Marks'

Standard Handbook for Mechanical Engineers

Section 1

Mathematical Tables and Measuring Units

BY

GEORGE F. BAUMEISTER *President, EMC Process Co., Newport, DE*
JOHN T. BAUMEISTER *Manager, Product Compliance Test Center, Unisys Corp.*

1.1 MATHEMATICAL TABLES
by George F. Baumeister

Segments of Circles . . . 1-2
Regular Polygons . . . 1-4
Binomial Coefficients . . . 1-4
Compound Interest and Annuities . . . 1-5
Statistical Distributions . . . 1-9
Decimal Equivalents . . . 1-15

1.2 MEASURING UNITS
by John T. Baumeister

U.S. Customary System (USCS) . . . 1-16
Metric System . . . 1-17
The International System of Units (SI) . . . 1-17
Systems of Units . . . 1-24
Temperature . . . 1-25
Terrestrial Gravity . . . 1-25
Mohs Scale of Hardness . . . 1-25
Time . . . 1-25
Density and Relative Density . . . 1-26
Conversion and Equivalency Tables . . . 1-27

1.1 MATHEMATICAL TABLES

by George F. Baumeister

References for mathematical tables: Dwight, “Mathematical Tables of Elementary and Some Higher Mathematical Functions,” McGraw-Hill. Dwight, “Tables of Integrals and Other Mathematical Data,” Macmillan. Jahnke and Emde, “Tables of Functions,” B. G. Teubner, Leipzig, or Dover. Pierce-Foster, “A Short Table of Integrals,” Ginn. “Mathematical Tables from Handbook of Chemistry and Physics,” Chemical Rubber Co. “Handbook of Mathematical Functions,” NBS.

Table 1.1.1 Segments of Circles, Given *h/c*

Given: h = height; c = chord. To find the diameter of the circle, the length of arc, or the area of the segment, form the ratio h/c, and find from the table the value of (diam/c), (arc/c); then, by a simple multiplication,

$$\text{diam} = c \times (\text{diam}/c)$$
$$\text{arc} = c \times (\text{arc}/c)$$
$$\text{area} = h \times c \times (\text{area}/h \times c)$$

The table gives also the angle subtended at the center, and the ratio of h to D.

h/c	Diam/c	Diff	Arc/c	Diff	Area/$h \times c$	Diff	Central angle, v	Diff	h/Diam	Diff
.00			1.000	0	.6667	0	0.00°	458	.0000	4
1	25.010	12490	1.000	1	.6667	2	4.58	458	.0004	12
2	12.520	*4157	1.001	1	.6669	2	9.16	457	.0016	20
3	8.363	*2073	1.002	2	.6671	4	13.73	457	.0036	28
4	6.290	*1240	1.004	3	.6675	5	18.30	454	.0064	35
.05	5.050	*823	1.007	3	.6680	6	22.84°	453	.0099	43
6	4.227	*586	1.010	3	.6686	7	27.37	451	.0142	50
7	3.641	*436	1.013	4	.6693	8	31.88	448	.0192	58
8	3.205	*337	1.017	4	.6701	9	36.36	446	.0250	64
9	2.868	*268	1.021	5	.6710	10	40.82	442	.0314	71
.10	2.600	*217	1.026	6	.6720	11	45.24°	439	.0385	77
1	2.383	*180	1.032	6	.6731	12	49.63	435	.0462	83
2	2.203	*150	1.038	6	.6743	13	53.98	432	.0545	88
3	2.053	*127	1.044	7	.6756	14	58.30	427	.0633	94
4	1.926	*109	1.051	8	.6770	15	62.57	423	.0727	99
.15	1.817	*94	1.059	8	.6785	16	66.80°	418	.0826	103
6	1.723	*82	1.067	8	.6801	17	70.98	413	.0929	107
7	1.641	*72	1.075	9	.6818	18	75.11	409	.1036	111
8	1.569	*63	1.084	10	.6836	19	79.20	403	.1147	116
9	1.506	56	1.094	9	.6855	20	83.23	399	.1263	116
.20	1.450	50	1.103	11	.6875	21	87.21°	392	.1379	120
1	1.400	44	1.114	10	.6896	22	91.13	387	.1499	123
2	1.356	39	1.124	12	.6918	23	95.00	381	.1622	124
3	1.317	35	1.136	11	.6941	24	98.81	375	.1746	127
4	1.282	32	1.147	12	.6965	24	102.56	370	.1873	127
.25	1.250	28	1.159	12	.6989	25	106.26°	364	.2000	128
6	1.222	26	1.171	13	.7014	27	109.90	358	.2128	130
7	1.196	23	1.184	13	.7041	27	113.48	352	.2258	129
8	1.173	21	1.197	14	.7068	28	117.00	345	.2387	130
9	1.152	19	1.211	14	.7096	29	120.45	341	.2517	130
.30	1.133	17	1.225	14	.7125	29	123.86°	334	.2647	130
1	1.116	15	1.239	15	.7154	31	127.20	328	.2777	129
2	1.101	13	1.254	15	.7185	31	130.48	322	.2906	128
3	1.088	13	1.269	15	.7216	32	133.70	316	.3034	128
4	1.075	11	1.284	16	.7248	32	136.86	311	.3162	127
.35	1.064	10	1.300	16	.7280	34	139.97°	305	.3289	125
6	1.054	8	1.316	16	.7314	34	143.02	299	.3414	124
7	1.046	8	1.332	17	.7348	35	146.01	293	.3538	123
8	1.038	7	1.349	17	.7383	36	148.94	288	.3661	122
9	1.031	6	1.366	17	.7419	36	151.82	282	.3783	119
.40	1.025	5	1.383	18	.7455	37	154.64°	277	.3902	119
1	1.020	5	1.401	18	.7492	38	157.41	271	.4021	116
2	1.015	4	1.419	18	.7530	38	160.12	266	.4137	115
3	1.011	3	1.437	18	.7568	39	162.78	261	.4252	112
4	1.008	2	1.455	19	.7607	40	165.39	256	.4364	111
.45	1.006	3	1.474	19	.7647	40	167.95°	251	.4475	109
6	1.003	1	1.493	19	.7687	41	170.46	245	.4584	107
7	1.002	1	1.512	19	.7728	41	172.91	241	.4691	105
8	1.001	1	1.531	20	.7769	42	175.32	237	.4796	103
9	1.000	0	1.551	20	.7811	43	177.69	231	.4899	101
.50	1.000		1.571		.7854		180.00°		.5000	

* Interpolation may be inaccurate at these points.

Table 1.1.2 Segments of Circles, Given *h/D*

Given: h = height; D = diameter of circle. To find the chord, the length of arc, or the area of the segment, form the ratio h/D, and find from the table the value of (chord/D), (arc/D), or (area/D^2); then by a simple multiplication,

$$\text{chord} = D \times (\text{chord}/D)$$
$$\text{arc} = D \times (\text{arc}/D)$$
$$\text{area} = D^2 \times (\text{area}/D^2)$$

This table gives also the angle subtended at the center, the ratio of the arc of the segment of the whole circumference, and the ratio of the area of the segment to the area of the whole circle.

h/D	Arc/D	Diff	Area/D^2	Diff	Central angle, v	Diff	Chord/D	Diff	Arc/Circum	Diff	Area/Circle	Diff
.00	0.000	2003	.0000	13	0.00°	2296	.0000	*1990	.0000	*638	.0000	17
1	.2003	*835	.0013	24	22.96	*956	.1990	*810	.0638	*265	.0017	31
2	.2838	*644	.0037	32	32.52	*738	.2800	*612	.0903	*205	.0048	39
3	.3482	*545	.0069	36	39.90	*625	.3412	*507	.1108	*174	.0087	47
4	.4027	*483	.0105	42	46.15	*553	.3919	*440	.1282	*154	.0134	53
.05	.4510	*439	.0147	45	51.68°	*504	.4359	*391	.1436	*139	.0187	58
6	.4949	*406	.0192	50	56.72	*465	.4750	*353	.1575	*130	.0245	63
7	.5355	*380	.0242	52	61.37	*435	.5103	*323	.1705	121	.0308	67
8	.5735	*359	.0294	56	65.72	*411	.5426	*298	.1826	114	.0375	71
9	.6094	*341	.0350	59	69.83	*391	.5724	*276	.1940	108	.0446	74
.10	.6435	*326	.0409	61	73.74°	*374	.6000	*258	.2048	104	.0520	78
1	.6761	*314	.0470	64	77.48	*359	.6258	*241	.2152	100	.0598	82
2	.7075	*302	.0534	66	81.07	*347	.6499	*227	.2252	96	.0680	84
3	.7377	*293	.0600	68	84.54	*335	.6726	*214	.2348	93	.0764	87
4	.7670	*284	.0668	71	87.89	*326	.6940	*201	.2441	91	.0851	90
.15	.7954	276	.0739	72	91.15°	316	.7141	*191	.2532	88	.0941	92
6	.8230	270	.0811	74	94.31	309	.7332	*181	.2620	86	.1033	94
7	.8500	263	.0885	76	97.40	302	.7513	*171	.2706	83	.1127	97
8	.8763	258	.0961	78	100.42	295	.7684	162	.2789	82	.1224	99
9	.9021	252	.1039	79	103.37	289	.7846	154	.2871	81	.1323	101
.20	0.9273	248	.1118	81	106.26°	284	.8000	146	.2952	79	.1424	103
1	0.9521	243	.1199	82	109.10	279	.8146	139	.3031	77	.1527	104
2	0.9764	240	.1281	84	111.89	274	.8285	132	.3108	76	.1631	107
3	1.0004	235	.1365	84	114.63	271	.8417	125	.3184	75	.1738	108
4	1.0239	233	.1449	86	117.34	266	.8542	118	.3259	74	.1846	109
.25	1.0472	229	.1535	88	120.00°	263	.8660	113	.3333	73	.1955	111
6	1.0701	227	.1623	88	122.63	260	.8773	106	.3406	72	.2066	112
7	1.0928	224	.1711	89	125.23	256	.8879	101	.3478	72	.2178	114
8	1.1152	222	.1800	90	127.79	254	.8980	95	.3550	70	.2292	115
9	1.1374	219	.1890	92	130.33	251	.9075	90	.3620	70	.2407	116
.30	1.1593	217	.1982	92	132.84°	249	.9165	85	.3690	69	.2523	117
1	1.1810	215	.2074	93	135.33	247	.9250	80	.3759	69	.2640	119
2	1.2025	214	.2167	93	137.80	245	.9330	74	.3828	68	.2759	119
3	1.2239	212	.2260	95	140.25	242	.9404	70	.3896	67	.2878	120
4	1.2451	210	.2355	95	142.67	241	.9474	65	.3963	67	.2998	121
.35	1.2661	209	.2450	96	145.08°	240	.9539	61	.4030	67	.3119	122
6	1.2870	208	.2546	96	147.48	238	.9600	56	.4097	66	.3241	123
7	1.3078	206	.2642	97	149.86	237	.9656	52	.4163	66	.3364	123
8	1.3284	206	.2739	97	152.23	235	.9708	47	.4229	65	.3487	124
9	1.3490	204	.2836	98	154.58	235	.9755	43	.4294	65	.3611	124
.40	1.3694	204	.2934	98	156.93°	233	.9798	39	.4359	65	.3735	125
1	1.3898	203	.3032	98	159.26	233	.9837	34	.4424	65	.3860	126
2	1.4101	202	.3130	99	161.59	231	.9871	31	.4489	64	.3986	126
3	1.4303	202	.3229	99	163.90	232	.9902	26	.4553	64	.4112	126
4	1.4505	201	.3328	100	166.22	230	.9928	22	.4617	64	.4238	126
.45	1.4706	201	.3428	99	168.52°	230	.9950	18	.4681	64	.4364	127
6	1.4907	201	.3527	100	170.82	230	.9968	14	.4745	64	.4491	127
7	1.5108	200	.3627	100	173.12	229	.9982	10	.4809	64	.4618	127
8	1.5308	200	.3727	100	175.41	230	.9992	6	.4873	63	.4745	128
9	1.5508	200	.3827	100	177.71	229	.9998	2	.4936	64	.4873	127
.50	1.5708		.3927		180.00°		1.0000		.5000		.5000	

* Interpolation may be inaccurate at these points.

Table 1.1.3 Regular Polygons

n = number of sides

$v = 360°/n$ = angle subtended at the center by one side

a = length of one side $= R\left(2\sin\frac{v}{2}\right) = r\left(2\tan\frac{v}{2}\right)$

R = radius of circumscribed circle $= a\left(\frac{1}{2}\csc\frac{v}{2}\right) = r\left(\sec\frac{v}{2}\right)$

r = radius of inscribed circle $= R\left(\cos\frac{v}{2}\right) = a\left(\frac{1}{2}\cot\frac{v}{2}\right)$

$$\text{Area} = a^2\left(\tfrac{1}{4}n\cot\frac{v}{2}\right) = R^2\left(\tfrac{1}{2}n\sin v\right) = r^2\left(n\tan\frac{v}{2}\right)$$

n	v	$\frac{\text{Area}}{a^2}$	$\frac{\text{Area}}{R^2}$	$\frac{\text{Area}}{r^2}$	$\frac{R}{a}$	$\frac{R}{r}$	$\frac{a}{R}$	$\frac{a}{r}$	$\frac{r}{R}$	$\frac{r}{a}$
3	120°	0.4330	1.299	5.196	0.5774	2.000	1.732	3.464	0.5000	0.2887
4	90°	1.000	2.000	4.000	0.7071	1.414	1.414	2.000	0.7071	0.5000
5	72°	1.721	2.378	3.633	0.8507	1.236	1.176	1.453	0.8090	0.6882
6	60°	2.598	2.598	3.464	1.0000	1.155	1.000	1.155	0.8660	0.8660
7	51°.43	3.634	2.736	3.371	1.152	1.110	0.8678	0.9631	0.9010	1.038
8	45°	4.828	2.828	3.314	1.307	1.082	0.7654	0.8284	0.9239	1.207
9	40°	6.182	2.893	3.276	1.462	1.064	0.6840	0.7279	0.9397	1.374
10	36°	7.694	2.939	3.249	1.618	1.052	0.6180	0.6498	0.9511	1.539
12	30°	11.20	3.000	3.215	1.932	1.035	0.5176	0.5359	0.9659	1.866
15	24°	17.64	3.051	3.188	2.405	1.022	0.4158	0.4251	0.9781	2.352
16	22°.50	20.11	3.062	3.183	2.563	1.020	0.3902	0.3978	0.9808	2.514
20	18°	31.57	3.090	3.168	3.196	1.013	0.3129	0.3168	0.9877	3.157
24	15°	45.58	3.106	3.160	3.831	1.009	0.2611	0.2633	0.9914	3.798
32	11°.25	81.23	3.121	3.152	5.101	1.005	0.1960	0.1970	0.9952	5.077
48	7°.50	183.1	3.133	3.146	7.645	1.002	0.1308	0.1311	0.9979	7.629
64	5°.625	325.7	3.137	3.144	10.19	1.001	0.0981	0.0983	0.9968	10.18

Table 1.1.4 Binomial Coefficients

$(n)_0 = 1 \quad (n)_1 = n \quad (n)_2 = \frac{n(n-1)}{1\times 2} \quad (n)_3 = \frac{n(n-1)(n-2)}{1\times 2\times 3}$ etc. in general $(n)_r = \frac{n(n-1)(n-2)\cdots[n-(r-1)]}{1\times 2\times 3\times\cdots\times r}$. Other notations: $nC_r = \binom{n}{r} = (n)_r$

n	$(n)_0$	$(n)_1$	$(n)_2$	$(n)_3$	$(n)_4$	$(n)_5$	$(n)_6$	$(n)_7$	$(n)_8$	$(n)_9$	$(n)_{10}$	$(n)_{11}$	$(n)_{12}$	$(n)_{13}$
1	1	1	......	......	......	......	......	......	......	......	......	......	......	......
2	1	2	1	......	......	......	......	......	......	......	......	......	......	......
3	1	3	3	1	......	......	......	......	......	......	......	......	......	......
4	1	4	6	4	1	......	......	......	......	......	......	......	......	......
5	1	5	10	10	5	1	......	......	......	......	......	......	......	......
6	1	6	15	20	15	6	1	......	......	......	......	......	......	......
7	1	7	21	35	35	21	7	1	......	......	......	......	......	......
8	1	8	28	56	70	56	28	8	1	......	......	......	......	......
9	1	9	36	84	126	126	84	36	9	1	......	......	......	......
10	1	10	45	120	210	252	210	120	45	10	1	......	......	......
11	1	11	55	165	330	462	462	330	165	55	11	1	......	......
12	1	12	66	220	495	792	924	792	495	220	66	12	1	......
13	1	13	78	286	715	1287	1716	1716	1287	715	286	78	13	1
14	1	14	91	364	1001	2002	3003	3432	3003	2002	1001	364	91	14
15	1	15	105	455	1365	3003	5005	6435	6435	5005	3003	1365	455	105

NOTE: For $n = 14$, $(n)_{14} = 1$; for $n = 15$, $(n)_{14} = 15$, and $(n)_{15} = 1$.

Table 1.1.5 Compound Interest. Amount of a Given Principal

The amount A at the end of n years of a given principal P placed at compound interest today is $A = P \times x$ or $A = P \times y$, according as the interest (at the rate of r percent per annum) is compounded annually, or continuously; the factor x or y being taken from the following tables.

Values of x (interest compounded annually: $A = P \times x$)

Years	$r = 2$	3	4	5	6	7	8	10	12
1	1.0200	1.0300	1.0400	1.0500	1.0600	1.0700	1.0800	1.1000	1.1200
2	1.0404	1.0609	1.0816	1.1025	1.1236	1.1449	1.1664	1.2100	1.2544
3	1.0612	1.0927	1.1249	1.1576	1.1910	1.2250	1.2597	1.3310	1.4049
4	1.0824	1.1255	1.1699	1.2155	1.2625	1.3108	1.3605	1.4641	1.5735
5	1.1041	1.1593	1.2167	1.2763	1.3382	1.4026	1.4693	1.6105	1.7623
6	1.1262	1.1941	1.2653	1.3401	1.4185	1.5007	1.5869	1.7716	1.9738
7	1.1487	1.2299	1.3159	1.4071	1.5036	1.6058	1.7138	1.9487	2.2107
8	1.1717	1.2668	1.3686	1.4775	1.5938	1.7182	1.8509	2.1436	2.4760
9	1.1951	1.3048	1.4233	1.5513	1.6895	1.8385	1.9990	2.3579	2.7731
10	1.2190	1.3439	1.4802	1.6289	1.7908	1.9672	2.1589	2.5937	3.1058
11	1.2434	1.3842	1.5395	1.7103	1.8983	2.1049	2.3316	2.8531	3.4785
12	1.2682	1.4258	1.6010	1.7959	2.0122	2.2522	2.5182	3.1384	3.8960
13	1.2936	1.4685	1.6651	1.8856	2.1329	2.4098	2.7196	3.4523	4.3635
14	1.3195	1.5126	1.7317	1.9799	2.2609	2.5785	2.9372	3.7975	4.8871
15	1.3459	1.5580	1.8009	2.0789	2.3966	2.7590	3.1722	4.1772	5.4736
16	1.3728	1.6047	1.8730	2.1829	2.5404	2.9522	3.4259	4.5950	6.1304
17	1.4002	1.6528	1.9479	2.2920	2.6928	3.1588	3.7000	5.0545	6.8660
18	1.4282	1.7024	2.0258	2.4066	2.8543	3.3799	3.9960	5.5599	7.6900
19	1.4568	1.7535	2.1068	2.5270	3.0256	3.6165	4.3157	6.1159	8.6128
20	1.4859	1.8061	2.1911	2.6533	3.2071	3.8697	4.6610	6.7275	9.6463
25	1.6406	2.0938	2.6658	3.3864	4.2919	5.4274	6.8485	10.835	17.000
30	1.8114	2.4273	3.2434	4.3219	5.7435	7.6123	10.063	17.449	29.960
40	2.2080	3.2620	4.8010	7.0400	10.286	14.974	21.725	45.259	93.051
50	2.6916	4.3839	7.1067	11.467	18.420	29.457	46.902	117.39	289.00
60	3.2810	5.8916	10.520	18.679	32.988	57.946	101.26	304.48	897.60

NOTE: This table is computed from the formula $x = [1 + (r/100)]^n$.

Values of y (interest compounded continuously: $A = P \times y$)

Years	$r = 2$	3	4	5	6	7	8	10	12
1	1.0202	1.0305	1.0408	1.0513	1.0618	1.0725	1.0833	1.1052	1.1275
2	1.0408	1.0618	1.0833	1.1052	1.1275	1.1503	1.1735	1.2214	1.2712
3	1.0618	1.0942	1.1275	1.1618	1.1972	1.2337	1.2712	1.3499	1.4333
4	1.0833	1.1275	1.1735	1.2214	1.2712	1.3231	1.3771	1.4918	1.6161
5	1.1052	1.1618	1.2214	1.2840	1.3499	1.4191	1.4918	1.6487	1.8221
6	1.1275	1.1972	1.2712	1.3499	1.4333	1.5220	1.6161	1.8221	2.0544
7	1.1503	1.2337	1.3231	1.4191	1.5220	1.6323	1.7507	2.0138	2.3164
8	1.1735	1.2712	1.3771	1.4918	1.6161	1.7507	1.8965	2.2255	2.6117
9	1.1972	1.3100	1.4333	1.5683	1.7160	1.8776	2.0544	2.4596	2.9447
10	1.2214	1.3499	1.4918	1.6487	1.8221	2.0138	2.2255	2.7183	3.3201
11	1.2461	1.3910	1.5527	1.7333	1.9348	2.1598	2.4109	3.0042	3.7434
12	1.2712	1.4333	1.6161	1.8221	2.0544	2.3164	2.6117	3.3201	4.2207
13	1.2969	1.4770	1.6820	1.9155	2.1815	2.4843	2.8292	3.6693	4.7588
14	1.3231	1.5220	1.7507	2.0138	2.3164	2.6645	3.0649	4.0552	5.3656
15	1.3499	1.5683	1.8221	2.1170	2.4596	2.8577	3.3201	4.4817	6.0496
16	1.3771	1.6161	1.8965	2.2255	2.6117	3.0649	3.5966	4.9530	6.8210
17	1.4049	1.6653	1.9739	2.3396	2.7732	3.2871	3.8962	5.4739	7.6906
18	1.4333	1.7160	2.0544	2.4596	2.9447	3.5254	4.2207	6.0496	8.6711
19	1.4623	1.7683	2.1383	2.5857	3.1268	3.7810	4.5722	6.6859	9.7767
20	1.4918	1.8221	2.2255	2.7183	3.3201	4.0552	4.9530	7.3891	11.023
25	1.6487	2.1170	2.7183	3.4903	4.4817	5.7546	7.3891	12.182	20.086
30	1.8221	2.4596	3.3201	4.4817	6.0496	8.1662	11.023	20.086	36.598
40	2.2255	3.3201	4.9530	7.3891	11.023	16.445	24.533	54.598	121.51
50	2.7183	4.4817	7.3891	12.182	20.086	33.115	54.598	148.41	403.43
60	3.3201	6.0496	11.023	20.086	36.598	66.686	121.51	403.43	1339.4

FORMULA: $y = e^{(r/100) \times n}$.

Table 1.1.6 Principal Which Will Amount to a Given Sum

The principal P, which, if placed at compound interest today, will amount to a given sum A at the end of n years $P = A \times x'$ or $P = A \times y'$, according as the interest (at the rate of r percent per annum) is compounded annually, or continuously; the factor x' or y' being taken from the following tables.

Values of x' (interest compounded annually: $P = A \times x'$)									
Years	$r = 2$	3	4	5	6	7	8	10	12
1	.98039	.97087	.96154	.95238	.94340	.93458	.92593	.90909	.89286
2	.96117	.94260	.92456	.90703	.89000	.87344	.85734	.82645	.79719
3	.94232	.91514	.88900	.86384	.83962	.81630	.79383	.75131	.71178
4	.92385	.88849	.85480	.82270	.79209	.76290	.73503	.68301	.63552
5	.90573	.86261	.82193	.78353	.74726	.71299	.68058	.62092	.56743
6	.88797	.83748	.79031	.74622	.70496	.66634	.63017	.56447	.50663
7	.87056	.81309	.75992	.71068	.66506	.62275	.58349	.51316	.45235
8	.85349	.78941	.73069	.67684	.62741	.58201	.54027	.46651	.40388
9	.83676	.76642	.70259	.64461	.59190	.54393	.50025	.42410	.36061
10	.82035	.74409	.67556	.61391	.55839	.50835	.46319	.38554	.32197
11	.80426	.72242	.64958	.58468	.52679	.47509	.42888	.35049	.28748
12	.78849	.70138	.62460	.55684	.49697	.44401	.39711	.31863	.25668
13	.77303	.68095	.60057	.53032	.46884	.41496	.36770	.28966	.22917
14	.75788	.66112	.57748	.50507	.44230	.38782	.34046	.26333	.20462
15	.74301	.64186	.55526	.48102	.41727	.36245	.31524	.23939	.18270
16	.72845	.62317	.53391	.45811	.39365	.33873	.29189	.21763	.16312
17	.71416	.60502	.51337	.43630	.37136	.31657	.27027	.19784	.14564
18	.70016	.58739	.49363	.41552	.35034	.29586	.25025	.17986	.13004
19	.68643	.57029	.47464	.39573	.33051	.27651	.23171	.16351	.11611
20	.67297	.55368	.45639	.37689	.31180	.25842	.21455	.14864	.10367
25	.60953	.47761	.37512	.29530	.23300	.18425	.14602	.09230	.05882
30	.55207	.41199	.30832	.23138	.17411	.13137	.09938	.05731	.03338
40	.45289	.30656	.20829	.14205	.09722	.06678	.04603	.02209	.01075
50	.37153	.22811	.14071	.08720	.05429	.03395	.02132	.00852	.00346
60	.30478	.16973	.09506	.05354	.03031	.01726	.00988	.00328	.00111

FORMULA: $x' = [1 + (r/100)]^{-n} = 1/x$.

Values of y' (interest compounded continuously: $P = A \times y'$)									
Years	$r = 2$	3	4	5	6	7	8	10	12
1	.98020	.97045	.96079	.95123	.94176	.93239	.92312	.90484	.88692
2	.96079	.94176	.92312	.90484	.88692	.86936	.85214	.81873	.78663
3	.94176	.91393	.88692	.86071	.83527	.81058	.78663	.74082	.69768
4	.92312	.88692	.85214	.81873	.78663	.75578	.72615	.67032	.61878
5	.90484	.86071	.81873	.77880	.74082	.70469	.67032	.60653	.54881
6	.88692	.83527	.78663	.74082	.69768	.65705	.61878	.54881	.48675
7	.86936	.81058	.75578	.70469	.65705	.61263	.57121	.49659	.43171
8	.85214	.78663	.72615	.67032	.61878	.57121	.52729	.44933	.38289
9	.83527	.76338	.69768	.63763	.58275	.53259	.48675	.40657	.33960
10	.81873	.74082	.67032	.60653	.54881	.49659	.44933	.36788	.30119
11	.80252	.71892	.64404	.57695	.51685	.46301	.41478	.33287	.26714
12	.78663	.69768	.61878	.54881	.48675	.43171	.38289	.30119	.23693
13	.77105	.67706	.59452	.52205	.45841	.40252	.35345.	.27253	.21014
14	.75578	.65705	.57121	.49659	.43171	.37531	.32628	.24660	.18637
15	.74082	.63763	.54881	.47237	.40657	.34994	.30119	.22313	.16530
16	.72615	.61878	.52729	.44933	.38289	.32628	.27804	.20190	.14661
17	.71177	.60050	.50662	.42741	.36059	.30422	.25666	.18268	.13003
18	.69768	.58275	.48675	.40657	.33960	.28365	.23693	.16530	.11533
19	.68386	.56553	.46767	.38674	.31982	.26448	.21871	.14957	.10228
20	.67032	.54881	.44933	.36788	.30119	.24660	.20190	.13534	.09072
25	.60653	.47237	.36788	.28650	.22313	.17377	.13534	.08208	.04979
30	.54881	.40657	.30119	.22313	.16530	.12246	.09072	.04979	.02732
40	.44933	.30119	.20190	.13534	.09072	.06081	.04076	.01832	.00823
50	.36788	.22313	.13534	.08208	.04979	.03020	.01832	.00674	.00248
60	.30119	.16530	.09072	.04979	.02732	.01500	.00823	.00248	.00075

FORMULA: $y' = e^{-(r/100)\times n} = 1/y$.

Table 1.1.7 Amount of an Annuity

The amount S accumulated at the end of n years by a given annual payment Y set aside at the end of each year is $S = Y \times v$, where the factor v is to be taken from the following table (interest at r percent per annum, compounded annually).

