliwatt and is found by taking 10 times the log of the ratio of actual power to the reference power of one millwatt.

dBm

Conversion from Power to Dbm

$$P_{(dbm)} = 10 \log \frac{P}{1mw}$$

Where :

$P_{(dbm)}$ = power in dbm
P = actual power
1mw = reference power

Conversion from Dbm to Power

$$Power(mW) = (1mW) anti\log\left(\frac{dBm}{10}\right)$$

Power Ratio

$$PowerRatio(PR) = \frac{Pout}{Pin}$$

Conversion from Power Ratios to Decibels

$$dB = 10\log PR \quad \text{or} \quad dB = 10\log\left(\frac{Pout}{Pin}\right)$$

Conversion from Decibels to Power Ratios

$$PR = anti\log\left(\frac{db}{10}\right)$$

dBm Gains and Losses

1. Amplifiers add
2. Attenuation subtracts

READING COLOR CODES FOR RESISTORS

The charts on the following pages reflect how color codes are designated for both resistors and capacitors. While not every combination is shown, most popular color codes markings are indicated.

Some resistors have the ohmic value and tolerance printed right on the side of the resistor itself. It is easy to identify this type of resistor. The alpha-numeric code may be broken down as follows :

EXAMPLE : part number **RN60D1001F**

RN - This code represents the type of resistor. This designation referes to a high stability, fixed film resistor. Other desgnations are **RCR** (a carbon resistor) and **RW** (a fixed wire wound resistor)

60 - This number represents the power rating of the resistor(wattage). In this case, the power rating is 1/8 watt. Other examples are **10** (1/4 watt) and **25** (1 watt)

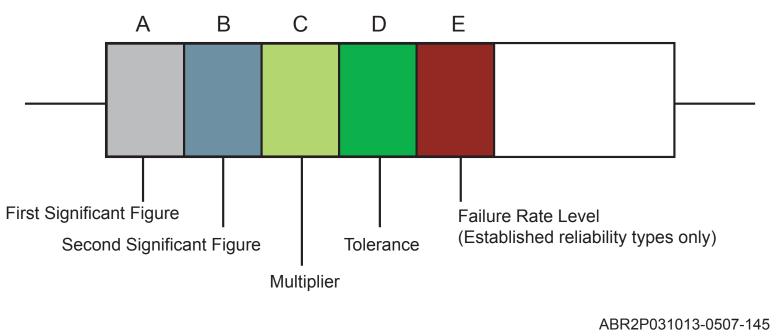
D - This letter designates the temperature coefficient, usually stated in ppm/°C. This resistor has a temperature coefficient of 200 ppm/°C.

1001 - This is the ohmic value of the resistor. The last number in this group of numbers represents how many zeros are to be added to the remainng group of numbers. For 1001, the value is 100 ohms with one zero added to it, or 1000 ohms. Another example is 4023; this indicates 402 ohms with three zeros added, or 402,000 ohms.Another code indicates fractional values. In 53R4, the **R** stands for a decimal place, so this value is 53.4 ohms.

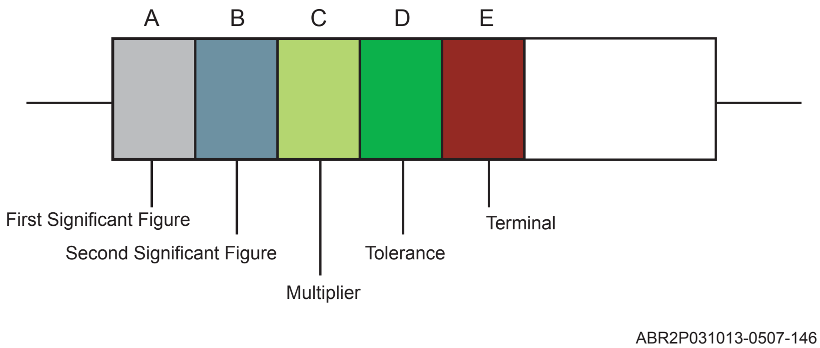
F - This code represents the tolerance of the resistor. The **F** is 1%. the other codes used are as follows : **G** = 2%; **J** = 5%; **K** = 10%, and **M** = 20%.

COLOR CODE MARKING FOR RESISTORS

COMPOSITION TYPE RESISTORS



FILM TYPE RESISTORS



NOTE : BANDS “A” THRU “D” ARE OF EQUAL WIDTH

Band A : The first significant figure of the resistance value.

Band B : The second significant value of the resistance value.

Band C : The multiplier is the factor by which the two significant figures are multiplied to yield the nominal resistance value

Band D : The resistor’s tolerance

Band E : When used on composition resistors, band E indicates the established reliability failure rate level. On film resistors, this band is approximately 1.5 times the width of the other bands, and indicates type of terminal.

COLOR CODE CHART

BAND “A”		**BAND “B”**		**BAND “C”**		**BAND “D”**		**BAND “E”**		
COLOR	1st FIG	COLOR	2nd FIG	COLOR	MULTI	COLOR	TOLERANCE	COLOR	FAIL RATE	TERMINAL
BLACK	0	BLACK	0	BLACK	1	SILVER	±10%	BROWN	1%	
BROWN	1	BROWN	1	BROWN	10	GOLD	±5%	RED	0.1%	
RED	2	RED	2	RED	100	RED	±2%	ORANGE	0.01%	
ORANGE	3	ORANGE	3	ORANGE	1000	NONE	±20%	YELLOW	0.001%	
YELLOW	4	YELLOW	4	YELLOW	10000			WHITE		SOLDER
GREEN	5	GREEN	5	GREEN	100000					
BLUE	6	BLUE	6	BLUE	1000000					
PURPLE (VIOLET)	7	PURPLE (VIOLET)	7							
GRAY	8	GRAY	8	SILVER	0.01					
WHITE	9	WHITE	9	GOLD	0.1					

Bad **B**ooze **R**ots **O**ur **Y**oung **G**uts **B**ut **V**odka **G**oes **W**ell

READING COLOR CODES FOR CAPACITORS

Different marking schemes are used on capacitors mainly because of the varying needs fulfilled by the various capacitor types. Temperature coefficient is of minor importance in an electrolytic filter capacitor, but it is very important in ceramic trimmers for attenuator use. you never find temperature coefficient on an electrolytic label, but it is always present on ceramic trimmers.

CERAMIC DISC CAPACITORS - Information is usually printed. Capacitance is in pf. Capacitance tolerance is shown in percent or by letter. Temperature coefficient is indicated by P200 which means +200ppm/°C which means +200 P/M/°C, or N100 for -100 P/M/°C, etc.

M = ± 20%
K = ± 10%
J = ± 5%
G = ± 2%
F = ± 1%

CERAMIC TUBULAR CAPACITORS - These capacitors are usually white enamel coated with parallel radial leads and look like "dog bones". The code consists of color dots which indicate temperature coefficient,capacitance, and tolerance

BUTTON MICA CAPACITORS - The most difficult part of reading the code on these capacitors is to remember to read the dots moving in a clockwise direction. The dots are usually printed more to one side than the other.

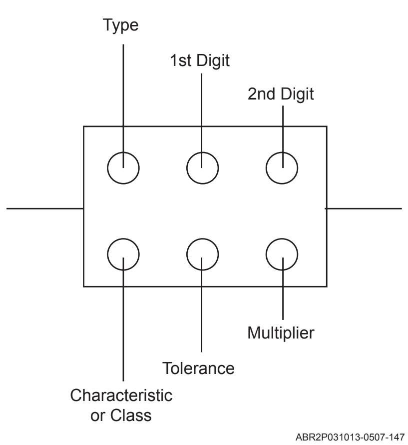
MOLDED MICA CAPACITORS - This was once a very popular type, rectangular with dots and arrow or similar directional indicator. Standard color code applies.

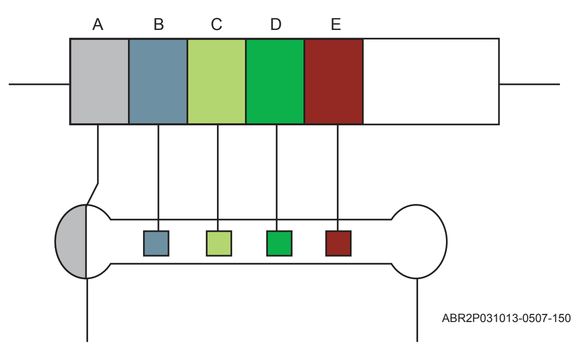
DIPPED MICA CAPACITORS - This type of capacitor has a printed label like that appearing on ceramic disk capacitors.

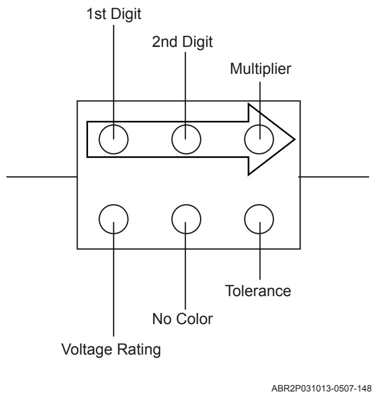
PAPER AND FILM CAPACITORS - Aluminum and tantalum electrolytic capacitors, in nearly all cases, have printed or stamped labels indicating capacitance, tolerance,and voltage ratings.Other characteristics are usually unimportant.

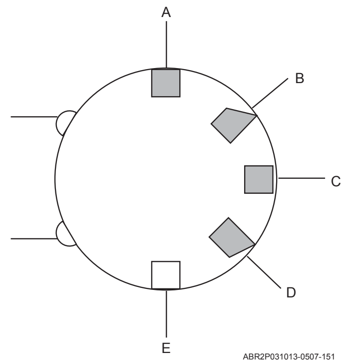
AIR TRIMMERS - The same information appies as with paper and film capacitors. Often, only the range is indicated.

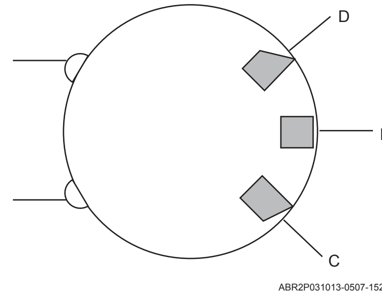
CAPACITOR COLOR CODES











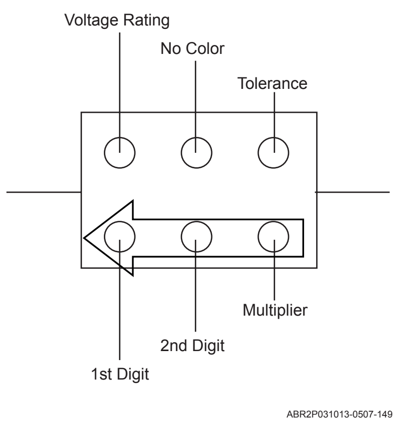
A Temperature Coefficient

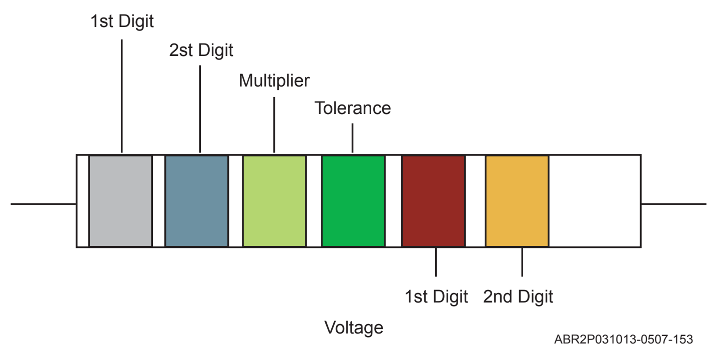
B 1st Digit

C 2nd Digit

D Multiplier

E Tolerance





CAPACITOR COLOR CODE NUMBERING SYSTEMS

6-DOT RMA-JAN-AWS Standard Capacitor Color Code

COLOR	TYPE	1st DIGIT	2nd DIGIT	MULTIPLIER	TOLERANCE (percent)	CHARACTERISTIC or CLASS
Black	JAN Mica	0	0	1		
Brown		1	1	10	1	Applies to
Red		2	2	100	2	temperature
Orange		3	3	1000	3	coefficients or
Yellow		4	4	10000	4	methods of testing
Green		5	5	100000	5	
Blue		6	6	1000000	6	
Purple		7	7	10000000	7	
Gray		8	8	100000000	8	
White	RMA mica	9	9	1000000000	9	
Gold				.1		
Silver	AWS paper			.01	10	
Body					20	

5-Color Capacitor Color Code

COLOR	1st DIGIT	2nd DIGIT	MULTIPLIER	TOLERANCE (percent)	VOLTAGE
Black	0	0	1		
Brown	1	1	10	1	100
Red	2	2	100	2	200
Orange	3	3	1000	3	300
Yellow	4	4	10000	4	400
Green	5	5	100000	5	500
Blue	6	6	1000000	6	600
Purple	7	7	10000000	7	700
Gray	8	8	100000000	8	800
White	9	9	1000000000	9	900
Gold			.1		1000
Silver			.01	10	2000
Body				20	

Ceramic Capacitor Color Code

COLOR	1st DIGIT	2nd DIGIT	MULTIPLIER	TOLERANCE over 10pf	TOLERANCE under 10 pf	TEMPERATURE
Black	0	0	1	±20%	2.0 pf	0
Brown	1	1	10	±1%		-30
Red	2	2	100	±2%		-80
Orange	3	3	1000			-150
Yellow	4	4	10000			-220
Green	5	5		±5%	0.5 pf	-330
Blue	6	6				-470
Purple	7	7				-750
Gray	8	8	.01		0.25 pf	+30
White	9	9	.1	±10%	1.0 pf	+500 to -330
Gold				±.5%		+100

DIRECT CURRENT (DC) CALCULATIONS

SERIES DC CIRCUITS

Total resistance = the sum of the individual resistances

$R_T = R_1 + R_2 + R_3 + \ldots\ldots\ldots\ldots$

Total Voltage = the sum of the individual voltage drops

$E_a = E_{R1} + E_{R2} + E_{R3} + \ldots\ldots\ldots\ldots$

Total Current is determined by the Total Resistance (RT) of the circuit and Applied Voltage (Ea). It will be the same value at any point within the circuit.

$$I_T = \frac{E_A}{R_T}$$

$I_t = I_{R!} = I_{R2} = I_{R3} = \ldots\ldots\ldots\ldots$

Total Power = sum of all power losses in the circuit.

$P_T = P_{R1} + P_{R2} + P_{R3} + \ldots\ldots\ldots\ldots$

PARALLEL DC CIRCUITS

Total Resistance = the reciprocal of the sum of the reciprocals.

For Multiple Branches:

$$R_T = \frac{1}{\frac{1}{R_{B1}} + \frac{1}{R_{B2}} + \frac{1}{R_{B3}} + \ldots\ldots\ldots}$$

For branches of <u>like</u> value:

Where R_B = resistance of one branch, N_B=# of branches

$$R_t = \frac{R_B}{N_B}$$

For <u>Only Two</u> Branches:

$$R_t = \frac{R_{B1} * R_{B2}}{R_{B1} + R_{B2}}$$

Total Voltage is applied to each branch of a parallel circuit

$E_A = E_{B1} = E_{B2} = E_{B3} = \ldots$

Total current = sum of the current in the individual branches.

