UNITS AND CONVERSION FACTORS

E.J. ROSCHKE
PROPULSION DIVISION
JET PROPULSION LABORATORY

NOTE:

Many years ago I was given a copy of this document, prepared in handwriting, some time in the early 1960's. I did not know the author, E.J. Roschke. I have found it to be such a useful reference that I decided to have an electronic version prepared. Recently, I spoke with Dr. Roschke, now retired from the Jet Propulsion Laboratory to learn of the document's origin. In the early 1960's a group of research engineers, largely having backgrounds in mechanical engineering, were engaged in the new field of electric propulsion. They experienced practical annoyances with the mingling of units from mechanical engineering, electrical engineering and physics. That situation motivated Dr. Roschke to assemble this material.

Although I have carefully checked the values given here, it is quite possible that some typographical errors remain. I will appreciate learning any corrections that should be made.

F.E.C. Culick
Mechanical Engineering
California Institute of Technology
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UNITS AND CONVERSION FACTORS
Table of Contents

Table of Contents – continued

References used in compiling these charts and tables are listed below in the order of "most usage".

1. Halliday, D. & Resnick, R., Physics – For Students of Science and Engineering, John Wiley, New York, 1960.
2. Forsythe, W.E., Smithsonian Physical Tables, 9th Revised Edition, Publ. 4169, Smithsonian Institution, Washington, D.C., 1954.
3. Scott, R.B., Cryogenic Engineering, D. Van Nostrand Inc., Princeton, New Jersey, 1959.
4. Hall, N.A., Thermodynamics of Fluid Flow, Second Printing with revisions, Prentice-Hall Inc., Englewood Cliffs, New Jersey, 1956.
5. Gray, D.E. (coordinating editor), American Institute of Physics Handbook, McGraw Hill Inc., New York, 1957.

Additional Note on Use of Conversion Tables, Part VII.

Multiply units appearing in left-hand column by appropriate numerical factor to obtain units appearing in upper row.

I. DECIMAL MULTIPLES AND SUB-MULTIPLES

Name	Symbol	Equivalent		Name	Symbol	Equivalent
tera	T	10^{12}		deci	d	10^{-1}
giga	G	10^{9}		centi	c	10^{-2}
mega	M	10^{6}		milli	m	10^{-3}
kilo	k	10^{3}		micro	μ	10^{-6}
hecto	h	10^{2}		nano	n	10^{-9}
deca	–	10		pico	p	10^{-12}

II. DESCRIPTION OF UNITS

MECHANICAL UNITS

Quantity	cgs	mks
Length	centimeter	meter
Mass	gram	kilogram
Time	second	second
Force	dyne	newton
Work, Energy	erg	joule
Power	–	watt
Dynamic Viscosity	poise	–
Kinematic Viscosity	stoke	–

ELECTRIC AND MAGNETIC UNITS

The esu and emu unit systems are cgs systems.
esu denotes "electrostatic unit", sometimes given prefix "stat", e.g. statcoulomb
emu denotes "electromagnetic unit", sometimes given prefix "ab", e.g. abcoulomb
Some emu units have special names:

Quantity	emu	mksq
Magnetic Flux, ϕ	$\left\{\begin{array}{l}\text{line}\\\text{maxwell}\end{array}\right\}$	weber
Magnetic Field Strength, **B**	gauss	weber/m^2
Magnetomotive Force, $\mathfrak{F}$	gilbert	amp-turn
Magnetic Vector, **H**	oersted	amp-turn/m.

mksq DIMENSIONS

Length	L
Mass	M
Time	T
Current	Q/T
Charge	Q

III. EQUIVALENT UNITS mksq SYSTEM

1 newton	=	1 kilogram-meter/(second)^2		
1 volt	=	1 newton-meter/coulomb		
1 amp	=	1 coulomb/second		
1 joule	=	1 newton-meter	=	1 coulomb-volt
1 weber	=	1 volt-second		
1 farad	=	1 coulomb/volt		
1 henry	=	1 weber/amp		
1 ohm	=	1 volt/amp		
1 watt	=	1 joule/sec		

IV. DIMENSIONS OF esu AND emu ELECTRIC AND MAGNETIC QUANTITIES

The fundamental dimensions in both systems are M, L, T. cgs units used.

Quantity	Symbol	esu $M^xL^yT^z$			emu $M^xL^yT^z$			$\frac{\text{emu}^*}{\text{esu}}$
		x	y	z	x	y	z	
Charge	q	½	$\frac{3}{2}$	-1	½	½	0	c
Field Intensity	**E**	½	-½	-1	½	$-\frac{3}{2}$	0	1/c
Elec. Displacement	**D**	½	-½	-1	½	½	-2	c
Charge Density	ρ	½	$-\frac{3}{2}$	-1	½	$-\frac{5}{2}$	0	c
Current Density	**j**	½	-½	-2	½	$-\frac{3}{2}$	-1	c
Elec. Potential	V	½	½	-1	½	$\frac{3}{2}$	-2	1/c
Total Current	I	½	$\frac{3}{2}$	-2	½	½	-1	c
Mag. Field Strength	**B**	½	$-\frac{3}{2}$	0	½	-½	-1	1/c
Mag. Vector	**H**	½	½	-2	½	-½	-1	c
Permittivity	ε	0	0	0	0	-2	2	c^2
Permeability	μ	0	-2	2	0	0	0	$1/c^2$
Conductivity	σ	0	0	-1	0	-2	1	c^2
Capacitance	C	0	1	0	0	-1	2	c^2
Inductance	L	0	-1	2	0	1	0	$1/c^2$
Resistance	R	0	-1	1	0	1	-1	$1/c^2$

*c = velocity of light (free space) in cm/sec ≈ 3×10^{10}

Thus: 1 emu of charge = 2.998×10^{10} esu of charge

or 1 abcoulomb = 2.998×10^{10} statcoulomb

V. DIMENSIONS AND UNITS FOR PHYSICAL QUANTITIES
mksq SYSTEM

A. MECHANICAL QUANTITIES

Quantity	Dimensions	Derived Units
Acceleration	LT^{-2}	meter/sec^2
Angle	0	radian
Angular Accleration	T^{-2}	radian/sec^2
Angular Momentum	ML^2T^{-1}	kgm-meter^2/sec
Angular Velocity	T^{-1}	radian/sec
Area	L^2	meter^2
Energy	ML^2T^{-2}	joule
Force	MLT^{-2}	newton
Frequency	T^{-1}	cycle/sec
Gravitational Field Strength	LT^{-2}	newton/kgm
Length	L	meter
Mass	M	kilogram
Mass Density	ML^{-3}	kgm/meter^2
Momentum	MLT^{-1}	kgm-meter/sec
Power	ML^2T^{-3}	watt
Pressure	$ML^{-1}T^{-2}$	newton/meter^2
Time	T	second
Torque	ML^2T^{-2}	newton/meter
Velocity	LT^{-1}	meter/sec
Viscosity (Dynamic)	$ML^{-1}T^{-1}$	kgm/meter-sec
Viscosity (Kinematic)	L^2T^{-1}	meter^2/sec
Volume	L^3	meter^3
Wave Length	L	meter
Work	ML^2T^{-2}	joule