	Values of v								
Years	$r = 2$	3	4	5	6	7	8	10	12
1	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2	2.0200	2.0300	2.0400	2.0500	2.0600	2.0700	2.0800	2.1000	2.1200
3	3.0604	3.0909	3.1216	3.1525	3.1836	3.2149	3.2464	3.3100	3.3744
4	4.1216	4.1836	4.2465	4.3101	4.3746	4.4399	4.5061	4.6410	4.7793
5	5.2040	5.3091	5.4163	5.5256	5.6371	5.7507	5.8666	6.1051	6.3528
6	6.3081	6.4684	6.6330	6.8019	6.9753	7.1533	7.3359	7.7156	8.1152
7	7.4343	7.6625	7.8983	8.1420	8.3938	8.6540	8.9228	9.4872	10.089
8	8.5830	8.8923	9.2142	9.5491	9.8975	10.260	10.637	11.436	12.300
9	9.7546	10.159	10.583	11.027	11.491	11.978	12.488	13.579	14.776
10	10.950	11.464	12.006	12.578	13.181	13.816	14.487	15.937	17.549
11	12.169	12.808	13.486	14.207	14.972	15.784	16.645	18.531	20.655
12	13.412	14.192	15.026	15.917	16.870	17.888	18.977	21.384	24.133
13	14.680	15.618	16.627	17.713	18.882	20.141	21.495	24.523	28.029
14	15.974	17.086	18.292	19.599	21.015	22.550	24.215	27.975	32.393
15	17.293	18.599	20.024	21.579	23.276	25.129	27.152	31.772	37.280
16	18.639	20.157	21.825	23.657	25.673	27.888	30.324	35.950	42.753
17	20.012	21.762	23.698	25.840	28.213	30.840	33.750	40.545	48.884
18	21.412	23.414	25.645	28.132	30.906	33.999	37.450	45.599	55.750
19	22.841	25.117	27.671	30.539	33.760	37.379	41.446	51.159	63.440
20	24.297	26.870	29.778	33.066	36.786	40.995	45.762	57.275	72.052
25	32.030	36.459	41.646	47.727	54.865	63.249	73.106	98.347	133.33
30	40.568	47.575	56.085	66.439	79.058	94.461	113.28	164.49	241.33
40	60.402	75.401	95.026	120.80	154.76	199.64	259.06	442.59	767.09
50	84.579	112.80	152.67	209.35	290.34	406.53	573.77	1163.9	2400.0
60	114.05	163.05	237.99	353.58	533.13	813.52	1253.2	3034.8	7471.6

FORMULA: $v \{[1 + (r/100)]^n - 1\} \div (r/100) = (x - 1) \div (r/100)$.

Table 1.1.8 Annuity Which Will Amount to a Given Sum (Sinking Fund)

The annual payment Y which, if set aside at the end of each year, will amount with accumulated interest to a given sum S at the end of n years is $Y = S \times v'$, where the factor v' is given below (interest at r percent per annum, compounded annually).

	Values of v'								
Years	$r = 2$	3	4	5	6	7	8	10	12
1	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2	.49505	.49261	.49020	.48780	.48544	.48309	.48077	.47619	.47170
3	.32675	.32353	.32035	.31721	.31411	.31105	.30803	.30211	.29635
4	.24262	.23903	.23549	.23201	.22859	.22523	.22192	.21547	.20923
5	.19216	.18835	.18463	.18097	.17740	.17389	.17046	.16380	.15741
6	.15853	.15460	.15076	.14702	.14336	.13980	.13632	.12961	.12323
7	.13451	.13051	.12661	.12282	.11914	.11555	.11207	.10541	.09912
8	.11651	.11246	.10853	.10472	.10104	.09747	.09401	.08744	.08130
9	.10252	.09843	.09449	.09069	.08702	.08349	.08008	.07364	.06768
10	.09133	.08723	.08329	.07950	.07587	.07238	.06903	.06275	.05698
11	.08218	.07808	.07415	.07039	.06679	.06336	.06008	.05396	.04842
12	.07456	.07046	.06655	.06283	.05928	.05590	.05270	.04676	.04144
13	.06812	.06403	.06014	.05646	.05296	.04965	.04652	.04078	.03568
14	.06260	.05853	.05467	.05102	.04758	.04434	.04130	.03575	.03087
15	.05783	.05377	.04994	.04634	.04296	.03979	.03683	.03147	.02682
16	.05365	.04961	.04582	.04227	.03895	.03586	.03298	.02782	.02339
17	.04997	.04595	.04220	.03870	.03544	.03243	.02963	.02466	.02046
18	.04670	.04271	.03899	.03555	.03236	.02941	.02670	.02193	.01794
19	.04378	.03981	.03614	.03275	.02962	.02675	.02413	.01955	.01576
20	.04116	.03722	.03358	.03024	.02718	.02439	.02185	.01746	.01388
25	.03122	.02743	.02401	.02095	.01823	.01581	.01368	.01017	.00750
30	.02465	.02102	.01783	.01505	.01265	.01059	.00883	.00608	.00414
40	.01656	.01326	.01052	.00828	.00646	.00501	.00386	.00226	.00130
50	.01182	.00887	.00655	.00478	.00344	.00246	.00174	.00086	.00042
60	.00877	.00613	.00420	.00283	.00188	.00123	.00080	.00033	.00013

FORMULA: $v' = (r/100) \div \{[1 + (r/100)]^n - 1\} = 1/v$.

Table 1.1.9 Present Worth of an Annuity

The capital C which, if placed at interest today, will provide for a given annual payment Y for a term of n years before it is exhausted is $C = Y \times w$, where the factor w is given below (interest at r percent per annum, compounded annually).

	Values of w								
Years	$r = 2$	3	4	5	6	7	8	10	12
1	.98039	.97087	.96154	.95238	.94340	.93458	.92593	.90909	.89286
2	1.9416	1.9135	1.8861	1.8594	1.8334	1.8080	1.7833	1.7355	1.6901
3	2.8839	2.8286	2.7751	2.7232	2.6730	2.6243	2.5771	2.4869	2.4018
4	3.8077	3.7171	3.6299	3.5460	3.4651	3.3872	3.3121	3.1699	3.0373
5	4.7135	4.5797	4.4518	4.3295	4.2124	4.1002	3.9927	3.7908	3.6048
6	5.6014	5.4172	5.2421	5.0757	4.9173	4.7665	4.6229	4.3553	4.1114
7	6.4720	6.2303	6.0021	5.7864	5.5824	5.3893	5.2064	4.8684	4.5638
8	7.3255	7.0197	6.7327	6.4632	6.2098	5.9713	5.7466	5.3349	4.9676
9	8.1622	7.7861	7.4353	7.1078	6.8017	6.5152	6.2469	5.7590	5.3282
10	8.9826	8.5302	8.1109	7.7217	7.3601	7.0236	6.7101	6.1446	5.6502
11	9.7868	9.2526	8.7605	8.3064	7.8869	7.4987	7.1390	6.4951	5.9377
12	10.575	9.9540	9.3851	8.8633	8.3838	7.9427	7.5361	6.8137	6.1944
13	11.348	10.635	9.9856	9.3936	8.8527	8.3577	7.9038	7.1034	6.4235
14	12.106	11.296	10.563	9.8986	9.2950	8.7455	8.2442	7.3667	6.6282
15	12.849	11.938	11.118	10.380	9.7122	9.1079	8.5595	7.6061	6.8109
16	13.578	12.561	11.652	10.838	10.106	9.4466	8.8514	7.8237	6.9740
17	14.292	13.166	12.166	11.274	10.477	9.7632	9.1216	8.0216	7.1196
18	14.992	13.754	12.659	11.690	10.828	10.059	9.3719	8.2014	7.2497
19	15.678	14.324	13.134	12.085	11.158	10.336	9.6036	8.3649	7.3658
20	16.351	14.877	13.590	12.462	11.470	10.594	9.8181	8.5136	7.4694
25	19.523	17.413	15.622	14.094	12.783	11.654	10.675	9.0770	7.8431
30	22.396	19.600	17.292	15.372	13.765	12.409	11.258	9.4269	8.0552
40	27.355	23.115	19.793	17.159	15.046	13.332	11.925	9.7791	8.2438
50	31.424	25.730	21.482	18.256	15.762	13.801	12.233	9.9148	8.3045
60	34.761	27.676	22.623	18.929	16.161	14.039	12.377	9.9672	8.3240

FORMULA: $w = \{1 - [1 + (r/100)]^{-n}\} \div [r/100] = v/x$.

Table 1.1.10 Annuity Provided for by a Given Capital

The annual payment Y provided for a term of n years by a given capital C placed at interest today is $Y = C \times w'$ (interest at r percent per annum, compounded annually; the fund supposed to be exhausted at the end of the term).

	Values of w'								
Years	$r = 2$	3	4	5	6	7	8	10	12
1	1.0200	1.0300	1.0400	1.0500	1.0600	1.0700	1.0800	1.1000	1.1200
2	.51505	.52261	.53020	.53780	.54544	.55309	.56077	.57619	.59170
3	.34675	.35353	.36035	.36721	.37411	.38105	.38803	.40211	.41635
4	.26262	.26903	.27549	.28201	.28859	.29523	.30192	.31547	.32923
5	.21216	.21835	.22463	.23097	.23740	.24389	.25046	.26380	.27741
6	.17853	.18460	.19076	.19702	.20336	.20980	.21632	.22961	.24323
7	.15451	.16051	.16661	.17282	.17914	.18555	.19207	.20541	.21912
8	.13651	.14246	.14853	.15472	.16104	.16747	.17401	.18744	.20130
9	.12252	.12843	.13449	.14069	.14702	.15349	.16008	.17364	.18768
10	.11133	.11723	.12329	.12950	.13587	.14238	.14903	.16275	.17698
11	.10218	.10808	.11415	.12039	.12679	.13336	.14008	.15396	.16842
12	.09456	.10046	.10655	.11283	.11928	.12590	.13270	.14676	.16144
13	.08812	.09403	.10014	.10646	.11296	.11965	.12652	.14078	.15568
14	.08260	.08853	.09467	.10102	.10758	.11434	.12130	.13575	.15087
15	.07783	.08377	.08994	.09634	.10296	.10979	.11683	.13147	.14682
16	.07365	.07961	.08582	.09227	.09895	.10586	.11298	.12782	.14339
17	.06997	.07595	.08220	.08870	.09544	.10243	.10963	.12466	.14046
13	.06670	.07271	.07899	.08555	.09236	.09941	.10670	.12193	.13794
19	.06378	.06981	.07614	.08275	.08962	.09675	.10413	.11955	.13576
20	.06116	.06722	.07358	.08024	.08718	.09439	.10185	.11746	.13388
25	.05122	.05743	.06401	.07095	.07823	.08581	.09368	.11017	.12750
30	.04465	.05102	.05783	.06505	.07265	.08059	.08883	.10608	.12414
40	.03656	.04326	.05052	.05828	.06646	.07501	.08386	.10226	.12130
50	.03182	.03887	.04655	.05478	.06344	.07246	.08174	.10086	.12042
60	.02877	.03613	.04420	.05283	.06188	.07123	.08080	.10033	.12013

FORMULA: $w' = [r/100] \div \{1 - [1 + (r/100)]^{-n}\} = 1/w = v' + (r/100)$.

Table 1.1.11 Ordinates of the Normal Density Function

$$f(x) = \frac{1}{\sqrt{2\pi}} e^{-x^2/2}$$

x	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
.0	.3989	.3989	.3989	.3988	.3986	.3984	.3982	.3980	.3977	.3973
.1	.3970	.3965	.3961	.3956	.3951	.3945	.3939	.3932	.3925	.3918
.2	.3910	.3902	.3894	.3885	.3876	.3867	.3857	.3847	.3836	.3825
.3	.3814	.3802	.3790	.3778	.3765	.3752	.3739	.3725	.3712	.3697
.4	.3683	.3668	.3653	.3637	.3621	.3605	.3589	.3572	.3555	.3538
.5	.3521	.3503	.3485	.3467	.3448	.3429	.3410	.3391	.3372	.3352
.6	.3332	.3312	.3292	.3271	.3251	.3230	.3209	.3187	.3166	.3144
.7	.3123	.3101	.3079	.3056	.3034	.3011	.2989	.2966	.2943	.2920
.8	.2897	.2874	.2850	.2827	.2803	.2780	.2756	.2732	.2709	.2685
.9	.2661	.2637	.2613	.2589	.2565	.2541	.2516	.2492	.2468	.2444
1.0	.2420	.2396	.2371	.2347	.2323	.2299	.2275	.2251	.2227	.2203
1.1	.2179	.2155	.2131	.2107	.2083	.2059	.2036	.2012	.1989	.1965
1.2	.1942	.1919	.1895	.1872	.1849	.1826	.1804	.1781	.1758	.1736
1.3	.1714	.1691	.1669	.1647	.1626	.1604	.1582	.1561	.1539	.1518
1.4	.1497	.1476	.1456	.1435	.1415	.1394	.1374	.1354	.1334	.1315
1.5	.1295	.1276	.1257	.1238	.1219	.1200	.1182	.1163	.1154	.1127
1.6	.1109	.1092	.1074	.1057	.1040	.1023	.1006	.0989	.0973	.0957
1.7	.0940	.0925	.0909	.0893	.0878	.0863	.0848	.0833	.0818	.0804
1.8	.0790	.0775	.0761	.0748	.0734	.0721	.0707	.0694	.0681	.0669
1.9	.0656	.0644	.0632	.0620	.0608	.0596	.0584	.0573	.0562	.0551
2.0	.0540	.0529	.0519	.0508	.0498	.0488	.0478	.0468	.0459	.0449
2.1	.0440	.0431	.0422	.0413	.0404	.0396	.0387	.0379	.0371	.0363
2.2	.0355	.0347	.0339	.0332	.0325	.0317	.0310	.0303	.0297	.0290
2.3	.0283	.0277	.0270	.0264	.0258	.0252	.0246	.0241	.0235	.0229
2.4	.0224	.0219	.0213	.0208	.0203	.0198	.0194	.0189	.0184	.0180
2.5	.0175	.0171	.0167	.0163	.0158	.0154	.0151	.0147	.0143	.0139
2.6	.0136	.0132	.0129	.0126	.0122	.0119	.0116	.0113	.0110	.0107
2.7	.0104	.0101	.0099	.0096	.0093	.0091	.0088	.0086	.0084	.0081
2.8	.0079	.0077	.0075	.0073	.0071	.0069	.0067	.0065	.0063	.0061
2.9	.0060	.0058	.0056	.0055	.0053	.0051	.0050	.0048	.0047	.0046
3.0	.0044	.0043	.0042	.0040	.0039	.0038	.0037	.0036	.0035	.0034
3.1	.0033	.0032	.0031	.0030	.0029	.0028	.0027	.0026	.0025	.0025
3.2	.0024	.0023	.0022	.0022	.0021	.0020	.0020	.0019	.0018	.0018
3.3	.0017	.0017	.0016	.0016	.0015	.0015	.0014	.0014	.0013	.0013
3.4	.0012	.0012	.0012	.0011	.0011	.0010	.0010	.0010	.0009	.0009
3.5	.0009	.0008	.0008	.0008	.0008	.0007	.0007	.0007	.0007	.0006
3.6	.0006	.0006	.0006	.0005	.0005	.0005	.0005	.0005	.0005	.0004
3.7	.0004	.0004	.0004	.0004	.0004	.0004	.0003	.0003	.0003	.0003
3.8	.0003	.0003	.0003	.0003	.0003	.0002	.0002	.0002	.0002	.0002
3.9	.0002	.0002	.0002	.0002	.0002	.0002	.0002	.0002	.0001	.0001

NOTE: x is the value in left-hand column + the value in top row.
$f(x)$ is the value in the body of the table. *Example:* $x = 2.14$; $f(x) = 0.0404$.

Table 1.1.12 Cumulative Normal Distribution

$$F(x) = \int_{-\infty}^{x} \frac{1}{\sqrt{2\pi}} e^{-t^2/2} dt$$

x	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
.0	.5000	.5040	.5080	.5120	.5160	.5199	.5239	.5279	.5319	.5359
.1	.5398	.5438	.5478	.5517	.5557	.5596	.5636	.5675	.5714	.5735
.2	.5793	.5832	.5871	.5910	.5948	.5987	.6026	.6064	.6103	.6141
.3	.6179	.6217	.6255	.6293	.6331	.6368	.6406	.6443	.6480	.6517
.4	.6554	.6591	.6628	.6664	.6700	.6736	.6772	.6808	.6844	.6879
.5	.6915	.6950	.6985	.7019	.7054	.7088	.7123	.7157	.7190	.7224
.6	.7257	.7291	.7324	.7357	.7389	.7422	.7454	.7486	.7517	.7549
.7	.7580	.7611	.7642	.7673	.7703	.7734	.7764	.7793	.7823	.7852
.8	.7881	.7910	.7939	.7967	.7995	.8023	.8051	.8078	.8106	.8133
.9	.8159	.8186	.8212	.8238	.8264	.8289	.8315	.8340	.8365	.8389
1.0	.8413	.8438	.8461	.8485	.8508	.8531	.8554	.8577	.8599	.8621
1.1	.8643	.8665	.8686	.8708	.8729	.8749	.8770	.8790	.8810	.8830
1.2	.8849	.8869	.8888	.8906	.8925	.8943	.8962	.8980	.8997	.9015
1.3	.9032	.9049	.9066	.9082	.9099	.9115	.9131	.9147	.9162	.9177
1.4	.9192	.9207	.9222	.9236	.9251	.9265	.9279	.9292	.9306	.9319
1.5	.9332	.9345	.9357	.9370	.9382	.9394	.9406	.9418	.9429	.9441
1.6	.9452	.9463	.9474	.9484	.9495	.9505	.9515	.9525	.9535	.9545
1.7	.9554	.9564	.9573	.9582	.9591	.9599	.9608	.9616	.9625	.9633
1.8	.9641	.9649	.9656	.9664	.9671	.9678	.9686	.9693	.9699	.9706
1.9	.9713	.9719	.9726	.9732	.9738	.9744	.9750	.9756	.9761	.9767
2.0	.9772	.9778	.9783	.9788	.9793	.9798	.9803	.9808	.9812	.9817
2.1	.9812	.9826	.9830	.9834	.9838	.9842	.9846	.9850	.9854	.9857
2.2	.9861	.9864	.9868	.9871	.9875	.9878	.9881	.9884	.9887	.9890
2.3	.9893	.9896	.9898	.9901	.9904	.9906	.9909	.9911	.9913	.9916
2.4	.9918	.9920	.9922	.9925	.9927	.9929	.9931	.9932	.9934	.9936
2.5	.9938	.9940	.9941	.9943	.9945	.9946	.9948	.9949	.9951	.9952
2.6	.9953	.9955	.9956	.9957	.9959	.9960	.9961	.9962	.9963	.9964
2.7	.9965	.9966	.9967	.9968	.9969	.9970	.9971	.9972	.9973	.9974
2.8	.9974	.9975	.9976	.9977	.9977	.9978	.9979	.9979	.9980	.9981
2.9	.9981	.9982	.9982	.9983	.9984	.9984	.9985	.9985	.9986	.9986
3.0	.9986	.9987	.9987	.9988	.9988	.9989	.9989	.9989	.9990	.9990
3.1	.9990	.9991	.9991	.9991	.9992	.9992	.9992	.9992	.9993	.9993
3.2	.9993	.9993	.9994	.9994	.9994	.9994	.9994	.9995	.9995	.9995
3.3	.9995	.9995	.9995	.9996	.9996	.9996	.9996	.9996	.9996	.9997
3.4	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9998

NOTE: $x = (a - \mu)/\sigma$ where a is the observed value, μ is the mean, and σ is the standard deviation.
x is the value in the left-hand column + the value in the top row.
$F(x)$ is the probability that a point will be less than or equal to x.
$F(x)$ is the value in the body of the table. *Example:* The probability that an observation will be less than or equal to 1.04 is .8508.
NOTE: $F(-x) = 1 - F(x)$.

Table 1.1.13 Cumulative Chi-Square Distribution

$$F(t) = \int_0^t \frac{x^{(n-2)/2} e^{-x/2} dx}{2^{n/2}[(n-2)/2]!}$$

n \ F	.005	.010	.025	.050	.100	.250	.500	.750	.900	.950	.975	.990	.995
1	.000039	.00016	.00098	.0039	.0158	.101	.455	1.32	2.70	3.84	5.02	6.62	7.86
2	.0100	.0201	.0506	.103	.211	.575	1.39	2.77	4.61	5.99	7.38	9.21	10.6
3	.0717	.155	.216	.352	.584	1.21	2.37	4.11	6.25	7.81	9.35	11.3	12.8
4	.207	.297	.484	.711	1.06	1.92	3.36	5.39	7.78	9.49	11.1	13.3	14.9
5	.412	.554	.831	1.15	1.61	2.67	4.35	6.63	9.24	11.1	12.8	15.1	16.7
6	.676	.872	1.24	1.64	2.20	3.45	5.35	7.84	10.6	12.6	14.4	16.8	18.5
7	.989	1.24	1.69	2.17	2.83	4.25	6.35	9.04	12.0	14.1	16.0	18.5	20.3
8	1.34	1.65	2.18	2.73	3.49	5.07	7.34	10.2	13.4	15.5	17.5	20.1	22.0
9	1.73	2.09	2.70	3.33	4.17	5.90	8.34	11.4	14.7	16.9	19.0	21.7	23.6
10	2.16	2.56	3.25	3.94	4.87	6.74	9.34	12.5	16.0	18.3	20.5	23.2	25.2
11	2.60	3.05	3.82	4.57	5.58	7.58	10.3	13.7	17.3	19.7	21.9	24.7	26.8
12	3.07	3.57	4.40	5.23	6.30	8.44	11.3	14.8	18.5	21.0	23.3	26.2	28.3
13	3.57	4.11	5.01	5.89	7.04	9.30	12.3	16.0	19.8	22.4	24.7	27.7	29.8
14	4.07	4.66	5.63	6.57	7.79	10.2	13.3	17.1	21.1	23.7	26.1	29.1	31.3
15	4.60	5.23	6.26	7.26	8.55	11.0	14.3	18.2	22.3	25.0	27.5	30.6	32.8
16	5.14	5.81	6.91	7.96	9.31	11.9	15.3	19.4	23.5	26.3	28.8	32.0	34.3
17	5.70	6.41	7.56	8.67	10.1	12.8	16.3	20.5	24.8	27.6	30.2	33.4	35.7
18	6.26	7.01	8.23	9.39	10.9	13.7	17.3	21.6	26.0	28.9	31.5	34.8	37.2
19	6.84	7.63	8.91	10.1	11.7	14.6	18.3	22.7	27.2	30.1	32.9	36.2	38.6
20	7.43	8.26	9.59	10.9	12.4	15.5	19.3	23.8	28.4	31.4	34.2	37.6	40.0
21	8.03	8.90	10.3	11.6	13.2	16.3	20.3	24.9	29.6	32.7	35.5	38.9	41.4
22	8.64	9.54	11.0	12.3	14.0	17.2	21.3	26.0	30.8	33.9	36.8	40.3	42.8
23	9.26	10.2	11.7	13.1	14.8	18.1	22.3	27.1	32.0	35.2	38.1	41.6	44.2
24	9.89	10.9	12.4	13.8	15.7	19.0	23.3	28.2	33.2	36.4	39.4	43.0	45.6
25	10.5	11.5	13.1	14.6	16.5	19.9	24.3	29.3	34.4	37.7	40.6	44.3	46.9
26	11.2	12.2	13.8	15.4	17.3	20.8	25.3	30.4	35.6	38.9	41.9	45.6	48.3
27	11.8	12.9	14.6	16.2	18.1	21.7	26.3	31.5	36.7	40.1	43.2	47.0	49.6
28	12.5	13.6	15.3	16.9	18.9	22.7	27.3	32.6	37.9	41.3	44.5	48.3	51.0
29	13.1	14.3	16.0	17.7	19.8	23.6	28.3	33.7	39.1	42.6	45.7	49.6	52.3
30	13.8	15.0	16.8	18.5	20.6	24.5	29.3	34.8	40.3	43.8	47.0	50.9	53.7

NOTE: n is the number of degrees of freedom.
Values for t are in the body of the table. *Example:* The probability that, with 16 degrees of freedom, a point will be ≤23.5 is .900.

Table 1.1.14 Cumulative "Student's" Distribution

$$F(t) = \int_{-\infty}^{t} \frac{\left(\frac{n-1}{2}\right)!}{\left(\frac{n-2}{2}\right)!\sqrt{\pi n}\left(1 + \frac{x^2}{n}\right)^{(n+1)/2}} dx$$

n \ F	.75	.90	.95	.975	.99	.995	.9995
1	1.000	3.078	6.314	12.70	31.82	63.66	636.3
2	.816	1.886	2.920	4.303	6.965	9.925	31.60
3	.765	1.638	2.353	3.182	4.541	5.841	12.92
4	.741	1.533	2.132	2.776	3.747	4.604	8.610
5	.727	1.476	2.015	2.571	3.365	4.032	6.859
6	.718	1.440	1.943	2.447	3.143	3.707	5.959
7	.711	1.415	1.895	2.365	2.998	3.499	5.408
8	.706	1.397	1.860	2.306	2.896	3.355	5.041
9	.703	1.383	1.833	2.262	2.821	3.250	4.781
10	.700	1.372	1.812	2.228	2.764	3.169	4.587
11	.697	1.363	1.796	2.201	2.718	3.106	4.437
12	.695	1.356	1.782	2.179	2.681	3.055	4.318
13	.694	1.350	1.771	2.160	2.650	3.012	4.221
14	.692	1.345	1.761	2.145	2.624	2.977	4.140
15	.691	1.341	1.753	2.131	2.602	2.947	4.073
16	.690	1.337	1.746	2.120	2.583	2.921	4.015
17	.689	1.333	1.740	2.110	2.567	2.898	3.965
18	.688	1.330	1.734	2.101	2.552	2.878	3.922
19	.688	1.328	1.729	2.093	2.539	2.861	3.883
20	.687	1.325	1.725	2.086	2.528	2.845	3.850
21	.686	1.323	1.721	2.080	2.518	2.831	3.819
22	.686	1.321	1.717	2.074	2.508	2.819	3.792
23	.685	1.319	1.714	2.069	2.500	2.807	3.768
24	.685	1.318	1.711	2.064	2.492	2.797	3.745
25	.684	1.316	1.708	2.060	2.485	2.787	3.725
26	.684	1.315	1.706	2.056	2.479	2.779	3.707
27	.684	1.314	1.703	2.052	2.473	2.771	3.690
28	.683	1.313	1.701	2.048	2.467	2.763	3.674
29	.683	1.311	1.699	2.045	2.462	2.756	3.659
30	.683	1.310	1.697	2.042	2.457	2.750	3.646
40	.681	1.303	1.684	2.021	2.423	2.704	3.551
60	.679	1.296	1.671	2.000	2.390	2.660	3.460
120	.677	1.289	1.658	1.980	2.385	2.617	3.373

NOTE: n is the number of degrees of freedom.

Values for t are in the body of the table. *Example:* The probability that, with 16 degrees of freedom, a point will be ≤ 2.921 is .995.

NOTE: $F(-t) = 1 - F(t)$.