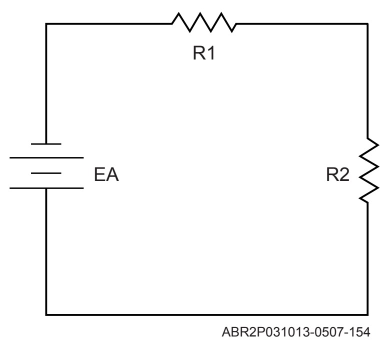
$I_t = I_{t1} + I_{t2} + I_{t3} + \ldots$

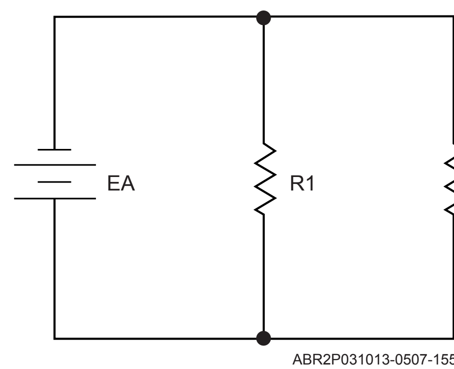
Total Power = sum of all power losses in the circuit

$P_t = P_{R1} + P_{R2} + P_{R3} + \ldots$

DIVIDER NETWORKS

The division of voltage and current in a circuit can be determined in the following manner :





Voltage Divider

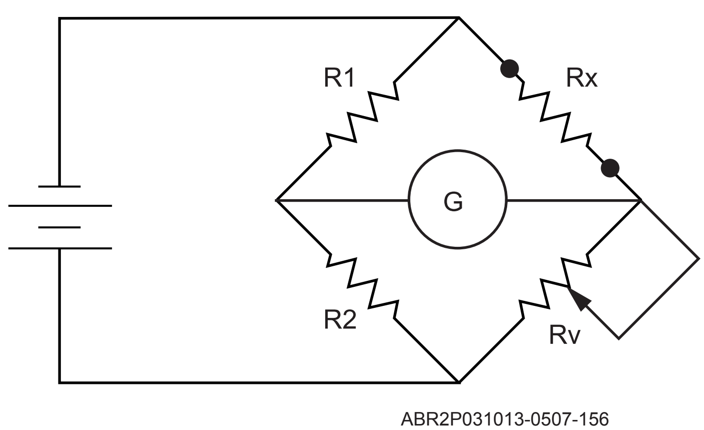
$$E_{R1} = \frac{R_1}{R_1 + R_2}(E_A)$$

Current Divider

$$I_{R1} = \frac{R_2}{R_1 + R_2}(I_t)$$

BRIDGE CIRCUITS

The relationships that exist in a bridge are indicated below



$$R_X = \frac{R_1(R_V)}{R_2} \qquad \frac{R_1}{R_2} = \frac{R_X}{R_V} \qquad \frac{R_1}{R_X} = \frac{R_2}{R_V} \qquad R_1(R_V) = R_2(R_X)$$

ALTERNATING CURRENT (AC) CALCULATIONS

SINE WAVE VOLTAGE CONVERSION CHART

	TO			
FROM	Effective (RMS)(VAC)	Average	Peak	Peak-to-Peak
Effective (RMS)(VAC)	1	0.900	1.414	2.828
Average	1.110	1	1.571	3.142
Peak	0.707	0.637	1	2.000
Peak-to-Peak	0.354	0.318	0.500	1

FREQUENCY AND PERIOD (TIME)

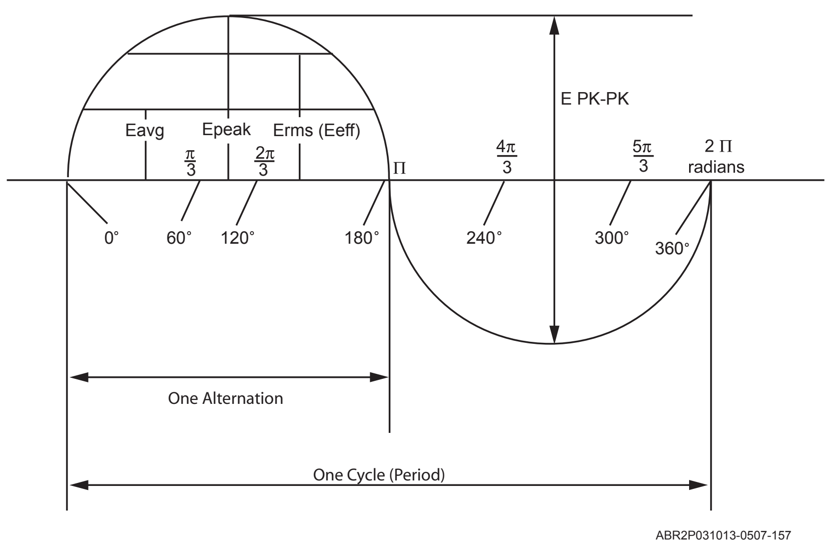
$$f = \frac{1}{p} \qquad p = \frac{1}{f}$$

WAVELENGTH

$$\lambda \, meters = \frac{300 * 10^6}{f} = (300 * 10^6)(p)$$

PHASE ANGLE

$$\theta = \frac{P_{meas}}{P_{tot}} * 360^0$$



TRANSFORMERS

The relationship between voltage, current, and number of turns in a transformer is shown in the following formulas:

$$\frac{Ep}{Es} = \frac{Is}{Ip} = \frac{Np}{Ns} \qquad \frac{(N_P)^2}{(N_S)^2} = \frac{Z_P}{Z_S}$$

Where:
E_P Voltage in primary
E_S Voltage in secondary
I_S Current in secondary
I_P Current in primary
N_P Number of turns in primary
N_S Number of turns in secondary
Z_P Impedance of the primary
Z_S Impedance of the secondary

INDUCTANCE

$$L = \frac{N^2 A\mu}{l}$$

Where :

L = Inductance measured in Henrys (h)
A = Cross sectional area
l = Length of coil
N = Number fo turns
μ = Permeability of core

CAPACATANCE

$$C = \frac{A*K}{D}$$

Where :

C = Capacatance measured in Farads (fd)
A = Area of Plates
K = Dielectric Constant
D = Distance between the plates

TOTAL INDUCTANCE

SERIES

$$L_T = L_1 + L_2 + L_3 + \ldots\ldots\ldots\ldots$$

PARALLEL

$$L_T = \frac{1}{\frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} + \ldots\ldots}$$

TOTAL CAPACITANCE

SERIES

$$C_T = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots\ldots}$$

PARALLEL

$$C_T = C_1 + C_2 + C_3 + \ldots\ldots\ldots\ldots$$

<u>REACTANCE</u>

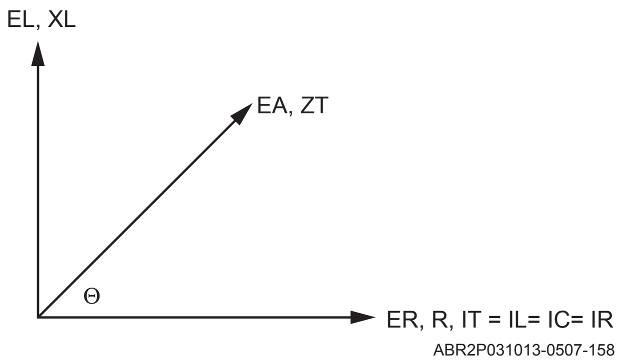
INDUCTANCE

$$X_L = 2\Pi FL$$

CAPACTANCE

$$X_C = \frac{1}{2\Pi FC}$$

SERIES RL



$$I_T = I_R = I_L$$

$$Z = \sqrt{R^2 + X_L{}^2}$$

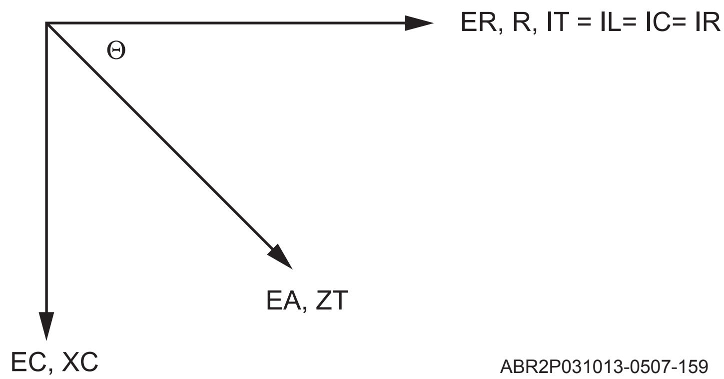
$$E_A = \sqrt{E_R{}^2 + E_L{}^2}$$

$$I_T = \frac{E_A}{Z}$$

$$\theta = TAN^{-1}\frac{X_L}{R}$$

$$\theta = TAN^{-1}\frac{E_L}{E_R}$$

SERIES RC



$$I_T = I_R = I_C$$

$$Z = \sqrt{R^2 + X_C{}^2}$$

$$E_A = \sqrt{E_R{}^2 + E_C{}^2}$$

$$I_T = \frac{E_A}{Z}$$

$$\theta = TAN^{-1}\frac{X_C}{R}$$

$$\theta = TAN^{-1}\frac{E_C}{E_R}$$

SERIES RCL

$$Z = \sqrt{R^2 + (X_L - X_C)}$$

$$E_A = \sqrt{E_R{}^2 + (E_L - E_C)}$$

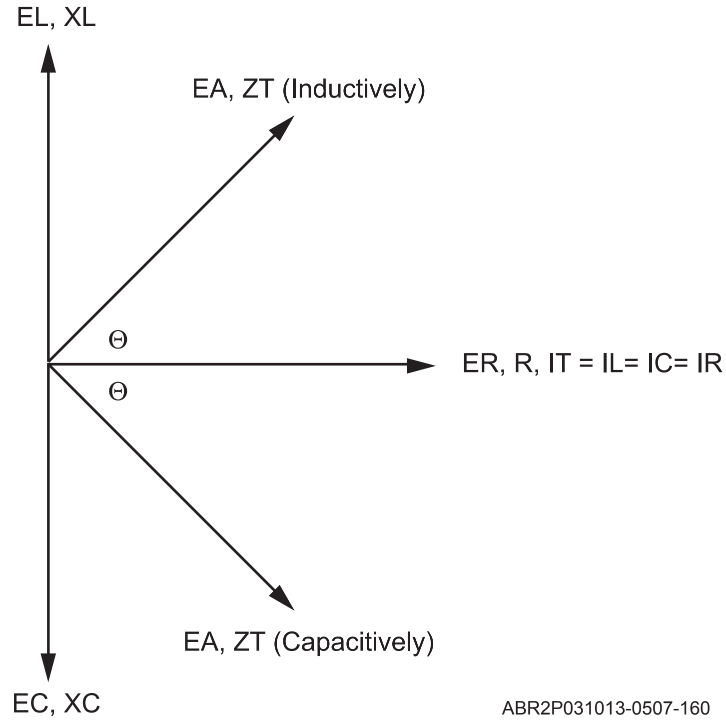
$$I_T = \frac{E_A}{Z}$$

$$\theta = TAN^{-1}\frac{X_C - X_L}{R}$$

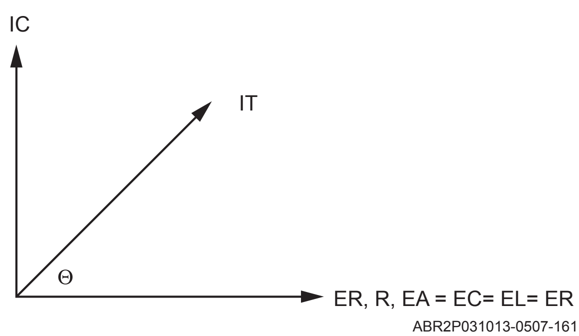
$$\theta = TAN^{-1}\frac{E_C - E_L}{E_R}$$

$$Q = \frac{X_L}{R}$$

$$BW = \frac{f_r R}{X_L}$$



PARALLEL RC



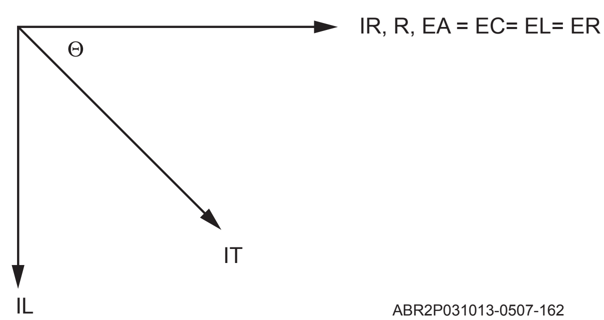
$$E_A = E_R = E_C$$

$$I_T = \sqrt{I_R{}^2 + I_C{}^2}$$

$$Z = \frac{E_A}{I_T}$$

$$\theta = \tan^{-1}\frac{I_C}{I_R}$$

PARALLEL RL



$$E_A = E_R = E_L$$

$$I_T = \sqrt{I_R{}^2 + I_L{}^2}$$

$$Z = \frac{E_A}{I_T}$$

$$\theta = \tan^{-1}\frac{I_L}{I_R}$$

PARALLEL RCL

$$E_A = E_R = E_L = E_C$$

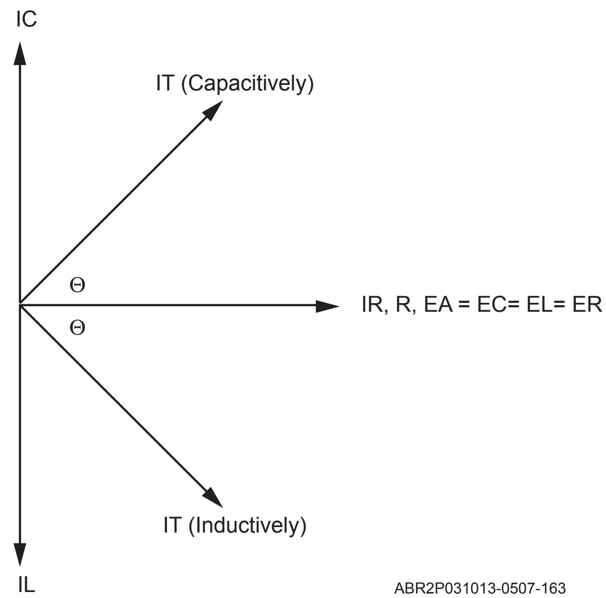
$$I_T = \sqrt{I_R{}^2 + (I_C - I_L)^2}$$

$$Z = \frac{E_A}{I_T}$$

$$\theta = \tan^{-1}\frac{I_C - I_L}{I_R}$$

$$Q = \frac{R}{X_L}$$

$$BW = \frac{f_r X_L}{R}$$



BANDWIDTH

$BW = \frac{f_r}{Q}$ SERIES $BW = \frac{f_r R}{X_L}$ PARALLEL $BW = \frac{f_r X_L}{R}$

POWER

TRUE POWER $P_T = (I_R)^2 * R$

APPARENT POWER $P_A = E_A(I_T)$

POWER FACTOR $PF = \frac{P_T}{P_A} = \cos\theta$

RESONANCE

$$f_r = \frac{1}{2\pi\sqrt{LC}} \qquad C = \frac{1}{4\pi^2(f_f)^2 L} \qquad L = \frac{1}{4\pi^2(f_r)^2 C}$$