B. THERMAL QUANTITIES*

Quantity	Dimensions	Derived Units
Enthalpy	ML^2T^{-2}	joule
Entropy	$ML^2T^{-2}\theta^{-1}$	joule/K°
Gas Constant	$L^2T^{-2}\theta^{-1}$	joule/kgm- K°
Internal Energy	ML^2T^{-2}	joule
Specific Heat	$L^2T^{-2}\theta^{-1}$	joule/kgm-K°
Temperature	θ	K°
Thermal Conductivity	$MLT^{-3}\theta^{-1}$	watt/meter- K°
Thermal Diffusivity	L^2T^{-1}	meter^2/sec
Heat Transfer Coefficient	$MT^{-3}\theta^{-1}$	watt/meter^2- K°

*The dimension of temperature is θ; the unit is K°

C. ELECTRIC AND MAGNETIC QUANTITIES

Quantity	Symbol	Dimensions	Derived Units
Charge	q	Q	coulomb
Field Intensity	**E**	$MLT^{-2}Q^{-1}$	volt/meter
Elec. Displacement	**D**	$L^{-2}Q$	coulomb/meter^2
Charge Density	ρ	$L^{-3}Q$	coulomb/meter^2
Current Density	**j**	$L^{-2}T^{-1}Q$	amp/meter^2
Elec. Potential	V	$ML^2T^{-2}Q^{-1}$	volt
Total Current	I	$T^{-1}Q$	coulomb/sec
Mag. Field Strength	**B**	$MT^{-1}Q^{-1}$	weber/meter^2
Mag. Vector	**H**	$L^{-1}T^{-1}Q$	amp(turn)/meter
Permittivity	ε	$M^{-1}L^{-3}T^2Q^2$	farad/meter
Permeability	μ	MLQ^{-2}	henry/meter
Conductivity	σ	$M^{-1}L^{-3}TQ^2$	1/ohm-meter
Capacitance	C	$M^{-1}L^{-2}T^2Q^2$	farad
Inductance	L	ML^2Q^{-2}	henry
Resistance	R	$ML^2T^{-1}Q^{-2}$	ohm

VI. CONVERSION OF mksq UNITS TO GAUSSIAN UNITS

Quantity	mksq Unit		Conversion Factor × Gaussian Unit*		
q	coulomb	=	10^{-1} c	statcoulomb	(esu)
E	volt/meter	=	10^{6}/c	statvolt/cm	(esu)
D	coulomb/meter^2	=	$4\pi \times 10^{-5}$ c	lines/cm^2	(esu)
ρ	coulomb/meter^3	=	10^{-7} c	statcoulomb/cm^3	(esu)
j	amp/meter^2	=	10^{-5}	abamp/cm^2	(emu)
V	volt	=	10^{8}/c	statvolt	(esu)
I	coulomb/sec : = amp	=	10^{-1}	abamp	(emu)
B	weber/meter^2	=	10^{4}	gauss	(emu)
H	amp-turn/meter	=	$4\pi \times 10^{-3}$	oersted	(emu)
μ	farad/meter	=	$4\pi \times 10^{-11}c^2$	—	(esu)
ε	henry/meter	=	$10^{7}/4\pi$	—	(emu)
σ	1/ohm-meter	=	10^{-11}	1/abohm-cm	(emu)
C	farad	=	$10^{-9}c^2$	statfarad	(esu)
L	henry	=	10^{9}	abhenry	(emu)
R	ohm	=	10^{9}	abohm	(emu)

*c = vel. of light (free space) in cm/sec ≈ 3×10^{10}

Use of table:
1 coulomb = 10^{-1} (3×10^{10}) statcoulomb = 3×10^{9} statcoulomb

VII. CONVERSION FACTORS

NOTE: mksq UNITS ARE **CAPITALIZED**
USE OF TABLES: EXAMPLE

1 degree = 2.778×10^{-3} revolutions

so, $16.7^{o} = 16.7 \times 2.778 \times 10^{-3}$ revolutions

A. PLANE ANGLE

		o	′	″	**RADIAN**	rev
1 degree	=	1	60	3600	1.745×10^{-2}	2.778×10^{-3}
1 minute	=	1.667×10^{-2}	1	60	2.909×10^{-4}	4.630×10^{-5}
1 second	=	2.778×10^{-4}	1.667×10^{-2}	1	4.848×10^{-4}	7.716×10^{-7}
1 **RADIAN**	=	57.30	3438	2.063×10^{5}	1	0.1592
1 revolution	=	360	2.16×10^{4}	1.296×10^{5}	6.283	1

1 revolution = 2 π **RADIANS** = 360^{o} , 1^{o} = 60′ = 3600″

B. SOLID ANGLE

1 sphere = 4 π steradians = 12.57 steradians

C. LENGTH

	cm	**METER**	km	in	ft	mile
1 centimeter =	1	10^{-2}	10^{-5}	0.3937	3.281×10^{-2}	6.214×10^{-6}
1 **METER** =	100	1	10^{-3}	39.37	3.281	6.214×10^{-4}
1 kilometer =	10^5	1000	1	3.937×10^{-4}	3281	0.6214
1 inch =	2.540	2.540×10^{-2}	2.540×10^{-3}	1	8.333×10^{-2}	1.578×10^{-5}
1 foot =	30.48	0.3048	3.048×10^{-4}	12	1	1.894×10^{-4}
1 statute mile =	1.609×10^5	1609	1.609	6.336×10^4	5280	1

1 foot = 1200/3937 meter
1 meter = 3937/1200 ft
1 angstrom (Å) = 10^{-10} meter
1 X-unit = 10^{-13} meter
1 micron = 10^{-6} meter
1 millimicron (mu) = 10^{-9} meter

1 light-year = 9.460×10^{12} km
1 par-sec = 3.084×10^{13} km
1 fathom = 6 ft
1 yard = 3 ft
1 rod = 16.5 ft
1 mil = 10^{-3} in

1 nautical mile = 1852 meters = 1.1508 statute miles
1 nautical mile = 6076.10 ft