Table 1.1.15 Cumulative *F* Distribution

m degrees of freedom in numerator; *n* in denominator

$$G(F) = \int_0^F \frac{[(m+n-2)/2]!m^{m/2}n^{n/2}x^{(m-2)/2}(n+mx)^{-(m+n)/2}dx}{[(m-2)/2]![(n-2)/2]!}$$

Upper 5% points ($F_{.95}$)

Degrees of freedom for denominator	Degrees of freedom for numerator: 1	2	3	4	5	6	7	8	9	10	12	15	20	24	30	40	60	120	∞
1	161	200	216	225	230	234	237	239	241	242	244	246	248	249	250	251	252	253	254
2	18.5	19.0	19.2	19.2	19.3	19.3	19.4	19.4	19.4	19.4	19.4	19.4	19.4	19.5	19.5	19.5	19.5	19.5	19.5
3	10.1	9.55	9.28	9.12	9.01	8.94	8.89	8.85	8.81	8.79	8.74	8.70	8.66	8.64	8.62	8.59	8.57	8.55	8.53
4	7.71	6.94	6.59	6.39	6.26	6.16	6.09	6.04	6.00	5.96	5.91	5.86	5.80	5.77	5.75	5.72	5.69	5.66	5.63
5	6.61	5.79	5.41	5.19	5.05	4.95	4.88	4.82	4.77	4.74	4.68	4.62	4.56	4.53	4.50	4.46	4.43	4.40	4.37
6	5.99	5.14	4.76	4.53	4.39	4.28	4.21	4.15	4.10	4.06	4.00	3.94	3.87	3.84	3.81	3.77	3.74	3.70	3.67
7	5.59	4.74	4.35	4.12	3.97	3.87	3.79	3.73	3.68	3.64	3.57	3.51	3.44	3.41	3.38	3.34	3.30	3.27	3.23
8	5.32	4.46	4.07	3.84	3.69	3.58	3.50	3.44	3.39	3.35	3.28	3.22	3.15	3.12	3.08	3.04	3.01	2.97	2.93
9	5.12	4.26	3.86	3.63	3.48	3.37	3.29	3.23	3.18	3.14	3.07	3.01	2.94	2.90	2.86	2.83	2.79	2.75	2.71
10	4.96	4.10	3.71	3.48	3.33	3.22	3.14	3.07	3.02	2.98	2.91	2.85	2.77	2.74	2.70	2.66	2.62	2.58	2.54
11	4.84	3.98	3.59	3.36	3.20	3.09	3.01	2.95	2.90	2.85	2.79	2.72	2.65	2.61	2.57	2.53	2.49	2.45	2.40
12	4.75	3.89	3.49	3.26	3.11	3.00	2.91	2.85	2.80	2.75	2.69	2.62	2.54	2.51	2.47	2.43	2.38	2.34	2.30
13	4.67	3.81	3.41	3.18	3.03	2.92	2.83	2.77	2.71	2.67	2.60	2.53	2.46	2.42	2.38	2.34	2.30	2.25	2.21
14	4.60	3.74	3.34	3.11	2.96	2.85	2.76	2.70	2.65	2.60	2.53	2.46	2.39	2.35	2.31	2.27	2.22	2.18	2.13
15	4.54	3.68	3.29	3.06	2.90	2.79	2.71	2.64	2.59	2.54	2.48	2.40	2.33	2.29	2.25	2.20	2.16	2.11	2.07
16	4.49	3.63	3.24	3.01	2.85	2.74	2.66	2.59	2.54	2.49	2.42	2.35	2.28	2.24	2.19	2.15	2.11	2.06	2.01
17	4.45	3.59	3.20	2.96	2.81	2.70	2.61	2.55	2.49	2.45	2.38	2.31	2.23	2.19	2.15	2.10	2.06	2.01	1.96
18	4.41	3.55	3.16	2.93	2.77	2.66	2.58	2.51	2.46	2.41	2.34	2.27	2.19	2.15	2.11	2.06	2.02	1.97	1.92
19	4.38	3.52	3.13	2.90	2.74	2.63	2.54	2.48	2.42	2.38	2.31	2.23	2.16	2.11	2.07	2.03	1.98	1.93	1.88
20	4.35	3.49	3.10	2.87	2.71	2.60	2.51	2.45	2.39	2.35	2.28	2.20	2.12	2.08	2.04	1.99	1.95	1.90	1.84
21	4.32	3.47	3.07	2.84	2.68	2.57	2.49	2.42	2.37	2.32	2.25	2.18	2.10	2.05	2.01	1.96	1.92	1.87	1.81
22	4.30	3.44	3.05	2.82	2.66	2.55	2.46	2.40	2.34	2.30	2.23	2.15	2.07	2.03	1.98	1.94	1.89	1.84	1.78
23	4.28	3.42	3.03	2.80	2.64	2.53	2.44	2.37	2.32	2.27	2.20	2.13	2.05	2.01	1.96	1.91	1.86	1.81	1.76
24	4.26	3.40	3.01	2.78	2.62	2.51	2.42	2.36	2.30	2.25	2.18	2.11	2.03	1.98	1.94	1.89	1.84	1.79	1.73
25	4.24	3.39	2.99	2.76	2.60	2.49	2.40	2.34	2.28	2.24	2.16	2.09	2.01	1.96	1.92	1.87	1.82	1.77	1.71
30	4.17	3.32	2.92	2.69	2.53	2.42	2.33	2.27	2.21	2.16	2.09	2.01	1.93	1.89	1.84	1.79	1.74	1.68	1.62
40	4.08	3.23	2.84	2.61	2.45	2.34	2.25	2.18	2.12	2.08	2.00	1.92	1.84	1.79	1.74	1.69	1.64	1.58	1.51
60	4.00	3.15	2.76	2.53	2.37	2.25	2.17	2.10	2.04	1.99	1.92	1.84	1.75	1.70	1.65	1.59	1.53	1.47	1.39
120	3.92	3.07	2.68	2.45	2.29	2.18	2.09	2.02	1.96	1.91	1.83	1.75	1.66	1.61	1.55	1.50	1.43	1.35	1.25
∞	3.84	3.00	2.60	2.37	2.21	2.10	2.01	1.94	1.88	1.83	1.75	1.67	1.57	1.52	1.46	1.39	1.32	1.22	1.00

Upper 1% points ($F_{.99}$)

Degrees of freedom for denominator	Degrees of freedom for numerator: 1	2	3	4	5	6	7	8	9	10	12	15	20	24	30	40	60	120	∞
1	4052	5000	5403	5625	5764	5859	5928	5982	6023	6056	6106	6157	6209	6235	6261	6287	6313	6339	6366
2	98.5	99.0	99.2	99.2	99.3	99.3	99.4	99.4	99.4	99.4	99.4	99.4	99.4	99.5	99.5	99.5	99.5	99.5	99.5
3	34.1	30.8	29.5	28.7	28.2	27.9	27.7	27.5	27.3	27.2	27.1	26.9	26.7	26.6	26.5	26.4	26.3	26.2	26.1
4	21.2	18.0	16.7	16.0	15.5	15.2	15.0	14.8	14.7	14.5	14.4	14.2	14.0	13.9	13.8	13.7	13.7	13.6	13.5
5	16.3	13.3	12.1	11.4	11.0	10.7	10.5	10.3	10.2	10.1	9.89	9.72	9.55	9.47	9.38	9.29	9.20	9.11	9.02
6	13.7	!0.9	9.78	9.15	8.75	8.47	8.26	8.10	7.98	7.87	7.72	7.56	7.40	7.31	7.23	7.14	7.06	6.97	6.88
7	12.2	9.55	8.45	7.85	7.46	7.19	6.99	6.84	6.72	6.62	6.47	6.31	6.16	6.07	5.99	5.91	5.82	5.74	5.65
8	11.3	8.65	7.59	7.01	6.63	6.37	6.18	6.03	5.91	5.81	5.67	5.52	5.36	5.28	5.20	5.12	5.03	4.95	4.86
9	10.6	8.02	6.99	6.42	6.06	5.80	5.61	5.47	5.35	5.26	5.11	4.96	4.81	4.73	4.65	4.57	4.48	4.40	4.31
10	10.0	7.56	6.55	5.99	5.64	5.39	5.20	5.06	4.94	4.85	4.71	4.56	4.41	4.33	4.25	4.17	4.08	4.40	3.91
11	9.65	7.21	6.22	5.67	5.32	5.07	4.89	4.74	4.63	4.54	4.40	4.25	4.10	4.02	3.94	3.86	3.78	3.69	3.60
12	9.33	6.93	5.95	5.41	5.06	4.82	4.64	4.50	4.39	4.30	4.16	4.01	3.86	3.78	3.70	3.62	3.54	3.45	3.36
13	9.07	6.70	5.74	5.21	4.86	4.62	4.44	4.30	4.19	4.10	3.96	3.82	3.66	3.59	3.51	3.43	3.34	3.25	3.17
14	8.86	6.51	5.56	5.04	4.70	4.46	4.28	4.14	4.03	3.94	3.80	3.66	3.51	3.43	3.35	3.27	3.18	3.09	3.00
15	8.68	6.36	5.42	4.89	4.56	4.32	4.14	4.00	3.89	3.80	3.67	3.52	3.37	3.29	3.21	3.13	3.05	2.96	2.87
16	8.53	6.23	5.29	4.77	4.44	4.20	4.03	3.89	3.78	3.69	3.55	3.41	3.26	3.18	3.10	3.02	2.93	2.84	2.75
17	8.40	6.11	5.19	4.67	4.34	4.10	3.93	3.79	3.68	3.59	3.46	3.31	3.16	3.08	3.00	2.92	2.83	2.75	2.65
18	8.29	6.01	5.09	4.58	4.25	4.01	3.84	3.71	3.60	3.51	3.37	3.23	3.08	3.00	2.92	2.84	2.75	2.66	2.57
19	8.19	5.93	5.01	4.50	4.17	3.94	3.77	3.63	3.52	3.43	3.30	3.15	3.00	2.92	2.84	2.76	2.67	2.58	2.49
20	8.10	5.85	4.94	4.43	4.10	3.87	3.70	3.56	3.46	3.37	3.23	3.09	2.94	2.86	2.78	2.69	2.61	2.52	2.42
21	8.02	5.78	4.87	4.37	4.04	3.81	3.64	3.51	3.40	3.31	3.17	3.03	2.88	2.80	2.72	2.64	2.55	2.46	2.36
22	7.95	5.72	4.82	4.31	3.99	3.76	3.59	3.45	3.35	3.26	3.12	2.98	2.83	2.75	2.67	2.58	2.50	2.40	2.31
23	7.88	5.66	4.76	4.26	3.94	3.71	3.54	3.41	3.30	3.21	3.07	2.93	2.78	2.70	2.62	2.54	2.45	2.35	2.26
24	7.82	5.61	4.72	4.22	3.90	3.67	3.50	3.36	3.26	3.17	3.03	2.89	2.74	2.66	2.58	2.49	2.40	2.31	2.21
25	7.77	5.57	4.68	4.18	3.86	3.63	3.46	3.32	3.22	3.13	2.99	2.85	2.70	2.62	2.53	2.45	2.36	2.27	2.17
30	7.56	5.39	4.51	4.02	3.70	3.47	3.30	3.17	3.07	2.98	2.84	2.70	2.55	2.47	2.39	2.30	2.21	2.11	2.01
40	7.31	5.18	4.31	3.83	3.51	3.29	3.12	2.99	2.89	2.80	2.66	2.52	2.37	2.29	2.20	2.11	2.02	1.92	1.80
60	7.08	4.98	4.13	3.65	3.34	3.12	2.95	2.82	2.72	2.63	2.50	2.35	2.20	2.12	2.03	1.94	1.84	1.73	1.60
120	6.85	4.79	3.95	3.48	3.17	2.96	2.79	2.66	2.56	2.47	2.34	2.19	2.03	1.95	1.86	1.76	1.66	1.53	1.38
∞	6.63	4.61	3.78	3.32	3.02	2.80	2.64	2.51	2.41	2.32	2.18	2.04	1.88	1.79	1.70	1.59	1.47	1.32	1.00

NOTE: *m* is the number of degrees of freedom in the numerator of *F*; *n* is the number of degrees of freedom in the denominator of *F*.
Values for *F* are in the body of the table.
G is the probability that a point, with *m* and *n* degrees of freedom will be ≤*F*.
Example: With 2 and 5 degrees of freedom, the probability that a point will be ≤13.3 is .99.
SOURCE: "Chemical Engineers' Handbook," 5th edition, by R. H. Perry and C. H. Chilton, McGraw-Hill, 1973. Used with permission.

Table 1.1.16 Standard Distribution of Residuals

a = any positive quantity
y = the number of residuals which are numerically $< a$
r = the probable error of a single observation
n = number of observations

$\frac{a}{r}$	$\frac{y}{n}$	Diff	$\frac{a}{r}$	$\frac{y}{n}$	Diff
0.0	.000	54	2.5	.908	13
1	.054	53	6	.921	10
2	.107	53	7	.931	10
3	.160	53	8	.941	9
4	.213	51	9	.950	7
0.5	.264	50	3.0	.957	6
6	.314	49	1	.963	6
7	.363	48	2	.969	5
8	.411	45	3	.974	4
9	.456	44	4	.978	4
1.0	.500	42	3.5	.982	3
1	.542	40	6	.985	2
2	.582	37	7	.987	3
3	.619	36	8	.990	1
4	.655	33	9	.991	2
1.5	.688	31	4.0	.993	6
6	.719	29	5.0	.999	
7	.748	27			
8	.775	25			
9	.800	23			
2.0	.823	20			
1	.843	19			
2	.862	17			
3	.879	16			
4	.895	13			

Table 1.1.17 Factors for Computing Probable Error

n	Bessel		Peters		n	Bessel		Peters	
	$\frac{0.6745}{\sqrt{(n-1)}}$	$\frac{0.6745}{\sqrt{n(n-1)}}$	$\frac{0.8453}{\sqrt{n(n-1)}}$	$\frac{0.8453}{n\sqrt{n-1}}$		$\frac{0.6745}{\sqrt{(n-1)}}$	$\frac{0.6745}{\sqrt{n(n-1)}}$	$\frac{0.8453}{\sqrt{n(n-1)}}$	$\frac{0.8453}{n\sqrt{n-1}}$
2	.6745	.4769	.5978	.4227	30	.1252	.0229	.0287	.0052
3	.4769	.2754	.3451	.1993	31	.1231	.0221	.0277	.0050
4	.3894	.1947	.2440	.1220	32	.1211	.0214	.0268	.0047
5	.3372	.1508	.1890	.0845	33	.1192	.0208	.0260	.0045
6	.3016	.1231	.1543	.0630	34	.1174	.0201	.0252	.0043
7	.2754	.1041	.1304	.0493	35	.1157	.0196	.0245	.0041
8	.2549	.0901	.1130	.0399	36	.1140	.0190	.0238	.0040
9	.2385	.0795	.0996	.0332	37	.1124	.0185	.0232	.0038
10	.2248	.0711	.0891	.0282	38	.1109	.0180	.0225	.0037
11	.2133	.0643	.0806	.0243	39	.1094	.0175	.0220	.0035
12	.2034	.0587	.0736	.0212	40	.1080	.0171	.0214	.0034
13	.1947	.0540	.0677	.0188	45	.1017	.0152	.0190	.0028
14	.1871	.0500	.0627	.0167	50	.0964	.0136	.0171	.0024
15	.1803	.0465	.0583	.0151	55	.0918	.0124	.0155	.0021
16	.1742	.0435	.0546	.0136	60	.0878	.0113	.0142	.0018
17	.1686	.0409	.0513	.0124	65	.0843	.0105	.0131	.0016
18	.1636	.0386	.0483	.0114	70	.0812	.0097	.0122	.0015
19	.1590	.0365	.0457	.0105	75	.0784	.0091	.0113	.0013
20	.1547	.0346	.0434	.0097	80	.0759	.0085	.0106	.0012
21	.1508	.0329	.0412	.0090	85	.0736	.0080	.0100	.0011
22	.1472	.0314	.0393	.0084	90	.0715	.0075	.0094	.0010
23	.1438	.0300	.0376	.0078	95	.0696	.0071	.0089	.0009
24	.1406	.0287	.0360	.0073	100	.0678	.0068	.0085	.0008
25	.1377	.0275	.0345	.0069					
26	.1349	.0265	.0332	.0065					
27	.1323	.0255	.0319	.0061					
28	.1298	.0245	.0307	.0058					
29	.1275	.0237	.0297	.0055					

Table 1.1.18 Decimal Equivalents

From minutes and seconds into decimal parts of a degree

0′	0°.0000	0″	0°.0000
1	.0167	1	.0003
2	.0333	2	.0006
3	.05	3	.0008
4	.0667	4	.0011
5′	.0833	5″	.0014
6	.10	6	.0017
7	.1167	7	.0019
8	.1333	8	.0022
9	.15	9	.0025
10′	0°.1667	10″	0°.0028
1	.1833	1	.0031
2	.20	2	.0033
3	.2167	3	.0036
4	.2333	4	.0039
15′	.25	15″	.0042
6	.2667	6	.0044
7	.2833	7	.0047
8	.30	8	.005
9	.3167	9	.0053
20′	0°.3333	20″	0°.0056
1	.35	1	.0058
2	.3667	2	.0061
3	.3833	3	.0064
4	.40	4	.0067
25′	.4167	25″	.0069
6	.4333	6	.0072
7	.45	7	.0075
8	.4667	8	.0078
9	.4833	9	.0081
30′	0°.50	30″	0°.0083
1	.5167	1	.0086
2	.5333	2	.0089
3	.55	3	.0092
4	.5667	4	.0094
35′	.5833	35″	.0097
6	.60	6	.01
7	.6167	7	.0103
8	.6333	8	.0106
9	.65	9	.0108
40′	0°.6667	40″	0°.0111
1	.6833	1	.0114
2	.70	2	.0117
3	.7167	3	.0119
4	.7333	4	.0122
45′	.75	45″	.0125
6	.7667	6	.0128
7	.7833	7	.0131
8	.80	8	.0133
9	.8167	9	.0136
50′	0°.8333	50″	0°.0139
1	.85	1	.0142
2	.8667	2	.0144
3	.8833	3	.0147
4	.90	4	.015
55′	.9167	55″	.0153
6	.9333	6	.0156
7	.95	7	.0158
8	.9667	8	.0161
9	.9833	9	.0164
60′	1.00	60″	0°.0167

From decimal parts of a degree into minutes and seconds (exact values)

0°.00	0′	0°.50	30′
1	0′ 36″	1	30′ 36″
2	1′ 12″	2	31′ 12″
3	1′ 48″	3	31′ 48″
4	2′ 24″	4	32′ 24″
0°.05	3′	0°.55	33′
6	3′ 36″	6	33′ 36″
7	4′ 12″	7	34′ 12″
8	4′ 48″	8	34′ 48″
9	5′ 24″	9	35′ 24″
0°.10	6′	0°.60	36′
1	6′ 36″	1	36′ 36″
2	7′ 12″	2	37′ 12″
3	7′ 48″	3	37′ 48″
4	8′ 24″	4	38′ 24″
0°.15	9′	0°.65	39′
6	9′ 36″	6	39′ 36″
7	10′ 12″	7	40′ 12″
8	10′ 48″	8	40′ 48″
9	11′ 24″	9	41′ 24″
0°.20	12′	0°.70	42′
1	12′ 36″	1	42′ 36″
2	13′ 12″	2	43′ 12″
3	13′ 48″	3	43′ 48″
4	14′ 24″	4	44′ 24″
0°.25	15′	0°.75	45′
6	15′ 36″	6	45′ 36″
7	16′ 12″	7	46′ 12″
8	16′ 48″	8	46′ 48″
9	17′ 24″	9	47′ 24″
0° .30	18′	0°.80	48′
1	18′ 36″	1	48′ 36″
2	19′ 12″	2	49′ 12″
3	19′ 48″	3	49′ 48″
4	20′ 24″	4	50′ 24″
0°.35	21′	0°.85	51′
6	21′ 36″	6	51′ 36″
7	22′ 12″	7	52′ 12″
8	22′ 48″	8	52′ 48″
9	23′ 24″	9	53′ 24″
0°.40	24′	0°.90	54′
1	24′ 36″	1	54′ 36″
2	25′ 12″	2	55′ 12″
3	25′ 48″	3	55′ 48″
4	26′ 24″	4	56′ 24″
0°.45	27′	0°.95	57′
6	27′ 36″	6	57′ 36″
7	28′ 12″	7	58′ 12″
8	28′ 48″	8	58′ 48″
9	29′ 24″	9	59′ 24″
0°.50	30′	1°.00	60′

0°.000	0″.0
1	3″.6
2	7″.2
3	10″.8
4	14″.4
0°.005	18″
6	21″.6
7	25″.2
8	28″.8
9	32″.4
0°.010	36″

Common fractions

8 ths	16 ths	32 nds	64 ths	Exact decimal values
			1	.01 5625
		1	2	.03 125
			3	.04 6875
	1	2	4	.06 25
			5	.07 8125
		3	6	.09 375
			7	.10 9375
1	2	4	8	.12 5
			9	.14 0625
		5	10	.15 625
			11	.17 1875
	3	6	12	.18 75
			13	.20 3125
		7	14	.21 875
			15	.23 4375
2	4	8	16	.25
			17	.26 5625
		9	18	.28 125
			19	.29 6875
	5	10	20	.31 25
			21	.32 8125
		11	22	.34 375
			23	.35 9375
3	6	12	24	.37 5
			25	.39 0625
		13	26	.40 625
			27	.42 1875
	7	14	28	.43 75
			29	.45 3125
		15	30	.46 875
			31	.48 4375
4	8	16	32	.50
			33	.51 5625
		17	34	.53 125
			35	.54 6875
	9	18	36	.56 25
			37	.57 8125
		19	38	.59 375
			39	.60 9375
5	10	20	40	.62 5
			41	.64 0625
		21	42	.65 625
			43	.67 1875
	11	22	44	.68 75
			45	.70 3125
		23	46	.71 875
			47	.73 4375
6	12	24	48	.75
			49	.76 5625
		25	50	.78 125
			51	.79 6875
	13	26	52	.81 25
			53	.82 8125
		27	54	.84 375
			55	.85 9375
7	14	28	56	.87 5
			57	.89 0625
		29	58	.90 625
			59	.92 1875
	15	30	60	.93 75
			61	.95 3125
		31	62	.96 875
			63	.98 4375

1.2 MEASURING UNITS

by John T. Baumeister

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U.S. CUSTOMARY SYSTEM (USCS)

The USCS, often called the "inch-pound system," is the system of units most commonly used for measures of weight and length (Table 1.2.1). The units are identical for practical purposes with the corresponding English units, but the capacity measures differ from those used in the British Commonwealth, the U.S. gallon being defined as 231 cu in and the bushel as 2,150.42 cu in, whereas the corresponding British Imperial units are, respectively, 277.42 cu in and 2,219.36 cu in (1 Imp gal = 1.2 U.S. gal, approx; 1 Imp bu = 1.03 U.S. bu, approx).

Table 1.2.1 U.S. Customary Units

Units of length	
12 inches	= 1 foot
3 feet	= 1 yard
5½ yards = 16½ feet	= 1 rod, pole, or perch
40 poles = 220 yards	= 1 furlong
8 furlongs = 1,760 yards = 5,280 feet	= 1 mile
3 miles	= 1 league
4 inches	= 1 hand
9 inches	= 1 span
Nautical units	
6,076.11549 feet	= 1 international nautical mile
6 feet	= 1 fathom
120 fathoms	= 1 cable length
1 nautical mile per hr	= 1 knot
Surveyor's or Gunter's units	
7.92 inches	= 1 link
100 links = 66 ft = 4 rods	= 1 chain
80 chains	= 1 mile
33⅓ inches	= 1 vara (Texas)
Units of area	
144 square inches	= 1 square foot
9 square feet	= 1 square yard
30¼ square yards	= 1 square rod, pole, or perch
160 square rods = 10 square chains = 43,560 square feet = 5,645 sq varas (Texas)	= 1 acre
640 acres = 1 square mile =	1 "section" of U.S. government-surveyed land
1 circular inch = area of circle 1 inch in diameter	= 0.7854 sq in
1 square inch	= 1.2732 circular inches
1 circular mil	= area of circle 0.001 in in diam
1,000,000 cir mils	= 1 circular inch
Units of volume	
1,728 cubic inches	= 1 cubic foot
231 cubic inches	= 1 gallon
27 cubic feet	= 1 cubic yard
1 cord of wood	= 128 cubic feet
1 perch of masonry	= 16½ to 25 cu ft
Liquid or fluid measurements	
4 gills	= 1 pint
2 pints	= 1 quart
4 quarts	= 1 gallon
7.4805 gallons	= 1 cubic foot

(There is no standard liquid barrel; by trade custom, 1 bbl of petroleum oil, unrefined = 42 gal. The capacity of the common steel barrel used for refined petroleum products and other liquids is 55 gal.)

Apothecaries' liquid measurements	
60 minims	= 1 liquid dram or drachm
8 drams	= 1 liquid ounce
16 ounces	= 1 pint

Water measurements

The miner's inch is a unit of water volume flow no longer used by the Bureau of Reclamation. It is used within particular water districts where its value is defined by statute. Specifically, within many of the states of the West the miner's inch is 1⁄50 cubic foot per second. In others it is equal to 1⁄40 cubic foot per second, while in the state of Colorado, 38.4 miner's inch is equal to 1 cubic-foot per second. In SI units, these correspond to $.32 \times 10^{-6}$ m^3/s, $.409 \times 10^{-6}$ m^3/s, and $.427 \times 10^{-6}$ m^3/s, respectively.

Dry measures	
2 pints	= 1 quart
8 quarts	= 1 peck
4 pecks	= 1 bushel

1 std bbl for fruits and vegetables = 7,056 cu in or 105 dry qt, struck measure

Shipping measures	
1 Register ton	= 100 cu ft
1 U.S. shipping ton	= 40 cu ft
	= 32.14 U.S. bu or 31.14 Imp bu
1 British shipping ton	= 42 cu ft
	= 32.70 Imp bu or 33.75 U.S. bu

Board measurements

(Based on nominal not actual dimensions; see Table 12.2.8)

1 board foot = {144 cu in = volume of board; 1 ft sq and 1 in thick}

The international log rule, based upon ¼ in kerf, is expressed by the formula

$$X = 0.904762(0.22\,D^2 - 0.71\,D)$$

where X is the number of board feet in a 4-ft section of a log and D is the top diam in in. In computing the number of board feet in a log, the taper is taken at ½ in per 4 ft linear, and separate computation is made for each 4-ft section.

Weights
(The grain is the same in all systems.)

Avoirdupois weights	
16 drams = 437.5 grains	= 1 ounce
16 ounces = 7,000 grains	= 1 pound
100 pounds	= 1 cental
2,000 pounds	= 1 short ton
2,240 pounds	= 1 long ton
1 std lime bbl, small	= 180 lb net
1 std lime bbl, large	= 280 lb net
Also (in Great Britain):	
14 pounds	= 1 stone
2 stone = 28 pounds	= 1 quarter
4 quarters = 112 pounds	= 1 hundredweight (cwt)
20 hundredweight	= 1 long ton
Troy weights	
24 grains	= 1 pennyweight (dwt)
20 pennyweights = 480 grains	= 1 ounce
12 ounces = 5,760 grains	= 1 pound

1 assay ton = 29,167 milligrams, or as many milligrams as there are troy ounces in a ton of 2,000 lb avoirdupois. Consequently, the number of milligrams of precious metal yielded by an assay ton of ore gives directly the number of troy ounces that would be obtained from a ton of 2,000 lb avoirdupois.

Apothecaries' weights	
20 grains	= 1 scruple ℈
3 scruples = 60 grains	= 1 dram ʒ
8 drams	= 1 ounce ℥
12 ounces = 5,760 grains	= 1 pound

Weight for precious stones
1 carat = 200 milligrams
(Used by almost all important nations)

Circular measures	
60 seconds	= 1 minute
60 minutes	= 1 degree
90 degrees	= 1 quadrant
360 degrees	= circumference
57.2957795 degrees (= 57°17′44.806″)	= 1 radian (or angle having arc of length equal to radius)

METRIC SYSTEM

In the United States the name **"metric system"** of length and mass units is commonly taken to refer to a system that was developed in France about 1800. The unit of length was equal to 1/10,000,000 of a quarter meridian (north pole to equator) and named the **metre.** A cube 1/10th metre on a side was the **litre,** the unit of volume. The mass of water filling this cube was the **kilogram,** or standard of mass; i.e., 1 litre of water = 1 kilogram of mass. Metal bars and weights were constructed conforming to these prescriptions for the metre and kilogram. One bar and one weight were selected to be the primary representations. The kilogram and the metre are now defined independently, and the litre, although for many years defined as the volume of a kilogram of water at the temperature of its maximum density, 4°C, and under a pressure of 76 cm of mercury, is now equal to 1 cubic decimeter.

In 1866, the U.S. Congress formally recognized metric units as a legal system, thereby making their use permissible in the United States. In 1893, the Office of Weights and Measures (now the National Bureau of Standards), by executive order, fixed the values of the U.S. yard and pound in terms of the meter and kilogram, respectively, as 1 yard = 3,600/3,937 m; and 1 lb = 0.453 592 4277 kg. By agreement in 1959 among the **national standards** laboratories of the **English-speaking nations,** the relations in use now are: 1 yd = 0.9144 m, whence 1 in = 25.4 mm exactly; and 1 lb = 0.453 592 37 kg, or 1 lb = 453.59 g (nearly).

THE INTERNATIONAL SYSTEM OF UNITS (SI)

In October 1960, the Eleventh General (International) Conference on Weights and Measures redefined some of the original metric units and expanded the system to include other physical and engineering units. This expanded system is called, in French, **Le Système International d'Unités** (abbreviated **SI**), and in English, **The International System of Units.**

The **Metric Conversion Act of 1975** codifies the voluntary conversion of the U.S. to the SI system. It is expected that in time all units in the United States will be in SI form. For this reason, additional tables of units, prefixes, equivalents, and conversion factors are included below (Tables 1.2.2 and 1.2.3).

SI consists of **seven base** units, **two supplementary** units, a series of **derived units** consistent with the base and supplementary units, and a series of approved prefixes for the formation of multiples and submultiples of the various units (see Tables 1.2.2 and 1.2.3). Multiple and submultiple prefixes in steps of 1,000 are recommended. (See ASTM E380-91a for further details.)

Base and **supplementary units** are **defined** [NIST Spec. Pub. 330 (2001)] as:

Metre The metre is defined as the length of path traveled by light in a vacuum during a time interval 1/299 792 458 of a second.

Kilogram The kilogram is the unit of mass; it is equal to the mass of the international prototype of the kilogram.

Second The second is the duration of 9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium 133 atom.

Ampere The ampere is that constant current which, if maintained in two straight parallel conductors of infinite length, of negligible cross section, and placed 1 metre apart in vacuum, would produce between these conductors a force equal to 2×10^{-7} newton per metre of length.

Kelvin The kelvin, unit of thermodynamic temperature, is the fraction 1/273.16 of the thermodynamic temperature of the triple point of water.

Mole The mole is the amount of substance of a system which contains as many elementary entities as there are atoms in 0.012 kilogram of carbon 12. (When the mole is used, the elementary entities must be specified and may be atoms, molecules, ions, electrons, other particles, or specified groups of such particles.)