RL TIME CONSTANTS

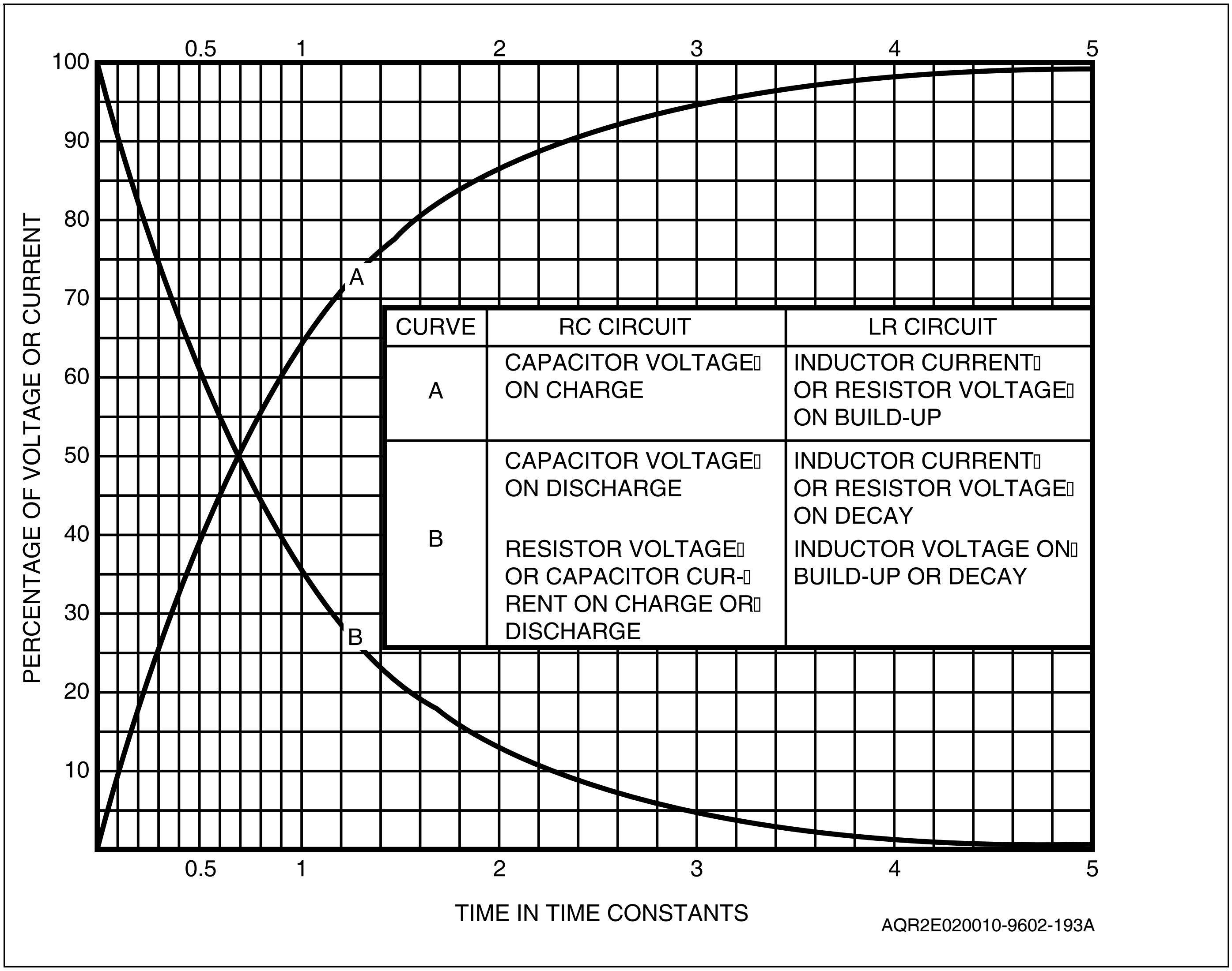
$$TC = \frac{L}{R}$$

$$\#TC = \frac{t}{TC}$$

RC TIME CONSTANTS

$$TC = R * C$$

$$\#TC's = \frac{t}{TC}$$



MICROWAVE FORMULA

VELOCITY CONSTANT (K):

$$K = \frac{1}{\sqrt{c'}} \quad K = \frac{\lambda g}{\lambda o} \quad K = \frac{Vg}{Vo}$$

CHARACTERISTIC IMPEDANCE (Zo):

$$Zo = \sqrt{\frac{L}{C}} \quad Zo = \frac{138}{\sqrt{c'}}\log\frac{D}{d} \quad Zo = \sqrt{Xl * Xc}$$

TIME DELAY (TD)

$$TD = n\sqrt{L * C}$$

VELOCITY OF PROPAGATION IN FREE SPACE (Vo):

$$Vo = \frac{30x10^{9}\,cm}{\sec} \quad Vo = \frac{300x10^{6}\,m}{\sec}$$

WAVELENGTH IN FREE SPACE:

$$\lambda o = \frac{Vo}{Freq} \quad \lambda o_{(M)} = \frac{300x10^{6}\,M / Sec}{Freq} \quad \lambda o_{(cm)} = \frac{30x10^{9}\,cm / Sec}{Freq}$$

VELOCITY OF PROPAGATION ON A TRANSMISSION LINE (Vg):

$$Vg = Vo * K$$

WAVELENGTH ON A TRANSMISSION LINE:

$$\lambda g = \frac{Vo * K}{Freq} \quad \lambda g = \frac{Vg}{Freq}$$

VOLTAGE STANDING WAVE RATIO (VSWR):

$$VSWR = \frac{E\max}{E\min} \quad VSWR = \sqrt{\frac{P\max}{P\min}} \quad VSWR = \frac{\sqrt{Pi} + \sqrt{\Pr}}{\sqrt{Pi} - \sqrt{\Pr}} \quad VSWR = \frac{Ei + Er}{Ei - Er} \quad VSWR = \frac{1 + P}{1 - P}$$

$$VSWR = \frac{Zo}{R_L} whenZo \rangle R_L \quad VSWR = \frac{R_L}{Zo} whenR_L \rangle Zo$$

VOLTAGE RELATIONSHIPS

$$E_I = \frac{E_{\max} + E_{\min}}{2} \quad E_R = \frac{E_{\max} - E_{\min}}{2} \quad E_{\max} = E_I + E_R \quad E_{\min} = E_I - E_R$$

REFLECTION COEFFICIENT:

$$P = \frac{E_R}{E_I} \quad P = \sqrt{\frac{P_R}{P_I}} \quad P = \frac{VSWR - 1}{VSWR = 1} \quad P = \frac{1}{\log^{-1}\frac{dB}{20}}$$

TRANSMISSION LOSS:

$$L_T = 10\log\frac{Pwr_{l\arg e}}{PWR_{small}} \quad L_T = 10\log\frac{P_{load}}{P_{source}}$$

POWER FORMULAS:

% Power Reflected: $P_{REF} = p^2 * 100$

% Power Absorbed $P_{ABS} = (1 - p^2) * 100$

$$Pwr_{REF} = Pwr_{INC} * p^2$$

$$Pwr_{ABS} = Pwr_{INC}(1 - p^2)$$

MISMATCH LOSS:

$$L_{mm} = 10\log\frac{Pwr_{INC}}{Pwr_{ABS}} \quad L_{mm} = 10\log\frac{1}{\left(1-p^2\right)}$$

SMITH CHART

$$Z_{normalized} = \frac{Z_{actual}}{Zo} \quad Z_{actual} = Z_{normalized} * Zo$$

RETURN LOSS:

$$L_R = 10\log\frac{Pwr_{INC}}{Pwr_{REF}} \quad L_R = 20\log\frac{E_I}{E_R} \quad L_R = 20\log\frac{1}{p} \quad L_R = 10\log\frac{1}{p^2}$$

WAVEGUIDE

$$F_{co} = \frac{Vo}{\lambda co} \quad \lambda co = 2a = \frac{2}{\sqrt{\frac{m^2}{a} + \frac{n^2}{b}}} \quad \lambda o = \frac{\lambda g}{\sqrt{1 = \left(\frac{\lambda g}{\lambda co}\right)^2}} = \frac{Vo}{F} \quad \lambda g = \frac{\lambda o}{\sqrt{1 - \left(\frac{\lambda o}{\lambda co}\right)^2}}$$

$$Vo = \sqrt{(Vp) * (Vg)} \quad Vp = \frac{Vo}{\sqrt{1 - \left(\frac{\lambda o}{\lambda co}\right)^2}} = \frac{Vo}{\sin\theta} \quad Vg = Vo * \sqrt{\frac{Vo}{1 + \left(\frac{\lambda o}{\lambda co}\right)^2}} = Vo * (\sin\theta)$$

DIRECTIONAL COUPLERS:

Different Arms $CF = 10\log\frac{Pwr_{IN}}{Pwr_{OUT}}$

Same Arm $LI = \log\frac{Pwr_{IN}}{Pwr_{OUT}}$

$$D = 10\log\frac{P_{P3}(fwd)}{P_{P3}(rev)} = Lr_4 + LI \quad CForLI = -10\log\left[1 - \log^{-1}\left(\frac{dB}{-10}\right)\right]$$

MOUNT CALIBRATION FACTORS

EFFECTIVE EFFICIENCY

$$\eta e = \frac{Kb}{\left(1 - p^2{}_{Meter}\right)} \quad \eta e = \frac{Pwr_{DCSUP}}{PWR_{DISSIPATED}} \quad \eta e = \frac{Pwr_{IND}}{Pwr_{ABS}}$$

CALIBRATION FACTORS

$$Kb = \eta E\left(1 - p^2{}_{Meter}\right) \quad Kb = \frac{Pwr_{DCSUB}}{Pwr_{INC}} \quad Kb = \frac{Pwr_{IND}}{Pwr_{Zo}}$$

REFLECTION COEFFICIENT OF THE MOUNT

$$P_{Meter} = \sqrt{1 - \left(\frac{Kb}{\eta e}\right)} \quad P_{Meter} = \sqrt{\frac{Pwr_{REFLECTED}}{Pwr_{INCIDENT}}}$$

LIMITS OF POWER

$$LIMITSOFPOWER_{IND} = \frac{Pwr_{zO} * kB}{(1 \pm P_G * P_L)^2}$$

NOMINAL POWER LEVELS

POWER AVAILABLE ON THE LINE

$$Pwr_{Zo} = PC(1 - p^2{}_g)$$

PC is conjugate power, generator power, or maximum power available.

POWER ABSORBED BY THE LOAD

$$Pwr_{ABS} = PWR_{Zo}(1 - p^2{}_L)$$

SECTION V GLOSSARY

abberration

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

abscissa

The horizontal or x-axis on a chart graft.

absolute measurement standard

Standards based on natural physical constrants whose values can be accurately repeated under controlled conditions.

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 -459.69°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.

absorption wave meter

An instrument for measuring wavelength containing a variable tuned circuit which absorbs a small portion of the radiated energy under measurement.

AC generator

(1) A rotating electric machine, generally know as an alternator, that converts mechanical power into alternating current power.

(2) A vacuum-tube oscillator, or any other device, that is designed for the purpose of producing an alternating current.

AC plate resistance

The ratio of a small change in plate voltage to the resulting change in plate current, other tube voltage remaining constant. Alternating current plate resistance is usually designed by r_p and is expressed in ohms. (It is often called dynamic plate resistance)

AC resistance

The total resistance offered by a device in an alternating current circuit, including resistance due to eddy current, hysteresis, dielectric, and corona loss as well as the direct current resistance. Also called high-frequency resistance and radio-frequency resistance.

accelerating electrode

An electrode used in cathode - ray tubes and other electronic tubes to increase the velocity of the electrons in a beam. Such an electrode is operated at a high positive potential with respect to the cathode.

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.

acceptor

A substance (impurity) which, when added to a pure semiconductor material, results in an increase in the number of holes so that major conduction through the material takes place as a transfer of the hole structure from molecule to molecule. Since this is equivalent to the transfer of a positive charge, the resulting alloy is called a P-type semiconductor.

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

acorn-tube

An acorn-shaped vacuum tube is designed for use at ultra-high frequencies. It has a low interelectrode capacitance because of the small size of electrodes, and low electron transit time because of the close spacing of the electrodes. The electrode leads are brought directly out through the sides of the tube. There is no base.

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.

adhesion

The molecular attraction exerted between the surfaces of bodies in contact.

admittance

The measure of ease with which an alternating current flows in a circuit. It is the reciprocal of impedance.

adsorption

The adhesion of one substance to the surface of another.

AGC (automatic gain control)

A circuit arrangement which continuously adjusts the gain of an amplifier in a specified manner in response to changes in the input signal. This is also called AVC (automatic volume control)

air core coil

A coil with no iron in its magnetic circuits no iron either inside or outside the wire).

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.

alpha
The current amplification factor when connected in a common base configuration.

alpha particle
(1) Particle identical with a helium nucleus emitted from the nucleus of a radioactive atom.

(2) A helium nucleus, consisting of two protons and two neutrons, with a double positive charge. Its mass is 4.002764 a mu (mass units).

alpha ray
A stream of fast-moving helium nuclei; a strongly ionizing and weakly penetrating radiation.

alphanumeric
Set of all alphabetic and numeric characters.

alternating current
An electric current that is continually varying in value and reversing its direction of flow at regular intervals. Each repetition, from zero to maximum in one direction and then to a maximum in the other direction and back to zero, this is called a cycle.

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.

ampere

Unit of electric current. The constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular sections, and placed 1 meter apart in a vacuum, will produce between these conductors a force equal to 2×10^{-7} newtons per meter of length. The practical unit of current.

amplifier

An amplifier is a device used to increase the voltage, current, or power of a signal to a desired level.

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.

amplification factor

The ratio of a small change in plate voltage to the small change in control grid voltage, under the conditions that the plate current remains unchanged and that all other electrode voltages are maintained constant. It is a measure of the effectiveness of the control grid voltage with respect to that of the plate voltage in controlling the plate current.

amplitude

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

amplitude modulation (AM)

A form of modulation in which the amplitude of the carrier is varied above and below its normal value in accordance with the amplitude of the modulating signal.

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 $\theta = \frac{\Omega}{t}$, 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.

anode

That electrode of an electron tube, or semi conductive material, toward which the principal electron stream flows. It is a positive potential with respect to the corresponding negative electrode called the cathode.

antenna

A conductor or system of conductors for radiating or receiving RF energy exclusive of the connecting wires, transmission line, or wave-guide between its main portion and the apparatus associated with it.

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."

Anti-Miller effect

The decrease in the effective grid-cathode capacitance of a vacuum tube due to the charge induced electro statically on the grid by the cathode thru the grid-cathode capacitance.

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.

apparent power

The power value obtained in an alternating current circuit by multiplying the effective values of voltage and current. The result is expressed in volt-amperes, and must be multiplied by the power factor to secure the average or true power in watts.

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.

aquadag

A graphite coating on the inside of cathode-ray tubes for collecting the secondary electrons emitted by the screen.

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.

armature

(1) A piece of ferromagnetic material that is placed between or across the pole pieces of a magnet in such a manner that it may have motion relative to the pole pieces.

(2) The buzzer, relay, magnetic phonograph pickup, or other electromagnetic device that depends on physical motion of a part of its magnetic circuit.

(3) Originally the rotating part of an electric motor or generator. It carries the conductors that have motion relative to the magnetic field.

armstrong oscillator

An inductive feedback oscillator.

artificial line

A network which simulates the electrical characteristics of a transmission line.

astable multivibrator

A free running multivibrator

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.

attenuation

(1) The ratio of initial to final load power, expressed in decibels, when a network is inserted into a measuring system in which both the generator and load impedances have been adjusted so that they are nonreflecting.

(2) The insertion loss measured in a nonreflecting system.

audio frequency

Any frequency in the range from about 20 to 20,000 Hz, corresponding to audible sound waves.

autocollimation

A process in which collimated rays of light emanating from an instrument, and carrying the image of a reticule, are aimed at a reflective surface. The reticule image is reflected back into the focal plane of the telescope for comparison with the actual reticule 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

An instrument designed for comparing tilt being received back from a mirror image of the reticule carried by the collimated light and then superimposing the image on the actual reticule. It contains at least an objective lens eyepiece reticule and light source to illuminate the reticule.

autotransformer

A transformer having one winding that is tapped somewhere along its length to provide three terminals. Usually, a part of the windings is considered the primary and the secondary includes all the turns on the coil.

auto reflection

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

autumn equinox

First day of autumn in the northern hemisphere. It usually falls on September 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.

avalanche breakdown

In semiconductors, the condition when the applied voltage is sufficiently large to cause the covalent structure of the crystal to break down. Sometimes called the Zener point.

AVC (automatic volume control)
See AGC

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, passes through a body, on which the body revolves.

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

axis, principal
A line through the centers of curvature of a refracting lens.

Ayrton-Perry winding
Consists of two parallel opposed windings, either in a single layer crossing at every turn, or one layer wound over the other.

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).

B+ (B plus)
The positive terminal of a B battery or other plate-voltage source for a vacuum tube, or the plate-circuit terminal to which the positive source terminal should be connected.

B- (B minus)
Symbol used to designate the point in a circuit to which the negative terminal of the plate supply is to be connected.

B-H curve

A characteristic curve showing the relation between magnetic induction (B) and magnetizing force (H) for a magnetic material. It shows the manner in which the permeability of a material varies with flux density. Also called "magnetization curve."