D. AREA

	METER^2	cm^2	ft^2	in^2	circ mil
1 **SQUARE METER** =	1	10^4	10.76	1550	1.974×10^9
1 square cm =	10^{-4}	1	1.076×10^{-3}	0.1550	1.974×10^5
1 square foot =	9.290×10^{-2}	929.0	1	144	1.833×10^8
1 square inch =	6.452×10^{-4}	6.452	6.944×10^{-3}	1	1.273×10^6
1 circular mil =	5.067×10^{-10}	5.067×10^{-6}	5.454×10^{-3}	7.854×10^{-7}	1

1 square mile = 27,878,400 ft^2 = 640 acres
1 acre = 43,560 ft^2 1 barn = 10^{-28} meter^2
1 hectare = 2.417 acres

E. VOLUME

	METER^3	cm^3	liter	ft^3	in^3
1 **CUBIC METER** =	1	10^6	1000	35.31	6.102×10^4
1 cubic cm =	10^{-6}	1	1.000×10^{-3}	3.531×10^{-8}	6.102×10^{-2}
1 liter =	1.000×10^{-3}	1000	1	3.531×10^{-2}	61.02
1 cubic foot =	2.832×10^{-2}	2.832×10^4	28.32	1	1728
1 cubic inch =	1.639×10^{-5}	16.39	1.639×10^{-2}	5.787×10^{-4}	1

1 U.S. fluid gallon = 4 U.S. fluid quarts = 8 U.S. fluid pints
=128 U.S. fluid ounces = 231 in^3
1 British imperial gallon = 277.42 in^3 (volume of 10 lb H_2O at 62^o F)
1 liter = 1000.028 cm^3 (volume of 1 kgm H_2O at its maximum density)

F. MASS

	gm	**KGM**	slug	amu	oz	lb	ton
1 gram =	1	0.001	6.852×10^{-5}	6.024×10^{23}	3.527×10^{-2}	2.205×10^{-3}	1.102×10^{-6}
1 **KILOGRAM** =	1000	1	6.852×10^{-2}	6.024×10^{26}	35.27	2.205	1.102×10^{-3}
1 slug =	1.459×10^{-4}	14.59	1	8.789×10^{27}	514.8	32.17	1.609×10^{-2}
1 amu =	1.660×10^{-24}	1.660×10^{-27}	1.137×10^{-28}	1	5.855×10^{-26}	3.660×10^{-27}	1.829×10^{-30}
1 ounce (avoirdupois) =	28.35	2.835×10^{-2}	1.943×10^{-3}	1.708×10^{25}	1	6.250×10^{-2}	3.125×10^{-5}
1 pound (avoirdupois) =	453.6	0.4536	3.108×10^{-2}	2.732×10^{26}	16	1	0.0005
1 ton =	9.072×10^{-5}	907.2	62.16	5.465×10^{29}	3.200×10^{4}	2000	1

NOTE FOR TABLE F: Portion of table enclosed in heavy lines must be used with caution because those units are not properly mass units but weight equivalents which depend on standard terrestrial acceleration due to gravity, i.e. g.

G. DENSITY

	slug/ft^3	**KGM/M**^{3}	gm/cm^3	lb/ft^3	lb/in^3
1 slug per ft^3 =	1	515.4	0.5154	32.17	1.862×10^{-2}
1 **KILOGRAM** per **METER**^{3} =	1.940×10^{-3}	1	0.001	6.243×10^{-2}	3.613×10^{-5}
1 gm per cm^3 =	1.940	1000	1	62.43	3.613×10^{-2}
1 pound per ft^3 =	3.108×10^{-2}	16.02	1.602×10^{-2}	1	5.787×10^{-4}
1 pound per in^3 =	53.71	2.768×10^{4}	27.68	1728	1

NOTE FOR TABLE G: Portion of table enclosed in heavy lines must be used with caution because those units are not mass-density units but weight-density units which depend on g.

H. TIME

		yr	day	hr	min	**SECOND**
1 year	=	1	365.2	8.766×10^3	5.259×10^3	3.156×10^7
1 day	=	2.738×10^{-3}	1	24	1440	8.640×10^4
1 hour	=	1.141×10^{-4}	4.167×10^{-2}	1	60	3600
1 minute	=	1.901×10^{-6}	6.944×10^{-4}	1.667×10^{-2}	1	60
1 **SECOND**	=	3.169×10^{-8}	1.157×10^{-5}	2.778×10^{-4}	1.667×10^{-2}	1

1 year = 365.24219879 days

I. SPEED

		ft/sec	km/hr	**METER/SEC**	miles/hr	cm/sec	knot
1 foot per second	=	1	1.097	0.3408	0.6818	30.48	0.5925
1 kilometer per hour	=	0.9113	1	0.2778	0.6214	27.78	0.5400
1 **METER** per **SECOND**	=	3.281	3.600	1	2.237	100	1.944
1 mile per hour	=	1.467	1.609	0.4770	1	44.70	0.8689
1 centimeter per sec	=	3.281×10^{-2}	3.600×10^{-2}	0.0100	2.237×10^{-2}	1	1.944×10^{-2}
1 knot	=	1.688	1.852	0.5144	1.151	51.44	1

1 knot = 1 nautical mile/hr

1 mile/min = 88 ft/sec
= 60 miles/hr

J. FORCE

		dyne	**NT**	lb	pdl	gf	kgf
1 dyne	=	1	10^{-5}	2.248×10^{-6}	7.233×10^{-5}	1.020×10^{-3}	1.020×10^{-6}
1 **NEWTON**	=	10^5	1	0.2248	7.233	102.0	0.1020
1 pound	=	4.480×10^5	4.448	1	32.17	453.6	0.4536
1 poundal	=	1.383×10^4	0.1383	3.108×10^{-2}	1	14.10	1.410×10^{-2}
1 gram-force	=	980.7	9.807×10^{-3}	2.205×10^{-3}	7.093×10^{-2}	1	0.001
1 kilogram-force	=	9.807×10^5	9.807	2.205	70.93	1000	1

NOTE FOR TABLE J: Portion of table enclosed in heavy lines must be used with caution because those units are not force units but weight equivalents of mass which depend on g.