Candela The candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540×10^{12} hertz and that has a radiant intensity in that direction of 1/683 watt per steradian.

Radian The unit of measure of a plane angle with its vertex at the center of a circle and subtended by an arc equal in length to the radius.

Steradian The unit of measure of a solid angle with its vertex at the center of a sphere and enclosing an area of the spherical surface equal to that of a square with sides equal in length to the radius.

SI conversion factors are listed in Table 1.2.4 alphabetically (adapted from ASTM E380-91a, "Standard Practice for Use of the International System of Units (SI) (the Modernized Metric System)." Conversion factors are written as a number greater than one and less than ten with six or fewer decimal places. This number is followed by the letter E (for exponent), a plus or minus symbol, and two digits which indicate the power of 10 by which the number must be multiplied to obtain the correct value. For example:

$$3.523\ 907\ \text{E} - 02 \text{ is } 3.523\ 907 \times 10^{-2} \text{ or } 0.035\ 239\ 07$$

An asterisk (*) after the sixth decimal place indicates that the conversion factor is exact and that all subsequent digits are zero. All other conversion factors have been rounded off.

Table 1.2.2 SI Units

Quantity	Unit	SI symbol	Formula
	Base units*		
Length	metre	m	
Mass	kilogram	kg	
Time	second	s	
Electric current	ampere	A	
Thermodynamic temperature	kelvin	K	
Amount of substance	mole	mol	
Luminous intensity	candela	cd	
	Supplementary units*		
Plane angle	radian	rad	
Solid angle	steradian	sr	
	Derived units*		
Acceleration	metre per second squared		m/s^2
Activity (of a radioactive source)	disintegration per second		(disintegration)/s
Angular acceleration	radian per second squared		rad/s^2
Angular velocity	radian per second		rad/s
Area	square metre		m^2
Density	kilogram per cubic metre		kg/m^3
Electric capacitance	farad	F	A · s/V
Electrical conductance	siemens	S	A/V
Electric field strength	volt per metre		V/m
Electric inductance	henry	H	V · s/A
Electric potential difference	volt	V	W/A
Electric resistance	ohm	Ω	V/A
Electromotive force	volt	V	W/A
Energy	joule	J	N · m
Entropy	joule per kelvin		J/K
Force	newton	N	kg · m/s^2
Frequency	hertz	Hz	1/s
Illuminance	lux	lx	lm/m^2
Luminance	candela per square metre		cd/m^2
Luminous flux	lumen	lm	cd · sr
Magnetic field strength	ampere per metre		A/m
Magnetic flux	weber	Wb	V · s
Magnetic flux density	tesla	T	Wb/m^2
Magnetic potential difference	ampere	A	
Power	watt	W	J/s
Pressure	pascal	Pa	N/m^2
Quantity of electricity	coulomb	C	A · s
Quantity of heat	joule	J	N · m
Radiant intensity	watt per steradian		W/sr
Specific heat capacity	joule per kilogram-kelvin		J/(kg · K)
Stress	pascal	Pa	N/m^2
Thermal conductivity	watt per metre-kelvin		W/(m · K)
Velocity	metre per second		m/s
Viscosity, dynamic	pascal-second		Pa · s
Viscosity, kinematic	square metre per second		m^2/s
Voltage	volt	V	W/A
Volume	cubic metre		m^3
Wave number	reciprocal metre		1/m
Work	joule	J	N · m
	Units in use with the SI†		
Time	minute	min	1 min = 60 s
	hour	h	1 h = 60 min = 3,600 s
	day	d	1 d = 24 h = 86,400 s
Plane angle	degree	°	$1^\circ = \pi/180$ rad
	minute‡	′	$1' = (1/60)^\circ = (\pi/10{,}800)$ rad
	second‡	″	$1'' = (1/60)' = (\pi/648{,}000)$ rad
Volume	litre	L	1 L = 1 dm^3 = 10^{-3} m^3
Mass	metric ton	t	1 t = 10^3 kg
	unified atomic mass unit§	u	1 u = $1.660\ 54 \times 10^{-27}$ kg
Energy	electronvolt§	eV	1 eV = $1.602\ 18 \times 10^{-19}$ J

* ASTM E380-91a.
† These units are not part of SI, but their use is both so widespread and important that the International Committee for Weights and Measures in 1969 recognized their continued use with the SI (see NIST Spec. Pub. 330).
‡ Use discouraged, except for special fields such as cartography.
§ Values in SI units obtained experimentally. These units are to be used in specialized fields only.

Table 1.2.3 SI Prefixes*

Multiplication factors	Prefix	SI symbol
1 000 000 000 000 000 000 000 000 = 10^{24}	yotta	Y
1 000 000 000 000 000 000 000 = 10^{21}	zetta	Z
1 000 000 000 000 000 000 = 10^{18}	exa	E
1 000 000 000 000 000 = 10^{15}	peta	P
1 000 000 000 000 = 10^{12}	tera	T
1 000 000 000 = 10^{9}	giga	G
1 000 000 = 10^{6}	mega	M
1 000 = 10^{3}	kilo	k
100 = 10^{2}	hecto†	h
10 = 10^{1}	deka†	da
0.1 = 10^{-1}	deci†	d
0.01 = 10^{-2}	centi†	c
0.001 = 10^{-3}	milli	m
0.000 001 = 10^{-6}	micro	μ
0.000 000 001 = 10^{-9}	nano	n
0.000 000 000 001 = 10^{-12}	pico	P
0.000 000 000 000 001 = 10^{-15}	femto	f
0.000 000 000 000 000 001 = 10^{-18}	atto	a
0.000 000 000 000 000 000 001 = 10^{-21}	zepto	z
0.000 000 000 000 000 000 000 001 = 10^{-24}	yocto	y

* ANSI/IEEE Std 268-1992.
† To be avoided where practical.

Table 1.2.4 SI Conversion Factors

To convert from	to	Multiply by
abampere	ampere (A)	1.000 000*E+01
abcoulomb	coulomb (C)	1.000 000*E+01
abfarad	farad (F)	1.000 000*E+09
abhenry	henry (H)	1.000 000*E−09
abmho	siemens (S)	1.000 000*E+09
abohm	ohm (Ω)	1.000 000*E−09
abvolt	volt (V)	1.000 000*E−08
acre-foot (U.S. survey)[a]	metre^3 (m^3)	1.233 489 E+03
acre (U.S. survey)[a]	metre^2 (m^2)	4.046 873 E+03
ampere, international U.S. (A_{INT-US})[b]	ampere (A)	9.998 43 E−01
ampere, U.S. legal 1948 (A_{US-48})	ampere (A)	1.000 008 E+00
ampere-hour	coulomb (C)	3.600 000*E+03
angstrom	metre (m)	1.000 000*E−10
are	metre^2 (m^2)	1.000 000*E+02
astronomical unit	metre (m)	1.495 98 E+11
atmosphere (normal)	pascal (Pa)	1.013 25 E+05
atmosphere (technical = 1 kg_f/cm^2)	pascal (Pa)	9.806 650*E+04
bar	pascal (Pa)	1.000 000*E+05
barn	metre^2 (m^2)	1.000 000*E−28
barrel (for crude petroleum, 42 gal)	metre^3 (m^3)	1.589 873 E−01
board foot	metre^3 (m^3)	2.359 737 E−03
British thermal unit (International Table)[c]	joule (J)	1.055 056 E+03
British thermal unit (mean)	joule (J)	1.055 87 E+03
British thermal unit (thermochemical)	joule (J)	1.054 350 E+03
British thermal unit (39°F)	joule (J)	1.059 67 E+03
British thermal unit (59°F)	joule (J)	1.054 80 E+03
British thermal unit (60°F)	joule (J)	1.054 68 E+03
Btu (thermochemical)/foot^2-second	watt/metre^2 (W/m^2)	1.134 893 E+04
Btu (thermochemical)/foot^2-minute	watt/metre^2 (W/m^2)	1.891 489 E+02
Btu (thermochemical)/foot^2-hour	watt/metre^2 (W/m^2)	3.152 481 E+00
Btu (thermochemical)/inch^2-second	watt/metre^2 (W/m^2)	1.634 246 E+06
Btu (thermochemical) · in/s · ft^2 · °F (*k*, thermal conductivity)	watt/metre-kelvin (W/m · K)	5.188 732 E+02
Btu (International Table) · in/s · ft^2 · °F (*k*, thermal conductivity)	watt/metre-kelvin (W/m · K)	5.192 204 E+02
Btu (thermochemical) · in/h · ft^2 · °F (*k*, thermal conductivity)	watt/metre-kelvin (W/m · K)	1.441 314 E−01
Btu (International Table) · in/h · ft^2 · °F (*k*, thermal conductivity)	watt/metre-kelvin (W/m · K)	1.442 279 E−01
Btu (International Table)/ft^2	joule/metre^2 (J/m^2)	1.135 653 E+04
Btu (thermochemical)/ft^2	joule/metre^2 (J/m^2)	1.134 893 E+04
Btu (International Table)/h · ft^2 · °F (*C*, thermal conductance)	watt/metre^2-kelvin (W/m^2 · K)	5.678 263 E+00
Btu (thermochemical)/h · ft^2 · °F (*C*, thermal conductance)	watt/metre^2-kelvin (W/m^2 · K)	5.674 466 E+00
Btu (International Table)/pound-mass	joule/kilogram (J/kg)	2.326 000*E+03

Table 1.2.4 SI Conversion Factors (*Continued*)

To convert from	to	Multiply by
Btu (thermochemical)/pound-mass	joule/kilogram (J/kg)	2.324 444 E+03
Btu (International Table)/lbm · °F (*c*, heat capacity)	joule/kilogram-kelvin (J/kg · K)	4.186 800*E+03
Btu (thermochemical)/lbm · °F (*c*, heat capacity)	joule/kilogram-kelvin (J/kg · K)	4.184 000*E+03
Btu (International Table)/s · ft^2 · °F	watt/metre^2-kelvin (W/m^2 · K)	2.044 175 E+04
Btu (thermochemical)/s · ft^2 · °F	watt/metre^2-kelvin (W/m^2 · K)	2.042 808 E+04
Btu (International Table)/hour	watt (W)	2.930 711 E−01
Btu (thermochemical)/second	watt (W)	1.054 350 E+03
Btu (thermochemical)/minute	watt (W)	1.757 250 E+01
Btu (thermochemical)/hour	watt (W)	2.928 751 E−01
bushel (U.S.)	metre^3 (m^3)	3.523 907 E−02
calorie (International Table)	joule (J)	4.186 800*E+00
calorie (mean)	joule (J)	4.190 02 E+00
calorie (thermochemical)	joule (J)	4.184 000*E+00
calorie (15°C)	joule (J)	4.185 80 E+00
calorie (20°C)	joule (J)	4.181 90 E+00
calorie (kilogram, International Table)	joule (J)	4.186 800*E+03
calorie (kilogram, mean)	joule (J)	4.190 02 E+03
calorie (kilogram, thermochemical)	joule (J)	4.184 000*E+03
calorie (thermochemical)/centimetre^2-minute	watt/metre^2 (W/m^2)	6.973 333 E+02
cal (thermochemical)/cm^2	joule/metre^2 (J/m^2)	4.184 000*E+04
cal (thermochemical)/cm^2 · s	watt/metre^2 (W/m^2)	4.184 000*E+04
cal (thermochemical)/cm · s · °C	watt/metre-kelvin (W/m · K)	4.184 000*E+02
cal (International Table)/g	joule/kilogram (J/kg)	4.186 800*E+03
cal (International Table)/g · °C	joule/kilogram-kelvin (J/kg · K)	4.186 800*E+03
cal (thermochemical)/g	joule/kilogram (J/kg)	4.184 000*E+03
cal (thermochemical)/g · °C	joule/kilogram-kelvin (J/kg · K)	4.184 000*E+03
calorie (thermochemical)/second	watt (W)	4.184 000*E+00
calorie (thermochemical)/minute	watt (W)	6.973 333 E−02
carat (metric)	kilogram (kg)	2.000 000*E−04
centimetre of mercury (0°C)	pascal (Pa)	1.333 22 E+03
centimetre of water (4°C)	pascal (Pa)	9.806 38 E+01
centipoise	pascal-second (Pa · s)	1.000 000*E−03
centistokes	metre^2/second (m^2/s)	1.000 000*E−06
chain (engineer or ramden)	meter (m)	3.048* E+01
chain (surveyor or gunter)	meter (m)	2.011 684 E+01
circular mil	metre^2 (m^2)	5.067 075 E−10
cord	metre^3 (m^3)	3.624 556 E+00
coulomb, international U.S. (C_{INT-US})[b]	coulomb (C)	9.998 43 E−01
coulomb, U.S. legal 1948 (C_{US-48})	coulomb (C)	1.000 008 E+00
cup	metre^3 (m^3)	2.365 882 E−04
curie	becquerel (Bq)	3.700 000*E+10
day (mean solar)	second (s)	8.640 000 E+04
day (sidereal)	second (s)	8.616 409 E+04
degree (angle)	radian (rad)	1.745 329 E−02
degree Celsius	kelvin (K)	$t_K = t_{°C} + 273.15$
degree centigrade	kelvin (K)	$t_K = t_{°C} + 273.15$
degree Fahrenheit	degree Celsius	$t_{°C} = (t_{°F} - 32)/1.8$
degree Fahrenheit	kelvin (K)	$t_K = (t_{°F} + 459.67)/1.8$
deg F · h · ft^2/Btu (thermochemical) (*R*, thermal resistance)	kelvin-metre^2/watt (K · m^2/W)	1.762 280 E−01
deg F · h · ft^2/Btu (International Table) (*R*, thermal resistance)	kelvin-metre^2/watt (K · m^2/ W)	1.761 102 E−01
degree Rankine	kelvin (K)	$t_K = t_{°R}/1.8$
dram (avoirdupois)	kilogram (kg)	1.771 845 E−03
dram (troy or apothecary)	kilogram (kg)	3.887 934 E−03
dram (U.S. fluid)	kilogram (kg)	3.696 691 E−06
dyne	newton (N)	1.000 000*E−05
dyne-centimetre	newton-metre (N · m)	1.000 000*E−07
dyne-centimetre^2	pascal (Pa)	1.000 000*E−01
electron volt	joule (J)	1.602 18 E−19
EMU of capacitance	farad (F)	1.000 000*E+09
EMU of current	ampere (A)	1.000 000*E+01
EMU of electric potential	volt (V)	1.000 000*E−08
EMU of inductance	henry (H)	1.000 000*E−09
EMU of resistance	ohm (Ω)	1.000 000*E−09
ESU of capacitance	farad (F)	1.112 650 E−12
ESU of current	ampere (A)	3.335 6 E−10
ESU of electric potential	volt (V)	2.997 9 E+02
ESU of inductance	henry (H)	8.987 552 E+11

Table 1.2.4 SI Conversion Factors (*Continued*)

To convert from	to	Multiply by
ESU of resistance	ohm (Ω)	8.987 552 E+11
erg	joule (J)	1.000 000*E−07
erg/centimetre^2-second	watt/metre^2 (W/m^2)	1.000 000*E−03
erg/second	watt (W)	1.000 000*E−07
farad, international U.S. (F_{INT-US})	farad (F)	9.995 05 E−01
faraday (based on carbon 12)	coulomb (C)	9.648 531 E+04
faraday (chemical)	coulomb (C)	9.649 57 E+04
faraday (physical)	coulomb (C)	9.652 19 E+04
fathom (U.S. survey)[a]	metre (m)	1.828 804 E+00
fermi (femtometer)	metre (m)	1.000 000*E−15
fluid ounce (U.S.)	metre^3 (m^3)	2.957 353 E−05
foot	metre (m)	3.048 000*E−01
foot (U.S. survey)[a]	metre (m)	3.048 006 E−01
foot^3/minute	metre^3/second (m^3/s)	4.719 474 E−04
foot^3/second	metre^3/second (m^3/s)	2.831 685 E−02
foot^3 (volume and section modulus)	metre^3 (m^3)	2.831 685 E−02
foot^2	metre^2 (m^2)	9.290 304*E−02
foot^4 (moment of section)[d]	metre^4 (m^4)	8.630 975 E−03
foot/hour	metre/second (m/s)	8.466 667 E−05
foot/minute	metre/second (m/s)	5.080 000*E−03
foot/second	metre/second (m/s)	3.048 000*E−01
foot^2/second	metre^2/second (m^2/s)	9.290 304*E−02
foot of water (39.2°F)	pascal (Pa)	2.988 98 E+03
footcandle	lumen/metre^2 (lm/m^2)	1.076 391 E+01
footcandle	lux (lx)	1.076 391 E+01
footlambert	candela/metre^2 (cd/m^2)	3.426 259 E+00
foot-pound-force	joule (J)	1.355 818 E+00
foot-pound-force/hour	watt (W)	3.766 161 E−04
foot-pound-force/minute	watt (W)	2.259 697 E−02
foot-pound-force/second	watt (W)	1.355 818 E+00
foot-poundal	joule (J)	4.214 011 E−02
ft^2/h (thermal diffusivity)	metre^2/second (m^2/s)	2.580 640*E−05
foot/second^2	metre/second^2 (m/s^2)	3.048 000*E−01
free fall, standard	metre/second^2 (m/s^2)	9.806 650*E+00
furlong	metre (m)	2.011 68 *E+02
gal	metre/second^2 (m/s^2)	1.000 000*E−02
gallon (Canadian liquid)	metre^3 (m^3)	4.546 090 E−03
gallon (U.K. liquid)	metre^3 (m^3)	4.546 092 E−03
gallon (U.S. dry)	metre^3 (m^3)	4.404 884 E−03
gallon (U.S. liquid)	metre^3 (m^3)	3.785 412 E−03
gallon (U.S. liquid)/day	metre^3/second (m^3/s)	4.381 264 E−08
gallon (U.S. liquid)/minute	metre^3/second (m^3/s)	6.309 020 E−05
gamma	tesla (T)	1.000 000*E−09
gauss	tesla (T)	1.000 000*E−04
gilbert	ampere-turn	7.957 747 E−01
gill (U.K.)	metre^3 (m^3)	1.420 653 E−04
gill (U.S.)	metre^3 (m^3)	1.182 941 E−04
grade	degree (angular)	9.000 000*E−01
grade	radian (rad)	1.570 796 E−02
grain (1/7,000 lbm avoirdupois)	kilogram (kg)	6.479 891*E−05
gram	kilogram (kg)	1.000 000*E−03
gram/centimetre^3	kilogram/metre^3 (kg/m^3)	1.000 000*E+03
gram-force/centimetre^2	pascal (Pa)	9.806 650*E+01
hectare	metre^2 (m^2)	1.000 000*E+04
henry, international U.S. (H_{INT-US})	henry (H)	1.000 495 E+00
hogshead (U.S.)	metre^3 (m^3)	2.384 809 E−01
horsepower (550 ft · lbf/s)	watt (W)	7.456 999 E+02
horsepower (boiler)	watt (W)	9.809 50 E+03
horsepower (electric)	watt (W)	7.460 000*E+02
horsepower (metric)	watt (W)	7.354 99 E+02
horsepower (water)	watt (W)	7.460 43 E+02
horsepower (U.K.)	watt (W)	7.457 0 E+02
hour (mean solar)	second (s)	3.600 000*E+03
hour (sidereal)	second (s)	3.590 170 E+03
hundredweight (long)	kilogram (kg)	5.080 235 E+01
hundredweight (short)	kilogram (kg)	4.535 924 E+01
inch	metre (m)	2.540 000*E−02
inch^2	metre^2 (m^2)	6.451 600*E−04
inch^3 (volume and section modulus)	metre^3 (m^3)	1.638 706 E−05
inch^3/minute	metre^3/second (m^3/s)	2.731 177 E−07
inch^4 (moment of section)[d]	metre^4 (m^4)	4.162 314 E−07
inch/second	metre/second (m/s)	2.540 000*E−02
inch of mercury (32°F)	pascal (Pa)	3.386 38 E+03

Table 1.2.4 SI Conversion Factors (*Continued*)

To convert from	to	Multiply by
inch of mercury (60°F)	pascal (Pa)	3.376 85 E+03
inch of water (39.2°F)	pascal (Pa)	2.490 82 E+02
inch of water (60°F)	pascal (Pa)	2.488 4 E+02
inch/second^2	metre/second^2 (m/s^2)	2.540 000*E−02
joule, international U.S. (J_{INT-US})[b]	joule (J)	1.000 182 E+00
joule, U.S. legal 1948 (J_{US-48})	joule (J)	1.000 017 E+00
kayser	1/metre (1/m)	1.000 000*E+02
kelvin	degree Celsius	$t_C = t_K - 273.15$
kilocalorie (thermochemical)/minute	watt (W)	6.973 333 E+01
kilocalorie (thermochemical)/second	watt (W)	4.184 000*E+03
kilogram-force (kgf)	newton (N)	9.806 650*E+00
kilogram-force-metre	newton-metre (N · m)	9.806 650*E+00
kilogram-force-second^2/metre (mass)	kilogram (kg)	9.806 650*E+00
kilogram-force/centimetre^2	pascal (Pa)	9.806 650*E+04
kilogram-force/metre^3	pascal (Pa)	9.806 650*E+00
kilogram-force/millimetre^2	pascal (Pa)	9.806 650*E+06
kilogram-mass	kilogram (kg)	1.000 000*E+00
kilometre/hour	metre/second (m/s)	2.777 778 E−01
kilopond	newton (N)	9.806 650*E+00
kilowatt hour	joule (J)	3.600 000*E+06
kilowatt hour, international U.S. (kWh_{INT-US})[b]	joule (J)	3.600 655 E+06
kilowatt hour, U.S. legal 1948 (kWh_{US-48})	joule (J)	3.600 061 E+06
kip (1,000 lbf)	newton (N)	4.448 222 E+03
kip/inch^2 (ksi)	pascal (Pa)	6.894 757 E+06
knot (international)	metre/second (m/s)	5.144 444 E−01
lambert	candela/metre^2 (cd/m^2)	3.183 099 E+03
langley	joule/metre^2 (J/m^2)	4.184 000*E+04
league, nautical (international and U.S.)	metre (m)	5.556 000*E+03
league (U.S. survey)[a]	metre (m)	4.828 041 E+03
league, nautical (U.K.)	metre (m)	5.559 552*E+03
light year (365.2425 days)	metre (m)	9.460 54 E+15
link (engineer or ramden)	metre (m)	3.048* E−01
link (surveyor or gunter)	metre (m)	2.011 68* E−01
litre[e]	metre^3 (m^3)	1.000 000*E−03
lux	lumen/metre^2 (lm/m^2)	1.000 000*E+00
maxwell	weber (Wb)	1.000 000*E−08
mho	siemens (S)	1.000 000*E+00
microinch	metre (m)	2.540 000*E−08
micron (micrometre)	metre (m)	1.000 000*E−06
mil	metre (m)	2.540 000*E−05
mile, nautical (international and U.S.)	metre (m)	1.852 000*E+03
mile, nautical (U.K.)	metre (m)	1.853 184*E+03
mile (international)	metre (m)	1.609 344*E+03
mile (U.S. survey)[a]	metre (m)	1.609 347 E+03
mile^2 (international)	metre^2 (m^2)	2.589 988 E+06
mile^2 (U.S. survey)[a]	metre^2 (m^2)	2.589 998 E+06
mile/hour (international)	metre/second (m/s)	4.470 400*E−01
mile/hour (international)	kilometre/hour	1.609 344*E+00
millimetre of mercury (0°C)	pascal (Pa)	1.333 224 E+02
minute (angle)	radian (rad)	2.908 882 E−04
minute (mean solar)	second (s)	6.000 000 E+01
minute (sidereal)	second (s)	5.983 617 E+01
month (mean calendar)	second (s)	2.268 000 E+06
oersted	ampere/metre (A/m)	7.957 747 E+01
ohm, international U.S. (Ω_{INT-US})	ohm (Ω)	1.000 495 E+00
ohm-centimetre	ohm-metre (Ω · m)	1.000 000*E−02
ounce-force (avoirdupois)	newton (N)	2.780 139 E−01
ounce-force-inch	newton-metre (N · m)	7.061 552 E−03
ounce-mass (avoirdupois)	kilogram (kg)	2.834 952 E−02
ounce-mass (troy or apothecary)	kilogram (kg)	3.110 348 E−02
ounce-mass/yard^2	kilogram/metre^2 (kg/m^2)	3.390 575 E−02
ounce (avoirdupois)(mass)/inch^3	kilogram/metre^3 (kg/m^3)	1.729 994 E+03
ounce (U.K. fluid)	metre^3 (m^3)	2.841 306 E−05
ounce (U.S. fluid)	metre^3 (m^3)	2.957 353 E−05
parsec	metre (m)	3.085 678 E+16
peck (U.S.)	metre^3 (m^3)	8.809 768 E−03
pennyweight	kilogram (kg)	1.555 174 E−03
perm (0°C)	kilogram/pascal-second-metre^2 (kg/Pa · s · m^2)	5.721 35 E−11
perm (23 °C)	kilogram/pascal-second-metre^2 (kg/Pa · s · m^2)	5.745 25 E−11

Table 1.2.4 SI Conversion Factors (*Continued*)

To convert from	to	Multiply by
perm-inch (0°C)	kilogram/pascal-second-metre (kg/Pa · s · m)	1.453 22 E−12
perm-inch (23°C)	kilogram/pascal-second-metre (kg/Pa · s · m)	1.459 29 E−12
phot	lumen/metre^2 (lm/m^2)	1.000 000*E+04
pica (printer's)	metre (m)	4.217 518 E−03
pint (U.S. dry)	metre^3 (m^3)	5.506 105 E−04
pint (U.S. liquid)	metre^3 (m^3)	4.731 765 E−04
point (printer's)	metre	3.514 598 E−04
poise (absolute viscosity)	pascal-second (Pa · s)	1.000 000*E−01
poundal	newton (N)	1.382 550 E−01
poundal/foot^2	pascal (Pa)	1.488 164 E+00
poundal-second/foot^2	pascal-second (Pa · s)	1.488 164 E+00
pound-force (lbf avoirdupois)	newton (N)	4.448 222 E+00
pound-force-inch	newton-metre (N · m)	1.129 848 E−01
pound-force-foot	newton-metre (N · m)	1.355 818 E+00
pound-force-foot/inch	newton-metre/metre (N · m/m)	5.337 866 E+01
pound-force-inch/inch	newton-metre/metre (N · m/m)	4.448 222 E+00
pound-force/inch	newton/metre (N/m)	1.751 268 E+02
pound-force/foot	newton/metre (N/m)	1.459 390 E+01
pound-force/foot^2	pascal (Pa)	4.788 026 E+01
pound-force/inch^2 (psi)	pascal (Pa)	6.894 757 E+03
pound-force-second/foot^2	pascal-second (Pa · s)	4.788 026 E+01
pound-mass (lbm avoirdupois)	kilogram (kg)	4.535 924 E−01
pound-mass (troy or apothecary)	kilogram (kg)	3.732 417 E−01
pound-mass-foot^2 (moment of inertia)	kilogram-metre^2 (kg · m^2)	4.214 011 E−02
pound-mass-inch^2 (moment of inertia)	kilogram-metre^2 (kg · m^2)	2.926 397 E−04
pound-mass/foot^2	kilogram/metre^2 (kg/m^2)	4.882 428 E+00
pound-mass/second	kilogram/second (kg/s)	4.535 924 E−01
pound-mass/minute	kilogram/second (kg/s)	7.559 873 E−03
pound-mass/foot^3	kilogram/metre^3 (kg/m^3)	1.601 846 E+01
pound-mass/inch^3	kilogram/metre^3 (kg/m^3)	2.767 990 E+04
pound-mass/gallon (U.K. liquid)	kilogram/metre^3 (kg/m^3)	9.977 637 E+01
pound-mass/gallon (U.S. liquid)	kilogram/metre^3 (kg/m^3)	1.198 264 E+02
pound-mass/foot-second	pascal-second (Pa · s)	1.488 164 E+00
quart (U.S. dry)	metre^3 (m^3)	1.101 221 E−03
quart (U.S. liquid)	metre^3 (m^3)	9.463 529 E−04
rad (radiation dose absorbed)	gray (Gy)	1.000 000*E−02
rem (dose equivalent)	sievert (Sv)	1.000 000*E−02
rhe	metre^2/newton-second (m^2/N · s)	1.000 000*E+01
rod (U.S. survey)[a]	metre (m)	5.029 210 E+00
roentgen	coulomb/kilogram (C/kg)	2.580 000*E−04
second (angle)	radian (rad)	4.848 137 E−06
second (sidereal)	second (s)	9.972 696 E−01
section (U.S. survey)[a]	metre^2 (m^2)	2.589 998 E+06
shake	second (s)	1.000 000*E−08
slug	kilogram (kg)	1.459 390 E+01
slug/foot^3	kilogram/metre^3 (kg/m^3)	5.153 788 E+02
slug/foot-second	pascal-second (Pa · s)	4.788 026 E+01
statampere	ampere (A)	3.335 641 E−10
statcoulomb	coulomb (C)	3.335 641 E−10
statfarad	farad (F)	1.112 650 E−12
stathenry	henry (H)	8.987 552 E+11
statmho	siemens (S)	1.112 650 E−12
statohm	ohm (Ω)	8.987 552 E+11
statvolt	volt (V)	2.997 925 E+02
stere	metre^3 (m^3)	1.000 000*E+00
stilb	candela/metre^2 (cd/m^2)	1.000 000*E+04
stokes (kinematic viscosity)	metre^2/second (m^2/s)	1.000 000*E−04
tablespoon	metre^3 (m^3)	1.478 676 E−05
teaspoon	metre^3 (m^3)	4.928 922 E−06
ton (assay)	kilogram (kg)	2.916 667 E−02
ton (long, 2,240 lbm)	kilogram (kg)	1.016 047 E+03
ton (metric)	kilogram (kg)	1.000 000*E+03
ton (nuclear equivalent of TNT)	joule (J)	4.184 000*E+09
ton (register)	metre^3 (m^3)	2.831 685 E+00
ton (short, 2,000 lbm)	kilogram (kg)	9.071 847 E+02
ton (short, mass)/hour	kilogram/second (kg/s)	2.519 958 E−01
ton (long, mass)/yard^3	kilogram/metre^3 (kg/m^3)	1.328 939 E+03
tonne	kilogram (kg)	1.000 000*E+03
torr (mm Hg, 0°C)	pascal (Pa)	1.333 22 E+02
township (U.S. survey)[a]	metre^2 (m^2)	9.323 994 E+07
unit pole	weber (Wb)	1.256 637 E−07

Table 1.2.4 SI Conversion Factors (*Continued*)

To convert from	to	Multiply by
volt, international U.S. (V_{INT-US})[b]	volt (V)	1.000 338 E+00
volt, U.S. legal 1948 (V_{US-48})	volt (V)	1.000 008 E+00
watt, international U.S. (W_{INT-US})[b]	watt (W)	1.000 182 E+00
watt, U.S. legal 1948 (W_{US-48})	watt (W)	1.000 017 E+00
watt/centimetre^2	watt/metre^2 (W/m^2)	1.000 000*E+04
watt-hour	joule (J)	3.600 000*E+03
watt-second	joule (J)	1.000 000*E+00
yard	metre (m)	9.144 000*E−01
yard^2	metre^2 (m^2)	8.361 274 E−01
yard^3	metre^3 (m^3)	7.645 549 E−01
yard^3/minute	metre^3/second (m^3/s)	1.274 258 E−02
year (calendar)	second (s)	3.153 600*E+07
year (sidereal)	second (s)	3.155 815 E+07
year (tropical)	second (s)	3.155 693 E+07

[a] Based on the U.S. survey foot (1 ft = 1,200/3,937 m).
[b] In 1948 a new international agreement was reached on absolute electrical units, which changed the value of the volt used in this country by about 300 parts per million. Again in 1969 a new base of reference was internationally adopted making a further change of 8.4 parts per million. These changes (and also changes in ampere, joule, watt, coulomb) require careful terminology and conversion factors for exact use of old information. Terms used in this guide are:
Volt as used prior to January 1948—volt, international U.S. (V_{INT-US})
Volt as used between January 1948 and January 1969—volt, U.S. legal 1948 (V_{INT-48})
Volt as used since January 1969—volt (V)
Identical treatment is given the ampere, coulomb, watt, and joule.
[c] This value was adopted in 1956. Some of the older International Tables use the value 1.055 04 E+03. The exact conversion factor is 1.055 055 852 62*E+03.
[d] Moment of inertia of a plane section about a specified axis.
[e] In 1964, the General Conference on Weights and Measures adopted the name "litre" as a special name for the cubic decimetre. Prior to this decision the litre differed slightly (previous value, 1.000028 dm^3), and in expression of precision, volume measurement, this fact must be kept in mind.