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.

ballast resistor

A self-regulating resistor, usually connected in the primary circuit of a power transformer, which tends to compensate for variations in line voltage.

ballast tube

A tube which contains a ballast resistor, usually an iron wire resistor in a hydrogen-filled bulb, which reduces the radiation of heat from the resistor.

band

Frequencies within two defined limits. Example: The standard broadcast band extends between 550 and 1600 kHz.

bandpass

The number of hertz, cycles per second, expressing the limiting frequencies at which the desired fraction (usually the half-power points) of the maximum output is obtained.

bandpass filter

A filter that passes a desired band of frequencies, while frequencies above and below the desired frequencies band are attenuated.

band rejection filter

An electrical device or circuit which suppresses an unwanted band of frequencies.

bandwidth

The number of cycles, kilocycles, or megacycles per second expressing the difference between the limiting frequencies of a frequency band. It can be applied to any entity having frequency limits, as a tuned circuit, a combination of tuned circuits, a modulated radio signal, or a group of radio station channel assignments.

barn

The unit expressing the probability of a specific nuclear reaction taking place in terms of cross-sectional area. It is 10^{-24} cm^2 . (See Cross Section)

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.

barretter
A bolometer consisting of an appropriately mounted short length pf very fine wire, usually platinum, or a metallic film which a positive temperature coefficient of resistance.

base
The center semiconductor region of a double junction (NPN or PNP) transistor. The base is comparable to the grid of an electron tube.

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.

beam-power tube
A vacuum tube having special deflecting electrodes that concentrate the electrons into a beam, giving high power output and other desirable characteristics. Another feature of this type is to minimize screen current and to create a concentration of electrons, between screen grid and plate, which acts as a suppressor grid.

beat frequency
One of the two additional frequencies obtained when signals of two different frequencies are combined in a nonlinear device. Their values are equal to the sum and difference, respectively, of the original frequencies.

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

beta
The current amplification factor of a transistor when connected in a common-emitter configuration.

beta particle
(1) Particle identical to an electron emitted from the nucleus of a radioactive atom.

(2) A charged particle emitted from the nucleus and having a mass and charge equal in magnitude to those of the electron.

beta ray
A stream of beta particles, more penetrating but less ionizing than alpha rays; a stream of high-speed electrons.

bias
(1) The average DC voltage between the control grid and cathode of a vacuum tube used to establish the quiescent operating condition of the tube.

(2) The average DC voltage between the base and emitter of a semiconductor used to establish the quiescent operating condition of the semiconductor.

bidirectional coupler
A device with two outputs, designed for insertion in a waveguide. It simultaneously samples and presents at one output a voltage that is largely a function of the wave traveling in one direction, and at the other output a voltage that is largely a function of the wave traveling in the opposite direction.

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.

binding energy
The energy represented by the difference in mass between the sum of the component parts and the actual mass of the nucleus.

bistable multivibrator
A circuit having two stable states. One side of the multivibrator will be cut off while the other side will be at a high level of conduction. This circuit is often called the Eccles-Jordan multivibrator in honor of the inventors. In some literature the bistable is mistakenly called a flip-flop multivibrator.

bleeder resistor
A resistor connected in parallel with the output of a power supply to improve voltage regulation by drawing a fixed bleeded current. Also used to dissipate the charge remaining in filter capacitors when the power supply is turned off.

blocked oscillator
A blocking oscillator is biased to cutoff and must be triggered. It develops a sharp pulse for each trigger input.

blocking capacitor
Any capacitor used in a circuit to block the flow of DC while allowing AC signal to pass.

blocking oscillator
A free running oscillator operating intermittently with grid bias increasing during oscillation to a point where oscillation stops, and then decreasing until oscillation resumed. The output consists of sharp pulses.

blooming
Term applied to a CRT when too many electrons strike the screen and increase spot size. This is usually caused by an improperly set intensity control.

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.

bolometer

A small resistive element used in the measurement of low and medium RF power. It is characterized by a large temperature coefficient of resistance which is capable of being properly matched to a transmission line. The barretter and thermistor are widely used bolometers.

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.

Boolean Algebra

The branch of symbolic that is used extensively for binary computer applications.

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.

breakdown voltage

The voltage at which the insulation between two conductors or parts will break down.

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.

broadband amplifier

An amplifier that maintains a flat response over a wide range of frequencies.

buffer

An isolating circuit used to avoid reaction of a driven circuit upon the corresponding driving circuit.

buncher

(1) The input resonant cavity in a conventional klystron oscillator.

(2) The electrode of a velocity-modulated tube which concentrates the electrons in a constant current electron beam into bunches.

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.

bus

An uninsulated conductor. Its cross section may be solid, hollow, square, or round.

by-pass capacitor

A capacitor that is used to provide a comparatively low impedance path for alternating currents around a circuit element.

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.

calibration

Is the comparison between items of equipennt, one of whuich is a measurement standard of known accuracy, to detect, correlate, adjust, and report any variation in the accuracy of the other item(s).

calibration chart

A chart prepared for a specific item to show the actual value of the parameter(s) calibrated. (Differences between nominal and actual).

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.

capacitance

(1) The ability to store electrical energy, measured in farads.

(2) The property of a capacitor or circuit which determines the amount of electrical energy which can be stored in it by applying a given voltage.

(3) In semiconductor diode, the small signal capacitance measured between the terminals of the diode under specified conditions of bias and frequency.

capacitive reactance

That type of reactance which is caused by the capacitance of a circuit. It is measured in ohms, designated by X_C, and is equal to the reciprocal of 2π FC ($\frac{1}{2\Pi FC}$), where C is in farads and F is in hertz.

capacitor

Two conducting surfaces, or sets of conducting surfaces, separated from each other by an insulating material (dielectric) such as air, paper, mica, glass, or oil. A capacitor stores electrical energy, blocks the flow of direct current, and limits the flow of alternating current to a degree dependent upon the capacitance and the frequency.

capacitor input filter

A filter which has a capacitor connected directly across (in parallel with) its input.

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.

carbon resistor

A resistor made of carbon particles and a ceramic binder molded into a cylindrical shape, with leads attached to opposite ends.

carrier frequency

The frequency of the unmodulated carrier wave, if sinusoidal, or the center frequency of the unmodulated carrier, when a recurring series of pulses is used.

cascade

In sequence, as tuning circuits, an amplifier stages used one after another.

cascade amplifier

An amplifier of several stages, the output of one being the input of the next.

cascode amplifier

A two-stage amplifier circuit combining a grounded-cathode input section with a grounded-grid output section. This amplifier provides good gain and low noise.

cathode

(1) The electron-emitting electrode of a semiconductor device.

(2) The electron-emitting electrode of a radio tube. Thermionic vacuum tubes employ heated cathodes. Gas tubes employ cold cathodes.

cathode interface

An additional tube capacitance caused by separation of the cathode coating from the metal. It causes an overshoot at the leading edge of a square wave.

cathode bias

A method of biasing a vacuum tube by placing the biasing resistor in the common cathode return circuit.

cathode ray tube (CRT)

An electron tube containing an electron gun that directs a beam of electrons at a fluorescent screen inside the large end of the tube. A glow is produced at the point where the beam strikes the screen. Electrostatic deflection plates or electromagnetic deflecting coils are used to sweep the beam over the screen and produce a pattern or complete image.

cavitation

Sudden formation and collapse of low-pressure bubbles in liquid by mechanical forces, such as the rotation of a turbine flow meter or a fuel pump.

cavity resonator

A space totally enclosed by a metallic conductor and excited in such a way that it becomes a source of electromagnetic oscillations. The size and shape of the enclosure determines the resonant frequency. For a cylinder, the maximum resonators wavelength is 2.61 times the radius. Cavity resonators have an extremely high Q factor, which can be as great as 50,000. They are used in ultrahigh frequency systems.

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.

Centigrade scale

See Celsius temperature scale

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.

certification
A document designation that standards and TMDE have been calibrated and meet established technical requirements, or that a PMEL has the capability to perform accurate measurements.

certified value
The value that can be obtained by using the most recent measurement techniques and equipment.

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

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.

characteristics
Functions of the equipment under test, that are checked.

characteristic curve
(1) A graph which shows the interrelation between two changing values, as the effect of a change in grid voltage on the plate current of a vacuum tube.

(2) A graph which shows the interrelation between two changing values, as the effect of a change in base voltage on the collector current of a transistor.

characteristic impedance
The ratio of applied voltage to steady state current at a given frequency for a uniform and infinitely long transmission line. It is measured in ohms and designated Z_O.

charge
(1) The electrical energy stored in a capacitor or held on an insulated object. An object having more electrons than normal has a negative charge. An object having fewer electrons than normal has a positive charge.

(2) To furnish electrical energy to a capacitor insulated metal object, or storage battery.

charging current
(1) The current flowing into a capacitor when a voltage is applied.

(2) A current flowing in the correct direction to charge a storage battery.

(3) The correct current at which a particular storage battery should be charged.

chassis

The metal framework on which the parts of the circuitry are mounted.

chemical compound

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

choke coil

An inductor that is used to limit or suppress the flow of alternating current without appreciably the flow of direct current. Also called an impedance coil.

chopper circuit

A circuit that produces a square wave from a DC voltage by opening and closing the circuit.

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.

circuit

A complete path over which electrons can flow from the negative terminal of a voltage source through parts and wires to the positive terminal of the same voltage source.

clamping circuit

A circuit in which either amplitude extreme of a waveform is maintained at a certain potential level. Also know as a DC restorer.

class A amplifier

(1).An amplifier in which plate current flows at all times and amplification is essentially linear. The grid voltage is chosen to place the operating point in such a way that the input signal voltage will swing over a straight portion of the tube characteristic curve at all times but will never swing positive and never swing down to the curve portion near cutoff.

(2) An amplifier in which collector current flows at all times and amplification is essentially linear. The base voltage is chosen to place the operating point in such a way that the input signal voltage will swing over a straight portion of the transistors characteristic curve at all times but will never swing positive (saturation) and never swing down to the curve portion near cutoff.

class B amplifier

(1) An amplifier in which the grid bias is at, or very near, cutoff so that the plate current is essentially zero when there is no input signal. Plate current then flows for approximately one-half of each input signal cycle. If grid current does not flow during any part of the input cycle, the subscript “1” is used; if grid current flows at any time, the subscript “2” is used. Class B operation is used in both radio frequency and audio frequency amplifiers, generally in push-pull stages.

(2) An amplifier in which the base bias is at, or very near, cutoff so that the collector current is essentially zero when there is no input signal. Collector current then flows for approximately one-half of each input signal cycle. If base current does not flow during any part of the input cycle, the subscript “1” is used; if base current flows at any time, the subscript “2” is used. Class B operation is used in both radio frequency and audio frequency amplifiers, generally in push-pull stages.

class C amplifier

(1) An amplifier in which the grid bias is considerably greater than cutoff, so that the plate current is zero with no input signal to the grid and flows for appreciably less than one-half of each input signal cycle. The grid may swing positive far beyond saturation.

(2) An amplifier in which the base bias is considerably greater than cutoff, so that the collector current is zero with no input signal to the grid and flows for appreciably less than one-half of each input signal cycle. The base may swing positive far beyond saturation.

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.

coaxial cable

A cable consisting of one conductor (usually a small copper tube or wire) and insulated from, another conductor of larger diameter (usually copper tubing or braid).

coaxial transmission line

Consists of two conductors, one of which is hollow. The second conductor is placed inside the hollow conductor and spaced uniformly throughout the length of the line. It can be used for frequencies up to 12.4 GHz.

coefficient of coupling

A numerical rating between 0 and 1 that specifies the degree of coupling between two circuits. Maximum coupling is 1 and no coupling is 0.

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. 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.

coincidence tube

An electronic tube that requires a positive potential on its control grid and suppressor grid before it will conduct.

cold cathode

A cathode that is not heated. Electrons may be pulled out of the cathode by field emission.

collector
An electrode of a transistor. One of the outer layers of a junction-type transistor. It corresponds roughly to the plate of a triode tube. It collects charge carriers.

collimation
The process of aligning the axis of the optical elements with respect to the mechanical axis of an instrument.

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.

color
(1) Effect produced on the eye and its associated nerves by light waves of different wavelength or frequency.

(2) That aspect of things that is caused by differing qualities of the light reflected or emitted by them, definable in terms of the observer or of the light.

(3) A property of light that depends on wavelength, whether absorbed or reflected by an object. Black is said to result from the absence of color (full absorption), and white from the presence of all colors mixed together (full reflection).

Colpitts oscillator
An oscillator in which the parallel-tuned tank circuit is connected between grid and plate. The tank capacitor consists of two series voltage divider capacitors. The regenerative feedback is developed across one of these capacitors.

commutator
A cylindrical arrangement of copper segments mounted radially on the shaft of anarmature, separated from each other and the armature by insulation, and connected to individual armature coils.

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.

composition resistor
A resistor made of a mixture of carbon and clay molded into a cylindrical shape with wire terminals imbedded in each end of the unit.

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.

conductance
The ability of a material to conduct or carry an electric current. Conductance is the reciprocal of resistance and is measured in mhos.

conduction band
The minimum energy level an electron must obtain to become a free electron.

conductivity
The specific conductance of a unit specimen of a material. Reciprocal of resistance.

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.

constant amplitude signal generator
A signal generator that keeps a constant amplitude as the frequency of the output is changed.

contact resistance
The resistance in ohms caused by the resistance of the contact of terminal connections, relays, and switches. The value of resistance is generally only a fraction of an ohm but is important because it can cause a large error in precise measurement of low value resistors.

continuous wave (CW)
An unmodulated, constant amplitude wave.

control grid
(1) That electrode in a vacuum tube which has the most effective control over the plate current passed by the tube. The control grid is usually the electrode nearest the cathode.

(2) In basic terms works very similar to the base of a transistor.

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.

copper-oxide rectifier

A rectifier consisting of a disk of copper coated with copper oxide on one side, with a soft lead washer providing electrical contact with the oxide surface. The resistance is considerably lower for electron flow from the copper to the oxide than for electron flow in the reverse direction; hence rectification is obtained in alternating current circuits.

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.

correction chart

A chart prepared for a specifi item to show corrections that must be applied to indicated reading to obtain actual values.

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 X 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:

$$F = \frac{Q_1 Q_2}{\in_s^2}$$

counter electromotive force

In an inductor, an induced voltage that opposes the inducing voltage at every instant of time in an effort to oppose any change in the magnetic flux linkage.

counting circuit

A circuit that receives uniform pulses representing units to be counted and produces a voltage in proportion to their frequency.

coupling

The means by which signals are transferred from one circuit to another circuit.

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 at which total reflection begins, when the angle of incidence of a light ray entering glass from air is increased to the extent that reflection, instead of refraction occurs.

critical coupling

The degree of coupling that provides maximum transfer of energy at the resonant frequency. Also called optimum coupling.

critical damping

The minimum viscous damping that will allow a displaced system to return to its initial position without oscillation about the neutral position.

critical frequency

A particular resonant frequency at which damage to or degradation of performance of equipment may or does result.

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.

crystal

Piezoelectric or oscillation-control crystal; a natural substance such as quartz or tourmaline, which is capable of producing a potential difference when subjected to mechanical pressure (deformation), or is capable of undergoing mechanical deformation when subjected to a potential difference. In a suitable feedback circuit, it vibrates at its mechanical resonant frequency and thereby produces stable electrical oscillations.

crystal controlled oscillator

An oscillator in which a crystal is used to determine the frequency and increase frequency stability.

crystal detector

Consists of a very small piece of semiconducting material mounted in a suitable container. It is widely used in microwave measurements due to its high sensitivity and wide frequency response.

crystal oven

An electrically heat enclosed space in which piezoelectric crystals are mounted so as to keep their temperature constant, thus assuring freedom from frequency drift due to temperature changes.

current saturation

The condition in which the plate current of a thermionic vacuum tube cannot be further increased by increasing the plate voltage. The electrons are then being drawn to the plate at the same rate as they are emitted from the cathode. Also called plate saturation or voltage saturation.

cutoff

(1) The minimum value of negative grid bias that will prevent the flow of plate current in a vacuum tube.