1 kgf = 9.80665 newton   1 lb = 32.17398 poundal

K. PRESSURE

	atm	$dyne/cm^2$	inch of water	cm Hg	**NT/METER**^{2}	lb/in^2	lb/ft^2
1 atmosphere =	1	1.013×10^{6}	406.8	76	1.013×10^{5}	14.70	2116
1 dyne per cm^2 =	9.869×10^{-7}	1	4.015×10^{-4}	7.501×10^{-5}	0.100	1.450×10^{-5}	2.089×10^{-3}
1 inch of water at 4°C[a] =	2.458×10^{-3}	2.491	1	0.1868	249.1	3.613×10^{-2}	5.202
1 centimeter of mercury at 0°C[a] =	1.316×10^{-2}	1.333×10^{4}	5.353	1	1333	0.1934	27.85
1 **NEWTON** per **METER**^{2} =	9.869×10^{-6}	10	4.015×10^{-3}	7.501×10^{-4}	1	1.450×10^{-4}	2.089×10^{-2}
1 pound per in^2 =	6.805×10^{-2}	6.895×10^{4}	27.68	5.171	6.895×10^{3}	1	144
1 pound per ft^2 =	4.725×10^{-4}	478.8	0.1922	3.591×10^{-2}	47.88	6.944×10^{-3}	1

[a] Where the acceleration of gravity has the standard value 9.80665 $meter/sec^2$

1 bar = 10^6 $dyne/cm^2$ 1 millibar = 10^3 $dyne/cm^2$

1 torr (mm Hg at 0°C) = 1.93367×10^{-2} lb/ft^2

L. ENERGY, WORK, HEAT

	Btu	erg	ft-lb	hp-hr	**JOULES**	cal	kw-hr	ev	Mev	kgm	amu
1 British thermal unit =	1	1.055×10^{10}	777.9	3.929×10^{-4}	1055	252.0	2.930×10^{-4}	6.585×10^{21}	6.585×10^{15}	1.174×10^{-14}	7.074×10^{12}
1 erg =	9.481×10^{-11}	1	7.376×10^{-8}	3.725×10^{-14}	10^{-7}	2.389×10^{-8}	2.778×10^{-14}	6.242×10^{11}	6.242×10^{5}	1.113×10^{-24}	670.5
1 foot-pound =	1.285×10^{-3}	1.356×10^{7}	1	5.051×10^{-7}	1.356	0.3239	3.766×10^{-7}	8.464×10^{18}	8.464×10^{12}	1.509×10^{-17}	9.092×10^{9}
1 horsepower-hour =	2545	2.685×10^{-13}	1.980×10^{6}	1	2.685×10^{6}	6.414×10^{5}	0.7457	1.676×10^{25}	1.676×10^{19}	2.988×10^{-11}	1.800×10^{16}
1 **JOULE** =	9.481×10^{-4}	10^{7}	0.7376	3.725×10^{-7}	1	0.2389	2.778×10^{-7}	6.242×10^{18}	6.242×10^{12}	1.113×10^{-17}	6.705×10^{9}
1 calorie =	3.968×10^{-3}	4.186×10^{7}	3.087	1.559×10^{-6}	4.186	1	1.163×10^{-6}	2.613×10^{19}	2.613×10^{13}	4.659×10^{-17}	2.807×10^{10}
1 kilowatt-hour =	3413	3.6×10^{13}	2.655×10^{6}	1.341	3.6×10^{6}	8.601×10^{5}	1	2.247×10^{25}	2.247×10^{19}	4.007×10^{-11}	2.414×10^{16}
1 electron volt =	1.519×10^{-22}	1.602×10^{-12}	1.182×10^{-19}	5.967×10^{-26}	1.602×10^{-19}	3.827×10^{-20}	4.450×10^{-26}	1	10^{-6}	1.783×10^{-36}	1.074×10^{-9}
1 million electron volts =	1.519×10^{-16}	1.602×10^{-6}	1.182×10^{-13}	5.967×10^{-20}	1.602×10^{-13}	3.827×10^{-14}	4.450×10^{-20}	10^{6}	1	1.783×10^{-30}	1.074×10^{-3}
1 kilogram =	8.521×10^{-13}	8.987×10^{23}	6.629×10^{16}	3.348×10^{10}	8.987×10^{16}	2.147×10^{16}	2.497×10^{10}	5.610×10^{35}	5.610×10^{29}	1	6.025×10^{26}
1 atomic mass unit =	1.415×10^{-13}	1.492×10^{-3}	1.100×10^{-10}	5.558×10^{-17}	1.492×10^{-10}	3.564×10^{-11}	4.145×10^{-17}	9.310×10^{8}	931.0	1.660×10^{-27}	1

(See notes, next page)

1 meter – kgf = 9.807 joule, 1 watt-sec = 1 joule = 1 nt-meter, 1 cm-dyne = 1 erg

Some conversions used in spectroscopy:

$1\ eV = 8065.7\ cm^{-1}$ $1\ cm^{-1} = 0.000124\ eV$

$1\ eV \approx 6000°K$ At 300°K, $\frac{3}{2}\ kT \approx 0.05\ eV$

NOTES FOR TABLE L: The electron volt is the kinetic energy an electron gains from being accelerated through the potential difference of one volt in an electric field. The units enclosed by heavy lines are not properly energy units; they arise from the relativistic mass-energy equivalent formula $E = mc^2$.

M. SPECIFIC ENERGY

	$\frac{cal}{gm}$	$\frac{erg}{gm}$	$\frac{\textbf{JOULE}}{\textbf{KGM}}$	$\frac{Btu}{lb_m}$	$\frac{ft - lb_f}{lb_m}$	$\frac{hp - hr}{lb_m}$
1 calorie per gram =	1	4.186×10^{7}	4.186×10^{3}	1.800	1.400×10^{3}	7.072×10^{-4}
1 erg per gram =	2.389×10^{-8}	1	10^{-4}	4.299×10^{-8}	3.346×10^{-5}	1.690×10^{-11}
1 **JOULE** per **KILOGRAM** =	2.389×10^{-4}	10^{4}	1	4.299×10^{-4}	0.3346	1.690×10^{-7}
1 Btu per pound (mass) =	0.5557	2.326×10^{7}	2.326×10^{3}	1	777.9	3.929×10^{-4}
1 foot-pound per pound (mass) =	7.142×10^{-4}	2.990×10^{4}	2.990	1.285×10^{-3}	1	5.051×10^{-7}
1 horsepower-hour per pound (mass) =	1.414×10^{3}	5.920×10^{10}	5.920×10^{6}	2.545	1.980×10^{6}	1

(SEE NOTE FOR TABLE N)

N. SPECIFIC ENERGY PER UNIT TEMPERATURE

	$\frac{\text{cal}}{\text{gm°C}}$	$\frac{\text{erg}}{\text{gm°C}}$	$\frac{\textbf{JOULE}}{\textbf{KGM °K}}$	$\frac{\text{Btu}}{\text{lb}_m\text{°F}}$	$\frac{\text{ft - lb}_f}{\text{lb}_m\text{°F}}$	$\frac{\text{hp - hr}}{\text{lb}_m\text{°F}}$
1 calorie per gram per degree C =	1	4.186×10^{7}	4.186×10^{3}	1.000	777.9	3.929×10^{-4}
1 erg per gram per degree C =	2.389×10^{-8}	1	10^{-4}	2.388×10^{-8}	1.859×10^{-5}	9.376×10^{-12}
1 **JOULE** per **KGM** per **DEGREE K** =	2.389×10^{-4}	10^{4}	1	2.388×10^{-4}	0.1859	9.376×10^{-8}
1 Btu per lb (mass) per degree F =	1.000	4.187×10^{7}	4.187×10^{3}	1	777.9	3.929×10^{-4}
1 foot-lb per lb (mass) per degree F =	1.286×10^{-3}	5.382×10^{4}	5.382	1.285×10^{-3}	1	5.051×10^{-7}
1 horsepower-hour per lb (mass) per degree F=	2.546×10^{3}	1.066×10^{11}	1.066×10^{7}	2.545	1.980×10^{6}	1