SYSTEMS OF UNITS

The principal units of interest to mechanical engineers can be derived from three base units which are considered to be dimensionally independent of each other. The British "gravitational system," in common use in the United States, uses units of **length, force,** and **time** as base units and is also called the "foot-pound-second system." The metric system, on the other hand, is based on the meter, kilogram, and second, units of **length, mass,** and **time,** and is often designated as the "MKS system." During the nineteenth century a metric "gravitational system," based on a kilogram-force (also called a "kilopond") came into general use. With the development of the International System of Units (SI), based as it is on the original metric system for mechanical units, and the general requirements by members of the European Community that only SI units be used, it is anticipated that the kilogram-force will fall into disuse to be replaced by the newton, the SI unit of force. Table 1.2.5 gives the base units of four systems with the corresponding derived unit given in parentheses.

In the definitions given below, the "standard kilogram body" refers to the international kilogram prototype, a platinum-iridium cylinder kept in the International Bureau of Weights and Measures in Sèvres, just outside Paris. The "standard pound body" is related to the kilogram by a precise numerical factor: 1 lb = 0.453 592 37 kg. This new "unified" pound has replaced the somewhat smaller Imperial pound of the United Kingdom and the slightly larger pound of the United States (see NBS Spec. Pub. 447). The "standard locality" means sea level, 45° latitude, or more strictly any locality in which the acceleration due to gravity has the value 9.80 665 m/s^2 = 32.1740 ft/s^2, which may be called the **standard acceleration** (Table 1.2.6).

The **pound force** is the force required to support the standard pound body against gravity, *in vacuo,* in the standard locality; or, it is the force which, if applied to the standard pound body, supposed free to move, would give that body the "standard acceleration." The word *pound* is used for the unit of both force and mass and consequently is ambiguous. To avoid uncertainty, it is desirable to call the units "pound force" and "pound mass," respectively. The slug has been defined as that mass which will accelerate at 1 ft/s^2 when acted upon by a one pound force. It is therefore equal to 32.1740 pound-mass.

The **kilogram force** is the force required to support the standard kilogram against gravity, *in vacuo,* in the standard locality; or, it is the force which, if applied to the standard kilogram body, supposed free to move, would give that body the "standard acceleration." The word *kilogram* is used for the unit of both force and mass and consequently is ambiguous. It is for this reason that the General Conference on Weights and Measures declared (in 1901) that the kilogram was the unit of mass, a concept incorporated into SI when it was formally approved in 1960.

The **dyne** is the force which, if applied to the standard gram body, would give that body an acceleration of 1 cm/s^2; i.e., 1 dyne = 1/980.665 of a gram force.

The **newton** is that force which will impart to a 1-kilogram mass an acceleration of 1 m/s^2.

Table 1.2.5 Systems of Units

Quantity	Dimensions of units in terms of L/M/F/T	British "gravitational system"	Metric "gravitational system"	CGS system	SI system
Length	L	1 ft	1 m	1 cm	1 m
Mass	M	(1 slug)		1 g	1 kg
Force	F	1 lb	1 kg	(1 dyne)	(1 N)
Time	T	1 s	1 s	1 s	1 s

Table 1.2.6 Acceleration of Gravity

Latitude, deg	g m/s²	g ft/s²	g/g^0	Latitude, deg	g m/s²	g ft/s²	g/g^0
0	9.780	32.088	0.9973	50	9.811	32.187	1.0004
10	9.782	32.093	0.9975	60	9.819	32.215	1.0013
20	9.786	32.108	0.9979	70	9.826	32.238	1.0020
30	9.793	32.130	0.9986	80	9.831	32.253	1.0024
40	9.802	32.158	0.9995	90	9.832	32.258	1.0026

NOTE: Correction for altitude above sea level: -3 mm/s² for each 1,000 m; -0.003 ft/s² for each 1,000 ft.
SOURCE: U.S. Coast and Geodetic Survey, 1912.

TEMPERATURE

The SI unit for thermodynamic temperature is the **kelvin, K,** which is the fraction 1/273.16 of the thermodynamic temperature of the triple point of water. Thus 273.16 K is the **fixed (base) point** on the **kelvin scale.**

Another unit used for the measurement of temperature is degrees **Celsius** (formerly **centigrade**), °C. The relation between a thermodynamic temperature T and a Celsius temperature t is

$$t = T - 273.15 \text{ K (the ice point of water)}$$

Thus the unit Celsius degree is equal to the unit kelvin, and a difference of temperature would be the same on either scale.

In the USCS temperature is measured in degrees **Fahrenheit, F.** The relation between the Celsius and the Fahrenheit scales is

$$t_{°C} = (t_{°F} - 32)/1.8$$

(For temperature-conversion tables, see Sec. 4.)

TERRESTRIAL GRAVITY

Standard acceleration of gravity is $g^0 = 9.80665$ m per sec per sec, or 32.1740 ft per sec per sec. This value g^0 is assumed to be the value of g at sea level and latitude 45°.

MOHS SCALE OF HARDNESS

This scale is an arbitrary one which is used to describe the hardness of several mineral substances on a scale of 1 through 10 (Table 1.2.7). The given number indicates a higher relative hardness compared with that of substances below it; and a lower relative hardness than those above it. For example, an unknown substance is scratched by quartz, but it, in turn, scratches feldspar. The unknown has a hardness of between 6 and 7 on the Mohs scale.

Table 1.2.7 Mohs Scale of Hardness

1. Talc	5. Apatite	8. Topaz
2. Gypsum	6. Feldspar	9. Sapphire
3. Calc-spar	7. Quartz	10. Diamond
4. Fluorspar		

TIME

Kinds of Time Three kinds of time are recognized by astronomers: sidereal, apparent solar, and mean solar time. The **sidereal day** is the interval between two consecutive transits of some fixed celestial object across any given meridian, or it is the interval required by the earth to make one complete revolution on its axis. The interval is constant, but it is inconvenient as a time unit because the noon of the sidereal day occurs at all hours of the day and night. The **apparent solar day** is the interval between two consecutive transits of the sun across any given meridian. On account of the variable distance between the sun and earth, the variable speed of the earth in its orbit, the effect of the moon, etc., this interval is not constant and consequently cannot be kept by any simple mechanisms, such as clocks or watches. To overcome the objection noted above, the **mean solar day** was devised. The mean solar day is the length of the average apparent solar day. Like the sidereal day it is constant, and like the apparent solar day its noon always occurs at approximately the same time of day. By international agreement, beginning Jan. 1, 1925, the astronomical day, like the civil day, is from midnight to midnight. The hours of the astronomical day run from 0 to 24, and the hours of the civil day usually run from 0 to 12 A.M. and 0 to 12 P.M. In some countries the hours of the civil day also run from 0 to 24.

The Year Three different kinds of year are used: the sidereal, the tropical, and the anomalistic. The **sidereal year** is the time taken by the earth to complete one revolution around the sun from a given star to the same star again. Its length is 365 days, 6 hours, 9 minutes, and 9 seconds. The **tropical year** is the time included between two successive passages of the vernal equinox by the sun, and since the equinox moves westward 50.2 seconds of arc a year, the tropical year is shorter by 20 minutes 23 seconds in time than the sidereal year. As the seasons depend upon the earth's position with respect to the equinox, the tropical year is the year of civil reckoning. The **anomalistic year** is the interval between two successive passages of the perihelion, viz., the time of the earth's nearest approach to the sun. The anomalistic year is used only in special calculations in astronomy.

The Second Although the second is ordinarily defined as 1/86,400 of the mean solar day, this is not sufficiently precise for many scientific purposes. Scientists have adopted more precise definitions for specific purposes: in 1956, one in terms of the length of the tropical year 1900 and, more recently, in 1967, one in terms of a specific atomic frequency.

Frequency is the reciprocal of time for 1 cycle; the unit of frequency is the **hertz** (Hz), defined as 1 cycle/s.

The Calendar The **Gregorian calendar,** now used in most of the civilized world, was adopted in Catholic countries of Europe in 1582 and in Great Britain and her colonies Jan. 1, 1752. The average length of the Gregorian calendar year is 365 ¼ − ³⁄₄₀₀ days, or 365.2425 days. This is equivalent to 365 days, 5 hours, 49 minutes, 12 seconds. The length of the tropical year is 365.2422 days, or 365 days, 5 hours, 48 minutes, 46 seconds. Thus the Gregorian calendar year is longer than the tropical year by 0.0003 day, or 26 seconds. This difference amounts to 1 day in slightly more than 3,300 years and can properly be neglected.

Standard Time Prior to 1883, each city of the United States had its own time, which was determined by the time of passage of the sun across the local meridian. A system of standard time had been used since its first adoption by the railroads in 1883 but was first legalized on Mar. 19, 1918, when Congress directed the Interstate Commerce Commission to establish limits of the standard time zones. Congress took no further steps until the **Uniform Time Act of 1966** was enacted, followed with an amendment in 1972. This legislation, referred to as "the Act," transferred the regulation and enforcement of the law to the Department of Transportation.

By the legislation of 1918, with some modifications by the Act, the contiguous United States is divided into four **time zones,** each of which, theoretically, was to span 15 degrees of longitude. The first, the **Eastern zone,** extends from the Atlantic westward to include most of Michigan and Indiana, the eastern parts of Kentucky and Tennessee, Georgia, and Florida, except the west half of the panhandle. **Eastern standard time** is based upon the mean solar time of the 75th meridian west of Greenwich, and is 5 hours slower than **Greenwich Mean Time (GMT).** (See also discussion of UTC below.) The second or **Central zone** extends westward to include most of North Dakota, about half of South Dakota and Nebraska, most of Kansas, Oklahoma, and all but the two most westerly counties of Texas. **Central standard time** is based upon the mean solar time of the 90th meridian west of Greenwich, and is 6 hours slower than GMT. The third or **Mountain zone** extends westward to include Montana, most of Idaho, one county of Oregon, Utah, and Arizona. **Mountain standard time** is based upon the mean solar time of the 105th meridian west of Greenwich, and is 7 hours slower than GMT. The fourth or **Pacific zone** includes all of the remaining 48 contiguous states. **Pacific standard time** is based on the mean solar time of the 120th meridian west of Greenwich, and is 8 hours slower than GMT. Exact locations of boundaries may be obtained from the Department of Transportation.

In addition to the above four zones there are four others that apply to the noncontiguous states and islands. The most easterly is the **Atlantic zone,** which includes Puerto Rico and the Virgin Islands, where the time is 4 hours slower than GMT. Eastern standard time is used in the Panama Canal strip. To the west of the Pacific time zone there are the **Yukon,** the **Alaska-Hawaii,** and **Bering zones** where the times are, respectively, 9, 10, and 11 hours slower than GMT. The system of standard time has been adopted in all civilized countries and is used by ships on the high seas.

The Act directs that from the first Sunday in April to the last Sunday in October, the time in each zone is to be advanced one hour for advanced time or daylight saving time (DST). However, any state-by-state enactment may exempt the entire state from using advanced time. By this provision Arizona and Hawaii do not observe advanced time (as of 1973). By the 1972 amendment to the Act, a state split by a time-zone boundary may exempt from using advanced time all that part which is in one zone without affecting the rest of the state. By this amendment, 80 counties of Indiana in the Eastern zone are exempt from using advanced time, while 6 counties in the northwest corner and 6 counties in the southwest, which are in Central zone, do observe advanced time.

Pursuant to its assignment of carrying out the Act, the Department of Transportation has stipulated that municipalities located on the boundary between the Eastern and Central zones are in the Central zone; those on the boundary between the Central and Mountain zones are in the Mountain zone (except that Murdo, SD, is in the Central zone); those on the boundary between Mountain and Pacific time zones are in the Mountain zone. In such places, when the time is given, it should be specified as Central, Mountain, etc.

Standard Time Signals The National Institute of Standards and Technology broadcasts time signals from **station WWV,** Ft. Collins, CO, and from **station WWVH,** near Kekaha, Kaui, HI. The broadcasts by WWV are on radio carrier frequencies of 2.5, 5, 10, 15, and 20 MHz, while those by WWVH are on radio carrier frequencies of 2.5, 5, 10, and 15 MHz. Effective Jan. 1, 1975, time announcements by both WWV and WWVH are referred to as **Coordinated Universal Time, UTC,** the international coordinated time scale used around the world for most timekeeping purposes. UTC is generated by reference to International Atomic Time (TAI), which is determined by the Bureau International de l'Heure on the basis of atomic clocks operating in various establishments in accordance with the definition of the second. Since the difference between UTC and TAI is defined to be a whole number of seconds, a "leap second" is periodically added to or subtracted from UTC to take into account variations in the rotation of the earth. Time (i.e., clock time) is given in terms of 0 to 24 hours a day, starting with 0000 at midnight at Greenwich zero longitude. The beginning of each 0.8-second-long audio tone marks the end of an announced time interval. For example, at 2:15 P.M., UTC, the voice announcement would be: "At the tone fourteen hours fifteen minutes Coordinated Universal Time," given during the last 7.5 seconds of each minute. The tone markers from both stations are given simultaneously, but owing to propagation interferences may not be received simultaneously.

Beginning 1 minute after the hour, a 600-Hz signal is broadcast for about 45 s. At 2 min after the hour, the standard musical pitch of 440 Hz is broadcast for about 45 s. For the remaining 57 min of the hour, alternating tones of 600 and 500 Hz are broadcast for the first 45 s of each minute (see NIST Spec. Pub. 432). The time signal can also be received via long-distance telephone service from Ft. Collins. In addition to providing the musical pitch, these tone signals may be of use as markers for automated recorders and other such devices.

DENSITY AND RELATIVE DENSITY

Density of a body is its mass per unit volume. With SI units densities are in kilograms per cubic meter. However, giving densities in grams per cubic centimeter has been common. With the USCS, densities are given in pounds per mass cubic foot.

Table 1.2.8 Relative Densities at 60°/60°F Corresponding to Degrees API and Weights per U.S. Gallon at 60°F

$$\left(\text{Calculated from the formula, relative density} = \frac{141.5}{131.5 + \text{deg API}}\right)$$

Degrees API	Relative density	Lb per U.S. gallon	Degrees API	Relative density	Lb per U.S. gallon
10	1.0000	8.328	56	0.7547	6.283
11	0.9930	8.270	57	0.7507	6.249
12	0.9861	8.212	58	0.7467	6.216
13	0.9792	8.155	59	0.7428	6.184
14	0.9725	8.099	60	0.7389	6.151
15	0.9659	8.044	61	0.7351	6.119
16	0.9593	7.989	62	0.7313	6.087
17	0.9529	7.935	63	0.7275	6.056
18	0.9465	7.882	64	0.7238	6.025
19	0.9402	7.830	65	0.7201	5.994
20	0.9340	7.778	66	0.7165	5.964
21	0.9279	7.727	67	0.7128	5.934
22	0.9218	7.676	68	0.7093	5.904
23	0.9159	7.627	69	0.7057	5.874
24	0.9100	7.578	70	0.7022	5.845
25	0.9042	7.529	71	0.6988	5.817
26	0.8984	7.481	72	0.6953	5.788
27	0.8927	7.434	73	0.6919	5.759
28	0.8871	7.387	74	0.6886	5.731
29	0.8816	7.341	75	0.6852	5.703
30	0.8762	7.296	76	0.6819	5.676
31	0.8708	7.251	77	0.6787	5.649
32	0.8654	7.206	78	0.6754	5.622
33	0.8602	7.163	79	0.6722	5.595
34	0.8550	7.119	80	0.6690	5.568
35	0.8498	7.076	81	0.6659	5.542
36	0.8448	7.034	82	0.6628	5.516
37	0.8398	6.993	83	0.6597	5.491
38	0.8348	6.951	84	0.6566	5.465
39	0.8299	6.910	85	0.6536	5.440
40	0.8251	6.870	86	0.6506	5.415
41	0.8203	6.830	87	0.6476	5.390
42	0.8155	6.790	88	0.6446	5.365
43	0.8109	6.752	89	0.6417	5.341
44	0.8063	6.713	90	0.6388	5.316
45	0.8017	6.675	91	0.6360	5.293
46	0.7972	6.637	92	0.6331	5.269
47	0.7927	6.600	93	0.6303	5.246
48	0.7883	6.563	94	0.6275	5.222
49	0.7839	6.526	95	0.6247	5.199
50	0.7796	6.490	96	0.6220	5.176
51	0.7753	6.455	97	0.6193	5.154
52	0.7711	6.420	98	0.6166	5.131
53	0.7669	6.385	99	0.6139	5.109
54	0.7628	6.350	100	0.6112	5.086
55	0.7587	6.316			

NOTE: The weights in this table are weights in air at 60°F with humidity 50 percent and pressure 760 mm.

Table 1.2.9 Relative Densities at 60°/60°F Corresponding to Degrees Baumé for Liquids Lighter than Water and Weights per U.S. Gallon at 60°F

$$\left(\text{Calculated from the formula, relative density } \frac{60°}{60°}\text{F} = \frac{140}{130 + \text{deg Baumé}}\right)$$

Degrees Baumé	Relative density	Lb per gallon	Degrees Baumé	Relative density	Lb per gallon
10.0	1.0000	8.328	56.0	0.7527	6.266
11.0	0.9929	8.269	57.0	0.7487	6.233
12.0	0.9859	8.211	58.0	0.7447	6.199
13.0	0.9790	8.153	59.0	0.7407	6.166
14.0	0.9722	8.096	60.0	0.7368	6.134
15.0	0.9655	8.041	61.0	0.7330	6.102
16.0	0.9589	7.986	62.0	0.7292	6.070
17.0	0.9524	7.931	63.0	0.7254	6.038
18.0	0.9459	7.877	64.0	0.7216	6.007
19.0	0.9396	7.825	65.0	0.7179	5.976
20.0	0.9333	7.772	66.0	0.7143	5.946
21.0	0.9272	7.721	67.0	0.7107	5.916
22.0	0.9211	7.670	68.0	0.7071	5.886
23.0	0.9150	7.620	69.0	0.7035	5.856
24.0	0.9091	7.570	70.0	0.7000	5.827
25.0	0.9032	7.522	71.0	0.6965	5.798
26.0	0.8974	7.473	72.0	0.6931	5.769
27.0	0.8917	7.425	73.0	0.6897	5.741
28.0	0.8861	7.378	74.0	0.6863	5.712
29.0	0.8805	7.332	75.0	0.6829	5.685
30.0	0.8750	7.286	76.0	0.6796	5.657
31.0	0.8696	7.241	77.0	0.6763	5.629
32.0	0.8642	7.196	78.0	0.6731	5.602
33.0	0.8589	7.152	79.0	0.6699	5.576
34.0	0.8537	7.108	80.0	0.6667	5.549
35.0	0.8485	7.065	81.0	0.6635	5.522
36.0	0.8434	7.022	82.0	0.6604	5.497
37.0	0.8383	6.980	83.0	0.6573	5.471
38.0	0.8333	6.939	84.0	0.6542	5.445
39.0	0.8284	6.898	85.0	0.6512	5.420
40.0	0.8235	6.857	86.0	0.6482	5.395
41.0	0.8187	6.817	87.0	0.6452	5.370
42.0	0.8140	6.777	88.0	0.6422	5.345
43.0	0.8092	6.738	89.0	0.6393	5.320
44.0	0.8046	6.699	90.0	0.6364	5.296
45.0	0.8000	6.661	91.0	0.6335	5.272
46.0	0.7955	6.623	92.0	0.6306	5.248
47.0	0.7910	6.586	93.0	0.6278	5.225
48.0	0.7865	6.548	94.0	0.6250	5.201
49.0	0.7821	6.511	95.0	0.6222	5.178
50.0	0.7778	6.476	96.0	0.6195	5.155
51.0	0.7735	6.440	97.0	0.6167	5.132
52.0	0.7692	6.404	98.0	0.6140	5.100
53.0	0.7650	6.369	99.0	0.6114	5.088
54.0	0.7609	6.334	100.0	0.6087	5.066
55.0	0.7568	6.300			

Relative density is the ratio of the density of one substance to that of a second (or reference) substance, both at some specified temperature. Use of the earlier term *specific gravity* for this quantity is discouraged. For solids and liquids water is almost universally used as the reference substance. Physicists use a reference temperature of 4°C (= 39.2°F); U.S. engineers commonly use 60°F. With the introduction of SI units, it may be found desirable to use 59°F, since 59°F and 15°C are equivalents.

For gases, relative density is generally the ratio of the density of the gas to that of air, both at the same temperature, pressure, and dryness (as regards water vapor). Because equal numbers of moles of gases occupy equal volumes, the ratio of the molecular weight of the gas to that of air may be used as the relative density of the gas. When this is done, the molecular weight of air may be taken as 28.9644.

The relative density of liquids is usually measured by means of a **hydrometer.** In addition to a scale reading in relative density as defined above, other arbitrary scales for hydrometers are used in various trades and industries. The most common of these are the **API** and **Baumé.** The API (American Petroleum Institute) scale is approved by the American Petroleum Institute, the ASTM, the U.S. Bureau of Mines, and the National Bureau of Standards and is recommended for exclusive use in the U.S. petroleum industry, superseding the Baumé scale for liquids lighter than water. The relation between **API degrees** and relative density (see Table 1.2.8) is expressed by the following equation:

$$\text{Degrees API} = \frac{141.5}{\text{rel dens } 60°/60°\text{F}} - 131.5$$

The relative densities corresponding to the indications of the **Baumé hydrometer** are given in Tables 1.2.9 and 1.2.10.

Table 1.2.10 Relative Densities at 60°/60°F Corresponding to Degrees Baumé for Liquids Heavier than Water

$$\left(\text{Calculated from the formula, relative density } \frac{60°}{60°}\text{F} = \frac{145}{145 - \text{deg Baumé}}\right)$$

Degrees Baumé	Relative density	Degrees Baumé	Relative density	Degrees Baumé	Relative density
0	1.0000	24	1.1983	48	1.4948
1	1.0069	25	1.2083	49	1.5104
2	1.0140	26	1.2185	50	1.5263
3	1.0211	27	1.2288	51	1.5426
4	1.0284	28	1.2393	52	1.5591
5	1.0357	29	1.2500	53	1.5761
6	1.0432	30	1.2609	54	1.5934
7	1.0507	31	1.2719	55	1.6111
8	1.0584	32	1.2832	56	1.6292
9	1.0662	33	1.2946	57	1.6477
10	1.0741	34	1.3063	58	1.6667
11	1.0821	35	1.3182	59	1.6860
12	1.0902	36	1.3303	60	1.7059
13	1.0985	37	1.3426	61	1.7262
14	1.1069	38	1.3551	62	1.7470
15	1.1154	39	1.3679	63	1.7683
16	1.1240	40	1.3810	64	1.7901
17	1.1328	41	1.3942	65	1.8125
18	1.1417	42	1.4078	66	1.8354
19	1.1508	43	1.4216	67	1.8590
20	1.1600	44	1.4356	68	1.8831
21	1.1694	45	1.4500	69	1.9079
22	1.1789	46	1.4646	70	1.9333
23	1.1885	47	1.4796		

CONVERSION AND EQUIVALENCY TABLES

Note for Use of Conversion Tables (Tables 1.2.11 through 1.2.34)

Subscripts after any figure, 0_s, 9_s, etc., mean that that figure is to be repeated the indicated number of times.

Table 1.2.11 Length Equivalents

Centimetres	Inches	Feet	Yards	Metres	Chains	Kilometres	Miles
1	0.3937	0.03281	0.01094	0.01	$0.0_{3}4971$	10^{-5}	$0.0_{5}6214$
2.540	1	0.08333	0.02778	0.0254	0.001263	$0.0_{4}254$	$0.0_{4}1578$
30.48	12	1	0.3333	0.3048	0.01515	$0.0_{3}3048$	$0.0_{3}1894$
91.44	36	3	1	0.9144	0.04545	$0.0_{3}9144$	$0.0_{3}5682$
100	39.37	3.281	1.0936	1	0.04971	0.001	$0.0_{3}6214$
2012	792	66	22	20.12	1	0.02012	0.0125
100000	39370	3281	1093.6	1000	49.71	1	0.6214
160934	63360	5280	1760	1609	80	1.609	1

(As used by metrology laboratories for precise measurements, including measurements of surface texture)*

Angstrom units Å	Surface texture (U.S.), microinch μin	Light bands,† monochromatic helium light count ‡	Surface texture foreign, μm	Precision measurements, § 0.0001 in	Close-tolerance measurements, 0.001 in (mils)	Metric unit, mm	USCS unit, in
1	0.003937	0.0003404	0.0001	$0.0_{4}3937$	$0.0_{5}3937$	$0.0_{6}1$	$0.0_{8}3937$
254	1	0.086	0.0254	0.01	0.001	$0.0_{4}254$	$0.0_{5}1$
2937.5	11.566	1	0.29375	0.11566	0.011566	$0.0_{3}29375$	$0.0_{4}11566$
10,000	39.37	3.404	1	0.3937	0.03937	0.001	$0.0_{4}3937$
25,400	100	8.646	2.54	1	0.1	0.00254	0.0001
254,000	1000	86.46	25.4	10	1	0.0254	0.001
10,000,000	39,370	3404	1000	393.7	39.37	1	0.03937
254,000,000	1,000,000	86,460	25,400	10,000	1000	25.4	1

* Computed by J. A. Broadston.
† One light band equals one-half corresponding wavelength. Visible-light wavelengths range from red at 6,500 Å to violet at 4,100 Å.
‡ One helium light band = 0.000011661 in = 2937.5 Å; one krypton 86 light band = 0.0000119 in = 3,022.5 Å; one mercury 198 light band = 0.00001075 in = 2,730 Å.
§ The designations "precision measurements," etc., are not necessarily used in all metrology laboratories.