(2) The maximum amount of reverse bias the will cause a transistor to turn off.

(3) In selective circuit, the frequency above and below which the circuit fails to respond.

cutoff frequency

Generally taken as the frequency at which the gain of a device is 3 db below its low frequency value. Used when referring to variations of alpha or beta with respect to frequency.

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.

damped waves

Alternating current waves that progressively decrease in amplitude during successive cycles.

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.

Damping (galvanometer)

When an induced current flows in a direction to oppose motion of the coil, the galvanometer is said to be damped and the coil moves slowly. It is possible to control damping in a galvanometer circuit by controlling the amount of induced current. For some particular value of external resistance placed across the terminals of the galvanometer the pointer will return to its zero position in a minimum time without swinging past zero. The galvanometer is then critically damped and the value of the external resistance is the external critical damping resistance (CDRX). When the external resistance is less than the CDRX, the pointer approaches zero sluggishly and the galvanometer is over damped. If the external resistance is greater than the CDRX, the pointer swings past zero and tends to oscillate and the galvanometer is under damped.

D'Arsonval movement

The basic moving coil meter movement. It consists of a coil of many turns suspended between the poles of a permanent magnet.

dbm

Units used in communications for measuring absolute power level; power in decibels measured from a 1 milliwatt reference level.

DC amplifier

An amplifier that is capable of amplifying small variations in direct current. It employs direct coupling between stages.

DC plate resistance

The value of the DC plate voltage divided by the DC plate current of a vacuum tube.

DC restorer

See clamping circuit

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.

decibel

A standard unit used for comparison of two quantities of electrical or acoustical (sound) power. One decibel is roughly the amount that the intensity of a pure sine wave sound must be changed in order for the change to be just barely detectable by the human ear. The amount of change in power level, expressed in decibels, is equal to 10 times the common logarithm of the ratio of the two powers.

decoupling network

A network that is used to prevent the interaction of two circuits.

definition

The fidelity with which an oscilloscope forms an image having fine detail. When the image is sharp and has definite lines and boundaries, the definition is said to be good.

deflecting coil

An inductor used to produce a magnetic field that will bend the electron beam a desired amount in the CRT of an oscilloscope. Also called the deflecting yoke.

deflection factor

The voltage required on the deflection plates to produce a unit deflection on the CRT screen. It is the reciprocal of the deflection sensitivity.

deflection sensitivity

The amount of displacement of the electron beam at the screen of a CRT per unit change in the deflecting field. Usually expressed in millimeters per volt applied between deflecting electrodes. It is the reciprocal of deflection factor.

degeneration

A circuit arrangement-wherein a signal is fed back from the output to the input in such a way that it tends to cancel the input signal. It is used to stabilize the operation of the circuit.

degree

(1) A unit division of a temperature scale.

(2) A unit of latitude or longitude, equal to 1/360 of a great circle.

(3) Mathematics: A planar unit of angular measure equal in magnitude to 1/360 of a circle. Synonym: arcdegree

(4) A degree (or degree of arc), usually symbolized by the symbol °, is a measurement of plane angles, or of a location along a great circle of a sphere, representing 1/360 of a full rotation. One degree is divided into 60 minutes (of arc), and one minute into 60 seconds (of arc). These units, also called the arcminute and arcsecond, are respectively represented by a single (‘) and double closing quotation (“) marks.

deionization potential

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

delay line

A real or artificial transmission line consisting of inductance and capacitance to delay a signal a prescribed amount.

delay time

The time required to change the charge of the emitter base capacitance from the reverse condition to the forward biased condition.

density

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

De Santy bridge

An AC bridge used to measure capacitance and dissipation factor. It is composed of resistors and a standard capacitor. A variable resistor is used to obtain the amplitude null and a variable resistor as used to obtain the phase null.

detection

The process of extracting the intelligence, audio or video frequency component from the modulated RF signal. Also called demodulation.

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.

dielectric
The insulating material between the plates of a capacitor; generally air, mica, paper, or oil. All insulating materials are dielectrics in that-they are capable of sustaining an electric field and undergoing electric polarization.

dielectric absorption
The property of an imperfect dielectric whereby all electric charges within the body of the material caused by an electric field are not returned by the field. Dielectric absorption increases with a decrease in frequency.

dielectric hysteresis
A power loss in a capacitor due to a lag in the placement of the electric field across a capacitor when an AC voltage is applied.

differential synchro
A synchro in which both rotor and stator are wound so that they produce rotating magnetic fields. Changing the position of the rotor causes a differential angle to be put into the system.

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.

direct coupling
The use of a conductor to connect two amplifier stages together and provide a direct path for signal currents. This allows very low frequencies and DC to pass between stages.

discriminator
A circuit whose output voltage varies in amplitude and polarity in accordance with the frequency of the applied signal. Its principal uses are as a demodulator in a frequency modulation receiver and as an automatic frequency controlling device.

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

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

dissipation factor (DF)
The ratio of the energy dissipated to the energy stored. It represents the total power loss of a capacitor or inductor.

dissipative loss
That portion of attenuation contributed to the actual dissipative of energy as compared to the reflection of energy, used when referring to dissipative losses only in lieu of the common term "attenuation."

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

distortion
Any deviation from the desired waveform.

distortion analyzer
A measuring instrument used to determine the distortion present on a sinusoidal waveform.

distributed capacitance
Capacitance distributed between wires, parts or conducting elements, and the ground, as distinguished from capacitance concentrated in a capacitor.

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

dominant mode
The waveguide mode that produces the longest operating wavelength, has the-greatest energy transfer efficiency, and has the simplest configuration.

donor
A substance (impurity) which, when added to a pure semiconductor material, results in .an increase in the number of free electrons so that major conduction through the material takes place as a movement of electrons. Since this is equivalent to the transfer of a negative charge, the resulting alloy is called an N-type semiconductor.

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

Doppler effect
The change in the observed frequency of a wave reaching an observer, due either to motion of the source (toward or away from the observer), motion of the observer, or a shift in the reflecting layer.

drift
The movement of majority carriers in an electric field supplied by an external source, that is, electrons move toward a positive pole, holes toward a negative pole.

drift space
In an electron tube, a region substantially free of externally applied alternating fields, in which relative repositioning of the electrons takes place.

dropping resistor
A series resistor used to decrease the voltage by the amount of the voltage drop across the resistor.

ductility
That property of a material which will permit it to be drawn into a wire.

duty cycle
Ratio of the on-time to the total time or the pulse width to pulse recurrence time.

dynamic plate resistance
See AC plate resistance

dynamic response
The ability of a measuring device to follow changes in a circuit or instrument under test. For example, the ability of the indication from a force measuring device to keep up with rapidly changing loads.

dynamic transfer curve
A curve that shows the variation of output current (dependent variable) with variation of input current under load conditions.

dynamometer movement
A meter using three electromagnetic coils. The dynamometer movement can be used to measure power, voltage, or current. It is test suited for measuring low frequency AC. However, it can also be used to measure DC.

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

Eccles-Jordan multivibrator
See bistable multivibrator

echo
A wave that has been reflected or otherwise returned with sufficient magnitude and delay to be seen (or heard) in some manner.

eddy currents
Circulating currents induced in a conductor by a varying magnetic field. These currents are undesirable in most instances because they represent loss of energy and cause heat. In the iron cores of transformers and other iron core devices carrying alternating current, laminated construction is used to shorten the paths for eddy currents and thus keep eddy current losses to a minimum.

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.

electrical angle

.A means of specifying a particular instant in an alternating current cycle. One cycle is considered equal to 360°, hence a half-cycle is ISO" and a quarter-cycle is 90°. If one voltage reaches a peak value a quarter of a cycle after another the electrical angle between the voltages (the phase difference) is 90°.

electric field

A region in space surrounding a charged object, or the electric component of the electromagnetic field associated with radio waves and with electrons in motion. Lines drawn to represent the direction in which the electric field will act on other charged objects are called electric lines of force.

electricity

A fundamental quantity in nature, consisting of electrons and protons at rest, or in motion. Electricity at rest has an electric field that possesses potential energy and can exert force, as in charged pith balls. Electricity in motion ordinarily consists of a movement of electrons through a conductor or through space.

electrode

A terminal at which electricity passes from one medium into another, as the individual elements of a vacuum tube, the plates of battery cells or the plates of capacitors.

electrolyte

The liquid, chemical paste, or other conducting medium used between the electrodes of a battery, electrolytic capacitor, or electrolytic rectifier.

electrolytic capacitor

A capacitor consisting of two metallic places separated by an electrolyte. Under the action of the applied DC voltage a film of hydrogen gas is formed on one plate. This film acts as the dielectric. The electrolyte is actually the negative electrode.

electromagnet

A core of soft iron that is temporarily magnetized by sending current through a coil or wire wound around the core.

electromagnetic spectrum

Total range of frequencies of electromagnetic waves.

electromagnetic waves

Radiation taking many different forms and exhibiting widely differing properties. Long wavelength radiations (radio waves) consist of electric and magnetic fields perpendicular to each other and the line of travel. As wavelength decreases, the radiation acts less like waves and more like energy particles.

electromagnetism

Magnetic effects produced by currents rather than by permanent magnets.

electromotive force (EMF)

Difference of electrical potential, or pressure, measured in volts. The property of a device which, tends to produce an electric current in a circuit.

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.

electron coupled oscillator

An oscillator circuit employing a screen grid tube so connected that its screen grid is used as a plate in connection with the control grid and cathode. It acts as an ordinary triode oscillator circuit, with the output taken from the plate circuit.

electron gun

The beam-forming structure in the neck of a CRT, consisting of an electron emitting cathode and associated electrodes that concentrate, control, and focus the stream of emitted electrons in a beam that produces a spot of the desired size on the screen at the end of the tube.

electron emission

The ejection of electrons from the surface of a material into surrounding space under the influence of heat, light, high voltage, impact, or any other cause. Quantitatively, electron emission is the rate at which electrons are emitted from an electrode.

electron volt

Energy required to move an electron between two points which have potential difference of 1 volt.

electronic switch

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

electronics

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

electrostatic

Pertaining to electricity at rest, such, as charges on an object (static electricity).

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

electrostatic unit of charge (Stat coulomb)
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.

electrostatic voltmeter
A voltmeter that works on the principle of attraction or repulsion of like electrical charges. The electrostatic voltmeter could be likened to a capacitor with, one movable plate, on which a pointer is mounted. The electrostatic voltmeter is used to measure high values of AC and DC voltages.

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.

envelope
(1) The glass or metal housing of a vacuum tube.

(2) A curve drawn to pass through the peaks of a graph showing the waveform of a modulated RF carrier signal.

equivalent circuit
A relatively simple circuit arrangement of resistors, inductors, and/or capacitors which is electrically equivalent to a more complicated circuit or device. Used to simplify circuit analysis.

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-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 X 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.

extinction potential

The lowest value to which the plate voltage of a gaseous tube can be reduced from a higher value under given conditions, without stopping the flow of plate current.

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.

fall time

(1) In transistors, the time needed for the output pulse to decrease from 0.9 to 0.1 of its maximum amplitude.

(2) In dead weight testers, a leak test wherein the system is closed and the rate of fall of the piston is indicative of the overall leakage.

(3) Often used to describe the decay time of a pulse.

farad

Unit of electric capacitance. The capacitance of a capacitor between the plates of which there appears a difference of potential of 1 volt when it is charged by a quantity of electricity equal to 1 coulomb.

feedback

The transfer of energy from the output circuit of a device back to its input. Degenerative feedback is the process whereby a part of the power in the output circuit reacts upon the input circuit in such a manner as to reduce initial power, thereby decreasing the amplification. Regenerative feedback is the process whereby a part of the power in the output of an amplifying device reacts upon the input circuit in such a manner as to increase the initial power, thereby increasing the amplification.

fermi level

The Fermi level in a semiconductor is located at that value of energy at which there is a 50% probability of an energy state at that level) being occupied by an electron. It is merely a mathematical marker in energy terms and is not a physical entity in the same sense as an atomic level.

fidelity

The degree with which equipment reproduces the essential characteristics of the signal which is impressed upon its input.

filament

Directly heated cathode which carries its own heating current, as distinguished from an indirectly heated cathode.

filter

A network of resistors, inductors, and capacitors, or any one or two of these, which offers comparatively little opposition to certain frequencies or to direct current, while blocking the passage of other frequencies. An example is the filter used in a power supply, which allows the direct current to pass, but filters out the ripple.

firing potential

The grid-cathode voltage required in a gaseous triode to make the tube conduct or fire.

fixed bias

A bias voltage of constant value, such as obtained from a battery, generator, or other power supply.

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

(1) Also known as; cross hair, reticule. In optics a superimposed reference line. For two parallel lines called; bifilar.

(2) See also; reticule

fission products
The elements and/or particles produced by fission.

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

flat line
A transmission line that has no standing waves. At every point along the line the amplitude of voltage is the same.

flat response
Term used to indicate that the gain varies only slightly within a stated frequency range. The response curve plotted for such an amplifier is almost a straight line.

fluorescence
The property of emitting electromagnetic radiation, usually as visible light due to the absorption of radiation from some other source.

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.

flux linkage
A value obtained by multiplying the number of turns in a coil by-the number of magnetic lines of force passing through the turns.

fly back
A portion of the time base in the operation of a CRT in which the spot is returning to the starting point.

fly wheel effect
The ability of a resonant circuit because of its energy storage, to operate continuously from short pulses of energy of constant frequency and phase.

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.

focusing anode
One of the electrodes in a CRT, the potential of which may be varied to focus the electron beam.

focusing control
The control that is used to obtain a sharp, clear image on the screen of a CRT in a television system or an oscilloscope.

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.

form factor
Term used in describing the quantity of rectified current. It is the ratio of the effective current to the average current (1.11 in the case of a sinewave).

forward bias
Voltage applied across a semiconductor in order to neutralize repelling forces at the junction and permit a flow of current in a forward direction at low resistance.

Foster-Seely discriminator
A discriminator that produces a DC voltage output proportional to the deviation of frequency from a center frequency.

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.

foot-pound
A term used in the study of torque representing a force of 1 pound applied perpendicular to a moment arm 1 foot long.

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 distortion
Distortion caused when different frequency components in a signal are given unequal amplification.

frequency divider
A circuit which produces an output frequency equal to a submultiple of the input frequency.

frequency meter
An instrument for measuring the frequency of an AC signal.

frequency modulation (FM)
A form of modulation in which the frequency of the carrier is varied in accordance with the frequency of the modulating signal. The amplitude of the carrier remains constant at all times.

frequency multiplier
A circuit that is used to develop multiples of a precise frequency.

frequency response
The operating range over which a circuit or device handles all frequencies uniformly.

frequency response curve
A graph showing the frequency response of a circuit or device.

full-wave rectification
Rectification in which both halves of each alternating current cycle are used to produce direct current.

fundamental frequency
The lowest frequency component of a complex waveform.

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 square or 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. The primary end for linear measurements.

gain
The ratio of output voltage, current, or power in an amplifier stage or system to the input voltage, current, or power, respectively; usually expressed in decibels. Increasing the gain means increasing output signal strength.

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

(1) The current amplification factor when connected in a common collector configuration.

(2) Reflection coefficient of voltage in microwave applications.

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.

generator

(1) A machine that changes mechanical energy into electrical energy.

(2) An oscillator that generates an alternating voltage at a desired drequency when energized with DC or low frequency AC power.

geometry

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

gilbert

The unit of magnetomotive force in the centimeter-gram-second electromagnetic system.

glow-discharge voltage regulator

A gas tube (VR tube) that varies in resistance between about 5,000 and 30,000 ohms, depending on the value of the applied voltage. It is used to maintain the supply voltage constant.

glow lamp

A lamp in which light is produced by a glow discharge between two electrodes in an evacuated envelope into which a small quantity of gas such as neon or argon has been introduced.