NOTE FOR TABLES M & N: The engineering units enclosed within the heavy lines have been properly related to the pound mass rather than the pound force because these specific thermal quantities depend on unit mass and have nothing to do with weight. However, in engineering practice it is customary to relate energy and energy per degree to weight. Thus we speak of Btu/lb, ft-lb/lb and hp-hr/lb of weight. The conversion factors given in Tables M & N are equally valid for this purpose if the local acceleration of gravity if the earth standard value of $g = 32.174$ ft/sec^2 = 9.80665 meter/sec^2. This is true because the pound-force and the pound-mass are numerically equal at standard gravity. It should be realized that relating specific quantities to weight, rather than mass, involves a change of concept because weight and mass are not dimensional equivalents. The relation between units of mass and weight is not a relation between the concepts of mass and weight. The units are related by

$$lb_f = 32.174 \; lb_m \; ft/sec^2$$

O. POWER

	Btu/hr	Btu/sec	ft-lb/min	ft-lb/sec	hp	cal/sec	kw	**WATT**
1 British thermal unit per hour =	1	2.778×10^{-4}	12.97	0.2161	3.929×10^{-4}	7.000×10^{-2}	2.930×10^{-4}	0.2930
1 British thermal unit per second =	3600	1	4.669×10^{4}	777.9	1.414	252.0	1.055	1.055×10^{3}
1 foot-pound per minute =	7.713×10^{-2}	2.142×10^{-5}	1	1.667×10^{-2}	3.030×10^{-5}	5.399×10^{-3}	2.260×10^{-5}	2.260×10^{-2}
1 foot-pound per second =	4.628	1.286×10^{-3}	60	1	1.818×10^{-3}	0.3239	1.356×10^{-3}	1.356
1 horsepower =	2545	0.7069	3.3×10^{4}	550	1	178.2	0.7457	745.7
1 calorie per second =	14.29	0.3950	1.852×10^{2}	3.087	5.613×10^{-3}	1	4.186×10^{-3}	4.186
1 kilowatt =	3413	0.9481	4.425×10^{4}	737.6	1.341	238.9	1	1000
1 **WATT** =	3.413	9.481×10^{-4}	44.25	0.7376	1.341×10^{-3}	0.2389	0.001	1

P. HEAT FLUX*

	cal / sec - cm^2	kilocal / hr – m^2	**WATT** / **M^2**	watt / in^2	Btu / hr- ft^2	Btu / sec- in^2	hp / ft^2
1 calorie per sec per centimeter^2 =	1	3.600×10^4	4.185×10^4	27.00	1.327×10^4	2.560×10^{-2}	5.212
1 kilocalorie per hour per meter^2 =	2.778×10^{-5}	1	1.163	7.500×10^{-4}	0.3687	7.112×10^{-7}	1.448×10^{-4}
1 **WATT** per **METER**^{2} =	2.390×10^{-5}	0.8602	1	6.452×10^{-4}	0.3171	6.117×10^{-7}	1.246×10^{-4}
1 watt per inch^2 =	3.704×10^{-2}	1.333	1550	1	491.5	9.481×10^{-4}	0.1931
1 British thermal unit per hour per foot^2 =	7.535×10^{-5}	2.713	3.153	2.035×10^{-3}	1	1.929×10^{-6}	3.928×10^{-4}
1 British thermal unit per sec per inch^2 =	39.06	1.406×10^6	1.635×10^6	1.055×10^3	5.184×10^5	1	203.6
1 horsepower per foot^2 =	0.1918	6.905×10^2	8027	5.179	2.546×10^3	4.911×10^{-3}	1

*Also power per unit area

Q. HEAT TRANSFER COEFFICIENT, h

	cal / sec–cm^2 °C	**WATT** / **M^2** °K	watt / in^2 °C	Btu / hr - ft^2 °F	Btu / sec - in^2 °F	hp / ft^2 °F
1 calorie per sec per centimeter^2 - ºC =	1	4.185×10^4	27.00	7.372×10^3	1.422×10^{-2}	2.895
1 **WATT** per **METER**^{2} per **DEG KELVIN** =	2.390×10^{-5}	1	6.452×10^{-4}	0.1762	3.398×10^{-7}	6.922×10^{-5}
1 watt per inch^2 per deg Centigrade =	3.704×10^{-2}	1550	1	273.1	5.267×10^{-4}	0.1073
1 Btu per hour per per foot^2 - ºF =	1.356×10^{-4}	5.675	3.663×10^{-3}	1	1.929×10^{-6}	3.928×10^{-4}
1 Btu per sec per inch^2 - ºF =	70.31	2.943×10^6	1.899×10^3	5.184×10^5	1	203.6
1 horsepower per foot^2 - ºF =	0.3452	1.445×10^4	9.322	2.546×10^3	4.911×10^{-3}	1

R. R. THERMAL CONDUCTIVITY, k

	$\frac{\text{cal}}{\text{sec–cm}°C}$	$\frac{\textbf{WATTS}}{\textbf{METER}°\text{K}}$	$\frac{\text{watts}}{\text{in}°\text{C}}$	$\frac{\text{Btu}}{\text{hr - ft}°\text{F}}$	$\frac{\text{Btu}}{\text{sec - in}°\text{F}}$	$\frac{\text{hp}}{\text{ft}°\text{F}}$
1 calorie per sec per centimeter-deg C =	1	418.5	10.63	241.9	5.600×10^{-3}	9.503×10^{-2}
1 **WATT** per **METER** per **DEG KELVIN** =	2.390×10^{-3}	1	2.540×10^{-2}	0.5781	1.338×10^{-5}	2.271×10^{-4}
1 watt per inch per deg Centigrade =	9.407×10^{-2}	39.37	1	22.76	5.269×10^{-4}	8.939×10^{-3}
1 Btu per hour per foot-deg F =	4.134×10^{-3}	1.730	4.394×10^{-2}	1	2.315×10^{-3}	3.929×10^{-4}
1 Btu per sec per inch-deg F =	1.786×10^{2}	7.474×10^{4}	1.898×10^{3}	4.320×10^{4}	1	16.97
1 horsepower per foot-deg F =	10.52	4403	111.8	2546	5.894×10^{-2}	1