Table 1.2.12 Conversion of Lengths*

	Inches to millimetres	Millimetres to inches	Feet to metres	Metres to feet	Yards to metres	Metres to yards	Miles to kilometres	Kilometres to miles
1	25.40	0.03937	0.3048	3.281	0.9144	1.094	1.609	0.6214
2	50.80	0.07874	0.6096	6.562	1.829	2.187	3.219	1.243
3	76.20	0.1181	0.9144	9.843	2.743	3.281	4.828	1.864
4	101.60	0.1575	1.219	13.12	3.658	4.374	6.437	2.485
5	127.00	0.1969	1.524	16.40	4.572	5.468	6.047	3.107
6	152.40	0.2362	1.829	19.69	5.486	6.562	9.656	3.728
7	177.80	0.2756	2.134	22.97	6.401	7.655	11.27	4.350
8	203.20	0.3150	2.438	26.25	7.315	8.749	12.87	4.971
9	228.60	0.3543	2.743	29.53	8.230	9.843	14.48	5.592

* EXAMPLE: 1 in = 25.40 mm.

Common fractions of an inch to millimetres (from 1⁄64 to 1 in)

64ths	Millimetres	64ths	Millimetres	64th	Millimetres	64ths	Millimetres	64ths	Millimetres	64ths	Millimetres
1	0.397	13	5.159	25	9.922	37	14.684	49	19.447	57	22.622
2	0.794	14	5.556	26	10.319	38	15.081	50	19.844	58	23.019
3	1.191	15	5.953	27	10.716	39	15.478	51	20.241	59	23.416
4	1.588	16	6.350	28	11.112	40	15.875	52	20.638	60	23.812
5	1.984	17	6.747	29	11.509	41	16.272	53	21.034.	61	24.209
6	2.381	18	7.144	30	11.906	42	16.669	54	21.431	62	24.606
7	2.778	19	7.541	31	12.303	43	17.066	55	21.828	63	25.003
8	3.175	20	7.938	32	12.700	44	17.462	56	22.225	64	25.400
9	3.572	21	8.334	33	13.097	45	17.859				
10	3.969	22	8.731	34	13.494	46	18.256				
11	4.366	23	9.128	35	13.891	47	18.653				
12	4.762	24	9.525	36	14.288	48	19.050				

Decimals of an inch to millimetres (0.01 to 0.99 in)

	0	1	2	3	4	5	6	7	8	9
.0		0.254	0.508	0.762	1.016	1.270	1.524	1.778	2.032	2.286
.1	2.540	2.794	3.048	3.302	3.556	3.810	4.064	4.318	4.572	4.826
.2	5.080	5.334	5.588	5.842	6.096	6.350	6.604	6.858	7.112	7.366
.3	7.620	7.874	8.128	8.382	8.636	8.890	9.144	9.398	9.652	9.906
.4	10.160	10.414	10.668	10.922	11.176	11.430	11.684	11.938	12.192	12.446
.5	12.700	12.954	13.208	13.462	13.716	13.970	14.224	14.478	14.732	14.986
.6	15.240	15.494	15.748	16.002	16.256	16.510	16.764	17.018	17.272	17.526
.7	17.780	18.034	18.288	18.542	18.796	19.050	19.304	19.558	19.812	20.066
.8	20.320	20.574	20.828	21.082	21.336	21.590	21.844	22.098	22.352	22.606
.9	22.860	23.114	23.368	23.622	23.876	24.130	24.384	24.638	24.892	25.146

Millimetres to decimals of an inch (from 1 to 99 mm)

	0.	1.	2.	3.	4.	5.	6.	7.	8.	9.
0		0.0394	0.0787	0.1181	0.1575	0.1969	0.2362	0.2756	0.3150	0.3543
1	0.3937	0.4331	0.4724	0.5118	0.5512	0.5906	0.6299	0.6693	0.7087	0.7480
2	0.7874	0.8268	0.8661	0.9055	0.9449	0.9843	1.0236	1.0630	1.1024	1.1417
3	1.1811	1.2205	1.2598	1.2992	1.3386	1.3780	1.4173	1.4567	1.4961	1.5354
4	1.5748	1.6142	1.6535	1.6929	1.7323	1.7717	1.8110	1.8504	1.8898	1.9291
5	1.9685	2.0079	2.0472	2.0866	2.1260	2.1654	2.2047	2.2441	2.2835	2.3228
6	2.3622	2.4016	2.4409	2.4803	2.5197	2.5591	2.5984	2.6378	2.6772	2.7165
7	2.7559	2.7953	2.8346	2.8740	2.9134	2.9528	2.9921	3.0315	3.0709	3.1102
8	3.1496	3.1890	3.2283	3.2677	3.3071	3.3465	3.3858	3.4252	3.4646	3.5039
9	3.5433	3.5827	3.6220	3.6614	3.7008	3.7402	3.7795	3.8189	3.8583	3.8976

Table 1.2.13 Area Equivalents
(1 hectare = 100 ares = 10,000 centiares or square metres)

Square metres	Square inches	Square feet	Square yards	Square rods	Square chains	Roods	Acres	Square miles or sections
1	1550	10.76	1.196	0.0395	0.002471	0.0_39884	0.0_32471	0.0_63861
0.0_36452	1	0.006944	0.0_37716	0.0_42551	0.0_51594	0.0_66377	0.0_61594	0.0_92491
0.09290	144	1	0.1111	0.003673	0.0_32296	0.0_49183	0.0_42296	0.0_73587
0.8361	1296	9	1	0.03306	0.002066	0.0_38264	0.0002066	0.0_63228
25.29	39204	272.25	30.25	1	0.0625	0.02500	0.00625	0.0_59766
404.7	627264	4356	484	16	1	0.4	0.1	0.0001562
1012	1568160	10890	1210	40	2.5	1	0.25	0.0_33906
4047	6272640	43560	4840	160	10	4	1	0.001562
2589988		27878400	3097600	102400	6400	2560	640	1

Table 1.2.14 Conversion of Areas*

	Sq in to sq cm	Sq cm to sq in	Sq ft to sq m	Sq m to sq ft	Sq yd to sq m	Sq m to sq yd	Acres to hectares	Hectares to acres	Sq mi to sq km	Sq km to sq mi
1	6.452	0.1550	0.0929	10.76	0.8361	1.196	0.4047	2.471	2.590	0.3861
2	12.90	0.3100	0.1858	21.53	1.672	2.392	0.8094	4.942	5.180	0.7722
3	19.35	0.4650	0.2787	32.29	2.508	3.588	1.214	7.413	7.770	1.158
4	25.81	0.6200	0.3716	43.06	3.345	4.784	1.619	9.884	10.360	1.544
5	32.26	0.7750	0.4645	53.82	4.181	5.980	2.023	12.355	12.950	1.931
6	38.71	0.9300	0.5574	64.58	5.017	7.176	2.428	14.826	15.540	2.317
7	45.16	1.085	0.6503	75.35	5.853	8.372	2.833	17.297	18.130	2.703
8	51.61	1.240	0.7432	86.11	6.689	9.568	3.237	19.768	20.720	3.089
9	58.06	1.395	0.8361	96.88	7.525	10.764	3.642	22.239	23.310	3.475

* EXAMPLE: 1 in^2 = 6.452 cm^2.

Table 1.2.15 Volume and Capacity Equivalents

Cubic inches	Cubic feet	Cubic yards	U.S. Apothecary fluid ounces	U.S. quarts		U.S. gallons	U.S. bushels	Cubic decimetres or litres
				Liquid	Dry			
1	0.0_35787	0.0_42143	0.5541	0.01732	0.01488	0.0_24329	0.0_34650	0.01639
1728	1	0.03704	957.5	29.92	25.71	7.481	0.8036	28.32
46656	27	1	25853	807.9	694.3	202.2	21.70	764.6
1.805	0.001044	0.0_43868	1	0.03125	0.02686	0.007812	0.0_38392	0.02957
57.75	0.03342	0.001238	32	1	0.8594	0.25	0.02686	0.9464
67.20	0.03889	0.001440	37.24	1.164	1	0.2909	0.03125	1.101
231	0.1337	0.004951	128	4	3.437	1	0.1074	3.785
2150	1.244	0.04609	1192	37.24	32	9.309	1	35.24
61.02	0.03531	0.001308	33.81	1.057	0.9081	0.2642	0.02838	1

Table 1.2.16 Conversion of Volumes or Cubic Measure*

	Cu in to mL	mL to cu in	Cu ft to cu m	Cu m to cu ft	Cu yd to cu m	Cu m to cu yd	Gallons to cu ft	Cu ft to gallons
1	16.39	0.06102	0.02832	35.31	0.7646	1.308	0.1337	7.481
2	32.77	0.1220	0.05663	70.63	1.529	2.616	0.2674	14.96
3	49.16	0.1831	0.08495	105.9	2.294	3.924	0.4010	22.44
4	65.55	0.2441	0.1133	141.3	3.058	5.232	0.5347	29.92
5	81.94	0.3051	0.1416	176.6	3.823	6.540	0.6684	37.40
6	98.32	0.3661	0.1699	211.9	4.587	7.848	0.8021	44.88
7	114.7	0.4272	0.1982	247.2	5.352	9.156	0.9358	52.36
8	131.1	0.4882	0.2265	282.5	6.116	10.46	1.069	59.84
9	147.5	0.5492	0.2549	317.8	6.881	11.77	1.203	67.32

* EXAMPLE: 1 in^3 = 16.39 mL.

Table 1.2.17 Conversion of Volumes or Capacities*

	Fluid ounces to mL	mL to fluid ounces	Liquid pints to litres	Litres to liquid pints	Liquid quarts to litres	Litres to liquid quarts	Gallons to litres	Litres to gallons	Bushels to hectolitres	Hectolitres to bushels
1	29.57	0.03381	0.4732	2.113	0.9463	1.057	3.785	0.2642	0.3524	2.838
2	59.15	0.06763	0.9463	4.227	1.893	2.113	7.571	0.5284	0.7048	5.676
3	88.72	0.1014	1.420	6.340	2.839	3.170	11.36	0.7925	1.057	8.513
4	118.3	0.1353	1.893	8.454	3.785	4.227	15.14	1.057	1.410	11.35
5	147.9	0.1691	2.366	10.57	4.732	5.284	18.93	1.321	1.762	14.19
6	177.4	0.2092	2.839	12.68	5.678	6.340	22.71	1.585	2.114	17.03
7	207.0	0.2367	3.312	14.79	6.624	7.397	26.50	1.849	2.467	19.86
8	236.6	0.2705	3.785	16.91	7.571	8.454	30.28	2.113	2.819	22.70
9	266.2	0.3043	4.259	19.02	8.517	9.510	34.07	2.378	3.171	25.54

* EXAMPLE: 1 fluid oz = 29.57 mL.

Table 1.2.18 Mass Equivalents

		Ounces		Pounds		Tons		
Kilograms	Grains	Troy and apoth	Avoirdupois	Troy and apoth	Avoirdupois	Short	Long	Metric
1	15432	32.15	35.27	2.6792	2.205	$0.0_{2}1102$	$0.0_{3}9842$	0.001
$0.0_{4}6480$	1	$0.0_{2}2083$	$0.0_{2}2286$	$0.0_{3}1736$	$0.0_{3}1429$	$0.0_{7}7143$	$0.0_{7}6378$	$0.0_{7}6480$
0.03110	480	1	1.09714	0.08333	0.06857	$0.0_{4}3429$	$0.0_{4}3061$	$0.0_{4}3110$
0.02835	437.5	0.9115	1	0.07595	0.0625	$0.0_{4}3125$	$0.0_{4}2790$	$0.0_{4}2835$
0.3732	5760	12	13.17	1	0.8229	$0.0_{3}4114$	$0.0_{3}3673$	$0.0_{3}3732$
0.4536	7000	14.58	16	1.215	1	0.0005	$0.0_{3}4464$	$0.0_{3}4536$
907.2	140_{6}	29167	320_{3}	2431	2000	1	0.8929	0.9072
1016	15680_{4}	32667	35840	2722	2240	1.12	1	1.016
1000	15432356	32151	35274	2679	2205	1.102	0.9842	1

Table 1.2.19 Conversion of Masses*

	Grains to grams	Grams to grains	Ounces (avdp) to grams	Grams to ounces (avdp)	Pounds (avdp) to kilograms	Kilograms to pounds (avdp)	Short tons (2000 lb) to metric tons	Metric tons (1000 kg) to short tons	Long tons (2240 lb) to metric tons	Metric tons to long tons
1	0.06480	15.43	28.35	0.03527	0.4536	2.205	0.907	1.102	1.016	0.984
2	0.1296	30.86	56.70	0.07055	0.9072	4.409	1.814	2.205	2.032	1.968
3	0.1944	46.30	85.05	0.1058	1.361	6.614	2.722	3.307	3.048	2.953
4	0.2592	61.73	113.40	0.1411	1.814	8.818	3.629	4.409	4.064	3.937
5	0.3240	77.16	141.75	0.1764	2.268	11.02	4.536	5.512	5.080	4.921
6	0.3888	92.59	170.10	0.2116	2.722	13.23	5.443	6.614	6.096	5.905
7	0.4536	108.03	198.45	0.2469	3.175	15.43	6.350	7.716	7.112	6.889
8	0.5184	123.46	226.80	0.2822	3.629	17.64	7.257	8.818	8.128	7.874
9	0.5832	138.89	255.15	0.3175	4.082	19.84	8.165	9.921	9.144	8.858

* EXAMPLE: 1 grain = 0.06480 grams.

Table 1.2.20 Pressure Equivalents

				Columns of mercury at temperature 0°C and g = 9.80665 m/s²		Columns of water at temperature 15°C and g = 9.80665 m/s²	
Pascals N/m²	Bars 10^5 N/m²	Poundsf per in²	Atmospheres	cm	in	cm	in
1	10^{-5}	0.000145	0.00001	0.00075	0.000295	0.01021	0.00402
100000	1	14.504	0.9869	75.01	29.53	1020.7	401.8
6894.8	0.068948	1	0.06805	5.171	2.036	70.37	27.703
101326	1.0132	14.696	1	76.000	29.92	1034	407.1
1333	0.0133	0.1934	0.01316	1	0.3937	13.61	5.357
3386	0.03386	0.4912	0.03342	2.540	1	34.56	13.61
97.98	0.0009798	0.01421	0.000967	0.07349	0.02893	1	0.3937
248.9	0.002489	0.03609	0.002456	0.1867	0.07349	2.540	1

Table 1.2.21 Conversion of Pressures*

	Lb/in^2 to bars	Bars to lb/in^2	Lb/in^2 to atmospheres	Atmospheres to lb/in^2	Bars to atmospheres	Atmospheres to bars
1	0.06895	14.504	0.06805	14.696	0.98692	1.01325
2	0.13790	29.008	0.13609	29.392	1.9738	2.0265
3	0.20684	43.511	0.20414	44.098	2.9607	3.0397
4	0.27579	58.015	0.27218	58.784	3.9477	4.0530
5	0.34474	72.519	0.34823	73.480	4.9346	5.0663
6	0.41368	87.023	0.40826	88.176	5.9215	6.0795
7	0.48263	101.53	0.47632	102.87	6.9085	7.0927
8	0.55158	116.03	0.54436	117.57	7.8954	8.1060
9	0.62053	130.53	0.61241	132.26	8.8823	9.1192

* EXAMPLE: 1 lb/in^2 = 0.06895 bar.

Table 1.2.22 Velocity Equivalents

cm/s	m/s	m/min	km/h	ft/s	ft/min	mi/h	Knots
1	0.01	0.6	0.036	0.03281	1.9685	0.02237	0.01944
100	1	60	3.6	3.281	196.85	2.237	1.944
1.667	0.01667	1	0.06	0.05468	3.281	0.03728	0.03240
27.78	0.2778	16.67	1	0.9113	54.68	0.6214	0.53996
30.48	0.3048	18.29	1.097	1	60	0.6818	0.59248
0.5080	0.005080	0.3048	0.01829	0.01667	1	0.01136	0.00987
44.70	0.4470	26.82	1.609	1.467	88	1	0.86898
51.44	0.5144	30.87	1.852	1.688	101.3	1.151	1

Table 1.2.23 Conversion of Linear and Angular Velocities*

	cm/s to ft/min	ft/min to cm/s	cm/s to mi/h	mi/h to cm/s	ft/s to mi/h	mi/h to ft/s	rad/s to r/min	r/min to rad/s
1	1.97	0.508	0.0224	44.70	0.682	1.47	9.55	0.1047
2	3.94	1.016	0.0447	89.41	1.364	2.93	19.10	0.2094
3	5.91	1.524	0.0671	134.1	2.045	4.40	28.65	0.3142
4	7.87	2.032	0.0895	178.8	2.727	5.87	38.20	0.4189
5	9.84	2.540	0.1118	223.5	3.409	7.33	47.75	0.5236
6	11.81	3.048	0.1342	268.2	4.091	8.80	57.30	0.6283
7	13.78	3.556	0.1566	312.9	4.773	10.27	66.84	0.7330
8	15.75	4.064	0.1790	357.6	5.455	11.73	76.39	0.8378
9	17.72	4.572	0.2013	402.3	6.136	13.20	85.94	0.9425

* EXAMPLE: 1 cm/s = 1.97 ft/min.

Table 1.2.24 Acceleration Equivalents

cm/s^2	m/s^2	m/(h · s)	km/(h · s)	ft/(h · s)	ft/s^2	ft/min^2	mi/(h · s)	knots/s
1	0.01	36.00	0.036	118.1	0.03281	118.1	0.02237	0.01944
100	1	3600	3.6	11811	3.281	11811	2.237	1.944
0.02778	0.0002778	1	0.001	3.281	0.0009113	3.281	0.0006214	0.0005400
27.78	0.2778	1000	1	3281	0.9113	3281	0.6214	0.5400
0.008467	0.00008467	0.3048	0.0003048	1	0.0002778	1	0.0001894	0.0001646
30.48	0.3048	1097	1.097	3600	1	3600	0.6818	0.4572
0.008467	0.00008467	0.3048	0.0003048	1	0.0002778	1	0.0001894	0.0001646
44.70	0.4470	1609	1.609	5280	1.467	5280	1	0.8690
51.44	0.5144	1852	1.852	6076	1.688	6076	1.151	1

Table 1.2.25 Conversion of Accelerations*

	cm/s^2 to ft/min^2	km/(h · s) to mi/(h · s)	km/(h · s) to knots/s	ft/s^2 to mi/(h · s)	ft/s^2 to knots/s	ft/min^2 to cm/s^2	mi/(h · s) to km/(h · s)	mi/(h · s) to knots/s	knots/s to mi/(h · s)	knots/s to km/(h · s)
1	118.1	0.6214	0.5400	0.6818	0.4572	0.008467	1.609	0.8690	1.151	1.852
2	236.2	1.243	1.080	1.364	0.9144	0.01693	3.219	1.738	2.302	3.704
3	354.3	1.864	1.620	2.045	1.372	0.02540	4.828	2.607	3.452	5.556
4	472.4	2.485	2.160	2.727	1.829	0.03387	6.437	3.476	4.603	7.408
5	590.6	3.107	2.700	3.409	2.286	0.04233	8.046	4.345	5.754	9.260
6	708.7	3.728	3.240	4.091	2.743	0.05080	9.656	5.214	6.905	11.11
7	826.8	4.350	3.780	4.772	3.200	0.05927	11.27	6.083	8.056	12.96
8	944.9	4.971	4.320	5.454	3.658	0.06774	12.87	6.952	9.206	14.82
9	1063	5.592	4.860	6.136	4.115	0.07620	14.48	7.821	10.36	16.67

* EXAMPLE: 1 cm/s^2 = 118.1 ft/min^2.

Table 1.2.26 Energy or Work Equivalents

Joules or Newton-metres	Kilogramf-metres	Foot-poundsf	Kilowatt hours	Metric horsepower-hours	Horsepower-hours	Litre-atmospheres	Kilocalories	British thermal units
1	0.10197	0.7376	$0.0_{6}2778$	$0.0_{6}3777$	$0.0_{6}3725$	0.009869	$0.0_{3}2388$	$0.0_{3}9478$
9.80665	1	7.233	$0.0_{5}2724$	$0.0_{5}37037$	$0.0_{5}3653$	0.09678	0.002342	0.009295
1.356	0.1383	1	$0.0_{6}3766$	$0.0_{6}51206$	$0.0_{6}50505$	0.01338	$0.0_{3}3238$	0.001285
3.600×10^6	3.671×10^5	2.655×10^6	1	1.3596	1.341	35528	859.9	3412
2.648×10^6	270000	1.9529×10^6	0.7355	1	0.9863	26131	632.4	2510
2.6845×10^6	2.7375×10^5	1.98×10^6	0.7457	1.0139	1	26493	641.2	2544
101.33	10.333	74.74	$0.0_{4}2815$	$0.0_{4}3827$	$0.0_{4}3775$	1	0.02420	0.09604
4186.8	426.9	3088	0.001163	0.001581	0.001560	41.32	1	3.968
1055	107.6	778.2	$0.0_{3}2931$	$0.0_{3}3985$	$0.0_{3}3930$	10.41	0.25200	1

Table 1.2.27 Conversion of Energy, Work, Heat*

	Ft · lbf to joules	Joules to ft · lbf	Ft · lbf to Btu	Btu to ft · lbf	Kilogramf-metres to kilocalories	Kilocalories to kilogramf-metres	Joules to calories	Calories to joules
1	1.3558	0.7376	0.001285	778.2	0.002342	426.9	0.2388	4.187
2	2.7116	1.4751	0.002570	1,556	0.004685	853.9	0.4777	8.374
3	4.0674	2.2127	0.003855	2,334	0.007027	1,281	0.7165	12.56
4	5.4232	2.9503	0.005140	3,113	0.009369	1,708	0.9554	16.75
5	6.7790	3.6879	0.006425	3,891	0.01172	2,135	1.194	20.93
6	8.1348	4.4254	0.007710	4,669	0.01405	2,562	1.433	25.12
7	9.4906	5.1630	0.008995	5,447	0.01640	2,989	1.672	29.31
8	10.8464	5.9006	0.01028	6,225	0.01874	3,415	1.911	33.49
9	12.2022	6.6381	0.01156	7,003	0.02108	3,842	2.150	37.68

* EXAMPLE: 1 ft · lbf = 1.3558 J.

Table 1.2.28 Power Equivalents

Horsepower	Kilowatts	Metric horsepower	Kgf · m per s	Ft · lbf per s	Kilocalories per s	Btu per s
1	0.7457	1.014	76.04	550	0.1781	0.7068
1.341	1	1.360	102.0	737.6	0.2388	0.9478
0.9863	0.7355	1	75	542.5	0.1757	0.6971
0.01315	0.009807	0.01333	1	7.233	0.002342	0.009295
0.00182	0.001356	0.00184	0.1383	1	$0.0_{3}3238$	0.001285
5.615	4.187	5.692	426.9	3088	1	3.968
1.415	1.055	1.434	107.6	778.2	0.2520	1

Table 1.2.29 Conversion of Power*

	Horsepower to kilowatts	Kilowatts to horsepower	Metric horsepower to kilowatts	Kilowatts to metric horsepower	Horsepower to metric horsepower	Metric horsepower to horsepower
1	0.7457	1.341	0.7355	1.360	1.014	0.9863
2	1.491	2.682	1.471	2.719	2.028	1.973
3	2.237	4.023	2.206	4.079	3.042	2.959
4	2.983	5.364	2.942	5.438	4.055	3.945
5	3.729	6.705	3.677	6.798	5.069	4.932
6	4.474	8.046	4.412	8.158	6.083	5.918
7	5.220	9.387	5.147	9.520	7.097	6.904
8	5.966	10.73	5.883	10.88	8.111	7.891
9	6.711	12.07	6.618	12.24	9.125	8.877

* EXAMPLE: 1 hp = 0.7457 kW.

Table 1.2.30 Density Equivalents*

Grams per mL	Lb per cu in	Lb per cu ft	Short tons (2,000 lb) per cu yd	Lb per U.S. gal
1	0.03613	62.43	0.8428	8.345
27.68	1	1728	23.33	231
0.01602	0.0_35787	1	0.0135	0.1337
1.187	0.04287	74.7	1	9.902
0.1198	0.004329	7.481	0.1010	1

* EXAMPLE: 1 g per mL = 62.43 lb per cu ft.

Table 1.2.31 Conversion of Density

	Grams per mL to lb per cu ft	Lb per cu ft to grams per mL	Grams per mL to short tons per cu yd	Short tons per cu yd to grams per mL
1	62.43	0.01602	0.8428	1.187
2	124.86	0.03204	1.6856	2.373
3	187.28	0.04805	2.5283	3.560
4	249.71	0.06407	3.3711	4.746
5	312.14	0.08009	4.2139	5.933
6	374.57	0.09611	5.0567	7.119
7	437.00	0.11213	5.8995	8.306
8	499.43	0.12814	6.7423	9.492
9	561.85	0.14416	7.5850	10.679
10	624.28	0.16018	8.4278	11.866

Table 1.2.32 Thermal Conductivity

Calories per cm · s · °C	Watts per cm · °C	Calories per cm · h · °C	Btu · ft per ft² · h · °F	Btu · in per ft² · day · °F
1	4.1868	3,600	241.9	69,670
0.2388	1	860	57.79	16,641
0.0002778	0.001163	1	0.0672	19.35
0.004134	0.01731	14.88	1	288
0.00001435	0.00006009	0.05167	0.00347	1

Table 1.2.33 Thermal Conductance

Calories per cm² · s · °C	Watts per cm² · °C	Calories per cm² · h · °C	Btu per ft² · h · °F	Btu per ft² · day · °F
1	4.1868	3,600	7,373	176,962
0.2388	1	860	1,761	42,267
0.0002778	0.001163	1	2.048	49.16
0.0001356	0.0005678	0.4882	1	24
0.000005651	0.00002366	0.02034	0.04167	1

Table 1.2.34 Heat Flow

Calories per cm² · s	Watts per cm²	Calories per cm² · h	Btu per ft² · h	Btu per ft² · day
1	4.1868	3,600	13,272	318,531
0.2388	1	860	3,170	76,081
0.0002778	0.001163	1	3.687	88.48
0.00007535	0.0003154	0.2712	1	24
0.000003139	0.00001314	0.01130	0.04167	1

Marks'

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Revised by a staff of specialists

EUGENE A. AVALLONE *Editor*

Consulting Engineer; Professor of Mechanical Engineering, Emeritus
The City College of the City University of New York

THEODORE BAUMEISTER III *Editor*

Retired Consultant, Information Systems Department
E. I. du Pont de Nemours & Co.