Go and No-go gages

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

Gon

The metric system of defining a decimal degree with 100 decimal degrees in a right angle, or 400 decimal degrees in a circle.

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.

grass

The pattern on the CRT display of a radar or similar system, which is produced by the random noise output of the receiver.

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 proportional to the product of their mass and inversely proportional 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.

grid bias

The DC difference in potential between the control grid and the cathode of a vacuum tube.

grid circuit

The circuit connected between the grid and cathode of a vacuum tube, forming the input circuit to the tube.

grid leak

The resistance in the grid circuit of a vacuum tube.

grid leak bias
The bias obtained by grid current flowing through the grid leak resistance. The amount of grid leak bias depends on the amplitude of the signal input.

grid leak resistor
A resistor used in the grid circuit of a vacuum tube to provide a discharge path for the grid coupling capacitor. The value of the resistor determines the average value of the grid leak bias.

grid limiting
Limiting the positive grid voltage of a vacuum tube circuit by means of a high resistance grid resistor.

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.

guarding
A feature provided on many high-precision measuring instruments which refers to the use of special circuitry, insulated from ground, to provide freedom from adverse effects of leakage currents. The stray current is bypassed through a noncritical path so that it does not affect the accuracy of measurement.

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.

half power points
The 70.7% point of a curve.

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.

Hartley oscillator
An oscillator circuit characterized by a tuned circuit having a tapped winding whose outer ends is connected to the grid and plate, respectively, of the vacuum tube, with the tap going to the cathode.

hay (parallel inductance) bridge
An AC bridge that permits measurement of inductors with a high Q in terms of- capacitance. The bridge contains resistors and a variable standard capacitor. The amplitude null is obtained with the variable standard capacitor and the phase null with a variable resistor.

head
The vertical depth of any point below the free surface of a liquid.

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.

heat sink
A device for the absorption or transfer of heat away from a device.

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

Helipot
A multi-turn spirally wound potentiometer used in many instruments to get a high resolution.

Henry
Unit of electric inductance. The inductance of a closed circuit in which the electromotive force of 1 volt is produced when the electric current in the circuit varies uniformly at a rate of 1 ampere per second.

hertz
A unit of frequency equal to 1 cycle per second.

Heterodyne
The mixing of two alternating currents of different frequencies in a nonlinear impedance device which generates a current having the sum and difference frequencies, either or both of which may be selected by properly tuning the output.

high-frequency resistance
See AC resistance

high pass filter
A filter designed to pass currents at all frequencies above a critical frequency, while substantially reducing the amplitudes of currents of all frequencies below this critical frequency.

hole
A mobile vacancy in the electronic valance structure of a semiconductor, which acts as a positive electronic charge.

Hooke's Law
Within the limits of perfect elasticity, stress is directly proportional to strain.

horizontal
Of, relating to, or near the horizon. An orientation relating to, or in parallel with the horizon; at right angles to a vertical line.

horizontal sweep
The scanning motion from left to right across a CRT.

horizontally polarized waves
Electromagnetic waves in which the electric field (E) is parallel to the horizon (or Earth's surface).

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.

hygrograph
An instrument for automatic recording of variations in atmospheric humidity.

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.

hysteresis loss
Power loss in an iron core transformer or other alternating current device due to the magnetic hysteresis.

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.

imaginary number
The indicated square root of a negative number.

impedance (Z)
An indication of the total opposition that a circuit offers to the flow of alternating current or any other varying current at a particular frequency, measured in ohms.

impedance coil
See choke coil

impedance match
The condition in which the impedance of a connected load is equal to the internal impedance of the source, thereby giving maximum transfer of energy from source to load.

impedance triangle
A diagram which is a right-angle triangle with sides proportional to the resistance and reactance of an alternating current circuit. The hypotenuse represents the impedance of the circuit. The cosine of the angle between the sides representing resistance and impedance is the power factor of the circuit.

incident ray
A ray of light entering into a lens or mirror.

incident wave
Energy moving from the generator toward the termination of a transmission line.

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

incremental attenuation
The difference in attenuation between a given setting and the zero setting of an attenuator.

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

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

inductance
The property of a circuit that opposes any change in current, or property of an electric circuit or two neighboring circuits which determines how much electromotive force will be induced in one of the circuits by a change of current in either of them. Inductance is measured in henrys and designated by L.

induced voltage
A voltage produced in a circuit by a change in the number of magnetic lines of force passing through a coil in the circuit.

inductive reactance
That type of reactance which is due to the inductance of a circuit or coil. It is measured in ohms, designated by X_L and is equal to $2\pi FL$.

inductronic amplifier
A sensitive DC automatic potentiometer. It senses a small difference in EMF and develops a corrective voltage in a voltmeter calibration system.

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.

insertion loss
A special case of substitution loss. The ratio of the initial load power to the final load power, expressed in decibels, when a network is inserted into a measuring system. The value of insertion loss measured depends upon the reflection coefficients of the generator and load as well as the network under test.

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

intensity modulation
Control of the brilliance of the trace on the screen of a CRT. This is also known as "Z axis modulation."

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
(1) Is the selection of the nearest graduation when a measurement lies between. The observational equivalent to the rounding off process in computation.

(2) Mathematically determining a point between two known values.

intrinsic attenuation
The attenuation 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.

inverse peak voltage
The peak value of the instantaneous voltage across a rectifier tube during the half of the cycle in which current does not flow.

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.

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.

ionization potential
The potential necessary to separate 1 electron from an atom.

ionizing event
An event in which an ion is produced.

iron vane movement
A meter movement in which the movable element is an iron vane which is drawn into the magnetic field produced by flow of the current being measured. Iron vane meters have a square law response and scale.

isobars
Elements having the same mass number but different atomic numbers.

isolation transformer
Used in conjunction with AC bridge circuits to isolate the AC null detector from the AC power source. Isolation transformers can also provide a greater measure of safety for personnel.

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.

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

j

The square root of minus one (-1).

JAN specification

A military specification which covers all branches of the military.

jitter

Small, rapid variations in a waveform due to mechanical disturbances or to changes in the supply voltages.

Johnson (thermal) noise

The noise caused by the thermal agitation of charges in a conductor. It is proportional to the absolute temperature and the frequency bandwidth over which the noise is measured.

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.

junction transistor

A type of transistor employing a sandwich type of construction where the .outside layers are quite thick as compared to the thin center layer. The semiconductor material is used alternately to form PNP or NPN transistors.

k

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

keeper

Iron or steel bar placed across the poles of a horseshoe magnet. The keeper prevents gradual demagnetization by providing a low reluctance path for the magnetic circuit.

Kelvin bridge

A double Wheatstone bridge requiring two conditions of balance. Primarily used for precision measurement of low value resistances.

Kelvin degree

Unit of temperature. The unit of temperature determined by the Carnot cycle with the triple-point temperature of water defined as exactly 273.16°K.

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.

Kirchhoff's Laws
(1) The sum of the currents flowing to a given point in a circuit is equal to the sum of the currents flowing away from that point.

(2) The algebraic sum of the voltage drops in any closed path in a circuit is equal to the algebraic sum of the electromotive forces in that path. Also called the laws of electric networks.

Klystron
A vacuum tube for converting DC energy into RF energy by alternating current that delivers power to a cavity resonator.

laminated core
An iron core for a coil, transformer, armature, etc., built up from laminations stamped from sheet iron or steel. The laminations are more or less insulated from each other by surface oxides and sometimes by application of varnish. Laminated construction is used to minimize the effect of eddy currents.

lapping
A smoothing or polishing operation.

laser
An optical cavity capable of oscillating in the visible and non-visible 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.

lecher wire
A transmission line which uses the characteristics of standing waves for the determination of wavelength at the higher frequencies.

leakage current
(1) Undesirable flow of current through or over the surface of an Insulating material or insulator.

(2) The flow of direct current through a capacitor.

(3) The alternating current that passes through a rectifier without being rectified.

(4) The current that flows between two or more electrodes of a tube by any path other than across the vacuous space between the electrodes.

leakage inductance
The difference between the total inductance of a transformer winding and that used in transferring energy from one winding to another.

left-hand rule

(1) For generators: If the thumb, first, and-second fingers of the left hand are stretched at right angles to one another, with the thumb representing the direction of motion, the first finger representing the direction of magnetic lines of force, and the second finger representing the direction of electron flow, the relations between the directions will then be correct for a conductor in the armature of a generator.

(2) For a current-carrying wire: If the fingers of the left hand are placed around the wire in such a way that the thumb points in the direction of electron flow, the fingers will be pointing in the direction of the magnetic field.

lens

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

lens, converging

See convex

lens, diverging

See concave

Lenz's Law

The current induced in a circuit as a result of its motion in a magnetic field is in such a direction that it exerts a mechanical force opposing the motion. Also called "law of induced current."

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 micro inches.

light beam chopper

A circuit that produces a square wave from DC. It uses photosensitive resistors, a light beam, and a synchronous motor turning a disc with apertures, to control the operation of the photosensitive resistors.

lighthouse tube

A single tube oscillator operating at a frequency of about 2500 MHz. It gets its name because of its construction which resembles a lighthouse.

limited calibration

A calibartion performed which does not check all of the required parameters.

limited certification

A limited certification (Yellow Form) is used to document the limitation (Red Line).

limiter (clipper)
A circuit which removes amplitude variations from the signal by cutting off all positive and/or negative peaks that exceed certain amplitude.

line of force
An imaginary line in an electric or magnetic field that coincides in direction with the field intensity at each point. It was conceived by Faraday, and is used for convenience in the study of magnetic and electric fields. When used as a unit of magnetic flux, a line of force is sometimes called a maxwell.

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.

linearity check
The process of checking the meter across the entire scale, at specified or cardinal points on a designated range.

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

Lissajous pattern
A family of scope patterns used to show phase relationships, make frequency comparison measurements, and indicate the percentage of AM modulation.

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.

load line
A straight line drawn across a series of plate current-plats' voltage characteristic curves on a graph to show how plate current will change with grid voltage when a specified plate load resistance is used. The slope of the load line is proportional to the reciprocal of the plate load impedance in ohms.

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.

logarithmic meter scale
A nonlinear scale used with a moving coil meter, where the pointer deflection is directly proportional to the logarithm of the applied voltage. Power is directly proportional to the logarithm of the applied voltage if the meter has a linear voltage response.

logic
The synthesizing of a network of logical elements to perform a specified function.

logic circuits
Circuits whose functions can be described by simple statements of formal logic using the connective words and, or, not.

logic diagram
A circuit diagram which represents the function of logic circuits and their interconnections without necessarily expressing their construction or engineering details.

logical element
In a computer or data processing system, the smallest building blocks which can be represented by operators in an appropriate system of symbolic logic.

loop
The point, line, or surface of a stationary wave system, at which maximum amplitude exists.

loose coupling
A small amount of coupling between two coils or circuits.

lossy
An adjective applied to a dielectric material which dissipates energy.

lossy line
A transmission line with a high degree of attenuation.

low pass filter
A filter designed to pass currents at all frequencies below a critical frequency, while substantially attenuating the amplitude of other frequencies.

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.

luminous flux
The visible energy emitted by a source per unit time. MKS system - The meter-kilogram-second system.

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.

magnetic induction
(1) The magnetic quantity (number of magnetic lines of force) that determines how much voltage will be induced in a conductor moving through a particular point in a magnetic field. It is expressed in gausses. It is also called magnetic flux density.

(2) The process of magnetizing an object by bringing it into the magnetic field of an electromagnet or permanent magnet.

magnetic saturation
That condition in an iron core in which further increases in magnetizing force produces little or no increase in magnetic flux density.

magnetism
A property possessed by iron, steel, and certain other materials when in a particular condition of internal structure, by which these materials can exert a mechanical force on neighboring masses of magnetic materials and can cause voltages to be induced in conducting bodies moving relative to the magnetized bodies.

magneto motive force
Magnetic potential difference. Expressed in gilberts, that is, ergs per magnetic pole.

magnetron
A high vacuum thermionic tube (containing two electrodes) in which the flow of electrons from cathode to anode is controlled by an externally applied magnetic field. It is used for generating microwaves.

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.

majority carriers
In semiconductors, the type of carrier constituting more than half of the total number of carriers. The majority carrier may be either holes or free electrons found in P-type or N-type semiconductors, respectively.

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

manganin
An alloy used in making precision wire wound resistors because of its low temperature coefficient of resistivity. Many standard resistors are made of manganin.

marker generator
A generator that develops pulses (markers) from a-calibrated circuit. These markers are used to calibrate the time base of an oscilloscope.

mantissa
Fractional value used as part of a floating point number. For example, the mantissa in the number 0.9873 X 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.

master line
A line, either horizontal or vertical, between the master point and a second arbitrary reference point.

matched line
A transmission line terminated in its characteristic impedance in order to maximize power flow and minimize the voltage standing wave ratio.

matter
Anything which has weight and occupies space.

Maxwell (series inductance) bridge
An AC bridge that permits measurement of inductors with a low Q, in terms of capacitance. The bridge contains resistors and a variable standard capacitor. The amplitude null is obtained with the variable standard capacitor and the phase null with a variable resistor.

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, l.

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.

metallic insulator
A shorted quarter wave section of a microwave transmission line which acts as an electrical insulator at the frequency for which its length is one quarter wavelength.

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.

microphonic
A condition in which mechanical movement of a vacuum tube, variable capacitor, or other part in an amplifier system causes corresponding variations in circuit current.

microwave
Electromagnetic waves in the frequency range from 300 MHz up to the infra-red spectrum which starts at 30 GHz.

mil
1) A unit of length equal to one thousandth of an inch, or 0.001 inch.

2) A unit of angular measurement equal to 1/6400 of a complete revolution or circle (202 ½ seconds).

Military Specification Code
A code developed to insure that devices purchased by the government would meet the military standards regardless of the manufacturer.

Miller effect
The increase in the effective grid-plate capacitance of a vacuum tube due to the charge induced electrostatically on the grid by the plate through the grid-plate capacitance.

Miller integrator
A circuit used to develop a linear sawtooth (ramp) voltage.

minority carrier
In semiconductor devices there always exists a small but measurable reverse current which results from the presence of current carriers which are opposite to the predominate carriers. These may be either holes or excess electrons found in N-type or P-type semiconductors, respectively.

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

mixer
That stage in a super heterodyne receiver in which the incoming modulated radio frequency signal is mixed with the signal from the local oscillator to produce the intermediate frequency signal.

MKS system
The meter-kilogram-second system.

mode
(1) One of several types of electromagnetic waves that may be sustained in a given resonant system. Each type of vibration is designated as a particular mode and has its own particular electric and magnetic field configuration.

(2) One of several methods of exciting a resonant system.

modulation
The process in which the amplitude, frequency, or phase of a carrier wave is varied with time in accordance with an intelligence signal.

modulation index
In frequency modulation, the ratio of the frequency deviation to the modulation frequency. It determines the number of significant sidebands and bandwidth occupied.

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.

monitoring
Periodic or continuous determination of the amount of some quantity. This is often achieved by use of a recorder.

monochromatic light
Light of only one wavelength or color.

monostable multivibrator
Referring to a circuit with one stable state. The circuit requires one trigger to perform a complete cycle. This circuit is also called a one-shot multivibrator or a, flip-flop multivibrator.

moving coil meter
The basic D'Arsonval meter movement consisting of an electromagnetic coil mounted between the poles of a permanent magnet.

multivibrator
A form of relaxation oscillator which uses two stages, so coupled that the input of each one is derived from the output of the other. A multivibrator can be free running or synchronized. Its frequency can be determined by the value of its own circuit parameters or an external synchronizing voltage. The output is essentially a square or rectangular wave.

mutual inductance
The common property of two associated electric circuits determining, for a given rate of change of current in one of the circuits, the amount of electromotive force induced in the other. Mutual inductance is measured in henrys.