S. ABSOLUTE OR DYNAMIC VISCOSITY, μ

	centipoise	poise	$\frac{kgm_f\text{–sec}}{\text{meter}^2}$	$\frac{\text{lb – sec}}{\text{ft}^2}$	$\frac{\textbf{KGM}}{\textbf{M–SEC}}$	$\frac{\text{lb}_m}{\text{ft – sec}}$
1 centipoise =	1	10^{-2}	1.020×10^{-4}	2.089×10^{-5}	10^{-3}	6.720×10^{-4}
1 poise =	100	1	1.020×10^{-2}	2.089×10^{-3}	0.100	6.720×10^{-2}
1 kg (force) – sec per meter^2 =	9.807×10^3	98.07	1	0.2048	9.807	6.590
1 lb (force) – sec per foot^2 =	4.788×10^4	4.788×10^2	4.882	1	47.88	32.174
1 **KILOGRAM** per **METER-SEC** =	10^3	10	0.1020	2.089×10^{-2}	1	0.6720
1 lb (mass) per foot – sec =	1.488×10^3	14.88	0.1518	3.108×10^{-2}	1.488	1

NOTE FOR TABLE S: The absolute viscosity μ is properly expressed in force units according to its definition. In heat transfer and fluid mechanics it is usually expressed in mass-equivalent units to avoid the use of a conversion factor in Reynolds Number. Mass units have been used in the portion of the table enclosed in heavy lines. The proper force units for μ in the mksq system are **NEWTON-SEC** per **METER**^{2}; they are seldom used. The poise is the cgs force unit and is defined by

$$1 \text{ poise} = 1 \ \frac{\text{dyne - second}}{\text{centimeter}^2}$$

T. KINEMATIC VISCOSITY, $\nu = \mu/\rho$

	centistoke	stoke	**METER^2/SEC**	ft^2/sec
1 centistoke =	1	10^{-2}	10^{-6}	1.076×10^{-5}
1 stoke =	100	1	10^{-4}	1.076×10^{-3}
1 **METER^2/SEC** =	10^6	10^4	1	10.76
1 ft^2/sec =	9.290×10^4	929.0	9.290×10^{-2}	1

1 stoke = 1 centimeter^2/sec

AA. ELECTRIC CHARGE

	abcoul	amp-hr	**COUL**	faraday	statcoul
1 abcoulomb (1 emu) =	1	2.778×10^{-3}	10	1.036×10^{-4}	2.998×10^{10}
1 ampere-hour =	360	1	3600	3.730×10^{-2}	1.079×10^{13}
1 **COULOMB** =	0.100	2.778×10^{-4}	1	1.036×10^{-5}	2.998×10^{9}
1 faraday =	9.652×10^{3}	26.81	9.652×10^{4}	1	2.893×10^{14}
1 statcoulomb (1 esu) =	3.336×10^{-11}	9.266×10^{-14}	3.336×10^{-10}	3.456×10^{-15}	1

1 electronic charge $= 1.602 \times 10^{-19}$ coulombs

$= (1.602 \times 10^{-19})(2.998 \times 10^{9})$ statcoulomb

$= 4.8 \times 10^{-10}$ esu

BB. ELECTRIC CURRENT

	abamp	**AMP**	statamp
1 abampere (1 emu) =	1	10	2.998×10^{10}
1 **AMPERE** =	0.100	1	2.998×10^{9}
1 statampere (1 esu) =	3.336×10^{-11}	3.336×10^{-10}	1

CC. ELECTRIC POTENTIAL, ELECTROMOTIVE FORCE

	abv	**VOLT**	statv
1 abvolt (1 emu) =	1	10^{-8}	3.336×10^{-11}
1 **VOLT** =	10^{8}	1	3.336×10^{-3}
1 statvolt (1 esu) =	2.998×10^{10}	299.8	1

DD. ELECTRIC RESISTANCE

		abohm	**OHM**	statohm
1 abohm (1 emu)	=	1	10^{-9}	1.113×10^{-21}
1 **OHM**	=	10^{9}	1	1.113×10^{-12}
1 statohm (1 esu)	=	8.987×10^{20}	8.987×10^{11}	1

EE. ELECTRIC RESISTIVITY, RECIPROCAL CONDUCTIVITY

		abohm-cm	ohm-cm	**OHM-M**	statohm-cm	ohm-circ mil/ft
1 abohm-centimeter (1 emu)	=	1	10^{-9}	10^{-11}	1.113×10^{-21}	6.015×10^{-3}
1 ohm-centimeter	=	10^{9}	1	0.0100	1.113×10^{-12}	6.015×10^{6}
1 **OHM-METER**	=	10^{11}	100	1	1.113×10^{-10}	6.015×10^{8}
1 statohm-centimeter (1 esu)	=	8.987×10^{20}	8.987×10^{11}	8.987×10^{9}	1	5.406×10^{18}
1 ohm-circular mil per foot	=	166.2	1.662×10^{-7}	1.662×10^{-9}	1.850×10^{-19}	1

FF. CAPACITANCE

		abf	**FARAD**	μf	statf
1 abfarad (1 emu)	=	1	10^{9}	10^{15}	8.987×10^{20}
1 **FARAD**	=	10^{-9}	1	10^{6}	8.987×10^{11}
1 microfarad	=	10^{-15}	10^{-6}	1	8.987×10^{5}
1 statfarad (1 esu)	=	1.113×10^{-21}	1.113×10^{-12}	1.113×10^{-6}	1

GG. INDUCTANCE

	abhenry	**HENRY**	μh	stathenry
1 abhenry (1 emu) =	1	10^{-9}	0.001	1.113×10^{-21}
1 **HENRY** =	10^{9}	1	10^{6}	1.113×10^{-12}
1 microhenry =	10^{3}	10^{-6}	1	1.113×10^{-18}
1 stathenry (1 esu) =	8.987×10^{20}	8.987×10^{11}	8.987×10^{17}	1

HH. MAGNETIC FLUX

	maxwell	kiloline	**WEBER**
1 maxwell (1 line or 1 emu) =	1	0.001	10^{-8}
1 kiloline =	1000	1	10^{-5}
1 **WEBER** =	10^{8}	10^{5}	1

1 esu = 2.998 webers

II. MAGNETOMOTIVE FORCE

	abamp-turn	**AMP-TURN**	gilbert
1 abamp-turn =	1	10	12.57
1 **AMP-TURN** =	0.100	1	1.257
1 gilbert =	7.958×10^{-2}	0.7958	1