ALI M. SADEGH *Editor*

Consulting Engineer; Professor of Mechanical Engineering
The City College of the City University of New York

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Contents

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Contributors ix
The Editors xiii
Preface to the Eleventh Edition xv
Preface to the First Edition xvii
Symbols and Abbreviations xix

1. Mathematical Tables and Measuring Units 1-1
1.1 Mathematical Tables 1-1
1.2 Measuring Units 1-16

2. Mathematics 2-1
2.1 Mathematics 2-2
2.2 Computers 2-40

3. Mechanics of Solids and Fluids 3-1
3.1 Mechanics of Solids 3-2
3.2 Friction 3-20
3.3 Mechanics of Fluids 3-29
3.4 Vibration 3-61

4. Heat 4-1
4.1 Thermodynamics 4-2
4.2 Thermodynamic Properties of Substances 4-32
4.3 Radiant Heat Transfer 4-63
4.4 Transmission of Heat by Conduction and Convection 4-79

5. Strength of Materials 5-1
5.1 Mechanical Properties of Materials 5-2
5.2 Mechanics of Materials 5-14
5.3 Pipeline Flexure Stresses 5-51
5.4 Nondestructive Testing 5-57
5.5 Experimental Stress and Strain Analysis 5-63
5.6 Mechanics of Composite Materials 5-71

6. Materials of Engineering 6-1
6.1 General Properties of Materials 6-3
6.2 Iron and Steel 6-12
6.3 Iron and Steel Castings 6-34
6.4 Nonferrous Metals and Alloys; Metallic Specialties 6-46
6.5 Corrosion 6-92
6.6 Paints and Protective Coatings 6-111
6.7 Wood 6-115
6.8 Nonmetallic Materials 6-131
6.9 Cement, Mortar, and Concrete 6-162

6.10 Water . . . 6-171
6.11 Lubricants and Lubrication . . . 6-180
6.12 Plastics . . . 6-189
6.13 Fiber Composite Materials . . . 6-206

7. Fuels and Furnaces . . . 7-1
7.1 Fuels . . . 7-2
7.2 Carbonization of Coal and Gas Making . . . 7-30
7.3 Combustion Furnaces . . . 7-43
7.4 Municipal Waste Combustion . . . 7-48
7.5 Electric Furnaces and Ovens . . . 7-54

8. Machine Elements . . . 8-1
8.1 Mechanism . . . 8-3
8.2 Machine Elements . . . 8-10
8.3 Gearing . . . 8-83
8.4 Fluid-Film Bearings . . . 8-111
8.5 Bearings with Rolling Contact . . . 8-127
8.6 Packings, Gaskets, and Seals . . . 8-133
8.7 Pipe, Pipe Fittings, and Valves . . . 8-138

9. Power Generation . . . 9-1
9.1 Sources of Energy . . . 9-3
9.2 Steam Boilers . . . 9-29
9.3 Steam Engines . . . 9-56
9.4 Steam Turbines . . . 9-58
9.5 Power-Plant Heat Exchangers . . . 9-78
9.6 Internal-Combustion Engines . . . 9-93
9.7 Gas Turbines . . . 9-127
9.8 Nuclear Power . . . 9-138
9.9 Hydraulic Turbines . . . 9-154

10. Materials Handling . . . 10-1
10.1 Materials Holding, Feeding, and Metering . . . 10-2
10.2 Lifting, Hoisting, and Elevating . . . 10-4
10.3 Dragging, Pulling, and Pushing . . . 10-22
10.4 Loading, Carrying, and Excavating . . . 10-26
10.5 Conveyor Moving and Handling . . . 10-42
10.6 Automatic Guided Vehicles and Robots . . . 10-63
10.7 Material Storage and Warehousing . . . 10-69

11. Transportation . . . 11-1
11.1 Automotive Engineering . . . 11-3
11.2 Railway Engineering . . . 11-18
11.3 Marine Engineering . . . 11-40
11.4 Aeronautics . . . 11-58
11.5 Jet Propulsion and Aircraft Propellers . . . 11-83
11.6 Astronautics . . . 11-104
11.7 Pipeline Transmission . . . 11-139
11.8 Containerization . . . 11-149

12. Building Construction and Equipment . . . 12-1
12.1 Industrial Plants . . . 12-2
12.2 Structural Design of Buildings . . . 12-19
12.3 Reinforced Concrete Design and Construction . . . 12-37
12.4 Air Conditioning, Heating, and Ventilating . . . 12-49
12.5 Illumination . . . 12-88
12.6 Sound, Noise, and Ultrasonics . . . 12-96

13. Manufacturing Processes . . . 13-1
13.1 Foundry Practice and Equipment . . . 13-3

13.2 Plastic Working of Metals 13-9
13.3 Welding and Cutting 13-29
13.4 Machining Processes and Machine Tools 13-50
13.5 Surface Texture Designation, Production, and Quality Control 13-72
13.6 Woodcutting Tools and Machines 13-77
13.7 Precision Cleaning 13-80

14. Fans, Pumps, and Compressors 14-1
14.1 Displacement Pumps 14-2
14.2 Centrifugal Pumps 14-15
14.3 Compressors 14-26
14.4 High-Vacuum Pumps 14-39
14.5 Fans 14-46

15. Electrical and Electronics Engineering 15-1
15.1 Electrical Engineering 15-2
15.2 Electronics 15-68

16. Instruments and Controls 16-1
16.1 Instruments 16-2
16.2 Automatic Controls 16-21
16.3 Surveying 16-52

17. Industrial Engineering 17-1
17.1 Operations Management 17-3
17.2 Cost Accounting 17-11
17.3 Engineering Statistics and Quality Control 17-18
17.4 Methods Engineering 17-25
17.5 Cost of Electric Power 17-31
17.6 Human Factors and Ergonomics 17-39
17.7 Automatic Manufacturing 17-43

18. The Regulatory Environment 18-1
18.1 Environmental Control 18-2
18.2 Occupational Safety and Health 18-18
18.3 Fire Protection 18-22
18.4 Patents, Trademarks, and Copyrights 18-27

19. Refrigeration, Cryogenics, and Optics 19-1
19.1 Mechanical Refrigeration 19-2
19.2 Cryogenics 19-26
19.3 Optics 19-41

20. Emerging Technologies 20-1
20.1 An Introduction to Microelectromechanical Systems (MEMS) 20-3
20.2 Introduction to Nanotechnology 20-13
20.3 Ferroelectrics/Piezoelectrics and Shape Memory Alloys 20-20
20.4 Introduction to the Finite-Element Method 20-28
20.5 Computer-Aided Design, Computer-Aided Engineering, and Variational Design 20-44
20.6 Introduction to Computational Fluid Dynamics 20-51
20.7 Experimental Fluid Dynamics 20-63
20.8 Introduction to Biomechanics 20-79
20.9 Human Injury Tolerance and Anthropometric Test Devices 20-104
20.10 Air-Inflated Fabric Structures 20-108
20.11 Robotics, Mechatronics, and Intelligent Automation 20-118
20.12 Rapid Prototyping 20-132
20.13 Miscellany 20-135

Index follows Section 20

Contributors

Abraham Abramowitz* *Consulting Engineer; Professor of Electrical Engineering, Emeritus, The City College of The City University of New York* (ILLUMINATION)
Vincent M. Altamuro *President, VMA Inc., Toms River, NJ* (MATERIAL HOLDING, FEEDING, AND METERING. CONVEYOR MOVING AND HANDLING. AUTOMATED GUIDED VEHICLES AND ROBOTS. MATERIAL STORAGE AND WAREHOUSING. METHODS ENGINEERING. AUTOMATIC MANUFACTURING. INDUSTRIAL PLANTS)
Charles A. Amann *Principal Engineer, KAB Engineering* (AUTOMOTIVE ENGINEERING)
Farid M. Amirouche *Professor of Mechanical and Industrial Engineering, University of Illinois at Chicago* (INTRODUCTION TO THE FINITE-ELEMENT METHOD. COMPUTER-AIDED DESIGN, COMPUTER-AIDED ENGINEERING, AND VARIATIONAL DESIGN)
Yiannis Andreopoulos *Professor of Mechanical Engineering, The City College of the City University of New York* (EXPERIMENTAL FLUID MECHANICS)
William Antis* *Technical Director, Maynard Research Council, Inc., Pittsburgh, PA* (METHODS ENGINEERING)
Glenn E. Asauskas *Lubrication Engineer, Chevron Corp.* (LUBRICANTS AND LUBRICATION)
Dennis N. Assanis *Professor of Mechanical Engineering, University of Michigan* (INTERNAL COMBUSTION ENGINES)
Eugene A. Avallone *Consulting Engineer; Professor of Mechanical Engineering, Emeritus, The City College of The City University of New York* (MECHANICAL PROPERTIES OF MATERIALS. GENERAL PROPERTIES OF MATERIALS. PIPE, PIPE FITTINGS, AND VALVES. SOURCES OF ENERGY. STEAM ENGINES. MISCELLANY)
Klemens C. Baczewski *Consulting Engineer* (CARBONIZATION OF COAL AND GAS MAKING)
Glenn W. Baggley* *Former Manager, Regenerative Systems, Bloom Engineering Co., Inc.* (COMBUSTION FURNACES)
Frederick G. Baily *Consulting Engineer; Steam Turbines, General Electric Co.* (STEAM TURBINES)
Robert D. Bartholomew *Associate, Sheppard T. Powell Associates, LLC* (CORROSION)
George F. Baumeister *President, EMC Process Corp., Newport, DE* (MATHEMATICAL TABLES)
John T. Baumeister *Manager, Product Compliance Test Center, Unisys Corp.* (MEASURING UNITS)
E. R. Behnke* *Product Manager, CM Chain Division, Columbus, McKinnon Corp.* (CHAINS)
John T. Benedict* *Retired Standards Engineer and Consultant, Society of Automotive Engineers* (AUTOMOTIVE ENGINEERING)
Bernadette M. Bennett, Esq. *Associate; Carter, DeLuca, Farrell and Schmidt, LLP Melville, NY* (PATENTS, TRADEMARKS, AND COPYRIGHTS)
Louis Bialy *Director, Codes & Product Safety, Otis Elevator Company* (ELEVATORS, DUMBWAITERS, AND ESCALATORS)
Malcolm Blair *Technical and Research Director, Steel Founders Society of America* (IRON AND STEEL CASTINGS)
Omer W. Blodgett *Senior Design Consultant, Lincoln Electric Co.* (WELDING AND CUTTING)
B. Douglas Bode *Engineering Supervisor, Product Customization and Vehicle Enhancement, Construction and Forestry Div., John Deere* (OFF-HIGHWAY VEHICLES AND EARTHMOVING EQUIPMENT)
Donald E. Bolt* *Engineering Manager, Heat Transfer Products Dept., Foster Wheeler Energy Corp.* (POWER PLANT HEAT EXCHANGERS)
G. David Bounds *Senior Engineer, Duke Energy Corp.* (PIPELINE TRANSMISSION)
William J. Bow* *Director, Retired, Heat Transfer Products Department, Foster Wheeler Energy Corp.* (POWER PLANT HEAT EXCHANGERS)

*Contributions by authors whose names are marked with an asterisk were made for the previous edition and have been revised or rewritten by others for this edition. The stated professional position in these cases is that held by the author at the time of his or her contribution.

James L. Bowman* *Senior Engineering Consultant, Rotary-Reciprocating Compressor Division, Ingersoll-Rand Co.* (COMPRESSORS)
Walter H. Boyes, Jr. *Editor-in-Chief/Publisher, Control Magazine* (INSTRUMENTS)
Richard L. Brazill *Technology Specialist, ALCOA Technical Center, ALCOA* (ALUMINUM AND ITS ALLOYS)
Frederic W. Buse* *Chief Engineer, Standard Pump Division, Ingersoll-Rand Co.* (DISPLACEMENT PUMPS)
Charles P. Butterfield *Chief Engineer, National Wind Technology Center, National Renewable Energy Laboratory* (WIND POWER)
C. L. Carlson* *Late Fellow Engineer, Research Labs., Westinghouse Electric Corp.* (NONFERROUS METALS AND ALLOYS. METALS AND ALLOYS FOR NUCLEAR ENERGY APPLICATIONS)
Scott W. Case *Professor of Engineering Science & Mechanics, Virginia Polytechnic Institute and State University* (MECHANICS OF COMPOSITE MATERIALS)
Vittorio (Rino) Castelli *Senior Research Fellow, Retired, Xerox Corp.; Engineering Consultant* (FRICTION. FLUID FILM BEARINGS)
Paul V. Cavallaro *Senior Mechanical Research Engineer, Naval Underwater Warfare Center* (AIR-INFLATED FABRIC STRUCTURES)
Eric L. Christiansen *Johnson Space Center, NASA* (METEOROID/ORBITAL DEBRIS SHIELDING)
Robin O. Cleveland *Associate Professor of Aerospace and Mechanical Engineering, Boston University* (SOUND, NOISE, AND ULTRASONICS)
Gary L. Cloud *Professor, Department of Mechanical Engineering, Michigan State University* (EXPERIMENTAL STRESS AND STRAIN ANALYSIS)
Ashley C. Cockerill *Vice President and Event Coordinator, nanoTech Business, Inc.* (ENGINEERING STATISTICS AND QUALITY CONTROL)
Timothy M. Cockerill *Senior Project Manager, University of Illinois* (ELECTRONICS)
Thomas J. Cockerill *Advisory Engineer, International Business Machines Corp.* (COMPUTERS)
Aaron Cohen *Retired Center Director, Lyndon B. Johnson Space Center, NASA; Zachry Professor, Texas A&M University* (ASTRONAUTICS)
Arthur Cohen *Former Manager, Standards and Safety Engineering, Copper Development Assn.* (COPPER AND COPPER ALLOYS)
D. E. Cole *Director, Office for Study of Automotive Transportation, Transportation Research Institute, University of Michigan* (INTERNAL COMBUSTION ENGINES)
James M. Connolly *Section Head, Projects Department, Jacksonville Electric Authority* (COST OF ELECTRIC POWER)
Alexander Couzis *Professor of Chemical Engineering, The City College of the City University of New York* (INTRODUCTION TO NANOTECHNOLOGY)
Terry L. Creasy *Assistant Professor of Mechanical Engineering, Texas A&M University* (STRUCTURAL COMPOSITES)
M. R. M. Crespo da Silva* *University of Cincinnati* (ATTITUDE DYNAMICS, STABILIZATION, AND CONTROL OF SPACECRAFT)
Richard A. Dahlin *Vice President, Engineering, Walker Magnetics* (LIFTING MAGNETS)
Benjamin C. Davenny *Acoustical Consultant, Acentech Inc., Cambridge, MA* (SOUND, NOISE, AND ULTRASONICS)
William H. Day *President, Longview Energy Associates, LLC; formerly Founder and Board Chairman, The Gas Turbine Association* (GAS TURBINES)
Benjamin B. Dayton *Consulting Physicist, East Flat Rock, NC* (HIGH-VACUUM PUMPS)
Horacio M. de la Fuente *Senior Engineer, NASA Johnson Space Center* (TRANSHAB)
Donald D. Dodge *Supervisor, Retired, Product Quality and Inspection Technology, Manufacturing Development, Ford Motor Co.* (NONDESTRUCTIVE TESTING)
Andrew M. Donaldson *Project Director, Parsons E&C, Reading, PA* (COST OF ELECTRIC POWER)
Joseph S. Dorson *Senior Engineer, Columbus McKinnon Corp.* (CHAIN)
James Drago *Manager, Engineering, Garlock Sealing Technologies* (PACKING, GASKETS, AND SEALS)
Michael B. Duke *Chief, Solar Systems Exploration, Johnson Space Center, NASA* (DYNAMIC ENVIRONMENTS)
F. J. Edeskuty *Retired Associate, Las Alamos National Laboratory* (CRYOGENICS)

O. Elnan* *University of Cincinnati* (SPACE-VEHICLE TRAJECTORIES, FLIGHT MECHANICS, AND PERFORMANCE. ORBITAL MECHANICS)

Robert E. Eppich *Vice President, Technology, American Foundry Society* (IRON AND STEEL CASTINGS)

C. James Erickson* *Retired Principal Consultant, Engineering Department, E. I. du Pont de Nemours & Co.* (ELECTRICAL ENGINEERING)

George H. Ewing* *Retired President and Chief Executive Officer, Texas Eastern Gas Pipeline Co. and Transwestern Pipeline Co.* (PIPELINE TRANSMISSION)

Heimir Fanner *Chief Design Engineer, Ariel Corp.* (COMPRESSORS)

Erich A. Farber *Distinguished Service Professor Emeritus, Director Emeritus of Solar Energy and Energy Conversion Lab., University of Florida* [STIRLING (HOT AIR) ENGINES. SOLAR ENERGY. DIRECT ENERGY CONVERSION]

Raymond E. Farrell, Esq. *Partner; Carter, DeLuca, Farrell and Schmidt, LLP, Melville, NY* (PATENTS, TRADEMARKS, AND COPYRIGHTS)

D. W. Fellenz* *University of Cincinnati* (SPACE-VEHICLE TRAJECTORIES, FLIGHT MECHANICS, AND PERFORMANCE. ATMOSPHERIC ENTRY)

Chuck Fennell *Program Manager, Dalton Foundries* (FOUNDARY PRACTICE AND EQUIPMENT)

Arthur J. Fiehn* *Late Retired Vice President, Project Operations Division, Burns & Roe, Inc.* (COST OF ELECTRIC POWER)

Sanford Fleeter *McAllister Distinguished Professor, School of Mechanical Engineering, Purdue University* (JET PROPULSION AND AIRCRAFT PROPELLERS)

Luc G. Fréchette *Professor of Mechanical Engineering, Université de Sherbrooke, Canada* [AN INTRODUCTION TO MICROELECTROMECHANICAL SYSTEMS (MEMS)]

William L. Gamble *Professor Emeritus of Civil and Environmental Engineering, University of Illinois at Urbana-Champaign* (CEMENT, MORTAR, AND CONCRETE. REINFORCED CONCRETE DESIGN AND CONSTRUCTION)

Robert F. Gambon *Power Plant Design and Development Consultant* (COST OF ELECTRIC POWER)

Burt Garofab *Senior Engineer, Pittston Corp.* (MINES, HOISTS, AND SKIPS. LOCOMOTIVE HAULAGE, COAL MINES)

Siamak Ghofranian *Senior Engineer, Rockwell Aerospace* (DOCKING OF TWO FREE-FLYING SPACECRAFT)

Samuel V. Glorioso *Section Chief, Metallic Materials, Johnson Space Center, NASA* (STRESS CORROSION CRACKING)

Norman Goldberg *Consulting Engineer, Economides and Goldberg* (AIR-CONDITIONING, HEATING, AND VENTILATING)

Andrew Goldenberg *Professor of Mechanical and Industrial Engineering, University of Toronto, Canada; President and CEO of Engineering Service Inc. (ESI) Toronto* (ROBOTICS, MECHATRONICS, AND INTELLIGENT AUTOMATION)

David T. Goldman* *Late Deputy Manager, U.S. Department of Energy, Chicago Operations Office* (MEASURING UNITS)

Frank E. Goodwin *Executive Vice President, ILZRO, Inc.* (BEARING METALS. LOW-MELTING-POINT METALS AND ALLOYS. ZINC AND ZINC ALLOYS)

Don Graham *Manager, Turning Products, Carboloy, Inc.* (CEMENTED CARBIDES)

David W. Green *Supervisory Research General Engineer, Forest Products Lab., USDA* (WOOD)

Leonard M. Grillo *Principal, Grillo Engineering Co.* (MUNICIPAL WASTE COMBUSTION)

Walter W. Guy *Chief, Crew and Thermal Systems Division, Johnson Space Center, NASA* (SPACECRAFT LIFE SUPPORT AND THERMAL MANAGEMENT)

Marsbed Hablanian *Retired Manager of Engineering and R&D, Varian Vacuum Technologies* (HIGH-VACUUM PUMPS)

Christopher P. Hansen *Structures and Mechanism Engineer, NASA Johnson Space Center* (PORTABLE HYPERBARIC CHAMBER)

Harold V. Hawkins* *Late Manager, Product Standards and Services, Columbus McKinnon Corp.* (DRAGGING, PULLING, AND PUSHING. PIPELINE FLEXURE STRESSES)

Keith L. Hawthorne *Vice President—Technology, Transportation Technology Center, Inc.* (RAILWAY ENGINEERING)

V. Terrey Hawthorne *Late Senior Engineer, LTK Engineering Services* (RAILWAY ENGINEERING)

J. Edmund Hay *U.S. Department of the Interior* (EXPLOSIVES)

Terry L. Henshaw *Consulting Engineer, Magnolia, TX* (DISPLACEMENT PUMPS. CENTRIFUGAL PUMPS)

Roland Hernandez *Research Engineer, Forest Products Lab., USDA* (WOOD)

David T. Holmes *Manager of Engineering, Lift-Tech International Div. of Columbus McKinnon Corp.* (MONORAILS. OVERHEAD TRAVELING CRANES)

Hoyt C. Hottel *Late Professor Emeritus, Massachusetts Institute of Technology* (RADIANT HEAT TRANSFER)

Michael W. Hyer *Professor of Engineering Science & Mechanics, Virginia Polytechnic Institute and State University* (MECHANICS OF COMPOSITE MATERIALS)

Timothy J. Jacobs *Research Fellow, Department of Mechanical Engineering, University of Michigan* (INTERNAL COMBUSTION ENGINES)

Michael W. M. Jenkins *Professor, Aerospace Design, Georgia Institute of Technology* (AERONAUTICS)

Peter K. Johnson *Consultant* (POWDERED METALS)

Randolph T. Johnson *Naval Surface Warfare Center* (ROCKET FUELS)

Robert L. Johnston *Branch Chief, Materials, Johnson Space Center, NASA* (METALLIC MATERIALS FOR AEROSPACE APPLICATIONS. MATERIALS FOR USE IN HIGH-PRESSURE OXYGEN SYSTEMS)

Byron M. Jones* *Retired Assistant Professor of Electrical Engineering, School of Engineering, University of Tennessee at Chattanooga* (ELECTRONICS)

Scott K. Jones *Professor, Department of Accounting & MIS, Alfred Lerner College of Business & Economics, University of Delaware* (COST ACCOUNTING)

Robert Jorgensen *Engineering Consultant* (FANS)

Serope Kalpakjian *Professor Emeritus of Mechanical and Materials Engineering, Illinois Institute of Technology* (MACHINING PROCESSES AND MACHINE TOOLS)

Igor J. Karassik* *Late Senior Consulting Engineer, Ingersoll Dresser Pump Co.* (CENTRIFUGAL AND AXIAL FLOW PUMPS)

Jonathan D. Kemp *Vibration Consultant, Acentech, Inc., Cambridge, MA* (SOUND, NOISE, AND ULTRASONICS)

J. Randolph Kissell *President, The TGB Partnership* (ALUMINUM AND ITS ALLOYS)

John B. Kitto, Jr. *Babcock & Wilcox Co.* (STEAM BOILERS)

Andrew C. Klein *Professor of Nuclear Engineering, Oregon State University; Director of Training, Education and Research Partnership, Idaho National Laboratories* (NUCLEAR POWER. ENVIRONMENTAL CONTROL. OCCUPATIONAL SAFETY AND HEALTH. FIRE PROTECTION)

Doyle Knight *Professor of Mechanical and Aerospace Engineering, Rutgers University* (INTRODUCTION TO COMPUTATIONAL FLUID MECHANICS)

Ronald M. Kohner *President, Landmark Engineering Services, Ltd.* (DERRICKS)

Ezra S. Krendel *Emeritus Professor of Operations Research and Statistics, University of Pennsylvania* (HUMAN FACTORS AND ERGONOMICS. MUSCLE GENERATED POWER)

A. G. Kromis* *University of Cincinnati* (SPACE-VEHICLE TRAJECTORIES, FLIGHT MECHANICS, AND PERFORMANCE)

Srirangam Kumaresan *Biomechanics Institute, Santa Barbara, California* (HUMAN INJURY TOLERANCE AND ANTHROPOMETRIC TEST DEVICES)

L. D. Kunsman* *Late Fellow Engineer, Research Labs, Westinghouse, Electric Corp.* (NONFERROUS METALS AND ALLOYS. METALS AND ALLOYS FOR NUCLEAR ENERGY APPLICATIONS)

Colin K. Larsen *Vice President, Blue Giant U.S.A. Corp.* (SURFACE HANDLING)

Stan Lebow *Research Forest Products Technologist, Forest Products Lab., USDA* (WOOD)

John H. Lewis *Engineering Consultant; Formerly Engineering Staff, Pratt & Whitney Division, United Technologies Corp.; Adjunct Associate Professor, Hartford Graduate Center, Renssealear Polytechnic Institute* (GAS TURBINES)

Jackie Jie Li *Professor of Mechanical Engineering, The City College of the City University of New York* (FERROELECTRICS/PIEZOELECTRICS AND SHAPE MEMORY ALLOYS)

Peter E. Liley *Professor Emeritus of Mechanical Engineering, Purdue University* (THERMODYNAMICS, THERMODYNAMIC PROPERTIES OF SUBSTANCES)

James P. Locke *Flight Surgeon, NASA Johnson Space Center* (PORTABLE HYPERBARIC CHAMBER)

Ernst K. H. Marburg *Manager, Product Standards and Service, Columbus McKinnon Corp.* (LIFTING, HOISTING, AND ELEVATING. DRAGGING, PULLING, AND PUSHING. LOADING, CARRYING, AND EXCAVATING)

Larry D. Means *President, Means Engineering and Consulting* (WIRE ROPE)

Leonard Meirovitch *University Distinguished Professor Emeritus, Department of Engineering Science and Mechanics, Virginia Polytechnic Institute and State University* (VIBRATION)

George W. Michalec *Late Consulting Engineer* (GEARING)

Duane K. Miller *Manager, Engineering Services, Lincoln Electric Co.* (WELDING AND CUTTING)

Patrick C. Mock *Principal Electron Optical Scientist, Science and Engineering Associates, Inc.* (OPTICS)

Thomas L. Moser *Deputy Associate Administrator, Office of Space Flight, NASA Headquarters, NASA* (SPACE-VEHICLE STRUCTURES)

George J. Moshos* *Professor Emeritus of Computer and Information Science, New Jersey Institute of Technology* (COMPUTERS)

Eduard Muljadi *Senior Engineer, National Wind Technology Center, National Renewable Energy Laboratory* (WIND POWER)

Otto Muller-Girard* *Consulting Engineer* (INSTRUMENTS)

James W. Murdock *Late Consulting Engineer* (MECHANICS OF FLUIDS)

Gregory V. Murphy *Professor, Department of Electrical and Computer Engineering, College of Engineering, University of Alabama* (AUTOMATIC CONTROLS)

Joseph F. Murphy *Research General Engineer, Forest Products Lab., USDA* (WOOD)

John Nagy *Retired Supervisory Physical Scientist, U.S. Department of Labor, Mine Safety and Health Administration* (DUST EXPLOSIONS)

B. W. Niebel* *Professor Emeritus of Industrial Engineering, The Pennsylvania State University* (INDUSTRIAL ECONOMICS AND MANAGEMENT)

James J. Noble *Formerly Research Associate Professor of Chemical and Biological Engineering, Tufts University* (RADIANT HEAT TRANSFER)

Charles Osborn *Business Manager, Precision Cleaning Division, PTI Industries, Inc.* (PRECISION CLEANING)

D. J. Patterson *Professor of Mechanical Engineering, Emeritus, University of Michigan* (INTERNAL COMBUSTION ENGINES)

Harold W. Paxton *United States Steel Professor Emeritus, Carnegie Mellon University* (IRON AND STEEL)

Richard W. Perkins *Professor Emeritus of Mechanical, Aerospace, and Manufacturing Engineering, Syracuse University* (WOODCUTTING TOOLS AND MACHINES)

W. R. Perry* *University of Cincinnati* (ORBITAL MECHANICS. SPACE-VEHICLE TRAJECTORIES, FLIGHT MECHANICS, AND PERFORMANCE)

Kenneth A. Phair *Senior Project Engineer, Shaw Stone & Webster* (GEOTHERMAL POWER)
Orvis E. Pigg *Section Head, Structural Analysis, Johnson Space Center, NASA* (SPACE VEHICLE STRUCTURES)
Henry O. Pohl *Chief, Propulsion and Power Division, Johnson Space Center, NASA* (SPACE PROPULSION)
Nicholas R. Rafferty *Retired Technical Associate, E. I. du Pont de Nemours & Co., Inc.* (ELECTRICAL ENGINEERING)
Rama Ramakumar *PSO/Albrecht Naeter Professor and Director, Engineering Energy Laboratory, Oklahoma State University* (WIND POWER)
Pascal M. Rapier* *Scientist III, Retired, Lawrence Berkeley Laboratory* (ENVIRONMENTAL CONTROL. OCCUPATIONAL SAFETY AND HEALTH. FIRE PROTECTION)
James D. Redmond *President, Technical Marketing Services, Inc.* (STAINLESS STEELS)
Darrold E. Roen *Late Manager, Sales & Special Engineering & Government Products, John Deere* (OFF-HIGHWAY VEHICLES)
Ivan L. Ross* *International Manager, Chain Conveyor Division, ACCO* (OVERHEAD CONVEYORS)
Robert J. Ross *Supervisory Research General Engineer, Forest Products Lab., USDA* (WOOD)
J. W. Russell* *University of Cincinnati* (SPACE-VEHICLE TRAJECTORIES, FLIGHT MECHANICS, AND PERFORMANCE. LUNAR- AND INTERPLANETARY FLIGHT MECHANICS)
A. J. Rydzewski *Consultant, DuPont Engineering, E. I. du Pont de Nemours and Company* (MECHANICAL REFRIGERATION)
Ali M. Sadegh *Professor of Mechanical Engineering, The City College of The City University of New York* (MECHANICS OF MATERIALS. NONMETALLIC MATERIALS. MECHANISM. MACHINE ELEMENTS. SURFACE TEXTURE DESIGNATION, PRODUCTION, AND QUALITY CONTROL. INTRODUCTION TO BIOMECHANICS. AIR-INFLATED FABRIC STRUCTURES. RAPID PROTOTYPING.)
Anthony Sances, Jr. *Biomechanics Institute, Santa Barbara, CA* (HUMAN INJURY TOLERANCE AND ANTHROPOMETRIC TEST DEVICES)
C. Edward Sandifer *Professor, Western Connecticut State University, Danbury, CT* (MATHEMATICS)
Erwin M. Saniga *Dana Johnson Professor of Information Technology and Professor of Operations Management, University of Delaware* (OPERATIONS MANAGEMENT)
Adel F. Sarofim *Presidential Professor of Chemical Engineering, University of Utah* (RADIANT HEAT TRANSFER)
Martin D. Schlesinger *Late Consultant, Wallingford Group, Ltd.* (FUELS)
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Matthew S. Schmidt *Senior Engineer, Rockwell Aerospace* (DOCKING OF TWO FREE-FLYING SPACECRAFT)
Wiliam C. Schneider *Retired Assistant Director Engineering/Senior Engineer, NASA Johnson Space Center; Visiting Professor, Texas A&M University* (ASTRONAUTICS)
James D. Shearouse, III *Late Senior Development Engineer, The Dow Chemical Co.* (MAGNESIUM AND MAGNESIUM ALLOYS)
David A. Shifler *Metallurgist, MERA Metallurgical Services* (CORROSION)
Rajiv Shivpuri *Professor of Industrial, Welding, and Systems Engineering, Ohio State University* (PLASTIC WORKING OF METALS)
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William T. Simpson *Research Forest Products Technologist, Forest Products Lab., USDA* (WOOD)
Kenneth A. Smith *Edward R. Gilliland Professor of Chemical Engineering, Massachusetts Institute of Technology* (TRANSMISSION OF HEAT BY CONDUCTION AND CONVECTION)
Lawrence H. Sobel* *University of Cincinnati* (VIBRATION OF STRUCTURES)
James G. Speight *Western Research Institute* (FUELS)
Robert D. Steele *Project Manager, Voith Siemens Hydro Power Generation, Inc.* (HYDRAULIC TURBINES)
Stephen R. Swanson *Professor of Mechanical Engineering, University of Utah* (FIBER COMPOSITE MATERIALS)
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Peter L. Tea, Jr. *Professor of Physics Emeritus, The City College of the City University of New York* (MECHANICS OF SOLIDS)
Anton TenWolde *Supervisory Research Physicist, Forest Products Lab., USDA* (WOOD)
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Charles O. Velzy *Consultant* (MUNICIPAL WASTE COMBUSTION)
Harry C. Verakis *Supervisory Physical Scientist, U.S. Department of Labor, Mine Safety and Health Administration* (DUST EXPLOSIONS)
Arnold S. Vernick *Former Associate, Geraghty & Miller, Inc.* (WATER)
Robert J. Vondrasek* *Assistant Vice President of Engineering, National Fire Protection Assoc.* (COST OF ELECTRIC POWER)
Michael W. Washo *Senior Engineer, Retired, Eastman Kodak, Co.* (BEARINGS WITH ROLLING CONTACT)
Larry F. Wieserman *Senior Technical Supervisor, ALCOA* (ALUMINUM AND ITS ALLOYS)
Robert H. White *Supervisory Wood Scientist, Forest Products Lab., USDA* (WOOD)
John W. Wood, Jr. *Manager, Technical Services, Garlock Klozure* (PACKING, GASKETS, AND SEALS)

The Editors

EUGENE A. AVALLONE, Editor, is Professor of Mechanical Engineering, Emeritus, The City College of the City University of New York. He has been engaged for many years as a consultant to industry and to a number of local and national governmental agencies.