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.

natural frequency
(1) The natural resonant frequency of an object

(2) The frequency at which an object will vibrate, when struck.

negative feedback
See degenerative feedback

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.

negative resistance

A resistance that varies with current in such a way that when the current increases the voltage drop across the resistance decreases. This characteristic is possessed by an electric arc and by vacuum tube circuits under certain conditions.

network

A system of interconnected resistors, inductors, or capacitors or any combination thereof.

neon

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

neutrino

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

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.

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.

neutralization

The process of canceling the voltage fed back through the interelectrode capacitance of an amplifier tube by providing an equal voltage of opposite phase. Generally this is necessary only with triode tubes.

neutron

A neutral particle found in the nucleus of an atom.

node

Any point, line, or surface in a stationary wave system at which the amplitude of the wave shaping variable is minimum.

noise

The sum of all undesirable signals. These may be generated within the circuit in question and/or induced from external circuits. Noise can be caused by atmospheric conditions as well. Noise is characterized by randomness of amplitude and frequency distribution.

noise suppression
A circuit used in a receiver or amplifier to reduce noise.

nominal value
This is normally the value indicated by the manufacturer.

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.

nonaxial loading
The condition existing when a force, or a component of a force, is not aligned with the major axis (primary loading axis) of the force measuring device to which it is applied.

noncorrosive flux
Flux that is free from acid and other substances which might cause corrosion in soldering.

nonlinear device
A device having a response that is not directly or inversely proportional to a given variable.

nonresonant line
A transmission line on which there are no standing waves at the operating frequency. Also called a "flat line."

non-sinusodial wave
Any waveform that differs from that of a sine wave.

nor-gate
A gate whose output is energized only when no signals are present-at the inputs. A combination of a Nor and an Or gate.

normal
Perpendicular to a tangent at a point of tangency.

normalized impedance
In microwave, the complex impedance of the transmission line in use is normalized to the Z_o of the line for. use with the Smith chart, that is, the number in use has been modified to conform to a reference value.

not-circuit
A circuit used to invert a binary signal.

N-type semiconductor
An extrinsic semiconductor in which the conduction electron density exceeds the hole density.

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.

oersted
The unit of magnetic intensity (magnetizing force) in the cgs electromagnetic system. The value of the magnetic intensity in oersteds, at any point in a vacuum, is equal to the force in dynes exerted on a unit magnetic pole placed at the point.

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.

open circuit voltage
The voltage at the terminals of a battery or other voltage source when no load is connected.

operating conditions
Those conditions, such as ambient temperature, pressure-, vibration, humidity, etc., to which a device is subjected, but does not include the variable measured by the device.

operating point
That point on a grid voltage-plate current characteristic curve of a vacuum tube which corresponds to the direct voltage values being used for the grid and plate. Also called quiescent point.

operational amplifier
An amplifier having DC stability and immunity to oscillation, generally achieved by using a large amount of negative feedback. Used- to perform analogue-computer functions such as summing and integrating.

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 by these axes 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 surveying
Used to take measurements over a vast scale; referenced to north.

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.

optimum coupling
See critical coupling

ordinate
The vertical or y-axis on a chart or graph.

oscillator

Any nonrotating device for generating and maintaining oscillations of a frequency determined by the physical constants of the system.

oscilloscope

An instrument that shows the instantaneous voltage waveform of a signal. It can be used to measure voltage, period, and frequency of a signal. Phase relationship and percentage of AM modulation can also be measured with an oscilloscope.

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.

output impedance

The impedance as measured between the output terminals of a circuit. For maximum power transfer, the load impedance should match or be equal to this output impedance.

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.

padder

Any small capacitor inserted in series with a main capacitor to adjust its capacity to some predetermined value.

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.

parallel circuit
A circuit in which two or more components are connected across the same pair of lines or terminals so that the current is divided between the components.

parallel resonant circuit
A circuit consisting of inductance and capacitance connected in parallel. This is also known as a "tank" circuit. It offers high line impedance to .the resonant frequency. It is often used to determine the frequency in an oscillator circuit.

paramagnetic
A term used to describe materials with magnetic permeability greater than that of a vacuum, such as iron, cobalt, and nickel.

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.

paraphrase inverter
A phase inverter consisting of one or two amplifiers which provides two output signals of opposite polarity from a single source.

parasitic oscillations
Undesired, self-sustaining oscillations at a frequency different from the operating frequency, occurring chiefly in vacuum tube circuits.

Pascal's Law
The pressure applied on a confined fluid is transmitted undiminished in every direction.

peaking coil
A coil placed in an amplifier circuit to obtain better high frequency response.

peak inverse plate voltage (rating)
The maximum instantaneous plate voltage the tube can withstand in the direction opposite to the direction in which the tube is designed to pass current.

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).

peak voltage

A maximum voltage which can be applied to electrolytic capacitors for a period not to exceed 30 seconds. Also called "surge" voltage. Also, the maximum instantaneous value of an alternating quantity.

Peltier effect

When two unlike conductors are joined and kept at a constant temperature while a current passes through the junction, heat is generated or absorbed at the junction. This is in addition to the I^2R loss. The Peltier effect is the inverse of the Seebeck effect.

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.

pentode

A five-electrode vacuum tube containing an anode, a cathode, a control grid and two additional electrodes ordinarily in the form of grids.

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.

permanent magnet

A magnet which retains its magnetism without the action of external electric or magnetic fields.

perpendicular

Being at right angles to a given line or plane.

persistence

A measure of the length of time that phosphorescent light is emitted from the screen of a CRT.

phantastron

A stable circuit whose operation is similar to that of a monostable multivibrator. It can only be triggered when in the quiescent condition. The circuit values determine the time required to return to quiescence. The phantastron is often used as a frequency divider.

phase distortion

An undesired alteration of a signal waveform caused by different phase shifts for various harmonics within a complex waveform.

phase inverter

A stage in an amplifier or other circuit whose chief function is to change the phase of a signal by 180°.

phase shift oscillator
An oscillator produced by connecting, between the output and the input of an amplifier, a network producing a 180° phase shift for the desired frequency of operation.

phase splitter
A circuit that produces two output signals of equal magnitude and opposite polarity from one amplifier using a single signal input.

phase velocity
(1) The velocity with which a point of a certain phase in an electromagnetic wave travels in the direction of propagation.

(2) An illusion that wave peaks travel through a waveguide faster than the speed of light. It appears because the elementary waves travel at an angle to the walls of the guide. The true speed is group velocity.

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.

pickup
See transducer

Pierce oscillator
An oscillator in which a piezoelectric crystal unit is connected between the grid and the plate of an electronic tube, in what is essentially a Colpitts oscillator. The capacitive voltage division is provided by the grid-cathode and plate-cathode capacitances of the circuit.

piezoelectric effect
Generation of a voltage between opposite faces of certain crystals (such as quartz) as a result of strain due to pressure or twisting and the reverse effect in which application of a voltage to opposite faces of the crystal causes deformation to occur at the frequency of the applied voltage.

pigtail
A flexible metallic connection usually consisting of braided wire used between a stationary terminal and a terminal having a limited range of motion.

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

$$h = \frac{E}{\nu} = 6.6 \times 10^{-27} \text{erg - sec}$$

plate resistance
The ratio of a small change in plate voltage to the corresponding small change in plate current.

plate saturation
See current saturation

plate voltage
The DC voltage that exists between the plate and cathode of a vacuum tube.

plug-in
Having terminals such that connections are made automatically by plugging the device into a socket or series of jacks.

plumbing
Common slang term for microwave coaxial or waveguide circuits.

plunge
To rotate the telescope of a theodolite 180° about the horizontal axis of the instrument.

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

polar coordinates
A system of coordinates in which a point is located by its distance from a fixed point and the angle that the line from this fixed point to the given point makes with a fixed reference line called the polar axis.

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 feedback
See regenerative feedback

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.

power
The time rate of doing work, or the rate of expending, transferring, or transforming energy. It is measured in watts.

power amplifier
An amplifier designed to produce a gain in signal power, as distinguished from a voltage amplifier.

power factor
The ratio of the actual power of an alternating or pulsating current, as measured by a wattmeter, to the apparent power, as indicated by ammeter and voltmeter readings; it is equal to the cosine of the phase angle between a sinusoidal voltage and the resulting sinusoidal current.

power supply
An electronic circuit that produces the multiple output voltage currents required to operate other electronic circuits from a single power source.

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 incorrect (I.E. Reading on the wrong scale). 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.

primary winding
The transformer winding which is connected to the source of power.

principle axis
Line through the centers of curvature of a refracting lens.

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, . . which describes the basic state of atomic system in quantum theory.

printed circuit technique
A method by which circuit connections and many of the components are printed or painted on a plane surface with conductive or resistive media. These techniques permit the construction of extremely compact circuits.

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.

probe
A probe is a link between the measuring instrument and the circuit under test. It is considered as part of the measuring equipment. Probes are used for isolation, to extend the voltage range of the measuring equipment or to rectify an AC input.

program
For computers, a set of instructions arranged in proper sequence to instruct a computer to perform a desired operation or operations.

propagation
In communications or electronics the travel of electromagnetic waves or sound waves through a medium, or the travel of a sudden electrical disturbance or sharp change in value along a line or scale.

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.

pulse
A nonsinusoidal waveform resulting from a sudden change in voltage or current levels for a specified period of time.

pulse amplitude modulation (PAM)
The form of modulation in which the amplitude of a pulse carrier is varied in accordance with the amplitude and frequency of the modulating signal.

pulse recurrence frequency (PRF)
The rate, usually given in pulses per second, at which pulses occur.

pulse repetition time (PRT)
Time from the beginning of one pulse to the start of the next. Equal to 1/PRF.

pulse width
The elapsed time between the 50 percent point in the rise of a pulse to the 50 percent point in the trailing edge of the pulse.

punch through
It is unique to transistors and results when the reverse bias supply completely ionizes the base region.

push-pull amplifier
An amplifier circuit containing two tubes arranged with the control grids connected to opposite ends of the input transformer secondary winding or to other out-of -phase feed points and with the plates connected to opposite ends of the output transformer primary winding. Grid voltage is then a maximum on one tube when it is minimum on the other tube, so that the sum of the plate currents is constant. Signal components add in the output to give twice the output of a single tube. This arrangement also tends to cancel even harmonics that would otherwise cause distortion.

pyrometer
A device for measuring high temperatures, generally above 600 degrees Celsius; also known as an optical pyrometer.

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

quadrature
Two alternating quantities are in quadrature when the phase angle between them is 90° .

quality (Q)
A quality factor rating applied to a coil, capacitor, or resonant circuit. The ratio of the energy stored in a circuit to the energy dissipated.

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.

quartz crystal

A thin square or rectangular slice of quartz which, when precision-ground and smoothed, will vibrate at a frequency determined by its thickness and its original position in the natural quartz.

quiescence

A term used to describe the state of a circuit that exists before a-trigger is applied. A stable operating condition.

radar

Radio detection and ranging. Widely used in military and civilian applications.

radian

The angle for which the arc length is equal to the radius. There are 2π 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.

radio

General term denoting radio wave transmission and reception.

radioactivity
The spontaneous, uncontrollable disintegration of the nucleus of an atom with the emission of particles and rays.

radio-frequency resistance
See AC resistance

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

ramp voltage
A popular name for a positive linear saw tooth waveform. It is composed of a sine wave fundamental and an infinite number of odd and even harmonics. The even harmonics starting out of phase and the odd frequencies starting in phase.

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 = 459.69 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.

RC constant
The time constant of a resistor-capacitor, equal in Seconds, to the value of the resistance multiplied by the value of the capacitance.

RC coupling
Resistor-capacitor coupling between two circuits. It has a long time constant and produces negligible wave shaping of a nonsinusoidal waveform.

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.

reactance
The opposition in ohms offered to the flow of an alternating current by inductance or capacitance in a circuit. It is the component of the impedance of a circuit which is not due to resistance.

reactive kick
Surge currents produced in a galvanometer circuit when power is interrupted. These are due to the discharge of the circuit's capacitance and inductance. Reactive kick causes violent deflection of the galvanometer.

recorder
An instrument that makes a graphic record in which the value of a quantity (voltage, current, power, temperature) varies with time.

rectangular wave
periodic wave which alternately assumes one of two fixed values, the time of transition being negligible in comparison with the duration of each fixed value.

rectification
The process of converting AC into a unidirectional current by removing or inverting that part of the wave lying on one side of the zero amplitude axis.

rectifier
The component that accomplishes the process of rectification of AC.

reference level
The level used as a starting point when designating the value of an alternating quantity or a change in the quantity by means of decibel units. A common reference value in voltage, current, and power designations is 0.001 watt for 0 db. For sound loudness, the reference level is usually the threshold of hearing.

reference line
A line from which all other measurements are taken.

reference plane
A reference line that has been rotated through 360 degrees.

reflected Impedance
The impedance value that appears to exist across the input of a transformer or any four-terminal passive network as a result of the characteristics of the impedance connected across the output.

reflected wave
The sky radio wave, reflected back to Earth from an ionosphere layer.

reflection
The change in direction of waves after striking a surface.

reflection coefficient (F)
The magnitude and phase angle of the reflected wave on a transmission line.

reflex klystron
A velocity-modulated klystron serving as a feedback oscillator.

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.

regenerative feedback
A method of securing increased output from an amplifier, by feeding part of the output back in such a way as to reinforce the input signal. It is also called positive feedback.

regulated power supply
A power supply containing a regulator device for maintaining constant voltage or constant current under changing load conditions.

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.

relaxation oscillator
A device which generates a nonsinusoidal wave by the charge and discharge of a capacitor through a resistor.

relay
The most common type of relay is an electromechanical device by means of which a current change in one circuit produces an armature movement that opens or closes contacts to produce a change in the electrical condition of another circuit.

reluctance
The property of a magnetic circuit that determines the amount of magnetic flux that will be produced as a result of the application of a given magnetomotive force.

remote cutoff tube
A tetrode or pentode tube in which the spacing of the control grid wires is wider at the center than at the ends. It is also called a "variable mu" tube. It will give higher amplification of small signals and less amplification of larger signals.

repeatability
See precision

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

reset
To place a binary circuit in the initial state.

residual loss

(1) The minimum or initial loss of a variable attenuator or isolator

(2) The loss or attenuation of a component which is ideally lossless.

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.

resolver

A type of transformer used for solving a vector for two mutually perpendicular components or resolving a vector into two mutually perpendicular components.

resonance

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

resonant cavity

A form of resonant circuit in which the current is distributed on the inner surface of an enclosed chamber. By making the chamber of the proper dimensions, the circuit can be made to have a high Q at microwave frequencies. The resonant frequency of a cavity can be changed by the adjustment of screws that protrude into the cavity or by changing the shape of the cavity. The cross-section of the cavity may be circular, rectangular, or any other shape.

resonant frequency

(1)Frequency, of a crystal unit, for a particular mode of vibration to which, discounting dissipation, the effective impedance of the unit is zero.

(2) That frequency, for a given resonant circuit, at which the inductive reactance is equal to the capacitive reactance.

resonant line

One having standing waves.

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.

retentivity
The ability of a material to retain its magnetism.

reticule
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

retrace
The path traced by the electron beam in a CRT in going from the end of one line to the start of the next line or trace.

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

reverse current
The small flow of electricity between the junction of a diode receiving reverse bias; usually measured as only a few microamperes in contrast to a forward current measured in milliamperes.

rheostat
A variable resistor having one fixed and one movable terminal. rho - The magnitude of the reflection coefficient.

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.

ringing
Damped oscillations occurring as the transient response of a resonant circuit to a shock excitation. Usually occurs as an unwanted effect in poorly designed circuits.

ripple
The AC components present in the output of a DC generator, rectifier system, or power supply.

rise time
The time needed for the leading edge of a pulse to rise from the 10 percent reference point to the 90 percent reference point.

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.

rotating joint
A device for permitting one section of a transmission line to rotate continuously with respect to another and still maintain a matched impedance.

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

(2) The rotating plates of a variable capacitor.

saturable reactor
A device consisting of a DC winding and an AC winding on the same core. The DC winding is used to vary the core saturation and thus controls the impedance to current in the AC winding.