1 pragilbert = 4π amp-turn
1 esu = 2.655×10^{-11} amp-turn

JJ. MAGNETIC FIELD STRENGTH, **B**

	gauss	$\frac{\text{kiloline}}{\text{in}^2}$	$\frac{\textbf{WEBER}}{\textbf{METER}^2}$	milligauss	gamma
1 gauss (line per cm^2) =	1	6.452×10^{-2}	10^{-4}	1000	10^5
1 kiloline per in^2 =	155.0	1	1.550×10^{-2}	1.550×10^5	1.550×10^7
1 **WEBER PER METER^2** =	10^4	64.52	1	10^7	10^9
1 milligauss =	10^{-3}	6.452×10^{-6}	10^{-7}	1	100
1 gamma =	10^{-5}	6.452×10^{-8}	10^{-9}	10^{-2}	1

1 esu = 2.998×10^6 weber/meter^2

10^4 gauss = 1 tesla

KK. MAGNETIC VECTOR, **H**

	$\frac{\text{abamp} - \text{turn}}{\text{cm}}$	$\frac{\text{amp} - \text{turn}}{\text{cm}}$	$\frac{\textbf{AMP} - \textbf{TURN}}{\textbf{METER}}$	$\frac{\text{amp} - \text{turn}}{\text{in}}$	oersted
1 abampere-turn per centimeter =	1	10	1000	25.40	12.57
1 ampere-turn per centimeter =	0.100	1	100	2.54	1.257
1 **AMPERE-TURN PER METER** =	10^{-3}	10^{-2}	1	2.540×10^{-2}	1.257×10^{-2}
1 ampere-turn per inch =	3.937×10^{-2}	0.3937	39.37	1	0.4947
1 oersted =	7.958×10^{-2}	0.7958	79.58	2.021	1

1 oersted = 1 gilbert/cm

1 esu = 2.655×10^{-9} amp-turn/meter

1 praoersted = 4π amp-turn/meter

VIII. ELECTROMAGNETIC CONSTANTS OF FREE SPACE

Maxwell was able to show analytically that the constant appearing in a wave equation derived for free space (perfect vacuum), for the case $\rho_e = \sigma_c = 0$, was the square of the velocity of propagation of electromagnetic waves in free space. The experiments of Hertz verified that this velocity was the velocity of light in free space and that

$$c^2 = \frac{1}{\mu_0 \varepsilon_0}$$

where μ_0 is the permeability of free space and ε_0 is the permittivity of free space. This equation is true for any system of units; in the mksq system

c	=	2.997925×10^{8} meter/sec
μ_0	=	1.256637×10^{-6} henry/meter
ε_0	=	8.85416×10^{-12} farad/meter

IX. ELECTROMAGNETIC CONSTANTS OF MATERIALS

The permeability and permittivity of materials are usually given relative to the values of free space.

Relative permeability	Magnetic Susceptibility
$\kappa_m = \dfrac{\mu}{\mu_0}$	$\kappa_m = 1 + \chi_m$
Relative permittivity	Electric Susceptibility
$\kappa_e = \dfrac{\varepsilon}{\varepsilon_0}$	$\kappa_e = 1 + \chi_e$
(Dielectric constant)	

When looking up values of electromagnetic constants of materials care must be taken to be sure what values are specified, i.e. μ, κ_m or χ_m and ε, κ_e or χ_e. The usual values given are κ_e and χ_m.

κ_m is a number near unity and may be greater or less than unity; χ_m may be positive or negative but is small compared to unity. κ_e is always greater than unity and may be significantly larger than unity; χ_e is always positive and may be large compared to unity:

$\kappa_m \lessgtr 1$, $\kappa_m \sim 1$	$\kappa_c \geq 1$
$\chi_m \lessgtr 0$, $\chi_m << 1$	$\chi_e \geq 0$
κ_m is temperature dependent	possible $\chi_e >> 1$

X. SOME IMPORTANT DIMENSIONAL CONSTANTS (*mksq* units)

Name	Symbol	Computational Value	Best Experimental Value
Speed of light	c	3.00×10^{8} meter/sec	$(2.997930 \pm 0.000003) \times 10^{8}$
Universal Gravitational Const.	G	6.67×10^{-11} nt-m^2/kgm^2	$(6.673 \pm 0.003) \times 10^{-11}$
Avogadro's Number	N_0	6.02×10^{23} /mole	$(6.02486 \pm 0.00016) \times 10^{23}$
Universal Gas Constant	R	8.32 joule/mole °K	8.31696 ± 0.00034
Standard Volume of Ideal Gas		2.24×10^{-2} meter^3	$(2.24207 \pm 0.00006) \times 10^{-2}$
Planck's Constant	h	6.63×10^{-34} joule/sec	$(6.62517 \pm 0.00023) \times 10^{-34}$
Boltzmann's Constant	k	1.38×10^{-23} joule/°K	$(1.38044 \pm 0.00007) \times 10^{-23}$
Mechanical Equiv. of Heat	J	4.19 joule/cal	4.1855 ± 0.0004
Triple Point of Water		273.16 °K	273.16 °K exactly
Ice Point of Water	Σ_0	273.16 °K	273.16 °K ± 0.0002
Maximum Density of Water (at 3.98°C, 1 atm)		1 gm/cm^3	0.999973
Permeability of Free Space	μ_0	1.26×10^{-6} henry/meter	$4\pi \times 10^{-7}$ exactly
Permittivity of Free Space	ε_0	8.85×10^{-12} farad/meter	$(8.85415 \pm 0.00002) \times 10^{-12}$
Electronic Charge	e	1.60×10^{-19} coulomb	$(1.60206 \pm 0.00003) \times 10^{-19}$
Electronic Rest Mass	m_e	9.11×10^{-31} kgm	$(9.1083 \pm 0.0003) \times 10^{-31}$
Proton Rest Mass	m_p	1.67×10^{-27} kgm	$(1.67239 \pm 0.00004) \times 10^{-27}$
Neutron Rest Mass	m_n	1.67×10^{-27} kgm	$(1.67470 \pm 0.00004) \times 10^{-27}$
Mass-Energy Relation	$c^2 = E/m$	8.99×10^{16} meter^2/sec^2	$(8.98758 \pm 0.00003) \times 10^{16}$
Magnetic Moment of Electron		9.28×10^{-32} joule-m^2/weber	$(9.2837 \pm 0.0002) \times 10^{-32}$
Compton Wavelength of Electron	λ_c	2.43×10^{-12} meter	$(2.42626 \pm 0.00002) \times 10^{-12}$
First Bohr Orbit Radius in Hydrogen Atom	a_0	5.29×10^{-11} meter	$(5.29172 \pm 0.00002) \times 10^{-11}$
Stefan-Boltzmann Const.	σ	5.67×10^{-8} joule/sec(°K)^4 meter^2	$(5.6687 \pm 0.0019) \times 10^{-8}$