THEODORE BAUMEISTER, III, Editor, is now retired from Du Pont where he was an internal consultant. His specialties are operations research, business decision making, and long-range planning. He has also taught financial modeling in the United States, South America, and the Far East.

ALI M. SADEGH, Editor, is Professor of Mechanical Engineering, The City College of the City University of New York. He is also Director of the Center for Advanced Engineering Design and Development. He is actively engaged in research in the areas of machine design, manufacturing, and biomechanics.

Preface to the Eleventh Edition

The evolutionary trends underlying modern engineering practice are grounded not only on the tried and true principles and techniques of the past, but also on more recent and current advances. Thus, in the preparation of the eleventh edition of "Marks'," the Editors have considered the broad enterprise falling under the rubric of "Mechanical Engineering" and have added to and/or amended the contents to include subject areas that will be of maximum utility to the practicing engineer. That said, the Editors note that the publication of this eleventh edition has been accomplished through the combined and coordinated efforts of contributors, readers, and the Editors.

First, we recognize, with pleasure, the input from our many contributors—past, continuing, and those newly engaged. Their contributions have been prepared with care, and are authoritative, informative, and concise.

Second, our readers, who are practitioners in their own wise, have found that the global treatment of the subjects presented in the "Marks'" permits of great utility and serves as a convenient ready reference. The reading public has had access to "Marks'" since 1916, when Lionel S. Marks edited the first edition. This eleventh edition follows 90 years later. During the intervening years, "Marks'" and "Handbook for Mechanical Engineers" have become synonymous to a wide readership which includes mechanical engineers, engineers in the associated disciplines, and others. Our readership derives from a wide spectrum of interests, and it appears many find the "Marks'" useful as they pursue their professional endeavors.

The Editors consider it a given that every successive edition must balance the requests to broaden the range or depth of subject matter printed, the incorporation of new material which will be useful to the widest possible audience, and the requirement to keep the size of the Handbook reasonable and manageable. We are aware that the current engineering practitioner learns quickly that the revolutionary developments of the recent past soon become standard practice. By the same token, it is prudent to realize that as a consequence of rapid developments, some cutting-edge technologies prove to have a short shelf life and soon are regarded as obsolescent—if not obsolete.

The Editors are fortunate to have had, from time to time, input from readers and reviewers, who have proffered cogent commentary and suggestions; a number are included in this edition. Indeed, the synergy between Editors, contributors, and readers has been instrumental in the continuing usefulness of successive editions of "Marks' Standard Handbook for Mechanical Engineers."

The reader will note that a considerable portion of the tabular data and running text continue to be presented in dual units; i.e., USCS and SI. The date for a projected full transition to SI units is not yet firm, and the "Marks'" reflects that. We look to the future in that regard.

Society is in an era of information technology, as manifest by the practicing engineer's working tools. For example: the ubiquitous personal computer, its derivative use of software programs of a vast variety and number, printers, computer-aided design and drawing, universal access to the Internet, and so on. It is recognized, too, that the great leaps forward which are thereby enhanced still require the engineer to exercise sound and rational judgment as to the reliability of the solutions provided.

Last, the Handbook is ultimately the responsibility of the Editors. The utmost care has been exercised to avoid errors, but if any inadvertently are included, the Publisher and Editors will appreciate being so informed. Corrections will be incorporated into subsequent printings.

Ardsley, NY EUGENE A. AVALLONE
Newark, DE THEODORE BAUMEISTER III
Franklin Lakes, NJ ALI M. SADEGH

Preface to the First Edition*

This Handbook is intended to supply both the practicing engineer and the student with a reference work which is authoritative in character and which covers the field of mechanical engineering in a comprehensive manner. It is no longer possible for a single individual or a small group of individuals to have so intimate an acquaintance with any major division of engineering as is necessary if criticial judgment is to be exercised in the statement of current practice and the selection of engineering data. Only by the cooperation of a considerable number of specialists is it possible to obtain the desirable degree of reliability. This Handbook represents the work of fifty specialists.

Each contributor is to be regarded as responsible for the accuracy of his section. The number of contributors required to ensure sufficiently specialized knowledge for all the topics treated is necessarily large. It was found desirable to enlist the services of thirteen specialists for an adequate handling of the "Properties of Engineering Materials." Such topics as "Automobiles," "Aeronautics," "Illumination," "Patent Law," "Cost Accounting," "Industrial Buildings," "Corrosion," "Air Conditioning, "Fire Protection," "Prevention of Accidents," etc., though occupying relatively small spaces in the book, demanded each a separate writer.

A number of the contributions which deal with engineering practice, after examination by the Editor-in-Chief, were submitted by him to one or more specialists for criticism and suggestions. Their cooperation has proved of great value in securing greater accuracy and in ensuring that the subject matter does not embody solely the practice of one individual but is truly representative.

An accuracy of four significant figures has been assumed as the desirable limit; figures in excess of this number have been deleted, except in special cases. In the mathematical tables only four significant figures have been kept.

The Editor-in-Chief desires to express here his appreciation of the spirit of cooperation shown by the Contributors and of their patience in submitting to modifications of their sections. He wishes also to thank the Publishers for giving him complete freedom and hearty assistance in all matters relating to the book from the choice of contributors to the details of typography.

Cambridge, Mass. LIONEL S. MARKS
April 23, 1916

*Excerpt.

Symbols and Abbreviations

For symbols of chemical elements, see Sec. 6; for abbreviations applying to metric weights and measures and SI units, Sec. 1; SI unit prefixes are listed on p. 1–19.

Pairs of parentheses, brackets, etc., are frequently used in this work to indicate corresponding values. For example, the statement that "the cost per kW of a 30,000-kW plant is $86; of a 15,000-kW plant, $98; and of an 8,000-kW plant, $112," is condensed as follows: The cost per kW of a 30,000 (15,000) [8,000]-kW plant is $86 (98) [112].

In the citation of references readers should always attempt to consult the latest edition of referenced publications.

A or Å	Angstrom unit = 10^{-10} m; 3.937×10^{-11} in
A	mass number = N + Z; ampere
AA	arithmetical average
AAA	Am. Automobile Assoc.
AAMA	American Automobile Manufacturers' Assoc.
AAR	Assoc. of Am. Railroads
AAS	Am. Astronautical Soc.
ABAI	Am. Boiler & Affiliated Industries
abs	absolute
a.c.	aerodynamic center
a-c, ac	alternating current
ACI	Am. Concrete Inst.
ACM	Assoc. for Computing Machinery
ACRMA	Air Conditioning and Refrigerating Manufacturers Assoc.
ACS	Am. Chemical Soc.
ACSR	aluminum cable steel-reinforced
ACV	air cushion vehicle
A.D.	anno Domini (in the year of our Lord)
AEC	Atomic Energy Commission (U.S.)
a-f, af	audio frequency
AFBMA	Anti-friction Bearings Manufacturers' Assoc.
AFS	Am. Foundrymen's Soc.
AGA	Am. Gas Assoc.
AGMA	Am. Gear Manufacturers' Assoc.
ahp	air horsepower
AIChE	Am. Inst. of Chemical Engineers
AIEE	Am. Inst. of Electrical Engineers (see IEEE)
AIME	Am. Inst. of Mining Engineers
AIP	Am. Inst. of Physics
AISC	American Institute of Steel Construction, Inc.
AISE	Am. Iron & Steel Engineers
AISI	Am. Iron and Steel Inst.
Al. Assn.	Aluminum Association
a.m.	ante meridiem (before noon)
a-m, am	amplitude modulation
Am. Mach.	Am. Machinist (New York)
AMA	Acoustical Materials Assoc.
AMCA	Air Moving & Conditioning Assoc., Inc.
amu	atomic mass unit
AN	ammonium nitrate (explosive); Army-Navy Specification
AN-FO	ammonium nitrate-fuel oil (explosive)
ANC	Army-Navy Civil Aeronautics Committee
ANS	Am. Nuclear Soc.
ANSI	American National Standards Institute
antilog	antilogarithm of
API	Am. Petroleum Inst.
approx	approximately
APWA	Am. Public Works Assoc.
AREA	Am. Railroad Eng. Assoc.
ARI	Air Conditioning and Refrigeration Inst.
ARS	Am. Rocket Soc.
ASCE	Am. Soc. of Civil Engineers
ASHRAE	Am. Soc. of Heating, Refrigerating, and Air Conditioning Engineers
ASLE	Am. Soc. of Lubricating Engineers
ASM	Am. Soc. of Metals
ASME	Am. Soc. of Mechanical Engineers
ASST	Am. Soc. of Steel Treating
ASTM	Am. Soc. for Testing and Materials
ASTME	Am. Soc. of Tool & Manufacturing Engineers
atm	atmosphere
Auto. Ind.	Automotive Industries (New York)
avdp	avoirdupois
avg, ave	average
AWG	Am. Wire Gage
AWPA	Am. Wood Preservation Assoc.
AWS	American Welding Soc.
AWWA	American Water Works Assoc.
b	barns
bar	barometer
B&S	Brown & Sharp (gage); Beams and Stringers
bbl	barrels
B.C.	before Christ
B.C.C.	body centered cubic
Bé	Baumé (degrees)
B.G.	Birmingham gage (hoop and sheet)
bgd	billions of gallons per day
BHN	Brinnell Hardness Number
bhp	brake horsepower
BLC	boundary layer control
B.M.	board measure; bench mark
bmep	brake mean effective pressure
B of M, BuMines	Bureau of Mines

BOD	biochemical oxygen demand
bp	boiling point
Bq	bequerel
bsfc	brake specific fuel consumption
BSI	British Standards Inst.
Btu	British thermal units
Btub, Btu/h	Btu per hr
bu	bushels
Bull.	Bulletin
Buweaps	Bureau of Weapons, U.S. Navy
BWG	Birmingham wire gage
c	velocity of light
°C	degrees Celsius (centigrade)
C	coulomb
CAB	Civil Aeronautics Board
CAGI	Compressed Air & Gas Inst.
cal	calories
C-B-R	chemical, biological & radiological (filters)
CBS	Columbia Broadcasting System
cc, cm^3	cubic centimetres
CCR	critical compression ratio
c to c	center to center
cd	candela
c.f.	centrifugal force
cf.	confer (compare)
cfh, ft^3/h	cubic feet per hour
cfm, ft^3/min	cubic feet per minute
C.F.R.	Cooperative Fuel Research
cfs, ft^3/s	cubic feet per second
cg	center of gravity
cgs	centimetre-gram-second
Chm. Eng.	Chemical Eng'g (New York)
chu	centrigrade heat unit
C.I.	cast iron
cir	circular
cir mil	circular mils
cm	centimetres
CME	Chartered Mech. Engr. (IMechE)
C.N.	cetane number
coef	coefficient
COESA	U.S. Committee on Extension to the Standard Atmosphere
col	column
colog	cologarithm of
const	constant
cos	cosine of
$\cos^{-1}$	angle whose cosine is, inverse cosine of
cosh	hyperbolic cosine of
$\cosh^{-1}$	inverse hyperbolic cosine of
cot	cotangent of
$\cot^{-1}$	angle whose cotangent is (see $\cos^{-1}$)
coth	hyperbolic cotangent of
$\coth^{-1}$	inverse hyperbolic cotangent of
covers	coversed sine of
c.p.	circular pitch; center of pressure
cp	candle power
cp	coef of performance
CP	chemically pure
CPH	close packed hexagonal
cpm	cycles per minute
cycles/min	
cps, cycles/s	cycles per second
CSA	Canadian Standards Assoc.
csc	cosecant of
$\csc^{-1}$	angle whose cosecant is (see $\cos^{-1}$)
csch	hyperbolic cosecant of
csch^{-1}	inverse hyperbolic cosecant of
cu	cubic
cyl	cylinder
db, dB	decibel
d-c, dc	direct current
def	definition
deg	degrees
diam. (dia)	diameter
DO	dissolved oxygen
D_2O	deuterium (heavy water)
d.p.	double pole
DP	Diametral pitch
DPH	diamond pyramid hardness
DST	daylight saving time
d^2 tons	breaking strength, d = chain wire diam. in.
DX	direct expansion
e	base of Napierian logarithmic system (= 2.7182+)
EAP	equivalent air pressure
EDR	equivalent direct radiation
EEI	Edison Electric Inst.
eff	efficiency
e.g.	exempli gratia (for example)
ehp	effective horsepower
EHV	extra high voltage
El. Wld.	Electrical World (New York)
elec	electric
elong	elongation
emf	electromotive force
Engg.	Engineering (London)
Engr.	The Engineer (London)
ENT	emergency negative thrust
EP	extreme pressure (lubricant)
ERDA	Energy Research & Development Administration (successor to AEC; see also NRC)
Eq.	equation
est	estimated
etc.	et cetera (and so forth)
et seq.	et sequens (and the following)
eV	electron volts
evap	evaporation
exp	exponential function of
exsec	exterior secant of
ext	external
°F	degrees Fahrenheit
F	farad
FAA	Federal Aviation Agency
F.C.	fixed carbon, %
FCC	Federal Communications Commission; Federal Constructive Council
F.C.C.	face-centered-cubic (alloys)
ff.	following (pages)
fhp	friction horsepower
Fig.	figure
F.I.T.	Federal income tax
f-m, fm	frequency modulation
F.O.B.	free on board (cars)
FP	fore perpendicular
FPC	Federal Power Commission
fpm, ft/min	feet per minute
fps	foot-pound-second system
ft/s	feet per second
F.S.	Federal Specifications
FSB	Federal Specifications Board
fsp	fiber saturation point
ft	feet
fc	foot candles
fL	foot lamberts
ft · lb	foot-pounds
g	acceleration due to gravity
g	grams
gal	gallons

gc	gigacycles per second
GCA	ground-controlled approach
g · cal	gram-calories
gd	Gudermannian of
G.E.	General Electric Co.
GEM	ground effect machine
GFI	gullet feed index
G.M.	General Motors Co.
GMT	Greenwich Mean Time
GNP	gross national product
gpcd	gallons per capita day
gpd	gallons per day, grams per denier
gpm, gal/min	gallons per minute
gps, gal/s	gallons per second
gpt	grams per tex
H	henry
h	Planck's constant = 6.624×10^{-27} org-sec
$\hbar$	Planck's constant, $\hbar = h/2\pi$
HEPA	high efficiency particulate matter
h-f, hf	high frequency
hhv	high heat value
horiz	horizontal
hp	horsepower
h-p	high-pressure
HPAC	Heating, Piping, & Air Conditioning (Chicago)
hp · hr	horsepower-hour
hr, h	hours
HSS	high speed steel
H.T.	heat-treated
HTHW	high temperature hot water
Hz	hertz = 1 cycle/s (cps)
IACS	International Annealed Copper Standard
IAeS	Institute of Aerospace Sciences
ibid.	ibidem (in the same place)
ICAO	International Civil Aviation Organization
ICC	Interstate Commerce Commission
ICE	Inst. of Civil Engineers
ICI	International Commission on Illumination
I.C.T.	International Critical Tables
I.D., ID	inside diameter
i.e.	id est (that is)
IEC	International Electrotechnical Commission
IEEE	Inst. of Electrical & Electronics Engineers (successor to AIEE, *q.v.*)
IES	Illuminating Engineering Soc.
i-f, if	intermediate frequency
IGT	Inst. of Gas Technology
ihp	indicated horsepower
IMechE	Inst. of Mechanical Engineers
imep	indicated mean effective pressure
Imp	Imperial
in., in	inches
in · lb, in · lb	inch-pounds
INA	Inst. of Naval Architects
Ind. & Eng. Chem.	Industrial & Eng'g Chemistry (Easton, PA)
int	internal
i-p, ip	intermediate pressure
ipm, in/min	inches per minute
ipr	inches per revolution
IPS	iron pipe size
IRE	Inst. of Radio Engineers (see IEEE)
IRS	Internal Revenue Service
ISO	International Organization for Standardization
isoth	isothermal
ISTM	International Soc. for Testing Materials
IUPAC	International Union of Pure & Applied Chemistry
J	joule
J&P	joists and planks
Jour.	Journal
JP	jet propulsion fuel
k	isentropic exponent; conductivity
K	degrees Kelvin (Celsius abs)
K	Knudsen number
kB	kilo Btu (1000 Btu)
kc	kilocycles
kcps	kilocycles per second
kg	kilograms
kg · cal	kilogram-calories
kg · m	kilogram-metres
kip	1000 lb or 1 kilo-pound
kips	thousands of pounds
km	kilometres
kmc	kilomegacycles per second
kmcps	kilomegacycles per second
kpsi	thousands of pounds per sq in
ksi	one kip per sq in, 1000 psi (lb/in^2)
kts	knots
kVA	kilovolt-amperes
kW	kilowatts
kWh	kilowatt-hours
L	lamberts
l, L	litres
£	Laplace operational symbol
lb	pounds
L.B.P.	length between perpendiculars
lhv	low heat value
lim	limit
lin	linear
ln	Napierian logarithm of
loc. cit.	loco citato (place already cited)
log	common logarithm of
LOX	liquid oxygen explosive
l-p, lp	low pressure
LPG	liquified petroleum gas
lpw, lm/W	lumens per watt
lx	lux
L.W.L.	load water line
lm	lumen
m	metres
M	thousand; Mach number; moisture, %
mA	milliamperes
Machy.	Machinery (New York)
max	maximum
MBh	thousands of Btu per hr
mc	megacycles per second
m.c.	moisture content
Mcf	thousand cubic feet
mcps	megacycles per second
Mech. Eng.	Mechanical Eng'g (ASME)
mep	mean effective pressure
METO	maximum, except during take-off
me V	million electron volts
MF	maintenance factor
mhc	mean horizontal candles
mi	mile
MIL-STD	U.S. Military Standard
min	minutes; minimum
mip	mean indicated pressure
MKS	metre-kilogram-second system
MKSA	metre-kilogram-second-ampere system
mL	millilamberts
ml, mL	millilitre = 1.000027 cm^3
mlhc	mean lower hemispherical candles
mm	millimetres

mm-free	mineral matter free
mmf	magnetomotive force
mol	mole
mp	melting point
MPC	maximum permissible concentration
mph, mi/h	miles per hour
MRT	mean radiant temperature
ms	manuscript; milliseconds
msc	mean spherical candles
MSS	Manufacturers Standardization Soc. of the Valve & Fittings Industry
mu	micron, micro
MW	megawatts
MW day	megawatt day
MWT	mean water temperature
n	polytropic exponent
N	number (in mathematical tables)
N	number of neutrons; newton
N_s	specific speed
NA	not available
NAA	National Assoc. of Accountants
NACA	National Advisory Committee on Aeronautics (see NASA)
NACM	National Assoc. of Chain Manufacturers
NASA	National Aeronautics and Space Administration
nat.	natural
NBC	National Broadcasting Company
NBFU	National Board of Fire Underwriters
NBS	National Bureau of Standards (see NIST)
NCN	nitrocarbonitrate (explosive)
NDHA	National District Hearing Assoc.
NEC®	National Electric Code® (National Electrical Code® and NEC® are registered trademarks of the National Fire Protection Association, Inc., Quincy, MA.)
NEMA	National Electrical Manufacturers Assoc.
NFPA	National Fire Protection Assoc.
NIST	National Institute of Standards and Technology
NLGI	National Lubricating Grease Institute
nm	nautical miles
No. (Nos.)	number(s)
NPSH	net positive suction head
NRC	Nuclear Regulator Commission (successor to AEC; see also ERDA)
NTP	normal temperature and pressure
O.D., OD	outside diameter (pipes)
O.H.	open-hearth (steel)
O.N.	octane number
op. cit.	opere citato (work already cited)
OSHA	Occupational Safety & Health Administration
OSW	Office of Saline Water
OTS	Office of Technical Services, U.S. Dept. of Commerce
oz	ounces
p. (pp.)	page (pages)
Pa	pascal
P.C.	propulsive coefficient
PE	polyethylene
PEG	polyethylene glycol
P.E.L.	proportional elastic limit
PETN	an explosive
pf	power factor
PFI	Pipe Fabrication Inst.
PIV	peak inverse voltage
p.m.	post meridiem (after noon)
PM	preventive maintenance
P.N.	performance number
ppb	parts per billion
PPI	plan position indicator
ppm	parts per million
press	pressure
Proc.	Proceedings
PSD	power spectral density, g^2/cps
psi, lb/in^2	lb per sq in
psia	lb per sq in. abs
psig	lb per sq in. gage
pt	point; pint
PVC	polyvinyl chloride
Q	10^{18} Btu
qt	quarts
q.v.	quod vide (which see)
r	roentgens
R	gas constant
R	deg Rankine (Fahrenheit abs); Reynolds number
rad	radius; radiation absorbed dose; radian
RBE	see rem
R-C	resistor-capacitor
RCA	Radio Corporation of America
R&D	research and development
RDX	cyclonite, a military explosive
rem	Roentgen equivalent man (formerly RBE)
rev	revolutions
r-f, rf	radio frequency
RMA	Rubber Manufacturers Assoc.
rms	square root of mean square
rpm, r/min	revolutions per minute
rps, r/s	revolutions per second
RSHF	room sensible heat factor
ry.	railway
s	entropy
s	seconds
S	sulfur, %; siemens
SAE	Soc. of Automotive Engineers
sat	saturated
SBI	steel Boiler Inst.
scfm	standard cu ft per min
SCR	silicon controlled rectifier
sec	secant of
$\sec^{-1}$	angle whose secant is (see $\cos^{-1}$)
Sec.	Section
sech	hyperbolic secant of
sech^{-1}	inverse hyperbolic secant of
segm	segment
SE No.	steam emulsion number
SEI	Structural Engineering Institute
sfc	specific fuel consumption, lb per hphr
sfm, sfpm	surface feet per minute
shp	shaft horsepower
SI	International System of Units (Le Systéme International d'Unites)
sin	sine of
$\sin^{-1}$	angle whose sine is (see $\cos^{-1}$)
sinh	hyperbolic sine of
$\sinh^{-1}$	inverse hyperbolic sine of
SME	Society of Manufacturing Engineers (successor to ASTME)
SNAME	Soc. of Naval Architects and Marine Engineers
SP	static pressure
sp	specific
specif	specification
sp gr	specific gravity
sp ht	specific heat
spp	species unspecified (botanical)
SPS	standard pipe size
sq	square
sr	steradian
SSF	sec Saybolt Furol
SSU	seconds Saybolt Universal (same as SUS)
std	standard

SUS	Saybolt Universal seconds (same as SSU)
SWG	Standard (British) wire gage
T	tesla
TAC	Technical Advisory Committee on Weather Design Conditions (ASHRAE)
tan	tangent of
$\tan^{-1}$	angle whose tangent is (see $\cos^{-1}$)
tanh	hyperbolic tangent of
$\tanh^{-1}$	inverse hyperbolic tangent of
TDH	total dynamic head
TEL	tetraethyl lead
temp	temperature
THI	temperature-humidity (discomfort) index
thp	thrust horsepower
TNT	trinitrotoluol (explosive)
torr	= 1 mm Hg = 1.332 millibars (1/760) atm = (1.013250/760) dynes per cm^2
TP	total pressure
tph	tons per hour
tpi	turns per in
TR	transmitter-receiver
Trans.	Transactions
T.S.	tensile strength; tensile stress
tsi	tons per sq in
ttd	terminal temperature difference
UHF	ultra high frequency
UKAEA	United Kingdom Atomic Energy Authority
UL	Underwriters' Laboratory
ult	ultimate
UMS	universal maintenance standards
USAF	U.S. Air Force
USCG	U.S. Coast Guard
USCS	U.S. Commercial Standard; U.S. Customary System
USDA	U.S. Dept. of Agriculture
USFPL	U.S. Forest Products Laboratory
USGS	U.S. Geologic Survey
USHEW	U.S. Dept. of Health, Education & Welfare
USN	U.S. Navy
USP	U.S. pharmacopoeia
USPHS	U.S. Public Health Service
USS	United States Standard
USSG	U.S. Standard Gage
UTC	Coordinated Universal Time
V	volt
VCF	visual comfort factor
VCI	visual comfort index
VDI	Verein Deutscher Ingenieure
vel	velocity
vers	versed sine of
vert	vertical
VHF	very high frequency
VI	viscosity index
viz.	videlicet (namely)
V.M.	volatile matter, %
vol	volume
VP	velocity pressure
vs.	versus
W	watt
Wb	weber
W&M	Washburn & Moen wire gage
w.g.	water gage
WHO	World Health Organization
W.I.	wrought iron
W.P.A.	Western Pine Assoc.
wt	weight
yd	yards
Y.P.	yield point
yr	year(s)
Y.S.	yield strength; yield stress
z	atomic number, figure of merit
Zeit.	Zeitschrift
Δ	mass defect
μc	microcurie
σ, s	Boltzmann constant
μ	micro (= 10^{-6}), as in μs
μm	micrometre (micron) = 10^{-6} m (10^{-3} mm)
Ω	ohm

MATHEMATICAL SIGNS AND SYMBOLS

$+$	plus (sign of addition)
$+$	positive
$-$	minus (sign of subtraction)
$-$	Negative
$\pm(\mp)$	plus or minus (minus or plus)
$\times$	times, by (multiplication sign)
$\cdot$	multiplied by
$\div$	sign of division
/	divided by
:	ratio sign, divided by, is to
::	equals, as (proportion)
$<$	less than
$>$	greater than
$\ll$	much less than
$\gg$	much greater than
$=$	equals
$\equiv$	identical with
$\sim$	similar to
$\approx$	approximately equals
$\cong$	approximately equals, congruent
$\leqslant$	equal to or less than
$\geqslant$	equal to or greater than
$\mp$ $\neq$	not equal to
$\rightarrow$ $\doteq$	approaches
$\propto$	varies as
∞	infinity
$\sqrt{\ }$	square root of
$\sqrt[3]{\ }$	cube root of
$\therefore$	therefore
$\parallel$	parallel to
() [] {}	parentheses, brackets and braces; quantities enclosed by them to be taken together in multiplying, dividing, etc.
$\overline{AB}$	length of line from A to B
π	pi (= 3.14159^{+})
$^\circ$	degrees
$'$	minutes
$''$	seconds
$\angle$	angle
dx	differential of x
Δ	(delta) difference
Δx	increment of x
$\partial u/\partial x$	partial derivative of u with respect to x
$\int$	integral of

$\int_b^a$	integral of, between limits *a* and *b*
$\oint$	line integral around a closed path
Σ	(sigma) summation of
$f(x)$, $F(x)$	functions of x
$\exp x = e^x$	[$e = 2.71828$ (base of natural, or Napierian, logarithms)]
∇	del or nabla, vector differential operator
∇^2	Laplacian operator
£	Laplace operational symbol
4!	factorial $4 = 4 \times 3 \times 2 \times 1$
$\|x\|$	absolute value of x
$\dot{x}$	first derivative of x with respect to time
$\ddot{x}$	second derivative of x with respect to time
$\mathrm{A} \times \mathrm{B}$	vector product; magnitude of A times magnitude of B times sine of the angle from A to B; $AB \sin \overline{AB}$
$\mathrm{A} \cdot \mathrm{B}$	scalar product; magnitude of A times magnitude of B times cosine of the angle from A to B; $AB \cos \overline{AB}$

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