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

saturation current
The collector current flowing with a zero emitter current. Sometimes called leakage current or collector cutoff current. Abbreviated Ic_o or Icb_o .

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.

Schering bridge
An AC bridge comprised of resistors and capacitors used to measure the capacitance and dissipation factor of a capacitor. Variable capacitors are used to obtain the amplitude and phase nulls.

Schmitt trigger circuit

A variation of a bistable. multivibrator. It always produces a rectangular or square wave output of constant amplitude, regardless of the input waveform. It is widely used as a wave-shaping circuit.

screen

A metal partition or shield used to isolate an instrument or device from external magnetic or electric fields.

screen grid

A grid of a vacuum tube placed between the control grid and the plate, and usually maintained at a fixed positive potential for the purpose of reducing the electrostatic influence of the plate in the space between the screen grid and the cathode.

second

(1) A unit of time equal to one sixtieth of a minute, or the time needed for a cesium-133 atom to perform 9,192,631,770 complete oscillations.

(2) Mathematics. A unit of angular measure equal to one sixtieth of a minute.

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.

Seebeck effect

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

selectivity

The degree to which a receiver is capable of discriminating between signals of different carrier frequencies

self-bias

Production of grid bias voltage, by a vacuum tube itself, by the flow of plate and other electrode currents through a resistor in the cathode lead. The resulting voltage drop across this resistor serves as the grid bias.

semiconductor

A class of solids whose electrical conductivity is between that of a conductor and that of an insulator.

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.

series circuit

An electrical circuit in which the component parts are connected end to end to form a single continuous path for the current.

series motor

A commutator-type motor having armature and field windings in series. Characteristics are high starting torque, variation of speed with load, and dangerously high speed on no-load.

series resonant circuit

An inductor and capacitor in series, having electrical values such that the inductive reactance of the inductor is equal to the capacitive reactance of the capacitor at the frequency being handled. At resonance, the circuit current is a maximum and the voltage across either the inductor or the capacitor may be several times the voltage applied to the combination.

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.

shaded poles

A moving coil meter movement that has its permanent magnet poles offset to produce a logarithmic response.

sharp cutoff

Term applied to a tube or grid of a tube in which the control grid spirals are uniformly spaced. The result is that as grid voltage is made negative, plate current decreases steadily to cutoff.

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.

shielded wire
Insulated wire covered with a metal shield, usually of tinned braided copper wire.

shielding
A construction feature of electrical instruments which refers to the grounding of the metal case and top plate, thus serving as an electrostatic shield and diverts external charges that might otherwise pass through the measuring circuit.

short circuit
A low resistance connection between two points of different potential in a circuit.

short' waves
A general term usually applied to a wavelength shorter than the lower limit of the standard U.S. broadcasting band (200 meters).

shunt
(1) A precision low-value resistor placed across the terminals of an ammeter to increase the range by allowing a definite part of the circuit current to go around the meter.

(2) Any part connected, or the act of connecting any part of a circuit in parallel with some other part.

shunt box
A precision low resistance voltage divider used to enable measurements of high currents.

sidebands
The new frequencies above and below the carrier frequency produced as a result of the frequency modulation of the carrier. The sum frequencies form the upper sideband, the difference frequencies form the lower sidebands.

signal-to-noise-ratio
Ratio of signal amplitude to the amplitude of the noise. This is an important consideration when the input signal is of very low amplitude.

signal tracing
This consists of checking the input and output stages of an amplifier for the desired signal to localize a malfunction.

silicon controller rectifier (SCR)
A three-junction semiconductor device which is capable of handling large values of current and voltage. It is similar to the gas-filled thyratron tube, yet it has a variety of applications for which a. thyratron tube is not generally used.

sine wave
A wave in which the amplitude varies as the sine of an angle or time function.

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

single phase
Pertaining to a circuit or device that is energized by a single alternating voltage.

skin effect
The tendency of high frequency alternating currents to concentrate near the surface of a conductor, thus increasing the effective resistance of the conductor. The skin effect increases with frequency.

Smith chart
A diagram used to find the impedances, wavelength, and standing wave ratio of a transmission line.

Snell's Law
(Index of refraction) x (sine of incident angle) = (index of refraction) x (sine of refracted angle).

soft tube
A vacuum tube that has been fully evacuated then injected with enough gas to change its operating characteristics appreciably. Examples are: neon, thyratron, VR tubes. However, a vacuum tube in which a gas has developed is sometimes called a "soft tube" or a "gassy tube."

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 gun
A soldering iron having an appearance similar to that of a pistol. Usually has a fast-heating resistance element at the tip.

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

soldering iron
A device used to apply heat to a joint which is to be made permanent by soldering.

solenoid
An electromagnet having an energizing coil which is approximately cylindrical in form, acting on an armature positioned in the center of the coil.

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.

special calibration
When a TI is calibrated to full specification IAW 33K series technical order but additional parameters are calibrated (not specified in the 33K series TO.). Theses parameters are certified using additional technical data found in maintenance Tos, commercial data manuals, or other applicable technical information.

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.

spectral lines
Sidebands of a modulated RF signal as displayed on spectrum analyzer CRT.

spectroscope
Any of various instruments for forming and examining the optical spectra.

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.

spectrum analysis
The study of energy distribution across the frequency spectrum for a given electrical signal.

spectrum analyzer
A test instrument which provides a visual or panoramic display of the radio frequency electrical signal on a CRT, in the form of a graphical plot of amplitude (Y axis) and frequency (X axis).

spectrum width
The widest range of frequencies that can be observed or a spectrum analyzer CRT in a single sweep.

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.

square law detection
The term applied to the response of a detector whose response is a function of the square of the input voltage. Square law detection is used for microwave power measurements.

square law scale
A scale in which the deflection is proportional to the square of the applied voltage or current. The iron vane type meter movement has a square law response. Therefore they. must use a square law scale.

square wave
The waveform of a quantity that shifts abruptly from one to the other of two definite values producing a square waveform. The square wave is considered to consist of a sine wave fundamental frequency and an infinite number of odd harmonics, all starting in phase. RMS, average, and peak values of this waveform are the same.

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 cell
A very accurate battery used as a voltage standard. There are two types used, the saturated (normal) and the unsaturated cell. The saturated cell is used as the voltage standard.

standard deflection
A standard deflection of a galvanometer is defined as a deflection of the center of the light beam 1 millimeter in the scale when the scale is the optical equivalent of 1 meter from the reflecting mirror.

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.

standing wave ratio (SWR)
The ratio of voltage (or current) at a loop (maximum) on a transmission line to the value at a node (minimum). It is equal to the ratio of the characteristic impedance to the impedance of the load connected to the output end of the line.

static error
The maximum difference between the true quantity and the indicated quantity when the applied (true) quantity is not changing.

stator
A portion of a machine which contains the stationary .parts of the magnetic circuit, with their associated windings.

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.

storage circuit
Any circuit in which information can be stored. Often called a memory circuit.

storage time (Ts)
The time required to drain off the injected minority carriers in the base caused by saturating the collector.

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.

stray capacitance
A capacitance that exists between circuit elements, between adjacent conductors, and between those elements and conductors and the equipment chassis.

stray inductance
The inductance that exists between circuit elements, between adjacent conductors, and between those elements and conductors and the chassis.

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.

substitution loss
The ratio of the initial to final load power, expressed in decibels, when an initial waveguide junction (a connector pair, two-port network, etc.) is removed and another substituted in its place.

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.

super heterodyne
A receiver in which the incoming signal is mixed with a locally generated signal to produce an intermediate frequency that is then amplified and detected.

support equipment
Equipment used to verify the operation of other equipment, including a broard category of equipment and tools used to maintain mission equipment.

suppressor grid
An electrode used in an electron tube to minimize the effects of unwanted secondary emission from the plate.

surface tension
The tendency of the surface of a liquid to contract.

swamping resistor
A resistor placed in parallel with a tank circuit to reduce the Q.

sweep voltage
The periodically varying voltage produced by a sweep oscillator and applied to the deflecting plates of a CRT to give a displacement that is a function of time.

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).

tank circuit
A resonant circuit, consisting of inductance and capacitance in parallel, or series; one value is usually variable.

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.

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

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

tertiary winding
A third winding added to a transformer in addition to the conventional primary and secondary winding. In most applications it is used as an additional secondary winding.

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 (TI)
The device which is being compared with the calibration standard. The test instrument is the instrument whose accuracy is being tested, some times refered to as unit under test (UUT) or device under test.

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

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

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

thermal converter meters
Meters that employ a thermocouple to convert the meter input to a DC voltage proportional to the EMS value of the input. They are widely used for accurate measurement of AC voltage and current.

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.

thermionic emission
The evaporation of electrons from a heated surface.

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.

Thyratron

A hot-cathode gas-filled triode or tetrode which is used as an electronic switch. It controls electrostatically (with grids) the starting of the unidirectional current flow. To cut off the discharge, the plate-cathode potential must be reduced to the extinguishing potential for the particular gas and pressure used.

tickler coil

A small coil connected in series with a vacuum tube plate circuit and inductively coupled to the grid circuit to provide regenerative feedback.

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.

time base

The time reference plotted along the X-axis of a CRT.

time constant

The time required for a quantity that varies exponentially to change by an amount equal to 0.632 times the total change that will occur. In a capacitor-resistor circuit, it is the number of seconds required for the capacitor to reach 63.2 percent of its full charge after a voltage is applied. In an inductor-resistor circuit, it is the number of seconds required for the current to reach 63.2 percent of its final value.

time delay relay

A relay with a heating element designed to delay full circuit operation until the filaments of the vacuum tubes have had time to reach operating" temperatures.

time signals

One of the technical radio broadcast services of NBS radio stations.

TMDE (Test, Measurement and Diagnostic Equipment)

Those devices used to test,measure, evaluate, inspect, or otherwise examine materials, supplies, equipment, and systems to identify or isolate any actual or potential malfunction, or to determin compliance with specifications eatablished in technical documents.

Toroid

A doughnut-shaped coll wound on a core of the same configuration. A toroid coil produces little Interference to other circuits and is relatively unaffected by the magnetic fields of other circuits.

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.

trace
The path followed by the spot as it is in motion across the screen of a CRT.

traceability
The ability to referance all measurements back to a higher level of accuracy and eventually to the National Institute of Standards and Technology (NIST).

transconductance
The ratio of the amplification factor of a vacuum tube to its AC plate resistance expressed in mhos or micromhos. The change in plate current divided by the change in grid voltage when the plate voltage is held constant.

transducer
(1) Generally, a device which converts energy from one form into another, always retaining the characteristic amplitude variations of the energy converted.

(2) A device which transfers energy from one circuit to another without changing the form of energy.

(3) A device which converts vibratory motion into an electrical signal that is a function of some parameter of the experienced motion.

transfer method
An accurate method of measuring voltages and currents using a thermocouple meter and the universal potentiometer. It consists of measuring the Input, and then duplicating the input reading with an internal source. The internal source voltage is then read with, the universal potentiometer.

transformer
An electrical device which, by electromagnetic induction, converts electrical energy from one voltage-current level to another voltage-current level.

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.

transit time
(1) In electron tubes, the time required for an electron to travel from one electrode to another.

(2) In semiconductors, the time required for the charge carrier to travel from the emitter to the collector.

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

transient response
The ability of an amplifier circuit to reproduce faithfully the shape and amplitude of transient voltages.

transistor
An electronic device for rectification and/or amplification consisting of semiconducting material to which contact is made by three or more electrodes which are metal points or soldered junctions. In general, the resistance between two electrodes is controlled by the current supplied to another electrode.

translucent
Shining or glowing through; admitting and diffusing light so that objects beyond cannot be clearly distinguished.

transmission
Transfer of electric energy from one location to another through conductors or by radiation. The transfer always is accompanied by energy loss.

transmitter
A comprehensive term applying to all of the equipment used for generating and amplifying an RF carrier signal, modulating this carrier with intelligence, and radiating the modulated RF carrier into space.

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.

transverse electric (TE) mode
A field configuration in a waveguide in which all components of the electric field lie in a plane that is transverse, or perpendicular to the direction of propagation.

transverse magnetic (TM) mode
A field configuration in a waveguide in which all components of the magnetic field lie in a plane that is transverse, or perpendicular, to the direction of propagation.

traveling wave
Energy moving toward the termination of a waveguide or energy reflected from the termination.

trickle charge
The continuous charging of a storage battery at a low rate over a prolonged period of time.

trigger
(1) To start action in a circuit, which then functions for a period of time under its own control.

(2) A short pulse, either positive or negative, which can be used to set into motion a chain of events.

trimmer
Any small capacitor inserted in parallel with a main capacitor to adjust its capacity to some predetermined level.

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 power
The average value of power consumed by a circuit during one complete cycle of AC. In a DC circuit, the power is equal to the current times the voltage. In an AC circuit, the true power is equal to the current times the voltage, times the power factor. The formula, $P = I^2R$, will give the true power in any circuit.

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.

tube
The word "tube," without any qualification, refers to an electronic tube.

tuning
(1) Adjusting the inductance or capacitance (or both) in a coil-capacitor circuit.

(2) Adjusting all circuits in electronic equipment for optimum performance.

tuning fork
A convenient device for producing a comparatively pure harmonic vibration frequency at nearly constant value. They are usually made of steel and are designed to vibrate at their natural resonant frequency.

tunnel diode
A very heavily doped PN junction.

turn-off time (Ts and Tf)
The time required for the Ic wave to go from its maximum value to 10 percent of its maximum value. It can be expressed as the sum of the storage time and the fall time. Ts is storage time, and Tf is fall time.

turn-on-time (Td and Tr)
The sum of the delay time and the rise time. This is the time necessary for Ic to go from its minimum value to 90 percent of its maximum value. Tr is rise time, and Td is delay time.

turns ratio
The ratio of the number of turns in the primary windings to the number of turns in the secondary winding of a transformer.

twin "T" network
A network of capacitors and resistors that will provide maximum attenuation and a 180° phase shift to a selected frequency. Other harmonics will be attenuated much less and they will appear to receive a negligible phase shift.

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.

two-wire transmission line
Two metallic conductors spaced equidistant apart and separated by dielectric or metallic insulators, used for frequencies up to 200. MHz.

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.

unblanking

A signal applied to the control grid of a CRT to allow the CRT to conduct. This is also called gating.

uncertainty

The degree of doubt concerning the exactness of a measurement. It is the estimated maximum amount that the numerical value of a measured quantity may differ from the true value. In some cases it is refered to as accuracy.

undamped wave

A continuous wave with undamped oscillation. unifilar - Having or using one fiber, wire, or thread.

unifilar

Having or using one fiber, wire or thread.

uniform line

A transmission line that has identical electrical properties throughout its length.

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.

unit under test (UUT)

See test instrument

unity coupling

Perfect magnetic coupling between two coils, so that all the magnetic flux produced by the primary winding passes through the entire secondary winding.

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.

vacuum tube voltmeter (VTVM)

A voltmeter that has a high input impedance and therefore takes only a small amount of power from the circuit. The small power input is amplified before being applied to the meter movement of the VTVM.

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.

variable-mu tube
A vacuum tube having the control grid wires irregularly spaced so that at different points within its operating range the grid has a different amount of control over the electron stream. This shifts the operating point from one section of the characteristic curve to another. Thus, by adjusting the grid bias voltage over a comparatively wide range the amplification factor and mutual conductance can be varied.

vector quantity
A quantity having both magnitude and direction, as a force or a velocity.

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
(1) Being or situated at right angles to the horizon, or to level ground: perpendicular, plumb, upright.

(2) In science, parallel with the direction of the force 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.

video frequencies
A wide range of frequencies including the audio range and frequencies as high as 4 MHz. Some video amplifiers will amplify frequencies as high as 10 MHz.

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.

Volt
Unit of electric potential difference and electromotive force. The difference of electric potential between two points of a conducting wire carrying a constant current of 1 ampere, when the power dissipated between these points is equal to 1 watt.

voltage saturation
See current saturation

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...)

Zener point
See avalanche breakdown

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