XI. SOME IMPORTANT DIMENSIONLESS GROUPS

Name	Group	Field of Use
Biot	$(\mathrm{Bi}) = hL/k$	Conduction heat transfer
Euler	$(\mathrm{Eu}) = p/\rho V^2$	Fluid mechanics
Fourier	$(\mathrm{Fo}) = \alpha\tau/L^2$	Conduction heat transfer
Froude	$(\mathrm{Fr}) = V\sqrt{Lg}$	Fluid mechanics
Graetz	$(\mathrm{Grz}) = \dot{w}\, c_p/kL$	Heat transfer, free convection
Grashof	$(\mathrm{Grf}) = L^3\, \rho^2 g\beta\Delta t/\mu^2$	Heat transfer, free convection
Hartmann	$(\mathrm{Ha}) = (\sigma_c B_0^2 L^2 / \mu)^{1/2}$	MHD
Knudsen	$(\mathrm{Kn}) = \lambda/L$	Fluid mech., rarified gas flow
Lewis	$(\mathrm{Le}) = (\mathrm{Sc})/(\mathrm{Pr}) = \alpha/D$	Conv. heat & mass transfer
Mach	$(\mathrm{M}) = V/a$	High speed flow
Nusselt	$(\mathrm{Nu}) = hL/k$	Convection heat transfer
Péclet	$(\mathrm{Pe}) = (\mathrm{Re})(\mathrm{Pr})$	Convection heat transfer
Prandtl	$(\mathrm{Pr}) = \mu c_p/k$	Convection heat transfer
Reynolds	$(\mathrm{Re}) = VL\rho/\mu$	Fluid mech., heat transfer
Magnetic Reynolds	$(\mathrm{Re})_\mathrm{m} = \mu\sigma_c\, VL$	MHD
Schmidt	$(\mathrm{Sc}) = \mu/\rho D$	Conv. heat & mass transfer
Stanton	$(\mathrm{St}) = h/c_p\, V\rho$	Convection heat transfer
Weber	$(\mathrm{We}) = \rho V^2 L/\sigma$	Fluid mechanics, free surface
———	$(\mathrm{N}) = (\mathrm{Ha})^2/(\mathrm{Re})$	MHD
———	$(\mathrm{S}) = (\mathrm{Ha})^2/(\mathrm{Re})(\mathrm{Re})_\mathrm{m}$	MHD

Symbols:

- B_0 – Applied mag. field
- D – Diffusion coefficient
- L – Characteristic length
- V – Fluid velocity
- a – Acoustic velocity
- g – Gravity
- h – Heat transfer coefficient
- k – Thermal conductivity
- p – Static pressure
- ρ – Density
- λ - Mean free path (molecular)
- Δt – Temperature difference
- $\dot{w}$ - Mass rate of flow
- c_p – Specific heat (const. pressure)
- α - Thermal diffusivity
- β - Thermal expansion coefficient
- σ - Surface tension
- σ_c – Electric conductivity
- μ - Viscosity or magnetic permeability
- τ - Time interval

XII. THE PERFECT GAS LAW

A. NOMENCLATURE, DEFINITIONS, AND EQUATIONS

In the following discussion the elementary particle under consideration is the molecule. Care must be taken to use consistent units, especially to make the proper distinction between mass and weight units. The units of the gas constant must be consistent with those used for density or specific volume.

NOMENCLATURE:

Symbol	Definition in cgs Units
ρ	Density in grams per cm^3
k	Boltzmann's Constant in ergs/molecule K°
m	Mass of molecule in grams
n	Particle Number Density in molecules/cm^3
p	Pressure in dynes/ cm^2
υ	Specific Volume in cm^3 per gram
υ_N	Specific Molar Volume in cm^3 /gm-mole
M	Molecular Weight in gm/gm-mole
N	Number of moles
N_0	Avogadro's Number, no. of molecules per gm-mole
R	Gas Constant in ergs/gm K°
R_0	Universal Gas Constant in ergs/gm-mole K°
T	Absolute Temperature, degrees Kelvin
V	Total Volume in cubic centimeters
W	"Weight" of Gas in grams

Avogadro's Law: All ideal gases at the same temperature and pressure have the same specific molar volume. At STP (0°C, 1 atm), υ_N = 22.4 liters/gm-mole = 22400 cm^3/gm-mole = 359 ft^3/lb-mole. At the same temperature and pressure all ideal gases contain the same number of molecules per unit volume.

Definition of the mole: The gm-mole is the amount of an ideal gas which will occupy the same volume as 32 gm of oxygen at STP; the pound-mole is similarly related to 32 lb of oxygen. The weight of a mole of gas is numerically equal to the molecular weight of the gas.

Forms of the Perfect Gas Law:

$p\upsilon = RT$ $\qquad$ $p = \rho RT = nkT$

$p\upsilon_N = R_0 T$ $\qquad$ $pV = WRT = N R_0 T$

Useful Relations:

$\rho = nm$ $\qquad$ $N_0 = n\upsilon_N$

$m = M/N_0$ $\qquad$ $\upsilon_N = V/N$

$R = R_0/M$ $\qquad$ $N = W/M$

$R_0 = N_0 k$

B. VALUES OF UNIVERSAL GAS CONSTANT, BOLTZMANN'S CONSTANT AND AVOGADRO'S NUMBER IN DIFFERENT UNITS

Units	R_0	Units	R_0
ft-lb/lb-mole R°	1544	cal/gm-mole K°	1.987
ft-lb/lb-mole K°	2779	cm^3 atm/gm-mole K°	82.06
ft-lb/lb-mole R°	3.407	liter atm/gm-mole K°	0.08206
Btu/lb-mole R°	1.987	ergs/gm-mole K°	8.313×10^7
ft^3 atm/lb-mole R°	0.729	**JOULES/KGM-MOLE K°**	8313
ft^3 atm/lb-mole K°	1.315	psia ft^3/lb-mole R°	10.71

Units	k	Units	N_0
ergs/molecule K°	1.38×10^{-16}	molecules/gm-mole	6.023×10^{23}
JOULES/MOLECULE K°	1.38×10^{-23}	**MOLECULES/KGM-MOLE**	6.023×10^{26}
ft-lb/molecule R°	5.655×10^{-24}	molecules/lb-mole	2.73×10^{26}
Btu/molecule R°	7.267×10^{-27}		

1 atm = 1.013×10^6 dynes/cm^2

1 erg = 1 dyne-cm

1 erg = 10^{-7} joule

1 ft-lb = 1.356 10^7 ergs